A Machine Learning Model to Guide the Synthesis of Supported Palladium Catalysts

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A Machine Learning Model to Guide the Synthesis of Supported Palladium Catalysts

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To my father Süleyman Tıraş

ABSTRACT

Supported Pd catalysts are widely used in petrochemical, pharmaceutical and automotive industries. While Pd catalysts appear as a great opportunity to achieve extraordinary performances, the high cost of these materials makes it crucial to investigate efficient ways to design the catalysts. It is known that these catalysts widely preferred in structure-sensitive reactions. The structure-sensitive nature of these reactions creates an opportunity for researchers to achieve better performances via tuning the Pd particle size. Metal particle size is highly linked to the synthesis conditions, but the effects of synthesis condition parameters are hard to define due to high number of variables and the complexity of procedures. In this thesis, the relation between metal particle size and synthesis conditions was investigated by using machine learning (ML) and high activity of supported Pd catalyst was studied. In the first part of this thesis, methodology for both computational and experimental studies were introduced. Initially, the studies on supported Pd catalysts published in 2000-2023 were collected from literature. The collected data contains 1543 data points in total and 1322 of them used in the model. Synthesis method, metal loading, support, support surface area (SSA), precursor, solvent, solvent pH, support point zero charge (PZC), and support calcination/calcination/ reduction conditions were selected as the catalyst preparation parameters. Dispersion and Pd particle size were collected and used as the target variables. In pre-analysis of the data, relations between the variables, their individual relation with target variables and the preferences in literature were discussed. In the second part, dispersion and size predictive models developed via random forest regression model with 5-fold cross-validation in RStudio were introduced. The model enables to decide synthesis conditions to achieve desired metal dispersion or particle size. After the predictive models were built, a list of catalysts was synthesized, and their metal dispersion were measured via CO chemisorption experiments. The predictive models were used to predict experimental results and the precision of the models was discussed. Machine learning models presented here offer broad potential for directing the experimental efforts for the synthesis of supported Pd catalysts with desired structures for any target reaction and propose a potential to utilize the expensive Pd metal in the most efficient way. In the last section of this thesis, the promising performance of supported Pd catalysts was investigated with the selected reaction, hydrogenation of Dicyclopentadiene (DCPD) and importance of achieving high Pd dispersion in the synthesis was highlighted.

ÖZETÇE

Destekli Pd katalizörleri petrokimya, ilaç ve otomotiv sektörlerinde sıkça kullanılmaktadır. Pd katalizörleri, olağanüstü performanslar elde etmek için harika bir fırsat olarak görünse de, bu malzemelerin yüksek maliyeti, katalizörleri tasarlamanın verimli yollarını araştırmayı çok önemli hale getiriyor. Bu katalizörlerin yapıya duyarlı reaksiyonlarda sıkça kullanıldığı bilinmektedir. Reaksiyonların yapıya duyarlı doğası araştırmacılar için Pd parçaçık boyutu ile oynayarak daha iyi performansları elde etme fırsatı oluşturmaktadır. Metal parçacık boyutu büyük oranda sentez koşullarına bağlıdır, fakat sentez parametrelerinin etkisini tanımlamak yüksek sayıda değişken olması ve prosedürlerin karmaşıklığı sebebiyle oldukça zordur. Bu tezde, metal parçacık boyutu ve sentez koşulları arasındaki ilişki makine öğrenmesi (ML) ile araştırılmış ve destekli Pd katalizörlerinin yüksek aktivitesi çalışılmıştır. Tezin ilk kısımında, hesaplamalı ve deneysel çalışmaların metodolojisi verilmiştir. Öncelikle, destekli Pd katalizörleri üzerine yapılan, 2000-2023 yılları arasında yayınlanmış çalışmalar literatürden toplanmıştır. Toplanan veri toplamda 1543 veri noktası içerir ve bunların 1322 tanesi modelde kullanılmıştır. Sentez yöntemi, metal yükleme, destek, destek yüzey alanı (SSA), öncü, çözücü, çözücü pH'ı, destek maddesinin sıfır yük noktası (PZC) ve destek kalsinasyon/kalsinasyon/indirgeme koşulları katalizör hazırlama parametreleri olarak seçilmiştir. Pd dağılım ve parçaçık boyutu verileri de toplanmış ve hedef değişken olarak kullanılmıştır. Verinin ön-analizinde, parametreler arası ilişkiler, onların hedef değişkenler ile bireysel ilişkisi ve literatürdeki tercihler tartışılmıştır. İkinci kısımda 5 katlamalı çapraz doğruma ile rassal orman regresyonu modelini RStudio'da kullanarak oluşturulan dağılım ve parçacık boyutu tahmin modelleri sunulmuştur. Model, istenilen metal parçacık boyutuna ya da dağılıma ulaşmak için gerekli sentez koşullarına karar vermeyi sağlamaktadır. Tahmin modelleri oluşturulduktan sonra, katalizörler sentezlenmiş ve bunların metal dağılımı, CO kimyasal adsorpsiyon deneyleri yoluyla ölçülmüştür. Tahmin modelleri, deneysel sonuçları tahmin etmek için kullanılmış ve modellerin doğruluğu tartışılmıştır. Burada sunulan makine öğrenimi modelleri, herhangi bir hedef reaksiyon için istenen yapılara sahip desteklenen Pd katalizörlerinin sentezine yönelik deneysel çabaları yönlendirmek için geniş bir potansiyel sunar ve pahalı Pd metalini en verimli şekilde kullanma potansiyeli önerir. Bu tezin son bölümünde, destekli Pd katalizörlerinin gelecek vaadeden performansı, seçilen reaksiyon olan Disiklopentadienin (DCPD) hidrojenasyonu ile incelenmiş ve sentezde yüksek Pd dağılımı sağlamının önemi gösterilmiştir.

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Abbreviations

ML	Machine Learning
ARM	Association Rule Mining
DCPD	Dicyclopentadiene
THDCPD	Tetrahydrodicyclopentadiene
RMSE	Root Mean Squared Error
MAE	Mean Absolute Error
TEM	Transmission Electron Microscopy
XRD	X-Ray Diffraction
SSA	Support Surface Area
PZC	Point Zero Charge
NA	Not available
ND	Not determined

Chapter 1: Introduction

Supported Palladium (Pd) catalysts are highly important in the heterogeneous catalysis area due to their excellent performance in various reactions. Not only supported Pd catalysts are an attractive choice for researchers, but also, they have enormous influence on the industry. These catalysts have been widely preferred in the different sectors such as automotive, pharmaceutical, petrochemical industry. In 2022, Pd market size value was noted as 16.5 billion USD and it is expected to reach 24 billion USD in 2030 due to increase in the demand of Pd as a catalytic converter.[1]

While supported Pd catalysts are discussed, one phenomenon appears to be key to understand how to work with these catalysts. Catalytic reactions have unique characteristics which make it complex to define a certain, one-way path to increase catalytic activity. While this complexity makes it hard to work on catalytic performance, it is known that defining the dominant factor for the activity can be a key to reach the desired performance. Catalytic reactions happen at the fluid-solid interface by using catalyst active sites.[2] Thus, surface characteristics may have a high influence on the reaction rate. These reactions which are highly sensitive to structural changes are called structure-sensitive reactions. Metal particle size is a dominant factor for these reactions.[3,4] In 1969, Boudart explained the concept of structure-sensitive reactions and defined the importance of metal particle size for these processes.[3] This structural dependence creates an opportunity for researchers to increase the efficiency via tuning metal particle size and finding optimum metal dispersion for the target reaction where metal dispersion indicates the available surface metal atoms.[5] It is seen that supported Pd catalysts are commonly used in structure-sensitive reactions where the structural changes affect the reaction performance. For these reactions, structure dependent catalytic properties are observed, and different particle sizes result in different activities. Literature showed numerous examples where researchers identified the required optimum metal particle size of supported Pd catalysts for the maximum activity.

Kawabata and coworkers studied hydrodechlorination of aryl chlorides in their study via using Al-MCM41 supported Pd catalysts. They concluded that the activity depends

on the Pd particle size and fine Pd metal particles are beneficial to achieve high catalytic activity.[6] Murata and coworkers studied with alumina supported Pd catalysts in methane combustion reaction.[7] Different crystalline phases of alumina selected as the support, and it is stated that the activity is affected by metal particle size.[7] Pd/α-Al_2O_3 and Pd/θ-Al_2O_3 gave highest activity for the metal particle size of 5-10 nm and they highlighted the relation between TOF and Pd particle size.[7] Gopinath and coworkers also worked with supported Pd catalysts. They used Pd/CeO_2 catalyst for chlorobenzene hydrodechlorination reaction and indicated that Pd particle size has an influence on the catalytic activity where large Pd particles are more favorable for better activity.[8] Binder and coworkers worked about Pd particle size effect for ethene hydrogenation reaction.[9] SiO_2 and TiO_2 supported Pd catalysts showed structure-sensitive behavior where metal particle size was in the range of 1-9 nm.[9] This situation shows the vital need of precise synthesis of supported Pd catalysts to reach desired catalytic structure. Furthermore, controlled synthesis offers maximum utilization of highly expensive supported Pd catalysts.

There are several parameters which might affect the catalyst structure. Synthesis method, preference of Pd precursor and solvent, pre-treatment conditions (in example calcination and reduction conditions) or modifications on support are examples of parameters which can be a way to adjust metal particle size. Researchers tend to change these synthesis parameters mostly by using their past experiences or applying a trial-and-error procedure due to lack of knowledge on the exact correlations between synthesis conditions and metal particle size. As Marshall and coworkers stated in their study, synthesis of heterogeneous catalysis is one of the least discussed topics in data management and it still waits to unravel.[10] In this respect, detailed analysis of the literature on the use of different synthesis parameters and using machine learning (ML) algorithms to develop strategies to rationally design supported Pd catalysts with desired Pd dispersion and particle size is of paramount importance.

While literature offers a massive amount of data for the researchers, machine learning tools appear as an excellent opportunity to convert this data into an easily understandable and applicable model for future studies. ML is not only a remarkable method to make predictions about designed experiment results, but it is also an effective way to visualize current findings especially for complex processes which contain a high number of variables.[11]

In this thesis, rational synthesis of supported Pd catalysts and the high capacity of these catalysts in target reaction were studied. Firstly, experimental data on the synthesis of supported Pd catalysts published between the years 2000-2023 was collected. The data includes 365 articles with 1543 data points. The collected data is provided in the Supplementary Information (SI). Synthesis method, theoretical and actual metal loading wt%, support, support source, support surface area (SA), modifications on support, support calcination conditions, precursor, solvent, solvent pH value, pH adjustment (whether there is pH adjustment or not), support point zero charge (PZC) value, reduction and calcination conditions, determination method of dispersion, dispersion, metal particle size from chemisorption/TEM/XRD results, reactions for performance test were collected. Also, the year of publication, paper title, first author, journal, country, and reference link were added to the data. The selected articles were found via Scopus and Web of Science by using keywords “Pd catalysts”, “supported Pd catalysts”. NA (Not Available) and ND (Not Determined) were used for the unknown missing points in the data. This thesis includes the analysis of the collected data, Pd particle size and dispersion predictive models, comparison between predictions derived from predictive models and experimental results and lastly performance tests of supported Pd catalysts.

Chapter 2 includes the methodology which contains construction of dataset, pre-analysis tools, development of machine learning models, experimental methodologies for catalyst synthesis, metal dispersion measurements and performance tests. In Chapter 3, pre-analysis of the data where the correlations between parameters and researchers’ preferences discussed was completed. Pd particle size and dispersion predictive models were introduced. In this section, the accuracy of the predictive model was checked with the comparison of experimental results and model predictions. Limitations and interpretations of the models were also discussed in this chapter. In Chapter 4, to illustrate the high activity of supported Pd catalysts, performance tests were taken in the target reaction. Selective hydrogenation of cyclic olefins (DCPD) was selected and both continuous and batch processes were studied. While the promising nature of supported Pd catalysts were proved in this chapter, also the opportunities in DCPD hydrogenation process were shown. Findings from computational and experimental results were discussed in Chapter 5. Effect of catalyst synthesis parameters and promising performance of supported Pd catalysts were summarized and outlook for future studies were given.

Chapter 2: Methodology

In this chapter, computational and experimental methodologies were explained in detail. Initially, the decision-making process in the data collection were explained, supported Pd catalysts synthesis studies from literature were discussed. Synthesis methods in the data were defined and the parameters of collected data were given with their ranges/definitions. Then, computational tools and their background information were explained. In the final part of Chapter 2, experimental studies (catalyst synthesis, dispersion measurement and performance tests of supported Pd catalysts) were introduced and methods related to them were described.

2.1. Construction of the Database

The dataset contains 365 articles that were published between 2000 and 2023 where 1322 instances were used for analysis and the machine learning models.[6–9,12–372] In the data collection process, studies were selected with the consideration of the given synthesis information and the availability of Pd particle size or Pd dispersion measurements. Data collection was done objectively to reflect the majority of supported Pd catalyst preparation procedures and none of the journals or authors were prioritized. Articles with novel methods and instances with significant missing information were eliminated to avoid inaccuracy in the model. Also, articles which used metallic organic frameworks (MOFs) as the support were not added to the dataset due to structural differences of MOF supported Pd catalysts where the catalyst structural properties can be studied via tuning the relation between organic linkers of MOFs and Pd ions.[373] The selected articles were found via Scopus and Web of Science by using keywords “Pd catalysts”, “supported Pd catalysts”. NA (Not Available) and ND (Not Determined) were used for the unknown missing points in the data. The difference between these two abbreviations is that while NA indicates the data points where researchers did not perform or give that information on purpose, ND points to the unknown and unmentioned information. The collected data can be seen in Appendix C of the thesis.

The selected articles were classified based on their synthesis techniques. The collected data includes eight different catalyst synthesis methods: Impregnation,

deposition-precipitation, liquid-phase reduction, sol-gel, ion-exchange, photo-deposition, polyol and microwave-assisted synthesis. These synthesis methods were chosen by the researchers and their definitions must be given in order to understand general synthesis conditions.

In the synthesis of supported heterogeneous catalysts, researchers often prefer impregnation methods due to their simplicity. While impregnation methods offer easy application and successful anchoring of the metal on support surface, the control on the interaction with support and metal is limited with this method.[374] Most common impregnation methods are wet impregnation and incipient wetness impregnation (IWI) techniques. In wet impregnation, a precursor solution is prepared with an excess amount of solvent. On the other hand, the amount of solvent is controlled in IWI.[374] Support pore volume is checked and only the amount of solvent which fills support pore volume is used in this technique.[374] Thus, powder form of support is protected while mixing the support with precursor solution in IWI. The controlled amount of solvent makes IWI more advantageous compared to wet impregnation to achieve desired metal loading by avoiding any loss of metal precursor solution. Zero-valent metal particles are achieved by applying pre-treatments to impregnated and dried powders.[374] Although impregnation methods do not offer strong control over metal particle size, pre-treatment conditions can be a way to achieve desired dispersion and metal particle size.

The second most common synthesis method in the collected data was determined as deposition-precipitation method. In this technique, controlled precipitation of metal precursor which occurs only on the support surface is achieved by using a precipitation or reducing agent.[374] Studies that preferred deposition-precipitation method commonly used Na_2CO_3 as the reducing agent and operated a pH adjustment. Precipitation method was also noted as deposition-precipitation in the data due to the same logic behind these techniques.[375] Third method was the liquid-phase reduction method (reductive deposition). This method offers selective deposition of metal on the support surface.[374] In this technique, before dispersing of metal on support, metal precursor salt is reduced with a reducing agent which was initially dissolved in the aqueous or organic media.[374] Common reducing agents are sodium borohydride, hydrazine, and ethylene glycol.[374] In sol-gel technique, precursors and solvents are mixed initially to form a homogeneous solution. After completing hydrolysis and polymerization, sol formation is completed. Then, refluxing and stirring are completed and, the prepared sol turned into gel form.

Lastly, the aging and drying processes are performed and aerogel/xerogel/cryogel form is reached. Final products were collected after calcination.[376] In the ion-exchange method, the exchange of ions happens within the surface of the support. Support initially mixed with a solution which contains a different ion from the ion that supports caries. The support ion and solution ion are exchanged based on electrostatic interaction.[377] Photo-deposition is also one of the synthesis methods that can be seen in the collected data. In this technique, UV irradiation is used for photocatalytic deposition. Initially, support and precursor solutions are mixed. The suspension is purged with Nitrogen or Argon which is followed by UV irradiation.[154,219] In the data, researchers which preferred photo-deposition used UV irradiation with high pressure Hg lamp or 400W UV light.[154,219] Polyol techniques were also seen in the collected data where Pd colloidal particles were synthesized and deposited on the support. The last synthesis method was microwave-assisted synthesis, with only 13 instances in the dataset, where microwave irradiation is used to anchor Pd nanoparticles on the support.[85,118]

After the synthesis method was noted in the dataset, other variables were decided and collected based on the general provided information in the articles (frequency of appearance) and past experiences on supported Pd catalyst synthesis (domain knowledge). Pd dispersion % and size of the Pd particles were selected as output variables and input variables (descriptors) included details about metal loading, calcination, and reduction conditions as well as support material and precursor details.

Two of descriptors were decided as point zero charge (PZC) values of support materials and precursor solution pH value to reflect the importance of metal-support interaction and its effect on metal dispersion. Zhu and coworkers explained the limitation of IWI where there is no control over metal-support interaction.[378] They suggested that this interaction can be improved via using electrostatic adsorption mechanisms and introduced “charge-enhanced dry impregnation”.[378] PZC values of support materials indicate the pH value which the support surface is neutrally charged and it is an important factor for the determination of metal precursor.[378] Zhu and coworkers explained that selecting cationic metal precursors for the supports with low PZC such as SiO_2 and preferring anionic metal precursors for the supports with high PZC such as Al_2O_3 can be a way to improve metal dispersion and achieve strong metal-support interaction.[378] In the dataset, this opposite correlation between Pd precursor solution pH and support PZC was investigated, and metal-support interaction was highlighted with the help of electrostatic

interaction discussion. During the data collection phase of the project, it was observed that support PZC values were not mentioned in the majority of the articles. To be able to consider the effects of these variables, Kosmulski's study which includes different metal oxides PZC values was used for the estimation.[379] Selected estimation information for PZC was added to the "Support PZC Reference" column of the dataset. No estimation was done for carbon materials due to the complexity of reflecting variations of PZC values for different carbon sources which was observed in the study of Hu and coworkers.[177] They reported the different carbon materials PZC values which proved the significant differences between materials.[177] As an example, while PZC was given as < 7 for carbon nanotubes (CNT) and it was measured as > 7 for graphite.[177]

In the data, the most common metal particle size and dispersion determination techniques were noted as: H_2 Chemisorption, CO Chemisorption, O_2 Chemisorption, Transmission Electron Microscope (TEM), and X-Ray Diffraction (XRD). In chemisorption experiments, Pd active sites absorb selected molecules such as CO, O_2 and H_2 until all the active sites become unavailable. Then, the amount of molecules which were chemisorbed by the active sites were calculated to measure available active sites which gives the Pd dispersion. Chemisorption techniques are promising to measure dispersion when the average particle size is less than 2 nm where TEM and XRD are not able to detect these small particles.[5] Thus, in the particle size information, chemisorption results are prioritized compared to TEM and XRD. If the researcher supplied Pd particle size based on the chemisorption result, it was used in the model. If Pd particle size were given by using TEM and XRD, Pd particle size value from TEM was used due to the assumptions and limitations of Pd particle size determination with XRD (Scherrer equation).[380,381] And lastly, Pd particle size results which were given by using XRD were used if both TEM and chemisorption values were missing.

Also, reactions for performance tests, the year of publication, paper title, first author, journal, country, and reference link were added to the data which were not directly used in the analysis. The studies which were used in the data can be found in Bibliography section. List of input/output variables and their ranges/categories are given in Table 2.1.

Table 2.1. Details for input (descriptors) and output variables: The variables and their ranges in the dataset.

Variables	**Information related to the variables or the range of the variables**
Synthesis method	Impregnation, deposition-precipitation, liquid-phase reduction, sol-gel, ion-exchange, photo-deposition, polyol, microwave-assisted synthesis and commercial.
Theoretical metal loading wt. %	0-100
Actual metal loading wt. %	0-100
Support surface area (m^2/g)	1-3600
Support	Selected support, total 52 categories involved in the dataset.
Support source	Chemicals used, purchasing information, support synthesis details were in this column.
Operation on support (promoter/modification)	Information on promoter or modification if it is done.
Support calcination temperature (K)	298-1573
Support calcination time (hr)	1-48
Precursor	Selected Pd precursor, total 13 categories involved in the dataset.
Solvent for precursor	Selected solvent for the precursor solution, total 35 categories involved in the dataset.

Solvent precursor pH	1-13.20
pH adjustment (Yes or No)	Information whether pH adjustment was done or not was noted.
PZC support	1-12
Calcination time (hr)	0.5-25
Calcination temperature (K)	298-1473
Reduction Solvent/Gas	Solvent or gas to reduce the prepared catalysts were noted. Information used to separate chemical reduction from others.
Reduction time (hr)	0.08-28.5
Reduction temperature (K)	273-1173
Method for dispersion/size determination	Method information for metal dispersion or metal particle size determination was noted.
Dispersion (%)	0-100
Std dev	Standard deviation reported for dispersion
Size (Å) (Chemisorption)	3-5600
Std dev	Standard deviation reported for Pd particle size from chemisorption
Size (Å) (XRD)	11-472
Std dev	Standard deviation reported for Pd particle size from XRD
Size (Å) S(TEM)	6-5500

Std dev	Standard deviation reported for Pd particle size from TEM
Reaction	Target reaction selected in the article. "Reaction name" + "of" + reactant chemical name(s)
Year	2000-2023
First Author	First author of corresponding article.
Country	Country(s) of articles were noted.
Reference title	Article titles were given in this column.
Journal	Journal information was collected.
Link of reference	DOI information was given in this column for easy access.
Notes	Additional information which was not included in the selected variables was noted here. Also, the assumptions were written here.
Support PZC Reference	If the estimation of PZC value was done by using Kosmulski's study, selected material was noted here.

2.2. Analysis of Database and Development of Machine Learning Models

Pre-analysis of the data was done using simple descriptive statistics and association rule mining (ARM) algorithm. Random forest and decision tree algorithms were used for regression and classification purposes respectively. All models were developed using 80-20 % train-test split ratio and five-fold cross validation. Hyperparameters giving the lowest root mean square error (rmse) or highest accuracy were selected, and the performance of the optimum model was tested on the test set. Feature importance of the variables was done using Boruta analysis. R is used in development of the models and

rpart, Boruta, ggplot2, arules, ggbeeswarm and *randomForest* packages were utilized.[382–387]

2.2.1. Association Rule Mining (ARM) Algorithm

All descriptors were discretized and correlation between variables and output variables were explained with ARM algorithm. It was preferred in the model to understand If-Then patterns which were not easily recognized by eye. ARM is highly common in different areas of machine learning studies, especially in market basket data analysis where customers' product preferences are explored.[388] This *if product A, then product B* relation is known as the rule of A→B. In example, ARM helps to understand how likely to see product B in the customer basket when product A is purchased. In the same logic, ARM was found favorable to understand how likely to see interaction between parameter A and parameter B by interpreting the supported Pd catalysts synthesis data.

Three factors must be defined while discussing ARM technique: support, confidence, and lift. These factors are the indicators of strong interaction between the factors. While support shows how much likely to see parameter A and parameter B together, confidence indicates how frequently if item A, then item B occurs in the data set.[389] Lift, on the other hand, is a pointer whether the interaction exist or not.[389] The formula of these factors can be seen in the below:[389]

$$\text{Support}\ (\text{A}, \text{B}) = \frac{\text{frequency}\ (\text{A}, \text{B})}{\text{Total number of transactions}\ (\text{N})} \tag{2.1}$$

$$\text{Confidence}\ (\text{A} \rightarrow \text{B}) = \frac{\text{frequency}\ (\text{A}, \text{B})}{\text{frequency}\ (\text{A})} \tag{2.2}$$

$$\text{Lift}\ (\text{A} \rightarrow \text{B}) = \frac{\text{Support}\ (\text{A}, \text{B})}{\text{Support}\ (\text{A}) \times \text{Support}\ (\text{B})} \tag{2.3}$$

To understand lift better, formula can be reorganized as the following:

$$\text{Lift}\,(A \rightarrow B) = \frac{\text{Support}\,(A, B)}{\text{Support}\,(A) \times \text{Support}\,(B)} = \frac{\frac{\text{frequency}\,(A, B)}{N}}{\frac{\text{frequency}\,(A)}{N} \times \frac{\text{frequency}\,(B)}{N}} \quad (2.4)$$

$$\text{Lift}\,(A \rightarrow B) = \frac{\text{frequency}\,(A, B) \times N}{\text{frequency}\,(A) \times \text{frequency}\,(B)} \quad (2.5)$$

Thus, if lift is higher than 1.0, it indicates a positive relation between A and B.[390] If lift is 1.0, it means there is no significant relation.[390]

ARM was studied with two different approaches in the study. The whole dataset was used in the first approach without separating Pd particle size. In the second approach, the dataset was separated into four groups based on Pd particle size and correlations between input variables were investigated for each Pd particle size group. The aim was to identify strong correlations between two input variables which are also linked to certain Pd particle size groups. ARM was performed via Apriori algorithm. Apriori algorithm uses a simple iteration loop to assess relations. In each iteration step, confidence and support values were calculated and they were compared with the chosen minimum confidence and minimum support values. If they were lower than minimum value, they were avoided in the other step and so on. Thus, deciding minimum confidence and support value had a significant influence on the model. Minimum confidence and minimum support values were decided as 0.001 and 0.001, respectively. The levels of the discretization were given in Table 2.2.

Table 2.2. ARM categories (categories 1, 2, 3 and 4).

Parameters	**Categories**			
	1	**2**	**3**	**4**
Synthesis method	Wet impregnation	IWI	Deposition-precipitation	Liquid-phase reduction
Metal loading wt. %	<1	1-3	3-5	5-10
Support Surface Area (m^2/g)	<10	10-50	50-100	100-500
Support	Carbon	γ-Al_2O_3	mixed-Al_2O_3	SiO_2
Precursor	$PdCl_2$	$Pd(NO_3)_2$	$Pd(acac)_2$	$Pd(NH_3)_4(NO_3)_2$
Solvent	water	aqueous hydrochloric acid	HCl	acetone
Support calcination, calcination and reduction temperature (K)	<300	300-500	500-600	600-700
Solvent pH and support PZC	<7	>7		
Size (Å)	< 20	20-50	50-100	>100

Table 2.3. ARM categories (categories 5, 6 and 7).

Parameters	Categories		
	5	**6**	**7**
Synthesis method	Commercial	Sol-gel	Others
Metal loading wt. %	10-20	>20	
Support Surface Area (m^2/g)	500-1000	>1000	
Support	TiO_2	Others	
Precursor	$Pd(OAc)_2$	Others	
Solvent	toluene	Others	
Support calcination, calcination and reduction temperature (K)	700-800	>800	

2.2.2. Boruta Algorithm for Variable Selection

Variable selection is an important topic for the model. Instead of using all the variables in the data set, the variables which have low correlation with the dependent variable (dispersion or metal particle size) must be removed from the model to increase the accuracy. This is an essential step to simplify a complex system and to avoid unnecessary variables in the model. Boruta is an algorithm for parameter selection by calculating the importance of the variables. Boruta algorithm initially creates new data by shuffling the variables. In this new data set, each of the variables from original data set has a shadow feature. Shadow features contain randomized data of the corresponding features.[391]

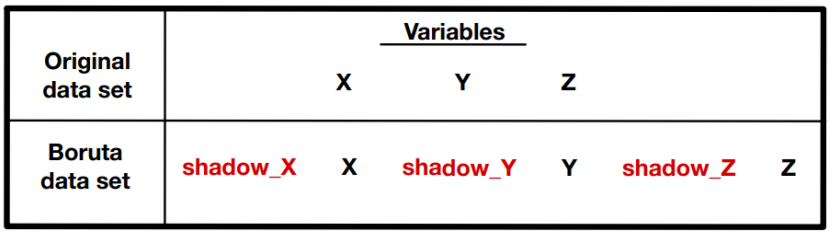

Figure 2.1. Boruta Algorithm Shadow Features.

The importance of variables is decided by comparing these shadow features with features themselves. Figure 2.1 shows an example of Boruta data set. In example, if variable X has higher importance than shadow feature of X, Boruta algorithm stated this feature as important. The importance comparison between features and shadow features are repeated for several times by using binomial distribution. In that way, Boruta ensures that features importance is not higher or lower than shadow feature by chance via iteration.

2.2.3. Handling Missing Points in the Dataset

In the model development, missing points were handled initially. The missing values in the descriptors were filled with the mean/mode of the training set or the decided value and the details were given in Table 2.4.

Table 2.4. Filling missing points for input variables.

Missing Variable	Used Value
Precursor	Most common one (mode)
Solvent	Most common one (mode)
Support SA	Mean value
Support PZC Value	Mean value
Solvent pH	Mean value
Support Calcination Temperature	Room Temperature (298 K)
Calcination Temperature	Room Temperature (298 K)
Reduction Temperature	Room Temperature (298 K)
Support Calcination Time	2 hours
Calcination Time	2 hours
Reduction Time	2 hours

Missing pre-treatment time values were taken as 2 hours for all the missing points. It is seen that the data has two different scenarios where pre-treatment values were not given. In the first case, pre-treatment was done by the researchers, but the corresponding time was not given. 2 hours was appropriate for these ones due to the commonness of this time interval. In the second case, both the time and the temperature of pre-treatment were not given. It is assumed that researchers did not perform any pre-treatment for these ones. The temperatures were assumed room temperature for these data points as it is seen in Table 2.4. Thus, the time of the pre-treatment does not affect the outcome. Therefore, using 2 hours is appropriate also for these cases.

The missing values for output variables (Pd dispersion and Pd particle size) were handled differently. In the classification tree, output variable, Pd particle size, missing points were not filled, only reported chemisorption results for Pd particle size were used. However, in the random forest prediction model, a different strategy was applied. Each data point in the dataset has the information on at least one of the output variables (metal dispersion or metal particle size). It is known that dispersion and metal particle size are correlated to each other, and the missing one can be estimated by using the given output variable. The relation between dispersion and particle size (geometric shape is assumed as sphere) can be seen in the following relation:[5]

$$V_M = \frac{m}{\rho N_{Av}} \tag{2.6}$$

where m is the atomic mass, ρ is the bulk density and N_{Av} is Avogadro's number. The relation between dispersion and particle size (geometric shape is assumed as sphere):[5]

$$D_M = 0.6\left(\frac{V_M}{A_M}\right) d(nm) \tag{2.7}$$

Equation 2.7 shows that dispersion and particle size are correlated with a constant which depends on geometric shape and metal. Therefore, the data points where both dispersion and particle size were given together might be used to estimate this constant. The largest dataset of Pd particle size and dispersion results reported together belongs to the CO chemisorption experiment which includes 316 instances. Thus, the constant from

CO chemisorption results was calculated and used to estimate all the missing output variables. Figure 1 shows the constant which was found as 1.038.

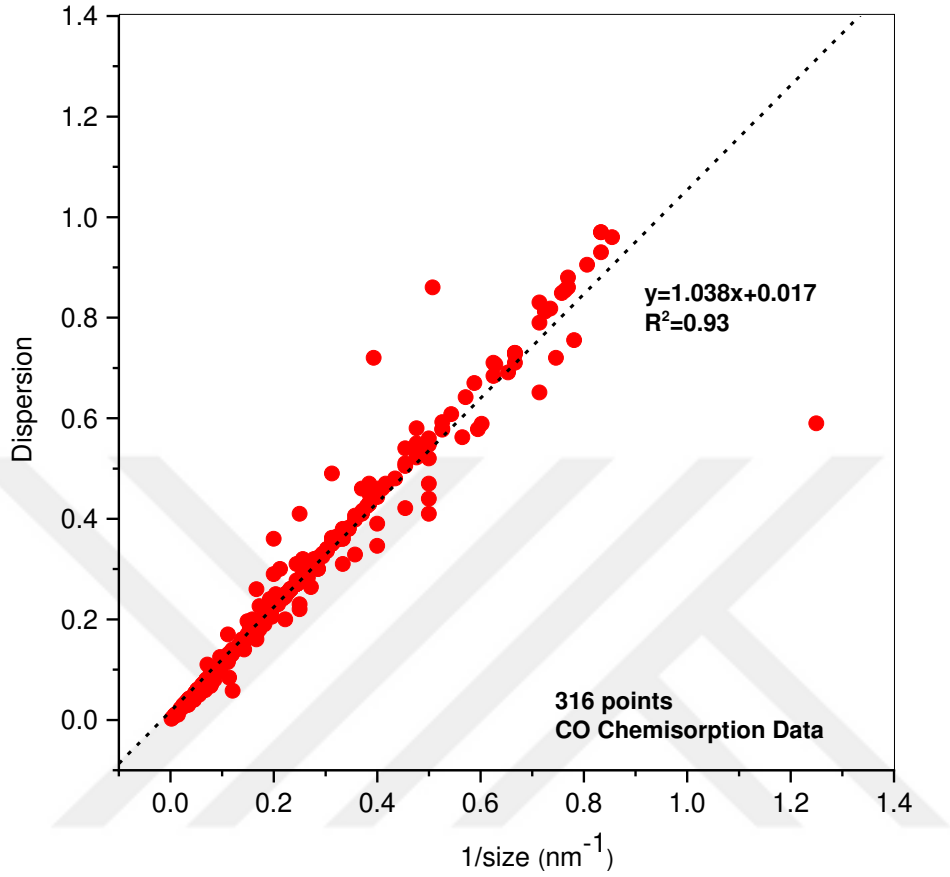

Figure 2.2. CO Chemisorption constant determination*.

2.2.4. Random Forest Regression Model with 5-Fold Cross-Validation

Decision trees are categorized as classification trees and regression trees based on the type of outcome. While classification trees show categories as an outcome, regression trees are used for numeric decisions. Regression trees are very accurate tools to show patterns in existing data, but it is not easy to classify new data with it due to its lack of flexibility. To overcome this challenge, random forest regression was performed. Metal particle size predictive model and dispersion predictive model were prepared via random forest regression model with 5-fold cross-validation.

* CO chemisorption constant was discussed based on the researchers' selection.

One of the problems in model preparation is about testing. The performance of prediction model is mistakenly decided, when testing is done with the samples which are also used for the model preparation. Using a single data set for testing and training creates overfitting problem. 5-fold cross-validation was used to avoid this problem in the model. Firstly, the data is separated into two groups as test and train data. In the model, a split ratio of 0.80 was used. The train data was built with randomly chosen 80% of the data and the remaining part was called test data. After this procedure, train data was also separated into 5 groups. While 4 of them were used to build the model, the remaining one was used to validate the model. Selecting 4 out of 5 data groups repeated until each of the data groups used for validation (which corresponds to 5 times for this model).

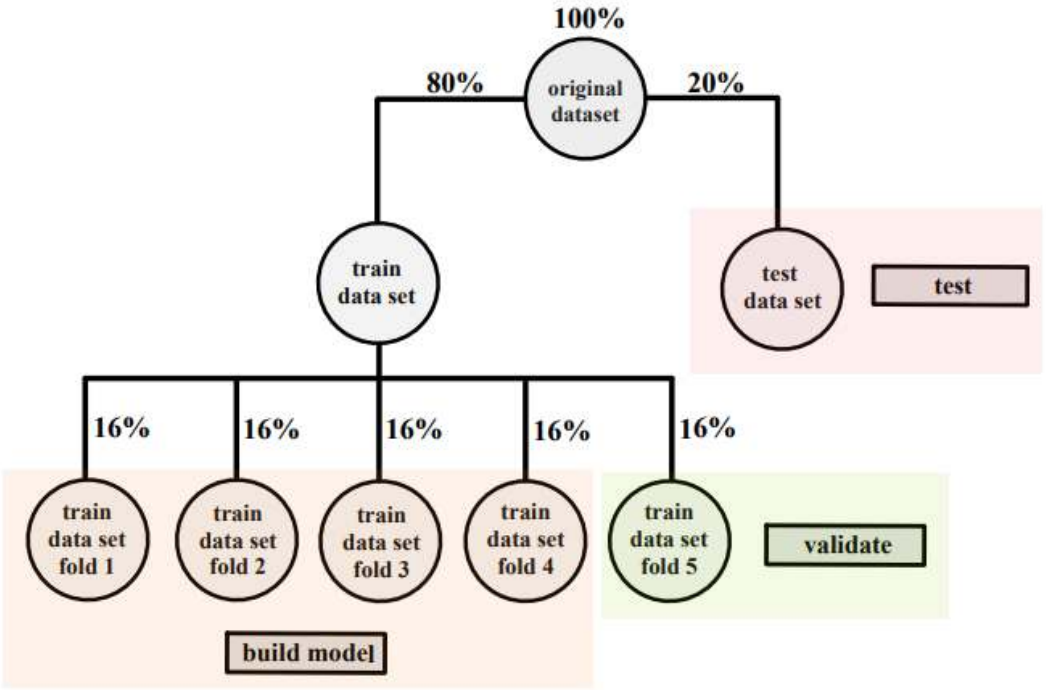

Figure 2.3. 5-fold cross validation.

After preparing the train and test data set, random forest model was studied. The initial step was the resampling train data which is called bootstrapping. In this technique, bootstrapped data and original data had the same number of samples, but some of the original data samples were duplicated inside of bootstrapped data. Thus, bootstrapped data missed some of the original data samples which were called out-of-bag data set. Bootstrapping technique offered an accuracy check by creating an out-of-bag data set. The bootstrapped data was used in the model to build regression trees. A certain number of node sizes and number of trees were chosen while building the trees. The intervals for

number of trees and node size number were decided by repeating the procedure until optimum values were found. After the trees were prepared, the outcome was predicted via these trees. This step is called bagging. In the final step, to check the accuracy of the model, out-of-bag data was tested with the model. Accuracy was improved via returning step 2 and changing n_{trees} and $n_{node\ size}$. Summary of the model was illustrated with 5 steps in below:

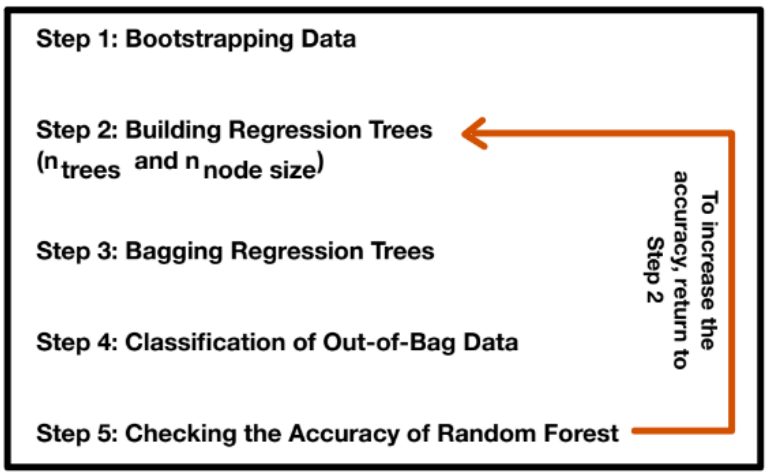

Figure 2.4. Random forest regression model steps.

Average absolute difference (mean absolute error (MAE)) between actual and predicted data, R^2 values and root mean squared error (RMSE) were calculated for different n_{fold}, n_{trees} and $n_{node\ sizes}$. MAE, R^2 and RMSE formulas can be seen below:

$$MAE = \frac{\left|x_{observed} - x_{prredicted}\right|}{n} \tag{2.8}$$

$$R^2 = 1 - \frac{\text{sum squared regression}}{\text{total sum of squares}} \tag{2.9}$$

$$\sqrt{MSE} = \sqrt{\frac{\sum_{i=1}^{n}(x_{observed} - x_{predicted})^2}{n}} \tag{2.10}$$

where $x_{observed}$ indicates the collected data dispersion/size results, $x_{predicted}$ is the estimated dispersion/size via the model and n is the total number of data.

In the final step, test data set was used to see the performance of the model with unseen data. The same parameters (MAE, RMSE and R^2 values) were also calculated for the test data.

Predictive modeling for Pd dispersion % and Pd particle size was done using Random Forest algorithm. The maximum features (mtry) and number of trees (ntree) parameters were tuned as hyperparameters. Grid search was used to find the best hyperparameter set and mtry of 5 and ntree of 50 was selected as the best model for both Pd dispersion and particle size prediction models. To increase the accuracy of Pd particle size predictive model, data points which have a particle size of > 50 nm were excluded.

2.2.5. Classification Tree with 5-Fold Cross-Validation

Classification tree uses process of binary recursive partitioning. The data is splitting into 2 branches in each step where each of these branches represents the parameters which are important for the target variable. The initial splitting of root node is one of most important steps of classification trees.

Different trees which give better predictions were discussed by following described procedure. In the study, similar with random forest regression, initially, the original data set was separated as train and test data with a split ratio of 0.80 to avoid overfitting problem. Train data was used to build the classification tree and test data was used to predict unseen data by the developed classification tree. Complexity parameter and minimum split number were decided by optimizing the accuracy while building the tree with train data. 5-fold cross-validation was used to improve the performance of classification tree. Minimum split number was checked from 2 to 50, complexity number was checked from 0.01 to 0.2. Minimum split number was decided as 5 and complexity parameter was decided as 0.01.

The performance of the regression models was not satisfactory for the Pd particle size, in order to achieve reliable heuristics, a decision tree algorithm was used for classification of Pd size. Only particle size values which were reported via completing chemisorption experiments were used. The size values in the training set were categorized into 3 equal sized classes and the same limits were applied to testing set values. Categories can be seen in Table 2.5. The non-numeric input variables were also categorized for the

classification tree. The categories were given in Table 2.6 and Table 2.7. The accuracy of the training and testing sets were 0.74 and 0.53, respectively.

Table 2.5. Determined size limits in classification trees.

Target Variable	**Limits**		
Size (Å)	< 50	50-100	> 100

Table 2.6. Classification tree categories for non-numeric input variables (categories 1, 2, and 3).

Parameters	**Categories**		
	1	**2**	**3**
Synthesis Method	Wet impregnation	IWI	Deposition- precipitation
Support	Carbon	γ-Al_2O_3	mixed-Al_2O_3
Precursor	$PdCl_2$	$Pd(NO_3)_2$	$Pd(acac)_2$
Solvent	water	aq. hydrochloric acid	HCl
pH adjustment	Yes	No	

Table 2.7. Classification tree categories for non-numeric input variables (categories 4, 5, and 6).

Parameters	**Categories**		
	4	**5**	**6**
Synthesis Method	Liquid-phase reduction	Sol-gel	Others

Support	SiO_2	TiO_2	Others
Precursor	$Pd(NH_3)_4(NO_3)_2$	$Pd(OAc)_2$	Others
Solvent	acetone	toluene	Other

2.3. Experimental Methodology

2.3.1. Materials

In the catalysts preparation, $Pd(NO_3)_2.xH_2O$ (Aldrich) and $PdCl_2$ (Aldrich) were used as palladium precursors. γ-Al_2O_3 (Alfa Aesar), MgO (Merck) and SiO_2 were used as the supports. Support SiO_2 was prepared from fumed silica (Aldrich). In the calcination of supports and dried catalysts, muffle furnace Nabertherm P330 was used. 10 vol.% H_2 in Ar from Air Liquide was used for the reduction of calcined catalysts. The materials which were used for CO chemisorption experiments were 5 vol.% CO in He supplied from Elite Gaz and pure helium which was purchased from Air Liquide.

DCPD (purity ~93%) and hexane (purity > 95%) were purchased from Merck. Methanol (purity ≥ 99.5%) was purchased from ISOLAB. These materials were used for performance test of supported Pd catalysts. 10 wt.% Pd/C was purchased from Aldrich and used as the reference catalyst in the performance tests. In the reaction, pure hydrogen and pure helium supplied from Air Liquide were also used.

2.3.2. Catalyst Synthesis

In the catalyst synthesis, IWI was selected due to its commonness in the collected data. The experiment conditions were selected with respect to the dataset, and it can be found in the below tables.

Table 2.8. Experiment parameters – 1.

Exp. No	Method	Pd Loading wt%	Support
1	IWI	4	γ-Al_2O_3
2	IWI	4	MgO
3	IWI	4	SiO_2

Table 2.9. Experiment parameters – 2.

Exp. No	Support Calcination Temperature (K)	Support Calcination Time (hr)	Precursor	Solvent	pH adjustment
1	773	4	$PdCl_2$	Aq. HCl	No
2	973	5	$Pd(NO_3)_2$	water	No
3	793	5	$Pd(NO_3)_2$	water	No

Table 2.10. Experiment parameters – 3.

Exp. No	Support PZC	Calcination Time (hr)	Calcination Temperature (K)	Reduction Time (hr)	Reduction Temperature (K)
1	8.5	4	673	2	623
2	10	4	723	1	573
3	3	4	673	1	593

2.3.3. Dispersion Measurements

Dispersion determination was done via CO chemisorption. Micrometrics Autochem II was used for CO chemisorption analysis of the prepared catalysts. Approximately 40 mg of the calcined catalysts were reduced under H_2/Ar flow at corresponding reduction temperatures (300-400 ˚C) for 1-2 hours. Then, samples were cooled down to 25 ˚C under He flow, and they were waited at room temperature for 1 hr. After that, CO chemisorption was performed under CO/He flow at the same temperature. 5 vol.% CO was used for the analysis. The stoichiometric factor of CO:Pd was taken as 1:1 for Pd dispersion measurements.[392–395]

2.3.4. Performance Tests: Experimental Setup

2.3.4.1. Continuous Process

DCPD hydrogenation reaction was performed with a continuous flow reactor. The stainless-steel reactor placed into the furnace (Thermcraft Model XST-3-0-12-1C). Helium was used in the setup as an inert gas. Initially, the catalysts were reduced in H_2 flow. Reduction temperatures were set based on the CO chemisorption results. After completing reduction, the temperature decreased to reaction temperature. System was pressurized at this temperature with hydrogen via back pressure regulator (Swagelok). After reaction pressure and temperature were stabilized, liquid reactant mixture was sent to the reactor. Hexane was used to dilute DCPD with volumetric ratio of 1:9 (DCPD:Hexane). The liquid mixture was supplied to the reactor via iscopump (Teledyne Isco Model 500D). The reaction was done at 90 ˚C and 7 bar. The liquid products were collected every 15 minutes and the initial first hour was ignored to avoid unsteady state conditions. Collected samples were manually injected to gas chromatograph (GC) Agilent GC 7820A Column HP-Innowax to analyze the products. Liquid flow rate set as 1 mL/min and catalyst amount was used as 12 mg for each of the run.

2.3.4.2. Batch Process

Batch reaction was studied with Amar Equipments Autoclave Equipment No. 3338. Initially, DCPD was mixed with the solvent (hexane or methanol). Then, catalyst was added to the liquid mixture. The final mixture placed into the autoclave and system initially filled and pressurized with H_2 flow. After reaching the reaction pressure set point,

the temperature was set. When the reaction temperature was achieved, rotation was started which was taken as the reaction start time. 500 rpm was selected as the rotation speed. Reaction pressure was set as 9 bar. Reaction temperature was chosen as 60 °C. Catalyst amount, reaction duration and liquid mixture volume were used as the independent variable.

Chapter 3: Pre-Analysis of the Data & Pd Dispersion and Particle Size Predictive Models

In this chapter, predictive models were introduced. Models were discussed separately for dispersion and particle size estimation. The reliability of models was investigated via comparing with experimental results.

3.1. Pre-analysis of the Database

The dataset was represented in a MS Excel file. This dataset contains 365 articles with 1543 instances. Here, the aim was to provide a dataset which can be easily accessed and to offer a useful handbook for researchers to search synthesis conditions in their daily work. This document was shared in the Appendix C where red ones indicate the excluded data points in the models. A second MS excel file was also prepared via using this main document. It covers estimations for missing output variables and additional calculations such as metal loading difference between actual and theoretical metal loading values. In this document, novel methods and articles with significant missing information were excluded. This dataset represents 1322 different instances where different synthesis conditions were studied along with various Pd dispersion values. All the analysis and machine learning models were prepared via using this document. This document was not attached to Appendix to avoid duplication.

In pre-analysis of the data, synthesis methods findings are given in Figure 3.1 and Figure 3.2. While the novel methods were excluded in the study to avoid misinterpretation, it is still clear that researchers tend to use impregnation techniques as it is seen in Figure 3.1. In the decision of synthesis method, researchers consider several factors. The first factor is the applicability of these techniques. Ideally, synthesis methods should offer low operational cost and avoid complex procedures which might cause deviations between different batches. Impregnation techniques appear as an outstanding choice based on these expectations. Another important point in synthesis method selection is related to metal loading. As explained in Introduction, Pd is highly expensive material and achieving desired metal loading in the synthesis is crucial for the researchers.

Thereupon, the synthesis method must offer strong control over metal loading. In the study, to understand the success of synthesis methods on achieving desired metal loading, both theoretical and actual metal loading values were collected. While theoretical metal loading indicates the researcher's intention, actual metal loading shows the final metal loading that they reached after the synthesis. Figure 3.2 shows the average differences between actual and theoretical metal loadings % for various methods. Average difference (AD) between actual and theoretical metal loadings were found with the following formula:

$$\mathrm{AD} = \frac{\sum_{n=1}^{N} \text{Theoretical metal loading wt.\%} - \text{Actual metal loading}}{N} \quad (3.1)$$

where N is the number of instances where both theoretical and actual metal loading wt. % provided for that synthesis method. It appears that microwave-assisted synthesis, which has the highest difference between theoretical and actual metal loading, does not offer strong control over metal loading and loss of Pd precursor solution recorded. Not only impregnation techniques show the lowest metal loading difference, also it is possible to address the difference between different impregnation techniques. As introduced in Methodology, IWI uses a controlled amount of solvent which is different from wet impregnation. While wet impregnation gives an average difference of 0.1, IWI gives the best performance with 0.004 average difference.

Dispersion distribution based on the synthesis method was also assessed in Figure 3.3. The highest dispersion (100%) data points belong to impregnation techniques which can be directly related to the commonness of this method. While wet impregnation shows a normal distribution trend, an accumulation at 0-25 % was identified. The dispersion distribution of deposition-precipitation, as another option, shows the potential of the method to achieve high Pd dispersion % values even though it is significantly less frequent than impregnation in the dataset. Huang and coworkers stated the advantages of deposition-precipitation technique previously in their work and they compared Pd/TiO_2 catalysts which were synthesized with impregnation and deposition-precipitation.[395] They indicated that deposition-precipitation offers better performance due to their chemisorbed oxygen generation/activation capacity.[396]

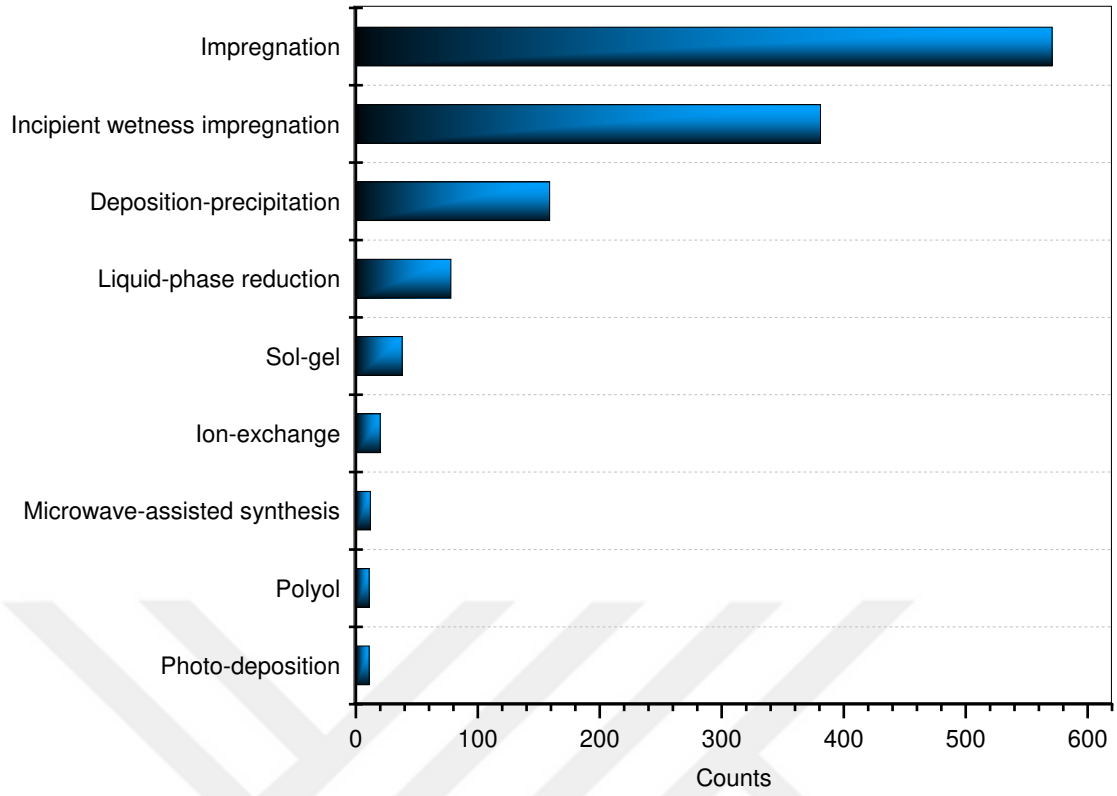

Figure 3.1. Distribution of synthesis method selection in the dataset.

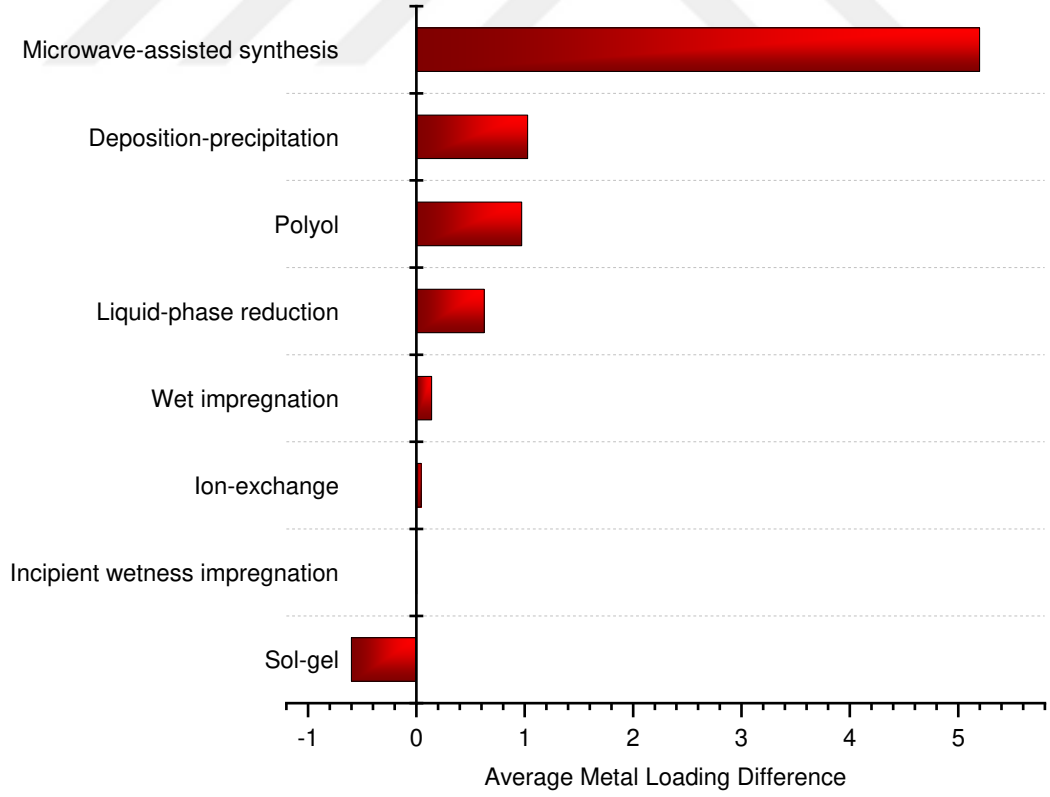

Figure 3.2. Average metal loading differences for different synthesis methods.

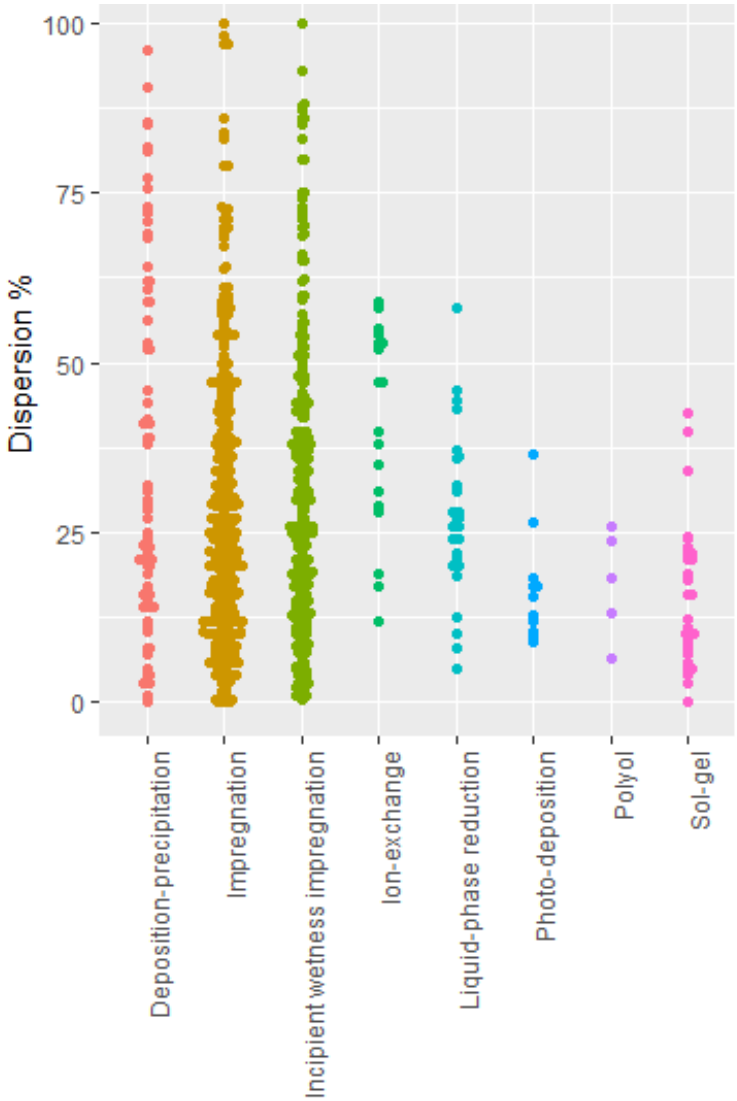

Figure 3.3. Dispersion distribution for synthesis methods.

Support selection seen in Figure 3.4 proves the predominance of carbon and alumina supported Pd catalysts in the dataset. Carbon is a widespread choice as a support in catalytic systems due to its high surface area, stability under high temperature conditions, good resistance to acidic and basic environment and its availability.[397] Different types of carbon appear as a possible preference for researchers. In the reported studies, activated carbon, mesoporous carbon, carbon monoliths, graphene, carbon black, carbon nanotubes, carbon nano globules, carbon crystallites, microcrystalline cellulose were seen as carbon sources. The fundamental difference of these sources is that their surface areas are quite different from each other. For instance, while wood-based activated carbon has 980 m^2/g, graphite has a surface area of 14 m^2/g.[270,310] Carbon black and activated carbon

can be seen as the common preference between these different carbon sources which is related to the high surface area of these materials. It should be remembered that carbon sources are determining factors for pre-treatment decisions.

Dispersion distribution for common supports is represented in Figure 3.5 which shows the complexity of understanding the relation between metal dispersion and the support selection. The higher Pd dispersion results (>75 %) were collected for alumina supports which was followed by cerium oxide. The unique feature of cerium oxide as support was previously introduced by de Souza and coworkers which was the higher concentration of oxygen vacancies of Pd/CeO_2 compared to Pd/Al_2O_3, Pd/TiO_2 and Pd/ZrO_2.[398] It is known that the strong metal-support interaction can be achieved by the support oxygen vacancies and it might be the reason of high Pd dispersion results seen for Pd/CeO_2 in Figure 3b.[399]

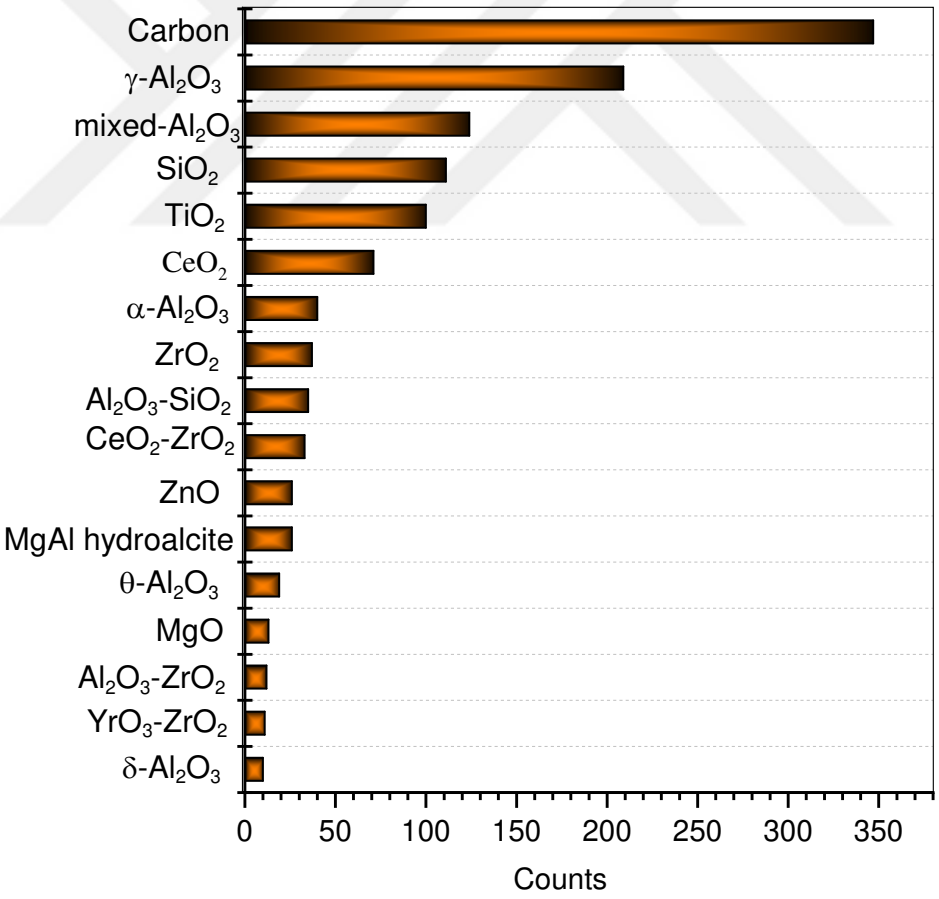

Figure 3.4. Distribution of support selection in the dataset.

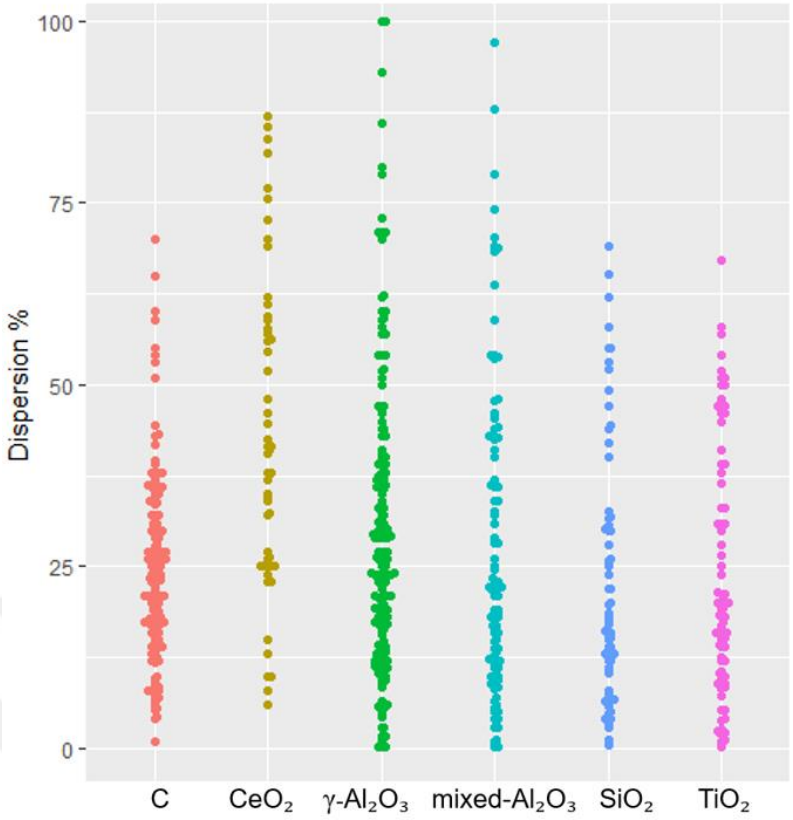

Figure 3.5. Dispersion distribution of common supports of the dataset.

Pd loadings were also observed. The Pd metal loading distribution is presented in Figure 3.6. Even though most of the studies preferred 1-5 wt. % Pd loading, low (< 0.5 wt. %) and high (>20 wt. %) Pd loading preference differs for carbon supported catalysts compared to metal oxides supported ones. In Figure 3.7, while working with Pd/C, researchers preferred to select higher metal loading wt. % which might be linked to the high surface of carbon materials. On the contrary, while working with carbon-supported and oxide-supported Pd catalysts in the same study, Pinna and coworkers preferred to select Pd loading which is 10 times lower than oxide-supported catalysts to prevent large differences on dispersion.[31] Pinna and coworkers explained this difference with the egg-shell distribution of carbon supported Pd catalysts.[31]

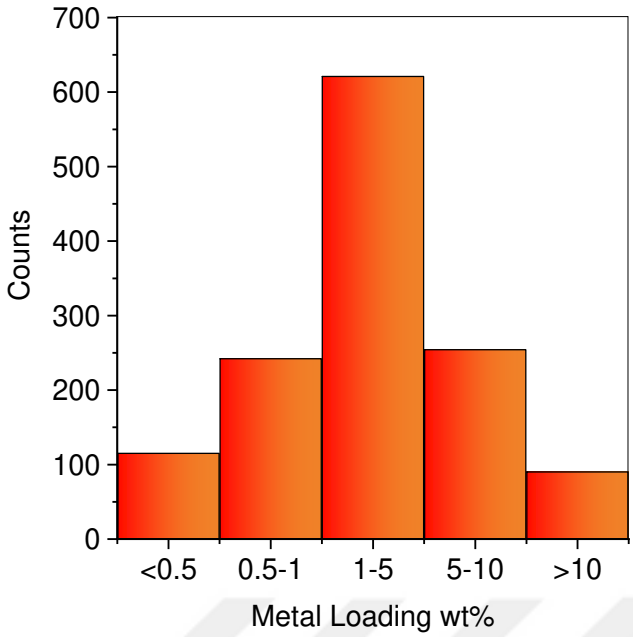

Figure 3.6. Distribution of metal loading in the dataset[*].

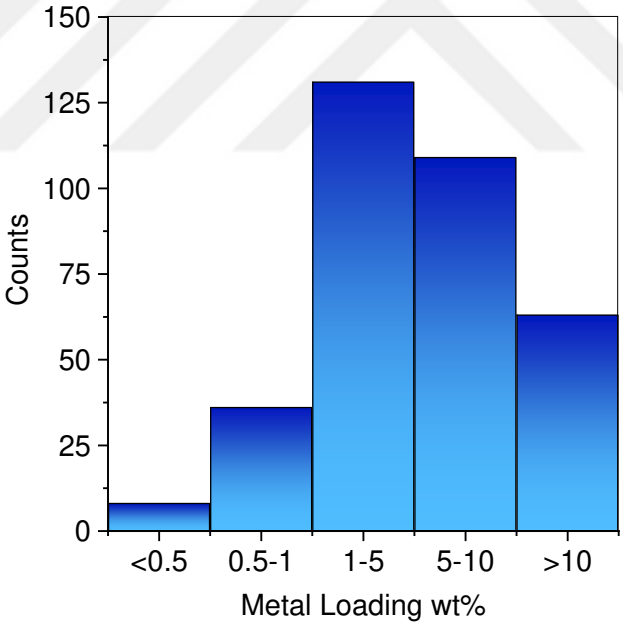

Figure 3.7. Distribution of metal loading in the dataset for carbon supported Pd catalysts only[†].

[*] If theoretical Pd loading wt.% was given, it was used as the Pd metal loading wt.%. If theoretical Pd loading wt.% was not provided, actual Pd loading wt.% was used.

[†] If theoretical Pd loading wt.% was given, it was used as the Pd metal loading wt.%. If theoretical Pd loading wt.% was not provided, actual Pd loading wt.% was used.

Pd dispersion results based on Pd metal loading are illustrated in Figure 3.8. The results show that it is possible to achieve any Pd dispersion value with metal loadings which are less than < 1 wt.%. According to the analysis, high metal loadings (> 5 wt.%) do not appear to be promising to have Pd dispersion which is more than 75 %.

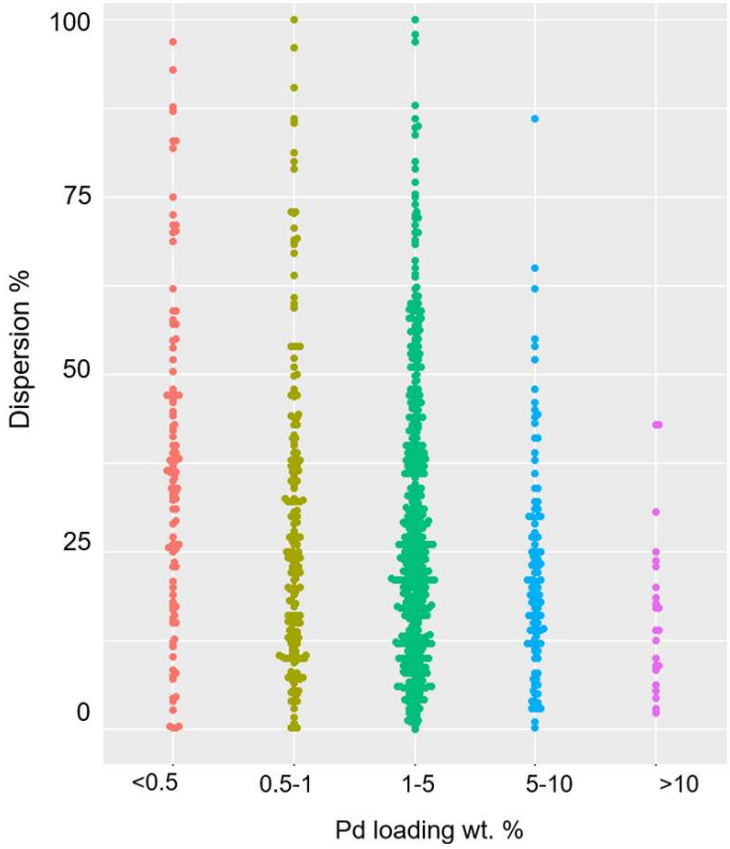

Figure 3.8. Pd loading wt.% and Pd dispersion correlation.

Table 3.1. Pd precursors in the dataset and the corresponding calculated price comparison factors‡.

Precursor	Price Comparison Factor
$PdCl_2$	1.00
$Pd(NO_3)_2$	1.74
$Pd(acac)_2$	1.76
$Pd(OAc)_2$	1.49

‡ The price comparison factor was calculated approximately which corresponds to the cost of purchasing 1 gram of Pd. Precursors with more than 50 instances in the dataset were represented here.

$Pd(NH_3)_4\,(NO_3)_2$	4.22
$Pd(NH_3)_4\,Cl_2$	1.87

Precursor selection is highly related to the costs of Pd. In Table 3.1, prices of popular Pd precursors were compared via calculating a price comparison factor. While $PdCl_2$ appears to be the least expensive option, $Pd(NH_3)_4\,(NO_3)_2$ is found to be the most expensive one. Pd precursor prices and the frequency of these precursors in the dataset were found to be directly linked to each other. Figure 3.9 proves that the most common precursors in the dataset are also the least expensive options for the researchers: $Pd(acac)_2$, $Pd(NO_3)_2$, $Pd(OAc)_2$ and $PdCl_2$. The most common precursor is identified as $PdCl_2$. Pd dispersion distributions for $PdCl_2$ in Figure 3.10 approves that $PdCl_2$ is an excellent choice with its lower cost and its potential to achieve desired metal dispersion.

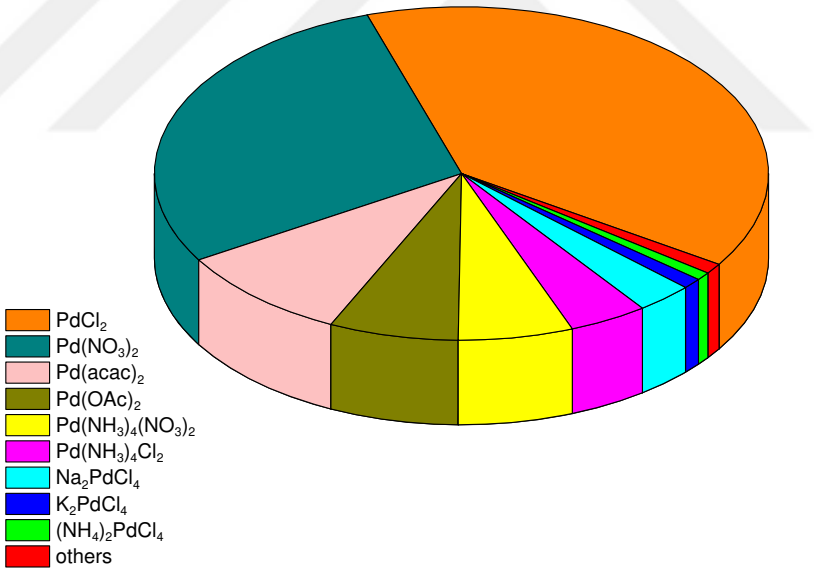

Figure 3.9. Distribution of Pd precursors in the dataset[§].

[§] Precursors with ≤ 10 instances were given in the distribution.

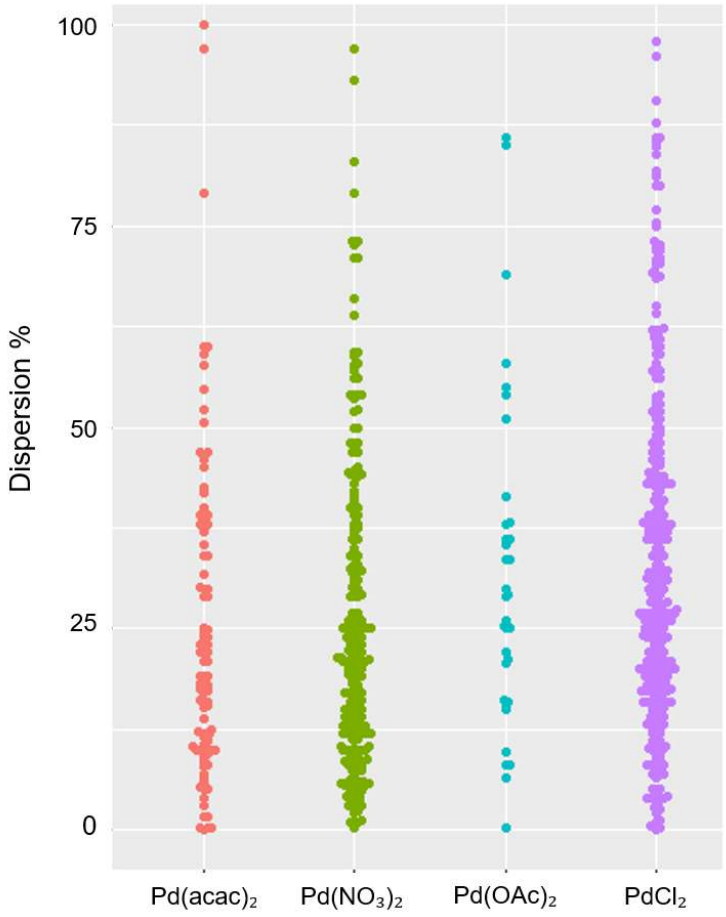

Figure 3.10. Dispersion distribution for common Pd precursors.

Calcination and reduction temperature were also discussed in Figure 3.11 and Figure 3.12. Analysis proves that increase in calcination temperature after 900 K generally resulted in decrease in Pd dispersion. Same trend was observed for the reduction temperature with an exception at 1200 K. Also, while the instances where calcination was not performed had a similar average Pd dispersion with the instances where calcination was done, significant difference between instances with and without reduction was observed.

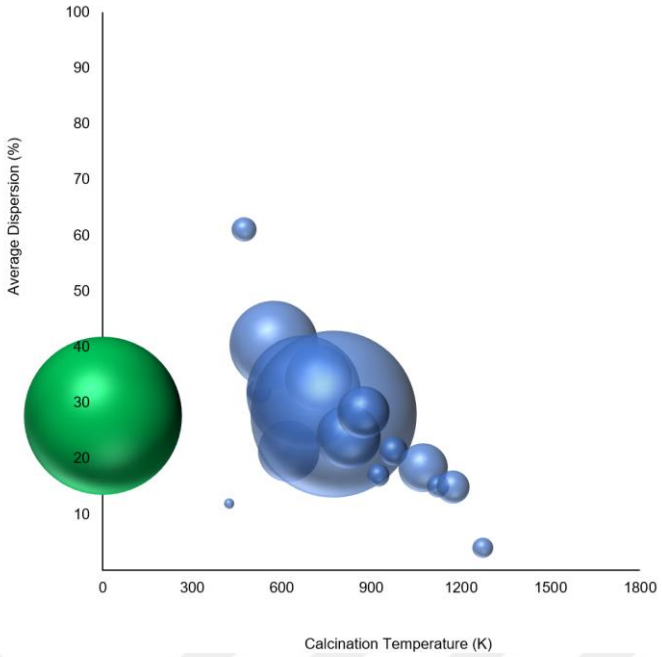

Figure 3.11. Distribution of calcination temperature in the dataset[**].

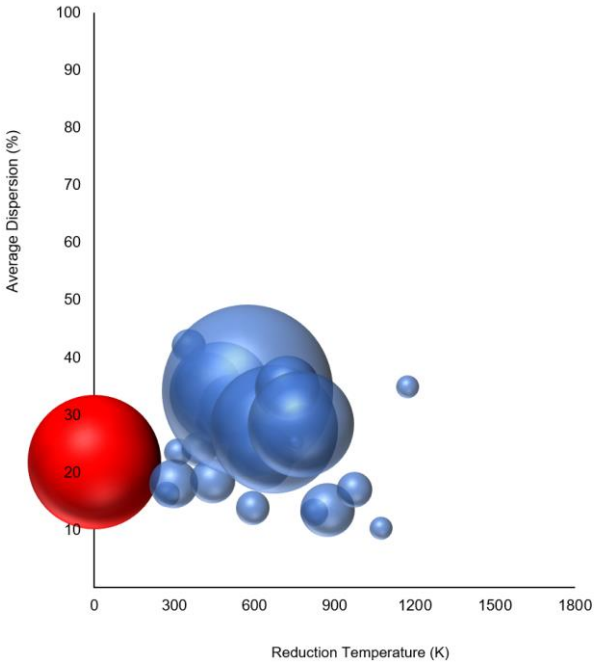

Figure 3.12. Distribution of reduction temperature in the dataset[††].

[**] Green bubble represents the data points where the pre-treatment was not performed or not given. Bubble size indicates the counts of the instances at that temperature. Pd/C catalysts were excluded from these analyses.

[††] Red bubble represents the data points where the pre-treatment was not performed or not given. Bubble size indicates the counts of the instances at that temperature. Pd/C catalysts were excluded from these analyses.

3.1.1. ARM Results

ARM commonly is preferred in marketing to discover the correlations which are hard to notice by eye and used in this study to analyze the relations between synthesis parameters. Pd particle size was categorized into four categories: < 2, 2-5, 5-10 and >10 n and input variables were discretized into maximum 7 categories which were discussed prior in Methodology. Two operations were completed with ARM. Initially, all the categorized variables were studied together, and correlations were searched. In the latter, the dataset was grouped into 4 groups via using Pd particle categories and correlations between input variables were searched with respect to Pd particle size. In ARM, lift values were used to understand whether there is a positive correlation between two variables. If lift is higher than 1.0, it indicates that there is a positive correlation.[390] If it is 1.0, there is no significant correlation between parameters that can be stated.[390]

The obtained results show that four correlations appear to be linked for precursor and solvent relation: $Pd(acac)_2$ and toluene, $Pd(acac)_2$ and acetone, $Pd(NO_3)_2$ and water, $PdCl_2$ and aqueous hydrochloric acid. The strongest correlation is identified between $Pd(acac)_2$ and toluene. Lift values for these relations were presented in the following tables.

Table 3.2. ARM lift results for Pd particle size < 2 nm.

Pd Particle Size: < 2 nm			
solvent (RHS)	**Precursor (LHS)**		
	$PdCl_2$	**$Pd(NO_3)_2$**	**$Pd(acac)_2$**
water	<1	**1.49**	<1
aqueous HCl	**2.53**	<1	<1
HCl	**2.53**	<1	<1
acetone	<1	<1	<1
toluene	<1	<1	**9.5**

Table 3.3. ARM lift results for Pd particle size 2 -5 nm.

Pd Particle Size: 2-5 nm			
Solvent (RHS)	**Precursor (LHS)**		
	$PdCl_2$	**$Pd(NO_3)_2$**	**$Pd(acac)_2$**
water	<1	**2.18**	<1
aqueous HCl	**2.46**	<1	<1
HCl	**2.46**	<1	<1
acetone	<1	<1	**8.76**
toluene	<1	<1	**8.76**

Table 3.4. ARM lift results for Pd particle size 5-10 nm.

Pd Particle Size: 5-10 nm			
Solvent (RHS)	**Precursor (LHS)**		
	$PdCl_2$	**$Pd(NO_3)_2$**	**$Pd(acac)_2$**
water	<1	**2.03**	<1
aqueous HCl	**2.78**	<1	<1
HCl	**2.78**	<1	<1
acetone	<1	<1	**8.52**
toluene	<1	<1	**9.47**

Table 3.5. ARM lift results for Pd particle size > 10 nm.

Pd Particle Size: > 10 nm			
Solvent (RHS)	**Precursor (LHS)**		
	$PdCl_2$	**$Pd(NO_3)_2$**	**$Pd(acac)_2$**
water	<1	**1.30**	<1
aqueous HCl	**3.18**	<1	<1
HCl	**3.18**	<1	<1
acetone	<1	<1	**10.08**
toluene	<1	<1	**8.40**

In Figure 3.13 and Table 3.6, synthesis methods and Pd particle size relations are illustrated. Although positive correlation was identified with impregnation techniques and Pd particle size > 10 nm, the lift values were measured close to 1. Sol-gel and liquid-phase reduction methods were found to be correlated with Pd particle size of 2-5 nm and the strongest correlation was calculated between deposition-precipitation method and Pd particle size < 2 nm. Consequently, deposition-precipitation appears to be a great option for lower Pd particle sizes which might be linked to pH adjustment.

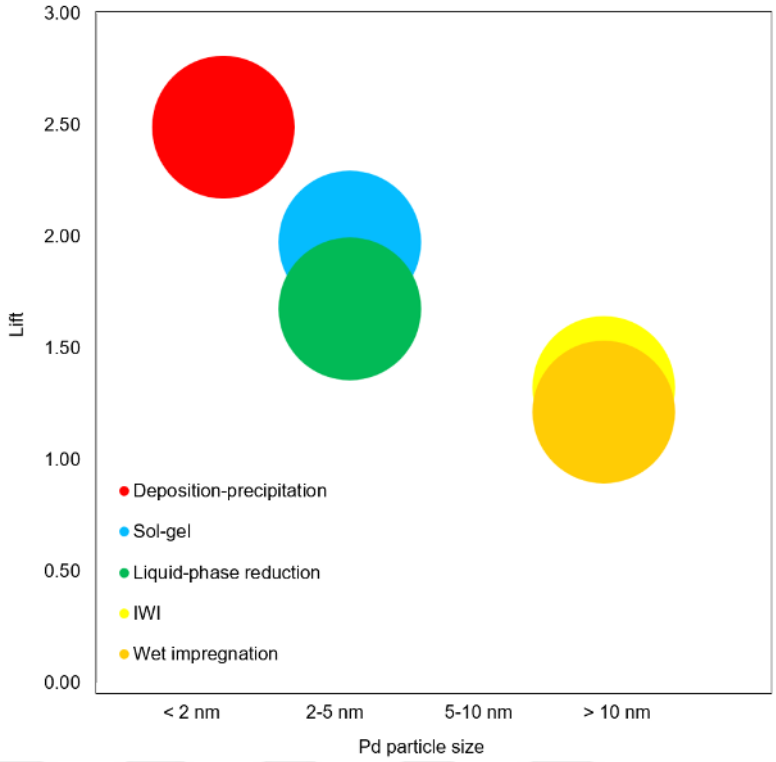

Figure 3.13. ARM Results Analysis: Relation between synthesis methods and Pd particle sizes.

Table 3.6. ARM lift results for method and Pd particle size relation.

Method (LHS)	Pd Particle Size (RHS)	Lift
Deposition-precipitation	< 2 nm	**2.49**
Sol-gel	2-5 nm	**1.98**
Liquid-phase reduction	2-5 nm	**1.68**
IWI	> 10 nm	**1.32**
Wet impregnation	> 10 nm	**1.21**

Moreover, in Figure 3.14 and Table 3.7, support surface area and Pd particle size relation were given. While lowest support surface area is found to be correlated with Pd particle size > 10 nm, the correlations again proves that Pd particle size estimation is quite complex and observing a linear relation is not possible.

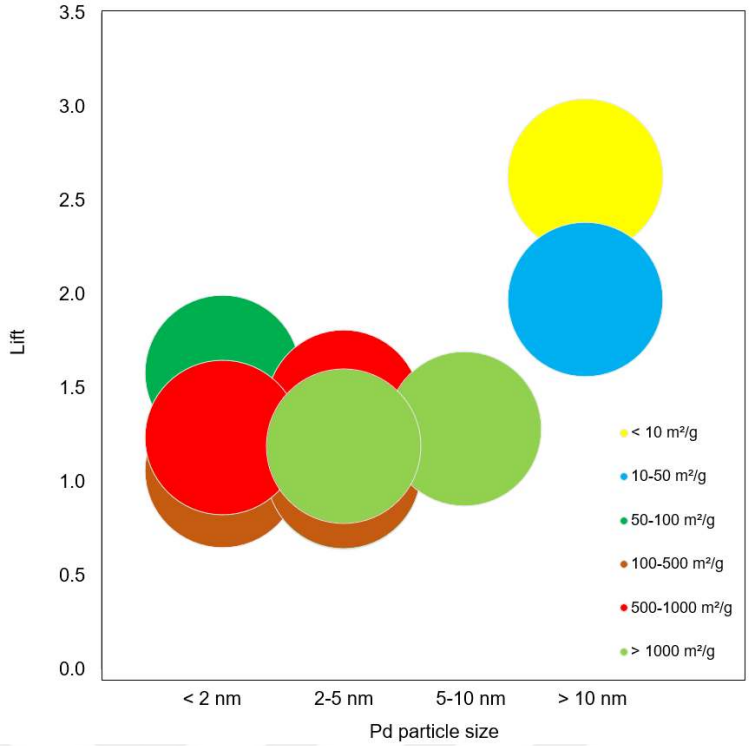

Figure 3.14. ARM Results Analysis: Relation between SSA and Pd particle sizes.

Table 3.7. ARM lift results for support surface area and Pd particle size relation.

Support Surface Area (LHS)	Pd Particle Size (RHS)	Lift
< 10 m²/g	> 10 nm	**2.63**
10-50 m²/g	> 10 nm	**1.97**
50-100 m²/g	< 2 nm	**1.58**
500-1000 m²/g	2-5 nm	**1.40**
> 1000 m²/g	5-10 nm	**1.28**
500-1000 m²/g	< 2 nm	**1.24**
> 1000 m²/g	2-5 nm	**1.19**
100-500 m²/g	2-5 nm	**1.06**

100-500 m²/g	< 2 nm	**1.06**
50-100 m²/g	2-5 nm	**1.05**

When ARM results between PZC and solvent pH relation were discussed, it is seen that correlation was only identified between PZC < 7 and solvent pH > 7. It was expected to see this correlation to achieve strong metal-support interaction in the synthesis. Interestingly, the opposite correlation where PZC > 7 and solvent pH < 7 was not found significantly correlated. The reason might be related to the low frequency of data points where pH adjustment procedure was applied. These findings highlight that there might be a potential opportunity to improve metal-support interaction which seems to be not popular as it is expected.

Table 3.8. ARM lift results for support PZC and solvent pH relation.

PZC	Solvent pH	Lift
< 7	> 7	**1.76**
> 7	< 7	**0.96**
< 7	< 7	**0.40**
> 7	> 7	**0.29**

3.1.2. Classification tree results

Classification trees are useful tools to visualize the effects of decisions. Here, the classification tree is prepared to provide a simple way to make decisions for synthesis of supported Pd catalysts. Each branch in the tree represents a decision for the input variables. Initially, Pd particle size was divided into three groups: < 5 nm, 5-10 nm, > 10 nm. Then, randomly selected 80% of the dataset (train data) was divided into five groups for cross-validation. In cross validation, four groups were used for construction of the tree and the rest were used to validate the model. This process was repeated five times until using each of these five data groups used for validation. After model hyperparameters

were decided based on five-fold cross validation, the remaining 20% of the dataset which was not seen by the model in the construction was used for the accuracy testing. Complexity parameter (cp) and minimum split number were decided as 0.01 and 5, respectively. Figure 3.15 shows the classification tree where the nodes represent synthesis parameters decisions with different Pd particle sizes.

In the first node, the whole classification tree dataset is seen. 55% of the dataset represents Pd particle size less than 5 nm. Data is first divided via checking Pd loading which is a reasonable generalization based on the high influence of metal loading on metal particle size. If Pd loading less than <0.87 wt.%, the tree continues to branch from the left side. It corresponds to 25% of the dataset and most of the dataset (75%) has a Pd particle size less than 5 nm. This path indicates that when researchers have considerably low Pd loading, it is likely to synthesize supported Pd catalysts which have metal particle size less than 5 nm. When the path to node 4 is discussed, the strong correlations between deposition-precipitation, sol-gel and liquid-phase reduction methods and small Pd particle size are seen which satisfy the ARM results. Node 4 represents 21% of the dataset and the percentage of achieving Pd particle size less than 5 nm is still quite high at this point. The classification tree represented here has an overall accuracy of 0.74 which shows the capability of the tree for quick estimation of Pd particle size during experiment design.

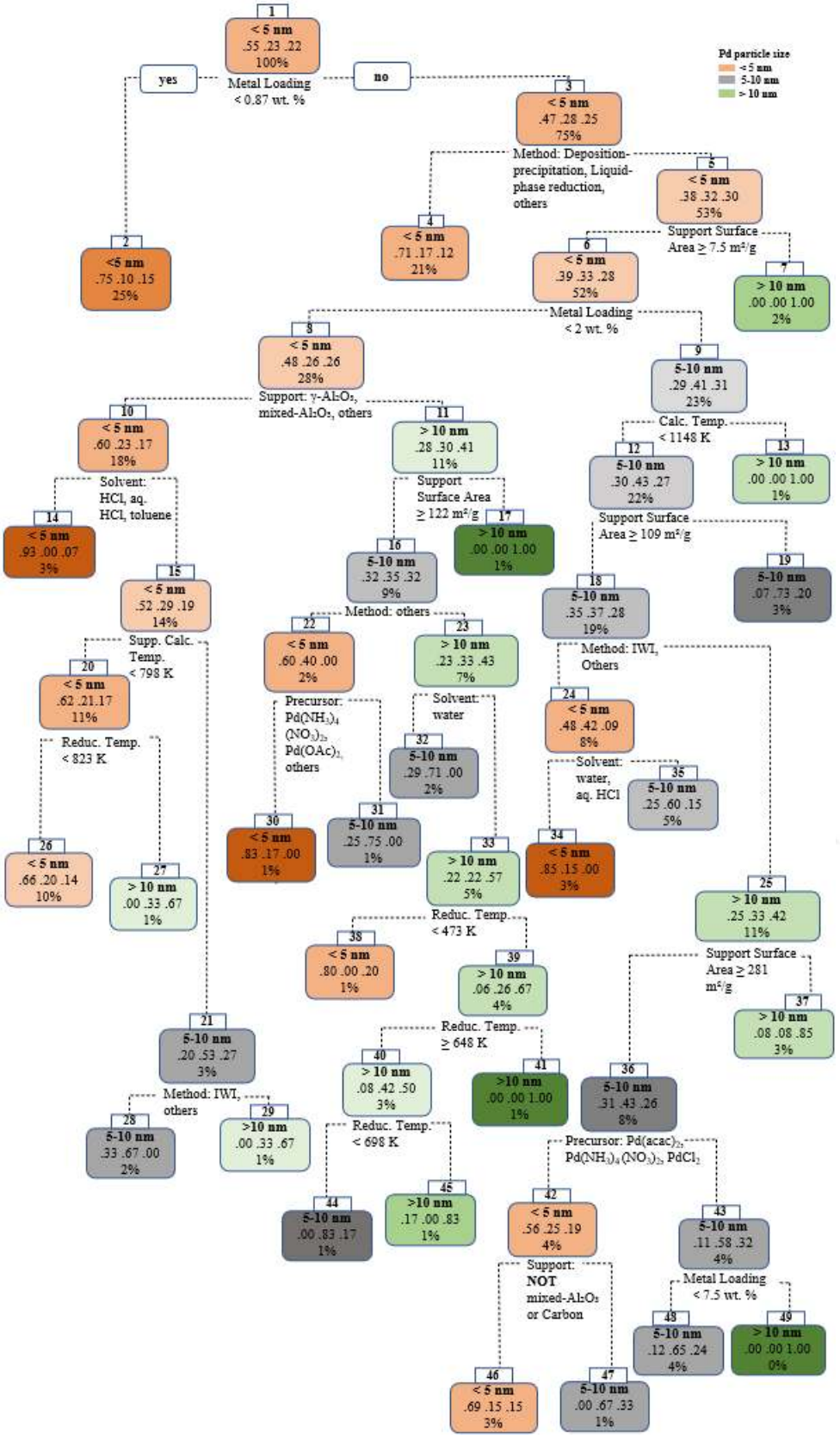

Figure 3.15. Classification tree result.

3.2. Development of the ML Models for Dispersion Prediction

Variable selection has a crucial role in model development. While ML creates an opportunity to work with systems which have a high number of variables, unnecessary variables must be avoided to increase the model accuracy. In this study, variable selection was done with the help of Boruta algorithm. As it is seen in Figure 3.16, all the variables were found important and included in the Random Forest models. The most important input variables were identified as metal loading, support surface area and PZC which reassure the domain knowledge on supported catalyst synthesis.

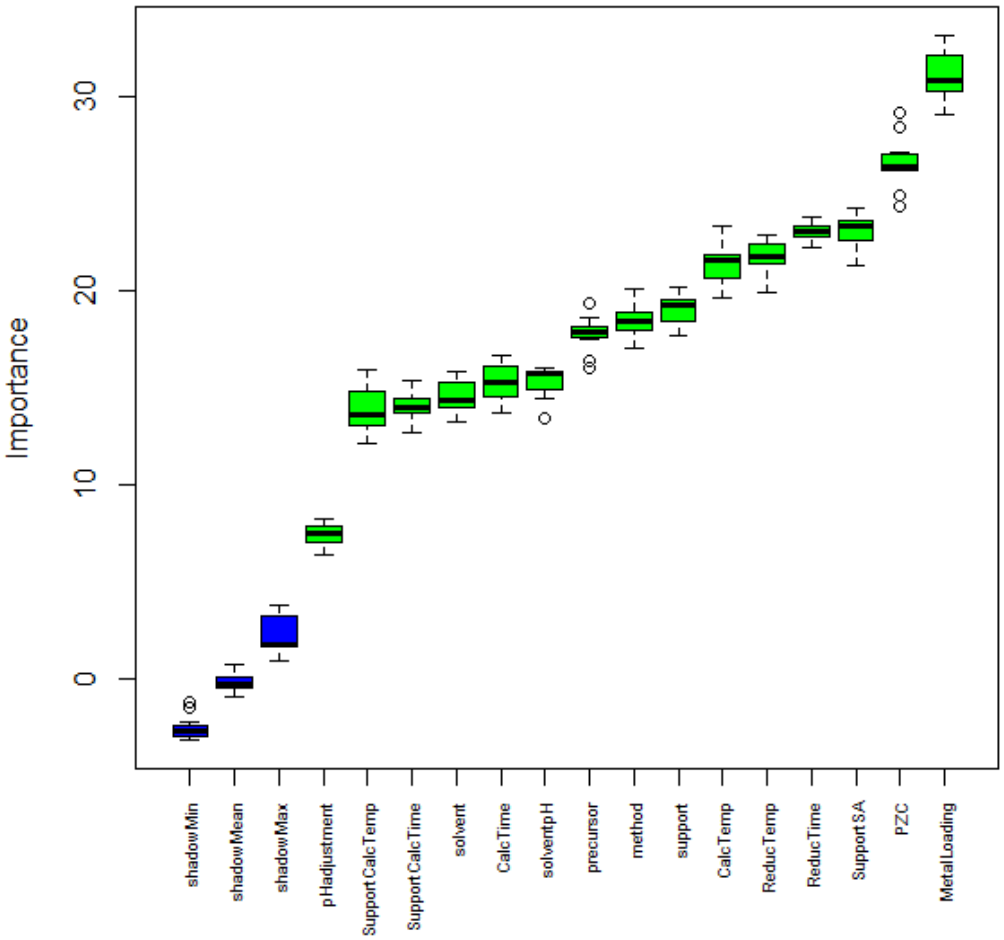

Figure 3.16. Boruta importance plots of input variables for dispersion predictive model.

After variable selection, dispersion predictive models were built. The random forest model was decided to be the best option for dispersion prediction after considering the other models. Like the classification tree, the dataset was divided into two groups as training and testing data. Train data contains 80% of the dataset which was randomly selected. This data was also divided into five datasets. While building the model with four

of these datasets, the remaining dataset was used for validation. The process repeated five times while also changing the hyperparameters. After completing this step, hyperparameters were decided based on lowest rmse, mean absolute error and highest R^2 results. Finally, models were developed for training and testing data.

The optimum parameters were found 50 for the optimum tree number and 5 for the optimum number for each split. R^2, rmse and mae were calculated as 0.84, 8.32 and 5.90 for the training set. For test data, on the other hand, mean absolute error, rmse and R^2 were found 10.91, 15.02 and 0.46, respectively. It is seen that the model overestimates low dispersion (< 40 %) and underestimate high dispersion (> 60 %) results. The reason behind this situation might be related to absence of a variable which has an impact on the Pd dispersion or not being able to reflect the importance of one of the input variables fully. The results can be seen in Figure 3.17 for train and test data sets.

To overcome the challenges and achieve better fit, a correction function was used. In the model, the best fit with lowest rmse was identified and a correction function was defined as *1.13x-5.43*. After applying the correction function, R^2, rmse and mae were calculated as 0.85, 7.89 and 5.51 for the training set, respectively. Test model results for R^2, rmse and mae were calculated as 0.45, 15.22, and 10.95, respectively. Results were in illustrated in Figure 3.18 which shows the better fit of predictions with respect to the observed data compared to the results without correction factor. The model still tends to underestimate high dispersion values which may happen due to low frequency of the high dispersion values in the dataset.

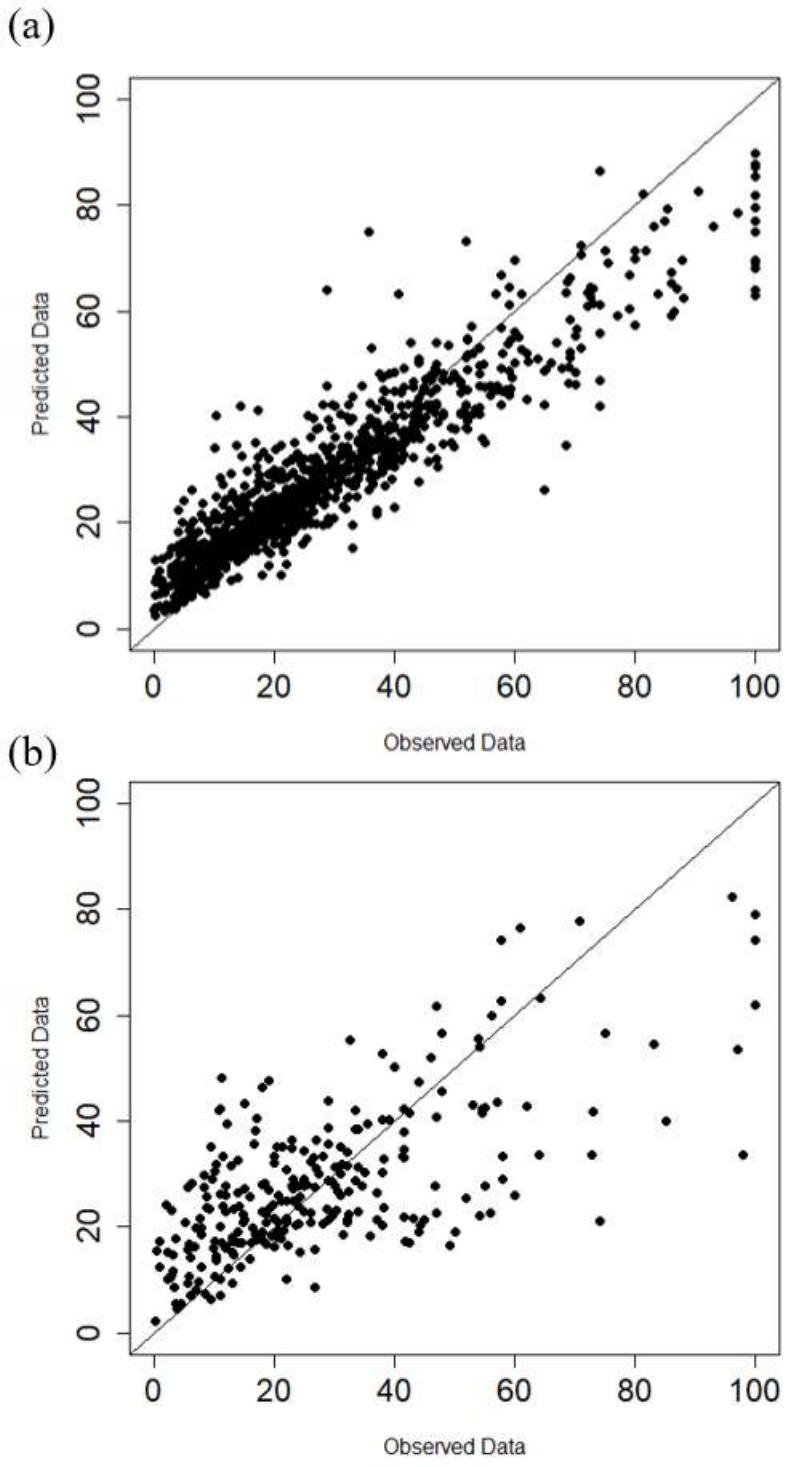

Figure 3.17. Dispersion prediction before correction function. a, Train data results. b, Test data results.

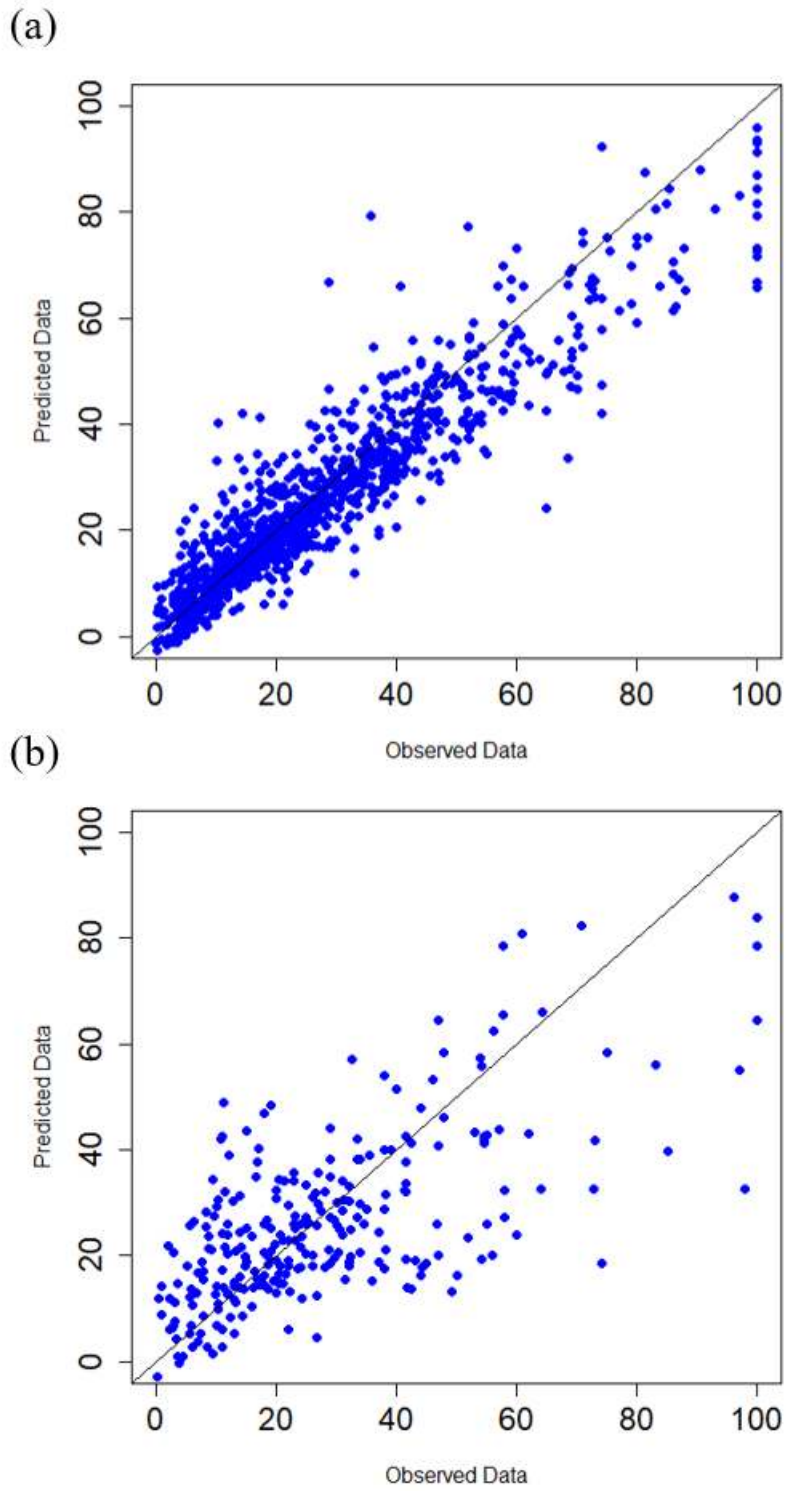

Figure 3.18. Dispersion prediction after correction function. a, Train data results. b, Test data results.

3.3. Development of the ML Models for Pd Particle Size Prediction

Predictive models were developed for both Pd dispersion and Pd particle size. Similar steps were taken for Pd particle size predictive model development. Initially, variable selection was done via Boruta algorithm.

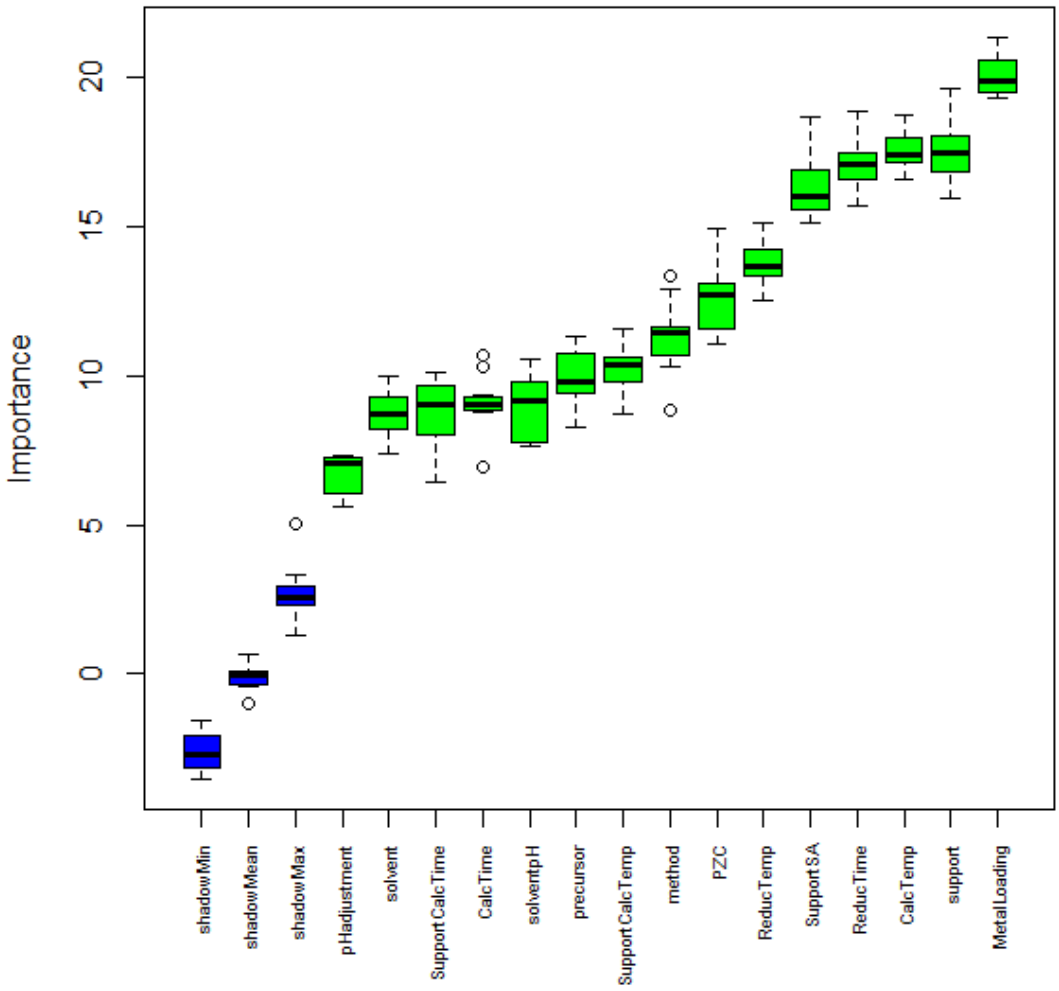

Figure 3.19. Boruta importance plots of input variables for metal particle size predictive model.

While there are some differences observed compared to Boruta results of dispersion predictive model, it is again seen that all the variables are important for the prediction. Metal loading was identified as the most important variable like dispersion predictive model. On the other hand, ranking of PZC is found quite different than the other model.

After variable selection, the hyperparameters were discussed via cross validation and set as 50 for ntree and 5 for mtry. Then, model results were taken for train and test data sets. Mean absolute error, rmse and R^2 values were calculated for these datasets. Again, to increase the accuracy of model, correction function was defined as *1.17x-10*. All the

results were given in Table 3.9. Pd particle size predictive model is found to be less reliable compared to Pd dispersion predictive model which might be linked to the shorter range of Pd dispersion values. The results with and without correction factor were given in Figure 3.20 and 3.21.

Table 3.9. Pd particle size prediction results.

		mae	rmse	R^2
Before correction function	Train data	25.48	40.89	0.62
	Test data	35.62	57.43	0.42
After correction function	Train data	24.16	38.45	0.67
	Test data	34.92	55.97	0.45

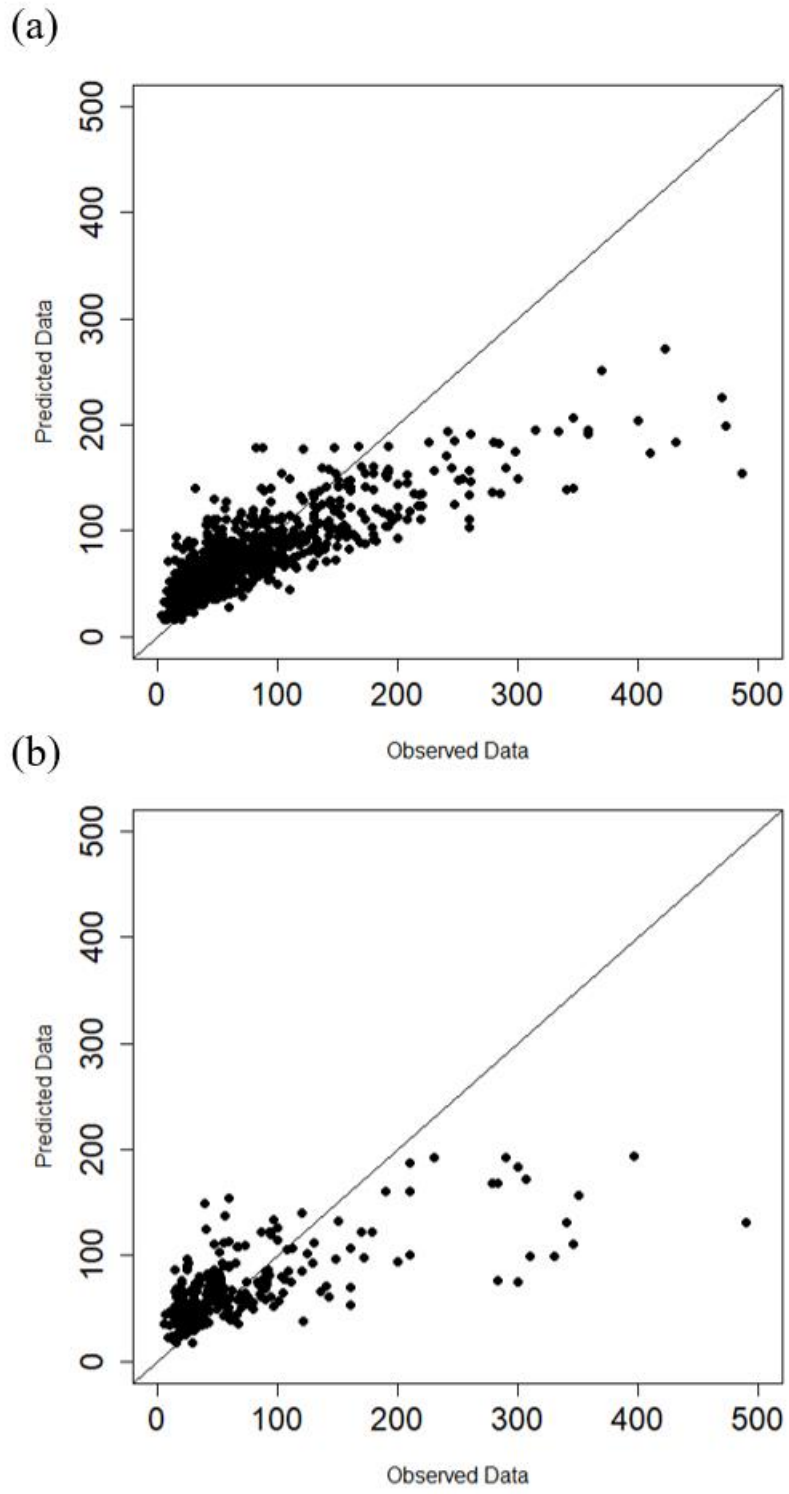

Figure 3.20. Pd particle size prediction before correction function. a, Train data results. b, Test data results.

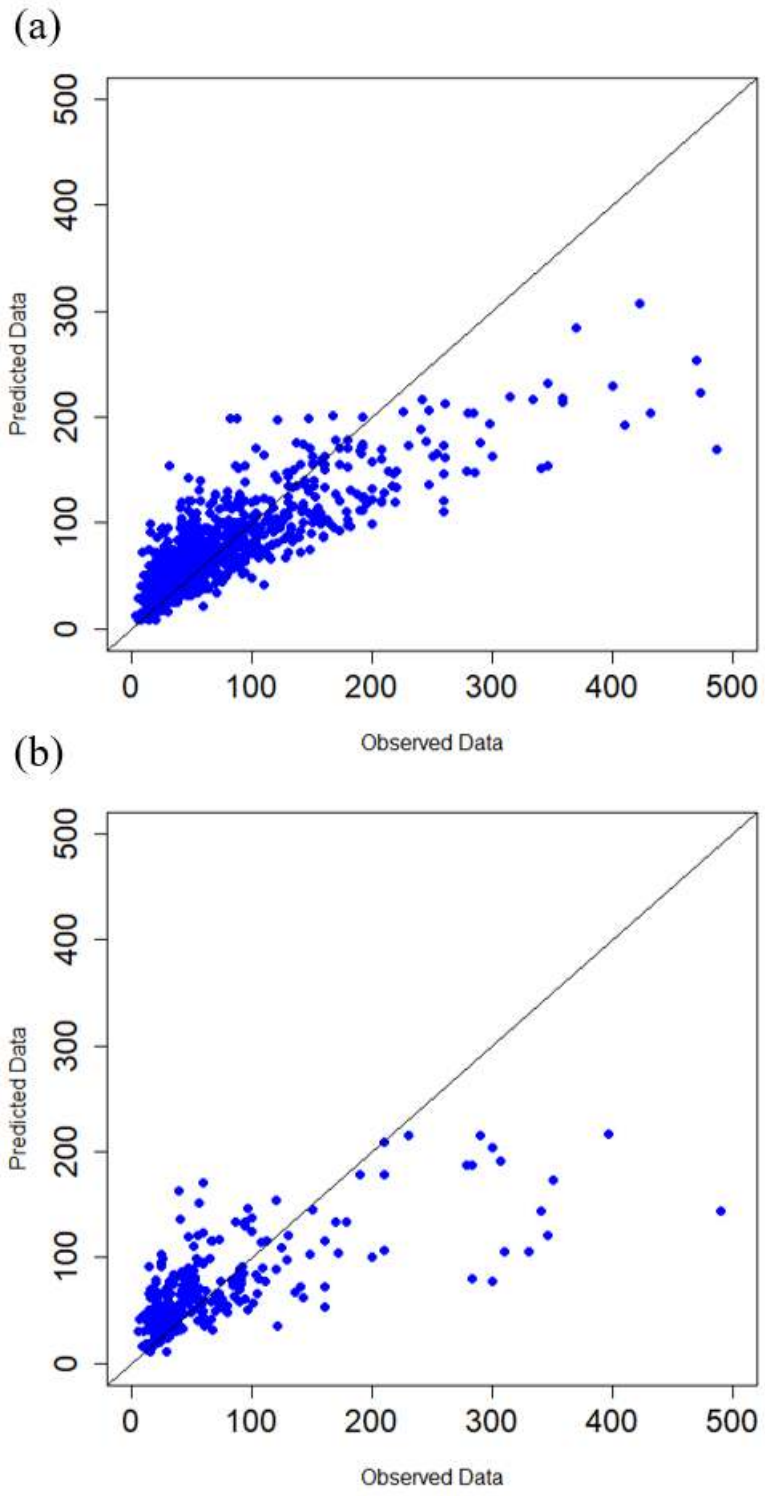

Figure 3.21. Pd particle size prediction after correction function. a, Train data results. b, Test data results.

3.4. Validation of the Machine Learning Models by Experiments

The aim of this study is to provide a model which can be used to predict Pd dispersion after deciding synthesis conditions. Although the predictive models were tested by using testing data. It was also tested via comparison with experimental results to understand the reliability. Initially, synthesis conditions were decided based on the dataset (considering common preferences) and Pd dispersion values for these planned experiments were predicted via the model. Then, these predictions were compared with dispersion measurements which were done with CO chemisorption experiments. Table 3.10 shows the predicted and measured dispersion values. The comparison proves the success and usability of the model in the daily work of researchers. Experimental data documents and corresponding model code were provided in Appendix which can be easily edited and used for dispersion prediction by researchers.

It is known that experimental studies always have a certain error due to the dependence on instruments and human operations. In this study, using experimental data to build the ML model creates some challenges. To reflect the effect of fluctuations and address the differences between predictions of the model and experimental measurements, each experiment repeated with same parameters. As it is seen in Table 3.10, differences can be quite significant between two runs taken from CO chemisorption which proves the success of the predictive model where predictions have similar pattern with the experiment results.

Table 3.10. Pd dispersion predictions and experimental results.

Exp. No.	Catalyst	Measured Pd Dispersion % RUN 1	Measured Pd Dispersion % RUN 2	Avg. of Measurements %	Predicted Pd Dispersion %
1	Pd/γ-Al_2O_3	20.65	31.04	25.84	36.04
2	Pd/MgO	15.54	14.36	14.95	16.07
3	Pd/SiO_2	14.41	19.95	17.18	14.38

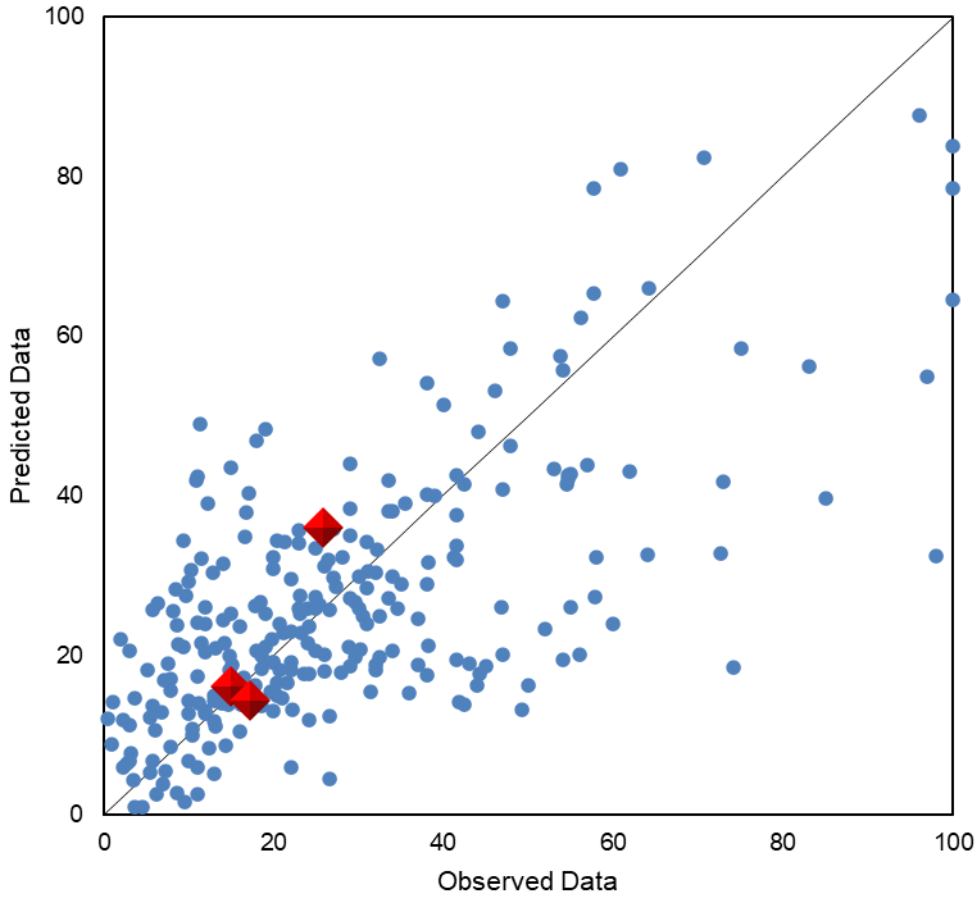

Figure 3.22. Pd dispersion predictive model results for test data with addition of experimental results.

The comparison proves the success and usability of the model in the daily work of researchers. Experimental data documents and corresponding model code were provided in Appendix which can be easily edited and used for dispersion prediction by researchers.

In conclusion, the prediction capacity of the models is noticeable especially with the consideration of challenges of working with experimental data in the model development. While the high number of data points decreases the effects of experimental errors and standard deviations of the measurements, they still have a significant influence on the performance of the model. Marshall and coworkers suggested considering FAIR data concept as a solution to data collection in heterogeneous catalysis area which might be the solution to improve the performance of models.[10] The presented models are not only useful as predictive models, but also, these models are good indicators for the need of data management methods in the heterogeneous catalysis area.

Chapter 4: Performance Tests in Selective Hydrogenation Reaction of Cyclic Olefins

Rational synthesis of supported Pd catalysts might be highly advantageous to achieve desired performances as it was explained in the introduction part. To provide more understanding about this, the findings from developed models for catalyst synthesis were used in the performance tests. In this chapter, target reaction was initially discussed via comparison of commercial and synthesized supported Pd catalysts to prove the advantages of supported Pd catalyst which has high Pd dispersion. In the second part, opportunities within the process were identified and continuous process was investigated.

4.1. Selective Hydrogenation of Cyclic Olefins

Dicyclopentadiene (DCPD) is one of the byproducts of naphtha pyrolysis process and it is commonly used as an intermediate to produce high volumetric density fuels, JP-10. JP-10 is a promising jet fuel which offers higher volumetric density (approx. more than 11%) compared to conventional jet fuels (JP-8).[400] It contains mainly exo-THDCPD (tetrahydrodicyclopentadiene) (96.5%), very low amount of endo-THDCPD (2.5%) and adamantane (1%).[400] Its' production mechanism includes two processes: catalytic hydrogenation reaction of DCPD to endo-THDCPD and isomerization reaction of endo-THDCPD to exo-THDCPD. In this chapter, DCPD hydrogenation to endo-THDCPD was performed.

The reaction pathway of DCPD hydrogenation to endo-THDCPD contains two steps.[401] In the first step, DCPD converts to 8,9-Dihydrodicyclopentadiene (DHDCPD) by breaking nonbornene (NB) bond. Although 3,4-DHDCPD is also a possible product of this initial step, it is known that 8,9-DHDCPD is the dominant one due to higher strength of cyclopentene (CP) bond compared to NB bond.[402] In the second step, CP bond breaks and endo-THDCPD is formed.

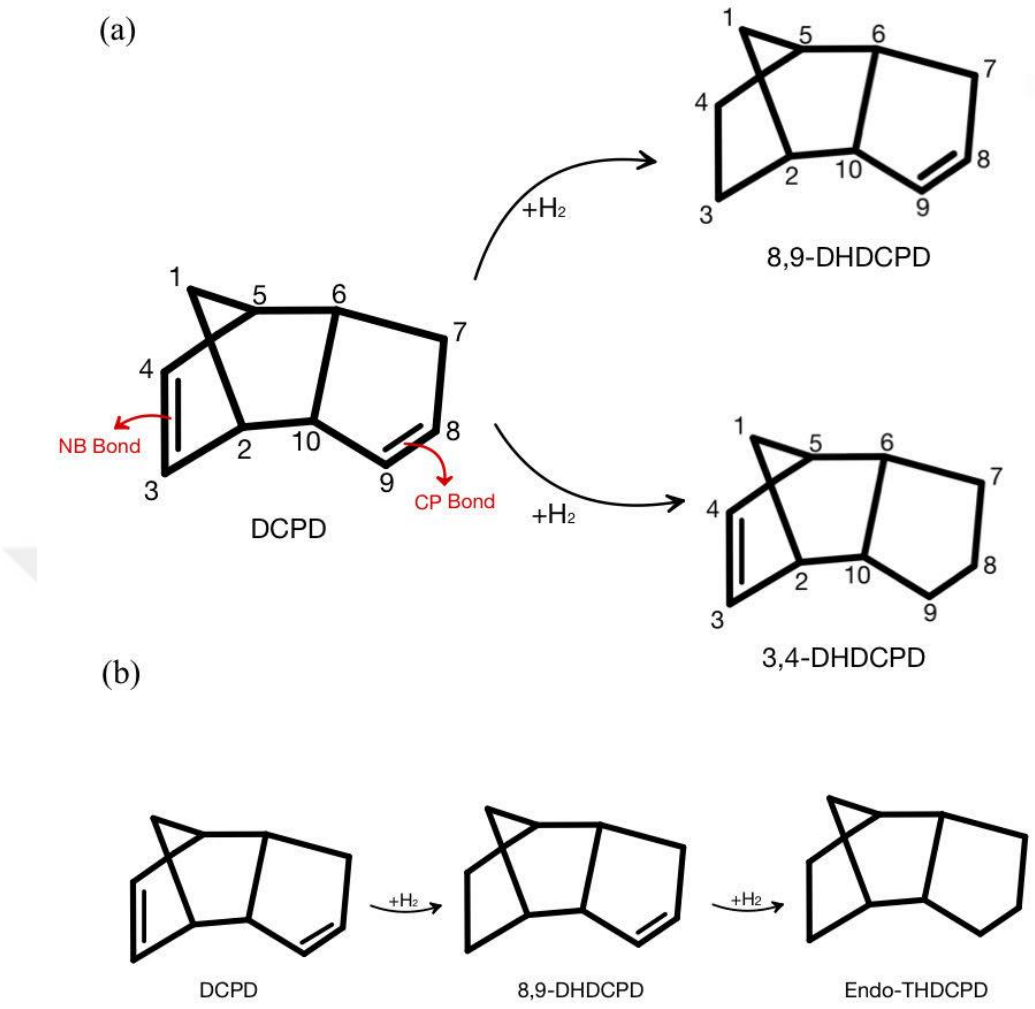

Figure 4.1. DCPD Hydrogenation Reaction Path. a, DCPD hydrogenation to 8,9-DHDCPD and 3,4-DHDCPD. b, Two-steps process of DCPD hydrogenation to Endo-THDCPD.

In the previous works, catalytic hydrogenation of DCPD to endo-THDCPD has been generally studied with nickel or palladium catalysts in the batch system. While batch process offers some certain advantages such as ability to control temperature increase due to the highly exothermic nature of this reaction, continuous process is considerably more advantageous to increase the overall efficiency. In example, in continuous processes, it is possible using the catalysts more than one cycle and there is no need to filtrate catalyst from products. These factors are crucial especially for this reaction, because Pd is an expensive catalyst and using only once is economically invisible.

In the previous studies, Wang et al reported 100% conversion of DCPD and 97.1% endo-THDCPD selectivity with 20 wt% Ni/γ-Al_2O_3 (at 150˚C and 10 bar, LHSV 20 h^{-1}).[403] Zou et al. recorded 98.5% endo-THDCPD yield at 15 bar and 130˚C with SRNA-4 in batch system.[402] While high selectivity and conversion values were achieved, optimal reaction conditions with appropriate metal loadings and space velocity remain as the challenges of this process.

In this study, different supports of Pd, Pd/γ-Al_2O_3, Pd/C and Pd/TiO_2 were studied for DCPD hydrogenation reaction at mild conditions (90 or 60 ˚C and 8 or 9 bar) in a batch and continuous processes.

4.2. Supported Pd Catalysts Performance in Batch Process

Commercial catalyst, 10 wt.% Pd/C, is commonly preferred in the industry and academia. While it offers high activity, this catalyst is quite expensive due to its relatively high metal loading. Initially, a catalyst with lower Pd loading which has a high metal dispersion (>50 %) was synthesized via using the findings of the metal dispersion prediction model. 4 wt.% Pd/γ-Al_2O_3 was synthesized and Pd dispersion was measured 88 % via CO chemisorption. The chemisorption experiment result can be seen in Appendix B.

Results of batch process reactions proves the highly active behavior of γ-Al_2O_3 supported Pd catalyst and commercial Pd/C catalyst. These two catalysts compared via using same system parameters. Catalyst amount was selected as 20 mg. Liquid mixture was 25 mL where 20 mL was methanol and 5 mL was DCPD. 4 wt% Pd/γ-Al_2O_3 and 10 wt% Pd/C gave complete conversion of DCPD in 60 ℃ and 9 bar. The selectivity of desired product, endo-THDCPD, was also 100 % for both catalysts. This situation

highlights the importance of achieving high Pd dispersion. While the synthesized catalyst has significantly lower Pd loading compared to commercial catalyst, it is found that they are both able to achieve complete conversion of DCPD to endo-THDCPD.

To define the other key parameters in the reaction, solvent was changed in the second step. When these experiments were repeated with a different solvent, difference on endo-THDCPD selectivity was perceived. In these experiments, catalyst amount, temperature, pressure, liquid mixture amount and DCPD:solvent volumetric ratio was used as same with the previous runs. Instead of methanol, hexane was selected as the solvent. Complete conversion was again recorded for 4 wt.% Pd/γ-Al_2O_3 and 10 wt.% Pd/C, but while 100 % endo-THDCPD selectivity was seen for Pd/C, 71.5 % endo-THDCPD selectivity was recorded with Pd/γ-Al_2O_3. Thus, it is believed that while using γ-Al_2O_3 as the support, solvent methanol can be more advantageous compared to hexane in batch process.

After proving the high activity of these catalysts in DCPD hydrogenation reaction, to understand the catalytic activity better, catalyst amount was lowered, and liquid mixture amount were increased. In these runs, only 8 mg catalyst with 40 mL liquid mixture (DCPD:solvent = 1:3) was used. Again, similar with the previous runs, both catalysts gave complete conversion and nearly 85 % selectivity of endo-THDCPD where methanol used as solvent. When the solvent was changed to hexane, prepared 4 wt% Pd/γ-Al_2O_3 gave 91 % conversion and 12 % selectivity of endo-THDCPD. Commercial catalyst, on the other hand, gave 99.53 % conversion of DCPD and 3.2 % endo-THDCPD selectivity. This finding satisfies the initial understanding about the advantage of methanol as the solvent. In the last step, catalyst amount was decreased to 5 mg and similar results were obtained.

Experiment parameters were summarized in Table 4.1 and Table 4.2. Results were illustrated in Figure 4.2 and Figure 4.3.

The results proves that synthesized catalyst which has high Pd dispersion (88 %) has a comparable performance with the commercial catalyst. This situation might be a great way to decrease metal loading and increase the efficiency.

Table 4.1. Batch Process Experiment Parameters for 10 wt. % Pd/C.

Catalyst	Exp. No	Parameters
10 wt.% Pd/C	Pd/C-1	Catalyst Amount: 20 mg Liq. mixture: 25 mL Solvent: Hexane DCPD: Solvent = 1:4
	Pd/C-2	Catalyst Amount: 20 mg Liq. mixture: 25 mL Solvent: Methanol DCPD: Solvent = 1:4
	Pd/C-3	Catalyst Amount: 8 mg Liq. mixture: 40 mL Solvent: Hexane DCPD: Solvent = 1:3
	Pd/C-4	Catalyst Amount: 8 mg Liq. mixture: 40 mL Solvent: Methanol DCPD: Solvent = 1:3
	Pd/C-5	Catalyst Amount: 5 mg Liq. mixture: 40 mL Solvent: Hexane DCPD: Solvent = 1:3
	Pd/C-6	Catalyst Amount: 5 mg Liq. mixture: 40 mL Solvent: Methanol DCPD: Solvent = 1:3

Table 4.2. Batch Process Experiment Parameters for 4 wt. % Pd/γ-Al_2O_3.

Catalyst	Exp. No	Parameters
4 wt.% Pd/γ-Al_2O_3	Pd/Al-1	Catalyst Amount: 20 mg Liq. mixture: 25 mL Solvent: Hexane DCPD: Solvent = 1:4
	Pd/Al-2	Catalyst Amount: 20 mg Liq. mixture: 25 mL Solvent: Methanol DCPD: Solvent = 1:4
	Pd/Al-3	Catalyst Amount: 8 mg Liq. mixture: 40 mL Solvent: Hexane DCPD: Solvent = 1:3
	Pd/Al-4	Catalyst Amount: 8 mg Liq. mixture: 40 mL Solvent: Methanol DCPD: Solvent = 1:3
	Pd/Al-5	Catalyst Amount: 5 mg Liq. mixture: 40 mL Solvent: Hexane DCPD: Solvent = 1:3

	Pd/Al-6	Catalyst Amount: 5 mg Liq. mixture: 40 mL Solvent: Methanol DCPD: Solvent = 1:3

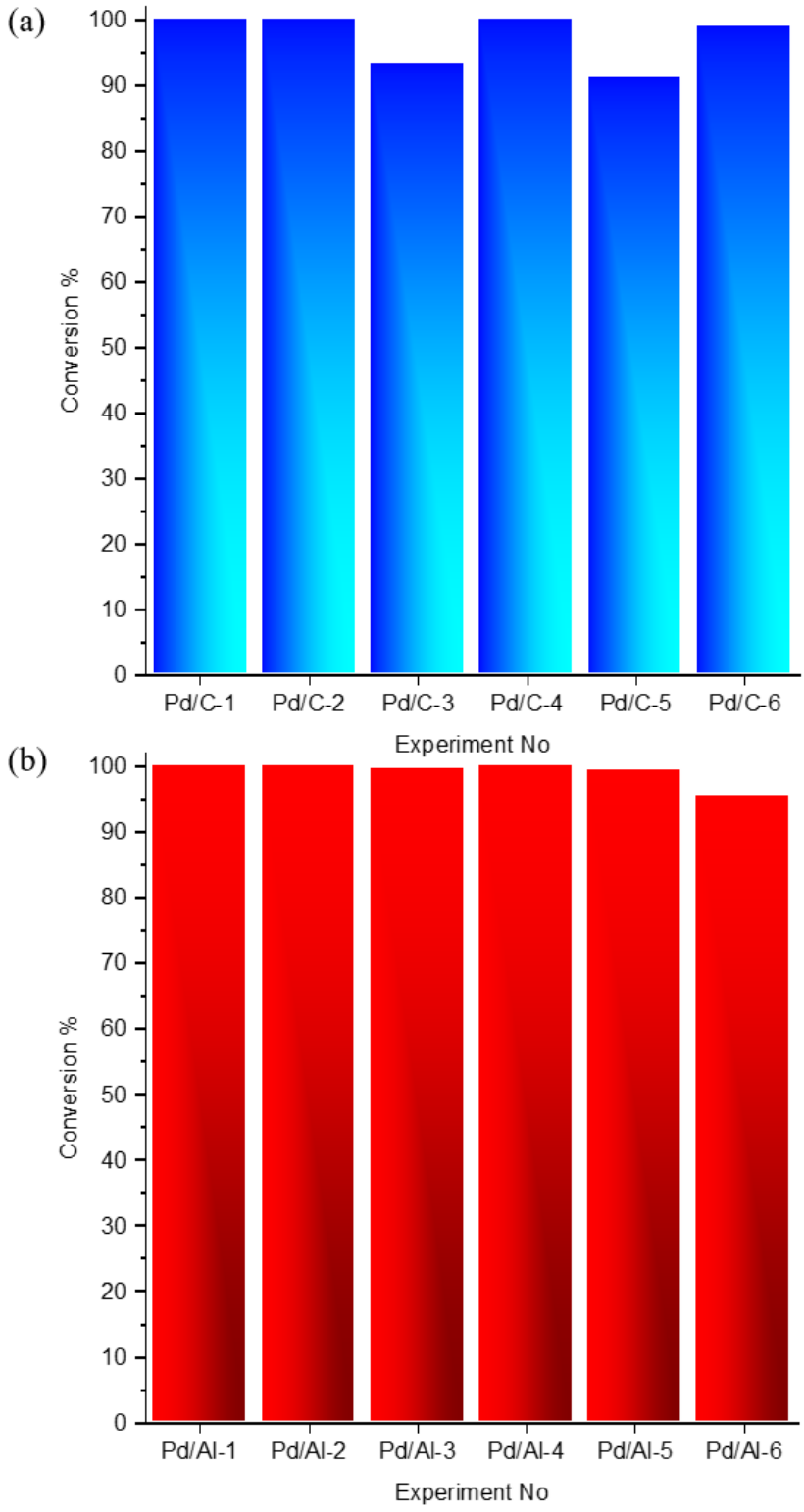

Figure 4.2. Experiment results for DCPD conversion % in batch process. a, Commercial catalyst results. b, Synthesized catalyst results.

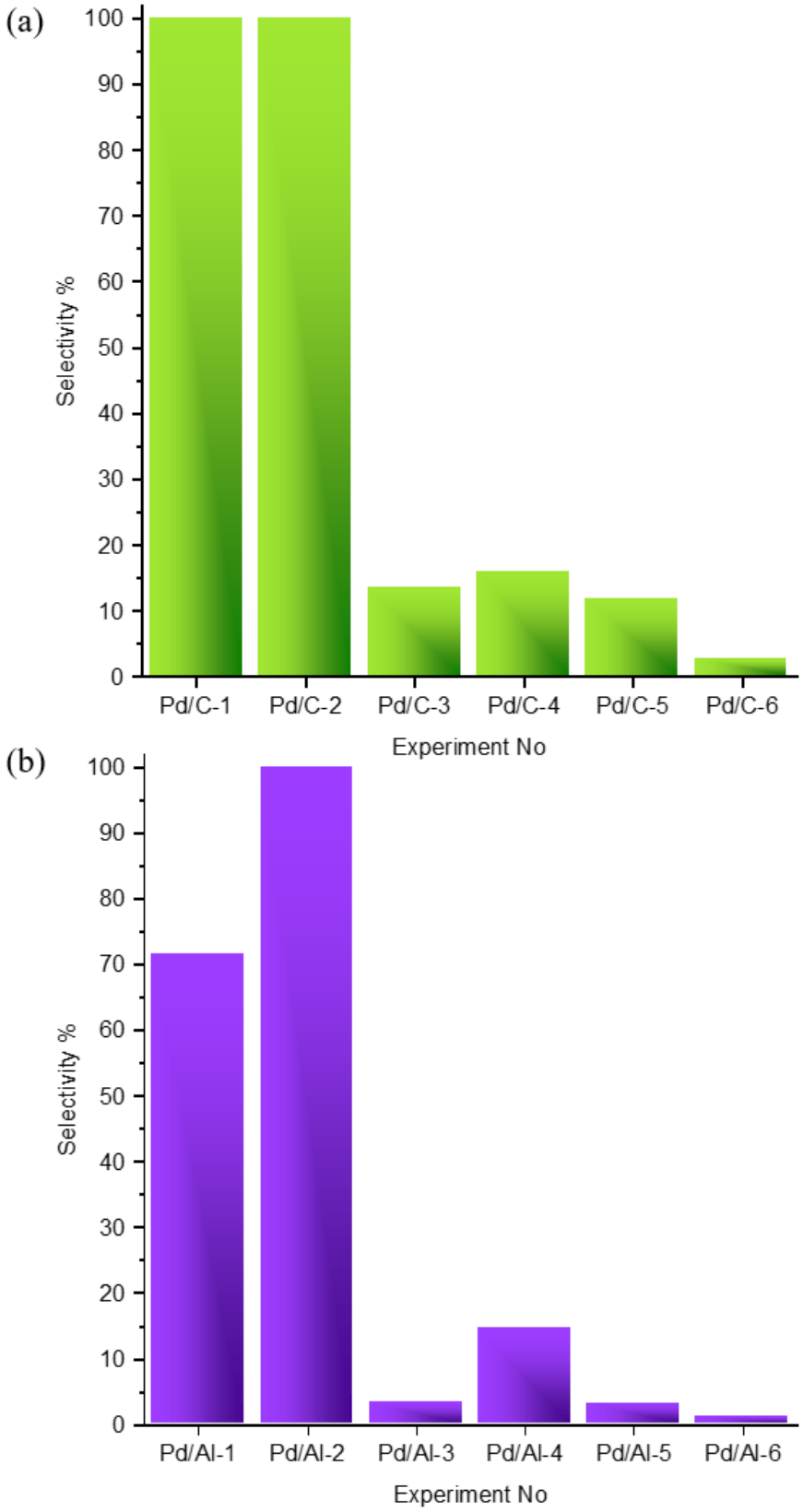

Figure 4.3. Experiment results for endo-THDCPD selectivity % in batch process. a, Commercial catalyst results. b, Synthesized catalyst results.

4.3. Supported Pd Catalysts Performance in Continuous Process

DCPD hydrogenation reaction has generally studied in batch process as it is mentioned before. While batch process offers some operational advantages, continuous process might a key to achieve higher overall efficiency.

The process includes three phases: gas (H_2), liquid mixture of reactant (DCPD and solvent) and solid (supported Pd catalyst). This nature of the reaction creates challenges which are related to mass transfer limitations. The aim in the study, initially, was understanding whether continuous process was possible to use for DCPD hydrogenation reaction. Figure 4.4 shows the set-up of DCPD hydrogenation continuous process.

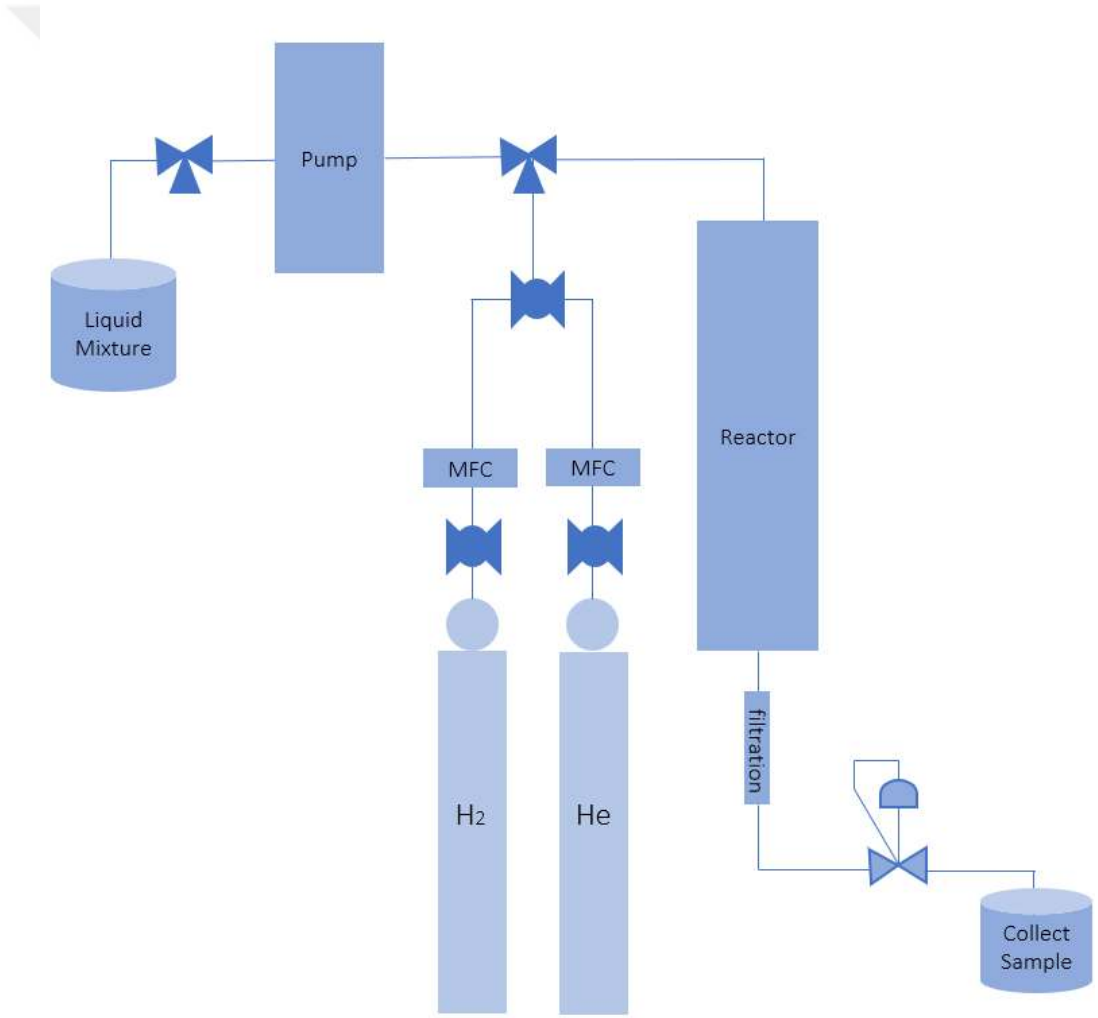

Figure 4.4. DCPD hydrogenation reaction set-up for continuous flow.

After the set-up was built, repeated runs were taken to understand the success of the set-up. The catalysts were selected as the same with batch process which were 4 wt.% Pd/γ-Al_2O_3 and commercial catalyst. Two runs were done for each catalyst, and results can be seen in Figure 4.5.

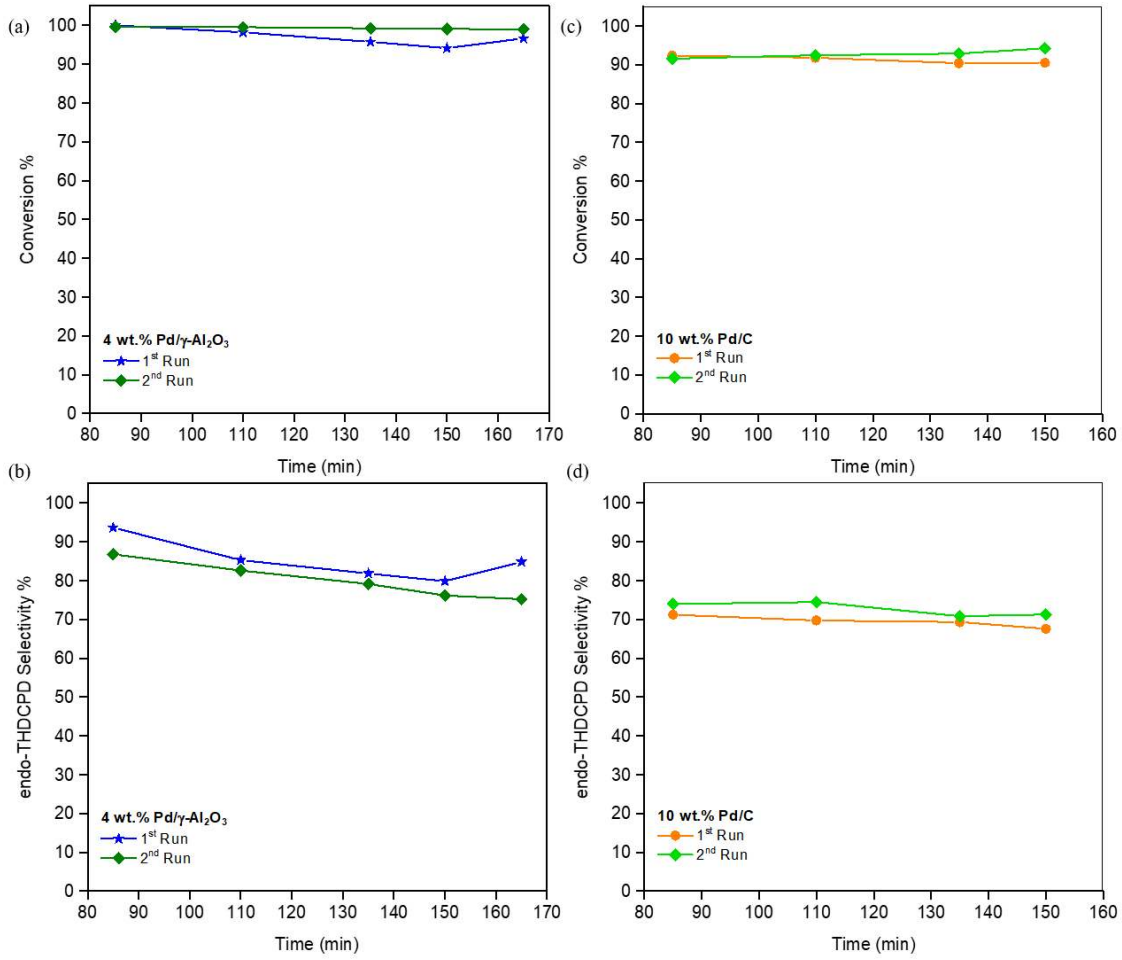

Figure 4.5. DCPD hydrogenation reaction results for 4 wt.% Pd/γ-Al_2O_3 and 10 wt.% Pd/C. a, DCPD conversion results for 4 wt.% Pd/γ-Al_2O_3. b, endo-THDCPD selectivity results for 4 wt.% Pd/γ-Al_2O_3. c, DCPD conversion results for 10 wt.% Pd/C. d, endo-THDCPD selectivity results for 10 wt.% Pd/C.

While DCPD conversion results were quite similar for both catalysts, the differences for endo-THDCPD selectivity % were observed. Results show the applicability of continuous process for the reaction, and it shows that making comparison between catalysts which has significant differences for conversion and selectivity is possible.

In the second part of the continuous process study, three synthesized catalysts with different Pd dispersion values were compared. As it was stated in section 4.2, Pd

dispersion of 4 wt.% Pd/γ-Al_2O_3 was measured 88 % via CO chemisorption. Also, the synthesized 4 wt.% Pd/γ-Al_2O_3 in ML study section with a dispersion of 31 % was used in the study. To distinguish these two catalysts, 4 wt.% Pd/γ-Al_2O_3 which has a metal dispersion of 88 % was called 4 wt.% Pd/γ-Al_2O_3 – HD and 4 wt.% Pd/γ-Al_2O_3 which has a metal dispersion of 31 % was called 4 wt.% Pd/γ-Al_2O_3 – LD. In this part, also 4 wt.% Pd/TiO_2 was synthesized and Pd dispersion of catalyst was measured as 44 %. The chemisorption experiment results were given in Appendix.

Results which can be seen in Figure 4.6 show both support effect and Pd dispersion effect. It is very clear that γ-Al_2O_3 supported catalysts give better performance with higher DCPD conversion and endo-THDCPD selectivity compared to Pd/TiO_2 even when metal dispersion is lower than TiO_2 supported catalyst. When two alumina supported catalysts were compared, metal dispersion influence on endo-THDCPD selectivity was proved. These findings highlight the importance of Pd dispersion and rational catalyst synthesis.

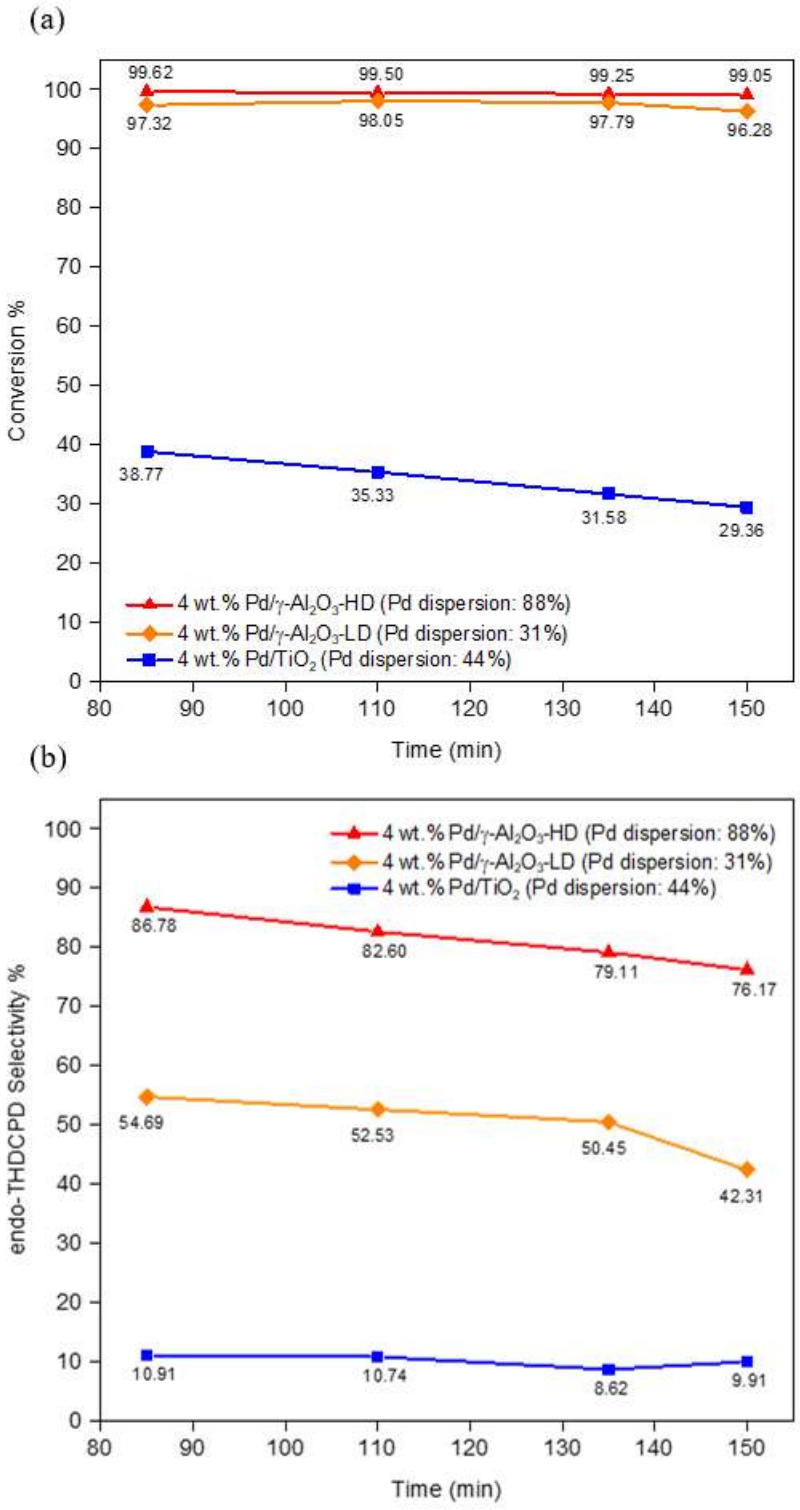

Figure 4.6. DCPD hydrogenation reaction results comparison of 4 wt.% Pd/γ-Al_2O_3-HD, 4 wt.% Pd/γ-Al_2O_3-LD and 4 wt.% Pd/TiO_2. a, DCPD conversion results. b, endo-THDCPD selectivity results.

4.4. Discussion and Conclusion

DCPD hydrogenation reaction was worked both in continuous flow and batch process. In batch process, several factors were studied. Starting with the solvent effect, the effect of solvent change on DCPD conversion was not observed where 20 mg commercial catalyst was used. On the other hand, when catalyst amount was decreased to 8 mg, it is seen that higher selectivity and higher conversion were achievable with methanol for 10 wt% Pd/C. 4 wt% Pd/γ-Al_2O_3 showed the favorable behavior of methanol even 20 mg of catalyst was used in the endo-THDCPD selectivity. While 100% selectivity of endo-THDCPD was reached with methanol, 71.59% endo-THDCPD selectivity was recorded with hexane. When the catalyst amount was decreased to 8 mg of 4 wt% Pd/γ-Al_2O_3, both selectivity and conversion increased when methanol was chosen over hexane such like in the reaction with 10 wt% Pd/C. It is understood that while Pd/γ-Al_2O_3 was more affected from solvent change based on the selectivity of desired product decrease, conversion was less effected by the solvent preference compared to Pd/C. Secondly, catalyst amount and liquid mixture amount can be discussed. While 20 mg catalyst with 25 mL liquid mixture (DCPD:Solvent: 1:4) offers high performance, decreasing catalyst amount to 8 mg, increasing liquid mixture to 40 mL and changing volumetric ratio of DCPD: Solvent to 1:3 did not cause significant change on DCPD conversion. This situation shows the high capacity of the used catalysts. On the other hand, selectivity of endo-THDCPD was drastically decreased with these changes. When Pd/C-4 and Pd/Al-4 experiments are discussed, it is seen that there is no significant difference between two catalysts based on conversion and selectivity. This situation shows the advantage of prepared catalyst due to its lower metal loading compared to commercial catalyst.

While continuous process offers more control on the process and makes able to collect product in the short time intervals, it has some difficulties for DCPD hydrogenation reaction due to its three-phase nature. Also, stabilizing reaction temperature and pressure was quite challenging due to highly exothermic nature of the reaction which can be the reason of differences between runs. It is observed that achieving complete conversion with the used catalysts is possible which shows the applicability of the design process. While DCPD conversion results were quite similar in repeated runs, endo-THDCPD selectivity differences between runs were observed. In this study, while the applicability of continuous operation was understood, challenges of the designed system were also identified. When two different supported Pd catalysts with different

supports and different Pd dispersion were compared. It is seen that Pd 4 wt.% Pd/γ-Al_2O_3 offers better performance compared to 4 wt.% Pd/TiO_2 even metal dispersion is lower. The effect of metal dispersion is seen specially in endo-THDCPD selectivity when two alumina supported catalysts with different metal dispersion were compared. This result highlights the importance of Pd dispersion on the performance.

In conclusion, DCPD hydrogenation reaction is an excellent example to show the high capacity of supported Pd catalysts. This reaction can be studied in continuous process with considerations of mass transfer limitations and high exothermic condition.

Chapter 5: Conclusion and Outlook on Future Research

5.1. Conclusion

Data driven studies have become prominent in the last decade. While the discussions on different approaches in machine learning studies continue, it should be highlighted that machine learning tools not only offer great understanding on complex subjects, but it is also a great tool to rationally design experiments. Machine learning studies in heterogeneous catalysis are still in the beginning stages and there are many opportunities to discover. ML can be particularly useful to understand catalytic structure better and achieve controlled design of the supported metal catalysts.

In this study, experimental data on supported Pd catalysts were collected and used to develop a Pd dispersion predictive model. The dataset includes 365 articles with 1543 instances where 1322 instances were used for the analysis. Output variables were decided as Pd dispersion and Pd particle size. The article selection was done via using Web of Science and Scopus. Initially, pre-analysis of the data was completed. The preferences and correlations between variables via ARM algorithm were discussed. Impregnation methods were found beneficial to achieve theoretical metal loading. Deposition-precipitation method, on the other hand, is found promising for synthesizing fine Pd particles. Alumina supported Pd catalysts represent the collected highest Pd dispersion results which was explained with the high number of these catalysts in the dataset. It is seen that CeO_2 follows the alumina supported catalysts which might be related to the high concentration of oxygen vacancies of this support. The presented model was developed by random forest regression model, and it shows a remarkable ability to estimate Pd dispersion for decided synthesis conditions and offers rational synthesis of supported Pd catalysts. The training and testing set of the dataset rmse values for dispersion predictive model were found 7.89 and 15.22, respectively. The model was also studied via comparison with experimental results. Three different supports (MgO, Al_2O_3 and SiO_2) were selected and these catalysts were prepared via IWI technique. The metal dispersion measurements of synthesized catalysts were done by CO chemisorption experiments. Later, measured and predicted dispersion results were compared. While the model gave

quite accurate estimations for Pd/SiO_2 and Pd/MgO, it overestimates the dispersion of Pd/Al_2O_3. Also, a classification tree for Pd particle size was developed to provide a guide on Pd particle size and its relations with synthesis parameters. The classification tree was prepared via separating Pd particle size into three groups (<5 nm, 5-10 nm and >10 nm) which has an overall accuracy of 0.74.

While heterogeneous catalysis synthesis is a crucial topic for industry and academia, data about this subject is very limited. Experimental data, especially catalyst synthesis parameters, is not given in detail or in a certain format in most of the studies. Thus, it is quite challenging to collect these data points and create one format which is sufficient to reflect the given information for all the studies. In the synthesis process, successful synthesis of supported Pd catalysts usually requires several unsuccessful trials which are not accessible as data currently. Creating a certain format for catalyst synthesis information and publication of unsuccessful trials can be a key to increase the efficiency of these promising predictive models.

Researchers have been searching for new approaches in catalyst design to increase the overall efficiency. While novel synthesis methods have been continuing to introduce, it is still highly complex to work about catalyst synthesis. Thus, better strategies in catalyst design must be adapted for future studies.

In this thesis, machine learning tools were selected to monitor experimental results. The aim was to have a strong understanding about the outcomes of preparation parameter decisions. Collected data was presented in the thesis and trends for different variables were introduced. It is believed that researchers can use the data as a resource to check different studies and their outcome (Pd metal particle size and dispersion). Data proves not only the various possibility for preparation but also the wide range use of supported Pd catalyst by giving the selected reaction in the studies.

Predictive models were introduced in the thesis for dispersion and Pd particle size predictions. The model performances were summarized in the following table.

Model was also used to estimate the experimental data. Initially, different synthesis conditions were decided. Then, the synthesized catalysts dispersions were measured via CO chemisorption. The model performance in estimating the experimental data was summarized in below:

5.2. Outlook on Future Research

Trends show that ML will increase their influence in both industry and the academia. Researchers can publish only their successful experiments currently which makes impossible to add unsuccessful experiment data in the predictive model. In this study, unsuccessful experiments refer to the synthesized catalysts which found not useful for the target reaction or metal particle size of the catalyst was found too large/too small and not reported by the researcher. While articles commonly include only several synthesized catalysts, it is known that many more catalyst synthesized throughout the project which were eliminated in the publication process. As the attention on ML increased, the availability of unsuccessful experiment data might be increased. Thus, the precision and accuracy of future models can be improved.

It is believed that models can be developed for different noble metals such as Platinum, Iridium or Ruthenium. Also, support specific models can be developed to overcome difficulties in the estimation due to structural differences between supports. Number of data can be increased by using an open-access data source. Overall, it is expected that ML will be big part of future studies and it offers a great opportunities in the area of catalyst design.

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Appendix A: R Codes for Pre-analysis and Predictive Models

Pre-analysis Code

```
# Downloading necessary tools for Classification Tree, Random Forest, Pre-analysis,
Boruta Importance Plots:

library(tidyverse)
library(rpart)
library(rpart.plot)
library(readxl)
library(caret)
library(plyr)
library(dplyr)
library(Boruta)
library(caTools)
library(randomForest)
library(party)
library(ggplot2)
library(readr)
library(Metrics)
library(ggbeeswarm)

# Read the data from Excel: Repeat this step before plotting each graph.

dataPd = read_excel('C:/Users/kt/Desktop/PdData-R.xlsx')

dataPd$given_dispersion <- na.omit(dataPd$given_dispersion)
columns <- c(27)
dataPd[, columns] <- lapply(columns, function(x) as.numeric(dataPd[[x]]))
glimpse(dataPd)

# Beeswarm plots in ggplot2:

# Metal Loading vs. Dispersion:

dataPd[,5] <-
as.factor(ifelse(dataPd[,5]<0.5,"1",ifelse(dataPd[,5]<1,"2",ifelse(dataPd[,5]<5,"3",
ifelse(dataPd[,5]<10,"4","5")))))

ggplot(dataPd, aes(x = MetalLoading, y = given_dispersion, color = MetalLoading)) +
  geom_beeswarm(cex = 0.5)+
  ggtitle("Metal Loading vs. Dispersion")+
  labs(x = "Pd Loading wt.%",y = "Dispersion %")+
  theme(axis.text.x = element_text(angle=90, hjust=1))

# Precursor vs. Dispersion:

  dataPd <-dataPd[dataPd$precursor=='Pd(NO3)2' | dataPd$precursor=='PdCl2'|
                    dataPd$precursor=='Pd(acac)2'|dataPd$precursor=='Pd(OAc)2',]
  ggplot(dataPd, aes(x = precursor, y = given_dispersion, color = precursor)) +
  geom_beeswarm(cex = 0.5)+
  ggtitle("Precursor vs. Dispersion")+
  labs(x = "Precursor",y = "Dispersion %")+
```

```
  theme(axis.text.x = element_text(angle=90, hjust=1))

# Support vs. Dispersion:

  dataPd <-dataPd[dataPd$support=='mixed-Al2O3' | dataPd$support=='gamma-Al2O3'|
                  dataPd$support=='C'| dataPd$support=='SiO2'|
                  dataPd$support=='CeO2'|  dataPd$support=='TiO2',]

  ggplot(dataPd, aes(x = support, y = given_dispersion, color=support)) +
  geom_beeswarm(cex = 0.5)+ ggtitle("Support vs. Dispersion")+
  labs(x = "Support",y = "Dispersion %")+
  theme(axis.text.x = element_text(angle=90, hjust=1))

# Solvent vs. Dispersion:

  dataPd <-dataPd[dataPd$solvent=='water' | dataPd$solvent=='aqueous hydrochloric acid'|
                  dataPd$solvent=='toluene'| dataPd$solvent=='HCl'|
                  dataPd$support=='aqueous ethanol'|  dataPd$solvent=='acetone',]

  ggplot(dataPd, aes(x = solvent, y = given_dispersion, color=solvent)) +
  geom_beeswarm(cex = 0.5)+ ggtitle("Solvent vs. Dispersion")+
  labs(x = "Solvent",y = "Dispersion %")+
  theme(axis.text.x = element_text(angle=90, hjust=1))

# pH adjustment vs. Dispersion:

  ggplot(dataPd, aes(x = pHadjustment, y = given_dispersion, color=pHadjustment)) +
  geom_beeswarm(cex = 0.5)+ ggtitle("pH adjustment vs. Dispersion")+
  labs(x = "pH adjustment",y = "Dispersion %")+
  theme(axis.text.x = element_text(angle=90, hjust=1))

# Method vs. Dispersion:

  dataPd <-dataPd[dataPd$method=='Deposition-precipitation' |
dataPd$method=='Impregnation'|
                  dataPd$method=='Polyol' | dataPd$method=='Sol-gel'|
                  dataPd$method=='Incipient wetness impregnation'|
dataPd$method=='Ion-exchange'|
                  dataPd$method=='Liquid-phase reduction'|  dataPd$method=='Photo-
deposition',]
  ggplot(dataPd, aes(x = method, y = given_dispersion, color=method)) +
    geom_beeswarm(cex = 0.5)+ ggtitle("Synthesis Method vs. Dispersion")+
    labs(x = "Synthesis Method",y = "Dispersion %")+
    theme(axis.text.x = element_text(angle=90, hjust=1))
```

ARM Code (without grouping based on Pd particle size)

```
# Association Rule Mining Algorithm:

# Download necessary tools:

library(readxl)
library(arules)
library(arulesViz)

# Read the data from Excel:
```

```
dataPd = read_excel('C:/Users/kt/Desktop/PdData-R.xlsx')

#Select columns for model (size from chemisorption is selected instead of dispersion)

dataPd <- dataPd[,c(1,5,6,8,11,13,14,15,17,20,23,33)]
dataPd <- dataPd[dataPd$size_chem != "NA",]

# Convert other columns into numeric:

columns <- c(2,3,5,8,9,10,11,12)
dataPd[, columns] <- lapply(columns, function(x) as.numeric(dataPd[[x]]))

glimpse(dataPd)

# Print data and convert into factors for Method, Precursor,
#   Support, pH adjustment, Reduction Solvent/Gas:

glimpse(dataPd)
names <- c(1,4,6,7)
dataPd[,names] <- lapply(dataPd[,names] , factor)

# Size Data is categorized into 4 groups as <2nm, 2-5 nm,  5-10 nm, and >10 nm:

dataPd[,12] <-
as.factor(ifelse(dataPd[,12]<20,"1",ifelse(dataPd[,12]<50,"2",ifelse(dataPd[,12]<100,"3"
,"4")))


# Synthesis Method Categories:

dataPd[,1] <-
as.factor(ifelse(dataPd[,1]=="Impregnation","1",ifelse(dataPd[,1]=="Incipient wetness
impregnation","2",
          ifelse(dataPd[,1]=="Deposition-precipitation","3",ifelse(dataPd[,1]=="Liquid-
phase reduction","4",
                   ifelse(dataPd[,1]=="Commercial","5",ifelse(dataPd[,1]=="Sol-
gel","6","7")))))))

# Metal Loading: Less than 1 wt% is 1, Between 1-3 wt% is 2, Between 3-5 wt% is 3,
# Between 5-10 wt% is 4, Between 10-20 is 5, Higher than 20 wt% is 6:

dataPd[,2] <-
as.factor(ifelse(dataPd[,2]<1,"1",ifelse(dataPd[,2]<3,"2",ifelse(dataPd[,2]<5,"3",
                      ifelse(dataPd[,2]<10,"4",ifelse(dataPd[,2]<20,"5","6"))))))

# Support SA: Less than 10 is 1, between 10-50 is 2, between 50-100 is 3, between 100-
500 is 4,
#    between 500-1000 is 5, more than 1000 is 6:

dataPd[,3] <-
as.factor(ifelse(dataPd[,3]<10,"1",ifelse(dataPd[,3]<50,"2",ifelse(dataPd[,3]<100,"3",

ifelse(dataPd[,3]<500,"4",ifelse(dataPd[,3]<1000,"5","6"))))))

# Support: Carbon 1, gamma-Al2O3 2, SiO2 4,
#     mixed-Al2O3 3, TiO2 5, Others 6:
```

```
dataPd[,4] <- as.factor(ifelse(dataPd[,4]=="C","1",ifelse(dataPd[,4]=="gamma-Al2O3","2",

ifelse(dataPd[,4]=="SiO2","4",ifelse(dataPd[,4]=="mixed-Al2O3","3",
                                     ifelse(dataPd[,4]=="TiO2","5","6"))))))

# Support Calcination Temperature: Less than 300K is 1, between 500K is 2, between 600K
is 3, between 700K is 4,
#    between 800K is 5, more than 800K is 6:

dataPd[,5] <-
as.factor(ifelse(dataPd[,5]<300,"1",ifelse(dataPd[,5]<500,"2",ifelse(dataPd[,5]<600,"3",
                            ifelse(dataPd[,5]<700,"4",ifelse(dataPd[,5]<800,"5","6"))))))

# Precursor: PdCl2 is 1, Pd(NO3)2 is 2, Pd(acac)2 is 3,
#     (NH3)4Pd(NO3)2 is 4, Pd(OAc)2 is 5, Others 6:

dataPd[,6] <-
as.factor(ifelse(dataPd[,6]=="PdCl2","1",ifelse(dataPd[,6]=="Pd(NO3)2","2",

ifelse(dataPd[,6]=="Pd(acac)2","3",ifelse(dataPd[,6]=="Pd(NH3)4(NO3)2","4",
                                  ifelse(dataPd[,6]=="Pd(OAc)2","5","6"))))))

# Solvent:

dataPd[,7] <- as.factor(ifelse(dataPd[,7]=="water","1",ifelse(dataPd[,7]=="aqueous
hydrochloric acid","2",

ifelse(dataPd[,7]=="HCl","3",ifelse(dataPd[,7]=="acetone","4",
                                    ifelse(dataPd[,7]=="toluene","5","6"))))))

# solvent pH:

dataPd[,8] <- as.factor(ifelse(dataPd[,8]<7,"1",ifelse(dataPd[,8]>7,"2","3")))

# support PZC:

dataPd[,9] <- as.factor(ifelse(dataPd[,9]<7,"1",ifelse(dataPd[,9]>7,"2","3")))


# Calcination Temperature: Less than 300K is 1, between 500K is 2, between 600K is 3,
between 700K is 4,
#    between 800K is 5, more than 800K is 6:

dataPd[,10] <-
as.factor(ifelse(dataPd[,10]<300,"1",ifelse(dataPd[,10]<500,"2",ifelse(dataPd[,10]<600,"
3",

ifelse(dataPd[,10]<700,"4",ifelse(dataPd[,10]<800,"5","6"))))))

# Reduction Temperature: Less than 300K is 1, between 500K is 2, between 600K is 3,
between 700K is 4,
#    between 800K is 5, more than 800K is 6:


dataPd[,11] <-
as.factor(ifelse(dataPd[,11]<300,"1",ifelse(dataPd[,11]<500,"2",ifelse(dataPd[,11]<600,"
3",
                 ifelse(dataPd[,11]<700,"4",ifelse(dataPd[,11]<800,"5","6"))))))
```

```
# Relations

rules <- apriori(dataPd,parameter = list(minlen=2,maxlen=2,supp=.001, conf=.001),control
= list(verbose=F))
rules_df <- DATAFRAME(rules, setStart = '', setEnd = '', itemSep = ' + ')
rules_df$count <- NULL
head(rules_df)
inspectDT(rules_df)
ARMresultfile_allrelation <- write_xlsx(rules_df)
```

ARM Code (with grouping based on Pd particle size)

```
# Association Rule Mining Algorithm:

# Download necessary tools:

library(readxl)
library(arules)
library(arulesViz)

# Read the data from Excel:

dataPd = read_excel('C:/Users/kt/Desktop/PdData-R.xlsx')

#Select columns for model (size from chemisorption is selected instead of dispersion)

dataPd <- dataPd[,c(1,5,6,8,11,13,14,15,17,20,23,33)]
dataPd <- dataPd[dataPd$size_chem != "NA",]

# Convert other columns into numeric:

columns <- c(2,3,5,8,9,10,11,12)
dataPd[, columns] <- lapply(columns, function(x) as.numeric(dataPd[[x]]))

glimpse(dataPd)

# Print data and convert into factors for Method, Precursor,
#   Support, pH adjustment, Reduction Solvent/Gas:

glimpse(dataPd)
names <- c(1,4,6,7)
dataPd[,names] <- lapply(dataPd[,names] , factor)



# Size Data is categorized into 4 groups as <2nm, 2-5 nm,  5-10 nm, and >10 nm:

dataPd[,12] <-
as.factor(ifelse(dataPd[,12]<20,"1",ifelse(dataPd[,12]<50,"2",ifelse(dataPd[,12]<100,"3"
,"4"))))

# Synthesis Method Categories:

dataPd[,1] <-
as.factor(ifelse(dataPd[,1]=="Impregnation","1",ifelse(dataPd[,1]=="Incipient wetness
impregnation","2",
```

```
              ifelse(dataPd[,1]=="Deposition-
precipitation","3",ifelse(dataPd[,1]=="Liquid-phase reduction","4",
              ifelse(dataPd[,1]=="Commercial","5",ifelse(dataPd[,1]=="Sol-
gel","6","7")))))))

# Metal Loading: Less than 1 wt% is 1, Between 1-3 wt% is 2, Between 3-5 wt% is 3,
# Between 5-10 wt% is 4, Between 10-20 is 5, Higher than 20 wt% is 6:

dataPd[,2] <-
as.factor(ifelse(dataPd[,2]<1,"1",ifelse(dataPd[,2]<3,"2",ifelse(dataPd[,2]<5,"3",
                        ifelse(dataPd[,2]<10,"4",ifelse(dataPd[,2]<20,"5","6"))))))

# Support SA: Less than 10 is 1, between 10-50 is 2, between 50-100 is 3, between 100-
500 is 4,
#    between 500-1000 is 5, more than 1000 is 6:

dataPd[,3] <-
as.factor(ifelse(dataPd[,3]<10,"1",ifelse(dataPd[,3]<50,"2",ifelse(dataPd[,3]<100,"3",
                        ifelse(dataPd[,3]<500,"4",ifelse(dataPd[,3]<1000,"5","6"))))))

# Support: Carbon 1, gamma-Al2O3 2, SiO2 4,
#     mixed-Al2O3 3, TiO2 5, Others 6:

dataPd[,4] <- as.factor(ifelse(dataPd[,4]=="C","1",ifelse(dataPd[,4]=="gamma-Al2O3","2",
                        ifelse(dataPd[,4]=="SiO2","4",ifelse(dataPd[,4]=="mixed-
Al2O3","3",
                        ifelse(dataPd[,4]=="TiO2","5","6"))))))

# Support Calcination Temperature: Less than 300K is 1, between 500K is 2, between 600K
is 3, between 700K is 4,
#    between 800K is 5, more than 800K is 6:


dataPd[,5] <-
as.factor(ifelse(dataPd[,5]<300,"1",ifelse(dataPd[,5]<500,"2",ifelse(dataPd[,5]<600,"3",

ifelse(dataPd[,5]<700,"4",ifelse(dataPd[,5]<800,"5","6"))))))

# Precursor: PdCl2 is 1, Pd(NO3)2 is 2, Pd(acac)2 is 3,
#     (NH3)4Pd(NO3)2 is 4, Pd(OAc)2 is 5, Others 6:

dataPd[,6] <-
as.factor(ifelse(dataPd[,6]=="PdCl2","1",ifelse(dataPd[,6]=="Pd(NO3)2","2",

ifelse(dataPd[,6]=="Pd(acac)2","3",ifelse(dataPd[,6]=="Pd(NH3)4(NO3)2","4",
                        ifelse(dataPd[,6]=="Pd(OAc)2","5","6"))))))

# Solvent:

dataPd[,7] <- as.factor(ifelse(dataPd[,7]=="water","1",ifelse(dataPd[,7]=="aqueous
hydrochloric acid","2",
                        ifelse(dataPd[,7]=="HCl","3",ifelse(dataPd[,7]=="acetone","4",
                        ifelse(dataPd[,7]=="toluene","5","6"))))))

# solvent pH:

dataPd[,8] <- as.factor(ifelse(dataPd[,8]<7,"1",ifelse(dataPd[,8]>7,"2","3")))
```

```
# support PZC:

dataPd[,9] <- as.factor(ifelse(dataPd[,9]<7,"1",ifelse(dataPd[,9]>7,"2","3")))


# Calcination Temperature: Less than 300K is 1, between 500K is 2, between 600K is 3,
between 700K is 4,
#    between 800K is 5, more than 800K is 6:

dataPd[,10] <-
as.factor(ifelse(dataPd[,10]<300,"1",ifelse(dataPd[,10]<500,"2",ifelse(dataPd[,10]<600,"
3",
                         ifelse(dataPd[,10]<700,"4",ifelse(dataPd[,10]<800,"5","6"))))))

# Reduction Temperature: Less than 300K is 1, between 500K is 2, between 600K is 3,
between 700K is 4,
#    between 800K is 5, more than 800K is 6:

dataPd[,11] <-
as.factor(ifelse(dataPd[,11]<300,"1",ifelse(dataPd[,11]<500,"2",ifelse(dataPd[,11]<600,"
3",
                         ifelse(dataPd[,11]<700,"4",ifelse(dataPd[,11]<800,"5","6"))))))
dataPd_2nm <-dataPd[dataPd$size_chem==1,]

dataPd_5nm <-dataPd[dataPd$size_chem==2,]

dataPd_10nm <-dataPd[dataPd$size_chem==3,]

dataPd_others <-dataPd[dataPd$size_chem==4,]

dataPd_2nm  <- dataPd_2nm[,c(1,2,3,4,5,6,7,8,9,10,11)]
dataPd_5nm  <- dataPd_5nm[,c(1,2,3,4,5,6,7,8,9,10,11)]
dataPd_10nm  <- dataPd_10nm[,c(1,2,3,4,5,6,7,8,9,10,11)]
dataPd_others  <- dataPd_others[,c(1,2,3,4,5,6,7,8,9,10,11)]


# Relations for Size less than 2 nm:

rules_2nm <- apriori(dataPd_2nm,parameter = list(minlen=2,maxlen=2,supp=.001,
conf=.001),control = list(verbose=F))
rules_df1 <- DATAFRAME(rules_2nm, setStart = '', setEnd = '', itemSep = ' + ')
rules_df1$count <- NULL
head(rules_df1)
inspectDT(rules_df1)
ARMresultfile1 <- write_xlsx(rules_df1)


# Relations for Size less than 5 nm:

rules_5nm <- apriori(dataPd_5nm,parameter = list(minlen=2,maxlen=2,supp=.001,
conf=.001),control = list(verbose=F))
rules_df2 <- DATAFRAME(rules_5nm, setStart = '', setEnd = '', itemSep = ' + ')
rules_df2$count <- NULL
head(rules_df2)
inspectDT(rules_df2)
ARMresultfile2 <- write_xlsx(rules_df2)

# Relations for Size less than 10 nm:
```

```
rules_10nm <- apriori(dataPd_10nm,parameter = list(minlen=2,maxlen=2,supp=.001,
conf=.001),control = list(verbose=F))
rules_df3 <- DATAFRAME(rules_10nm, setStart = '', setEnd = '', itemSep = ' + ')
rules_df3$count <- NULL
head(rules_df3)
inspectDT(rules_df3)
ARMresultfile3 <- write_xlsx(rules_df3)

# Relations for Size more than 10 nm:

rules_others <- apriori(dataPd_others,parameter = list(minlen=2,maxlen=2,supp=.001,
conf=.001),control = list(verbose=F))
rules_df4 <- DATAFRAME(rules_others, setStart = '', setEnd = '', itemSep = ' + ')
rules_df4$count <- NULL
head(rules_df4)
inspectDT(rules_df4)
ARMresultfile4 <- write_xlsx(rules_df4)

# DIFFERENT GRAPH TYPES:

plot.new()

# Graph 1:

plot(rules_2nm, method="scatter",measure = c("support", "lift"), shading = "confidence",
     engine="ggplot2")

plot(rules_5nm, method="scatter",measure = c("support", "lift"), shading = "confidence",
     engine="ggplot2")

plot(rules_10nm, method="scatter",measure = c("support", "lift"), shading =
"confidence",
     engine="ggplot2")

plot(rules_others, method="scatter",measure = c("support", "lift"), shading =
"confidence",
     engine="ggplot2")

# Graph 2:

plot(rules_2nm, measure=c("support","lift"),engine = "ggplot2", main = NULL, limit =
100) +
  scale_color_gradient2(low = "red", mid = "orange", high = "blue",
                        midpoint = 1, limits = c(0,20)) +
  labs(x ="Support", y = "Lift", color = "Confidence") +
  theme_classic()

# Graph 3:

subrules <- head(rules_2nm, n = 10, by = "lift")
plot(subrules, method = "graph")

# Graph 4:

plot(rules_2nm, method = "two-key plot")

# Graph 5:
```

```
selected_rules <- subset(rules_2nm, subset = lift > 1)
plot(selected_rules, method = "grouped")

# Graph 6:

selected_rules <- subset(rules_2nm, subset = lift > 5)
plot(selected_rules, method = "graph",  engine = "htmlwidget")
```

Classification Tree Code

```
# Classification Tree:

dataPd = read_excel('C:/Users/kt/Desktop/PdData-R.xlsx')

#Select columns for model (size from chemisorption is selected instead of dispersion)

dataPd <- dataPd[,c(1,5,6,8,11,13,14,20,23,33)]
dataPd <- dataPd[dataPd$size_chem != "NA",]

# Filling missing data points:

dataPd$precursor[is.na(dataPd$precursor)] <- "others"
dataPd$solvent[is.na(dataPd$solvent)] <- "others"

# Convert other columns into numeric:

columns <- c(2,3,5,8,9,10)
dataPd[, columns] <- lapply(columns, function(x) as.numeric(dataPd[[x]]))
glimpse(dataPd)

# Filling missing numeric data points:

dataPd$SupportSA[is.na(dataPd$SupportSA)] <- mean(dataPd$SupportSA,na.rm = TRUE)
dataPd$SupportCalcTemp[is.na(dataPd$SupportCalcTemp)] <- 298
dataPd$CalcTemp[is.na(dataPd$CalcTemp)] <- 298
dataPd$ReducTemp[is.na(dataPd$ReducTemp)] <- 298


# Print data and convert into factors for Method,Support, Precursor, pH adjustment:

glimpse(dataPd)
names <- c(1,4,6,7)
dataPd[,names] <- lapply(dataPd[,names], factor)


# Size Data is categorized into 3 groups:

dataPd[,10] <- as.factor(ifelse(dataPd[,10]<50,"1",ifelse(dataPd[,10]<100,
                                                          "2","3")))

# Synthesis Method Categories:

dataPd[,1] <-
as.factor(ifelse(dataPd[,1]=="Impregnation","1",ifelse(dataPd[,1]=="Incipient wetness
impregnation","2",
```

```
          ifelse(dataPd[,1]=="Deposition-precipitation","3",ifelse(dataPd[,1]=="Liquid-
phase reduction","4",
          ifelse(dataPd[,1]=="Sol-gel","5","6"))))))


# Support: Carbon 1, gamma-Al2O3 2, SiO2 4,
#     mixed-Al2O3 3, TiO2 5, Others 6:

dataPd[,4] <- as.factor(ifelse(dataPd[,4]=="C","1",ifelse(dataPd[,4]=="gamma-Al2O3","2",
                           ifelse(dataPd[,4]=="SiO2","4",ifelse(dataPd[,4]=="mixed-
Al2O3","3",
                                      ifelse(dataPd[,4]=="TiO2","5","6"))))))

# Precursor: PdCl2 is 1, Pd(NO3)2 is 2, Pd(acac)2 is 3,
#     (NH3)4Pd(NO3)2 is 4, Pd(OAc)2 is 5, Others 6:

dataPd[,6] <-
as.factor(ifelse(dataPd[,6]=="PdCl2","1",ifelse(dataPd[,6]=="Pd(NO3)2","2",

ifelse(dataPd[,6]=="Pd(acac)2","3",ifelse(dataPd[,6]=="Pd(NH3)4(NO3)2","4",
                                          ifelse(dataPd[,6]=="Pd(OAc)2","5","6"))))))

# Solvent:

dataPd[,7] <- as.factor(ifelse(dataPd[,7]=="water","1",ifelse(dataPd[,7]=="aqueous
hydrochloric acid","2",
                          ifelse(dataPd[,7]=="HCl","3",ifelse(dataPd[,7]=="acetone","4",
                                       ifelse(dataPd[,7]=="toluene","5","6"))))))

set.seed(100)
# Split data into two groups:
# Test and Train Data Set with Split Ratio 0.80

indx <- createDataPartition(dataPd$size_chem, p=.8,list=FALSE, times=1)
train <- dataPd[indx,]
test <- dataPd[-indx,]


k=5 # 5-fold cross validation (reference paper)
sample_class <- sample(nrow(train))
CrossVal_class <- train[sample_class,]
foldcolumn <- cut(seq(1,nrow(CrossVal_class)), breaks=k,labels=FALSE)
NewData_class <- cbind(foldcolumn,CrossVal_class)
glimpse(NewData_class)


accuracy_Max=0
t=0
x=numeric()
y=numeric()
accuracy=numeric()
results=data.frame(accuracy,x,y)

for (x in seq(from=2, to=50, by=1)) {
  for (y in seq(from=0.01, to=0.2, by=0.01)){
      for (i in 1:k)
        {
        train_class=NewData_class[which(!NewData_class[,1]==i),]
```

```
        train_class=train_class[,-1]
        value=NewData_class[which(NewData_class[,1]==i),]
        value=value[,-1]

        control <- rpart.control(minsplit = x, cp = y)
        fit <- rpart(size_chem~., data = data.frame(train_class), method = 'class',
control=control)
        predict_unseen <-predict(fit, data.frame(value), type = 'class')
        table_mat <- table(value$size_chem, predict_unseen)

      # TP(True Positive), TN (True Negative),
      # FP (False Positive), FN (False Negative),
      # Accuracy: (TP+TN)/(TP+TN+FP+FN)

        accuracy <- sum(diag(table_mat))/sum(table_mat)
        t=t+1
        results[t,1]=accuracy
        results[t,2]=x
        results[t,3]=y

        }
      }
}
resultfile <- write_xlsx(results)

control <- rpart.control(minsplit = 5, cp = 0.01)
fit_main <- rpart(size_chem~., data = data.frame(train), method = 'class',
control=control)

png(filename="C:/Users/kt/classTreeFinal.png",width=2000, height=1000)

rpart.plot(fit_main, box.palette="auto", shadow.col="gray", under.cex = 2, main="Pd
Catalysts",cex=0.6)

dev.off()

prediction_train <-predict(fit_main, data.frame(train), type = 'class')
table_mat_train <- table(train$size_chem, prediction_train)
accuracy_Train <- sum(diag(table_mat_train))/sum(table_mat_train)
accuracy_Train

prediction_test <-predict(fit_main, data.frame(test), type = 'class')
table_mat_test <- table(test$size_chem, prediction_test)
accuracy_Test <- sum(diag(table_mat_test))/sum(table_mat_test)
accuracy_Test
```

Dispersion Predictive Model Code

```
# Downloading necessary tools for n-fold Classification, Classification Tree, Boruta
Importance Plots:

library(tidyverse)
library(rpart)
library(rpart.plot)
library(readxl)
library(caret)
library(plyr)
library(dplyr)
```

```
library(Boruta)
library(caTools)
library(randomForest)
library(party)
library(ggplot2)
library(readr)
library(Metrics)
library(writexl)
library(gam)
library(gganimate)

mode <- function(x) {   # Create mode function
  unique_x <- unique(x)
  mode <- unique_x[which.max(tabulate(match(x, unique_x)))]
  mode
}

# Read the data from Excel:

dataPd = read_excel('C:/Users/kt/Desktop/PdData-R.xlsx')

#Select columns for model (exclude Support Source, operation on support, normalized
support area,difference pH,
#         Determination techniques, CO Chemisorption Constant, H2 Chemisorption
Constant, standard deviations, dispersion,
#         estimation for dispersion, size estimation, size, year, country, reaction,
title, link, author)

dataPd <- dataPd[,c(1,5,6,8,11,12,13,14,15,16,17,19,20,22,23,30)]

# Convert other columns into numeric:

columns <- c(2,3,5,6,9,11,12,13,14,15,16)
dataPd[, columns] <- lapply(columns, function(x) as.numeric(dataPd[[x]]))
glimpse(dataPd)

# Print data and convert into factors for Method, Precursor,
#   Support, pH adjustment, Reduction Solvent/Gas:

glimpse(dataPd)
names <- c(1,4,7,8,10)
dataPd[,names] <- lapply(dataPd[,names] , factor)


# TO DEAL WITH NA - IMPUTATION:

dataPd$precursor[is.na(dataPd$precursor)] <- mode(dataPd$precursor)
dataPd$solvent[is.na(dataPd$solvent)] <- mode(dataPd$solvent)
dataPd$SupportSA[is.na(dataPd$SupportSA)] <- mean(dataPd$SupportSA,na.rm = TRUE)
dataPd$SupportCalcTemp[is.na(dataPd$SupportCalcTemp)] <- 298
dataPd$SupportCalcTime[is.na(dataPd$SupportCalcTime)] <- 2
dataPd$solventpH[is.na(dataPd$solventpH)] <- mean(dataPd$solventpH,na.rm = TRUE)
dataPd$PZC[is.na(dataPd$PZC)] <- mean(dataPd$PZC,na.rm = TRUE)
dataPd$CalcTime[is.na(dataPd$CalcTime)] <- 2
dataPd$CalcTemp[is.na(dataPd$CalcTemp)] <- 298
dataPd$ReducTemp[is.na(dataPd$ReducTemp)] <- 298
dataPd$ReducTime[is.na(dataPd$ReducTime)] <- 2
```

```
# To produce same sequence we are deciding a fixed number:
set.seed(123)

# Split data into two groups:
# Test and Train Data Set with Split Ratio: 0.80:

index <- createDataPartition(dataPd$dispersion, p=.80, list=FALSE, times=1)
train <- dataPd[index,]
test <- dataPd[-index,]
dim(train)
dim(test)

# Cross Validation (Prepare matrix with number of folds):

k=5 # 5-fold cross validation (reference paper)
sample <- sample(nrow(train))
CrossVal <- train[sample,]      # Train Data is duplicated with excluding out-of-bag
data??
foldcolumn <- cut(seq(1,nrow(CrossVal)), breaks=k,labels=FALSE)
NewData <- cbind(foldcolumn,CrossVal)
glimpse(NewData)

# Random Forest Model for Predictions:

t=0
error=numeric()
r_square=numeric()
rootmse=numeric()
prediction=numeric()
val.y=numeric()
i=numeric()
j=numeric()
n=numeric()

results=data.frame(error,rootmse,r_square,i,j,n)

# j for Number of Trees, i for Number of Folds
# and n for Number of Node Size:

for (j in seq(from=50, to=200, by=50))
{
  for (n in seq(from=5, to=50, by=5))
  {

    for (i in 1:k)
    {

      train=NewData[which(!NewData[,1]==i),]
      train=train[,-1]
      value=NewData[which(NewData[,1]==i),]
      value=value[,-1]

      avg=mean(value[,ncol(value)])

      set.seed(123)
      model= randomForest(dispersion~ .,data=train, ntree=j,nodesize=5,mtry=n,
importance =T, na.action=na.omit)
```

```
      prediction <- c(prediction,predict(model,value[,-ncol(value)]))
      val.y = c(val.y,value[,ncol(value)])
      par(new=TRUE)
      plot(value[,ncol(value)], predict(model,value[,-ncol(value)]),
           main="Validation Data Results of Random Forest with 5-Folds Classification"
           ,xlab="Observed Data",ylab="Predicted Data",
           pch=19,cex.axis=1.5,xlim=c(0,100),ylim=c(0,100),cex.lab=1,col=i)
      abline(0,1,lwd=1,col="red")

      error = mae(as.matrix(prediction),as.matrix(val.y)) #calculate mean absolute error
for prediction
      r_square <- 1-(sum((prediction-val.y)^2)/sum((val.y-avg)^2)) #calculate r-square
for prediction
      rootmse=rmse(prediction,val.y)  #calculate r-root mean square error for prediction

      t=t+1
      results[t,1]=error
      results[t,2]=rootmse
      results[t,3]=r_square
      results[t,4]=i
      results[t,5]=j
      results[t,6]=n

      print(c("Program is running","j=",j,"n=",n,"i=",i))

    }
  }
}

# Save Results File:
resultfile <- write_xlsx(results)

  NTREE_OPT <- 50   # PUT THE OPTIMUM TREE NUMBER BY USING RMSE, ERROR, R-SQUARE FROM
ABOVE
  MTRY_OPT <- 5  # PUT THE OPTIMUM NUMBER OF VARIABLES FOR EACH SPLIT BY USING RMSE,
ERROR, R-SQUARE FROM ABOVE

  train_model <- data.frame(train)

# Train Data Results:

  error_train=numeric()
  r_square_train=numeric()
  rootmse_train=numeric()
  prediction_train=numeric()
  val_train=numeric()
  avg_train=numeric()

  avg_train=mean(train_model[,ncol(train_model)])

  set.seed(123)
  model_train = randomForest(dispersion ~ .,data=train_model,
ntree=NTREE_OPT,nodesize=5,mtry=MTRY_OPT, importance =T, na.action=na.omit)

  prediction_train <- c(prediction_train,predict(model_train,train_model[,-
ncol(train_model)]))
  val_train <- c(val_train,train_model[,ncol(train_model)])
```

```
  plot(x=train_model[,ncol(train_model)],y=prediction_train,
       main="Train Data Results with 5-Folds Classification",
       xlab="Observed Data" ,
       ylab="Predicted Data",
       pch=19,col="black",
       cex.axis=1.5,
       xlim=c(0,100),
       ylim=c(0,100),
       cex.lab=1)
  abline(0,1,lwd=1,col="black")

  # MAE, R2 and Root MSE values for train data before correction function:

  error_T = mae(as.matrix(prediction_train),as.matrix(val_train)) #calculate mean
absolute error for prediction
  r_square_T <- 1-(sum((prediction_train-val_train)^2)/sum((val_train-avg_train)^2))
#calculate r-square for prediction
  rootmse_T = rmse(prediction_train,val_train)  #calculate r-root mean square error for
prediction

  print(c("Train Data Results Before
CF:","MAE:",error_T,"RootMSE:",rootmse_T,"R2:",r_square_T))

  # Correction Function Optimization:

  a=0
  error_cf=numeric()
  r_square_cf=numeric()
  rootmse_cf=numeric()
  m=numeric()
  k=numeric()
  results_cf=data.frame(error_cf,rootmse_cf,r_square_cf,m,k)
  for (m in seq(from=1.0, to=1.9, by=0.01))
  {

    for (k in seq(from=2, to=8, by=0.01))
    {
      train_cf= prediction_train*m-k
      error_cf = mae(as.matrix(train_cf),as.matrix(val_train))
      r_square_cf <- 1-(sum((train_cf-val_train)^2)/sum((val_train-avg_train)^2))
      rootmse_cf = rmse(train_cf,val_train)

      a=a+1
      results_cf[a,1]=error_cf
      results_cf[a,2]=rootmse_cf
      results_cf[a,3]=r_square_cf
      results_cf[a,4]=m
      results_cf[a,5]=k
    }
  }
  resultfile_cf <- write_xlsx(results_cf)

  prediction_corrected = prediction_train*1.13-5.43


  plot(x=train_model[,ncol(train_model)],y=prediction_corrected,
       main="Train Data Results with 5-Folds Classification",
       xlab="Observed Data" ,
```

```
      ylab="Predicted Data",
      pch=19,col="red",
      cex.axis=1.5,
      xlim=c(0,100),
      ylim=c(0,100),
      cex.lab=1)
  abline(0,1,lwd=1,col="black")


  # MAE, R2 and Root MSE values for train data after correction function:

  error_TCF = mae(as.matrix(prediction_corrected),as.matrix(val_train)) #calculate mean
absolute error for prediction
  r_square_TCF <- 1-(sum((prediction_corrected-val_train)^2)/sum((val_train-
avg_train)^2)) #calculate r-square for prediction
  rootmse_TCF = rmse(prediction_corrected,val_train)  #calculate r-root mean square
error for prediction


  print(c("Train Data Results After CF:","MAE:",error_TCF,
          "Root MSE:",rootmse_TCF,"R squared:",r_square_TCF))

# Test Model with Test Data:

  test <- data.frame(test)

  set.seed(123)

  tes=numeric()
  error_test=numeric()
  rsquare_test=numeric()
  rmse_test=numeric()
  prediction_test=numeric()

  prediction_test <- c(prediction_test,predict(model_train,test[,-ncol(test)]))
  tes <- c(tes,test[,ncol(test)])
  aveg=mean(test[,ncol(test)])

  error_cf_test=numeric()
  rquare_cf_test=numeric()
  rmse_cf_test=numeric()
  results_cf_2=data.frame(error_cf,rootmse_cf,r_square_cf,error_cf_test,rmse_cf_test,
                          rquare_cf_test,m,k)

  prediction_test_corrected=prediction_test*1.13-5.43

  plot(x=test[,ncol(test)],y=prediction_test_corrected,
       main="Test Data Results with 5-Folds Classification",
       xlab="Observed Data" ,
       ylab="Predicted Data",
       pch=19,col="red",
       cex.axis=1.5,
       xlim=c(0,100),
       ylim=c(0,100),
       cex.lab=1)
  abline(0,1,lwd=1,col="black")

  plot(x=test[,ncol(test)],y=prediction_test,
```

```
     main="Test Data Results with 5-Folds Classification",
     xlab="Observed Data" ,
     ylab="Predicted Data",
     pch=19,col="black",
     cex.axis=1.5,
     xlim=c(0,100),
     ylim=c(0,100),
     cex.lab=1)
abline(0,1,lwd=1,col="black")

# MAE, R2 and Root MSE values for train data before correction function:

error_TE=mae(as.matrix(tes),as.matrix(prediction_test))

rsquare_TE=1-(sum((prediction_test-tes)^2)/sum((tes-aveg)^2))

rmse_TE=rmse(tes,prediction_test)

print(c("Test Data Results Before CF:","Error:",error_TE,
       "Root MSE:",rmse_TE,"R squared:",rsquare_TE))

# MAE, R2 and Root MSE values for train data after correction function:

error_TECF=mae(as.matrix(tes),as.matrix(prediction_test_corrected))

rsquare_TECF=1-(sum((prediction_test_corrected-tes)^2)/sum((tes-aveg)^2))

rmse_TECF=rmse(tes,prediction_test_corrected)

print(c("Test Data Results After CF:","Error:",error_TECF,
       "Root MSE:",rmse_TECF,"R squared:",rsquare_TECF))

# Experimental Data for Testing the Data:


exp = read_excel('C:/Users/kt/Desktop/experimentdata.xlsx')

# Print data and convert into factors for Method, Precursor,
#   Support, pH adjustment, Reduction Solvent/Gas:


exp <- exp[,c(1,5,6,8,11,12,13,14,15,16,17,19,20,22,23,30)]

# Convert other columns into numeric:

columns_exp <- c(2,3,5,6,9,11,12,13,14,15,16)
exp[, columns_exp] <- lapply(columns_exp, function(x) as.numeric(exp[[x]]))
glimpse(exp)

# Print data and convert into factors for Method, Precursor,
#   Support, pH adjustment, Reduction Solvent/Gas:

glimpse(exp)
names_exp <- c(1,4,7,8,10)
exp[,names_exp] <- lapply(exp[,names_exp] , factor)


# TO DEAL WITH NA - IMPUTATION:
```

```
exp$precursor[is.na(exp$precursor)] <- mode(exp$precursor)
exp$solvent[is.na(exp$solvent)] <- mode(exp$solvent)
exp$SupportSA[is.na(exp$SupportSA)] <- mean(exp$SupportSA,na.rm = TRUE)
exp$SupportCalcTemp[is.na(exp$SupportCalcTemp)] <- 298
exp$SupportCalcTime[is.na(exp$SupportCalcTime)] <- 2
exp$solventpH[is.na(exp$solventpH)] <- median(exp$solventpH,na.rm = TRUE)
exp$PZC[is.na(exp$PZC)] <- mean(exp$PZC,na.rm = TRUE)
exp$CalcTime[is.na(exp$CalcTime)] <- 2
exp$CalcTemp[is.na(exp$CalcTemp)] <- 298
exp$ReducTemp[is.na(exp$ReducTemp)] <- 298
exp$ReducTime[is.na(exp$ReducTime)] <- 2

expt <- exp[1324:1326,]
glimpse(expt)

# To produce same sequence we are deciding a fixed number:

set.seed(123)

expdata=numeric()
error_exp=numeric()
rsquare_exp=numeric()
rmse_exp=numeric()
prediction_exp=numeric()
aveg_exp=numeric()

prediction_exp <- c(prediction_exp,predict(model_train,expt[,-ncol(expt)]))
expdata <- as.matrix(c(expdata,expt[,ncol(expt)]))
a <- as.matrix(expt[,ncol(expt)])
aveg_exp=mean(a)

prediction_exp_cf = prediction_exp*1.13-5.43
prediction_exp_cf

plot(x=a,y=prediction_exp_cf,
     main="Predicting Experimental Results",
     xlab="Experimental Data",
     ylab="Predicted Data",
     pch=19,cex=3,col="orange",
     cex.axis=1.5,
     xlim=c(0,100),
     ylim=c(0,100),
     cex.lab=1)
abline(0,1,lwd=1,col="black")


#Boruta Importance Plot:

data1 <- na.omit(dataPd)     # Get rid of columns with NA and ND
boruta.train <- Boruta(dispersion~., data = data1, doTrace = 2)
print(boruta.train)
plot(boruta.train, xlab = "", xaxt = "n")
lz<-lapply(1:ncol(boruta.train$ImpHistory),function(i)
  boruta.train$ImpHistory[is.finite(boruta.train$ImpHistory[,i]),i])
names(lz) <- colnames(boruta.train$ImpHistory)
Labels <- sort(sapply(lz,median))
axis(side = 1,las=2,labels = names(Labels),
```

```
       at = 1:ncol(boruta.train$ImpHistory), cex.axis = 0.55)
```

Size Predictive Model Code

```
# Downloading necessary tools for n-fold Classification, Classification Tree, Boruta
Importance Plots:

library(tidyverse)
library(rpart)
library(rpart.plot)
library(readxl)
library(caret)
library(plyr)
library(dplyr)
library(Boruta)
library(caTools)
library(randomForest)
library(party)
library(ggplot2)
library(readr)
library(Metrics)
library(writexl)
library(gam)


mode <- function(x) {   # Create mode function
  unique_x <- unique(x)
  mode <- unique_x[which.max(tabulate(match(x, unique_x)))]
  mode
}

# Read the data from Excel:

dataPd = read_excel('C:/Users/kt/Desktop/PdData-R.xlsx')


#Select columns for model (exclude Support Source, operation on support, normalized
support area,difference pH,
#         Determination techniques, CO Chemisorption Constant, H2 Chemisorption
Constant, standard deviations, dispersion,
#         estimation for dispersion, size estimation, size, year, country, reaction,
title, link, author)

dataPd <- dataPd[,c(1,5,6,8,11,12,13,14,15,16,17,19,20,22,23,40)]

# Convert other columns into numeric:

columns <- c(2,3,5,6,9,11,12,13,14,15,16)
dataPd[, columns] <- lapply(columns, function(x) as.numeric(dataPd[[x]]))
glimpse(dataPd)

# TO DEAL WITH NA - IMPUTATION:

dataPd$precursor[is.na(dataPd$precursor)] <- mode(dataPd$precursor)
dataPd$solvent[is.na(dataPd$solvent)] <- mode(dataPd$solvent)
dataPd$SupportSA[is.na(dataPd$SupportSA)] <- mean(dataPd$SupportSA,na.rm = TRUE)
dataPd$SupportCalcTemp[is.na(dataPd$SupportCalcTemp)] <- 298
dataPd$SupportCalcTime[is.na(dataPd$SupportCalcTime)] <- 2
dataPd$solventpH[is.na(dataPd$solventpH)] <- median(dataPd$solventpH,na.rm = TRUE)
```

```
dataPd$mixturepH[is.na(dataPd$mixturepH)] <- median(dataPd$mixturepH,na.rm = TRUE)
dataPd$PZC[is.na(dataPd$PZC)] <- mean(dataPd$PZC,na.rm = TRUE)
dataPd$CalcTime[is.na(dataPd$CalcTime)] <- 2
dataPd$CalcTemp[is.na(dataPd$CalcTemp)] <- 298
dataPd$ReducTemp[is.na(dataPd$ReducTemp)] <- 298
dataPd$ReducTime[is.na(dataPd$ReducTime)] <- 2

# Print data and convert into factors for Method, Precursor,
#   Support, pH adjustment, Reduction Solvent/Gas:

glimpse(dataPd)
names <- c(1,4,7,8,10)
dataPd[,names] <- lapply(dataPd[,names] , factor)

# Delete data with higher than 50 nm particle size:

dataPd<-dataPd[dataPd$size<500,]

# To produce same sequence we are deciding a fixed number:
set.seed(100)

# Split data into two groups:
# Test and Train Data Set with Split Ratio: 0.80:

index <- createDataPartition(dataPd$size, p=.80, list=FALSE, times=1)
train <- dataPd[index,]
test <- dataPd[-index,]
dim(train)
dim(test)

# Cross Validation (Prepare matrix with number of folds):

k=5 # 5-fold cross validation
sample <- sample(nrow(train))
CrossVal <- train[sample,]      # Train Data is duplicated with excluding out-of-bag
data??
foldcolumn <- cut(seq(1,nrow(CrossVal)), breaks=k,labels=FALSE)
NewData <- cbind(foldcolumn,CrossVal)
glimpse(NewData)

# Random Forest Model for Predictions:
t=0
error=numeric()
r_square=numeric()
rootmse=numeric()
prediction=numeric()
val.y=numeric()
i=numeric()
j=numeric()
n=numeric()

results=data.frame(error,rootmse,r_square,i,j,n)


# j for Number of Trees, i for Number of Folds
# and n for Number of mtry:

for (j in seq(from=50, to=200, by=50))
```

```
{
  for (n in seq(from=5, to=50, by=5))
  {
    for (i in 1:k)
    {

      train=NewData[which(!NewData[,1]==i),]
      train=train[,-1]
      value=NewData[which(NewData[,1]==i),]
      value=value[,-1]

      avg=mean(value[,ncol(value)])

      set.seed(123)
      model= randomForest(size~ .,data=train, ntree=j,nodesize=5,mtry=n, importance =T,
na.action=na.omit)

      prediction <- c(prediction,predict(model,value[,-ncol(value)]))
      val.y = c(val.y,value[,ncol(value)])
      par(new=TRUE)
      plot(value[,ncol(value)], predict(model,value[,-ncol(value)]),
           main="Validation Data Results of Random Forest with 5-Folds Classification"
           ,xlab="Observed Data",ylab="Predicted Data",
           pch=19,cex.axis=1.5,xlim=c(0,2000),ylim=c(0,2000),cex.lab=1,col=i)
      abline(0,1,lwd=1,col="red")

      error = mae(as.matrix(prediction),as.matrix(val.y)) #calculate mean absolute error
for prediction
      r_square <- 1-(sum((prediction-val.y)^2)/sum((val.y-avg)^2)) #calculate r-square
for prediction
      rootmse=rmse(prediction,val.y)  #calculate r-root mean square error for prediction

      t=t+1
      results[t,1]=error
      results[t,2]=rootmse
      results[t,3]=r_square
      results[t,4]=i
      results[t,5]=j
      results[t,6]=n

      print(c("Program is running","j=",j,"n=",n,"i=",i))

    }
  }
}

# Save Results File:
resultfile <- write_xlsx(results)

NTREE_OPT <- 50   # PUT THE OPTIMUM TREE NUMBER BY USING RMSE, ERROR, R-SQUARE FROM
ABOVE
MTRY_OPT <- 5   # PUT THE OPTIMUM NODE SIZE NUMBER BY USING RMSE, ERROR, R-SQUARE FROM
ABOVE

train <- na.omit(train)
train_model <- data.frame(train)

# Train Data Results:
```

```
error_train=numeric()
r_square_train=numeric()
rootmse_train=numeric()
prediction_train=numeric()
val_train=numeric()
avg_train=numeric()

avg_train=mean(train_model[,ncol(train_model)])

set.seed(123)
model_train = randomForest(size~ .,data=train_model,
ntree=NTREE_OPT,nodesize=20,mtry=MTRY_OPT, importance =T, na.action=na.omit)

predict(model_train,newdata = train[,-ncol(train)])

prediction_train <- c(prediction_train,predict(model_train,train[,-ncol(train)]))

val_train <- c(val_train,train_model[,ncol(train_model)])

# Correction Factor Optimization:
a=0
error_cf=numeric()
r_square_cf=numeric()
rootmse_cf=numeric()
m=numeric()
k=numeric()
results_cf=data.frame(error_cf,rootmse_cf,r_square_cf,m,k)
for (m in seq(from=1.0, to=1.9, by=0.01))
{
  for (k in seq(from=0, to=10, by=1))
  {
    train_cf= prediction_train*m-k
    error_cf = mae(as.matrix(train_cf),as.matrix(val_train))
    r_square_cf <- 1-(sum((train_cf-val_train)^2)/sum((val_train-avg_train)^2))
    rootmse_cf = rmse(train_cf,val_train)

    a=a+1
    results_cf[a,1]=error_cf
    results_cf[a,2]=rootmse_cf
    results_cf[a,3]=r_square_cf
    results_cf[a,4]=m
    results_cf[a,5]=k
  }
}
resultfile_cf <- write_xlsx(results_cf)

prediction_corrected = prediction_train*1.17-10

plot(x=train_model[,ncol(train_model)],y=prediction_corrected,
     main="Train Data Results with 5-Folds Classification",
     xlab="Observed Data" ,
     ylab="Predicted Data",
     pch=19,col="red",
     cex.axis=1.5,
     xlim=c(0,500),
     ylim=c(0,500),
     cex.lab=1)
```

```
abline(0,1,lwd=1,col="black")

plot(x=train_model[,ncol(train_model)],y=prediction_train,
     main="Train Data Results with 5-Folds Classification",
     xlab="Observed Data" ,
     ylab="Predicted Data",
     pch=19,col="black",
     cex.axis=1.5,
     xlim=c(0,500),
     ylim=c(0,500),
     cex.lab=1)
abline(0,1,lwd=1,col="black")

# MAE, R2 and Root MSE values for train data before correction function:

error_T = mae(as.matrix(prediction_train),as.matrix(val_train)) #calculate mean absolute
error for prediction
r_square_T <- 1-(sum((prediction_train-val_train)^2)/sum((val_train-avg_train)^2))
#calculate r-square for prediction
rootmse_T = rmse(prediction_train,val_train)  #calculate r-root mean square error for
prediction

print(c("Train Data Results Before
CF:","MAE:",error_T,"RootMSE:",rootmse_T,"R2:",r_square_T))

# MAE, R2 and Root MSE values for train data after correction function:

error_TCF = mae(as.matrix(prediction_corrected),as.matrix(val_train)) #calculate mean
absolute error for prediction
r_square_TCF <- 1-(sum((prediction_corrected-val_train)^2)/sum((val_train-avg_train)^2))
#calculate r-square for prediction
rootmse_TCF = rmse(prediction_corrected,val_train)  #calculate r-root mean square error
for prediction

print(c("Train Data Results After CF:","MAE:",error_TCF,
        "Root MSE:",rootmse_TCF,"R squared:",r_square_TCF))

# Test Model with Test Data:

test <- data.frame(test)

set.seed(123)

tes=numeric()
error_test=numeric()
rsquare_test=numeric()
rmse_test=numeric()
prediction_test=numeric()

prediction_test <- c(prediction_test,predict(model_train,test[,-ncol(test)]))
tes <- c(tes,test[,ncol(test)])
aveg=mean(test[,ncol(test)])

prediction_test_corrected=prediction_test*1.17-10

plot(x=test[,ncol(test)],y=prediction_test_corrected,
     main="Test Data Results with 5-Folds Classification",
     xlab="Observed Data" ,
```

```
     ylab="Predicted Data",
     pch=19,col="red",
     cex.axis=1.5,
     xlim=c(0,500),
     ylim=c(0,500),
     cex.lab=1)
abline(0,1,lwd=1,col="black")

plot(x=test[,ncol(test)],y=prediction_test,
     main="Test Data Results with 5-Folds Classification",
     xlab="Observed Data" ,
     ylab="Predicted Data",
     pch=19,
     cex.axis=1.5,
     xlim=c(0,500),
     ylim=c(0,500),
     cex.lab=1)
abline(0,1,lwd=1,col="black")

# MAE, R2 and Root MSE values for train data before correction function:

error_TE=mae(as.matrix(tes),as.matrix(prediction_test))

rsquare_TE=1-(sum((prediction_test-tes)^2)/sum((tes-aveg)^2))

rmse_TE=rmse(tes,prediction_test)

print(c("Test Data Results Before CF:","Error:",error_TE,
        "Root MSE:",rmse_TE,"R squared:",rsquare_TE))

# MAE, R2 and Root MSE values for train data after correction function:

error_TECF=mae(as.matrix(tes),as.matrix(prediction_test_corrected))

rsquare_TECF=1-(sum((prediction_test_corrected-tes)^2)/sum((tes-aveg)^2))

rmse_TECF=rmse(tes,prediction_test_corrected)

print(c("Test Data Results After CF:","Error:",error_TECF,
        "Root MSE:",rmse_TECF,"R squared:",rsquare_TECF))

#Boruta Importance Plot:
data1 <- dataPd
boruta.train <- Boruta(size~., data = data1, doTrace = 2)
print(boruta.train)
plot(boruta.train, xlab = "", xaxt = "n",main="Variable Importance")

lz<-lapply(1:ncol(boruta.train$ImpHistory),function(i)
  boruta.train$ImpHistory[is.finite(boruta.train$ImpHistory[,i]),i])

names(lz) <- colnames(boruta.train$ImpHistory)
Labels <- sort(sapply(lz,median))
axis(side = 1,las=2,labels = names(Labels),
     at = 1:ncol(boruta.train$ImpHistory), cex.axis = 0.55)
```

Appendix B: CO Chemisorption and Characterization Results

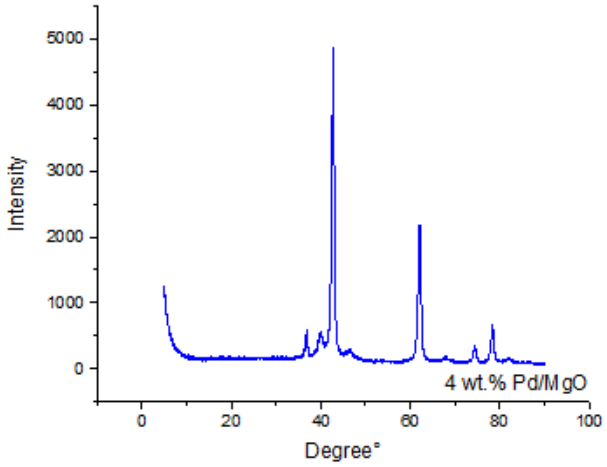

Figure B.1. XRD Result of Pd/MgO.

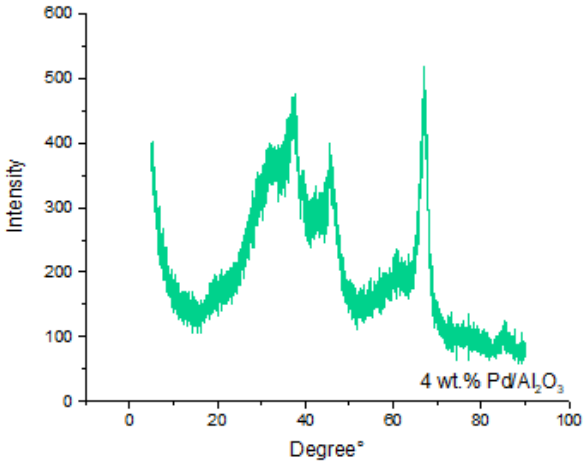

Figure B.2. XRD Result of Pd/Al_2O_3.

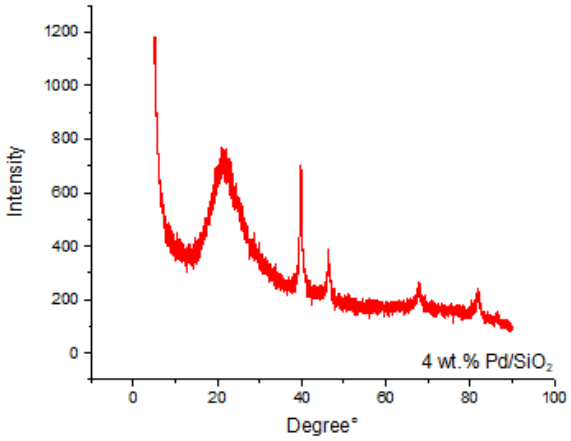

Figure B.3. XRD Result of Pd/SiO_2.

Table B.1. Exp. No:1 – CO chemisorption experiment – Run 1.

Active Loop Volume at 111.0 °C:	0.07114 cm³ STP
Cumulative Quantity:	1.74032 cm³/g STP
Metal Dispersion:	20.6534%
Metallic Surface Area:	3.6804 m²/g sample
Metallic Surface Area:	92.0105 m²/g metal
Active Particle Diameter (hemisphere):	5.4251 nm
Cubic Crystallite Size:	4.5209 nm

Table B.2. Exp. No:1 – CO chemisorption experiment – Run 2.

Active Loop Volume at 111.0 °C:	0.03557 cm³ STP
Cumulative Quantity:	2.61573 cm³/g STP
Metal Dispersion:	31.0424%
Metallic Surface Area:	5.5317 m²/g sample
Metallic Surface Area:	138.2936 m²/g metal
Active Particle Diameter (hemisphere):	3.6095 nm
Cubic Crystallite Size:	3.0079 nm

Table B.3. Exp. No:2 – CO chemisorption experiment – Run 1.

Active Loop Volume at 110.8 °C:	0.07115 cm³ STP
Cumulative Quantity:	1.30951 cm³/g STP
Metal Dispersion:	15.5408%
Metallic Surface Area:	2.7694 m²/g sample
Metallic Surface Area:	69.2339 m²/g metal
Active Particle Diameter (hemisphere):	7.2099 nm
Cubic Crystallite Size:	6.0082 nm

Table B.4. Exp. No:2 – CO chemisorption experiment – Run 2.

Active Loop Volume at 110.8 °C:	0.03557 cm³ STP
Cumulative Quantity:	1.21024 cm³/g STP
Metal Dispersion:	14.3626%
Metallic Surface Area:	2.5594 m²/g sample
Metallic Surface Area:	63.9851 m²/g metal
Active Particle Diameter (hemisphere):	7.8013 nm
Cubic Crystallite Size:	6.5011 nm

Table B.5. Exp. No:3 – CO chemisorption experiment – Run 1.

Active Loop Volume at 110.8 °C:	**0.07114 cm³ STP**
Cumulative Quantity:	1.21495 cm³/g STP
Metal Dispersion:	14.4185%

Metallic Surface Area:	2.5694 m²/g sample
Metallic Surface Area:	64.2343 m²/g metal
Active Particle Diameter (hemisphere):	7.7710 nm
Cubic Crystallite Size:	6.4759 nm

Table B.6. Exp. No:3 – CO chemisorption experiment – Run 2.

Active Loop Volume at 110.8 °C:	**0.03557 cm³ STP**
Cumulative Quantity:	1.68094 cm³/g STP
Metal Dispersion:	19.9487%
Metallic Surface Area:	3.5548 m²/g sample
Metallic Surface Area:	88.8710 m²/g metal
Active Particle Diameter (hemisphere):	5.6168 nm
Cubic Crystallite Size:	4.6806 nm

Table B.7. CO chemisorption experiment result for synthesized catalyst 4 wt.% Pd/γ-Al_2O_3 for DCPD hydrogenation reaction.

Active Loop Volume at 111.0 °C:	0.07111 cm³ STP
Cumulative Quantity:	3.72708 cm³/g STP
Metal Dispersion:	88.4629%
Metallic Surface Area:	15.7640 m²/g sample
Metallic Surface Area:	394.1005 m²/g metal
Active Particle Diameter (hemisphere):	1.2666 nm
Cubic Crystallite Size:	1.0555 nm

Table B.8. CO chemisorption experiment result for synthesized catalyst 4 wt.% Pd/TiO_2 for DCPD hydrogenation reaction.

Active Loop Volume at 111.5 °C:	0.03558 cm³ STP
Cumulative Quantity:	3.73430 cm³/g STP
Metal Dispersion:	44.3171%
Metallic Surface Area:	7.8973 m²/g sample
Metallic Surface Area:	197.4317 m²/g metal
Active Particle Diameter (hemisphere):	2.5283 nm
Cubic Crystallite Size:	2.1069 nm

Appendix C: Supported Pd Catalysts Dataset

Synthesis Method	Theoretical Metal Loading wt%	Actual Metal Loading wt%	SSA (m²/g)	Support	Support Source
Incipient wetness impregnation	1	0.91	156	gamma-Al2O3	from Engelhard-AL-3916P
Incipient wetness impregnation	5	5.09	156	gamma-Al2O3	from Engelhard-AL-3916P
Incipient wetness impregnation	10	9.32	156	gamma-Al2O3	from Engelhard-AL-3916P
Incipient wetness impregnation	15	14.52	156	gamma-Al2O3	from Engelhard-AL-3916P
Incipient wetness impregnation	1	0.85	156	gamma-Al2O3	from Engelhard-AL-3916P
Impregnation	ND	2.21	136	mixed-Al2O3	SPH569, Rhône Poulenc
Impregnation	ND	1.94	136	mixed-Al2O3	SPH569, Rhône Poulenc
Impregnation	0.5	0.51	ND	gamma-Al2O3	from Alfa Aesar
Impregnation	1	0.96	ND	gamma-Al2O3	from Alfa Aesar
Impregnation	5	4.92	ND	gamma-Al2O3	from Alfa Aesar
Impregnation	1	0.87	ND	gamma-Al2O3	from Alfa Aesar
Impregnation	5	4.12	ND	gamma-Al2O3	from Alfa Aesar
Impregnation	10	10.2	ND	gamma-Al2O3	from Alfa Aesar
Impregnation	1	ND	107	Mg-Al hydrotalcite	Al(NO3)3.9H2O and Mg(NO3)2.6H2O, molar ratio of Al: 0.15
Impregnation	1	ND	61	Mg-Al hydrotalcite	Al(NO3)3.9H2O and Mg(NO3)2.6H2O, molar ratio of Al: 0.20
Impregnation	1	ND	47	Mg-Al hydrotalcite	Al(NO3)3.9H2O and Mg(NO3)2.6H2O, molar ratio of Al: 0.25
Impregnation	1	ND	53	Mg-Al hydrotalcite	Al(NO3)3.9H2O and Mg(NO3)2.6H2O, molar ratio of Al: 0.30
Impregnation	1	ND	72	Mg-Al hydrotalcite	Al(NO3)3.9H2O and Mg(NO3)2.6H2O, molar ratio of Al: 0.35
Ion-exchange	1	ND	107	Mg-Al hydrotalcite	Al(NO3)3.9H2O and Mg(NO3)2.6H2O, molar ratio of Al: 0.15
Ion-exchange	1	ND	61	Mg-Al hydrotalcite	Al(NO3)3.9H2O and Mg(NO3)2.6H2O, molar ratio of Al: 0.20
Ion-exchange	1	ND	47	Mg-Al hydrotalcite	Al(NO3)3.9H2O and Mg(NO3)2.6H2O, molar ratio of Al: 0.25
Ion-exchange	1	ND	53	Mg-Al hydrotalcite	Al(NO3)3.9H2O and Mg(NO3)2.6H2O, molar ratio of Al: 0.30
Ion-exchange	1	ND	72	Mg-Al hydrotalcite	Al(NO3)3.9H2O and Mg(NO3)2.6H2O, molar ratio of Al: 0.35
Impregnation	1	ND	190	Mg-Al hydrotalcite	Al(NO3)3.9H2O and Mg(NO3)2.6H2O, molar ratio of Al: 0.15
Impregnation	1	ND	NA	Mg-Al hydrotalcite	Al(NO3)3.9H2O and Mg(NO3)2.6H2O, molar ratio of Al: 0.20
Impregnation	1	ND	210	Mg-Al hydrotalcite	Al(NO3)3.9H2O and Mg(NO3)2.6H2O, molar ratio of Al: 0.25
Impregnation	1	ND	220	Mg-Al hydrotalcite	Al(NO3)3.9H2O and Mg(NO3)2.6H2O, molar ratio of Al: 0.30
Impregnation	1	ND	240	Mg-Al hydrotalcite	Al(NO3)3.9H2O and Mg(NO3)2.6H2O, molar ratio of Al: 0.35
Impregnation	1	ND	160	Mg-Al hydrotalcite	Al(NO3)3.9H2O and Mg(NO3)2.6H2O, molar ratio of Al: 0.15
Impregnation	1	ND	173	Mg-Al hydrotalcite	Al(NO3)3.9H2O and Mg(NO3)2.6H2O, molar ratio of Al: 0.20
Impregnation	1	ND	165	Mg-Al hydrotalcite	Al(NO3)3.9H2O and Mg(NO3)2.6H2O, molar ratio of Al: 0.25
Impregnation	1	ND	182	Mg-Al hydrotalcite	Al(NO3)3.9H2O and Mg(NO3)2.6H2O, molar ratio of Al: 0.30
Impregnation	1	ND	190	Mg-Al hydrotalcite	Al(NO3)3.9H2O and Mg(NO3)2.6H2O, molar ratio of Al: 0.35
Sol-gel	1	ND	ND	mixed-Al2O3	Al[OCH(CH3)2]3 from Aldrich
Sol-gel	1	ND	ND	mixed-Al2O3	Al[OCH(CH3)2]3 from Aldrich
Incipient wetness impregnation	ND	1.25	ND	mixed-Al2O3	Degussa
Incipient wetness impregnation	ND	0.97	ND	Nb2O5	Nb2O5 was prepared by calcination of niobic acid CBMM
Incipient wetness impregnation	ND	1.03	ND	Al2O3-Nb2O5	0.98 wt% Nb2O5 was prepared by calcination of niobic acid CBMM
Incipient wetness impregnation	ND	0.91	ND	Al2O3-Nb2O5	5.66 wt% Nb2O5 was prepared by calcination of niobic acid CBMM
Incipient wetness impregnation	ND	1.10	ND	Al2O3-Nb2O5	9.10 wt% Nb2O5 was prepared by calcination of niobic acid CBMM
Incipient wetness impregnation	ND	0.94	ND	Al2O3-Nb2O5	21.90 wt% Nb2O5 was prepared by calcination of niobic acid CBMM
Impregnation	0.25	ND	46	TiO2	Anatase 87%, Aerosil P-25
Impregnation	0.5	ND	46	TiO2	Anatase 87%, Aerosil P-25
Impregnation	1	ND	46	TiO2	Anatase 87%, Aerosil P-25
Impregnation	3	ND	46	TiO2	Anatase 87%, Aerosil P-25
Impregnation	5	ND	46	TiO2	Anatase 87%, Aerosil P-25
Impregnation	10	ND	178	gamma-Al2O3	Harshaw 3996-R

Incipient wetness impregnation	ND	1.05	410	C	ND
Incipient wetness impregnation	ND	1.91	410	C	ND
Incipient wetness impregnation	ND	3.08	410	C	ND
Incipient wetness impregnation	ND	4.07	410	C	ND
Incipient wetness impregnation	ND	6	410	C	ND
Incipient wetness impregnation	ND	1	410	C	ND
Impregnation	ND	0.72	1200	C	carbon GAC 1240 ELF Attochem
Impregnation	ND	0.88	1200	C	carbon GAC 1240 ELF Attochem
Impregnation	ND	0.98	250	mixed-Al2O3	Rhone Poulenc
Impregnation	ND	2.85	431	SiO2	Ketjen F2
Incipient wetness impregnation	0.5	ND	ND	C	from Cabot (Sterling Series)
Commercial	5	5	NA	C	NA
Impregnation	0.5	ND	100	gamma-Al2O3	from Aldrich
Impregnation	0.5	ND	100	gamma-Al2O3	from Aldrich
Impregnation	0.5	ND	100	gamma-Al2O3	from Aldrich
Impregnation	0.5	ND	100	gamma-Al2O3	from Aldrich
Impregnation	0.5	ND	100	gamma-Al2O3	from Aldrich
Incipient wetness impregnation	0.5	ND	10	alpha-Al2O3	Alcoa A-16
Incipient wetness impregnation	1	0.83	10	alpha-Al2O3	Alcoa A-16
Incipient wetness impregnation	0.5	ND	1	mixed-Al2O3	Al(NO3)3·9H2O from Merck
Incipient wetness impregnation	1	0.81	1	mixed-Al2O3	Al(NO3)3·9H2O from Merck
Impregnation	0.5	ND	1200	C	granular coconut active carbon
Incipient wetness impregnation	5	ND	257	gamma-Al2O3	from Condea
Incipient wetness impregnation	5	ND	257	gamma-Al2O3	from Condea
Incipient wetness impregnation	5	ND	329	SiO2	from Akzo
Commercial	0.5	0.5	NA	gamma-Al2O3	NA
Incipient wetness impregnation	ND	0.7	ND	mixed-Al2O3	from Magneti Marelli Sistemi di Scarico
Incipient wetness impregnation	ND	2.80	ND	mixed-Al2O3	from Magneti Marelli Sistemi di Scarico
Impregnation	1	ND	300	SiO2	ND
Impregnation	5	ND	300	SiO2	ND
Impregnation	20	ND	300	SiO2	ND
Impregnation	0.2	ND	20	BeO	ND
Impregnation	1	ND	20	BeO	ND
Impregnation	5	ND	20	BeO	ND
Impregnation	20	ND	20	BeO	ND
Commercial	5	ND	NA	C	from N.E. Chemcat Co. Ltd
Commercial	5	ND	NA	mixed-Al2O3	from N.E. Chemcat Co. Ltd
Commercial	5	ND	NA	TiO2	from N.E. Chemcat Co. Ltd
Deposition-precipitation	1	0.7	ND	CeO2	Ce(SO4)2·8H2O
Deposition-precipitation	3	2.7	ND	CeO2	Ce(SO4)2·8H2O
Deposition-precipitation	5	4.4	ND	CeO2	Ce(SO4)2·8H2O
Deposition-precipitation	10	9	ND	CeO2	Ce(SO4)2·8H2O
Deposition-precipitation	1	0.9	ND	ZrO2	Zirconium isopropoxide
Deposition-precipitation	2.9	2.9	ND	ZrO2	Zirconium isopropoxide
Commercial	3	3	NA	CeO2	NA

Commercial	3	3	NA	ZrO2	NA
Incipient wetness impregnation	2	1.92	210	gamma-Al2O3	from Condea
Impregnation	1	ND	91	CeO2	from hydrolysis of ceric ammonium nitrate (S.D. Fine Chem., India)
Impregnation	1	ND	91	CeO2	from hydrolysis of ceric ammonium nitrate (S.D. Fine Chem., India)
Deposition-precipitation	1	ND	91	CeO2	from hydrolysis of ceric ammonium nitrate (S.D. Fine Chem., India)
Deposition-precipitation	1	ND	91	CeO2	from hydrolysis of ceric ammonium nitrate (S.D. Fine Chem., India)
Impregnation	1	ND	180	Al2O3-CeO2-BaO	Al:Ce:Ba=0.886:0.04:0.074
Impregnation	1	ND	170	Al2O3-CeO2-BaO	Al:Ce:Ba=0.85:0.08:0.07
Impregnation	1	ND	148	Al2O3-CeO2-BaO	Al:Ce:Ba=0.81:0.12:0.0675
Impregnation	1	ND	136	Al2O3-CeO2-BaO	Al:Ce:Ba=0.775:0.16:0.0645
Incipient wetness impregnation	5	ND	144	mixed-Al2O3	from Condea, Puralox HP 14–150
Sol-gel	1	ND	ND	mixed-Al2O3	aluminium-secbutoxide from Across
Sol-gel	1	ND	ND	mixed-Al2O3	aluminium-secbutoxide from Across
Sol-gel	1	ND	ND	mixed-Al2O3	aluminium-secbutoxide from Across
Sol-gel	1	ND	ND	mixed-Al2O3	aluminium-secbutoxide from Across
Sol-gel	1	ND	ND	mixed-Al2O3	aluminium-secbutoxide from Across
Sol-gel	1	ND	ND	mixed-Al2O3	aluminium-secbutoxide from Across
Sol-gel	1	ND	ND	mixed-Al2O3	aluminium-secbutoxide from Across
Sol-gel	1	ND	ND	mixed-Al2O3	aluminium-secbutoxide from Across
Sol-gel	1	ND	ND	mixed-Al2O3	aluminium-secbutoxide from Across
Sol-gel	1	ND	ND	mixed-Al2O3	aluminium-secbutoxide from Across
Sol-gel	1	ND	ND	mixed-Al2O3	aluminium-secbutoxide from Across

Sol-gel	1	ND	ND	mixed-Al2O3	aluminium-secbutoxide from Across
Sol-gel	1	ND	ND	mixed-Al2O3	aluminium-secbutoxide from Across
Impregnation	1	ND	ND	mixed-Al2O3	sol gel alumina
Impregnation	1	ND	ND	mixed-Al2O3	commercial alumina from Degussa
Incipient wetness impregnation	5	ND	600	SiO2	from Aldrich
Impregnation	2	ND	4	ZnO	from Wako Pure Chemical Industries
Sol-gel	ND	0.6	320	mixed-Al2O3	aluminum isopropoxide from Aldrich
Sol-gel	ND	0.6	30	TiO2	TIP from Acros
Incipient wetness impregnation	0.5	ND	320	mixed-Al2O3	aluminum isopropoxide from Aldrich
Incipient wetness impregnation	0.5	ND	30	TiO2	TIP from Acros
Impregnation	ND	0.3	240	gamma-Al2O3	from Alumina Shell S618
Impregnation	ND	0.3	240	gamma-Al2O3	from Alumina Shell S618
Impregnation	ND	0.6	240	gamma-Al2O3	from Alumina Shell S618
Impregnation	ND	0.6	240	gamma-Al2O3	from Alumina Shell S618
Impregnation	ND	1.46	240	gamma-Al2O3	from Alumina Shell S618
Impregnation	ND	1.46	240	gamma-Al2O3	from Alumina Shell S618
Impregnation	ND	2.77	240	gamma-Al2O3	from Alumina Shell S618
Impregnation	ND	2.77	240	gamma-Al2O3	from Alumina Shell S618
Incipient wetness impregnation	0.5	0.35	716	SiO2	from Grace Davison and Stream chemicals
Incipient wetness impregnation	0.5	0.29	277	SiO2	from Grace Davison and Stream chemicals
Ion-exchange	2	ND	301	SiO2	from Davison 59
Incipient wetness impregnation	2	ND	20	Ga2O3	alpha-Ga2O3, from Ga(NO3)3.xH2O from Strem
Incipient wetness impregnation	2	ND	64	Ga2O3	beta-Ga2O3, from Ga(NO3)3.xH2O from Strem
Impregnation	2	ND	260	alpha-Al2O3	from Harshaw
Impregnation	4	ND	260	alpha-Al2O3	from Harshaw
Impregnation	6	ND	260	alpha-Al2O3	from Harshaw
Impregnation	8	ND	260	alpha-Al2O3	from Harshaw
Impregnation	10	ND	260	alpha-Al2O3	from Harshaw
Impregnation	0.5	ND	716	SiO2	from Grace Davison Co. Ltd.
Impregnation	0.5	ND	716	SiO2	from Grace Davison Co. Ltd.
Impregnation	0.5	ND	716	SiO2	from Grace Davison Co. Ltd.
Impregnation	ND	0.58	ND	mixed-Al2O3	ND
Impregnation	ND	7	ND	mixed-Al2O3	ND
Impregnation	ND	2.10	ND	CeO2	ND
Impregnation	2	ND	40	ZnO	by thermal composition of ZnC2O4.2H2O
Impregnation	6	ND	40	ZnO	by thermal composition of ZnC2O4.2H2O
Impregnation	10	ND	40	ZnO	by thermal composition of ZnC2O4.2H2O
Impregnation	2	ND	110	CeO2	by thermal composition of cerium oxalate
Impregnation	6	ND	110	CeO2	by thermal composition of cerium oxalate
Impregnation	10	ND	110	CeO2	by thermal composition of cerium oxalate

Impregnation	2	ND	40	ZnO	by thermal composition of ZnC2O4.2H2O
Impregnation	2	ND	40	ZnO	by thermal composition of ZnC2O4.2H2O
Impregnation	2	ND	40	ZnO	by thermal composition of ZnC2O4.2H2O
Impregnation	2	ND	110	CeO2	by thermal composition of cerium oxalate
Impregnation	2	ND	110	CeO2	by thermal composition of cerium oxalate
Incipient wetness impregnation	1.2	ND	655	SiO2	avg. Diameter: 3 nm, from Fuji Silysia Chemical Ltd.
Incipient wetness impregnation	1.2	ND	280	SiO2	avg. Diameter: 10 nm, from Fuji Silysia Chemical Ltd.
Incipient wetness impregnation	1	ND	ND	TiO2	by solvothermal method using titanium(IV) n-butoxide (TNB) 97% from Aldrich -solvent: butanediol
Incipient wetness impregnation	1	ND	ND	TiO2	by solvothermal method using titanium(IV) n-butoxide (TNB) 97% from Aldrich -solvent: toluene
Incipient wetness impregnation	1	ND	ND	TiO2	sol–gel precipitation followed by SCFD
Incipient wetness impregnation	1	ND	ND	TiO2	sol–gel precipitation followed by SCFD
Incipient wetness impregnation	1	ND	ND	CeO2	sol–gel precipitation followed by SCFD
Incipient wetness impregnation	1	ND	ND	CeO2	sol–gel precipitation followed by SCFD
Incipient wetness impregnation	1	ND	ND	CeO2-TiO2	sol–gel precipitation followed by SCFD, TiO2:CeO2=5
Incipient wetness impregnation	1	ND	ND	CeO2-TiO2	sol–gel precipitation followed by SCFD, TiO2:CeO2=5
Impregnation	5	4.00	106	mixed-Al2O3	Aluminiumoxid C (Degussa)
Impregnation	1	0.91	106	mixed-Al2O3	Aluminiumoxid C (Degussa)
Impregnation	1	0.86	106	mixed-Al2O3	Aluminiumoxid C (Degussa)
Impregnation	1	0.93	106	mixed-Al2O3	Aluminiumoxid C (Degussa)
Impregnation	ND	0.7	9.5	alpha-Al2O3	Rhone Poulenc
Impregnation	ND	0.78	137	gamma-Al2O3	Condea, Puralox
Incipient wetness impregnation	ND	0.86	9.5	alpha-Al2O3	Rhone Poulenc
Incipient wetness impregnation	ND	0.77	137	gamma-Al2O3	Condea, Puralox
Ion-exchange	0.3	0.39	200	SiO2	ND
Ion-exchange	1	0.91	200	SiO2	ND
Ion-exchange	1.5	1.45	200	SiO2	ND
Ion-exchange	1	0.91	200	SiO2	ND
Ion-exchange	1	0.91	200	SiO2	ND
Impregnation	0.3	0.32	9	alpha-Al2O3	ND
Impregnation	0.3	0.3	215	gamma-Al2O3	ND
Impregnation	0.3	0.38	48	TiO2	ND
Impregnation	0.3	0.3	297	MgO	ND
Impregnation	0.3	0.28	40	ZnO	ND
Impregnation	0.3	0.3	127	CeO2	ND
Impregnation	0.3	0.31	87	CeO2-ZrO2	ND
Impregnation	1	ND	ND	ZrO2	by precipitation of zirconiumoxychloride with a solution of ammonium hydroxide
Impregnation	1	ND	ND	SiO2	hydrophilic silica, Aerosil 130, obtained from Degussa
Impregnation	1	ND	ND	SiO2	a methoxylatedhydrophobic silica, R972, obtained from Degussa
Impregnation	8	7.8	ND	C	activated carbon, from NORIT
Impregnation	8	8.5	ND	C	graphite, from Sigma–Aldrich
Impregnation	8	8.7	ND	C	graphitic carbon nanofiber, synthesized by the catalytic decomposition of ethylene over unsupported Ni
Impregnation	1	ND	ND	SiO2	from BASF D11-11
Impregnation	2	ND	65	gamma-Al2O3	Alfa-Aesar 39812
Impregnation	2	ND	65	gamma-Al2O3	Alfa-Aesar 39812

Impregnation	2	ND	65	gamma-Al2O3	Alfa-Aesar 39812
Impregnation	0.5	ND	65	gamma-Al2O3	Alfa-Aesar 39812
Impregnation	2	ND	65	gamma-Al2O3	Alfa-Aesar 39812
Impregnation	10	ND	65	gamma-Al2O3	Alfa-Aesar 39812
Incipient wetness impregnation	2	ND	10.4	CeO2	purity 99.9% from Aldrich
Incipient wetness impregnation	2	ND	2.7	Sm2O3	purity 99.9% from Acros Organics
Incipient wetness impregnation	2	ND	9.7	CeO2-Sm2O3	prepared by ball milling, CeO2 purity 99.9% from Aldrich, Sm2O3 purity 99.9% from Acros Organics, (CeO2)0.8(Sm2O3)0.2
Incipient wetness impregnation	2	ND	2.7	Sm2O3	purity 99.9% from Acros Organics
Impregnation	5	ND	ND	SiO2	ND
Impregnation	0.2	ND	ND	MgO	ND
Impregnation	2	ND	ND	MgO	ND
Impregnation	2	ND	ND	gamma-Al2O3	ND
Impregnation	2	ND	ND	C	activated carbon
Impregnation	ND	3	ND	SiO2	Cabosil from Fluka
Impregnation	5	ND	160	CeO2	Rhodia Rare Earth ceria HSA
Impregnation	5	ND	40	CeO2	Rhodia Rare Earth ceria LSA
Incipient wetness impregnation	5	ND	600	SiO2	Aldrich no. 7631-86-9
Incipient wetness impregnation	1	ND	600	SiO2	Aldrich no. 7631-86-9
Impregnation	1	0.95	10	alpha-Al2O3	from Rhone Poulanc
Impregnation	1	0.95	10	alpha-Al2O3	from Rhone Poulanc
Ion-exchange	ND	3.2	ND	C	carbon nanofibers over inconel sintered metal fiber filters
Ion-exchange	ND	4.8	ND	C	carbon nanofibers over inconel sintered metal fiber filters
Ion-exchange	ND	3.7	ND	C	carbon nanofibers over inconel sintered metal fiber filters
Ion-exchange	ND	5	ND	C	activated carbon fibers, AE1101, KoTHmex
Ion-exchange	ND	4.9	ND	C	activated carbon fibers, AE1101, KoTHmex
Impregnation	ND	3.31	800	SiO2	Porous Hollow Silica, prepared from CaCO3 and Na2SiO3
Incipient wetness impregnation	1	1.13	62	ZrO2	Zirconium Nitrate, from Aldrich
Incipient wetness impregnation	1	0.96	200	gamma-Al2O3	Commercial, from Harshaw
Incipient wetness impregnation	1	0.84	178	gamma-Al2O3	from Pural SB of Condea
Incipient wetness impregnation	1	0.84	178	gamma-Al2O3	from Pural SB of Condea
Incipient wetness impregnation	1	0.78	5	Nb2O5	Ammoniacal complex of niobium (CBMM)
Incipient wetness impregnation	1	0.78	5	Nb2O5	Ammoniacal complex of niobium (CBMM)
Incipient wetness impregnation	1	0.98	178	gamma-Al2O3	CBMM and Al2O3 from Pural SB of Condea
Incipient wetness impregnation	1	0.98	178	gamma-Al2O3	CBMM and Al2O3 from Pural SB of Condea
Impregnation	1	ND	36.6	MgAl2O4	pellets of alumina-stabilized magnesia (Mg/Al=7/1)
Incipient wetness impregnation	1	ND	18.30	TiO2	rutile TiO2, from anatase TiO2 from Aldrich
Incipient wetness impregnation	1	ND	39.3	TiO2	Titanium ethoxide (Ti 20%) from Aldrich
Incipient wetness impregnation	1	ND	26.8	TiO2	titanium(IV) n-butoxide (TNB) 97% from Aldrich
Incipient wetness impregnation	1	ND	64.4	TiO2	anatase TiO2 from Aldrich
Liquid-phase reduction	1	0.94	50	TiO2	anatase TiO2 from Degussa
Liquid-phase reduction	2	1.81	50	TiO2	anatase TiO2 from Degussa
Liquid-phase reduction	5	4.63	50	TiO2	anatase TiO2 from Degussa
Liquid-phase reduction	10	9.71	50	TiO2	anatase TiO2 from Degussa
Liquid-phase reduction	20	19.89	50	TiO2	anatase TiO2 from Degussa
Impregnation	0.5	ND	6	Si3N4	alpha silicon nitride powder from Goodfellow
Impregnation	0.5	ND	2	Si3N4	beta silicon nitride powder from Johnson Matthey
Impregnation	0.5	ND	66	Si3N4	amorphous powder from Johnson Matthey

Impregnation	0.5	ND	28	Si3N4	from crystallization of the SiN amorphous powder at high temperature under N2 flux, SiN-am from Johnson Matthey
Impregnation	0.5	ND	6	Si3N4	alpha silicon nitride powder from Goodfellow
Impregnation	0.5	ND	6	Si3N4	beta silicon nitride powder from Goodfellow
Impregnation	1	0.78	148	gamma-Al2O3	from Condeai Puralox
Incipient wetness impregnation	1	0.77	148	gamma-Al2O3	from Condeai Puralox
Impregnation	1	0.65	9	alpha-Al2O3	from Rhône-Poulenc
Incipient wetness impregnation	1	0.86	9	alpha-Al2O3	from Rhône-Poulenc
Incipient wetness impregnation	1	0.77	148	gamma-Al2O3	from Condeai Puralox
Impregnation	ND	0.12	246	C	Carbon-coated monoliths prepared from Polyfurfuryl Alcohol (PFA)
Impregnation	ND	0.16	498	C	Carbon-coated monoliths prepared from Polyfurfuryl Alcohol (PFA)
Impregnation	0.5	ND	183	TiO2	from titanium ethoxide
Impregnation	0.5	ND	184	ZrO2	from zirconium propoxide
Impregnation	0.5	ND	440	TiO2-ZrO2	from zirconium propoxide and titanium isopropoxide (50:50 metal molar ratio)
Impregnation	ND	0.6	ND	SiO2	from JRC-SIO8, Fuji Silysia Chemical
Impregnation	ND	0.6	ND	SiO2	from JRC-SIO9, Nikki Chemical
Impregnation	ND	0.6	ND	SiO2	non-porous Cab-OSil from M5, Acros Organics
Impregnation	ND	0.6	ND	gamma-Al2O3	from JRC-ALO8, Sumitomo Chemical
Commercial	5	5	ND	C	from Wako Pure Chemical
Incipient wetness impregnation	ND	0.94	136	BN	boron nitride powder from Starck
Incipient wetness impregnation	ND	0.95	136	BN	boron nitride powder from Starck
Incipient wetness impregnation	ND	0.89	136	BN	boron nitride powder from Starck
Incipient wetness impregnation	ND	0.94	136	BN	boron nitride powder from Starck
Incipient wetness impregnation	ND	0.99	136	BN	boron nitride powder from Starck
Incipient wetness impregnation	ND	0.94	136	BN	boron nitride powder from Starck
Incipient wetness impregnation	ND	0.74	136	BN	boron nitride powder from Starck
Deposition-precipitation	1	ND	ND	ZnO	from Zn(NO3)2
Incipient wetness impregnation	ND	0.06	180	gamma-Al2O3	Degussa
Incipient wetness impregnation	ND	0.44	180	gamma-Al2O3	Degussa
Incipient wetness impregnation	ND	0.84	180	gamma-Al2O3	Degussa
Incipient wetness impregnation	ND	1.48	180	gamma-Al2O3	Degussa
Incipient wetness impregnation	ND	2.02	180	gamma-Al2O3	Degussa
Incipient wetness impregnation	ND	4.72	180	gamma-Al2O3	Degussa
Incipient wetness impregnation	ND	8.54	180	gamma-Al2O3	Degussa
Incipient wetness impregnation	1	ND	243.8	SiO2	commercial, Strem Chemicals, Newburyport, MA, USA
Incipient wetness impregnation	3	ND	ND	ZrO2	Zirconium hydroxide is used
Incipient wetness impregnation	3	ND	ND	ZrO2	Zirconium hydroxide is used
Incipient wetness impregnation	3	ND	ND	ZrO2	Zirconium hydroxide is used
Incipient wetness impregnation	3	ND	ND	ZrO2	Zirconium hydroxide is used
Incipient wetness impregnation	0.3	ND	16.25	alpha-Al2O3	from Jiangsu Jiangyan Chemical Additive
Incipient wetness impregnation	0.3	ND	16.25	alpha-Al2O3	from Jiangsu Jiangyan Chemical Additive
Incipient wetness impregnation	0.3	ND	16.25	alpha-Al2O3	from Jiangsu Jiangyan Chemical Additive
Incipient wetness impregnation	0.3	ND	16.25	alpha-Al2O3	from Jiangsu Jiangyan Chemical Additive
Incipient wetness impregnation	0.3	ND	16.25	alpha-Al2O3	from Jiangsu Jiangyan Chemical Additive
Incipient wetness impregnation	0.3	ND	16.25	alpha-Al2O3	from Jiangsu Jiangyan Chemical Additive

Impregnation	0.5	ND	7	YrO3-ZrO2	yttria stabilized zirconia, A TYPE OF CERAMIC
Impregnation	0.5	ND	7	YrO3-ZrO2	yttria stabilized zirconia, A TYPE OF CERAMIC
Impregnation	0.5	ND	7	YrO3-ZrO2	yttria stabilized zirconia, A TYPE OF CERAMIC
Impregnation	0.5	ND	7	YrO3-ZrO2	yttria stabilized zirconia, A TYPE OF CERAMIC
Impregnation	0.5	ND	7	YrO3-ZrO2	yttria stabilized zirconia, A TYPE OF CERAMIC
Impregnation	0.5	ND	7	YrO3-ZrO2	yttria stabilized zirconia, A TYPE OF CERAMIC
Impregnation	0.5	ND	7	YrO3-ZrO2	yttria stabilized zirconia, A TYPE OF CERAMIC
Impregnation	0.5	ND	7	YrO3-ZrO2	yttria stabilized zirconia, A TYPE OF CERAMIC
Impregnation	0.5	ND	7	YrO3-ZrO2	yttria stabilized zirconia, A TYPE OF CERAMIC
Incipient wetness impregnation	0.5	ND	214	Mg-Al hydrotalcite	from Mg(NO3)2 and Al(NO3)3
Incipient wetness impregnation	1	ND	214	Mg-Al hydrotalcite	from Mg(NO3)2 and Al(NO3)3
Incipient wetness impregnation	2	ND	214	Mg-Al hydrotalcite	from Mg(NO3)2 and Al(NO3)3
Incipient wetness impregnation	5	ND	214	Mg-Al hydrotalcite	from Mg(NO3)2 and Al(NO3)3
Impregnation	0.5	ND	NA	C	Activated carbon powder
Liquid-phase reduction	0.5	ND	NA	C	Activated carbon powder
Deposition-precipitation	5	ND	6	C	non-activated carbon Sibunit
Deposition-precipitation	3	ND	6	C	non-activated carbon Sibunit
Deposition-precipitation	20	20	ND	C	Vulcan XC-72 Carbon
Deposition-precipitation	20	20	ND	C	Vulcan XC-72 Carbon
Deposition-precipitation	20	20	ND	C	Vulcan XC-72 Carbon
Deposition-precipitation	20	20	ND	C	Vulcan XC-72 Carbon
Deposition-precipitation	20	20	ND	C	Vulcan XC-72 Carbon
Incipient wetness impregnation	1	ND	12.3	alpha-Al2O3	100% alpha-Al2O3, obtained by calcination of gamma-Al2O3, gamma-Al2O3 from JRC Co., Ltd. Japan
Incipient wetness impregnation	1	ND	36.1	mixed-Al2O3	64% alpha-Al2O3, obtained by calcination of gamma-Al2O3, gamma-Al2O3 from JRC Co., Ltd. Japan
Incipient wetness impregnation	1	ND	45.4	mixed-Al2O3	47% alpha-Al2O3, obtained by calcination of gamma-Al2O3, gamma-Al2O3 from JRC Co., Ltd. Japan
Incipient wetness impregnation	1	ND	67.3	mixed-Al2O3	14% alpha-Al2O3, obtained by calcination of gamma-Al2O3, gamma-Al2O3 from JRC Co., Ltd. Japan
Incipient wetness impregnation	1	ND	244.1	gamma-Al2O3	from JRC Co., Ltd. Japan
Impregnation	0.5	ND	305	gamma-Al2O3	ND
Impregnation	0.8	ND	305	gamma-Al2O3	ND
Impregnation	1	ND	305	gamma-Al2O3	ND
Impregnation	2	ND	305	gamma-Al2O3	ND
Impregnation	4	ND	305	gamma-Al2O3	ND
Impregnation	6	ND	305	gamma-Al2O3	ND
Incipient wetness impregnation	ND	2.2	175	SiO2	from Degussa
Incipient wetness impregnation	ND	1.7	175	SiO2	from Degussa
Incipient wetness impregnation	ND	1.1	175	SiO2	from Degussa
Deposition-precipitation	1	ND	450	C	Sibunit, mesoporous carbon
Deposition-precipitation	1	ND	450	C	Sibunit, mesoporous carbon
Deposition-precipitation	1	ND	450	C	Sibunit, mesoporous carbon
Deposition-precipitation	1	ND	450	C	Sibunit, mesoporous carbon
Deposition-precipitation	1	ND	450	C	Sibunit, mesoporous carbon

Deposition-precipitation	1	ND	450	C	Sibunit, mesoporous carbon
Deposition-precipitation	1	ND	450	C	Sibunit, mesoporous carbon
Deposition-precipitation	1	ND	450	C	Sibunit, mesoporous carbon
Deposition-precipitation	1	ND	450	C	Sibunit, mesoporous carbon
Impregnation	0.5	ND	ND	C	carbon nanofibers, supplied from Applied Sciences (Ohio, USA)
Impregnation	1	ND	ND	C	carbon nanofibers, supplied from Applied Sciences (Ohio, USA)
Liquid-phase reduction	20	ND	ND	C	Vulcan XC-72
Liquid-phase reduction	20	ND	ND	C	Vulcan XC-72
Liquid-phase reduction	20	ND	ND	C	Vulcan XC-72
Liquid-phase reduction	20	ND	ND	C	Vulcan XC-72
Microwave-assisted synthesis	20	12.3	931	C	mesoporous carbon, SBA-15 as a hard template and benzene vapor as a carbon source
Microwave-assisted synthesis	20	13.6	764	C	mesoporous carbon, SBA-15 as a hard template and benzene vapor as a carbon source
Microwave-assisted synthesis	20	15.4	764	C	mesoporous carbon, SBA-15 as a hard template and benzene vapor as a carbon source
Microwave-assisted synthesis	20	16.2	764	C	mesoporous carbon, SBA-15 as a hard template and benzene vapor as a carbon source
Microwave-assisted synthesis	20	16.5	764	C	mesoporous carbon, SBA-15 as a hard template and benzene vapor as a carbon source
Impregnation	10	7.91	51.72	C	carbon nanotubes
Sol-gel	1	ND	ND	C	Darco G60, Aldrich
Sol-gel	1	ND	ND	TiO2	Degussa, P25
Commercial	5	5	NA	C	from NanoAmor
Deposition-precipitation	5	ND	695	mixed-Al2O3	n-Al2O3 (+), from NanoScale
Deposition-precipitation	5	ND	685	MgO	n-MgO, from NanoScale
Deposition-precipitation	5	ND	505	TiO2	n-TiO2, from NanoScale
Deposition-precipitation	5	ND	490	SiO2	n-SiO2, from NanoAmor
Deposition-precipitation	5	ND	275	mixed-Al2O3	n-Al2O3 (-), from NanoScale
Deposition-precipitation	5	ND	260	gamma-Al2O3	from Alfa Aesar
Deposition-precipitation	5	ND	240	SiO2	p-SiO2, from Alfa Aesar
Deposition-precipitation	5	ND	120	TiO2	p-TiO2, from Alfa Aesar
Deposition-precipitation	5	ND	70	ZnO	n-ZnO, from NanoScale
Deposition-precipitation	5	ND	60	CeO2	n-CeO2, from NanoScale
Deposition-precipitation	5	ND	45	CeO2-ZrO2	n-ZrO2 + CeO2, from NanoAmor
Deposition-precipitation	5	ND	40	mixed-Al2O3	Al(OH)3, from NanoAmor
Deposition-precipitation	5	ND	35	ZrO2	n-ZrO2, from NanoAmor
Deposition-precipitation	5	ND	35	SnO2	n-SnO2, from NanoAmor
Deposition-precipitation	5	ND	35	CuO	n-CuO, from NanoScale
Deposition-precipitation	ND	2.05	ND	Al2O3-SiO2	sodium-neutralized silica-alumina, SiO2/Al2O3:5.7
Deposition-precipitation	ND	2.05	ND	Al2O3-SiO2	sodium-neutralized silica-alumina, SiO2/Al2O3:5.7
Deposition-precipitation	ND	2.05	ND	Al2O3-SiO2	sodium-neutralized silica-alumina, SiO2/Al2O3:5.7
Incipient wetness impregnation	ND	2.05	ND	Al2O3-SiO2	sodium-neutralized silica-alumina, SiO2/Al2O3:5.7

Incipient wetness impregnation	ND	2.05	ND	Al2O3-SiO2	sodium-neutralized silica-alumina, SiO2/Al2O3:5.7
Incipient wetness impregnation	ND	2.05	ND	Al2O3-SiO2	sodium-neutralized silica-alumina, SiO2/Al2O3:5.7
Incipient wetness impregnation	ND	2.05	ND	Al2O3-SiO2	sodium-neutralized silica-alumina, SiO2/Al2O3:5.7
Incipient wetness impregnation	ND	2.05	ND	Al2O3-SiO2	sodium-neutralized silica-alumina, SiO2/Al2O3:5.7
Incipient wetness impregnation	ND	2.05	ND	Al2O3-SiO2	sodium-neutralized silica-alumina, SiO2/Al2O3:5.7
Impregnation	6	ND	315	SiO2	3-Aminopropyltriethoxysilane and phenyl isothiocyanate were reacted in methanol at room temperature (r.t.) for 2 h, yielding N-(phenyl)-N'-(3-triethoxysilylpropyl) thiourea.
Impregnation	6	ND	315	SiO2	3-Aminopropyltriethoxysilane and phenyl isothiocyanate were reacted in methanol at room temperature (r.t.) for 2 h, yielding N-(phenyl)-N'-(3-triethoxysilylpropyl) thiourea.
Impregnation	6	ND	315	SiO2	3-Aminopropyltriethoxysilane and phenyl isothiocyanate were reacted in methanol at room temperature (r.t.) for 2 h, yielding N-(phenyl)-N'-(3-triethoxysilylpropyl) thiourea.
Impregnation	6	ND	315	SiO2	3-Aminopropyltriethoxysilane and phenyl isothiocyanate were reacted in methanol at room temperature (r.t.) for 2 h, yielding N-(phenyl)-N'-(3-triethoxysilylpropyl) thiourea.
Impregnation	6	ND	315	SiO2	3-Aminopropyltriethoxysilane and phenyl isothiocyanate were reacted in methanol at room temperature (r.t.) for 2 h, yielding N-(phenyl)-N'-(3-triethoxysilylpropyl) thiourea.
Impregnation	6	ND	315	SiO2	3-Aminopropyltriethoxysilane and phenyl isothiocyanate were reacted in methanol at room temperature (r.t.) for 2 h, yielding N-(phenyl)-N'-(3-triethoxysilylpropyl) thiourea.
Impregnation	6	ND	315	SiO2	3-Aminopropyltriethoxysilane and phenyl isothiocyanate were reacted in methanol at room temperature (r.t.) for 2 h, yielding N-(phenyl)-N'-(3-triethoxysilylpropyl) thiourea.
Impregnation	6	ND	315	SiO2	3-Aminopropyltriethoxysilane and phenyl isothiocyanate were reacted in methanol at room temperature (r.t.) for 2 h, yielding N-(phenyl)-N'-(3-triethoxysilylpropyl) thiourea.
Incipient wetness impregnation	0.50	0.50	ND	Al2O3-CeO2	aqueous solution of cerium(III) nitrate hexahydrate (Sigma-Aldrich) was used to impregnate the γ-Al2O3 (Puralox/Catalox SBa Sasol)
Incipient wetness impregnation	1.00	1.09	ND	Al2O3-CeO2	aqueous solution of cerium(III) nitrate hexahydrate (Sigma-Aldrich) was used to impregnate the γ-Al2O3 (Puralox/Catalox SBa Sasol)
Deposition-precipitation	2	ND	ND	TiO2	TiO2 {1 0 0} anatase, synthesized from TiCl4
Deposition-precipitation	2	ND	ND	TiO2	TiO2 {1 0 1} NCs anatase, synthesized from TiCl4
Incipient wetness impregnation	5	ND	ND	alpha-Al2O3	by Aldrich
Impregnation	1	ND	ND	mixed-Al2O3	manufactured by Johnson Matthey
Impregnation	1	ND	ND	mixed-Al2O3	manufactured by Johnson Matthey
Impregnation	4	ND	243	C	Sibunit
Commercial	5	5	NA	C	Aldrich
Impregnation	ND	0.7	1200	C	GAC 1240 by ELF-Atochem
Commercial	5	5	NA	gamma-Al2O3	by Fluka A.G Buchs S.G.
Commercial	10	10	NA	gamma-Al2O3	by Fluka A.G Buchs S.G.
Impregnation	5	ND	1070	C	from MAST Carbons Ltd. Guildford, UK
Incipient wetness impregnation	1	0.86	9.2	alpha-Al2O3	Rhone Poulenc
Incipient wetness impregnation	1	0.77	134.4	gamma-Al2O3	Condea, Puralox
Impregnation	1	0.65	9.2	alpha-Al2O3	Rhone Poulenc

Impregnation	1	0.78	134.4	gamma-Al2O3	Condea, Puralox
Impregnation	0.4	ND	134	gamma-Al2O3	ND
Impregnation	0.4	ND	134	gamma-Al2O3	ND
Impregnation	0.5	ND	ND	TiO2	Degussa P25
Impregnation	0.5	ND	ND	TiO2	Degussa P25
Impregnation	0.5	ND	ND	TiO2	Degussa P25
Commercial	10	10	NA	C	Vulcan XC-72 from E-TEK, USA
Incipient wetness impregnation	5	ND	200	SiO2	Cab-O-Sil M5 silica
Impregnation	0.5	0.47	ND	CeO2	CeO2 nanorod, synthesized from hydrothermal method of Ce(NO3)3.6H2O and NaOH
Deposition-precipitation	10	ND	ND	C	Vulcan XC-72, Gashub
Incipient wetness impregnation	0.5	ND	135	SiO2	HiSil 210 from Pittsburg Plate Glass Co.
Incipient wetness impregnation	ND	1.68	ND	TiO2-SiO2	Ti(OCH(CH3)2)4 (Acros), SiO2 and toluene
Incipient wetness impregnation	ND	1.62	400	SiO2	MN Kieselgel 60
Incipient wetness impregnation	ND	1.96	40	TiO2	Merck
Incipient wetness impregnation	0.5	ND	ND	TiO2	macro-mesoporous titania, from ammonia and TTBOT
Incipient wetness impregnation	0.5	ND	ND	TiO2	from water and TTBOT
Deposition-precipitation	5	4.7	ND	BaSO4	ND
Commercial	5	5	ND	CaCO3	supplied from Johnson Matthey
Deposition-precipitation	5	3.5	ND	SiO2	purchased from Aldrich
Deposition-precipitation	5	4.5	ND	SiO2	purchased from Aldrich
Deposition-precipitation	5	4.9	ND	SiO2	purchased from Aldrich
Deposition-precipitation	5	3.5	ND	SiO2	Aerosil 380 from Degussa
Incipient wetness impregnation	5	4.3	ND	SiO2	Aerosil 380 from Degussa
Commercial	5	5	NA	C	from Johnson Matthey
Incipient wetness impregnation	ND	1.93	300	SiO2	Davisil 644 from Aldrich
Incipient wetness impregnation	ND	1.93	300	SiO2	Davisil 644 from Aldrich
Incipient wetness impregnation	ND	1.87	180	mixed-Al2O3	ND
Incipient wetness impregnation	ND	1.87	180	mixed-Al2O3	ND
Impregnation	0.5	0.6	ND	C	carbon nanofibre, from Applied Sciences (OH, USA)
Impregnation	1	1	ND	C	carbon nanofibre, from Applied Sciences (OH, USA)
Impregnation	0.5	0.55	ND	C	carbon nanofibre, from Applied Sciences (OH, USA)
Impregnation	1	0.98	ND	C	carbon nanofibre, from Applied Sciences (OH, USA)
Impregnation	0.5	0.55	ND	C	carbon nanofibre, from Applied Sciences (OH, USA)
Impregnation	1	1.02	ND	C	carbon nanofibre, from Applied Sciences (OH, USA)
Impregnation	0.5	0.58	ND	C	carbon nanofibre, from Applied Sciences (OH, USA)
Impregnation	1	1.06	ND	C	carbon nanofibre, from Applied Sciences (OH, USA)
Impregnation	0.5	0.54	ND	C	carbon nanofibre, from Applied Sciences (OH, USA)
Impregnation	0.5	0.55	ND	C	carbon nanofibre, from Applied Sciences (OH, USA)
Incipient wetness impregnation	3.5	ND	902.31	C	activated carbon, from Norit Americas Inc.
Incipient wetness impregnation	3.5	ND	902.31	C	activated carbon, from Norit Americas Inc.
Incipient wetness impregnation	3.5	ND	902.31	C	activated carbon, from Norit Americas Inc.
Deposition-precipitation	20	21.5	222	C	Vulcan XC-72R, from Cabot Corporation (USA)
Deposition-precipitation	20	21.27	158	C	Vulcan XC-72R, from Cabot Corporation (USA)
Deposition-precipitation	20	23.79	223	C	Vulcan XC-72R, from Cabot Corporation (USA)
Deposition-precipitation	20	22.48	229	C	Vulcan XC-72R, from Cabot Corporation (USA)
Deposition-precipitation	20	22.23	103	C	Vulcan XC-72R, from Cabot Corporation (USA)
Polyol	20	ND	ND	C	Vulcan XC-72
Polyol	20	ND	ND	C	Vulcan XC-72
Polyol	20	ND	ND	C	Vulcan XC-72

Polyol	20	ND	ND	C	Vulcan XC-72
Polyol	20	17.41	ND	C	Vulcan XC-72
Impregnation	20	17.18	ND	C	Vulcan XC-72
Incipient wetness impregnation	0.5	ND	1521	C	Kraft lignin by ENCE by acid precipitation from eucalyptus kraft black liquors
Incipient wetness impregnation	0.5	ND	1375	C	Kraft lignin by ENCE by acid precipitation from eucalyptus kraft black liquors
Incipient wetness impregnation	0.5	ND	1521	C	Kraft lignin by ENCE by acid precipitation from eucalyptus kraft black liquors
Impregnation	1	1	200	SiO2	by Sigma
Impregnation	3	3.1	200	SiO2	by Sigma
Impregnation	5	5	200	SiO2	by Sigma
Impregnation	10	10	200	SiO2	by Sigma
Impregnation	1	1	200	SiO2	by Sigma
Incipient wetness impregnation	1	1.01	100	theta-Al2O3	Sasol Puralox SBA 140
Incipient wetness impregnation	2	2.14	100	theta-Al2O3	Sasol Puralox SBA 140
Incipient wetness impregnation	4	3.94	100	theta-Al2O3	Sasol Puralox SBA 140
Impregnation	ND	1.64	ND	mixed-Al2O3	by Akzo Nobel
Impregnation	ND	2.23	ND	mixed-Al2O3	by Akzo Nobel
Impregnation	ND	2.33	ND	SiO2	by Akzo Nobel
Impregnation	ND	1.62	ND	C	Activated carbon by Norit ROX0.8
Impregnation	ND	2.33	ND	C	Activated carbon by Norit ROX0.9
Impregnation	ND	2.37	ND	C	Graphite by Evonik industries
Impregnation	ND	1.21	ND	C	carbon nanofibers
Impregnation	ND	1.48	ND	C	carbon nanofibers
Deposition-precipitation	2	ND	350	C	Mesoporous graphite like carbon (Sibunit)
Deposition-precipitation	2	ND	350	C	Mesoporous graphite like carbon (Sibunit)
Deposition-precipitation	2	ND	350	C	Mesoporous graphite like carbon (Sibunit)
Deposition-precipitation	2	ND	350	C	Mesoporous graphite like carbon (Sibunit)
Impregnation	0.3	ND	93	mixed-Al2O3	alumina sol from aluminum powder and HCl (Al/Cl molar ratio:1.40)
Impregnation	0.3	ND	152	Al2O3-SiO2	from Na2SiO3.9H2O, alumina sol, 2 wt% SiO2 loaded
Impregnation	0.3	ND	165	Al2O3-SiO2	from Na2SiO3.9H2O, alumina sol, 5 wt% SiO2 loaded
Impregnation	0.3	ND	187	Al2O3-SiO2	from Na2SiO3.9H2O, alumina sol, 8 wt% SiO2 loaded
Commercial	1	1	NA	gamma-Al2O3	Aldrich
Commercial	5	5	NA	gamma-Al2O3	Aldrich
Microwave-assisted synthesis	ND	1.9	138	gamma-Al2O3	Strem
Microwave-assisted synthesis	ND	2.1	138	gamma-Al2O3	Strem
Microwave-assisted synthesis	ND	2.2	138	gamma-Al2O3	Strem
Microwave-assisted synthesis	ND	0.7	138	gamma-Al2O3	Strem
Microwave-assisted synthesis	ND	0.7	138	gamma-Al2O3	Strem
Microwave-assisted synthesis	ND	4.8	138	gamma-Al2O3	Strem
Microwave-assisted synthesis	ND	2	138	gamma-Al2O3	Strem
Incipient wetness impregnation	1.5	ND	331	SiO2	Akzo
Impregnation	3	ND	1175.29	C	activated carbon purchased from SHHXTC
Impregnation	3	ND	1397.34	C	activated carbon purchased from SHHXTC
Incipient wetness impregnation	1	0.9	ND	TiO2	Degussa P 25
Liquid-phase reduction	1	1.1	ND	TiO2	Degussa P 25
Commercial	20	20	NA	C	NA
Liquid-phase reduction	ND	19.4	ND	C	Vulcan XC-72
Liquid-phase reduction	ND	21	ND	C	Vulcan XC-72 from Cabot Company (Boston, USA)
Liquid-phase reduction	ND	21	ND	C	Vulcan XC-72 from Cabot Company (Boston, USA)
Commercial	20	20	NA	C	activated carbon (wood based), Evonik Industries

Commercial	5	5	NA	C	activated carbon (wood based), Evonik Industries
Commercial	5	5	NA	C	activated carbon (wood based), Evonik Industries
Commercial	5	5	NA	C	activated carbon (wood based), Evonik Industries
Incipient wetness impregnation	5	ND	ND	C	activated carbon aerogel
Incipient wetness impregnation	5	ND	ND	C	activated carbon aerogel
Incipient wetness impregnation	5	ND	ND	C	activated carbon aerogel
Incipient wetness impregnation	5	ND	ND	C	activated carbon aerogel
Incipient wetness impregnation	5	ND	ND	C	activated carbon aerogel
Incipient wetness impregnation	2	ND	1326	C	activated carbon NC80 (PICA)
Liquid-phase reduction	5	ND	1217	C	activated carbon (200 mesh)
Liquid-phase reduction	5	ND	1532	C	mesoporous carbon (20-40 mesh)
Liquid-phase reduction	5	ND	1644	C	mesoporous carbon (200 mesh)
Liquid-phase reduction	5	ND	1441	C	mesoporous carbon (200 mesh)
Impregnation	ND	0.74	125	mixed-Al2O3	Rhone-Poulenc
Impregnation	ND	1.45	62	ZrO2	Sigma-Aldrich
Impregnation	ND	1.28	47	TiO2	Sigma-Aldrich
Liquid-phase reduction	20	ND	ND	C	Vulcan XC-72
Impregnation	3	ND	ND	C	carbon nanotubes, supplied by Prof. W.Fei from Tsinghua University
Impregnation	3	ND	ND	C	activated carbon, supplied from Shaowu Xinsen Chemical Industry
Incipient wetness impregnation	0.1	0.09	42	CeO2	by Sigma-Aldrich
Incipient wetness impregnation	0.1	0.08	57	MgO	by Sigma-Aldrich
Incipient wetness impregnation	0.1	0.09	45	MgZrO3	by Sigma-Aldrich
Incipient wetness impregnation	0.1	0.11	30	ZrO2	by Sigma-Aldrich
Incipient wetness impregnation	0.1	0.09	124	mixed-Al2O3	by Alfa Aesar
Incipient wetness impregnation	0.1	0.1	645	Al2O3-SiO2	by Sigma-Aldrich
Impregnation	60	60	ND	C	graphene, prepared with Hummers method, source: natural graphite supplied from Carbonix Co., Korea
Impregnation	1	0.85	ND	gamma-Al2O3	supplied from Alfa Aesar, USA
Impregnation	2	2.2	ND	gamma-Al2O3	supplied from Alfa Aesar, USA
Commercial	0.5	0.5	NA	C	activated carbon, supplied from Engelhard, Italy
Incipient wetness impregnation	0.5	ND	950	C	activated carbon, supplied from Merck
Incipient wetness impregnation	0.5	ND	950	C	activated carbon, supplied from Merck
Incipient wetness impregnation	ND	1.4	420	gamma-Al2O3	prepared with aluminum iso-propoxide, supplied from Aldrich
Incipient wetness impregnation	ND	1.5	420	gamma-Al2O3	prepared with aluminum iso-propoxide, supplied from Aldrich
Incipient wetness impregnation	ND	1.9	420	gamma-Al2O3	prepared with aluminum iso-propoxide, supplied from Aldrich
Incipient wetness impregnation	ND	2	420	gamma-Al2O3	prepared with aluminum iso-propoxide, supplied from Aldrich
Impregnation	2	1.96	14	LaFeO3	prepared with citric acid, water, La(NO3)3 (Fluka) and Fe(NO3)3 (Sigma-Aldrich)
Impregnation	2	1.89	14	LaFeO3	prepared with citric acid, water, La(NO3)3 (Fluka) and Fe(NO3)3 (Sigma-Aldrich)
Impregnation	2	1.95	14	LaFeO3	prepared with citric acid, water, La(NO3)3 (Fluka) and Fe(NO3)3 (Sigma-Aldrich)
Impregnation	2	2.01	14	LaFeO3	prepared with citric acid, water, La(NO3)3 (Fluka) and Fe(NO3)3 (Sigma-Aldrich)
Liquid-phase reduction	ND	5	1787	C	activated carbon made from coconut shells, supplied from Fujian Xinsen Carbon Co., Ltd.
Liquid-phase reduction	ND	5	1655	C	activated carbon made from coconut shells, supplied from Fujian Xinsen Carbon Co., Ltd.

Liquid-phase reduction	ND	5	1548	C	activated carbon made from coconut shells, supplied from Fujian Xinsen Carbon Co., Ltd.
Liquid-phase reduction	ND	5	1252	C	activated carbon made from coconut shells, supplied from Fujian Xinsen Carbon Co., Ltd.
Liquid-phase reduction	ND	5	664	C	activated carbon made from coconut shells, supplied from Fujian Xinsen Carbon Co., Ltd.
Liquid-phase reduction	ND	2	1846	C	activated carbon made from coconut shells, supplied from Fujian Xinsen Carbon Co., Ltd.
Impregnation	2.8	ND	1055	C	activated carbon, supplied from Calgon Carbon Corporation, USA
Liquid-phase reduction	5	ND	ND	C	single-walled carbon nanotubes, supplied from Unidym, High Purity HIPCO
Impregnation	20	ND	ND	C	Vulcan XC-72, supplied from Cabot Corp.
Impregnation	20	ND	ND	C	Vulcan XC-72, supplied from Cabot Corp.
Impregnation	20	ND	ND	C	Vulcan XC-72, supplied from Cabot Corp.
Impregnation	20	ND	ND	C	Vulcan XC-72, supplied from Cabot Corp.
Incipient wetness impregnation	5	ND	981	C	activated carbon, supplied from Filtrasorb-300, Calgon Carbon Co.
Incipient wetness impregnation	5	ND	981	C	activated carbon, supplied from Filtrasorb-300, Calgon Carbon Co.
Incipient wetness impregnation	5	ND	981	C	activated carbon, supplied from Filtrasorb-300, Calgon Carbon Co.
Incipient wetness impregnation	2	ND	387	C	activated carbon, (Sibunit carbon)
Incipient wetness impregnation	1	1	160	gamma-Al2O3	by Sasol Ltd.
Incipient wetness impregnation	1	0.99	160	gamma-Al2O3	by Sasol Ltd.
Incipient wetness impregnation	1	1	85	CeO2-ZrO2	by Rhodia Co., Ltd.
Incipient wetness impregnation	1	1.03	85	CeO2-ZrO2	by Rhodia Co., Ltd.
Impregnation	1	ND	180	SiO2	from Degussa
Impregnation	1	ND	180	SiO2	from Degussa
Impregnation	1	0.93	429	Al2O3-SiO2	mesoporous silica alumina (52 wt% Al2O3) from aqueous solutions of sodium metasilicate and aluminum nitrate
Impregnation	1	1.48	429	Al2O3-SiO2	mesoporous silica alumina (52 wt% Al2O3) from aqueous solutions of sodium metasilicate and aluminum nitrate
Impregnation	1	1.2	429	Al2O3-SiO2	mesoporous silica alumina (52 wt% Al2O3) from aqueous solutions of sodium metasilicate and aluminum nitrate
Impregnation	1	0.92	643	Al2O3-SiO2	mesoporous silica alumina (9 wt% Al2O3) from aqueous solutions of sodium metasilicate and aluminum nitrate
Impregnation	1	0.84	643	Al2O3-SiO2	mesoporous silica alumina (9 wt% Al2O3) from aqueous solutions of sodium metasilicate and aluminum nitrate
Impregnation	1	1.12	643	Al2O3-SiO2	mesoporous silica alumina (9 wt% Al2O3) from aqueous solutions of sodium metasilicate and aluminum nitrate
Incipient wetness impregnation	5	ND	ND	C	activated carbon, supplied from China Tangshan Jianxin Activated Carbon Co., Ltd.
Impregnation	1.4	ND	ND	Al2O3-La2O3	Al(NO3)3.9H2O + La(NO3)3
Commercial	20	19.9	NA	C	supplied from E-tek
Commercial	20	19.8	NA	C	supplied from E-tek
Impregnation	1	0.96	433	SiO2	by Sigma Aldrich
Impregnation	1	0.95	433	SiO2	by Sigma Aldrich
Impregnation	1	0.96	433	SiO2	by Sigma Aldrich
Impregnation	0.5	0.48	433	SiO2	by Sigma Aldrich
Impregnation	3	2.96	433	SiO2	by Sigma Aldrich
Impregnation	5	4.93	433	SiO2	by Sigma Aldrich
Impregnation	10	9.9	433	SiO2	by Sigma Aldrich
Impregnation	ND	1.05	ND	gamma-Al2O3	by Stem Chemicals

Impregnation	5	ND	320	SiO2	Degussa
Impregnation	5	ND	320	SiO2	Degussa
Impregnation	5	ND	130	mixed-Al2O3	Fluka 507C
Impregnation	5	ND	49	TiO2	P-25 Degussa
Incipient wetness impregnation	ND	0.6	35	ZrO2	MEL Chemicals
Impregnation	0.5	ND	46	mixed-Al2O3	alpha and theta Al2O3 (mixed phases), from Al(OH)2 (Sasol North Ameirca Inc.)
Impregnation	0.5	ND	46	mixed-Al2O3	alpha and theta Al2O3 (mixed phases), from Al(OH)2 (Sasol North Ameirca Inc.)
Impregnation	0.5	ND	46	mixed-Al2O3	alpha and theta Al2O3 (mixed phases), from Al(OH)2 (Sasol North Ameirca Inc.)
Impregnation	0.5	ND	46	mixed-Al2O3	alpha and theta Al2O3 (mixed phases), from Al(OH)2 (Sasol North Ameirca Inc.)
Incipient wetness impregnation	2	ND	404	SiO2	ND
Commercial	40	40	NA	C	from E-Tek
Incipient wetness impregnation	ND	3.6	ND	SiO2	from PQ Corporation (MS-3030)
Incipient wetness impregnation	ND	2.7	ND	gamma-Al2O3	from Sasol, type puralox SCCa-30/200
Sol-gel	ND	0.9	ND	C	carbon nanotubes (PR24PS) supplied by Pyrograf products, Inc.
Photo-deposition	ND	0.51	52.72	TiO2	P25, Degussa
Photo-deposition	ND	0.96	52.72	TiO2	P25, Degussa
Photo-deposition	ND	2.04	52.72	TiO2	P25, Degussa
Photo-deposition	ND	2.97	52.72	TiO2	P25, Degussa
Photo-deposition	ND	0.47	354.6	TiO2	TiO2 nanotube, from TiO2 Degussa P25 and NaOH
Photo-deposition	ND	0.97	354.6	TiO2	TiO2 nanotube, from TiO2 Degussa P25 and NaOH
Photo-deposition	ND	1.93	354.6	TiO2	TiO2 nanotube, from TiO2 Degussa P25 and NaOH
Photo-deposition	ND	2.93	354.6	TiO2	TiO2 nanotube, from TiO2 Degussa P25 and NaOH
Incipient wetness impregnation	10	ND	ND	C	carbon nanotubes
Impregnation	10	ND	106	mixed-Al2O3	ND
Impregnation	1	ND	106	mixed-Al2O3	ND
Impregnation	5	ND	106	mixed-Al2O3	ND
Impregnation	1	ND	106	mixed-Al2O3	ND
Impregnation	1	ND	106	mixed-Al2O3	ND
Impregnation	1.5	1.5	ND	mixed-Al2O3	high surface area Al2O3, prepared from propylene oxide, ethanol, water and AlCl3
Impregnation	1.5	1.5	238	gamma-Al2O3	prepared from bohemite (Condea)
Commercial	10	10	NA	mixed-Al2O3	activated alumina, from Aldrich
Liquid-phase reduction	ND	38.6	ND	C	graphene nanosheet, from Graphite powder which was obtained from Qingdao Henglide Graphite Co., Ltd
Incipient wetness impregnation	0.3	ND	ND	mixed-Al2O3	macro-mesoporous alumina, from aluminum tri-sec-butoxide
Impregnation	5	4.96	1698	C	activated carbon, supplied from Baoji Rock New Materials Co., Ltd., China
Impregnation	5	4.97	1579	C	activated carbon, supplied from Baoji Rock New Materials Co., Ltd., China
Impregnation	5	4.96	1647	C	activated carbon, supplied from Baoji Rock New Materials Co., Ltd., China
Impregnation	5	4.95	1515	C	activated carbon, supplied from Baoji Rock New Materials Co., Ltd., China
Incipient wetness impregnation	0.35	0.34	180	gamma-Al2O3	CK-300
Incipient wetness impregnation	0.35	0.34	180	gamma-Al2O3	CK-300
Incipient wetness impregnation	0.35	0.31	180	gamma-Al2O3	CK-300
Sol-gel	0.5	ND	ND	Al2O3-ZrO2	from aluminum secondary butoxide and zirconium butoxide
Impregnation	0.5	ND	ND	Al2O3-ZrO2	from aluminum secondary butoxide and zirconium butoxide
Impregnation	0.5	ND	ND	Al2O3-ZrO2	from aluminum secondary butoxide and zirconium butoxide

Incipient wetness impregnation	1	ND	ND	CeO2	from CeCl3.7H2O
Incipient wetness impregnation	1	ND	ND	ZrO2	from ZrOCl2.8H2O
Incipient wetness impregnation	1	ND	ND	CeO2-ZrO2	from ZrOCl2·8H2O and CeCl3.7H2O
Incipient wetness impregnation	1	ND	ND	MnO2	from Mn(NO3)2·H2O
Incipient wetness impregnation	1	ND	ND	SnO2	from SnCl4.5H2O
Incipient wetness impregnation	1	ND	ND	mixed-Al2O3	from boehmite
Incipient wetness impregnation	1	ND	ND	WO3	from WCl6
Incipient wetness impregnation	1	ND	ND	WO3-ZrO2	from WC6 and ZrOCl2.8H2O
Liquid-phase reduction	32	ND	ND	C	graphene, from Hummers method, by using graphite
Liquid-phase reduction	18	ND	ND	C	graphene, from Hummers method, by using graphite
Liquid-phase reduction	25	ND	ND	C	graphene, from Hummers method, by using graphite
Liquid-phase reduction	40	ND	ND	C	graphene, from Hummers method, by using graphite
Liquid-phase reduction	50	ND	ND	C	graphene, from Hummers method, by using graphite
Deposition-precipitation	10	ND	ND	TiO2	ND
Incipient wetness impregnation	ND	3.6	310	SiO2	from PQ Corporation (MS-3030)
Incipient wetness impregnation	8.5	8.7	148	gamma-Al2O3	from Johnson Matthey
Impregnation	8.5	ND	148	gamma-Al2O3	from Johnson Matthey
Incipient wetness impregnation	0.5	0.5	230	SiO2	Grace G62
Polyol	ND	20	ND	C	hydrogen-exfoliated graphene, from natural graphite using Hummers method
Impregnation	ND	0.55	ND	SiO2	ND
Impregnation	ND	0.55	ND	SiO2	ND
Impregnation	ND	0.53	ND	mixed-Al2O3	ND
Impregnation	ND	0.53	ND	mixed-Al2O3	ND
Impregnation	ND	0.52	ND	Al2O3-SiO2	Si/Al = 2/1
Impregnation	ND	0.3	ND	Al2O3-SiO2	Si/Al = 1/1
Impregnation	ND	0.52	ND	Al2O3-SiO2	Si/Al = 1/2
Impregnation	ND	0.52	ND	Al2O3-SiO2	Si/Al = 2/1
Impregnation	ND	0.3	ND	Al2O3-SiO2	Si/Al = 1/1
Impregnation	ND	0.3	ND	Al2O3-SiO2	Si/Al = 1/2
Impregnation	ND	0.52	ND	Al2O3-SiO2	Si/Al = 2/1
Impregnation	ND	0.39	ND	Al2O3-SiO2	Si/Al = 1/1
Impregnation	ND	0.56	ND	Al2O3-SiO2	Si/Al = 1/2
Commercial	1	1	NA	C	Aldrich
Commercial	5	5	NA	C	Aldrich
Incipient wetness impregnation	2	ND	ND	mixed-Al2O3	by Degussa
Incipient wetness impregnation	2	ND	ND	SiO2	by Degussa
Incipient wetness impregnation	2	ND	ND	Al2O3-SiO2	from AlCl3.6H2O, sodium silicate, acetic acid and NH4OH
Incipient wetness impregnation	2	ND	ND	C	graphene, synthesized from graphene oxide (Hummers method)
Incipient wetness impregnation	6	ND	ND	C	graphene, synthesized from graphene oxide (Hummers method)
Incipient wetness impregnation	10	ND	ND	C	graphene, synthesized from graphene oxide (Hummers method)
Impregnation	5	4.1	ND	C	carbon nanofibers, from Pyrograf Products
Impregnation	5	4.8	ND	C	carbon nanofibers, from Pyrograf Products
Impregnation	5	5.1	ND	C	carbon nanofibers, from Pyrograf Products
Impregnation	5	4.7	ND	C	carbon nanofibers, from Pyrograf Products
Impregnation	5	4.7	ND	C	carbon nanofibers, from Pyrograf Products
Commercial	5	5.4	NA	C	activated carbon, from Sigma Aldrich
Commercial	5	5.6	NA	mixed-Al2O3	from Sigma Aldrich

Liquid-phase reduction	ND	0.69	NA	C	graphene oxide, synthesized by the Hummers method, graphite powder from Alfa Aesar
Impregnation	ND	0.68	786	C	graphene, synthesized from graphene oxide (Hummers method)
Impregnation	ND	0.72	352	C	carbon nanotube, from Alfa Aesar
Impregnation	ND	0.71	497	C	activated carbon, from Alfa Aesar
Commercial	5	4.92	NA	C	activated carbon, from Alfa Aesar
Incipient wetness impregnation	2	1.87	150	mixed-Al2O3	ND
Deposition-precipitation	5	ND	980	C	wood based activated carbon
Deposition-precipitation	5	ND	980	C	wood based activated carbon
Deposition-precipitation	5	ND	980	C	wood based activated carbon
Impregnation	ND	0.9	546	C	activated carbon honeycomb monolith, from Jingdezhen Institute of Ceramic Materials, China
Impregnation	ND	0.91	583	C	activated carbon honeycomb monolith, from Jingdezhen Institute of Ceramic Materials, China
Impregnation	ND	0.88	619	C	activated carbon honeycomb monolith, from Jingdezhen Institute of Ceramic Materials, China
Impregnation	ND	0.85	632	C	activated carbon honeycomb monolith, from Jingdezhen Institute of Ceramic Materials, China
Liquid-phase reduction	2.5	ND	19	C	vapor growing carbon fiber, from Showa Denko
Liquid-phase reduction	2.5	ND	114	C	carbon nanotubes
Liquid-phase reduction	2.5	ND	3	C	graphite, from Shanghai Colloidal Chemical Plant
Liquid-phase reduction	2.5	ND	227	C	carbon black XC-72, from Shanghai Cabot Chemical Co. Ltd.
Liquid-phase reduction	2.5	ND	227	C	carbon black XC-72R, from Shanghai Cabot Chemical Co. Ltd.
Liquid-phase reduction	2.5	ND	50	C	carbon black XC-605, from Shanghai Cabot Chemical Co. Ltd.
Liquid-phase reduction	2.5	ND	70	C	carbon black U-CB, from Shanghai Chemical Reagent Company Limited
Liquid-phase reduction	2.5	ND	62	C	carbon black ML, from Shanghai Cabot Chemical Co. Ltd.
Liquid-phase reduction	2.5	ND	1458	C	carbon black BP-2000, from Shanghai Cabot Chemical Co. Ltd.
Liquid-phase reduction	2.5	ND	80	C	activated carbon (wood charcoal), from Shanghai Chemical Reagent Company Limited
Liquid-phase reduction	2.5	ND	758	C	activated carbon (coconut shell, from Shanghai Chemical Reagent Company Limited
Liquid-phase reduction	2.5	ND	1565	C	activated carbon (nut shell), from Shanghai Chemical Reagent Company Limited
Impregnation	2.5	ND	ND	SiO2	ND
Impregnation	2.5	ND	ND	gamma-Al2O3	ND
Impregnation	2.5	ND	ND	TiO2	ND
Impregnation	2.5	ND	ND	ZrO2	ND
Impregnation	2.5	ND	ND	CeO2	ND
Liquid-phase reduction	2.5	ND	227	C	carbon black XC-72, from Shanghai Cabot Chemical Co. Ltd.
Liquid-phase reduction	2.5	ND	227	C	carbon black XC-72, from Shanghai Cabot Chemical Co. Ltd.
Liquid-phase reduction	2.5	ND	227	C	carbon black XC-72, from Shanghai Cabot Chemical Co. Ltd.
Liquid-phase reduction	2.5	ND	227	C	carbon black XC-72, from Shanghai Cabot Chemical Co. Ltd.
Liquid-phase reduction	2.5	ND	227	C	carbon black XC-72, from Shanghai Cabot Chemical Co. Ltd.
Liquid-phase reduction	2.5	ND	227	C	carbon black XC-72, from Shanghai Cabot Chemical Co. Ltd.
Liquid-phase reduction	2.5	ND	227	C	carbon black XC-72, from Shanghai Cabot Chemical Co. Ltd.
Liquid-phase reduction	2.5	ND	227	C	carbon black XC-72, from Shanghai Cabot Chemical Co. Ltd.

Impregnation	5	ND	852	C	activated carbon, from Beijing Guanghua Timber Mill.
Liquid-phase reduction	1	ND	274	C	Vulcan XC-72R, from Cabot Corporation
Liquid-phase reduction	1	ND	32	MgO	from Inframat Advanced Materials
Liquid-phase reduction	1	ND	160	gamma-Al2O3	from Sasol
Impregnation	0.4	ND	250	mixed-Al2O3	Pural SB-1 Sasol
Impregnation	0.3	ND	340	SiO2	ND
Impregnation	0.6	ND	250	mixed-Al2O3	Pural SB-1 Sasol
Deposition-precipitation	2	ND	ND	C	Carbon nanofibers
Deposition-precipitation	2	ND	ND	C	Carbon nanofibers
Deposition-precipitation	1	ND	ND	C	Carbon nanofibers
Impregnation	4	ND	ND	C	Activated carbon
Impregnation	4	ND	ND	mixed-Al2O3	ND
Deposition-precipitation	ND	0.83	85.6	CeO2	from Ce(NO3)3.6H2O and ammonia
Deposition-precipitation	ND	0.85	83.2	ZrO2	from ZrOCl2.8H2O and ammonia
Deposition-precipitation	ND	0.9	92.5	CeO2-ZrO2	from ammonia, ZrOCl2 and Ce(NO3)3, ratio (ZrO2:CeO2)=0.8:0.2
Deposition-precipitation	ND	0.85	102.3	CeO2-ZrO2	from ammonia, ZrOCl2 and Ce(NO3)3, ratio (ZrO2:CeO2)=0.5:0.5
Deposition-precipitation	ND	0.5	94.9	CeO2-ZrO2	from ammonia, ZrOCl2 and Ce(NO3)3, ratio (ZrO2:CeO2)=0.2:0.8
Deposition-precipitation	ND	0.86	94.9	CeO2-ZrO2	from ammonia, ZrOCl2 and Ce(NO3)3, ratio (ZrO2:CeO2)=0.2:0.8
Deposition-precipitation	ND	1.74	94.9	CeO2-ZrO2	from ammonia, ZrOCl2 and Ce(NO3)3, ratio (ZrO2:CeO2)=0.2:0.8
Deposition-precipitation	ND	2.49	94.9	CeO2-ZrO2	from ammonia, ZrOCl2 and Ce(NO3)3, ratio (ZrO2:CeO2)=0.2:0.8
Incipient wetness impregnation	1	ND	1200	C	Activated Carbon, from Erkimia S.A.
Commercial	5	5	NA	C	activated carbon, from Sigma Aldrich
Commercial	1.2	1.2	NA	mixed-Al2O3	from Sigma Aldrich
Commercial	1	1	NA	C	from Sigma Aldrich
Incipient wetness impregnation	2	ND	ND	gamma-Al2O3	from Sasol
Incipient wetness impregnation	2	ND	ND	SiO2	from Sigma Aldrich
Incipient wetness impregnation	2	ND	ND	TiO2	from Millennium Inorganic Chemicals
Incipient wetness impregnation	1	ND	50	TiO2	Degussa P25
Incipient wetness impregnation	2	ND	50	TiO2	Degussa P25
Incipient wetness impregnation	3	ND	50	TiO2	Degussa P25
Incipient wetness impregnation	5	ND	50	TiO2	Degussa P25
Impregnation	1.5	ND	213	C	carbon nanotubes, Baytubes C 150 HP, Bayer
Impregnation	1.5	ND	429	C	carbon black, CP278-E
Commercial	1	1.02	ND	mixed-Al2O3	from Alfa Aesar
Impregnation	ND	1.35	ND	mixed-Al2O3	from Strem 13-2525
Impregnation	ND	1.44	ND	mixed-Al2O3	from Strem 13-2525
Impregnation	ND	1.13	ND	CeO2-ZrO2	from Alfa Aesar 39216
Impregnation	ND	0.54	ND	CeO2-ZrO2	from Alfa Aesar 39216
Impregnation	ND	0.52	ND	CeO2	from Alfa Aesar 12925
Impregnation	2	1.9	301	gamma-Al2O3	Süd-Chemie India Pvt. Ltd.
Impregnation	5	4.7	301	gamma-Al2O3	Süd-Chemie India Pvt. Ltd.
Impregnation	10	8.3	301	gamma-Al2O3	Süd-Chemie India Pvt. Ltd.
Impregnation	ND	0.8	115	TiO2	Euro Support Manufacturing B.V., AMERSFOORT, The Netherlands
Impregnation	ND	0.5	79	CeO2	Aldrich, Milano, Italy
Impregnation	ND	0.8	157	mixed-Al2O3	Aldrich
Impregnation	ND	0.8	140	mixed-Al2O3	Aldrich

Impregnation	ND	0.8	155	mixed-Al2O3	Aldrich
Impregnation	ND	0.8	145	mixed-Al2O3	Aldrich
Impregnation	ND	0.8	146	mixed-Al2O3	Aldrich
Incipient wetness impregnation	1	ND	111	CeO2-ZrO2	Ce(0.67)Zr(0.33)O2
Incipient wetness impregnation	1	ND	111	CeO2-ZrO2	Ce(0.67)Zr(0.33)O2
Incipient wetness impregnation	1	ND	111	CeO2-ZrO2	Ce(0.67)Zr(0.33)O2
Liquid-phase reduction	ND	7.8	ND	C	graphene, from Hummers method, by using natural graphite
Impregnation	1	0.83	ND	Mg-Al hydrotalcite	hydrotalcite, from Mg(NO3)2 and Al(NO3)3
Impregnation	1	0.81	ND	MgO	ND
Impregnation	1	0.8	ND	mixed-Al2O3	Sasol
Incipient wetness impregnation	0.5	ND	200	gamma-Al2O3	Sasol, Puralox SBA-200
Incipient wetness impregnation	5	ND	200	gamma-Al2O3	Sasol, Puralox SBA-200
Impregnation	ND	0.22	50.1	TiO2	Fluka
Deposition-precipitation	ND	0.72	50.1	TiO2	Fluka
Deposition-precipitation	ND	0.2	50.1	TiO2	Fluka
Incipient wetness impregnation	1	ND	215	gamma-Al2O3	by Sasol (TKA-432)
Incipient wetness impregnation	1	ND	215	gamma-Al2O3	by Sasol (TKA-432)
Incipient wetness impregnation	5	ND	6	alpha-Al2O3	from gamma-Al2O3, Sasol, TKA-432
Polyol	1	0.82	ND	SiO2	ND
Polyol	1	0.85	ND	gamma-Al2O3	ND
Impregnation	1	0.71	230	gamma-Al2O3	ND
Impregnation	5	4.54	230	gamma-Al2O3	ND
Impregnation	3	ND	ND	SiO2	from silica jel (Sigma Aldrich) and APTES
Impregnation	3	ND	ND	SiO2	from silica jel (Sigma Aldrich) and APTES
Impregnation	3	ND	ND	SiO2	from silica jel (Sigma Aldrich) and APTES
Impregnation	3	ND	ND	SiO2	from silica jel (Sigma Aldrich) and APTES
Impregnation	3	ND	ND	SiO2	from silica jel (Sigma Aldrich) and APTES
Incipient wetness impregnation	0.5	ND	ND	gamma-Al2O3	ND
Incipient wetness impregnation	0.1	ND	ND	gamma-Al2O3	ND
Incipient wetness impregnation	0.5	ND	ND	gamma-Al2O3	ND
Incipient wetness impregnation	0.5	ND	ND	gamma-Al2O3	ND
Incipient wetness impregnation	0.1	ND	51	TiO2	Sigma Aldrich P25
Incipient wetness impregnation	0.1	ND	51	TiO2	ND
Incipient wetness impregnation	0.1	ND	51	TiO2	ND
Incipient wetness impregnation	1	0.7	ND	gamma-Al2O3	prepared from Boehmite Catapal B (Sasol)
Impregnation	ND	4.5	ND	C	graphene oxide, Graphite oxidation
Impregnation	ND	4.6	ND	C	graphene oxide, Graphite oxidation
Impregnation	ND	4.5	ND	C	graphene oxide, Graphite oxidation
Impregnation	ND	4.6	ND	C	graphene oxide, Graphite oxidation
Incipient wetness impregnation	0.5	2.55	950	C	activated carbon, Merck
Incipient wetness impregnation	0.5	0.86	950	C	activated carbon, Merck
Incipient wetness impregnation	5	4.68	ND	ZnO	ND
Incipient wetness impregnation	5	4.66	ND	ZnO	ND
Incipient wetness impregnation	5	ND	ND	ZnO	ND
Incipient wetness impregnation	5	ND	ND	ZnO	ND
Incipient wetness impregnation	5	ND	ND	ZnO	ND
Incipient wetness impregnation	5	ND	ND	ZnO	ND
Incipient wetness impregnation	5	ND	ND	ZnO	ND
Incipient wetness impregnation	5	ND	ND	ZnO	ND
Sol-gel	5	5.6	ND	ZnO	ND
Sol-gel	5	5.6	ND	ZnO	ND
Sol-gel	5	5.6	ND	ZnO	ND

Sol-gel	5	5.6	ND	ZnO	ND
Sol-gel	5	5.6	ND	ZnO	ND
Sol-gel	5	5.6	ND	ZnO	ND
Impregnation	5	4.9	481	SiO2	from Tetraethylorthosilicate (TEOS)
Impregnation	5	4.8	316	Al2O3-SiO2	from co-precipitation of Tetraethylorthosilicate and Aluminium isopropoxide, Silica content: 10%
Impregnation	5	4.7	340	Al2O3-SiO2	from co-precipitation of Tetraethylorthosilicate and Aluminium isopropoxide, Silica content: 30%
Impregnation	5	4.9	200	Al2O3-SiO2	from co-precipitation of Tetraethylorthosilicate and Aluminium isopropoxide, Silica content: 50%
Impregnation	5	5	152	Al2O3-SiO2	from co-precipitation of Tetraethylorthosilicate and Aluminium isopropoxide, Silica content: 75%
Impregnation	5	4.9	211	mixed-Al2O3	from Aluminium isopropoxide
Incipient wetness impregnation	1	ND	ND	CeO2-SnO2	(NH4)2[Ce(NO3)6] and SnC2O4 were used which synthesized from CeCl3·6H2O and SnCl2, Sigma Aldrich
Incipient wetness impregnation	5	ND	ND	CeO2-SnO2	(NH4)2[Ce(NO3)6] and SnC2O4 were used which synthesized from CeCl3·6H2O and SnCl2, Sigma Aldrich
Impregnation	0.8	ND	273	ZrO2	precipitation of ZrOCl2 with ammonia at pH=10.6
Incipient wetness impregnation	1	ND	2.9	ZnO	ND
Incipient wetness impregnation	0.1	ND	2.9	ZnO	ND
Impregnation	1	ND	ND	gamma-Al2O3	by thermal decomposition of boehmite (Sasol, Pural Alumina)
Impregnation	2	ND	ND	gamma-Al2O3	by thermal decomposition of boehmite (Sasol, Pural Alumina)
Impregnation	2	ND	ND	gamma-Al2O3	by thermal decomposition of boehmite (Sasol, Pural Alumina)
Impregnation	2	ND	ND	gamma-Al2O3	by thermal decomposition of boehmite (Sasol, Pural Alumina)
Impregnation	2	ND	ND	gamma-Al2O3	by thermal decomposition of boehmite (Sasol, Pural Alumina)
Impregnation	0.5	ND	ND	theta-Al2O3	from Sumitomo Chemical Co. Ltd.
Impregnation	1	ND	ND	theta-Al2O3	from Sumitomo Chemical Co. Ltd.
Impregnation	2	ND	ND	theta-Al2O3	from Sumitomo Chemical Co. Ltd.
Impregnation	2	ND	ND	theta-Al2O3	from Sumitomo Chemical Co. Ltd.
Impregnation	2	ND	ND	theta-Al2O3	from Sumitomo Chemical Co. Ltd.
Impregnation	2	ND	ND	theta-Al2O3	from Sumitomo Chemical Co. Ltd.
Impregnation	0.2	ND	ND	alpha-Al2O3	from Sumitomo Chemical Co. Ltd.
Impregnation	0.5	ND	ND	alpha-Al2O3	from Sumitomo Chemical Co. Ltd.
Impregnation	1	ND	ND	alpha-Al2O3	from Sumitomo Chemical Co. Ltd.
Impregnation	2	ND	ND	alpha-Al2O3	from Sumitomo Chemical Co. Ltd.
Impregnation	2	ND	ND	alpha-Al2O3	from Sumitomo Chemical Co. Ltd.
Incipient wetness impregnation	1	ND	140	mixed-Al2O3	from Sasol
Incipient wetness impregnation	1	ND	70	CeO2-ZrO2	from Rhodia/Ford
Ion-exchange	ND	0.04	ND	alpha-Al2O3	Saint Gobain Norpro
Ion-exchange	ND	0.53	ND	TiO2	Evonik P25
Deposition-precipitation	0.5	ND	422	C	Sibunit
Deposition-precipitation	0.5	ND	422	C	Sibunit
Incipient wetness impregnation	1.2	1.18	298	Na2Ti6O13	nanotubular sodium titanate, synthesized by alkali hydrothermal treatment, Anatase TiO2 and NaOH
Incipient wetness impregnation	2.4	2.45	298	Na2Ti6O13	nanotubular sodium titanate, synthesized by alkali hydrothermal treatment, Anatase TiO2 and NaOH
Incipient wetness impregnation	3.6	3.56	298	Na2Ti6O13	nanotubular sodium titanate, synthesized by alkali hydrothermal treatment, Anatase TiO2 and NaOH
Incipient wetness impregnation	4.8	4.84	298	Na2Ti6O13	nanotubular sodium titanate, synthesized by alkali hydrothermal treatment, Anatase TiO2 and NaOH
Incipient wetness impregnation	6	6.01	298	Na2Ti6O13	nanotubular sodium titanate, synthesized by alkali hydrothermal treatment, Anatase TiO2 and NaOH
Polyol	1	ND	200	SiO2	Sigma
Polyol	1	ND	200	SiO2	Sigma

Polyol	1	ND	200	SiO2	Sigma
Impregnation	0.5	0.48	ND	alpha-Al2O3	ACROS ORGANICS, 99.0%
Impregnation	0.5	0.4	ND	CeO2	precipitation method via Ce(NO3)3·6H2O and NaOH
Commercial	0.5	0.5	ND	gamma-Al2O3	ACROS ORGANICS
Incipient wetness impregnation	1	1	35	C	carbon nanofiber, Pyrograph III, PR24-HHT
Incipient wetness impregnation	1	1	31	C	carbon nanofiber, Pyrograph III, PR24-HHT
Incipient wetness impregnation	1	1	33	C	carbon nanofiber, Pyrograph III, PR24-HHT
Incipient wetness impregnation	1	1	44	C	carbon nanofiber, Pyrograph III, PR24-PS
Incipient wetness impregnation	1	1	27	C	carbon nanofiber, Pyrograph III, PR24-PS
Incipient wetness impregnation	1	1	34	C	carbon nanofiber, Pyrograph III, PR24-PS
Incipient wetness impregnation	1	1	359	C	Multiwall carbon nanotubes, Nanocyl, 3100 Series, 95% Purity
Incipient wetness impregnation	1	1	24	C	Multiwall carbon nanotubes, Nanocyl, 3100 Series, 95% Purity
Incipient wetness impregnation	1	1	297	C	Multiwall carbon nanotubes, Nanocyl, 3100 Series, 95% Purity
Incipient wetness impregnation	5.4	4.6	200	C	carbon nanotubes, Baytubes C 150 HP, Bayer
Deposition-precipitation	5.1	4.8	200	C	carbon nanotubes, Baytubes C 150 HP, Bayer
Liquid-phase reduction	5.7	4	200	C	carbon nanotubes, Baytubes C 150 HP, Bayer
Liquid-phase reduction	5.5	3.4	200	C	carbon nanotubes, Baytubes C 150 HP, Bayer
Liquid-phase reduction	5.5	3.9	200	C	carbon nanotubes, Baytubes C 150 HP, Bayer
Liquid-phase reduction	5.7	3.8	200	C	carbon nanotubes, Baytubes C 150 HP, Bayer
Liquid-phase reduction	5.9	4.5	200	C	carbon nanotubes, Baytubes C 150 HP, Bayer
Commercial	5	5	NA	C	Activated Carbon, from Evonik
Commercial	5	5	NA	C	Activated Carbon, from Evonik
Commercial	5	5	NA	C	Activated Carbon, from Evonik
Commercial	5	5	NA	C	Activated Carbon, from Evonik
Impregnation	0.075	ND	ND	TiO2	TiO2 anatase, synthesized fron TiCl4
Impregnation	0.15	ND	ND	TiO2	TiO2 anatase, synthesized fron TiCl4
Impregnation	0.075	ND	ND	TiO2	TiO2 rutile, synthesized from TiCl4
Impregnation	0.075	ND	ND	TiO2	TiO2 rutile, synthesized from TiCl4
Impregnation	ND	1.19	ND	TiO2	P25 Degussa, 99.9%
Impregnation	ND	0.57	ND	TiO2	P25 Degussa, 99.9%
Impregnation	1	0.92	221.2	C	carbon nanotubes, Sigma Aldrich
Impregnation	3	2.94	221.2	C	carbon nanotubes, Sigma Aldrich
Impregnation	5	4.88	221.2	C	carbon nanotubes, Sigma Aldrich
Deposition-precipitation	5	ND	422	C	Sibunit
Deposition-precipitation	5	ND	422	C	Sibunit
Deposition-precipitation	5	ND	422	C	Sibunit
Deposition-precipitation	5	ND	422	C	Sibunit
Deposition-precipitation	5	ND	422	C	Sibunit
Deposition-precipitation	5	ND	422	C	Sibunit
Deposition-precipitation	5	ND	422	C	Sibunit
Deposition-precipitation	5	ND	422	C	Sibunit
Deposition-precipitation	5	ND	422	C	Sibunit

Deposition-precipitation	5	ND	422	C	Sibunit
Deposition-precipitation	5	ND	422	C	Sibunit
Deposition-precipitation	5	ND	422	C	Sibunit
Deposition-precipitation	5	ND	422	C	Sibunit
Deposition-precipitation	5	ND	422	C	Sibunit
Deposition-precipitation	5	ND	422	C	Sibunit
Deposition-precipitation	5	ND	422	C	Sibunit
Impregnation	2	1.59	152	C	multi-walled carbon nanotubes, C2H4
Impregnation	2	1.81	182	C	carbon nanotubes, C2H3N
Impregnation	2	2.06	338	C	carbon nanotubes, C4H4S
Impregnation	2	2.04	220	C	carbon nanotubes, C2H4
Incipient wetness impregnation	1	0.99	27.7	CeO2-ZrO2	76 mol CeO2 and 25 mol% ZrO2, prepared from ZrO(NO3)2 + Ce(NO3)2.6H2O, Treibacher Industrie AG
Impregnation	1	ND	320	C	Sibunit
Impregnation	1	ND	46	C	Sibunit
Impregnation	1	ND	304	C	Sibunit
Impregnation	1	ND	39	C	Sibunit
Photo-deposition	1	ND	ND	CeZrO4-δ	from cerium nitrate and zirconyl nitrate (Sigma Aldrich)
Photo-deposition	1	ND	ND	CeZrO4-δ	from cerium nitrate and zirconyl nitrate (Sigma Aldrich)
Photo-deposition	1	ND	ND	CeZrO4-δ	from cerium nitrate and zirconyl nitrate (Sigma Aldrich)
Incipient wetness impregnation	1	ND	196	C	carbon nanotubes, Bayer MaterialScience AG
Incipient wetness impregnation	1	ND	415	C	Department of Experimental Technologies, Institute of Hydrocarbons Processing
Incipient wetness impregnation	1	ND	202	gamma-Al2O3	Condea Chemie GmbH
Incipient wetness impregnation	0.9	ND	241	Mg-Al hydrotalcite	from precipitation of Mg(NO3)2 and Al(NO3)3
Incipient wetness impregnation	1	0.98	162	gamma-Al2O3	Sigma-Aldrich, ALOX560C
Deposition-precipitation	5.5	4.6	200	C	multi-walled carbon nanotubes, Baytubes C 150 HP, Bayer
Deposition-precipitation	5.5	1.4	200	C	multi-walled carbon nanotubes, Baytubes C 150 HP, Bayer
Deposition-precipitation	1.3	1.3	270	C	multi-walled carbon nanotubes, Baytubes C 150 HP, Bayer
Deposition-precipitation	2	1.8	270	C	multi-walled carbon nanotubes, Baytubes C 150 HP, Bayer
Deposition-precipitation	5.5	3.9	270	C	multi-walled carbon nanotubes, Baytubes C 150 HP, Bayer
Deposition-precipitation	11.2	3.7	270	C	multi-walled carbon nanotubes, Baytubes C 150 HP, Bayer
Deposition-precipitation	15.4	3.9	270	C	multi-walled carbon nanotubes, Baytubes C 150 HP, Bayer
Deposition-precipitation	2.1	1	270	C	multi-walled carbon nanotubes, Baytubes C 150 HP, Bayer
Deposition-precipitation	3.5	2.4	270	C	multi-walled carbon nanotubes, Baytubes C 150 HP, Bayer
Deposition-precipitation	5.7	4.4	270	C	multi-walled carbon nanotubes, Baytubes C 150 HP, Bayer
Deposition-precipitation	11	7.9	270	C	multi-walled carbon nanotubes, Baytubes C 150 HP, Bayer
Deposition-precipitation	15.4	9.6	270	C	multi-walled carbon nanotubes, Baytubes C 150 HP, Bayer
Deposition-precipitation	4.8	4.3	704	C	activated carbon, HCl-washed High Purity carbon, BASF
Deposition-precipitation	11.8	7.4	704	C	activated carbon, HCl-washed High Purity carbon, BASF
Deposition-precipitation	19.1	10.3	704	C	activated carbon, HCl-washed High Purity carbon, BASF
Incipient wetness impregnation	2	ND	141	gamma-Al2O3	ND
Incipient wetness impregnation	2	ND	141	gamma-Al2O3	ND
Incipient wetness impregnation	2	ND	141	gamma-Al2O3	ND
Incipient wetness impregnation	2	ND	141	gamma-Al2O3	ND
Incipient wetness impregnation	2	ND	109	theta-Al2O3	ND
Incipient wetness impregnation	0.2	ND	ND	C	carbon nanotubes
Incipient wetness impregnation	1	ND	ND	C	carbon nanotubes
Incipient wetness impregnation	2	ND	ND	C	carbon nanotubes
Incipient wetness impregnation	0.2	ND	ND	C	carbon nanotubes
Incipient wetness impregnation	1	ND	ND	C	carbon nanotubes
Incipient wetness impregnation	2	ND	ND	C	carbon nanotubes
Incipient wetness impregnation	1	ND	170	mixed-Al2O3	from SASOL

Incipient wetness impregnation	1	ND	170	mixed-Al2O3	from SASOL
Deposition-precipitation	1	ND	170	mixed-Al2O3	from SASOL
Deposition-precipitation	8	8.2	ND	CeO2	from Cerium nitrate
Deposition-precipitation	8	8.2	ND	CeO2	from Cerium nitrate
Deposition-precipitation	8	8.2	ND	CeO2	from Cerium nitrate
Deposition-precipitation	8	8.2	ND	CeO2	from Cerium nitrate
Deposition-precipitation	8	8.2	ND	CeO2	from Cerium nitrate
Deposition-precipitation	8	8.2	ND	CeO2	from Cerium nitrate
Incipient wetness impregnation	8	8.1	ND	CeO2	from Cerium nitrate
Incipient wetness impregnation	8	8.1	ND	CeO2	from Cerium nitrate
Incipient wetness impregnation	8	8.1	ND	CeO2	from Cerium nitrate
Incipient wetness impregnation	8	8.1	ND	CeO2	from Cerium nitrate
Impregnation	0.3	ND	95.8	delta-Al2O3	gamma-Al2O3 (Redkino Catalyst Plant, Russia; Specifications TU 6 68-5808009-306-85)
Impregnation	0.3	ND	95.8	delta-Al2O3	gamma-Al2O3 (Redkino Catalyst Plant, Russia; Specifications TU 6 68-5808009-306-85)
Impregnation	0.3	ND	95.8	delta-Al2O3	gamma-Al2O3 (Redkino Catalyst Plant, Russia; Specifications TU 6 68-5808009-306-85)
Impregnation	0.3	ND	95.8	delta-Al2O3	gamma-Al2O3 (Redkino Catalyst Plant, Russia; Specifications TU 6 68-5808009-306-85)
Impregnation	0.3	ND	95.8	delta-Al2O3	gamma-Al2O3 (Redkino Catalyst Plant, Russia; Specifications TU 6 68-5808009-306-85)
Impregnation	0.3	ND	95.8	delta-Al2O3	gamma-Al2O3 (Redkino Catalyst Plant, Russia; Specifications TU 6 68-5808009-306-85)
Impregnation	0.3	ND	95.8	delta-Al2O3	gamma-Al2O3 (Redkino Catalyst Plant, Russia; Specifications TU 6 68-5808009-306-85)
Impregnation	0.3	ND	95.8	delta-Al2O3	gamma-Al2O3 (Redkino Catalyst Plant, Russia; Specifications TU 6 68-5808009-306-85)
Impregnation	0.3	ND	95.8	delta-Al2O3	gamma-Al2O3 (Redkino Catalyst Plant, Russia; Specifications TU 6 68-5808009-306-85)
Liquid-phase reduction	1	ND	203.8	SiO2	ND
Liquid-phase reduction	1	ND	203.2	mixed-Al2O3	ND
Incipient wetness impregnation	2	ND	994	C	cylindrical activated carbon from Shanxi Xinhua Activated Carbon Co. Ltd.
Incipient wetness impregnation	2	ND	869	C	cylindrical activated carbon from Shanxi Xinhua Activated Carbon Co. Ltd.
Incipient wetness impregnation	2	ND	999	C	cylindrical activated carbon from Shanxi Xinhua Activated Carbon Co. Ltd.
Incipient wetness impregnation	2	ND	1057	C	cylindrical activated carbon from Shanxi Xinhua Activated Carbon Co. Ltd.
Incipient wetness impregnation	2	ND	1045	C	cylindrical activated carbon from Shanxi Xinhua Activated Carbon Co. Ltd.
Incipient wetness impregnation	2	ND	1043	C	cylindrical activated carbon from Shanxi Xinhua Activated Carbon Co. Ltd.
Incipient wetness impregnation	2	ND	1044	C	cylindrical activated carbon from Shanxi Xinhua Activated Carbon Co. Ltd.
Incipient wetness impregnation	2	ND	1009	C	cylindrical activated carbon from Shanxi Xinhua Activated Carbon Co. Ltd.
Incipient wetness impregnation	2	ND	846	C	cylindrical activated carbon from Shanxi Xinhua Activated Carbon Co. Ltd.
Impregnation	1	0.86	147.35	mixed-Al2O3	from Sigma Aldrich
Impregnation	1	0.78	188.82	mixed-Al2O3	from Aladdin Corporation

Liquid-phase reduction	5	4.9	135	gamma-Al2O3	from Aladdin Corporation
Liquid-phase reduction	5	4.8	170	SiO2	Degussa, Aerosil 200
Liquid-phase reduction	5	4.9	69	CeO2	Alfa Aesar
Liquid-phase reduction	5	5	35	ZrO2	Sigma Aldrich
Liquid-phase reduction	5	4.9	51	TiO2	Degussa P25
Incipient wetness impregnation	ND	0.8	ND	CeO2	from homogeneous precipitation method, from Ce(NO3)3 and urea
Incipient wetness impregnation	ND	0.8	ND	CeO2-ZrO2	Ce0.5Zr0.5O2 from homogeneous precipitation method, from Ce(NO3)3, urea and Zr(NO3)4
Liquid-phase reduction	ND	0.95	37	CeO2-ZrO2	kappa-Ce2Zr2O8 from Ce(NO3)3.6H2O and ZrO(NO3)2.x.H2O solution with ethyl alcohol
Liquid-phase reduction	ND	0.93	85	CeO2-ZrO2	tetragonal-Ce2Zr2O8 from Ce(NO3)3.6H2O and ZrO(NO3)2.x.H2O solution with water
Deposition-precipitation	ND	0.25	ND	CeO2	from Ce(NO3)3.6H2O and and NH3.H2O solution
Deposition-precipitation	ND	0.9	ND	CeO2	from Ce(NO3)3.6H2O and and NH3.H2O solution
Deposition-precipitation	ND	1.4	ND	CeO2	from Ce(NO3)3.6H2O and and NH3.H2O solution
Deposition-precipitation	ND	2.7	ND	CeO2	from Ce(NO3)3.6H2O and and NH3.H2O solution
Deposition-precipitation	ND	1.5	ND	mixed-Al2O3	from Wusi Chemical Reagent Co. Ltd.
Deposition-precipitation	ND	0.9	ND	SiO2	from Wusi Chemical Reagent Co. Ltd.
Deposition-precipitation	ND	0.7	ND	C	activated carbon
Incipient wetness impregnation	0.2	ND	96	CeO2	from coprecipitation method, Ce(NO3)3 and ammonia
Incipient wetness impregnation	0.2	ND	122	CeO2-ZrO2	Ce0.7Zr0.3O2 from coprecipitation method, Ce(NO3)3, ammonia and ZrO(NO3)2
Incipient wetness impregnation	0.2	ND	108	CeO2-ZrO2	Ce0.3Zr0.7O2 from coprecipitation method, Ce(NO3)3, ammonia and ZrO(NO3)2
Impregnation	0.5	0.49	537	SiO2	CTAB, ammonia, ethanol, water and TEOS were used
Impregnation	0.5	0.43	1540	SiO2	CTAB, ammonia, ethanol, water, TEOS and MPTMOS were used
Impregnation	0.5	0.48	225	gamma-Al2O3	from Weifang Co.
Impregnation	0.5	0.47	225	gamma-Al2O3	from Weifang Co.
Impregnation	0.5	0.48	225	gamma-Al2O3	from Weifang Co.
Impregnation	0.5	0.47	225	gamma-Al2O3	from Weifang Co.
Impregnation	0.5	0.47	225	gamma-Al2O3	from Weifang Co.
Impregnation	0.5	0.46	225	gamma-Al2O3	from Weifang Co.
Impregnation	0.5	0.48	225	gamma-Al2O3	from Weifang Co.
Impregnation	0.5	0.47	225	gamma-Al2O3	from Weifang Co.
Impregnation	0.5	0.47	225	gamma-Al2O3	from Weifang Co.
Impregnation	0.5	0.46	225	gamma-Al2O3	from Weifang Co.
Incipient wetness impregnation	ND	0.81	ND	TiO2	ND
Incipient wetness impregnation	ND	0.81	ND	TiO2	ND
Incipient wetness impregnation	ND	0.82	ND	TiO2	ND
Incipient wetness impregnation	ND	0.83	ND	TiO2	ND
Incipient wetness impregnation	ND	0.83	ND	TiO2	ND
Incipient wetness impregnation	ND	0.82	ND	TiO2	ND

Incipient wetness impregnation	ND	0.79	71	CeO2	CeCO2 nanorods, from NaOH hydrothermal method with Ce(NO3)2.6H2O
Impregnation	ND	0.77	93	CeO2	from NaOH and Ce(NO3)2.6H2O
Impregnation	ND	0.78	18.5	CeO2	from water, NaOH and Ce(NO3)2.6H2O
Impregnation	ND	0.8	6.2	CeO2	from water, Na3PO4 and Ce(NO3)2.6H2O
Impregnation	1	1.1	210	Nb2O5	from hydrothermal synthesis, NH4[NbO(C2O4)2(H2O)2].nH2O
Incipient wetness impregnation	0.25	0.23	ND	gamma-Al2O3	ND
Incipient wetness impregnation	0.5	0.47	ND	gamma-Al2O3	ND
Incipient wetness impregnation	1	0.93	ND	gamma-Al2O3	ND
Incipient wetness impregnation	2	1.9	ND	gamma-Al2O3	ND
Incipient wetness impregnation	4	3.6	ND	gamma-Al2O3	ND
Incipient wetness impregnation	0.25	0.47	ND	gamma-Al2O3	ND
Incipient wetness impregnation	0.5	0.93	ND	gamma-Al2O3	ND
Incipient wetness impregnation	1	1.9	ND	gamma-Al2O3	ND
Incipient wetness impregnation	2	3.6	ND	gamma-Al2O3	ND
Incipient wetness impregnation	1	ND	184	gamma-Al2O3	from boehmite, Puralox SBA 200
Incipient wetness impregnation	0.4	ND	123.7	Al2O3-MgO	10% MgO/Al2O3, prepared by multiple impregnations, from gamma Al2O3 and magnesium nitrate
Incipient wetness impregnation	0.4	ND	100.4	Al2O3-MgO	20% MgO/Al2O3, prepared by multiple impregnations, from gamma Al2O3 and magnesium nitrate
Incipient wetness impregnation	0.4	ND	83	Al2O3-MgO	30% MgO/Al2O3, prepared by multiple impregnations, from gamma Al2O3 and magnesium nitrate
Incipient wetness impregnation	0.4	ND	72.2	Al2O3-MgO	40% MgO/Al2O3, prepared by multiple impregnations, from gamma Al2O3 and magnesium nitrate
Incipient wetness impregnation	0.4	ND	167.6	gamma-Al2O3	ND
Impregnation	ND	0.85	ND	CeO2-ZrO2	prepared using solvent-thermal method, from Ce(NO3)3 and ZrO(NO3)2
Impregnation	ND	0.87	ND	CeO2-ZrO2	prepared using co-precipitation method, from Ce(NO3)3 and ZrO(NO3)2
Impregnation	ND	0.92	ND	CeO2-ZrO2	prepared using physical mixing method, from CeO2 and ZrO2
Incipient wetness impregnation	1	0.98	80	mixed-Al2O3	from Merck
Incipient wetness impregnation	2.5	2.57	80	mixed-Al2O3	from Merck
Incipient wetness impregnation	5	4.99	80	mixed-Al2O3	from Merck
Incipient wetness impregnation	7	7.15	80	mixed-Al2O3	from Merck
Incipient wetness impregnation	7	ND	80	mixed-Al2O3	from Merck
Incipient wetness impregnation	7	ND	80	mixed-Al2O3	from Merck
Incipient wetness impregnation	7	ND	1108	C	activated carbon, from Norit GAC 1240 W
Incipient wetness impregnation	7	ND	1108	C	activated carbon, from Norit GAC 1240 W
Incipient wetness impregnation	7	ND	1108	C	activated carbon, from Norit GAC 1240 W
Impregnation	0.5	ND	1300	C	carbon powder, Norit GSX
Impregnation	1	ND	1300	C	carbon powder, Norit GSX
Impregnation	5	ND	1300	C	carbon powder, Norit GSX
Impregnation	10	ND	1300	C	carbon powder, Norit GSX
Impregnation	15	ND	1300	C	carbon powder, Norit GSX
Impregnation	3	2.82	ND	CeO2	from Ce(NO3)3.6H2O and ethanol
Impregnation	3	2.87	ND	CeO2	from CTAB, Ce(NO3)3.6H2O and NaOH
Impregnation	3	2.76	ND	CeO2	from Ce(NO3)3.6H2O and NaOH
Impregnation	3	2.88	ND	CeO2	from Ce(NO3)3.6H2O and NH3.H2O
Impregnation	3	2.88	ND	CeO2	from Ce(NO3)3.6H2O and citric acid
Deposition-precipitation	3	1.97	230	mixed-Al2O3	from Kanto Chem
Deposition-precipitation	3	0.68	272	SiO2	G-10, from Fuji Silysia

Deposition-precipitation	3	2.75	60	TiO2	P25, from Aero-Sil
Deposition-precipitation	3	2.63	91	ZrO2	from Daiichi Kigenso Kagaku Kogyo
Impregnation	1	ND	3.6	alpha-Al2O3	from Shandong Aluminum Factory
Impregnation	1	ND	1.5	alpha-Al2O3	from Shanghai Reagent Company
Impregnation	5	ND	260	gamma-Al2O3	from Taimei Co.
Impregnation	5	ND	260	gamma-Al2O3	from Taimei Co.
Impregnation	5	ND	260	gamma-Al2O3	from Taimei Co.
Impregnation	5	ND	260	gamma-Al2O3	from Taimei Co.
Impregnation	5	ND	260	gamma-Al2O3	from Taimei Co.
Impregnation	5	ND	260	gamma-Al2O3	from Taimei Co.
Impregnation	5	ND	260	gamma-Al2O3	from Taimei Co.
Impregnation	5	ND	260	gamma-Al2O3	from Taimei Co.
Deposition-precipitation	3	ND	229	CeO2	from Ce(SO4)2
Deposition-precipitation	3	ND	365	ZrO2	from Zr(SO4)2
Deposition-precipitation	3	ND	241	CeO2-ZrO2	from Ce(SO4)2 and Zr(SO4)2, (Ce90Zr10)
Deposition-precipitation	3	ND	274	CeO2-ZrO2	from Ce(SO4)2 and Zr(SO4)2, (Ce70Zr30)
Deposition-precipitation	3	ND	309	CeO2-ZrO2	from Ce(SO4)2 and Zr(SO4)2, (Ce50Zr50)
Deposition-precipitation	5	ND	274	CeO2-ZrO2	from Ce(SO4)2 and Zr(SO4)2, (Ce70Zr30)

Deposition-precipitation	10	ND	274	CeO2-ZrO2	from Ce(SO4)2 and Zr(SO4)2, (Ce70Zr30)
Deposition-precipitation	3	ND	89	CeO2-ZrO2	from Ce(SO4)2 and Zr(SO4)2, (Ce70Zr30)
Deposition-precipitation	3	2.5	98	CeO2	from Daiichi Kigenso Kagaku Kogyo
Deposition-precipitation	3	2.5	98	CeO2	from Daiichi Kigenso Kagaku Kogyo
Deposition-precipitation	3	2.5	98	CeO2	from Daiichi Kigenso Kagaku Kogyo
Impregnation	ND	0.87	95	gamma-Al2O3	from Harshaw
Impregnation	ND	0.94	95	gamma-Al2O3	from Harshaw
Impregnation	ND	0.91	28	CeO2	from Aldrich
Impregnation	ND	0.87	28	CeO2	from Aldrich
Impregnation	ND	0.88	11	La2O3	from Aldrich
Impregnation	ND	0.85	11	La2O3	from Aldrich
Impregnation	3	ND	160	gamma-Al2O3	gamma-Al2O3 from Taiyuan
Impregnation	3	ND	ND	Al2O3-La2O3	gamma-Al2O3 from Taiyuan and La2O3 from lanthanum nitrate solution (La2O3: 5 wt%)
Impregnation	3	ND	ND	Al2O3-La2O3	gamma-Al2O3 from Taiyuan and La2O3 from lanthanum nitrate solution (La2O3: 10 wt%)
Impregnation	3	ND	ND	Al2O3-La2O3	gamma-Al2O3 from Taiyuan and La2O3 from lanthanum nitrate solution (La2O3: 15 wt%)
Impregnation	3	ND	ND	Al2O3-La2O3	gamma-Al2O3 from Taiyuan and La2O3 from lanthanum nitrate solution (La2O3: 20 wt%)
Impregnation	3	ND	ND	Al2O3-CeO2	gamma-Al2O3 from Taiyuan and CeO2 from cerium nitrate solution
Impregnation	3	ND	ND	La2O3-CeO2-Al2O3	gamma-Al2O3 from Taiyuan, CeO2 from cerium nitrate solution and La2O3 from lanthanum nitrate solution (La2O3: 5 wt%)
Impregnation	3	ND	ND	La2O3-CeO2-Al2O3	gamma-Al2O3 from Taiyuan, CeO2 from cerium nitrate solution and La2O3 from lanthanum nitrate solution (La2O3: 10 wt%)
Impregnation	3	ND	ND	La2O3-CeO2-Al2O3	gamma-Al2O3 from Taiyuan, CeO2 from cerium nitrate solution and La2O3 from lanthanum nitrate solution (La2O3: 15 wt%)
Impregnation	3	ND	ND	La2O3-CeO2-Al2O3	gamma-Al2O3 from Taiyuan, CeO2 from cerium nitrate solution and La2O3 from lanthanum nitrate solution (La2O3: 20 wt%)
Incipient wetness impregnation	ND	10.09	108	gamma-Al2O3	from Merck
Incipient wetness impregnation	ND	4.72	108	gamma-Al2O3	from Merck
Incipient wetness impregnation	ND	0.98	108	gamma-Al2O3	from Merck
Incipient wetness impregnation	ND	1.07	108	gamma-Al2O3	from Merck
Incipient wetness impregnation	ND	1.08	108	gamma-Al2O3	from Merck
Incipient wetness impregnation	ND	2.47	ND	TiO2	ND
Incipient wetness impregnation	ND	1.95	ND	TiO2	ND
Incipient wetness impregnation	ND	1.1	ND	TiO2	ND
Incipient wetness impregnation	ND	0.98	ND	Al2O3-TiO2	from Merck gamma-Al2O3 and Ti(O-i-C3H4)4 solution (6%TiO2-Al2O3)
Incipient wetness impregnation	ND	1.02	ND	Al2O3-TiO2	from Merck gamma-Al2O3 and Ti(O-i-C3H4)4 solution (10%TiO2-Al2O3)
Incipient wetness impregnation	ND	0.96	ND	Al2O3-TiO2	from Merck gamma-Al2O3 and Ti(O-i-C3H4)4 solution (20%TiO2-Al2O3)
Impregnation	ND	1.6	200	CeO2	from Rhodia
Impregnation	ND	1.6	218	gamma-Al2O3	prepared by calcinating pseudoboehmite at 773 K
Impregnation	ND	0.16	ND	SnO2	prepared by chemical precipitation from SnCl4.5H2O
Impregnation	ND	0.15	ND	SnO2	prepared by chemical precipitation from SnCl4.5H2O

Impregnation	ND	0.15	ND	SnO2	prepared by chemical precipitation from SnCl4.5H2O
Impregnation	ND	0.15	ND	SnO2	prepared by chemical precipitation from SnCl4.5H2O
Incipient wetness impregnation	0.5	0.47	ND	gamma-Al2O3	from pseudoboehmite (AlO(OH)), CHALCO Shandong Co.Ltd.
Incipient wetness impregnation	0.5	0.47	ND	theta-Al2O3	from bayerite which was prepared from NaAlO2, CHALCO Shandong Co.Ltd.
Incipient wetness impregnation	0.5	0.47	ND	alpha-Al2O3	from pseudoboehmite (AlO(OH)), CHALCO Shandong Co.Ltd.
Impregnation	1	ND	58.3	TiO2	from Degussa P25
Impregnation	1	ND	58.3	TiO2	from Degussa P25
Impregnation	10	ND	954	C	Mesoporous carbon xerogel, prepared by condensation of resorcinol and formaldehyde
Impregnation	10	ND	954	C	Mesoporous carbon xerogel, prepared by condensation of resorcinol and formaldehyde
Impregnation	ND	0.68	77	gamma-Al2O3	from Rhone-Poulenc
Impregnation	1	ND	55	ZrO2	from Zircon, India
Impregnation	1	ND	55	ZrO2	from Zircon, India
Deposition-precipitation	1	ND	55	ZrO2	from Zircon, India
Deposition-precipitation	1	ND	55	ZrO2	from Zircon, India
Impregnation	5	ND	174	TiO2	nanotubes from titanium dioxide
Impregnation	7	ND	174	TiO2	nanotubes from titanium dioxide
Incipient wetness impregnation	1	ND	ND	alpha-Al2O3	from Sigma-Aldrich
Incipient wetness impregnation	1	ND	ND	alpha-Al2O3	by solvothermal method from aluminum isopropoxide and toluene
Incipient wetness impregnation	0.18	ND	ND	mixed-Al2O3	ND
Incipient wetness impregnation	0.18	ND	ND	mixed-Al2O3	ND
Incipient wetness impregnation	0.18	ND	ND	mixed-Al2O3	ND
Incipient wetness impregnation	0.18	ND	ND	mixed-Al2O3	ND
Incipient wetness impregnation	0.18	ND	ND	mixed-Al2O3	ND
Incipient wetness impregnation	0.18	ND	ND	mixed-Al2O3	ND
Incipient wetness impregnation	0.18	ND	ND	mixed-Al2O3	ND
Impregnation	0.5	0.5	200	ZrO2	from Zirconiumn-propoxide and propanol
Impregnation	0.5	0.5	95	ZrO2	from Zirconiumn-propoxide and propanol
Impregnation	0.5	0.5	183	TiO2	from titanium isopropoxide
Impregnation	0.5	0.5	80	TiO2	from titanium isopropoxide
Impregnation	0.5	0.5	210	TiO2	supplied by Tioxide
Incipient wetness impregnation	1	ND	ND	Y2O3	from yytrium nitrate
Incipient wetness impregnation	1	ND	ND	CeO2	from cerium (IV) ammonium nitrate
Impregnation	ND	7.8	905	C	activated carbon from Norit (UK)
Impregnation	ND	8.5	14	C	graphite from Sigma-Aldrich
Incipient wetness impregnation	ND	1	220	gamma-Al2O3	from Engelhard
Incipient wetness impregnation	ND	1.1	177	Al2O3-ZrO2	10 wt% ZrO2/Al2O3, from zirconium acetate hydroxide
Incipient wetness impregnation	ND	1.3	156	Al2O3-ZrO2	20 wt% ZrO2/Al2O3, from zirconium acetate hydroxide
Deposition-precipitation	5	ND	121	gamma-Al2O3	from Chimet Laboratories
Deposition-precipitation	5	ND	121	gamma-Al2O3	from Chimet Laboratories
Deposition-precipitation	5	ND	121	gamma-Al2O3	from Chimet Laboratories
Impregnation	0.5	ND	247	Al2O3-SiO2	Al/Si ratio of 4.8

Incipient wetness impregnation	ND	0.5	ND	CeO2	ND
Incipient wetness impregnation	ND	0.5	ND	CeO2	ND
Incipient wetness impregnation	ND	2.4	ND	CeO2	ND
Impregnation	ND	0.1356	29.6	alpha-Al2O3	from Beijing Research Institute of Chemical Industry
Impregnation	ND	0.1316	29.6	alpha-Al2O3	from Beijing Research Institute of Chemical Industry
Impregnation	ND	0.1362	29.6	alpha-Al2O3	from Beijing Research Institute of Chemical Industry
Impregnation	1	ND	ND	CeO2	JRC-CEO-3 from Catalysis Society of Japan
Impregnation	1	ND	ND	TiO2	JRC-TIO-4 from Catalysis Society of Japan
Impregnation	1	ND	ND	mixed-Al2O3	from boehmite
Impregnation	1	ND	ND	ZrO2	JRC-ZRO-1 from Catalysis Society of Japan
Impregnation	1	ND	ND	SiO2	from Fuji Silysia Chemical Ltd. (Q-10)
Impregnation	ND	1.75	ND	ZrO2	from ZrOCl2 solution via precipitation method
Deposition-precipitation	ND	0.41	ND	ZrO2	from ZrOCl2 solution via precipitation method
Deposition-precipitation	ND	0.83	ND	ZrO2	from ZrOCl2 solution via precipitation method
Deposition-precipitation	ND	1.74	ND	ZrO2	from ZrOCl2 solution via precipitation method
Deposition-precipitation	ND	4.3	ND	ZrO2	from ZrOCl2 solution via precipitation method
Impregnation	5	ND	71	TiO2	Anatase from Jingrui New Material Corporation
Impregnation	5	ND	30	TiO2	Rutile from Jingrui New Material Corporation
Impregnation	5	ND	66	TiO2	P25 Degussa from Jingrui New Material Corporation
Impregnation	5	ND	626	C	mesoporous carbon
Impregnation	5	ND	1297	C	activated carbon
Impregnation	1	ND	215	gamma-Al2O3	from SASOL
Impregnation	1	ND	215	gamma-Al2O3	from SASOL
Impregnation	1	ND	215	gamma-Al2O3	from SASOL
Incipient wetness impregnation	ND	0.59	235	gamma-Al2O3	from Ling Feng Lt ed
Incipient wetness impregnation	ND	0.53	235	gamma-Al2O3	from Ling Feng Lt ed
Incipient wetness impregnation	ND	0.53	368	SiO2	from Ling Feng Lt ed
Incipient wetness impregnation	ND	0.54	368	SiO2	from Ling Feng Lt ed
Impregnation	1	0.97	430	SiO2	from Sigma-Aldrich Davisil, Grade 636
Impregnation	1	0.95	430	SiO2	from Sigma-Aldrich Davisil, Grade 636
Impregnation	1	0.96	430	SiO2	from Sigma-Aldrich Davisil, Grade 636
Incipient wetness impregnation	1	ND	134	gamma-Al2O3	from Catalysis Society of Japan
Incipient wetness impregnation	1	ND	134	gamma-Al2O3	from Catalysis Society of Japan
Incipient wetness impregnation	1	ND	134	gamma-Al2O3	from Catalysis Society of Japan
Incipient wetness impregnation	1	ND	134	gamma-Al2O3	from Catalysis Society of Japan
Impregnation	1	1.1	ND	C	activated carbon
Impregnation	1	1.2	ND	C	activated carbon
Impregnation	1	1.1	ND	C	activated carbon
Impregnation	ND	0.49	560	Al2O3-SiO2	amorphous silica-alumina from Shell
Impregnation	ND	2.07	180	gamma-Al2O3	from AR, Sinopharm Chemical Reagent Co., China
Impregnation	ND	1.98	ND	Al2O3-ZrO2	gamma-Al2O3 and Zr(NO3)4.5H2O from AR, Sinopharm Chemical Reagent Co., China
Impregnation	ND	2.7	ND	SiO2	prepared by sol-gel method from Si(OC2H5)4, Kanto Chemical Co., Japan
Impregnation	ND	2.7	ND	TiO2	prepared by sol-gel method from Ti(OCH(CH3)2)4, Kanto Chemical Co., Japan
Impregnation	ND	2.7	ND	TiO2-SiO2	TiO2 wt% 80, prepared by sol-gel method from Si(OC2H5)4 and Ti(OCH(CH3)2)4, Kanto Chemical Co., Japan

Impregnation	ND	2.7	ND	TiO2-SiO2	TiO2 wt% 50, prepared by sol-gel method from Si(OC2H5)4 and Ti(OCH(CH3)2)4, Kanto Chemical Co., Japan
Impregnation	ND	2.7	ND	TiO2-SiO2	TiO2 wt% 33, prepared by sol-gel method from Si(OC2H5)4 and Ti(OCH(CH3)2)4, Kanto Chemical Co., Japan
Impregnation	ND	0.3	240	gamma-Al2O3	from Alumina Shell S618
Impregnation	ND	0.6	240	gamma-Al2O3	from Alumina Shell S618
Impregnation	ND	1.46	240	gamma-Al2O3	from Alumina Shell S618
Impregnation	ND	2.77	240	gamma-Al2O3	from Alumina Shell S618
Ion-exchange	ND	0.31	240	gamma-Al2O3	from Alumina Shell S618
Impregnation	ND	0.3	240	gamma-Al2O3	from Alumina Shell S618
Impregnation	ND	0.6	240	gamma-Al2O3	from Alumina Shell S618
Impregnation	ND	1.46	240	gamma-Al2O3	from Alumina Shell S618
Impregnation	ND	2.77	240	gamma-Al2O3	from Alumina Shell S618
Ion-exchange	ND	0.31	240	gamma-Al2O3	from Alumina Shell S618
Incipient wetness impregnation	5	4.34	852	C	activated carbon from Beijing Guanghua Timber Factory
Incipient wetness impregnation	5	ND	852	C	activated carbon from Beijing Guanghua Timber Factory
Incipient wetness impregnation	ND	11	1.4	TiO2	anatase from Sigma-Aldrich
Incipient wetness impregnation	ND	2	1.3	TiO2	rutile from Sigma-Aldrich
Incipient wetness impregnation	ND	50	1.4	TiO2	aeroxide P25 nanopowder from Sigma-Aldrich
Impregnation	1	ND	ND	TiO2	from Alfa Aesar
Impregnation	1	ND	ND	TiO2	from Alfa Aesar
Impregnation	1	ND	ND	TiO2	from Alfa Aesar
Impregnation	1	ND	ND	TiO2	from Alfa Aesar
Impregnation	3	ND	ND	gamma-Al2O3	from Sigma Aldrich
Impregnation	3	ND	ND	gamma-Al2O3	from Sigma Aldrich
Impregnation	3	ND	ND	gamma-Al2O3	from Sigma Aldrich
Impregnation	0.5	ND	ND	MgO-CeO2	by co-precipitation method from nitrate precursor of nitrate and nitrate precursor of Mg
Impregnation	0.5	ND	ND	CeO2-ZrO2	by co-precipitation method from nitrate precursor of nitrate and nitrate precursor of Zr
Impregnation	0.5	ND	ND	Al2O3-CeO2	by co-precipitation method from nitrate precursor of nitrate and nitrate precursor of Al
Impregnation	0.5	ND	ND	CeO2-TiO2	by co-precipitation method from nitrate precursor of nitrate and nitrate precursor of Ti
Impregnation	5	4.1	ND	gamma-Al2O3	from Alfa Aesar
Impregnation	5	4.1	ND	MgO	from Alfa Aesar
Impregnation	5	4.1	ND	SiO2	from Alfa Aesar
Impregnation	5	4.49	1263	C	activated carbon from Wenzhou Favored Trading Co. Ltd.
Impregnation	5	4.7	1263	C	activated carbon from Wenzhou Favored Trading Co. Ltd.
Impregnation	5	4.56	1263	C	activated carbon from Wenzhou Favored Trading Co. Ltd.
Impregnation	5	4.61	1263	C	activated carbon from Wenzhou Favored Trading Co. Ltd.
Deposition-precipitation	ND	0.07	ND	TiO2	P25 from Evonik Degussa Germany
Deposition-precipitation	ND	0.16	ND	TiO2	P25 from Evonik Degussa Germany
Deposition-precipitation	ND	0.23	ND	TiO2	P25 from Evonik Degussa Germany
Deposition-precipitation	ND	0.09	ND	mixed-Al2O3	ND

Deposition-precipitation	ND	0.04	ND	SiO2	ND
Impregnation	0.05	ND	940	C	activated carbon from GBSP Norit
Impregnation	0.05	ND	904	C	activated carbon from GBSP Norit
Impregnation	0.05	ND	927	C	activated carbon from GBSP Norit
Impregnation	0.05	ND	916	C	activated carbon from GBSP Norit
Impregnation	1	0.98	ND	YrO3-ZrO2	Y2O3 stabilized ZrO2 from Tosoh Corporation Japan
Impregnation	1	1.01	ND	ZrO2	from Sigma-Aldrich
Impregnation	1	0.92	1782	C	activated carbon
Impregnation	1	1.03	1782	C	activated carbon
Incipient wetness impregnation	1.1	ND	350	SiO2	Aerosil 380 PE, Evonik
Incipient wetness impregnation	1.1	ND	211	SiO2-ZrO2	10% SiO2-ZrO2, from Daiichi Kigenso Kagaku Kogyo Co.
Incipient wetness impregnation	1.1	ND	325	ZrO2	JRC-ZRO-9, from Daiichi Kigenso Kagaku Kogyo Co.
Impregnation	1	0.91	14	mixed-Al2O3	from Aldrich
Impregnation	1	0.93	14	mixed-Al2O3	from Aldrich
Impregnation	1	0.89	14	mixed-Al2O3	from Aldrich
Impregnation	1	0.606	ND	CeO2	CeCO2 nanorods, from NaOH hydrothermal method with Ce(NO3)2.6H2O
Impregnation	1	0.642	ND	CeO2	from NaOH and Ce(NO3)2.6H2O
Impregnation	1	0.612	ND	CeO2	from Na3PO4 and Ce(NO3)2.6H2O
Impregnation	0.1	ND	ND	gamma-Al2O3	by thermal decomposition of boehmite (Sasol, PURAL alumina) at 500 °C for 1 h
Impregnation	0.2	ND	ND	gamma-Al2O3	by thermal decomposition of boehmite (Sasol, PURAL alumina) at 500 °C for 1 h
Impregnation	0.5	ND	ND	gamma-Al2O3	by thermal decomposition of boehmite (Sasol, PURAL alumina) at 500 °C for 1 h
Impregnation	1	ND	ND	gamma-Al2O3	by thermal decomposition of boehmite (Sasol, PURAL alumina) at 500 °C for 1 h
Impregnation	2	ND	ND	gamma-Al2O3	by thermal decomposition of boehmite (Sasol, PURAL alumina) at 500 °C for 1 h
Impregnation	2	ND	ND	gamma-Al2O3	by thermal decomposition of boehmite (Sasol, PURAL alumina) at 500 °C for 1 h
Impregnation	2	ND	ND	gamma-Al2O3	by thermal decomposition of boehmite (Sasol, PURAL alumina) at 500 °C for 1 h
Impregnation	2	ND	ND	gamma-Al2O3	by thermal decomposition of boehmite (Sasol, PURAL alumina) at 500 °C for 1 h
Impregnation	0.1	ND	ND	theta-Al2O3	(AKP-G07) was supplied from Sumitomo Chemical Co. Ltd
Impregnation	0.2	ND	ND	theta-Al2O3	(AKP-G07) was supplied from Sumitomo Chemical Co. Ltd
Impregnation	0.5	ND	ND	theta-Al2O3	(AKP-G07) was supplied from Sumitomo Chemical Co. Ltd
Impregnation	1	ND	ND	theta-Al2O3	(AKP-G07) was supplied from Sumitomo Chemical Co. Ltd
Impregnation	2	ND	ND	theta-Al2O3	(AKP-G07) was supplied from Sumitomo Chemical Co. Ltd
Impregnation	2	ND	ND	theta-Al2O3	(AKP-G07) was supplied from Sumitomo Chemical Co. Ltd
Impregnation	2	ND	ND	theta-Al2O3	(AKP-G07) was supplied from Sumitomo Chemical Co. Ltd
Impregnation	2	ND	ND	theta-Al2O3	(AKP-G07) was supplied from Sumitomo Chemical Co. Ltd
Sol-gel	0.5	ND	ND	Al2O3-ZrO2	2% ZrO2, from aluminium secondary butoxide (Across) and zirconium butoxide (Aldrich)
Sol-gel	0.5	ND	ND	Al2O3-ZrO2	5% ZrO2, from aluminium secondary butoxide (Across) and zirconium butoxide (Aldrich)

Sol-gel	0.5	ND	ND	Al2O3-ZrO2	15% ZrO2, from aluminium secondary butoxide (Across) and zirconium butoxide (Aldrich)
Sol-gel	0.5	ND	ND	mixed-Al2O3	from aluminium secondary butoxide (Across)
Sol-gel	0.5	ND	ND	ZrO2	from zirconium butoxide (Aldrich)
Sol-gel	0.5	ND	ND	Al2O3-ZrO2	2% ZrO2, from aluminium secondary butoxide (Across) and zirconium butoxide (Aldrich)
Sol-gel	0.5	ND	ND	Al2O3-ZrO2	5% ZrO2, from aluminium secondary butoxide (Across) and zirconium butoxide (Aldrich)
Sol-gel	0.5	ND	ND	Al2O3-ZrO2	15% ZrO2, from aluminium secondary butoxide (Across) and zirconium butoxide (Aldrich)
Sol-gel	0.5	ND	ND	mixed-Al2O3	from aluminium secondary butoxide (Across)
Sol-gel	0.5	ND	ND	ZrO2	from zirconium butoxide (Aldrich)
Incipient wetness impregnation	0.5	ND	1100	C	activate carbon (Chemviron SC XII)
Incipient wetness impregnation	1	ND	1100	C	activate carbon (Chemviron SC XII)
Incipient wetness impregnation	1	ND	1100	C	activate carbon (Chemviron SC XII)
Incipient wetness impregnation	1	ND	1100	C	activate carbon (Chemviron SC XII)
Incipient wetness impregnation	3	ND	1100	C	activate carbon (Chemviron SC XII)
Incipient wetness impregnation	5	ND	1100	C	activate carbon (Chemviron SC XII)
Incipient wetness impregnation	5	ND	1100	C	activate carbon (Chemviron SC XII)
Incipient wetness impregnation	10	10.2	ND	SiO2	from Sigma-Aldrich
Incipient wetness impregnation	10	10.2	ND	SiO2	from Sigma-Aldrich
Incipient wetness impregnation	10	10.2	ND	Ta2O5	from Sigma-Aldrich
Incipient wetness impregnation	10	10.2	ND	C	activated carbon from Norit (UK)
Incipient wetness impregnation	10	10.2	ND	C	graphite from Sigma-Aldrich
Liquid-phase reduction	5	3.6	ND	C	activated carbon from Norit activated charcoal from wood Sigma-Aldrich
Liquid-phase reduction	5	4.8	ND	C	activated carbon from Norit activated charcoal from wood Sigma-Aldrich
Liquid-phase reduction	5	3.7	ND	C	activated carbon from Norit activated charcoal from wood Sigma-Aldrich
Liquid-phase reduction	5	4.7	ND	C	activated carbon from Norit activated charcoal from wood Sigma-Aldrich
Liquid-phase reduction	5	4.9	ND	C	activated carbon from Norit activated charcoal from wood Sigma-Aldrich
Liquid-phase reduction	5	4.8	ND	C	activated carbon from Norit activated charcoal from wood Sigma-Aldrich
Liquid-phase reduction	5	4.2	ND	C	activated carbon from Norit activated charcoal from wood Sigma-Aldrich
Impregnation	1	ND	180	mixed-Al2O3	from Mizusawa Chemicals
Impregnation	1	ND	180	mixed-Al2O3	from Mizusawa Chemicals
Impregnation	1	ND	180	mixed-Al2O3	from Mizusawa Chemicals
Impregnation	1	ND	180	mixed-Al2O3	from Mizusawa Chemicals
Impregnation	1	ND	180	mixed-Al2O3	from Mizusawa Chemicals
Impregnation	1	ND	180	mixed-Al2O3	from Mizusawa Chemicals
Deposition-precipitation	5	ND	195	gamma-Al2O3	from Alfa Aesar
Deposition-precipitation	5	ND	199	gamma-Al2O3	from Alfa Aesar
Deposition-precipitation	5	ND	146	gamma-Al2O3	from Alfa Aesar
Deposition-precipitation	5	ND	54	gamma-Al2O3	from Alfa Aesar
Deposition-precipitation	5	ND	6	gamma-Al2O3	from Alfa Aesar
Incipient wetness impregnation	1	ND	305	mixed-Al2O3	ND
Incipient wetness impregnation	1	ND	305	mixed-Al2O3	ND
Incipient wetness impregnation	1	ND	305	mixed-Al2O3	ND
Incipient wetness impregnation	1	ND	305	mixed-Al2O3	ND
Incipient wetness impregnation	1	ND	305	mixed-Al2O3	ND

Impregnation	1	ND	48	MgO	from Harshaw MG-0601
Impregnation	1	ND	48	MgO	from Harshaw MG-0601
Impregnation	1	ND	48	MgO	from Harshaw MG-0601
Impregnation	1	ND	48	MgO	from Harshaw MG-0601
Impregnation	1	ND	48	MgO	from Harshaw MG-0601
Impregnation	1	ND	ND	gamma-Al2O3	from Stream Chem. Inc.
Impregnation	1	ND	ND	gamma-Al2O3	by sol-gel method (Al(OC4H9)3
Impregnation	1	ND	ND	Al2O3-La2O3	gamma-Al2O3 from Stream Chem. Inc. impregnated into aq. Solution of La(NO3)2, 12 wt% La
Impregnation	1	ND	ND	Al2O3-La2O3	by sol–gel method, in a round bottom flask containing alcooxide aluminum 2-butanol was added (Al(OC4H9)3, 12 wt% La
Template-ion exchange	0.41	ND	ND	MCM-41	sodium silicate and hexadecyltrimethylammonium bromide
Direct hydrothermal	0.45	ND	ND	MCM-41	sodium silicate and hexadecyltrimethylammonium bromide
Ion-exchange	0.2	ND	1015	HMS	Hexagonal molecular sieves, template: DDA
Ion-exchange	0.5	ND	1015	HMS	Hexagonal molecular sieves, template: DDA
Ion-exchange	0.2	ND	870	HMS	Hexagonal molecular sieves, template: DDA
Ion-exchange	0.9	ND	870	HMS	Hexagonal molecular sieves, template: DDA
Ion-exchange	2.10	ND	870	HMS	Hexagonal molecular sieves, template: DDA
Ion-exchange	0.6	ND	801	SBA-15	Hexagonally ordered SBA-15
Ion-exchange	2.10	ND	801	SBA-15	Hexagonally ordered SBA-15
Ion-exchange	2.10	ND	801	SBA-15	Hexagonally ordered SBA-15
Ion-exchange	0.1	ND	ND	HMS	Hexagonal molecular sieves, template: ODA
Ion-exchange	0.25	ND	ND	HMS	Hexagonal molecular sieves, template: ODA
Ion-exchange	1	ND	ND	HMS	Hexagonal molecular sieves, template: ODA
Ion-exchange	1.40	ND	ND	HMS	Hexagonal molecular sieves, template: ODA
Ion-exchange	4.40	ND	ND	HMS	Hexagonal molecular sieves, template: ODA
Impregnation	0.5	ND	921	MCM-41	CTAB:0.3NH3:4SiO2:-Na2O:200H2O
Impregnation	0.5	ND	921	MCM-41	CTAB:0.3NH3:4SiO2:-Na2O:200H2O
Impregnation	0.5	ND	921	MCM-41	CTAB:0.3NH3:4SiO2:-Na2O:200H2O
Incipient wetness impregnation	1.20	ND	631	USY (390)	SiO2/Al2O3=390 from Tosoh Co.
Incipient wetness impregnation	2	ND	ND	HZSM-5	made in Zeolite Plant of Nankai University, Tianjin, China
Incipient wetness impregnation with plasma treatment	2	ND	ND	HZSM-5	made in Zeolite Plant of Nankai University, Tianjin, China
Impregnation	0.8	ND	ND	Hbeta	Si/Al=12.5
Impregnation	0.8	ND	ND	Hbeta	Si/Al= 37.5
Impregnation	0.8	ND	ND	Hbeta	Si/Al= 75
Impregnation	0.8	ND	ND	HZSM-5	Si/Al=15 from Zeolyst International
Impregnation	0.8	ND	ND	HZSM-5	Si/Al=25 from Zeolyst International
Impregnation	0.8	ND	ND	HZSM-5	Si/Al=40 from Zeolyst International
Impregnation	0.5	ND	7	YSZ	yttria stabilized zirconia
Impregnation	0.5	ND	7	YSZ	yttria stabilized zirconia
Impregnation	0.5	ND	7	YSZ	yttria stabilized zirconia
Impregnation	0.5	ND	7	YSZ	yttria stabilized zirconia

Impregnation	0.5	ND	7	YSZ	yttria stabilized zirconia
Impregnation	0.5	ND	7	YSZ	yttria stabilized zirconia
Impregnation	0.5	ND	7	YSZ	yttria stabilized zirconia
Impregnation	0.5	ND	7	YSZ	yttria stabilized zirconia
Impregnation	0.5	ND	7	YSZ	yttria stabilized zirconia
Impregnation	0.5	ND	7	YSZ	yttria stabilized zirconia
Ion-exchange	0.2	ND	669	MCM-22	Si/Al=25, HMI as organic template
Ion-exchange	0.5	ND	669	MCM-22	Si/Al=25, HMI as organic template
Ion-exchange	1	ND	669	MCM-22	Si/Al=25, HMI as organic template
Ion-exchange	ND	1.9	358	MOR	zeolite mordenite, Si/Al=7.0
Ion-exchange	ND	0.53	ND	ZSM-5	Si/Al=20, synthesized in its sodium form
Ion-exchange	ND	0.53	ND	ZSM-5	Si/Al=20, synthesized in its sodium form
Ion-exchange	ND	0.53	ND	ZSM-5	Si/Al=20, synthesized in its sodium form
Ion-exchange	ND	0.53	ND	ZSM-5	Si/Al=20, synthesized in its sodium form
Ion-exchange	ND	0.53	ND	ZSM-5	Si/Al=20, synthesized in its sodium form
Ion-exchange	ND	0.53	ND	ZSM-5	Si/Al=20, synthesized in its sodium form
Ion-exchange	ND	0.53	ND	ZSM-5	Si/Al=20, synthesized in its sodium form
Ion-exchange	ND	0.45	ND	ZSM-5	Si/Al=20, synthesized in its sodium form
Ion-exchange	ND	0.51	ND	ZSM-5	Si/Al=20, synthesized in its sodium form
Ion-exchange	ND	0.62	ND	ZSM-5	Si/Al=20, synthesized in its sodium form
Ion-exchange	ND	0.92	ND	ZSM-5	Si/Al=20, synthesized in its sodium form
Ion-exchange	ND	1.17	ND	ZSM-5	Si/Al=20, synthesized in its sodium form
Ion-exchange	ND	1.31	ND	ZSM-5	Si/Al=20, synthesized in its sodium form
Incipient wetness impregnation	1	ND	339	SAPO-5	Al:45.6% P:45.9% Si:8.5% (MOL) template:pseudoboehmit (Condea Pural) + triethylamine (Aldrich)
Incipient wetness impregnation	1	ND	154	SAPO-11	Al:49.7% P:49.4% Si:0.9% (MOL) aluminumisopropoxide (Aldrich) + di-n-propylamine
Incipient wetness impregnation	1	ND	202	SAPO-11	Al:48.8% P:49.1% Si:2.1% (MOL) aluminumisopropoxide + di-n-propylamine
Incipient wetness impregnation	0.1	ND	174	SAPO-11	Al:61.0% P:36.6% Si:2.4% (MOL) pseudoboehmit + di-n-propylamine
Incipient wetness impregnation	0.25	ND	174	SAPO-11	Al:61.0% P:36.6% Si:2.4% (MOL) pseudoboehmit + di-n-propylamine
Incipient wetness impregnation	0.5	ND	174	SAPO-11	Al:61.0% P:36.6% Si:2.4% (MOL) pseudoboehmit + di-n-propylamine
Incipient wetness impregnation	1	ND	174	SAPO-11	Al:61.0% P:36.6% Si:2.4% (MOL) pseudoboehmit + di-n-propylamine
Incipient wetness impregnation	2	ND	174	SAPO-11	Al:61.0% P:36.6% Si:2.4% (MOL) pseudoboehmit + di-n-propylamine
Incipient wetness impregnation	0.1	ND	184	SAPO-11	Al:52.2% P:44.9% Si:2.9%pseudoboehmit + di-n-propylamine
Incipient wetness impregnation	0.25	ND	184	SAPO-11	Al:52.2% P:44.9% Si:2.9%pseudoboehmit + di-n-propylamine
Incipient wetness impregnation	0.5	ND	184	SAPO-11	Al:52.2% P:44.9% Si:2.9%pseudoboehmit + di-n-propylamine
Incipient wetness impregnation	1	ND	184	SAPO-11	Al:52.2% P:44.9% Si:2.9%pseudoboehmit + di-n-propylamine
Incipient wetness impregnation	2	ND	184	SAPO-11	Al:52.2% P:44.9% Si:2.9%pseudoboehmit + di-n-propylamine
Incipient wetness impregnation	1	ND	180	SAPO-11	Al:51.2% P:45.6% Si:3.2%pseudoboehmit + di-n-propylamine
Incipient wetness impregnation	1	ND	182	SAPO-11	Al:48.6% P:48.7% Si:2.7%pseudoboehmit + di-n-propylamine
Impregnation	1	ND	868	USY	Si/Al=13.0, from Zeolyst International
Impregnation	1	ND	636	beta	Si/Al=13.0, from Zeolyst International
Impregnation	1	ND	868	USY	Si/Al=13.0, from Zeolyst International
Impregnation	1	ND	636	beta	Si/Al=13.0, from Zeolyst International
Impregnation	1	ND	ND	MCM-41	prepared by gel of composition SiO2:CTABr:TMAOH:H2O = 1:0.15:0.26:24.3

Simultaneous self-assembling	1.5	1.39	1239	MCM-41	prepared MCM-41 framework
Simultaneous self-assembling	6	5.85	1239	MCM-41	prepared MCM-41 framework
ND	ND	8.64	1239	MCM-41	prepared MCM-41 framework
Impregnation	2.5	2.45	ND	SBA-15	ND
Strong electrostatic adsorption	8.7	ND	998	SBA-15	from Dr. Jianfeng Yao at Monash University
Strong electrostatic adsorption	4.6	ND	998	SBA-15	from Dr. Jianfeng Yao at Monash University
Incipient wetness impregnation	8.7	ND	998	SBA-15	from Dr. Jianfeng Yao at Monash University
Incipient wetness impregnation	4.6	ND	998	SBA-15	from Dr. Jianfeng Yao at Monash University
Impregnation	ND	0.84	460	beta	SiO2/Al2O3=25 (molar ratio), from Zeolyst
Impregnation	ND	0.69	59	MCM-41	prepared by CTAB as the template and TEOS as the Si source
Incipient wetness impregnation	0.5	0.41	921	MCM-41	using the gel composition of CTABr:0.3 NH3:4 SiO2:Na2O:200 H20
Incipient wetness impregnation	0.5	0.33	901	MCM-41	using the gel composition of CTABr:0.3 NH3:4 SiO2:Na2O:200 H20
Impregnation	1.69	1.46	400	SBA-15	ND
Impregnation	3.31	3.02	387	SBA-15	ND
Incipient wetness impregnation	1	0.9	272.4	ZSM-5	Chemie Uetikon AG
Incipient wetness impregnation	1	1.08	280	MCM-22	by Prof. Sibele Pergher
Impregnation	0.3	0.28	662	SBA-15	ND
Impregnation	0.3	0.27	1031	MCM-41	ND
Impregnation	0.3	0.28	1035	MCM-48	ND
Impregnation	0.3	0.28	348	beta	bought from Tianjin Chemical Plant
Impregnation	0.3	0.27	413	ZSM-5	bought from Tianjin Chemical Plant
Incipient wetness impregnation	1.5	ND	767	SBA-15	ND
Incipient wetness impregnation	1.5	ND	1072	MCM-41	ND
Incipient wetness impregnation	2.5	ND	767	SBA-15	NA
Incipient wetness impregnation	2.5	ND	1072	MCM-41	NA
Impregnation	ND	3.6	550	SBA-15	ND
Impregnation	ND	4.4	468	SBA-15	ND
Impregnation	ND	7.6	326	SBA-15	ND
Impregnation	ND	3.8	326	SBA-15	ND
Incipient wetness impregnation	0.5	0.18	800	SBA-15	ND
Ion-exchange	0.5	0.25	800	SBA-15	ND
Impregnation	1	ND	746	HMS	mesoporous silica with wormhole framework structure
Incipient wetness impregnation	ND	0.8	ND	beta	Si-Beta
Incipient wetness impregnation	ND	1.2	ND	beta	Al-Beta (Si/Al=50)
Incipient wetness impregnation	ND	1.4	819	MCM-41	Al-MCM-41 (Si/Al=50)
Incipient wetness impregnation	ND	1.4	825	MCM-41	Si-MCM-41
Liquid-phase Reduction	0.5	ND	ND	SBA-15	ND
Incipient wetness impregnation	5	ND	647	Al-SBA-15	Si/Al = 22
Incipient wetness impregnation	5	ND	683	Al-SBA-15	Si/Al = 100
Incipient wetness impregnation	5	ND	746	Al-SBA-15	Si/Al = 300
Incipient wetness impregnation	5	ND	795	Al-SBA-15	Si/Al = 500
Incipient wetness impregnation	5	ND	803	SBA-15	ND
Impregnation	ND	1.25	749	HY	HY ultrastable zeolite, CBV712, Zeolyst International, SiO2/Al2O3=12
Impregnation	ND	0.93	719	HY	HY ultrastable zeolite, CBV500, Zeolyst International, SiO2/Al2O3=5
Impregnation	ND	0.87	607	Hbeta	Hβ zeolite, CP814E, Zeolyst International, SiO2/Al2O3=25
Impregnation	ND	1.22	106	zeolite	FCC catalyst by Repsol YPF (Spain)
Incipient wetness impregnation	4.4	ND	664	SBA-15	ND
Incipient wetness impregnation	4.4	ND	664	SBA-15	ND
Plasma Reduction	2	ND	ND	SBA-15	ND
Impregnation	2	ND	ND	SBA-15	ND

Microwave-Assisted Synthesis	ND	7.8	ND	SBA-15	ND
Ion-exchange	1.35	ND	ND	NaX	NaX zeolite
Ion-exchange	1.35	ND	ND	NaX	NaX zeolite
Ion-exchange	1.35	ND	ND	NaX	NaX zeolite
Ion-exchange	1.35	ND	ND	NaX	NaX zeolite
Ion-exchange	1.35	ND	ND	NaX	NaX zeolite
Ion-exchange	1.35	ND	ND	NaX	NaX zeolite
Double Solvent Approach	ND	0.86	3600	MIL-101	ND
Impregnation	ND	2.9	1383	ZIF-8	ND
Sol-gel	0.5	ND	2353	MIL-101	ND
Sol-gel	2	ND	2110	MIL-101	ND
Sol-gel	3.3	ND	2064	MIL-101	ND
Sol-gel	4.1	ND	1916	MIL-101	ND
Impregnation	ND	0.46	900	HY	Si/Al: 2.7; Sigma-Aldrich
Ultrasonic assisted method	ND	2.7	80.66	zeolite Y	Aluminosilicate gel with molar ratio 1Al2O3: 4Na2O: 9SiO2:170H2O
Incipient wetness impregnation	ND	0.99	175	zeolite B	CP 811E-75 from Zeolyst Int., Si/Al = 31.7, in acid form
Atomic Layer Deposition	ND	9	1032	MCM-41	Nanjing, XFNANO Materials Tech Co.
Atomic Layer Deposition	ND	9	1032	MCM-41	Nanjing, XFNANO Materials Tech Co.
Atomic Layer Deposition	ND	9	1032	MCM-41	Nanjing, XFNANO Materials Tech Co.
Atomic Layer Deposition	ND	9	1032	MCM-41	Nanjing, XFNANO Materials Tech Co.
Atomic Layer Deposition	ND	9	1032	MCM-41	Nanjing, XFNANO Materials Tech Co.
Atomic Layer Deposition	ND	9	1032	MCM-41	Nanjing, XFNANO Materials Tech Co.
Liquid-phase reduction	1	ND	1163.8	MCM-41	ND

Impregnation	0.8	ND	353	ZSM-5	CBV3024E, SiO2/Al2O3 = 30 was distributed by Zeolyst International, USA
Controlled Particle Growth	ND	0.74	ND	SiO2	Aerosil 200 support Degussa
Controlled Particle Growth	ND	0.98	ND	SiO2	Aerosil 200 support Degussa
Microemulsion with destabilizer tetrahydrofuran	5	ND	144	mixed-Al2O3	from Condea, Puralox HP 14–150
Microemulsion without destabilizer tetrahydrofuran	5	ND	144	mixed-Al2O3	from Condea, Puralox HP 14–150
Flame spray pyrolysis	0.5	ND	196	SiO2	precursor of support: TEOS
Flame spray pyrolysis	0.5	ND	196	SiO2	precursor of support: TEOS
Flame spray pyrolysis	1	ND	196	SiO2	precursor of support: TEOS
Flame spray pyrolysis	2	ND	196	SiO2	precursor of support: TEOS
Flame spray pyrolysis	5	ND	196	SiO2	precursor of support: TEOS
Flame spray pyrolysis	10	ND	196	SiO2	precursor of support: TEOS
Deposition by electroless plating	ND	0.14	ND	C	activated carbon, supplied from American Technical Trading, Inc.
Deposition by electroless plating	ND	1.8	ND	C	activated carbon, supplied from American Technical Trading, Inc.
Polyol microwave assisted	20	ND	ND	C	multi-walled carbon nanotubes, suuplied from CNT Co., Ltd, Korea
Polyol microwave assisted	20	ND	ND	C	multi-walled carbon nanotubes, suuplied from CNT Co., Ltd, Korea
Polyol microwave assisted	20	ND	ND	C	multi-walled carbon nanotubes, suuplied from CNT Co., Ltd, Korea
Polyol microwave assisted	20	ND	ND	C	multi-walled carbon nanotubes, suuplied from CNT Co., Ltd, Korea
Polyol microwave assisted	20	ND	ND	C	multi-walled carbon nanotubes, suuplied from CNT Co., Ltd, Korea
Laser Synthesis	2.5	ND	ND	C	graphene from graphite (Alfa Aesar)
Dry plasma reduction	5	ND	852	C	activated carbon, from Beijing Guanghua Timber Mill.
Dry plasma reduction	5	ND	ND	TiO2	ND
Facile one-pot solution	ND	13.12	ND	C	Carboxylic group functionalized multi-walled nanotubes
Facile one-pot solution	ND	19.64	ND	C	Carboxylic group functionalized multi-walled nanotubes
Facile one-pot solution	ND	33.57	ND	C	Carboxylic group functionalized multi-walled nanotubes
Facile one-pot solution	ND	40.74	ND	C	Carboxylic group functionalized multi-walled nanotubes
Facile one-pot solution	ND	43.67	ND	C	Carboxylic group functionalized multi-walled nanotubes
Stagnation swirl flame	5	4.2	215	TiO2	from titanium tetraisopropoxide, Aldrich
Stagnation swirl flame	10	9.5	215	TiO2	from titanium tetraisopropoxide, Aldrich
Stagnation swirl flame	15	15.4	215	TiO2	from titanium tetraisopropoxide, Aldrich
One-pot gas–liquid interfacial plasma	ND	8.7	ND	C	carbon nanotubes, Beijing Cnano Technology Limited
One-pot gas–liquid interfacial plasma	ND	9.5	ND	C	carbon nanotubes, Beijing Cnano Technology Limited
One-pot gas–liquid interfacial plasma	ND	9.1	ND	C	carbon nanotubes, Beijing Cnano Technology Limited
Ultrasonic assisted method	2	1.97	ND	C	Mesoporous Carbon
Ultrasonic assisted method	2	2.05	844	C	Mesoporous Carbon
Ultrasonic assisted method	2	1.94	ND	C	Activated Carbon
Solution combustion	1	ND	ND	CeO2-SnO2	(NH4)2[Ce(NO3)6] and SnC2O4
Solution combustion	5	ND	ND	CeO2-SnO2	(NH4)2[Ce(NO3)6] and SnC2O4
Solution combustion	1	ND	ND	CeO2-SnO2	(NH4)2[Ce(NO3)6] and SnC2O4 were used which synthesized from CeCl3·6H2O and SnCl2, Sigma Aldrich
Solution combustion	5	ND	ND	CeO2-SnO2	(NH4)2[Ce(NO3)6] and SnC2O4 were used which synthesized from CeCl3·6H2O and SnCl2, Sigma Aldrich

Pyrolysis	1	0.9	ND	C	from birch (Betula pendula)
Pyrolysis	1	0.6	ND	C	from birch (Betula pendula)
Gas-phase cluster beam deposition	ND	0.3	ND	alpha-Al2O3	Saint Gobain Norpro
Gas-phase cluster beam deposition	ND	0.18	ND	TiO2	Evonik P25
Reverse micelle method	1	ND	100	Al2O3	Alfa Aesar, 99.9%
Reverse micelle method	1	ND	99	SiO2	Alfa Aesar, 99.9%
Reverse micelle method	1	ND	99	SiO2	Alfa Aesar, 99.9%
Reverse micelle method	1	ND	99	SiO2	Alfa Aesar, 99.9%
Reverse micelle method	1	ND	113	Si3N4	Alfa Aesar, 98.5%
Solution combustion	1	0.97	18.9	CeO2-ZrO2	75 mol CeO2 and 25 mol% ZrO2, prepared from ZrO(NO3)2 + (NH4)2Ce(NO3)6, Treibacher Industrie AG
Impregnation	ND	7	ND	Ce0.8Tb0.2Ox/La2O3-Al2O3	ND
Incipient wetness impregnation	2	ND	9.7	(CeO2)0.8(Sm2O3)0.2	prepared by ball milling, CeO2 purity 99.9% from Aldrich, Sm2O3 purity 99.9% from Acros Organics
Incipient wetness impregnation	2	1.89	80	CeO2/ZrO2/La2O3/Pr6O11	ND
Liquid-phase reduction	ND	ND	ND	C	vulcan XC-72R
Liquid-phase reduction	ND	ND	ND	C	vulcan XC-72R
Impregnation	ND	ND	ND	C	carbon nanotubes (f-MWCNTs)
Sol-gel	ND	ND	ND	TiO2	by Aldrich Chemical Co.
MOCVD	ND	ND	ND	SiO2	ND
MOCVD	ND	ND	ND	TiO2	ND
Impregnation	ND	ND	ND	C	MWNCT
Liquid-phase Reduction	ND	ND	ND	C	MWCNT
Polyol	ND	ND	ND	C	Vulcan XC-72R (Cabot)
Polyol	ND	ND	ND	C	Vulcan XC-72R (Cabot)
Polyol	ND	ND	ND	C	Vulcan XC-72R (Cabot)
Impregnation	ND	ND	ND	C	MWCNT
Impregnation	ND	ND	ND	C	MWCNT
Atomic Layer Deposition	ND	ND	ND	alpha-Al2O3	from MTI
Sonication	ND	ND	ND	C	polyamidoamine grafted MWCNT
Encapsulating	ND	ND	520	SiO2	ND
Encapsulating	ND	ND	198	SiO2@C	ND
Impregnation	ND	1.09	ND	Al2O3-BaCO3	from aq. solution of Ba(NO3)2 and gamma-Al2O3
Deposition-precipitation	5	ND	100	CaO	n-CaO, from NanoScale
Incipient wetness impregnation	0.5	0.47	ND	eta-Al2O3	from bayerite which was prepared from NaAlO2, CHALCO Shandong Co.Ltd.
Incipient wetness impregnation	1	ND	ND	SBA-15	prepared from P123 and sodium chloride
Incipient wetness impregnation	1	ND	ND	SBA-15	prepared from P123 and sodium chloride

Operation on support (promoter/modification)	Support Calcination Temp. (K)	Support Calcination Time (hr)	Precursor	Solvent for precursor
ND	ND	ND	PdCl2	ND
ND	ND	ND	PdCl2	ND
ND	ND	ND	PdCl2	ND
ND	ND	ND	PdCl2	ND
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	Pd(NO3)2	water
NA	NA	NA	Pd(acac)2	toluene
NA	NA	NA	Pd(acac)2	toluene
NA	NA	NA	Pd(acac)2	toluene
CeOx is promoter	673	4	Pd(acac)2	toluene
CeOx is promoter	673	4	Pd(acac)2	toluene
CeOx is promoter	673	4	Pd(acac)2	toluene
ND	NA	NA	PdCl2	ND
ND	NA	NA	PdCl2	ND
ND	NA	NA	PdCl2	ND
ND	NA	NA	PdCl2	ND
ND	NA	NA	PdCl2	ND
ND	NA	NA	PdCl2	ND
ND	NA	NA	PdCl2	ND
ND	NA	NA	PdCl2	ND
ND	NA	NA	PdCl2	ND
ND	NA	NA	PdCl2	ND
ND	723	18	Pd(NH3)4Cl2	water
ND	723	18	Pd(NH3)4Cl2	water
ND	723	18	Pd(NH3)4Cl2	water
ND	723	18	Pd(NH3)4Cl2	water
ND	723	18	Pd(NH3)4Cl2	water
ND	973	4	Pd(NH3)4Cl2	water
ND	973	4	Pd(NH3)4Cl2	water
ND	973	4	Pd(NH3)4Cl2	water
ND	973	4	Pd(NH3)4Cl2	water
ND	973	4	Pd(NH3)4Cl2	water
NH4OH is used	ND	ND	Pd(acac)2	acetone
HNO3 is used	ND	ND	Pd(acac)2	acetone
ND	823	16	PdCl2	HCl
ND	823	16	PdCl2	HCl
ND	823	16	PdCl2	HCl
ND	823	16	PdCl2	HCl
ND	823	16	PdCl2	HCl
ND	823	16	PdCl2	HCl
ND	ND	ND	PdCl2	ND
ND	ND	ND	PdCl2	ND
ND	ND	ND	PdCl2	ND
ND	ND	ND	PdCl2	ND
ND	ND	ND	PdCl2	ND
ND	ND	ND	Pd(NO3)2	water

ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
before impregnation, support was treated with nitric acid	573	6	Pd(NH3)4(NO3)2	ammonia
before impregnation, support was treated with nitric acid	573	6	Pd(NH3)4(NO3)2	ammonia
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	aqueous hydrochloric acid
NA	NA	NA	NA	NA
NA loading: 0%	ND	ND	Pd(NO3)2	water
NA loading: 1.8%	ND	ND	Pd(NO3)2	water
NA loading: 3.5%	ND	ND	Pd(NO3)2	water
NA loading: 7.0%	ND	ND	Pd(NO3)2	water
NA loading: 12.0%	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
support synthesized via combustion synthesis, urea and CO(NH2)2 are used as fuel	ND	ND	Pd(NO3)2	water
support synthesized via combustion synthesis, urea and CO(NH2)2 are used as fuel	ND	ND	Pd(NO3)2	water
ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
NA	NA	NA	NA	NA
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	Pd(OAc)2	ND
ND	ND	ND	Pd(OAc)2	ND
ND	ND	ND	Pd(OAc)2	ND
ND	ND	ND	Pd(OAc)2	ND
ND	ND	ND	Pd(OAc)2	ND
ND	ND	ND	Pd(OAc)2	ND
ND	ND	ND	Pd(OAc)2	ND
NA	NA	NA	NA	NA
NA	NA	NA	NA	NA
NA	NA	NA	NA	NA
ND	573	6	PdCl2	aqueous hydrochloric acid
ND	573	6	PdCl2	aqueous hydrochloric acid
ND	573	6	PdCl2	aqueous hydrochloric acid
ND	573	6	PdCl2	aqueous hydrochloric acid
ND	673	4	PdCl2	aqueous hydrochloric acid
ND	673	4	PdCl2	aqueous hydrochloric acid
NA	NA	NA	NA	NA

NA	NA	NA	NA	NA
ND	823	3	PdCl2	aqueous hydrochloric acid
ND	773	6	PdCl2	water
ND	773	6	Pd(NO3)2	water
ND	773	6	PdCl2	water
ND	773	6	Pd(NO3)2	water
ND	1273	5	Pd(acac)2	benzene
ND	1273	5	Pd(acac)2	benzene
ND	1273	5	Pd(acac)2	benzene
ND	1273	5	Pd(acac)2	benzene
ND	ND	ND	Pd(NO3)2	water
Gelation T: 25˚C; Aging D: 4 h; Aluminium-secbutoxide: 1 M; Acetic Acid:Aluminium-secbutoxide=3	ND	ND	Pd(acac)2	2-butanol
Gelation T: 40˚C; Aging D: 4 h; Aluminium-secbutoxide: 1 M; Acetic Acid:Aluminium-secbutoxide=3	ND	ND	Pd(acac)2	2-butanol
Gelation T: 25˚C; Aging D: 24 h; Aluminium-secbutoxide: 1 M; Acetic Acid:Aluminium-secbutoxide=3	ND	ND	Pd(acac)2	2-butanol
Gelation T: 40˚C; Aging D: 24 h; Aluminium-secbutoxide: 1 M; Acetic Acid:Aluminium-secbutoxide=3	ND	ND	Pd(acac)2	2-butanol
Gelation T: 25˚C; Aging D: 24 h; Aluminium-secbutoxide: 0.25 M; Acetic Acid:Aluminium-secbutoxide=3	ND	ND	Pd(acac)2	2-butanol
Gelation T: 25˚C; Aging D: 24 h; Aluminium-secbutoxide: 0.50 M; Acetic Acid:Aluminium-secbutoxide=3	ND	ND	Pd(acac)2	2-butanol
Gelation T: 25˚C; Aging D: 24 h; Aluminium-secbutoxide: 2 M; Acetic Acid:Aluminium-secbutoxide=3	ND	ND	Pd(acac)2	2-butanol
Gelation T: 25˚C; Aging D: 24 h; Aluminium-secbutoxide: 1 M; Acetic Acid:Aluminium-secbutoxide=1	ND	ND	Pd(acac)2	2-butanol
Gelation T: 25˚C; Aging D: 24 h; Aluminium-secbutoxide: 1 M; Acetic Acid:Aluminium-secbutoxide=6	ND	ND	Pd(acac)2	2-butanol
Gelation T: 25˚C; Aging D: 24 h; Aluminium-secbutoxide: 1 M; Acetic Acid:Aluminium-secbutoxide=10	ND	ND	Pd(acac)2	2-butanol
Gelation T: 25˚C; Aging D: 24 h; Aluminium-secbutoxide: 1 M; Acetic Acid:Aluminium-secbutoxide=3	ND	ND	Pd(acac)2	2-butanol
Gelation T: 25˚C; Aging D: 24 h; Aluminium-secbutoxide: 1 M; Acetic Acid:Aluminium-secbutoxide=1	ND	ND	Pd(acac)2	2-butanol

Gelation T: 25˚C; Aging D: 24 h; Aluminium-secbutoxide: 1 M; Acetic Acid:Aluminium-secbutoxide=6	ND	ND	Pd(acac)2	2-butanol
Gelation T: 25˚C; Aging D: 24 h; Aluminium-secbutoxide: 1 M; Acetic Acid:Aluminium-secbutoxide=10	ND	ND	Pd(acac)2	2-butanol
ND	1273	ND	Pd(acac)2	acetone
ND	ND	ND	PdCl2	HCl
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(acac)2	acetone
ND	ND	ND	Pd(acac)2	acetone
ND	ND	ND	Pd(acac)2	acetone
ND	ND	ND	Pd(acac)2	acetone
washed with diluted nitric acid and rinsed with water	ND	ND	Pd(acac)2	benzene
washed with diluted nitric acid and rinsed with water	ND	ND	Pd(acac)2	benzene
washed with diluted nitric acid and rinsed with water	ND	ND	Pd(acac)2	benzene
washed with diluted nitric acid and rinsed with water	ND	ND	Pd(acac)2	benzene
washed with diluted nitric acid and rinsed with water	ND	ND	Pd(acac)2	benzene
washed with diluted nitric acid and rinsed with water	ND	ND	Pd(acac)2	benzene
washed with diluted nitric acid and rinsed with water	ND	ND	Pd(acac)2	benzene
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(OAc)2	ammonia
ND	ND	ND	Pd(OAc)2	acetone
ND	ND	ND	Pd(OAc)2	acetone
ND	623	3	PdCl2	water
ND	623	3	PdCl2	water
ND	623	3	PdCl2	water
ND	623	3	PdCl2	water
ND	623	3	PdCl2	water
ND	ND	ND	PdCl2	ND
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	Pd(OAc)2	ND
ND	ND	ND	Pd(NH3)4(NO3)2	water
ND	ND	ND	Pd(NH3)4(NO3)2	water
ND	ND	ND	Pd(NH3)4(NO3)2	water
ND	673	4	Pd(NO3)2	water
ND	673	4	Pd(NO3)2	water
ND	673	4	Pd(NO3)2	water
ND	673	4	Pd(NO3)2	water
ND	673	4	Pd(NO3)2	water
ND	673	4	Pd(NO3)2	water

ND	673	4	Pd(NO3)2	water
ND	673	4	Pd(NO3)2	water
ND	673	4	Pd(NO3)2	water
ND	673	4	Pd(NO3)2	water
ND	673	4	Pd(NO3)2	water
ND	ND	ND	Pd(NH3)4Cl2	water
ND	ND	ND	Pd(NH3)4Cl2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	PdCl2	HCl
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(acac)2	toluene
dried under N2 at 423 K for 2 h	ND	ND	Pd(acac)2	toluene
dried under N2 at 423 K for 2 h	ND	ND	Pd(acac)2	toluene
dried under N2 at 423 K for 2 h	ND	ND	Pd(NO3)2	ND
dried under N2 at 423 K for 2 h	ND	ND	Pd(NO3)2	ND
were ground and sieved to retain particles with sizes of 0.10-0.04 mm	ND	ND	Pd(NH3)4(NO3)2	ND
were ground and sieved to retain particles with sizes of 0.10-0.04 mm	ND	ND	Pd(NH3)4(NO3)2	ND
were ground and sieved to retain particles with sizes of 0.10-0.04 mm	ND	ND	Pd(NH3)4(NO3)2	ND
were ground and sieved to retain particles with sizes of 0.10-0.04 mm	ND	ND	Pd(NH3)4(NO3)2	ND
were ground and sieved to retain particles with sizes of 0.10-0.04 mm	ND	ND	Pd(NH3)4(NO3)2	ND
ND	ND	ND	Pd(NH3)4(NO3)2	ND
ND	ND	ND	Pd(NH3)4(NO3)2	ND
ND	ND	ND	Pd(NH3)4(NO3)2	ND
ND	ND	ND	Pd(NH3)4(NO3)2	ND
ND	ND	ND	Pd(NH3)4(NO3)2	ND
ND	ND	ND	Pd(NH3)4(NO3)2	ND
ND	ND	ND	Pd(NH3)4(NO3)2	ND
ND	973	3	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(acac)2	acetone
ND	ND	ND	Pd(NO3)2	2-butanol
ND	ND	ND	Pd(NO3)2	2-butanol
ial oxidation under O2/He flow at 673 K fo	ND	ND	Pd(NO3)2	2-butanol
ND	ND	ND	Pd(acac)2	toluene
ND	ND	ND	Pd(NH3)4Cl2	water
ND	ND	ND	Pd(NH3)4Cl2	water

ND	ND	ND	Pd(NH3)4Cl2	water
ND	ND	ND	Pd(NH3)4Cl2	water
ND	ND	ND	Pd(NH3)4Cl2	water
ND	ND	ND	Pd(NH3)4Cl2	water
ND	1073	2	PdCl2	aqueous hydrochloric acid
ND	1073	2	PdCl2	aqueous hydrochloric acid
ND	1073	2	PdCl2	aqueous hydrochloric acid
ND	1073	2	PdCl2	aqueous hydrochloric acid
ND	ND	ND	Pd(NO3)2	aqueous nitric acid
ND	ND	ND	Pd(acac)2	toluene
ND	ND	ND	Pd(acac)2	toluene
ND	ND	ND	Pd(acac)2	toluene
ND	ND	ND	Pd(acac)2	toluene
ND	ND	ND	PdCl2	ND
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(acac)2	heptane
ND	ND	ND	Pd(acac)2	heptane
treated in ultrasonic bath	ND	ND	Na2PdCl4	water
treated in ultrasonic bath AND activated in H2O2	ND	ND	Na2PdCl4	water
treated in ultrasonic bath AND activated in H2O2	ND	ND	Pd(NH3)4Cl2	water
NA	ND	ND	Na2PdCl4	water
NA	ND	ND	Pd(NH3)4Cl2	water
ND	ND	ND	PdCl2	aqueous hydrochloric acid
NA	823	2	PdCl2	aqueous hydrochloric acid
NA	NA	NA	PdCl2	aqueous hydrochloric acid
NA	823	16	Pd(NO3)2	water
NA	823	16	Pd(NO3)2	water
NA	823	16	Pd(NO3)2	water
NA	823	16	Pd(NO3)2	water
10% Nb2O5 modified	823	16	Pd(NO3)2	water
10% Nb2O5 modified	823	16	Pd(NO3)2	water
ND	1248	4	Pd(NH3)4(NO3)2	ND
pre-treatment: calcination	1283	4	Pd(NO3)2	water
synthesized by sol-gel	723	2	Pd(NO3)2	water
synthesized by solvothermal method	NA	NA	Pd(NO3)2	water
NA	NA	NA	Pd(NO3)2	water
ND	ND	ND	K2PdCl4	water
ND	ND	ND	K2PdCl4	water
ND	ND	ND	K2PdCl4	water
ND	ND	ND	K2PdCl4	water
ND	ND	ND	K2PdCl4	water
ND	ND	ND	Pd(acac)2	toluene
ND	ND	ND	Pd(acac)2	toluene
ND	ND	ND	Pd(acac)2	toluene

ND	ND	ND	Pd(acac)2	toluene
ND	ND	ND	Pd(OAc)2	toluene
ND	ND	ND	Pd(OAc)2	water
ND	ND	ND	Pd(acac)2	toluene
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	Pd(acac)2	toluene
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	Pd(NO3)2	ND
Carbonized at 350°C	NA	NA	Pd(NH3)4(NO3)2	water
Carbonized at 800°C	NA	NA	Pd(NH3)4(NO3)2	water
ND	673	4	Pd(NO3)2	water
ND	673	4	Pd(NO3)2	water
ND	673	4	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	Pd(NO3)2	ND
NA	NA	NA	NA	NA
ND	ND	ND	Pd(acac)2	benzene
ND	ND	ND	Pd(acac)2	water
ND	ND	ND	Pd(acac)2	monoglyme
ND	ND	ND	Pd(acac)2	THF
ND	ND	ND	Pd(acac)2	diglyme
ND	ND	ND	Pd(acac)2	2-propanol
ND	ND	ND	Pd(acac)2	ethylene glycol
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NH3)4(NO3)2	ND
ND	ND	ND	Pd(NH3)4(NO3)2	ND
ND	ND	ND	Pd(NH3)4(NO3)2	ND
ND	ND	ND	Pd(NH3)4(NO3)2	ND
ND	ND	ND	Pd(NH3)4(NO3)2	ND
ND	ND	ND	Pd(NH3)4(NO3)2	ND
ND	ND	ND	Pd(NH3)4(NO3)2	ND
ND	ND	ND	Pd(NH3)4Cl2	ND
NA	673	3	Pd(acac)2	ND
Promoter: Li	673	3	Pd(acac)2	ND
Promoter: Na	673	3	Pd(acac)2	ND
Promoter: K	673	3	Pd(acac)2	ND
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	Pd(NO3)2	aqueous nitric acid

ND	ND	ND	PdCl2	ND
Promoted: Na=0.017 wt%	ND	ND	PdCl2	ND
Promoted: Na=0.034 wt%	ND	ND	PdCl2	ND
Promoted: Na=0.068 wt%	ND	ND	PdCl2	ND
Promoted: Na=0.0102 wt%	ND	ND	PdCl2	ND
ND	ND	ND	Pd(NO3)2	ND
Promoted: Li=0.020 wt%	ND	ND	Pd(NO3)2	ND
Promoted: Na=0.068 wt%	ND	ND	Pd(NO3)2	ND
Promoted: K=0.115 wt%	ND	ND	Pd(NO3)2	ND
Promoted: Cs=0.392 wt%	ND	ND	Pd(NO3)2	ND
ND	723	18	PdCl2	aqueous hydrochloric acid
ND	723	18	PdCl2	aqueous hydrochloric acid
ND	723	18	PdCl2	aqueous hydrochloric acid
ND	723	18	PdCl2	aqueous hydrochloric acid
Nitric acid treatment was carried out by heating an activated carbon in 10% nitcric acid solution. After that, the sample was washed with water until neutral and dried overnight at 100C	ND	ND	PdCl2	aqueous hydrochloric acid
Nitric acid treatment was carried out by heating an activated carbon in 10% nitcric acid solution. After that, the sample was washed with water until neutral and dried overnight at 100C	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	1448	2	Pd(NO3)2	water
ND	1373	2	Pd(NO3)2	water
ND	1373	3.333333333	Pd(NO3)2	water
ND	1373	4	Pd(NO3)2	water
ND	NA	NA	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
washed with HNO3	773	2	Pd(NH3)4Cl2	water
washed with HNO3	773	2	Pd(NH3)4Cl2	water
washed with HNO3	773	2	Pd(NH3)4Cl2	water
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid

ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
ND	ND	ND	(NH4)2PdCl4	aqueous ethylene glycol
ND	ND	ND	(NH4)2PdCl4	aqueous ethylene glycol
ND	ND	ND	(NH4)2PdCl4	aqueous ethylene glycol
ND	ND	ND	(NH4)2PdCl4	aqueous ethylene glycol
modified by means of oxidation treatment in 1.0 M HNO3 at room temperature for 0.5 h	ND	ND	PdCl2	ethylene glycol
modified by means of oxidation treatment in 1.0 M HNO3 at room temperature for 0.5 h	ND	ND	PdCl2	ethylene glycol
modified by means of oxidation treatment in 1.0 M HNO3 at room temperature for 0.5 h, support is mixed with PSS (PSS/Pd = 3)	ND	ND	PdCl2	ethylene glycol
modified by means of oxidation treatment in 1.0 M HNO3 at room temperature for 0.5 h, support is mixed with PSS (PSS/Pd = 5)	ND	ND	PdCl2	ethylene glycol
modified by means of oxidation treatment in 1.0 M HNO3 at room temperature for 0.5 h, support is mixed with PSS (PSS/Pd = 7)	ND	ND	PdCl2	ethylene glycol
refluxed by 10 M HCl at 120 for 1 h, and modified through oxidation by concentrated HNO3 under ultrasonication for 1 h	ND	ND	Pd(acac)2	toluene
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
NA	NA	NA	NA	NA
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	Pd(NO3)2	ND
NA	ND	ND	Na2PdCl4	water
NA	ND	ND	Na2PdCl4	water
NA	ND	ND	Na2PdCl4	water
K-doped from K2CO3 (K/Pd=4)	ND	ND	Na2PdCl4	water

K-doped from K2CO3 (K/Pd=4)	ND	ND	Na2PdCl4	water
K-doped from K2CO3 (K/Pd=4)	ND	ND	Na2PdCl4	water
K-doped from K2CO3 (K/Pd=20)	ND	ND	Na2PdCl4	water
K-doped from K2CO3 (K/Pd=20)	ND	ND	Na2PdCl4	water
K-doped from K2CO3 (K/Pd=20)	ND	ND	Na2PdCl4	water
refluxed in toluene at 25 °C for 15 h	ND	ND	Pd(OAc)2	dichloromethane
refluxed in toluene at 25 °C for 15 h	ND	ND	Pd(OAc)2	dichloromethane
refluxed in toluene at 25 °C for 15 h	ND	ND	Pd(OAc)2	dichloromethane
refluxed in toluene at 25 °C for 15 h	ND	ND	Pd(OAc)2	dichloromethane
refluxed in toluene at 25 °C for 15 h	ND	ND	Pd(OAc)2	dichloromethane
refluxed in toluene at 25 °C for 15 h	ND	ND	Pd(OAc)2	dichloromethane
refluxed in toluene at 25 °C for 15 h	ND	ND	Pd(OAc)2	dichloromethane
refluxed in toluene at 25 °C for 15 h	ND	ND	Pd(OAc)2	dichloromethane
refluxed in toluene at 25 °C for 15 h	ND	ND	Pd(OAc)2	dichloromethane
ND	873	4	PdCl2	ND
ND	873	4	PdCl2	ND
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	Pd(NO3)2	water
crushed before impregnation	ND	ND	ND	ND
crushed after impregnation	ND	ND	ND	ND
preoxideized with HNO3	ND	ND	PdCl2	HCl
NA	NA	NA	NA	NA
treated with HNO3	573	2	Pd(NH3)4(NO3)2	ammonia
NA	NA	NA	NA	NA
NA	NA	NA	NA	NA
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(acac)2	benzene

ND	ND	ND	Pd(acac)2	benzene
3 wt% La added	ND	ND	Pd(NO3)2	water
3 wt% La added	ND	ND	Pd(NO3)2	water
NA	873	3	(NH3)2Pd(NO2)2	ND
0.34 wt% Cs loaded	873	3	(NH3)2Pd(NO2)2	ND
0.68 wt% Cs loaded	873	3	(NH3)2Pd(NO2)2	ND
NA	NA	NA	NA	NA
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	573	2	Pd(NO3)2	ND
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	723	4	Pd(OAc)2	toluene
ND	ND	ND	Pd(OAc)2	toluene
ND	ND	ND	Pd(OAc)2	toluene
ND	773	ND	PdCl2	water
ND	773	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	NA	NA	NA	NA
3-aminopropyl functionalized	ND	ND	Pd(NH3)4Cl2	water
3-amino-(1-piperazino)propyl functionalize	ND	ND	Pd(NH3)4Cl2	water
3-(dimethylamino)propyl functionalized	ND	ND	Pd(NH3)4Cl2	water
ND	ND	ND	Pd(NH3)4Cl2	water
ND	ND	ND	Pd(NH3)4Cl2	water
NA	NA	NA	NA	NA
ND	ND	ND	Pd(NH3)4(NO3)2	water
ND	ND	ND	Pd(NH3)4(NO3)2	water
ND	ND	ND	Pd(NH3)4(NO3)2	water
ND	ND	ND	Pd(NH3)4(NO3)2	water
NA	ND	ND	PdCl2	aqueous hydrochloric acid
NA	ND	ND	PdCl2	aqueous hydrochloric acid
refluxed by 50% HNO3 at 373K for 48h	ND	ND	PdCl2	aqueous hydrochloric acid
refluxed by 50% HNO3 at 373K for 48h	ND	ND	PdCl2	aqueous hydrochloric acid
NA	ND	ND	PdCl2	isopropanol
NA	ND	ND	PdCl2	isopropanol
refluxed by 50% HNO3 at 373K for 48h	ND	ND	PdCl2	isopropanol
refluxed by 50% HNO3 at 373K for 48h	ND	ND	PdCl2	isopropanol
NA	ND	ND	PdCl2	isopropanol
NA	ND	ND	PdCl2	isopropanol
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
NA	NA	NA	(NH4)2PdCl4	aqueous ethylene glycol
treated with 5% HNO3, refluxed for a minimum of 16 h at 120 °C	ND	ND	(NH4)2PdCl4	aqueous ethylene glycol
treated with 0.07 M H3PO4, refluxed for a minimum of 16 h at 120 °C	ND	ND	(NH4)2PdCl4	aqueous ethylene glycol
treated with 0.2 M KOH, refluxed for a minimum of 16 h at 120 °C	ND	ND	(NH4)2PdCl4	aqueous ethylene glycol
treated with 10% H2O2, refluxed for a minimum of 16 h at 105 °C	ND	ND	(NH4)2PdCl4	aqueous ethylene glycol
ND	ND	ND	PdCl2	isopropanol
ND	ND	ND	PdCl2	isopropanol
ND	ND	ND	PdCl2	isopropanol

ND	ND	ND	PdCl2	isopropanol
ND	ND	ND	PdCl2	isopropanol
ND	ND	ND	PdCl2	water
treatment with H3PO4	ND	ND	PdCl2	aqueous hydrochloric acid
treatment with H3PO4 and thermal treatment at 900 °C	ND	ND	PdCl2	aqueous hydrochloric acid
treatment with H3PO4	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	1173	10	Pd(NO3)2	water
ND	1173	10	Pd(NO3)2	water
ND	1173	10	Pd(NO3)2	water
ND	ND	ND	Pd(acac)2	toluene
ND	ND	ND	Pd(acac)2	toluene
ND	ND	ND	Pd(acac)2	toluene
ND	ND	ND	Pd(acac)2	toluene
ND	ND	ND	Pd(acac)2	toluene
ND	ND	ND	Pd(acac)2	toluene
ND	ND	ND	Pd(acac)2	toluene
ND	ND	ND	Pd(acac)2	toluene
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	1233	4	PdCl2	water
ND	1233	4	PdCl2	water
ND	1233	4	PdCl2	water
ND	1233	4	PdCl2	water
NA	NA	NA	NA	NA
NA	NA	NA	NA	NA
treated under vacuum at 180 °C for 6 h	ND	ND	Pd(OAc)2	ethanol
treated under vacuum at 180 °C for 6 h	ND	ND	Pd(OAc)2	ethanol
treated under vacuum at 180 °C for 6 h	ND	ND	Pd(OAc)2	ethanol
treated under vacuum at 180 °C for 6 h	ND	ND	Pd(OAc)2	ethanol
treated under vacuum at 180 °C for 6 h	ND	ND	Pd(OAc)2	ethanol
treated under vacuum at 180 °C for 6 h	ND	ND	Pd(OAc)2	ethanol
treated under vacuum at 180 °C for 6 h	ND	ND	Pd(OAc)2	ethanol
ND	ND	ND	PdCl2	aqueous hydrochloric acid
treated with HNO3 at 90 °C for 4 h and washed with water	ND	ND	PdCl2	water
washed with water	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
NA	NA	NA	NA	NA
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
NA	NA	NA	NA	NA

NA	NA	NA	NA	NA
NA	NA	NA	NA	NA
NA	NA	NA	NA	NA
NA	ND	ND	Pd(NO3)2	water
activated by H3PO4 with weight ratio of 0.5	ND	ND	Pd(NO3)2	water
activated by H3PO4 with weight ratio of 1.0	ND	ND	Pd(NO3)2	water
activated by H3PO4 with weight ratio of 2.0	ND	ND	Pd(NO3)2	water
activated by H3PO4 with weight ratio of 3.0	ND	ND	Pd(NO3)2	water
crushed and sieved before impregnation	ND	ND	PdCl2	water
NA	ND	ND	PdCl2	aqueous hydrochloric acid
NA	ND	ND	PdCl2	aqueous hydrochloric acid
NA	ND	ND	PdCl2	aqueous hydrochloric acid
treated with HNO3	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
treated with HNO3 at 60 °C for 4 h	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
thermal exfoliation at 830 °C for 60 s in Ar	ND	ND	PdCl2	acetone
ND	ND	ND	Pd(acac)2	acetone
ND	ND	ND	Pd(acac)2	acetone
NA	NA	NA	NA	NA
NA	ND	ND	PdCl2	aqueous hydrochloric acid
treated with HNO3 for 20 min	ND	ND	PdCl2	aqueous hydrochloric acid
treated by lyophilisation	773	ND	Pd(NH3)4Cl2	water
treated by lyophilisation	773	ND	Pd(NH3)4Cl2	water
NA	1073	ND	Pd(NH3)4Cl2	water
NA	773	ND	Pd(NH3)4Cl2	water
ND	973	2	Pd(NO3)2	water
ND	973	2	Pd(NO3)2	water
ND	973	2	Pd(NO3)2	water
ND	973	2	Pd(NO3)2	water
treated with 0.8 M HNO3 at 366 K for 10 h	ND	ND	PdCl2	aqueous hydrochloric acid
treated with 1.7 M HNO3 at 366 K for 10 h	ND	ND	PdCl2	aqueous hydrochloric acid

treated with 3.5 M HNO3 at 366 K for 10 h	ND	ND	PdCl2	aqueous hydrochloric acid
treated with 7.7 M HNO3 at 366 K for 10 h	ND	ND	PdCl2	aqueous hydrochloric acid
treated with 14.9 M HNO3 at 366 K for 10 h	ND	ND	PdCl2	aqueous hydrochloric acid
treated with 1 M EDTA-2Na at 323 K for 4 h	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	ND
treated with HNO3/H2SO4 at 60 °C for 12 h	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
washed with HCl and HF	ND	ND	PdCl2	water
NA	773	2	Pd(NO3)2	water
15 wt% Ba loaded	773	2	Pd(NO3)2	water
NA	773	2	Pd(NO3)2	water
10 wt% Ba loaded	773	2	Pd(NO3)2	water
ND	773	4	Pd(acac)2	acetone
ND	773	4	Pd(acac)2	acetone
ND	773	6	Pd(OAc)2	acetone
ND	773	6	PdCl2	water
ND	773	6	Pd(NH3)4Cl2	water
treated with nitric acid at 75 °C for 2 h	673	2	Pd(OAc)2	acetone
treated with nitric acid at 75 °C for 2 h	673	2	PdCl2	water
treated with nitric acid at 75 °C for 2 h	673	2	Pd(NH3)4Cl2	water
treated with HNO3 for 3 h	ND	ND	PdCl2	HCl
ND	1173	4	PdCl2	ND
NA	NA	NA	NA	NA
NA	NA	NA	NA	NA
treated with HNO3 for 24 h	ND	ND	PdCl2	HCl
treated with HNO3 for 24 h	ND	ND	Pd(NO3)2	nitric acid
treated with HNO3 for 24 h	ND	ND	Pd(acac)2	acetylacetone
treated with HNO3 for 24 h	ND	ND	Pd(acac)2	acetylacetone
treated with HNO3 for 24 h	ND	ND	Pd(acac)2	acetylacetone
treated with HNO3 for 24 h	ND	ND	Pd(acac)2	acetylacetone
treated with HNO3 for 24 h	ND	ND	Pd(acac)2	acetylacetone
ND	823	2	Pd(NH3)4(NO3)2	water

ND	ND	ND	PdCl2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	1373	3	Pd(NO3)2	water
ND	1373	3	Pd(NO3)2	water
ND	1373	3	Pd(NO3)2	toluene
ND	1373	3	Pd(NO3)2	toluene
ND	ND	ND	Pd(NO3)2	water
NA	NA	NA	NA	NA
ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
treated with HNO3 at 373 K for 2 h and doped with nitrogen	ND	ND	PdCl2	HCl
NA	ND	ND	PdCl2	aqueous methanol
NA	ND	ND	PdCl2	aqueous methanol
NA	ND	ND	PdCl2	aqueous methanol
NA	ND	ND	PdCl2	aqueous methanol
HNO3 treatment	ND	ND	PdCl2	aqueous methanol
HNO3 treatment	ND	ND	PdCl2	aqueous methanol
HNO3 treatment	ND	ND	PdCl2	aqueous methanol
HNO3 treatment	ND	ND	PdCl2	aqueous methanol
HNO3 treatment at 393 K for 2 h	ND	ND	Pd(NO3)2	aqueous ethanol
ND	ND	ND	Pd(azide)	ND
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(acac)2	toluene
ND	NA	NA	PdCl2(PhCN)2	acetone
ND	773	10	PdCl2(PhCN)2	acetone
NA	NA	NA	NA	NA
ND	ND	ND	PdCl2	aqueous ethylene glycol
ND	1073	ND	PdCl2	water
NA	NA	NA	PdCl2	HCl
treated with H2O2 at 60 °C for 5 h	ND	ND	PdCl2	HCl
treated with HCl at 60 °C for 5 h	ND	ND	PdCl2	HCl
treated with HNO3 at 60 °C for 5 h	ND	ND	PdCl2	HCl
ND	823	4	PdCl2	HCl
ND	823	4	PdCl2	HCl
ND	823	4	Pd(NO3)2	aqueous nitric acid
ND	ND	ND	Pd(acac)2	2-butanol
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(acac)2	acetone

were coated onto monolith	773	ND	Pd(NO3)2	aqueous ethanol
were coated onto monolith	773	ND	Pd(NO3)2	aqueous ethanol
were coated onto monolith	773	ND	Pd(NO3)2	aqueous ethanol
were coated onto monolith	673	ND	Pd(NO3)2	aqueous ethanol
were coated onto monolith	823	ND	Pd(NO3)2	aqueous ethanol
were coated onto monolith	723	ND	Pd(NO3)2	aqueous ethanol
were coated onto monolith	1023	ND	Pd(NO3)2	aqueous ethanol
were coated onto monolith	1023	ND	Pd(NO3)2	aqueous ethanol
ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
functionalized with dopamine	ND	ND	Na2PdCl4	water
ND	ND	ND	PdCl2	HCl
modified with 3% boron	ND	ND	Pd(NO3)2	nitric acid
NA	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	ND
functionalized with hydrogen	ND	ND	PdCl2	aqueous ethylene glycol
ND	ND	ND	PdCl2	ND
ND	ND	ND	PdCl2	ND
ND	ND	ND	PdCl2	ND
ND	ND	ND	PdCl2	ND
ND	ND	ND	PdCl2	ND
ND	ND	ND	PdCl2	ND
ND	ND	ND	PdCl2	ND
ND	ND	ND	PdCl2	ND
ND	ND	ND	PdCl2	ND
ND	ND	ND	PdCl2	ND
ND	ND	ND	PdCl2	ND
ND	ND	ND	PdCl2	ND
ND	ND	ND	PdCl2	ND
NA	NA	NA	NA	NA
NA	NA	NA	NA	NA
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	943	2	Pd(NO3)2	water
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
treated with 68-70 wt% HNO3, refluxed for 14 h at 140 °C	ND	ND	Pd(NO3)2	acetone
treated with 68-70 wt% HNO3, refluxed for 14 h at 140 °C	ND	ND	Pd(NO3)2	acetone
treated with 68-70 wt% HNO3, refluxed for 14 h at 140 °C	ND	ND	Pd(NO3)2	acetone
treated with 68-70 wt% HNO3, refluxed for 14 h at 140 °C	ND	ND	Pd(NO3)2	acetone
treated with 68-70 wt% HNO3, refluxed for 14 h at 140 °C	ND	ND	Pd(NO3)2	xylene
NA	NA	NA	NA	NA
NA	NA	NA	NA	NA

ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	acetone
ND	ND	ND	PdCl2	acetone
ND	ND	ND	PdCl2	acetone
NA	NA	NA	NA	NA
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	Na2PdCl4	ND
ND	ND	ND	Na2PdCl4	ND
ND	ND	ND	Na2PdCl4	ND
NA	NA	NA	PdCl2	aqueous hydrochloric acid
treated with 2 N H3PO4 for 48 h at 25 °C	NA	NA	PdCl2	aqueous hydrochloric acid
NA	623	4	PdCl2	aqueous hydrochloric acid
treated with 2 N HCl for 48 h at 25 °C	623	4	PdCl2	aqueous hydrochloric acid
treated by 37 wt% HCl for 2 days at 25 °C	ND	ND	PdCl2	aqueous ethanol
treated by 37 wt% HCl for 2 days at 25 °C	ND	ND	PdCl2	aqueous ethanol
treated by 37 wt% HCl for 2 days at 25 °C	ND	ND	PdCl2	aqueous ethanol
treated by HNO3 for 2 h at 110 °C	ND	ND	PdCl2	aqueous ethanol
treated by 37 wt% HCl for 2 days at 25 °C	ND	ND	PdCl2	aqueous ethanol
treated by 37 wt% HCl for 2 days at 25 °C	ND	ND	PdCl2	aqueous ethanol
treated by 37 wt% HCl for 2 days at 25 °C	ND	ND	PdCl2	aqueous ethanol
treated by 37 wt% HCl for 2 days at 25 °C	ND	ND	PdCl2	aqueous ethanol
treated by 37 wt% HCl for 2 days at 25 °C	ND	ND	PdCl2	aqueous ethanol
treated by 37 wt% HCl for 2 days at 25 °C	ND	ND	PdCl2	aqueous ethanol
treated by 37 wt% HCl for 2 days at 25 °C	ND	ND	PdCl2	aqueous ethanol
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
treated by HNO3 for 2 h at 110 °C	ND	ND	PdCl2	aqueous ethanol
treated by HNO3 for 2 h at 110 °C	ND	ND	PdCl2	aqueous ethanol
treated by HNO3 for 2 h at 110 °C	ND	ND	PdCl2	aqueous ethanol
treated by HNO3 for 2 h at 110 °C	ND	ND	PdCl2	aqueous ethanol
treated by HNO3 for 2 h at 110 °C	ND	ND	PdCl2	aqueous ethanol
treated by HNO3 for 2 h at 110 °C	ND	ND	PdCl2	aqueous ethanol
treated by HNO3 for 2 h at 110 °C	ND	ND	PdCl2	aqueous ethanol
treated by HNO3 for 2 h at 110 °C	ND	ND	PdCl2	aqueous ethanol

pre-oxidized with 30 wt% HNO3 at 85 °C for 5 h	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	Pd(OAc)2	methanol
ND	ND	ND	Pd(OAc)2	methanol
ND	ND	ND	Pd(OAc)2	methanol
ND	793	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	793	ND	Pd(OAc)2	acetone
Nitrogen-doped	ND	ND	K2PdCl4	ND
ND	ND	ND	K2PdCl4	ND
ND	ND	ND	K2PdCl4	ND
ND	ND	ND	Pd(OAc)2	ND
ND	ND	ND	Pd(OAc)2	ND
ND	773	4	PdCl2	water
ND	773	4	PdCl2	water
ND	773	4	PdCl2	water
ND	773	4	PdCl2	water
ND	773	4	PdCl2	water
ND	773	4	PdCl2	water
ND	773	4	PdCl2	water
ND	773	4	PdCl2	water
ND	ND	ND	PdCl2	water
NA	NA	NA	NA	NA
NA	NA	NA	NA	NA
NA	NA	NA	NA	NA
ND	773	2	Pd(NO3)2	water
ND	773	2	Pd(NO3)2	water
ND	773	2	Pd(NO3)2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
NA	NA	NA	NA	NA
ND	ND	ND	Pd(NO3)2	nitric acid
ND	ND	ND	Pd(NH3)4(NO3)2	ND
ND	ND	ND	Pd(NO3)2	nitric acid
ND	ND	ND	Pd(NH3)4(NO3)2	ND
ND	ND	ND	Pd(NO3)2	nitric acid
Activated at 150 °C for 2h	ND	ND	Pd(NH3)4(NO3)2	water
Activated at 150 °C for 2h	ND	ND	Pd(NH3)4(NO3)2	water
Activated at 150 °C for 2h	ND	ND	Pd(NH3)4(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
Ce doped (5 mol%)	773	3	Pd(NO3)2	water

Ti doped (5 mol%)	773	3	Pd(NO3)2	water
Fe doped (5 mol%)	773	3	Pd(NO3)2	water
Mn doped (5 mol%)	773	3	Pd(NO3)2	water
ND	ND	ND	PdCl2	HCl
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	Pd(NH3)4(NO3)2	ND
ND	ND	ND	PdCl2	hydrazine
ND	ND	ND	Na2PdCl4	water
ND	ND	ND	Na2PdCl4	water
ND	1423	ND	Na2PdCl4	water
ND	ND	ND	Pd(NH3)4(NO3)2	ND
ND	ND	ND	Pd(NH3)4(NO3)2	ND
ND	573	4	PdCl2	water
ND	573	4	PdCl2	water
ND	573	4	PdCl2	urea
ND	NA	NA	Pd(NO3)2	water
ND	NA	NA	Pd(NO3)2	aqueous acetic acid
ND	1423	ND	Pd(NO3)2	water
ND	ND	ND	PdCl2	aqueous ethanol
ND	ND	ND	PdCl2	aqueous ethanol
ND	623	4	PdCl2	water
ND	623	4	PdCl2	water
HNO3 treatment	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
ND	ND	ND	Pd(OAc)2	methanol
ND	ND	ND	Pd(OAc)2	methanol
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NH3)4Cl2	water
ND	1023	4	Pd(OAc)2	methanol
ND	1023	4	Pd(OAc)2	methanol
ND	1023	4	Pd(OAc)2	methanol
ND	773	12	Pd(acac)2	ND
Reduced graphene oxide	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
Urea hydrothermal treatment, weight ratio of urea/GO = 150	ND	ND	PdCl2	water
Urea hydrothermal treatment, weight ratio of urea/GO = 300	ND	ND	PdCl2	water
NA	ND	ND	PdCl2	aqueous hydrochloric acid
HNO3 treatment	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
Acidified at pH=1 by H2SO4	ND	ND	PdCl2	water
Acidified at pH=1 by H2SO4	ND	ND	PdCl2	water
Acidified at pH=1 by H2SO4	ND	ND	PdCl2	water

Acidified at pH=1 by H2SO4	ND	ND	PdCl2	water
Acidified at pH=1 by H2SO4	ND	ND	PdCl2	water
Acidified at pH=1 by H2SO4	ND	ND	PdCl2	water
ND	773	15	Pd(NH3)4Cl2	water
ND	773	15	Pd(NH3)4Cl2	water
ND	773	15	Pd(NH3)4Cl2	water
ND	773	15	Pd(NH3)4Cl2	water
ND	773	15	Pd(NH3)4Cl2	water
ND	773	15	Pd(NH3)4Cl2	water
ND	773	1	Pd(NO3)2	acetone
ND	773	1	Pd(NO3)2	acetone
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	Pd(NO3)2	ND
thermal decomposition at 500 °C for 1 h	ND	ND	Pd(NO3)2	water
thermal decomposition at 500 °C for 1 h	ND	ND	Pd(NO3)2	water
thermal decomposition at 500 °C for 1 h	ND	ND	Pd(NO3)2	water
thermal decomposition at 500 °C for 1 h	ND	ND	Pd(NO3)2	water
thermal decomposition at 500 °C for 1 h	ND	ND	Pd(NO3)2	water
ND	773	1	Pd(NO3)2	water
ND	773	1	Pd(NO3)2	water
ND	773	1	Pd(NO3)2	water
ND	773	1	Pd(NO3)2	water
ND	773	1	Pd(NO3)2	water
ND	773	1	Pd(NO3)2	water
ND	773	1	Pd(NO3)2	water
ND	773	1	Pd(NO3)2	water
ND	773	1	Pd(NO3)2	water
ND	773	1	Pd(NO3)2	water
ND	773	1	Pd(NO3)2	water
ND	773	5	Pd(NO3)2	water
ND	773	5	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	Pd(OAc)2	dichloromethane
ND	ND	ND	Pd(OAc)2	dichloromethane
ND	ND	ND	Pd(OAc)2	dichloromethane
ND	ND	ND	Pd(OAc)2	dichloromethane
ND	ND	ND	Pd(OAc)2	dichloromethane
ND	ND	ND	Pd(OAc)2	water
ND	ND	ND	PdCl2	water

ND	ND	ND	PdCl2	ethylene glycol
ND	ND	ND	Pd(NO3)2	water
ND	773	4	Pd(NO3)2	water
NA	NA	NA	NA	NA
Heat treatment at 3300 K + HNO3 treatment at reflux for 8h	ND	ND	Pd(NO3)2	acetone
Chlorinated then reacted with hexadecylamine	ND	ND	Pd(NO3)2	acetone
Propylamine treatment	ND	ND	Pd(NO3)2	acetone
Heat treatment at 1373 K + HNO3 treatment at reflux for 3h	ND	ND	Pd(NO3)2	acetone
Chlorinated then reacted with hexadecylamine	ND	ND	Pd(NO3)2	acetone
Propylamine treatment	ND	ND	Pd(NO3)2	acetone
HNO3 treatment at reflux for 8h	ND	ND	Pd(NO3)2	acetone
Chlorinated then reacted with hexadecylamine	ND	ND	Pd(NO3)2	acetone
Propylamine treatment	ND	ND	Pd(NO3)2	acetone
Functionalization treatment by refluxing in 65%wt HNO3 for 1.5h	ND	ND	Pd(NH3)4(NO3)2	water
Functionalization treatment by refluxing in 65%wt HNO3 for 1.5h	ND	ND	Pd(NH3)4(NO3)2	water
Functionalization treatment by refluxing in 65%wt HNO3 for 1.5h	ND	ND	Pd(NH3)4(NO3)2	water
Functionalization treatment by refluxing in 65%wt HNO3 for 1.5h	ND	ND	Pd(NH3)4(NO3)2	water
Functionalization treatment by refluxing in 65%wt HNO3 for 1.5h	ND	ND	Pd(NH3)4(NO3)2	water
Functionalization treatment by refluxing in 65%wt HNO3 for 1.5h	ND	ND	Pd(NH3)4(NO3)2	water
Functionalization treatment by refluxing in 65%wt HNO3 for 1.5h	ND	ND	Pd(NH3)4(NO3)2	water
NA	NA	NA	NA	NA
NA	NA	NA	NA	NA
NA	NA	NA	NA	NA
NA	NA	NA	NA	NA
ND	773	3	PdCl2	ND
ND	773	3	PdCl2	ND
ND	773	3	PdCl2	ND
ND	773	3	PdCl2	ND
ND	ND	ND	K2PdCl4	water
ND	ND	ND	K2PdCl4	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid

ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
NA	ND	ND	Pd(NO3)2	acetone
N doped	ND	ND	Pd(NO3)2	acetone
S doped	ND	ND	Pd(NO3)2	acetone
Oxidized CNT from nitric acid oxidation	ND	ND	Pd(NO3)2	acetone
ND	1173	ND	Pd(NO3)2	nitric acid
NA	ND	ND	PdCl2	aqueous hydrochloric acid
High temperature graphitization at 1900C under N2 flow	ND	ND	PdCl2	aqueous hydrochloric acid
Not graphitized, HNO3 treatment	ND	ND	PdCl2	aqueous hydrochloric acid
Graphitized, HNO3 treatment	ND	ND	PdCl2	aqueous hydrochloric acid
ND	873	6	Pd(NO3)2	aqueous methanol
ND	873	6	Pd(NO3)2	aqueous methanol
ND	873	6	Pd(NO3)2	aqueous methanol
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	823	3	PdCl2	aqueous hydrochloric acid
HNO3 treatment	673	ND	Pd(NH3)4(NO3)2	water
NA	ND	ND	Pd(NH3)4(NO3)2	water
NA	ND	ND	Pd(NH3)4(NO3)2	water
refluxing in 65 wt% nitric acid for 1.5 h	ND	ND	Pd(NH3)4(NO3)2	water
refluxing in 65 wt% nitric acid for 1.5 h	ND	ND	Pd(NH3)4(NO3)2	water
refluxing in 65 wt% nitric acid for 1.5 h	ND	ND	Pd(NH3)4(NO3)2	water
refluxing in 65 wt% nitric acid for 1.5 h	ND	ND	Pd(NH3)4(NO3)2	water
refluxing in 65 wt% nitric acid for 1.5 h	ND	ND	Pd(NH3)4(NO3)2	water
refluxing in 65 wt% nitric acid for 1.5 h	ND	ND	Pd(NH3)4(NO3)2	water
refluxing in 65 wt% nitric acid for 1.5 h	ND	ND	Pd(NH3)4(NO3)2	water
refluxing in 65 wt% nitric acid for 1.5 h	ND	ND	Pd(NH3)4(NO3)2	water
refluxing in 65 wt% nitric acid for 1.5 h	ND	ND	Pd(NH3)4(NO3)2	water
refluxing in 30 wt% nitric acid for 0.5 h	ND	ND	Pd(NH3)4(NO3)2	water
refluxing in 30 wt% nitric acid for 0.5 h	ND	ND	Pd(NH3)4(NO3)2	water
refluxing in 30 wt% nitric acid for 0.5 h	ND	ND	Pd(NH3)4(NO3)2	water
ND	773	ND	Pd(NO3)2	water
ND	773	ND	Pd(NO3)2	water
ND	773	ND	Pd(NO3)2	water
ND	773	ND	Pd(NO3)2	water
ND	773	ND	Pd(NO3)2	water
HCl treatment	ND	ND	Pd(OAc)2	acetone
HCl treatment	ND	ND	Pd(OAc)2	acetone
HCl treatment	ND	ND	Pd(OAc)2	acetone
N-doped + HCl treatment	ND	ND	Pd(OAc)2	acetone
N-doped + HCl treatment	ND	ND	Pd(OAc)2	acetone
N-doped + HCl treatment	ND	ND	Pd(OAc)2	acetone
ND	ND	ND	Pd(NH3)4(NO3)2	water

ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	NA	NA	Pd(NO3)2	water
ND	NA	NA	Pd(NO3)2	water
ND	NA	NA	Pd(NO3)2	water
ND	NA	NA	Pd(NO3)2	water
ND	NA	NA	Pd(NO3)2	water
ND	NA	NA	Pd(NO3)2	water
ND	723	4	Pd(NO3)2	water
ND	723	4	Pd(NO3)2	water
ND	723	4	Pd(NO3)2	water
ND	723	4	Pd(NO3)2	water
Isothermal treatment at 900 °C	ND	ND	Pd(OAc)2	methylene chloride
Isothermal treatment at 900 °C	ND	ND	Pd(OAc)2	methylene chloride
Isothermal treatment at 900 °C	ND	ND	Pd(OAc)2	methylene chloride
Isothermal treatment at 900 °C	ND	ND	Pd(OAc)2	methylene chloride
Isothermal treatment at 900 °C	ND	ND	Pd(OAc)2	methylene chloride
Isothermal treatment at 900 °C	ND	ND	Pd(acac)2	benzene chloride
Isothermal treatment at 900 °C	ND	ND	Pd(acac)2	benzene chloride
Isothermal treatment at 900 °C	ND	ND	Pd(acac)2	benzene chloride
Isothermal treatment at 900 °C	ND	ND	Pd(acac)2	benzene chloride
Isothermal treatment at 900 °C	ND	ND	Pd(acac)2	benzene chloride
ND	ND	ND	Pd(OAc)2	HCl
ND	ND	ND	Pd(OAc)2	HCl
NA	ND	ND	PdCl2	HCl
washed with water and dried under vacuum at 373K for 4 h	ND	ND	PdCl2	HCl
washed with water and dried under vacuum at 433K for 4 h	ND	ND	PdCl2	HCl
washed with water and dried under vacuum at 443K for 4 h	ND	ND	PdCl2	HCl
washed with water and dried under vacuum at 453K for 4 h	ND	ND	PdCl2	HCl
washed with water and dried under vacuum at 463K for 4 h	ND	ND	PdCl2	HCl
washed with water and dried under vacuum at 473K for 4 h	ND	ND	PdCl2	HCl
washed with water and dried under vacuum at 493K for 4 h	ND	ND	PdCl2	HCl
washed with water and dried under vacuum at 533K for 4 h	ND	ND	PdCl2	HCl
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water

ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
ND	823	2	Pd(NO3)2	water
ND	823	2	Pd(NO3)2	water
PEG-600 added, heated at 100C for 12 h. Then incubated at 100C for 12 h. After reduction was done at 1400C for 4 h	873	4	Pd(NO3)2	water
CMK-3 added and stirred for 24 h. After ammonium hydroxide and water were added. Lastly, it was washed and dried at 110C.	873	4	Pd(NO3)2	water
thermal treatment was applied at 500C for 5 h	ND	ND	PdCl2	water
thermal treatment was applied at 500C for 5 h	ND	ND	PdCl2	water
thermal treatment was applied at 500C for 5 h	ND	ND	PdCl2	water
thermal treatment was applied at 500C for 5 h	ND	ND	PdCl2	water
ND	873	4	PdCl2	water
ND	873	4	PdCl2	water
s purified with HNO3 and dried at 105C for	ND	ND	PdCl2	water
PEG was added and spray-dried at 240C	773	5	Pd(NH3)4(NO3)2	ND
PEG was added and spray-dried at 240C	773	5	Pd(NH3)4(NO3)2	ND
PEG was added and spray-dried at 240C	773	5	Pd(NH3)4(NO3)2	ND
washed by an ethanol-HCl mixed solution for several times before drying	673	5	PdCl2	water
washed by an ethanol-HCl mixed solution for several times before drying	673	5	PdCl2	water
ND	723	3	PdCl2	HCl
ND	723	3	PdCl2	HCl
ND	723	3	PdCl2	HCl
ND	723	3	PdCl2	HCl
ND	723	3	PdCl2	HCl
ND	723	3	PdCl2	HCl
ND	723	3	PdCl2	HCl
ND	723	3	PdCl2	HCl
ND	723	3	PdCl2	HCl
ND	723	3	PdCl2	HCl
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water

heated to 100C for 24 h and washed several times	873	4	Pd(NO3)2	water
heated to 100C for 24 h and washed several times	673	4	Pd(NO3)2	water
heated to 180C for 24 h and washed several times	673	4	Pd(NO3)2	water
heated to 170C for 10 h and washed several times	673	4	Pd(NO3)2	water
washed with water	673	2	Pd(NO3)2	ND
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	773	2	Pd(NO3)2	ND
ND	823	4	Pd(OAc)2	acetone
ND	823	4	Pd(OAc)2	acetone
ND	823	4	Pd(OAc)2	acetone
ND	823	4	Pd(OAc)2	acetone
ND	ND	ND	Pd(OAc)2	acetone
reduced under H2 at 950 °C for 4 h	823	4	Pd(NO3)2	water
reduced under H2 at 950 °C for 4 h	823	4	Pd(NO3)2	water
reduced under H2 at 950 °C for 4 h	823	4	Pd(NO3)2	water
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	Pd(OAc)2	aqueous acetic acid
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(OAc)2	aqueous acetic acid
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	PdCl2	aqueous hydrochloric acid
acid-washed	ND	ND	Na2PdCl4	water
acid-washed	ND	ND	Na2PdCl4	water
acid-washed	ND	ND	Na2PdCl4	water
acid-washed	ND	ND	Na2PdCl4	water
acid-washed	ND	ND	Na2PdCl4	water
washed with water	773	3	PdCl2	HCl
washed with water	ND	ND	PdCl2	HCl
washed with water	773	3	PdCl2	HCl
washed with water	773	3	PdCl2	HCl
ND	773	3	PdCl2	HCl
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water

ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
no promoter	ND	ND	Pd(NO3)2	water
promoted with Ceria, (Ce(NO3)3 is added (Ce/Pd molar ratio: 0.25)	ND	ND	Pd(NO3)2	water
promoted with Ceria, (Ce(NO3)3 is added (Ce/Pd molar ratio: 0.5)	ND	ND	Pd(NO3)2	water
promoted with Ceria, (Ce(NO3)3 is added (Ce/Pd molar ratio: 1)	ND	ND	Pd(NO3)2	water
promoted with Ceria, (Ce(NO3)3 is added (Ce/Pd molar ratio: 2)	ND	ND	Pd(NO3)2	water
promoted with Ceria, (Ce(NO3)3 is added (Ce/Pd molar ratio: 3)	ND	ND	Pd(NO3)2	water
no promoter	ND	ND	Pd(NO3)2	water
promoted with Ceria, (Ce(NO3)3 is added (Ce/Pd molar ratio: 1)	ND	ND	Pd(NO3)2	water
promoted with Ceria, (Ce(NO3)3 is added (Ce/Pd molar ratio: 3)	ND	ND	Pd(NO3)2	water
hexadecyltrimethyl ammonium bromide dissolved in H2O is used in the support synthesis, solid precipitate is aged at 373 K for 4 days in a closed Teflon autoclave and washed/dried	673	5	PdCl2	aqueous hydrochloric acid
hexadecyltrimethyl ammonium bromide dissolved in H2O is used in the support synthesis, solid precipitate is aged at 373 K for 4 days in a closed Teflon autoclave and washed/dried	673	5	PdCl2	aqueous hydrochloric acid
hexadecyltrimethyl ammonium bromide dissolved in H2O is used in the support synthesis, solid precipitate is aged at 373 K for 4 days in a closed Teflon autoclave and washed/dried	673	5	PdCl2	aqueous hydrochloric acid
hexadecyltrimethyl ammonium bromide dissolved in H2O is used in the support synthesis, solid precipitate is aged at 373 K for 4 days in a closed Teflon autoclave and washed/dried	673	5	PdCl2	aqueous hydrochloric acid
hexadecyltrimethyl ammonium bromide dissolved in H2O is used in the support synthesis, solid precipitate is aged at 373 K for 4 days in a closed Teflon autoclave and washed/dried	673	5	PdCl2	aqueous hydrochloric acid
hexadecyltrimethyl ammonium bromide dissolved in H2O is used in the support synthesis, solid precipitate is aged at 373 K for 4 days in a closed Teflon autoclave and washed/dried	673	5	PdCl2	aqueous hydrochloric acid

hexadecyltrimethyl ammonium bromide dissolved in H2O is used in the support synthesis, solid precipitate is aged at 373 K for 4 days in a closed Teflon autoclave and washed/dried	673	5	PdCl2	aqueous hydrochloric acid
prepared by co-precipitation method	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(OAc)2	water
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	Pd(OAc)2	toluene
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	Pd(OAc)2	toluene
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	Pd(OAc)2	toluene
NA	773	4	PdCl2	ND
support prepared by impregnation	773	4	PdCl2	ND
support prepared by impregnation	773	4	PdCl2	ND
support prepared by impregnation	773	4	PdCl2	ND
support prepared by impregnation	773	4	PdCl2	ND
support prepared by impregnation	773	4	PdCl2	ND
support prepared by impregnation, lanthanum first and cerium second	773	4	PdCl2	ND
support prepared by impregnation, lanthanum first and cerium second	773	4	PdCl2	ND
support prepared by impregnation, lanthanum first and cerium second	773	4	PdCl2	ND
support prepared by impregnation, lanthanum first and cerium second	773	4	PdCl2	ND
ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
ND	ND	ND	PdCl2	HCl
ND	873	6	PdCl2	HCl
ND	873	6	PdCl2	HCl
ND	873	6	PdCl2	HCl
ND	ND	ND	Pd(NH3)4(NO3)2	ND
ND	ND	ND	Pd(NH3)4(NO3)2	ND
after preparation filtered, washed and dried	873	4	Pd(OAc)2	dichloromethane
after preparation filtered, washed and dried	1073	4	Pd(OAc)2	dichloromethane

after preparation filtered, washed and dried	1273	4	Pd(OAc)2	dichloromethane
after preparation filtered, washed and dried	1473	4	Pd(OAc)2	dichloromethane
ND	673	6	Pd(NO3)2	water
ND	1273	6	Pd(NO3)2	water
ND	1473	6	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
er ature and then it was further exposed to	673	10	K2PdCl4	water
er ature and then it was further exposed to	673	10	K2PdCl4	water
ND	ND	ND	Pd(acac)2	toluene
ND	ND	ND	PdCl2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	Pd(NO3)2	water
mixture heated at 120C for 20 h in autoclave, after cooled and aged for 2 days, washed	ND	ND	Pd(OAc)2	acetonitrile
mixture heated at 120C for 20 h in autoclave, after cooled and aged for 2 days, washed	ND	ND	Pd(OAc)2	acetonitrile
ND	ND	ND	Pd(NO3)2	ND
was purged completely by nitrogen before heating up to 300 C, held at this temperature for 2 h, cooled down and were washed with acetone repeatedly, and dried in air	1423	1	Pd(NO3)2	ND
ND	773	2	PdCl2	water
ND	1073	2	PdCl2	water
ND	1373	2	PdCl2	water
ND	1573	2	PdCl2	water
ND	1373	2	PdCl2	water
ND	1373	2	PdCl2	water
ND	1373	2	PdCl2	water
ND	673	4	Pd(NO3)2	water
ND	873	4	Pd(NO3)2	water
ND	673	4	Pd(NO3)2	water
ND	873	4	Pd(NO3)2	water
ND	773	5	Pd(NO3)2	water
ND	1073	ND	PdCl2	water
ND	1073	ND	PdCl2	water
hed with water and oven-dried at 383 K for	ND	ND	Pd(NO3)2	2-butanol
hed with water and oven-dried at 383 K for	ND	ND	Pd(NO3)2	2-butanol
ND	ND	ND	PdCl2	water
ND	823	4	PdCl2	water
ND	823	4	PdCl2	water
ND	ND	ND	Na2PdCl4	water
ND	ND	ND	Na2PdCl4	water
ND	ND	ND	Na2PdCl4	water
ND	773	4	PdCl2	aqueous hydrochloric acid

ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	PdCl2	ND
ND	ND	ND	PdCl2	ND
ND	ND	ND	PdCl2	ND
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	1173	3	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
washed and dried	773	4	PdCl2	ND
washed and dried	773	4	PdCl2	water
washed and dried	773	4	PdCl2	water
washed and dried	773	4	PdCl2	water
washed and dried	773	4	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
prepared from soluble and hydrolyzable carbohydrates with a metal chloride template	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
pre-dried	ND	ND	Pd(NO3)2	water
pre-dried	ND	ND	Pd(NO3)2	water
pre-dried	ND	ND	Pd(NO3)2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
treated with HNO3, then washed and dried overnight	ND	ND	(NH4)2PdCl4	aqueous hydrochloric acid
treated with HNO3, then washed and dried overnight	ND	ND	Pd(NO3)2	aqueous nitric acid
treated with HNO3, then washed and dried overnight	ND	ND	Pd(acac)2	acetylacetone
ND	1123	5	Pd(NH3)4(NO3)2	water
ND	1123	5	Pd(NH3)4(NO3)2	water
ND	1123	5	Pd(NH3)4(NO3)2	water
ND	1123	5	Pd(NH3)4(NO3)2	water
chemical activation with KOH	ND	ND	Pd(acac)2	tetrahydrofuran
chemical activation with KOH	ND	ND	Pd(NH3)4Cl2	water
chemical activation with KOH	ND	ND	PdCl2	aqueous hydrochloric acid
ND	773	4	Pd(NH3)4(NO3)2	water
ND	ND	ND	Pd(OAc)2	acetone
ND	823	5	Pd(OAc)2	acetone
ND	773	6	PdCl2	water
ND	773	6	PdCl2	water
ND	773	6	PdCl2	water

ND	773	6	PdCl2	water
ND	773	6	PdCl2	water
acid-washed	ND	ND	Pd(acac)2	benzene
acid-washed	ND	ND	Pd(acac)2	benzene
acid-washed	ND	ND	Pd(acac)2	benzene
acid-washed	ND	ND	Pd(acac)2	benzene
acid-washed	ND	ND	Pd(NH3)4(NO3)2	water
acid-washed	ND	ND	Pd(acac)2	benzene
acid-washed	ND	ND	Pd(acac)2	benzene
acid-washed	ND	ND	Pd(acac)2	benzene
acid-washed	ND	ND	Pd(acac)2	benzene
acid-washed	ND	ND	Pd(NH3)4(NO3)2	water
pre-oxidized with 30 wt% HNO3 at 85 °C for 5 h, and then washed with deionized water and dried at 120 °C for 2 h	ND	ND	PdCl2	ND
pre-oxidized with 30 wt% HNO3 at 85 °C for 5 h, and then washed with deionized water and dried at 120 °C for 2 h	ND	ND	PdCl2	ND
ND	ND	ND	Pd(NH3)4Cl2	water
ND	ND	ND	Pd(NH3)4Cl2	water
ND	ND	ND	Pd(NH3)4Cl2	water
NA	ND	ND	Pd(NO3)2	water
treated with 10 vol% H2/N2 at 200 °C	ND	ND	Pd(NO3)2	water
treated with 10 vol% H2/N2 at 400 °C	ND	ND	Pd(NO3)2	water
treated with 10 vol% H2/N2 at 600 °C	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
NH4OH was added to solution, stirred and dried overnight	773	ND	ND	ND
NH4OH was added to solution, stirred and dried overnight	773	ND	ND	ND
NH4OH was added to solution, stirred and dried overnight	773	ND	ND	ND
NH4OH was added to solution, stirred and dried overnight	773	ND	ND	ND
ND	ND	ND	Pd(NO3)2	aqueous nitric acid
ND	ND	ND	Pd(NO3)2	aqueous nitric acid
ND	ND	ND	Pd(NO3)2	aqueous nitric acid
ND	ND	ND	Pd(acac)2	toluene
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	K2PdCl4	water
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water

ND	ND	ND	PdCl2	water
NA	ND	ND	Na2PdCl4	aqueous hydrogen peroxide
dispersed in HNO3 solution at 80 °C for 2 h, washed and dried	ND	ND	Na2PdCl4	aqueous hydrogen peroxide
dispersed in 15 wt% H2O2 solution at 80 °C for 2 h, washed and dried	ND	ND	Na2PdCl4	aqueous hydrogen peroxide
nitrogen-doped, dissolved in urea, dried	973	4	Na2PdCl4	aqueous hydrogen peroxide
ND	ND	ND	Pd(NH3)4Cl2	water
ND	ND	ND	Pd(NH3)4Cl2	water
dried	ND	ND	Pd(NO3)2	water
dried	ND	ND	Pd(NH3)4Cl2	water
ND	ND	ND	Pd(NH3)4Cl2	water
ND	ND	ND	Pd(NH3)4Cl2	water
ND	ND	ND	Pd(NH3)4Cl2	water
ND	1473	3	Pd(acac)2	chloroform
ND	1473	3	Na2PdCl4	water
ND	1473	3	PdSO4	water
heated to 100 °C for 24 h and washed several times	773	4	Na2PdCl4	ethanol
heated to 180 °C for 24 h and washed several times	773	4	Na2PdCl4	ethanol
heated to 170 °C for 10 h and washed several times	773	4	Na2PdCl4	ethanol
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	773	1	Pd(NO3)2	water
ND	773	1	Pd(NO3)2	water
ND	773	1	Pd(NO3)2	water
ND	773	1	Pd(NO3)2	water
ND	773	1	Pd(NO3)2	water
ND	773	1	Pd(NO3)2	water
ND	773	1	Pd(NO3)2	water
ND	773	1	Pd(NO3)2	water
ND	ND	ND	Pd(acac)2	butanol
ND	ND	ND	Pd(acac)2	butanol

ND	ND	ND	Pd(acac)2	butanol
ND	ND	ND	Pd(acac)2	butanol
ND	ND	ND	Pd(acac)2	butanol
ND	ND	ND	Pd(acac)2	butanol
ND	ND	ND	Pd(acac)2	butanol
ND	ND	ND	Pd(acac)2	butanol
ND	ND	ND	Pd(acac)2	butanol
ND	ND	ND	Pd(acac)2	butanol
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	Pd(NO3)2	butanol
ND	ND	ND	Pd(OAc)2	butanol
ND	ND	ND	Pd(NO3)2	butanol
ND	ND	ND	Pd(NO3)2	butanol
ND	ND	ND	Pd(NO3)2	butanol
was washed with 0.1 M HCl and with wate	ND	ND	Pd(NO3)2	water
was washed with 0.1 M HCl and with wate	ND	ND	Pd(NO3)2	water
was washed with 0.1 M HCl and with wate	ND	ND	Pd(NO3)2	water
was washed with 0.1 M HCl and with wate	ND	ND	Pd(NO3)2	water
was washed with 0.1 M HCl and with wate	ND	ND	Na2PdCl4	water
was washed with 0.1 M HCl and with wate	ND	ND	Na2PdCl4	water
was washed with 0.1 M HCl and with wate	ND	ND	Na2PdCl4	water
ND	ND	ND	(NH3)2Pd(NO2)2	ND
ND	ND	ND	(NH3)2Pd(NO2)2	ND
ND	ND	ND	(NH3)2Pd(NO2)2	ND
ND	ND	ND	(NH3)2Pd(NO2)2	ND
ND	ND	ND	(NH3)2Pd(NO2)2	ND
ND	ND	ND	(NH3)2Pd(NO2)2	ND
ND	NA	NA	PdCl2	aqueous hydrochloric acid
ND	773	4	PdCl2	aqueous hydrochloric acid
ND	1173	4	PdCl2	aqueous hydrochloric acid
ND	1373	4	PdCl2	aqueous hydrochloric acid
ND	1423	4	PdCl2	aqueous hydrochloric acid
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water

NA	ND	ND	PdCl2	aqueous hydrochloric acid
NA	ND	ND	Pd(OAc)2	acetonitrile
NA	ND	ND	Pd(NH3)4Cl2	water
1 wt% CaCO3 added to support via impregnation	ND	ND	Pd(OAc)2	acetonitrile
2 wt% ammonium fluoride added to support via impregnation	ND	ND	Pd(OAc)2	acetonitrile
ND	773	4	Pd(NO3)2	water
ND	1123	4	Pd(NO3)2	water
ND	773	4	Pd(NO3)2	water
ND	1123	4	Pd(NO3)2	water
ND	823	6	Pd(NO3)2	water
ND	823	6	Pd(NO3)2	raw materials of MCM-41
ND	823	4	Pd(NH3)4Cl2	water
ND	823	4	Pd(NH3)4Cl2	water
ND	NA	NA	Pd(NH3)4Cl2	water
ND	NA	NA	Pd(NH3)4Cl2	water
ND	NA	NA	Pd(NH3)4Cl2	water
ND	NA	NA	Pd(NH3)4Cl2	water
ND	NA	NA	Pd(NH3)4Cl2	water
ND	NA	NA	Pd(NH3)4Cl2	water
ND	NA	NA	Pd(NH3)4Cl2	water
ND	NA	NA	Pd(NH3)4Cl2	water
ND	NA	NA	Pd(NH3)4Cl2	water
ND	NA	NA	Pd(NH3)4Cl2	water
ND	ND	ND	PdCl2	ND
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	Pd(OAc)2	ND
ND	ND	ND	Pd(NH3)4Cl2	water
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
Beta zeolites were supplied in the sodium form. ion-exchange was made three times with 1 M NH4NO3 aqueous solution.Calcination is done by two steps	823	15	Pd(NO3)2	water
Beta zeolites were supplied in the sodium form. ion-exchange was made three times with 1 M NH4NO3 aqueous solution.Calcination is done by two steps	823	15	Pd(NO3)2	water
Beta zeolites were supplied in the sodium form. ion-exchange was made three times with 1 M NH4NO3 aqueous solution.Calcination is done by two steps	823	15	Pd(NO3)2	water
ND	823	15	Pd(NO3)2	water
ND	823	15	Pd(NO3)2	water
ND	823	15	Pd(NO3)2	water
ND	ND	ND	PdCl2	ND
Promoted: Na=0.017 wt%	ND	ND	PdCl2	ND
Promoted: Na=0.034 wt%	ND	ND	PdCl2	ND
Promoted: Na=0.068 wt%	ND	ND	PdCl2	ND

Promoted: Na=0.0102 wt%	ND	ND	PdCl2	ND
ND	ND	ND	Pd(NO3)2	ND
Promoted: Li=0.020 wt%	ND	ND	Pd(NO3)2	ND
Promoted: Na=0.068 wt%	ND	ND	Pd(NO3)2	ND
Promoted: K=0.115 wt%	ND	ND	Pd(NO3)2	ND
Promoted: Cs=0.392 wt%	ND	ND	Pd(NO3)2	ND
ND	823	12	Pd(NO3)2	water
ND	823	12	Pd(NO3)2	water
ND	823	12	Pd(NO3)2	water
ND	673	3	Pd(NO3)2	ND
ND	ND	ND	Pd(NH3)4(NO3)2	water
ND	ND	ND	Pd(NH3)4(NO3)2	water
ND	ND	ND	Pd(NH3)4(NO3)2	water
ND	ND	ND	Pd(NH3)4(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NH3)4(NO3)2	water
ND	ND	ND	Pd(NH3)4(NO3)2	water
ND	ND	ND	Pd(NH3)4(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NH3)4Cl2	water
ND	ND	ND	Pd(NH3)4Cl2	water
ND	ND	ND	Pd(NH3)4Cl2	water
ND	ND	ND	Pd(NH3)4Cl2	water
ND	ND	ND	Pd(NH3)4Cl2	water
ND	ND	ND	Pd(NH3)4Cl2	water
ND	ND	ND	Pd(NH3)4Cl2	water
ND	ND	ND	Pd(NH3)4Cl2	water
ND	ND	ND	Pd(NH3)4Cl2	water
ND	ND	ND	Pd(NH3)4Cl2	water
ND	ND	ND	Pd(NH3)4Cl2	water
ND	ND	ND	Pd(NH3)4Cl2	water
ND	ND	ND	Pd(NH3)4Cl2	water
NA	823	15	Pd(NO3)2	water
NA	823	15	Pd(NO3)2	water
aggloramated with bentonite (65 wt%) and ion-exchanged with 1 M NH4Cl	823	15	Pd(NO3)2	water
aggloramated with bentonite (65 wt%) and ion-exchanged with 1 M NH4Cl	823	15	Pd(NO3)2	water
ND	ND	ND	Pd(acac)2	toluene

ND	ND	ND	PdCl2	water and ammonia
ND	ND	ND	PdCl2	water and ammonia
ND	ND	ND	PdCl2	water and NaOH
ND	ND	ND	PdCl2	water
ND	773	6	Pd(NH3)4Cl2	NA
ND	773	6	Pd(NH3)4Cl2	NA
ND	773	6	Pd(NH3)4Cl2	water
ND	773	6	Pd(NH3)4Cl2	water
ND	823	8	Pd(OAc)2	methanol
ND	823	5	Pd(OAc)2	methanol
NA	823	5	Pd(NO3)2	water
n an emulsion containing N,N-dimethyl-dec	823	5	Pd(NO3)2	water
ND	ND	ND	Pd(acac)2	CHCl3
ND	ND	ND	Pd(acac)2	CHCl3
ND	773	4	Pd(NH3)4(NO3)2	ND
ND	773	4	Pd(NH3)4(NO3)2	ND
ND	823	6	PdCl2	water
ND	823	6	PdCl2	water
ND	823	6	PdCl2	water
ND	ND	ND	PdCl2	water
ND	ND	ND	PdCl2	water
ND	773	6	PdCl2	aqueous hydrochloric acid
ND	773	6	PdCl2	aqueous hydrochloric acid
ND	773	6	PdCl2	aqueous hydrochloric acid
ND	773	6	PdCl2	aqueous hydrochloric acid
functionalized with PPh2 (%PPh2= 5)	353	24	PdCl2	toluene
functionalized with PPh2 (%PPh2= 10)	353	24	PdCl2	toluene
functionalized with PPh2 (%PPh2= 15)	353	24	PdCl2	toluene
functionalized with PPh2 (%PPh2=15)	353	24	PdCl2	toluene
ND	823	ND	Pd(NH3)4(NO3)2	water
ND	ND	48	Pd(NH3)4(NO3)2	water
ND	873	4	Pd(acac)2	toluene
ND	853	3	Pd(NH3)4Cl2	water
ND	853	3	Pd(NH3)4Cl2	water
ND	813	6	Pd(NH3)4Cl2	water
ND	813	6	Pd(NH3)4Cl2	water
ND	773	ND	Pd(NO3)2	aqueous ethanol
ND	823	2	PdCl2	aqueous hydrochloric acid
ND	823	2	PdCl2	aqueous hydrochloric acid
ND	823	2	PdCl2	aqueous hydrochloric acid
ND	823	2	PdCl2	aqueous hydrochloric acid
ND	823	2	PdCl2	aqueous hydrochloric acid
ND	823	2	Pd(NH3)4(NO3)2	water
ND	823	2	Pd(NH3)4(NO3)2	water
ND	823	2	Pd(NH3)4(NO3)2	water
ND	823	2	Pd(NH3)4(NO3)2	water
ND	ND	ND	PdCl2	HCl
ND	773	6	PdCl2	HCl
ND	773	3	Pd(NO3)2	water
ND	773	3	Pd(NO3)2	water

ND	ND	ND	PdCl2	HEPES
ND	ND	ND	[Pd(NH4)]2+	water
ND	ND	ND	[Pd(NH4)]2+	water
ND	ND	ND	[Pd(NH4)]2+	water
ND	ND	ND	[Pd(NH4)]2+	water
ND	ND	ND	[Pd(NH4)]2+	water
ND	ND	ND	[Pd(NH4)]2+	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	PdCl2	glucose
N-N dimethylformamide and ethanol treatments	ND	ND	PdCl2	water
N-N dimethylformamide and ethanol treatments	ND	ND	PdCl2	water
N-N dimethylformamide and ethanol treatments	ND	ND	PdCl2	water
N-N dimethylformamide and ethanol treatments	ND	ND	PdCl2	water
ND	673	4	Pd(NO3)2	water
ND	773	4	PdCl2	ethylene glycol
Washed with 1 M hydrochloric acid, distilled water and methanol, and dried	ND	ND	Pd(NH3)4(NO3)2	water
TiO2 was deposited onto MCM-41	ND	ND	Pd(hfac)2	ND
TiO2 was deposited onto MCM-41	ND	ND	Pd(hfac)2	ND
TiO2 was deposited onto MCM-41	ND	ND	Pd(hfac)2	ND
TiO2 was deposited onto MCM-41	ND	ND	Pd(hfac)2	ND
TiO2 was deposited onto MCM-41	ND	ND	Pd(hfac)2	ND
TiO2 was deposited onto MCM-41	ND	ND	Pd(hfac)2	ND
ND	ND	ND	Pd(OAC)2	HCl

ND	773	3	ND	ND
ND	ND	ND	Pd(OAc)2	toluene and ethanol
ND	ND	ND	PdCl2	aqueous ethanol
ND	ND	ND	Pd(NO3)2	cyclohexane
ND	ND	ND	Pd(NO3)2	cyclohexane
ND	ND	ND	Pd(acac)2	xylene
ND	ND	ND	Pd(acac)2	xylene
ND	ND	ND	Pd(acac)2	xylene
ND	ND	ND	Pd(acac)2	xylene
ND	ND	ND	Pd(acac)2	xylene
ND	ND	ND	Pd(acac)2	xylene
treated with HCl at 50 °C for 2 h	ND	ND	PdCl2	water and SnCl2
treated with HCl at 50 °C for 2 h	ND	ND	PdCl2	water and SnCl2
treated with HNO3 at 120 °C for 50 h	ND	ND	ND	ND
treated with HNO3 at 120 °C for 50 h	ND	ND	ND	ND
treated with HNO3 at 120 °C for 50 h	ND	ND	ND	ND
treated with HNO3 at 120 °C for 50 h	ND	ND	ND	ND
treated with HNO3 at 120 °C for 50 h	ND	ND	ND	ND
ND	ND	ND	Pd(NO3)2	water
pre-oxidized with 30 wt% HNO3 at 85 °C for 5 h	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	PdCl2	aqueous hydrochloric acid
ND	ND	ND	Pd(acac)2	xylene
ND	ND	ND	Pd(acac)2	xylene
ND	ND	ND	Pd(acac)2	xylene
ND	ND	ND	Pd(acac)2	xylene
ND	ND	ND	Pd(acac)2	xylene
ND	ND	ND	Pd(OAc)2	xylene
ND	ND	ND	Pd(OAc)2	xylene
ND	ND	ND	Pd(OAc)2	xylene
ND	ND	ND	Pd(NO3)2	water
Oxidation of purified CNTs with 4:1, vol/vol 96% H2SO4/30% H2O2	ND	ND	Pd(NO3)2	water
Oxidative acid treatment with 3:1, vol/vol 96% H2SO4/78% HNO3	ND	ND	Pd(NO3)2	water
NA	ND	ND	PdCl2	water
N-doped	ND	ND	PdCl2	water
NA	ND	ND	PdCl2	water
ND	ND	ND	Pd(NO3)2	water and glycine
ND	ND	ND	Pd(NO3)2	water and glycine
ND	ND	ND	Pd(NO3)2	aqueous nitric acid
ND	ND	ND	Pd(NO3)2	aqueous nitric acid

ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	Pd(NO3)2	ND
ND	ND	ND	K2PdCl4	toluene
ND	ND	ND	K2PdCl4	toluene
ND	ND	ND	K2PdCl4	toluene
ND	ND	ND	K2PdCl4	toluene
ND	ND	ND	K2PdCl4	toluene
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Pd(NH3)4(NO3)2	water
ND	1073	2	PdCl2	aqueous hydrochloric acid
ND	ND	ND	Pd(NO3)2	ND
trans-1,2-diaminocyclohexane-N,N,N',N'-tetraacetic acid used as stabilizer	ND	ND	PdCl2	water
NA	ND	ND	PdCl2	water
aminobenzenesulfonic monolayer was grafted onto MWCNTs surface	ND	ND	PdCl2	aqueous ethanol
ND	ND	ND	Pd(NO3)2	water
ND	ND	ND	Cp(allyl)Pd	ND
ND	ND	ND	Cp(allyl)Pd	ND
immersed in HNO3/H2SO4 solution	333	5	(NH4)2PdCl6	water
isopropanol treatment	ND	ND	(CTA)2PdCl6	water
as-received	NA	NA	(NH4)2PdCl4	ethylene glycol
as-received	NA	NA	(NH4)2PdCl4	ethylene glycol
as-received	NA	NA	(NH4)2PdCl4	ethylene glycol
functionalized with 1,10-phenanthroline	298	1	PdCl2	water
functionalized with H2SO4 - HNO3	ND	8	PdCl2	water
treated with ozone	ND	ND	Pd(hfac)2	formaldehyde
treated with HCl	ND	ND	PdCl2	water
ND	ND	ND	ND	ND
C Coating of SiO2	ND	ND	ND	ND
ned in air at 600°C for 1 h. Then, ammoniu	773	1	Pd(NO3)2	ND
ND	ND	ND	Pd(NO3)2	ND
ND	673	6	Pd(NO3)2	water
ND	773	12	Pd(NH3)4Cl2	water
ND	773	12	Pd(NH3)4Cl2	water

solvent precursor pH	pH adjustment (Yes or No)	PZC support	Calcination Time (hr)	Calc. Temp. (K)	Reduction Solvent/ Gas	Reduction Time (hr)	Reduction Temp. (K)
ND	No	8.5	4	773	H2	ND	773
ND	No	8.5	4	773	H2	ND	773
ND	No	8.5	4	773	H2	ND	773
ND	No	8.5	4	773	H2	ND	773
ND	No	8.5	4	773	H2	ND	773
ND	No	9.1	4	773	H2	2	573
ND	No	9.1	4	773	H2	2	573
ND	No	8.5	4	673	H2	2	673
ND	No	8.5	4	673	H2	2	673
ND	No	8.5	4	673	H2	2	673
ND	No	ND	4	673	H2	2	673
ND	No	ND	4	673	H2	2	673
ND	No	ND	4	673	H2	2	673
ND	No	7	ND	ND	H2	3	573
ND	No	7	ND	ND	H2	3	573
ND	No	7	ND	ND	H2	3	573
ND	No	7	ND	ND	H2	3	573
ND	No	7	ND	ND	H2	3	573
ND	No	7	ND	ND	H2	3	573
ND	No	7	ND	ND	H2	3	573
ND	No	7	ND	ND	H2	3	573
ND	No	7	ND	ND	H2	3	573
ND	No	7	ND	ND	H2	3	573
ND	No	7	ND	ND	H2	3	573
ND	No	7	ND	ND	H2	3	573
ND	No	7	ND	ND	H2	3	573
ND	No	7	ND	ND	H2	3	573
ND	No	7	ND	ND	H2	3	573
ND	No	7	ND	ND	H2	3	573
ND	No	7	ND	ND	H2	3	573
ND	No	7	ND	ND	H2	3	573
ND	No	7	ND	ND	H2	3	573
ND	No	7	ND	ND	H2	3	573
ND	No	7	ND	ND	H2	3	573
10	Yes	8	1	773	ND	ND	ND
4	Yes	8	1	773	ND	ND	ND
ND	No	8.8	2	773	H2	1	773
ND	No	ND	2	773	H2	1	773
ND	No	ND	2	773	H2	1	773
ND	No	ND	2	773	H2	1	773
ND	No	ND	2	773	H2	1	773
ND	No	6	2	723	H2	2	723
ND	No	6	2	723	H2	2	723
ND	No	6	2	723	H2	2	723
ND	No	6	2	723	H2	2	723
ND	No	6	2	723	H2	2	723
ND	No	8.5	5	723	H2	4	523

ND	No	ND	ND	ND	H2	3	523
ND	No	ND	ND	ND	H2	3	523
ND	No	ND	ND	ND	H2	3	523
ND	No	ND	ND	ND	H2	3	523
ND	No	ND	ND	ND	H2	3	523
ND	No	ND	ND	ND	H2	3	523
11	No	ND	ND	ND	H2	ND	723
11	No	ND	ND	ND	H2	ND	723
ND	No	8.5	ND	ND	H2	ND	723
ND	No	3	ND	ND	H2	ND	723
ND	No	ND	ND	ND	H2	3	573
NA	No	ND	NA	NA	H2	3	573
ND	No	8.5	6	773	H2	1	523
ND	No	8.5	6	773	H2	1	523
ND	No	8.5	6	773	H2	1	523
ND	No	8.5	6	773	H2	1	523
ND	No	8.5	6	773	H2	1	523
ND	No	8.5	3	773	H2	4	673
ND	No	8.5	3	773	H2	4	673
ND	No	9.6	3	773	H2	4	673
ND	No	9.6	3	773	H2	4	673
ND	No	ND	ND	ND	H2	1	298
ND	No	8.5	ND	773	H2	1	423
ND	No	8.5	ND	1073	H2	1	423
ND	No	3	NA	NA	H2	1	423
NA	No	8.5	NA	NA	H2	6	623
ND	No	8.5	ND	ND	H2	4	473
ND	No	8.5	ND	ND	H2	4	473
ND	No	3	3	673	H2	3	973
ND	No	3	3	673	H2	3	973
ND	No	3	3	673	H2	3	973
ND	No	7.1	3	673	H2	3	973
ND	No	7.1	3	673	H2	3	973
ND	No	7.1	3	673	H2	3	973
ND	No	7.1	3	673	H2	3	973
NA	No	ND	NA	NA	H2	0.5	473
NA	No	ND	NA	NA	H2	0.5	473
NA	No	ND	NA	NA	H2	0.5	473
10	Yes	6	3	673	H2	1	573
10	Yes	6	3	673	H2	1	573
10	Yes	6	3	673	H2	1	573
10	Yes	6	3	673	H2	1	573
10	Yes	6.7	3	673	H2	1	573
10	Yes	6.7	3	673	H2	1	573
NA	No	ND	NA	NA	H2	1	573

NA	No	ND	NA	NA	H2	1	573
ND	No	8.5	4	573	H2	3	573
ND	No	8.4	5	773	H2	0.5	573
ND	No	8.4	5	773	H2	0.5	573
10.50	Yes	8.4	5	773	H2	0.5	573
10.50	Yes	8.4	5	773	H2	0.5	573
ND	No	8.5	8	623	H2	6	623
ND	No	8.5	8	623	H2	6	623
ND	No	8.5	8	623	H2	6	623
ND	No	8.5	8	623	H2	6	623
ND	No	8.5	4	1273	ND	ND	ND
ND	No	8.3	2	773	ND	ND	ND
ND	No	8.3	2	773	ND	ND	ND
ND	No	8.3	2	773	ND	ND	ND
ND	No	8.3	2	773	ND	ND	ND
ND	No	8.3	2	773	ND	ND	ND
ND	No	8.3	2	773	ND	ND	ND
ND	No	8.3	2	773	ND	ND	ND
ND	No	8.3	2	773	ND	ND	ND
ND	No	8.3	2	773	ND	ND	ND
ND	No	8.3	2	1073	ND	ND	ND
ND	No	8.3	2	1073	ND	ND	ND

ND	No	8.3	2	1073	ND	ND	ND
ND	No	8.3	2	1073	ND	ND	ND
ND	No	7.5	2	773	ND	ND	ND
ND	No	8.8	2	773	ND	ND	ND
ND	No	3	0.5	673	H2	0.5	573
ND	No	8.9	3	773	H2	1	673
ND	No	8.6	1	973	H2	2	573
9	Yes	6.1	4	873	H2	2	573
ND	No	8.6	1	573	H2	2	573
ND	No	6.1	1	573	H2	2	573
ND	No	8.5	1	673	H2	1	573
ND	No	8.5	1	673	H2	17	873
ND	No	8.5	1	673	H2	1	573
ND	No	8.5	1	673	H2	17	873
ND	No	8.5	1	673	H2	1	573
ND	No	8.5	1	673	H2	17	873
ND	No	8.5	1	673	H2	1	573
ND	No	8.5	1	673	H2	17	873
ND	No	3	2	773	H2	2	298
ND	No	3	2	773	H2	2	298
11	Yes	3	2	673	H2	2	723
ND	No	8.4	2	673	H2	2	723
ND	No	8.4	2	673	H2	2	723
ND	No	6.7	ND	ND	H2	4	673
ND	No	6.7	ND	ND	H2	4	673
ND	No	6.7	ND	ND	H2	4	673
ND	No	6.7	ND	ND	H2	4	673
ND	No	6.7	ND	ND	H2	4	673
ND	No	3	2	773	H2	2	298
ND	No	3	2	773	H2	2	298
ND	No	3	2	773	H2	2	298
9	No	7.5	1	823	H2	1	773
9	No	7.5	1	823	H2	1	773
9	No	6	1	823	H2	1	773
ND	No	8.9	5	773	H2	ND	473
ND	No	8.9	5	773	H2	ND	473
ND	No	8.9	5	773	H2	ND	473
ND	No	6	5	773	H2	ND	473
ND	No	6	5	773	H2	ND	473
ND	No	6	5	773	H2	ND	473

ND	No	8.9	5	773	H2	ND	573
ND	No	8.9	5	773	H2	ND	673
ND	No	8.9	5	773	H2	ND	773
ND	No	6	5	773	H2	ND	673
ND	No	6	5	773	H2	ND	823
ND	No	3	3	573	H2	1	573
ND	No	3	3	573	H2	1	573
ND	No	5.7	2	773	H2	2	298
ND	No	5.7	2	773	H2	2	298
ND	No	6	1	773	H2	1	423
ND	No	6	1	773	H2	1	773
ND	No	6	1	773	H2	1	423
ND	No	6	1	773	H2	1	773
ND	No	ND	1	773	H2	1	423
ND	No	ND	1	773	H2	1	773
ND	No	8.8	1	473	H2	0.5	473
ND	No	8.8	1	473	H2	0.5	473
ND	No	8.8	1	473	H2	0.5	473
ND	No	8.8	1	473	H2	0.5	473
ND	No	6.7	2	773	H2	ND	573
ND	No	8.5	2	773	H2	ND	573
ND	No	6.7	2	773	H2	ND	573
ND	No	8.5	2	773	H2	ND	573
11	No	3	4	573	H2	2	673
11	No	3	4	573	H2	2	673
11	No	3	4	573	H2	2	673
11	No	3	NA	NA	H2	2	573
11	No	3	NA	NA	H2	2	773
ND	No	8.2	4	573	H2	2	673
ND	No	8.5	4	573	H2	2	673
ND	No	6	4	573	H2	2	673
ND	No	10	4	573	H2	2	573
ND	No	8.9	4	573	H2	2	673
ND	No	6	4	573	H2	2	673
ND	No	ND	4	573	H2	2	673
ND	No	6.6	ND	ND	H2	1	573
ND	No	3	ND	ND	H2	1	573
ND	No	3	ND	ND	H2	1	573
ND	No	7	ND	ND	H2	12	523
ND	No	7	ND	ND	H2	12	523
ND	No	7	ND	ND	H2	12	523
ND	No	3	4	673	H2	1	573
10.6	Yes	8.5	1	873	H2	3	673
10.6	Yes	8.5	3	873	H2	3	673

10.6	Yes	8.5	24	873	H2	3	673
10.6	Yes	8.5	3	873	H2	3	673
10.6	Yes	8.5	3	873	H2	3	673
10.6	Yes	8.5	3	873	H2	3	673
1	No	6	2	673	H2	1	673
1	No	8.3	2	673	H2	1	673
1	No	ND	2	673	H2	1	673
1	No	8.3	2	673	H2	1	773
ND	No	3	4	773	H2	2	533
ND	No	10	3	623	H2	3	623
ND	No	10	3	623	H2	3	623
ND	No	8.5	3	623	H2	3	623
ND	No	ND	NA	NA	H2	3	623
ND	No	3	ND	ND	H2	16	773
ND	No	6	ND	ND	H2	3	623
ND	No	6	ND	ND	H2	3	623
ND	No	3	0.5	673	H2	ND	573
ND	No	3	0.5	673	H2	ND	573
ND	No	8.2	1	773	H2	1	573
ND	No	8.2	1	1009	H2	1	1009
ND	No	ND	15	393	H2	1	423
ND	No	ND	15	393	H2	1	423
ND	No	ND	15	393	H2	1	423
ND	No	ND	15	393	H2	1	423
ND	No	ND	15	393	H2	1	423
ND	No	3	6	723	H2	3	673
ND	No	6.1	2	823	H2	1	773
ND	No	8.5	2	823	H2	1	773
ND	No	8.5	2	773	H2	1	573
ND	No	8.5	2	773	H2	1	773
ND	No	4	2	773	H2	1	773
ND	No	ND	2	773	H2	1	573
ND	No	ND	2	773	H2	1	773
ND	No	ND	2	773	H2	1	573
ND	No	ND	1	723	H2	4	798
ND	No	5.9	2	773	H2	2	773
ND	No	6.2	2	773	H2	2	773
ND	No	5.7	2	773	H2	2	773
ND	No	5.5	2	773	H2	2	773
11	Yes	6	ND	ND	ND	ND	ND
11	Yes	6	ND	ND	ND	ND	ND
11	Yes	6	ND	ND	ND	ND	ND
11	Yes	6	ND	ND	ND	ND	ND
11	Yes	6	ND	ND	ND	ND	ND
ND	No	ND	2	623	H2	ND	773
ND	No	ND	2	623	H2	ND	773
ND	No	ND	2	623	H2	ND	773

ND	No	ND	2	623	H2	ND	773
ND	No	ND	2	623	H2	ND	773
ND	No	ND	2	623	H2	ND	773
ND	No	8.5	2	673	H2	1	523
ND	No	8.5	2	773	H2	1	523
ND	No	6.7	2	673	H2	1	523
ND	No	6.7	2	773	H2	1	523
ND	No	8.5	2	773	H2	1	523
10	Yes	ND	ND	ND	H2	2	573
10	Yes	ND	ND	ND	H2	2	573
ND	No	6.2	4	673	H2	2	473
ND	No	6.1	4	673	H2	2	473
ND	No	ND	4	673	H2	2	473
ND	No	3	ND	ND	H2	1	1173
ND	No	3	ND	ND	H2	1	1173
ND	No	3	ND	ND	H2	1	1173
ND	No	8.5	ND	ND	H2	1	1173
NA	No	ND	NA	NA	H2	1	1173
ND	No	ND	10	773	NA	NA	NA
ND	No	ND	10	773	NA	NA	NA
ND	No	ND	10	773	NA	NA	NA
ND	No	ND	10	773	NA	NA	NA
ND	No	ND	10	773	NA	NA	NA
ND	No	ND	10	773	NA	NA	NA
ND	No	ND	10	773	NA	NA	NA
8	Yes	8.9	3	773	H2	ND	773
ND	No	8.5	2	773	H2	2	673
ND	No	8.5	2	773	H2	2	673
ND	No	8.5	2	773	H2	2	673
ND	No	8.5	2	773	H2	2	673
ND	No	8.5	2	773	H2	2	673
ND	No	8.5	2	773	H2	2	673
ND	No	8.5	2	773	H2	2	673
ND	No	8.5	2	773	H2	2	673
ND	No	3	3	723	H2	2	298
ND	No	8	2	573	H2	0.33	493
ND	No	8	2	573	H2	0.33	493
ND	No	8	2	573	H2	0.33	493
ND	No	8	2	573	H2	0.33	493
ND	Yes	8.2	4	473	H2	4	473
ND	Yes	8.2	4	573	H2	4	473
ND	Yes	8.2	4	773	H2	4	473
ND	Yes	8.2	4	573	H2	4	623
ND	Yes	8.2	4	573	H2	4	773
ND	Yes	8.2	4	573	H2	4	473

ND	No	ND	ND	ND	H2	1	673
ND	No	ND	ND	ND	H2	1	673
ND	No	ND	ND	ND	H2	1	673
ND	No	ND	ND	ND	H2	1	673
ND	No	ND	ND	ND	H2	1	673
ND	No	ND	ND	ND	H2	1	673
ND	No	ND	ND	ND	H2	1	673
ND	No	ND	ND	ND	H2	1	673
ND	No	ND	ND	ND	H2	1	673
ND	No	ND	ND	ND	H2	1	673
ND	No	7	5	723	H2	2	673
ND	No	7	5	723	H2	2	673
ND	No	7	5	723	H2	2	673
ND	No	7	5	723	H2	2	673
ND	No	7	ND	ND	H2	2	523
8.5	Yes	7	ND	ND	H2	2	313
ND	No	ND	ND	ND	H2	0.3333333	373
ND	No	ND	ND	ND	H2	0.3333333	373
9.5	Yes	ND	2	298	NaBH4	1	298
9.5	Yes	ND	2	393	NaBH4	1	298
9.5	Yes	ND	2	423	NaBH4	1	298
9.5	Yes	ND	2	448	NaBH4	1	298
9.5	Yes	ND	2	473	NaBH4	1	298
ND	No	8.2	2	823	H2	2	423
ND	No	8.5	2	823	H2	2	423
ND	No	8.5	2	823	H2	2	423
ND	No	8.5	2	823	H2	2	423
ND	No	8.5	2	823	H2	2	423
ND	No	8.5	3	773	H2	1	573
ND	No	8.5	3	773	H2	1	573
ND	No	8.5	3	773	H2	1	573
ND	No	8.5	3	773	H2	1	573
ND	No	8.5	3	773	H2	1	573
ND	No	8.5	3	773	H2	1	573
ND	No	4	NA	NA	H2	ND	473
ND	No	4	NA	NA	H2	ND	473
ND	No	4	NA	NA	H2	ND	473
8	Yes	ND	ND	ND	H2	1	423
8	Yes	ND	ND	ND	H2	1	423
8	Yes	ND	ND	ND	H2	1	423
8	Yes	ND	ND	ND	H2	1	423
8	Yes	ND	ND	ND	H2	1	423

8	Yes	ND	ND	ND	H2	1	423
8	Yes	ND	ND	ND	H2	1	423
8	Yes	ND	ND	ND	H2	1	423
8	Yes	ND	ND	ND	H2	1	423
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
13.20	Yes	ND	ND	ND	C2H6O2	ND	298
12.50	Yes	ND	ND	ND	C2H6O2	ND	298
12.10	Yes	ND	ND	ND	C2H6O2	ND	298
11.90	Yes	ND	ND	ND	C2H6O2	ND	298
11.00	Yes	ND	ND	ND	ND	ND	ND
11.00	Yes	ND	ND	ND	ND	ND	ND
11.00	Yes	ND	ND	ND	ND	ND	ND
11.00	Yes	ND	ND	ND	ND	ND	ND
11.00	Yes	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	H2	ND	403
1	Yes	ND	ND	ND	ND	ND	ND
1	Yes	ND	ND	ND	ND	ND	ND
NA	No	ND	NA	NA	H2	ND	443
ND	Yes	7.5	3	623	H2	ND	443
ND	Yes	10	3	623	H2	ND	443
ND	Yes	5.5	3	623	H2	ND	443
ND	Yes	3	3	623	H2	ND	443
ND	Yes	7.5	3	623	H2	ND	443
ND	Yes	8.5	3	623	H2	ND	443
ND	Yes	3	3	623	H2	ND	443
ND	Yes	5.5	3	623	H2	ND	443
ND	Yes	9.8	3	623	H2	ND	443
ND	Yes	6	3	623	H2	ND	443
ND	Yes	ND	3	623	H2	ND	443
ND	Yes	9.1	3	623	H2	ND	443
ND	Yes	6.5	3	623	H2	ND	443
ND	Yes	4.5	3	623	H2	ND	443
ND	Yes	9.2	3	623	H2	ND	443
ND	No	ND	ND	ND	H2	ND	393
ND	No	ND	ND	ND	H2	ND	673
ND	No	ND	ND	ND	H2	ND	823
ND	No	ND	ND	ND	H2	ND	393

ND	No	ND	ND	ND	H2	ND	673
ND	No	ND	ND	ND	H2	ND	823
ND	No	ND	ND	ND	H2	ND	393
ND	No	ND	ND	ND	H2	ND	673
ND	No	ND	ND	ND	H2	ND	823
ND	No	ND	NA	NA	NA	NA	NA
ND	No	ND	16	673	NA	NA	NA
ND	No	ND	16	773	NA	NA	NA
ND	No	ND	16	873	NA	NA	NA
ND	No	ND	16	673	H2	ND	298
ND	No	ND	16	773	H2	ND	298
ND	No	ND	16	873	H2	ND	298
ND	No	ND	16	773	H2	ND	523
ND	No	ND	16	873	H2	ND	523
ND	No	ND	4	673	H2	ND	923
ND	No	ND	4	673	H2	ND	923
10	Yes	6	2	623	H2	1	473
10	Yes	6	2	623	H2	1	473
ND	No	6.7	2	773	H2	1	773
ND	No	7.5	ND	ND	H2	0.5	313
ND	No	7.5	ND	ND	H2	0.5	313
5.5	No	ND	ND	ND	H2	0.5	373
NA	No	ND	ND	ND	H2	0.5	373
11	Yes	6	4	473	H2	2	673
NA	No	8.5	NA	NA	H2	2	673
NA	No	8.5	NA	NA	H2	2	673
ND	No	ND	ND	ND	NaBH4	2	298
9	No	8.2	2	773	H2	ND	573
9	No	8.5	2	773	H2	ND	573
ND	No	8.2	2	773	H2	ND	573

ND	No	8.5	2	773	H2	ND	573
ND	No	ND	3	873	ND	ND	ND
ND	No	ND	25	1173	ND	ND	ND
ND	No	ND	ND	ND	H2	2	573
ND	No	ND	ND	ND	H2	2	573
ND	No	ND	ND	ND	H2	2	573
NA	No	ND	NA	NA	ND	ND	ND
ND	No	3	3	673	H2	2	573
ND	No	6	2	623	H2	0.25	473
ND	No	ND	ND	ND	NaBH4	2	298
ND	No	3	4	673	H2	2	673
ND	No	ND	3	723	H2	1	473
ND	No	3	3	723	H2	1	473
ND	No	5	3	723	H2	1	473
ND	No	6	5	773	H2	2	473
ND	No	6	5	773	H2	2	473
ND	No	ND	ND	ND	CH2O	0.5	353
NA	No	ND	NA	NA	ND	ND	ND
ND	No	ND	ND	ND	CH2O	0.5	353
ND	No	ND	ND	ND	CH2O	0.5	353
ND	No	ND	ND	ND	CH2O	0.5	353
ND	No	3	ND	ND	CH2O	0.5	353
ND	No	3	2.5	723	H2	3.5	723
ND	No	ND	NA	NA	ND	ND	ND
ND	No	3	NA	NA	H2	ND	523
ND	No	3	5	523	H2	ND	523
ND	No	8.5	NA	NA	H2	ND	523
ND	No	8.5	5	523	H2	ND	523
ND	No	ND	ND	ND	H2	2	523
ND	No	ND	ND	ND	H2	2	523
ND	No	ND	ND	ND	H2	2	523
ND	No	ND	ND	ND	H2	2	523
ND	No	ND	ND	ND	H2	2	523
ND	No	ND	ND	ND	H2	2	523
ND	No	ND	ND	ND	H2	2	523
ND	No	ND	ND	ND	H2	2	523
ND	No	ND	ND	ND	H2	2	400
ND	No	ND	ND	ND	H2	2	673
ND	No	ND	ND	ND	CH2O	3	298
ND	No	ND	ND	ND	H2	ND	573
ND	No	ND	ND	ND	w Discharge	ND	298
11	Yes	ND	ND	ND	C2H6O2	ND	298
11	Yes	ND	ND	ND	C2H6O2	ND	298
11	Yes	ND	ND	ND	C2H6O2	ND	298
11	Yes	ND	ND	ND	C2H6O2	ND	298
11	Yes	ND	ND	ND	C2H6O2	ND	298
11	Yes	ND	ND	ND	C2H6O2	3	298
10	Yes	ND	ND	ND	C2H6O2	3	298
9	Yes	ND	ND	ND	C2H6O2	3	298

8	Yes	ND	ND	ND	C2H6O2	3	298
3.5	Yes	ND	ND	ND	NaBH4	3	353
8.50	Yes	ND	ND	ND	C2H6O2	3	343
ND	No	ND	ND	ND	H2	3	673
ND	No	ND	ND	ND	H2	3	673
ND	No	ND	ND	ND	H2	3	673
9	Yes	3	NA	NA	H2	2	573
9	Yes	3	NA	NA	H2	2	573
9	Yes	3	NA	NA	H2	2	573
9	Yes	3	NA	NA	H2	2	573
ND	No	3	2	573	H2	2	573
ND	No	7.5	10	873	H2	1	773
ND	No	7.5	10	873	H2	1	773
ND	No	7.5	10	873	H2	1	773
ND	No	8.5	1	523	H2	2	1073
ND	No	8.5	1	523	H2	2	1073
ND	No	3	1	523	H2	2	1073
ND	No	ND	1	523	H2	2	673
ND	No	ND	1	523	H2	2	523
ND	No	ND	1	523	H2	2	703
ND	No	ND	1	523	H2	2	523
ND	No	ND	1	523	H2	2	523
8	No	ND	ND	ND	H2	0.5	373
8	No	ND	ND	ND	H2	ND	423
8	No	ND	ND	ND	H2	ND	473
8	No	ND	ND	ND	H2	ND	573
3.5	Yes	7.5	4	723	ND	ND	ND
3.5	Yes	ND	4	723	ND	ND	ND
3.5	Yes	ND	4	723	ND	ND	ND
3.5	Yes	ND	4	723	ND	ND	ND
NA	No	8.5	NA	NA	ND	ND	ND
NA	No	8.5	NA	NA	ND	ND	ND
ND	No	8.5	ND	ND	ND	ND	ND
ND	No	8.5	ND	ND	ND	ND	ND
ND	No	8.5	ND	ND	ND	ND	ND
ND	No	8.5	ND	ND	ND	ND	ND
ND	No	8.5	ND	ND	ND	ND	ND
ND	No	8.5	ND	ND	ND	ND	ND
ND	No	8.5	ND	ND	ND	ND	ND
ND	No	3	3	773	H2	1	298
ND	No	ND	4	673	H2	4	573
ND	No	ND	4	673	H2	4	573
ND	No	6	2	773	H2	ND	673
ND	No	6	NA	NA	H2	ND	673
NA	No	ND	NA	NA	ND	ND	ND
9.5	Yes	ND	ND	ND	NaBH4	1	343
10	Yes	ND	ND	ND	NaBH4	1	298
10	Yes	ND	ND	ND	NaBH4	1	298
NA	No	ND	NA	NA	NA	NA	NA

NA	No	ND	NA	NA	H2	2	323
NA	No	ND	NA	NA	NA	NA	NA
NA	No	ND	NA	NA	H2	12	373
ND	No	ND	5	523	H2	6	393
ND	No	ND	5	523	H2	6	393
ND	No	ND	5	523	H2	6	393
ND	No	ND	5	523	H2	6	393
ND	No	ND	5	523	H2	6	393
ND	No	11.5	2	573	H2	2	623
12	Yes	ND	ND	ND	CH2O	ND	298
12	Yes	ND	ND	ND	CH2O	ND	298
12	Yes	ND	ND	ND	CH2O	ND	298
12	Yes	ND	ND	ND	CH2O	ND	298
ND	No	8.5	5	723	H2	1	573
ND	No	6.1	5	723	H2	1	573
ND	No	6	5	723	H2	1	573
7.5	Yes	ND	ND	ND	NaBH4	ND	298
9	Yes	ND	ND	ND	ND	ND	ND
9	Yes	ND	ND	ND	ND	ND	ND
ND	No	6	2	773	H2	1	623
ND	No	10	2	773	H2	1	623
ND	No	ND	2	773	H2	1	623
ND	No	8	2	773	H2	1	623
ND	No	8.5	2	773	H2	1	623
ND	No	ND	2	773	H2	1	623
ND	No	7	ND	ND	H2	3	523
ND	No	8.5	2	673	H2	1	573
ND	No	8.5	2	673	H2	1	573
NA	No	ND	NA	NA	H2	ND	303
ND	No	ND	ND	473	H2	ND	423
ND	No	ND	ND	473	H2	ND	423
ND	No	8.6	ND	773	H2	3	623
ND	No	8.6	ND	773	H2	3	623
ND	No	8.6	ND	773	H2	3	623
ND	No	8.6	ND	773	H2	3	623
ND	No	ND	2	573	H2	1	573
ND	No	ND	2	773	H2	1	573
ND	No	ND	2	973	H2	1	573
ND	No	ND	2	1273	H2	1	573
10.5	Yes	ND	ND	ND	N2H4	ND	353
10.5	Yes	ND	ND	ND	N2H4	ND	353

10.5	Yes	ND	ND	ND	N2H4	ND	353
10.5	Yes	ND	ND	ND	N2H4	ND	353
10.5	Yes	ND	ND	ND	N2H4	ND	353
10.5	Yes	ND	ND	ND	N2H4	ND	353
ND	No	ND	2	673	H2	3	623
ND	No	ND	ND	ND	NaBH4	2	298
ND	No	ND	ND	ND	H2	2	453
ND	No	ND	ND	ND	H2	2	573
ND	No	ND	ND	ND	H2	2	673
ND	No	ND	ND	ND	H2	2	773
ND	No	ND	ND	ND	H2	2	473
ND	No	ND	ND	ND	H2	2	573
ND	No	ND	ND	ND	H2	2	673
ND	No	ND	ND	ND	H2	3	673
ND	No	8.5	2	773	H2	0.5	473
ND	No	ND	2	773	H2	0.5	473
ND	No	ND	2	773	H2	0.5	473
ND	No	ND	2	773	H2	0.5	473
ND	No	3	2	573	H2	1	573
ND	No	3	2	573	H2	1	773
ND	No	6	ND	ND	H2	1	673
3	Yes	6	ND	ND	H2	1	673
10	Yes	6	ND	ND	H2	1	673
ND	No	3.8	ND	ND	H2	1	673
3	Yes	3.8	ND	ND	H2	1	673
10	Yes	3.8	ND	ND	H2	1	673
9.5	Yes	ND	ND	ND	ND	ND	ND
ND	No	9.5	2	823	H2	1	673
NA	No	ND	NA	NA	ND	ND	ND
NA	No	ND	NA	NA	ND	ND	ND
ND	No	3	3	1073	H2	0.5	873
ND	No	3	3	1073	H2	0.5	873
ND	No	3	3	1073	H2	0.5	873
ND	No	3	3	1073	H2	0.5	873
ND	No	3	3	1073	H2	0.5	873
ND	No	3	3	1073	H2	0.5	873
ND	No	3	3	1073	H2	0.5	873
7	Yes	8.5	2	723	ND	ND	ND

ND	No	3	4	773	H2	2	573
ND	No	3	4	773	H2	2	573
ND	No	8.5	4	773	H2	2	573
ND	No	6	4	773	H2	2	573
ND	No	6.1	1	1073	H2	3	773
ND	No	9.1	2	623	H2	ND	423
ND	No	9.1	2	623	H2	ND	773
ND	No	9.1	2	623	H2	ND	423
ND	No	9.1	2	623	H2	ND	773
ND	No	3	12	673	H2	2	573
NA	No	ND	NA	NA	ND	ND	ND
ND	No	3	5	773	ND	ND	ND
ND	No	7.1	5	773	ND	ND	ND
ND	No	5.2	ND	ND	ND	ND	ND
ND	No	6	ND	ND	ND	ND	ND
ND	No	6	ND	ND	ND	ND	ND
ND	No	6	ND	ND	ND	ND	ND
ND	No	6	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	573	H2	2	673
ND	No	8.5	ND	ND	H2	0.5	423
ND	No	8.5	ND	ND	H2	0.5	423
ND	No	8.5	ND	ND	H2	0.5	423
ND	No	8.5	ND	ND	H2	0.5	423
ND	No	8.5	ND	ND	H2	0.5	423
ND	No	9	ND	ND	ND	ND	ND
ND	No	9.5	ND	ND	ND	ND	ND
NA	No	8.5	NA	NA	ND	ND	ND
ND	No	ND	ND	ND	C2H6O2	ND	298
ND	No	12	ND	ND	H2	2	423
10	Yes	ND	ND	ND	H2	3	298
10	Yes	ND	ND	ND	H2	3	298
10	Yes	ND	ND	ND	H2	3	298
10	Yes	ND	ND	ND	H2	3	298
1	Yes	8.5	4	673	H2	1	673
1	Yes	8.5	4	673	H2	1	373
1	Yes	8.5	4	673	H2	1	423
ND	No	ND	ND	773	H2	ND	573
ND	No	ND	ND	773	H2	ND	573
ND	No	ND	ND	773	H2	ND	573

ND	No	6	3	773	ND	ND	ND
ND	No	6.1	3	773	ND	ND	ND
ND	No	ND	3	773	ND	ND	ND
ND	No	4.4	3	773	ND	ND	ND
ND	No	4.3	3	773	ND	ND	ND
ND	No	8.5	3	773	ND	ND	ND
ND	No	1.5	3	773	ND	ND	ND
ND	No	ND	3	773	ND	ND	ND
ND	No	ND	ND	ND	NaBH4	ND	298
ND	No	ND	ND	ND	NaBH4	ND	298
ND	No	ND	ND	ND	NaBH4	ND	298
ND	No	ND	ND	ND	NaBH4	ND	298
ND	No	ND	ND	ND	NaBH4	ND	298
9	Yes	ND	ND	ND	N2H4	12	298
ND	No	3	ND	773	ND	ND	ND
ND	No	8.5	2	773	ND	3	573
ND	No	8.5	2	773	ND	3	573
ND	No	3	3	673	ND	ND	ND
11	Yes	ND	ND	ND	C6H14O	7	383
ND	No	3	ND	ND	C6H14O	6	428
ND	No	3	ND	ND	H2	0.5	573
ND	No	8.5	ND	ND	C6H14O	6	428
ND	No	8.5	ND	ND	H2	0.5	573
ND	No	ND	ND	ND	C6H14O	6	428
ND	No	ND	ND	ND	C6H14O	6	428
ND	No	ND	ND	ND	C6H14O	6	428
ND	No	ND	ND	ND	H2	0.5	573
ND	No	ND	ND	ND	H2	0.5	573
ND	No	ND	ND	ND	H2	0.5	573
ND	No	ND	ND	ND	H2	0.5	573
ND	No	ND	ND	ND	H2	0.5	573
ND	No	ND	ND	ND	H2	0.5	573
NA	No	ND	NA	NA	ND	ND	ND
NA	No	ND	NA	NA	ND	ND	ND
ND	No	8.8	2	573	H2	4	588
ND	No	2.7	2	573	H2	4	588
ND	No	7.5	2	573	H2	4	588
ND	No	ND	ND	ND	H2	2	573
ND	No	ND	ND	ND	H2	2	573
ND	No	ND	ND	ND	H2	2	573
ND	No	ND	3	673	H2	3	673
ND	No	ND	3	673	H2	3	673
ND	No	ND	3	673	H2	3	673
ND	No	ND	3	673	H2	3	673
ND	No	ND	3	673	H2	3	673
NA	No	ND	ND	ND	ND	ND	ND
NA	No	7.5	ND	ND	ND	ND	ND

ND	No	ND	ND	ND	KBH4	ND	298
ND	No	ND	ND	ND	H2	1	573
ND	No	ND	ND	ND	H2	1	573
ND	No	ND	ND	ND	H2	1	573
NA	No	ND	ND	ND	ND	ND	ND
ND	No	8.5	3	823	H2	0.5	623
ND	No	ND	ND	ND	H2	ND	393
ND	No	ND	ND	ND	H2	ND	393
ND	No	ND	ND	ND	H2	ND	393
ND	No	8.6	ND	ND	H2	0.5	323
ND	No	4.7	ND	ND	H2	0.5	323
ND	No	5.6	ND	ND	H2	0.5	323
ND	No	4.3	ND	ND	H2	0.5	323
ND	No	8.5	ND	ND	CH2O	0.5	333
ND	No	6.5	ND	ND	CH2O	0.5	333
ND	No	8.8	ND	ND	CH2O	0.5	333
9	No	7.8	ND	ND	CH2O	0.5	333
ND	No	8.6	ND	ND	CH2O	0.5	333
ND	No	8.5	ND	ND	CH2O	0.5	333
ND	No	6.3	ND	ND	CH2O	0.5	333
ND	No	6.2	ND	ND	CH2O	0.5	333
ND	No	6.8	ND	ND	CH2O	0.5	333
ND	No	7.5	ND	ND	CH2O	0.5	333
ND	No	7.4	ND	ND	CH2O	0.5	333
ND	No	6.1	ND	ND	CH2O	0.5	333
ND	No	3	1	573	H2	1	573
ND	No	8.5	1	573	H2	1	573
ND	No	5.5	1	573	H2	1	573
ND	No	6.1	1	573	H2	1	573
ND	No	6	1	573	H2	1	573
9	No	7.8	ND	ND	CH2O	0.5	333
9	No	7.8	ND	ND	CH2O	0.5	333
13	No	7.8	ND	ND	CH2O	0.5	333
13	No	7.8	ND	ND	CH2O	0.5	333
9	No	7.8	ND	ND	CH2O	0.5	333
13	No	7.8	ND	ND	CH2O	0.5	333
7	No	7.8	ND	ND	CH2O	0.5	333
2	No	7.8	ND	ND	CH2O	0.5	333

ND	No	ND	ND	ND	NA	NA	NA
ND	No	ND	NA	NA	CH3OH	0.1666667	298
ND	No	10	NA	NA	CH3OH	0.1666667	298
ND	No	8.5	NA	NA	CH3OH	0.1666667	298
ND	No	ND	ND	723	H2	ND	773
ND	No	ND	NA	NA	H2	ND	523
ND	No	ND	ND	723	H2	ND	773
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
10.5	Yes	6.4	4	573	H2	2	573
10.5	Yes	6.3	4	573	H2	2	573
10.5	Yes	6.1	4	573	H2	2	573
10.5	Yes	6.5	4	573	H2	2	573
10.5	Yes	6.2	4	573	H2	2	573
10.5	Yes	6.2	4	573	H2	2	573
10.5	Yes	6.2	4	573	H2	2	573
10.5	Yes	6.2	4	573	H2	2	573
ND	No	ND	ND	ND	H2	2	523
NA	No	ND	NA	NA	ND	ND	ND
NA	No	8.5	NA	NA	H2	1	573
NA	No	ND	NA	NA	H2	1	573
ND	No	8.5	2	773	ND	ND	ND
ND	No	3	2	773	ND	ND	ND
ND	No	6	2	773	ND	ND	ND
ND	No	6	0.5	673	H2	0.5	573
ND	No	6	0.5	673	H2	0.5	573
ND	No	6	0.5	673	H2	0.5	573
ND	No	6	0.5	673	H2	0.5	573
ND	No	7.7	ND	823	H2	2	523
ND	No	6.1	ND	823	H2	2	523
NA	No	8.5	ND	ND	H2	2	523
ND	No	8.5	1	773	H2	2	523
ND	No	8.5	1	773	H2	2	523
ND	No	ND	1	773	H2	2	523
ND	No	ND	1	773	H2	2	523
ND	No	6	1	773	H2	2	523
ND	No	8.5	2	673	H2	2.5	523
ND	No	8.5	2	673	H2	2.5	523
ND	No	8.5	2	673	H2	2.5	523
ND	No	6	4	673	ND	ND	ND
ND	No	6	4	673	ND	ND	ND
ND	No	7.5	4	673	ND	ND	ND
ND	No	7.5	4	673	ND	ND	ND

ND	No	7.5	4	673	ND	ND	ND
ND	No	7.5	4	673	ND	ND	ND
ND	No	7.5	4	673	ND	ND	ND
ND	No	ND	2	773	H2	ND	ND
ND	No	ND	2	773	H2	ND	ND
ND	No	ND	2	773	H2	ND	ND
ND	No	ND	ND	ND	H2	1	573
ND	No	ND	ND	ND	H2	4	673
ND	No	10	ND	ND	H2	4	673
ND	No	8.5	ND	ND	H2	4	673
ND	No	8.5	2	773	H2	0.5	773
ND	No	8.5	2	773	H2	0.5	773
ND	No	6	3	573	ND	ND	ND
ND	No	6	3	573	ND	ND	ND
ND	No	6	3	573	ND	ND	ND
ND	No	8.5	4	673	ND	ND	ND
ND	No	8.5	4	673	ND	ND	ND
ND	No	8.2	4	673	ND	ND	ND
1.4	No	3	ND	ND	H2	4	623
1.4	No	8.5	ND	ND	H2	4	623
ND	No	8.5	4	773	H2	2	723
ND	No	8.5	4	773	H2	2	723
ND	No	3	2	773	H2	ND	573
ND	No	3	2	573	H2	ND	573
ND	No	3	2	673	H2	ND	573
ND	No	3	2	773	H2	ND	573
ND	No	3	2	1073	H2	ND	573
ND	No	8.5	5	573	H2	1	393
ND	No	8.5	5	573	H2	1	393
ND	No	8.5	5	573	H2	1	393
ND	No	8.5	5	573	H2	1	393
ND	No	6	2	573	H2	2	523
ND	No	6	2	573	H2	2	723
ND	No	6	2	573	H2	2	873
ND	No	8.5	4	623	H2	2	623
ND	No	ND	ND	ND	H2	8	313
ND	No	ND	ND	ND	H2	8	313
ND	No	ND	ND	ND	H2	8	313
ND	No	ND	ND	ND	H2	8	313
ND	No	ND	3	573	H2	1.5	423
ND	No	ND	3	573	H2	1.5	423
ND	No	8.9	ND	773	NA	NA	NA
ND	No	8.9	ND	773	H2	3	673
ND	No	8.9	ND	ND	NA	NA	NA
ND	No	8.9	ND	ND	H2	3	423
ND	No	8.9	ND	ND	H2	3	523
ND	No	8.9	ND	ND	H2	3	673
ND	No	8.9	ND	ND	H2	3	823
ND	No	8.9	ND	ND	H2	3	973
ND	No	8.9	ND	ND	NA	NA	NA
ND	No	8.9	ND	ND	H2	3	423
ND	No	8.9	ND	ND	H2	3	523

ND	No	8.9	ND	ND	H2	3	673
ND	No	8.9	ND	ND	H2	3	823
ND	No	8.9	ND	ND	H2	3	973
10.6	Yes	3	3	773	H2	2	573
10.6	Yes	ND	3	773	H2	2	573
10.6	Yes	ND	3	773	H2	2	573
10.6	Yes	ND	3	773	H2	2	573
10.6	Yes	ND	3	773	H2	2	573
10.6	Yes	8.6	3	773	H2	2	573
ND	No	ND	1	723	ND	ND	ND
ND	No	ND	1	723	ND	ND	ND
ND	No	ND	1	773	ND	ND	ND
ND	No	8.9	3	673	ND	ND	ND
ND	No	8.9	3	673	ND	ND	ND
ND	No	8.5	3	773	H2	0.25	473
ND	No	8.5	3	773	H2	0.25	473
ND	No	8.5	10	1073	H2	0.25	473
ND	No	8.5	10	1123	H2	0.25	473
ND	No	8.5	10	1173	H2	0.25	473
ND	No	9.3	3	773	H2	0.25	473
ND	No	9.3	3	773	H2	0.25	473
ND	No	9.3	3	773	H2	0.25	473
ND	No	9.3	10	1073	H2	0.25	473
ND	No	9.3	10	1123	H2	0.25	473
ND	No	9.3	10	1173	H2	0.25	473
ND	No	9.3	3	773	H2	0.25	473
ND	No	9.3	3	773	H2	0.25	473
ND	No	9.3	3	773	H2	0.25	473
ND	No	9.3	3	773	H2	0.25	473
ND	No	9.3	10	1073	H2	0.25	473
ND	No	8.5	5	773	ND	ND	ND
ND	No	ND	5	773	ND	ND	ND
ND	No	6.7	ND	ND	H2	2	523
ND	No	6	ND	ND	H2	2	523
5	Yes	ND	ND	ND	H2	1	573
5	Yes	ND	ND	ND	HCOONa	0.5	363
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
9.00	Yes	3	ND	ND	H2	2	573
9.00	Yes	3	ND	ND	H2	2	573

ND	No	3	ND	ND	H2	2	573
ND	No	6.7	4	673	H2	2	473
ND	No	6	4	673	H2	2	473
NA	No	8.5	4	673	H2	2	473
ND	No	ND	ND	ND	H2	ND	523
ND	No	ND	ND	ND	H2	ND	523
ND	No	ND	ND	ND	H2	ND	523
ND	No	ND	ND	ND	H2	ND	523
ND	No	ND	ND	ND	H2	ND	523
ND	No	ND	ND	ND	H2	ND	523
ND	No	ND	ND	ND	H2	ND	523
ND	No	ND	ND	ND	H2	ND	523
ND	No	ND	2	773	ND	ND	ND
3	Yes	ND	2	773	ND	ND	ND
10.3	Yes	ND	2	773	H2	1	363
10.3	Yes	ND	NA	NA	H2	1	363
10.3	Yes	ND	NA	NA	H2	1	363
10.3	Yes	ND	NA	NA	H2	1	363
10.3	Yes	ND	NA	NA	H2	1	363
NA	No	ND	4	373	ND	ND	ND
NA	No	ND	4	473	ND	ND	ND
NA	No	ND	4	673	ND	ND	ND
NA	No	ND	4	673	ND	ND	ND
0.1	Yes	6	12	773	H2	1	573
0.1	Yes	6	12	773	H2	1	573
0.1	Yes	5.9	12	773	H2	1	573
0.1	Yes	5.9	12	773	H2	1	723
ND	No	6	3	673	ND	ND	ND
ND	No	6	3	673	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
4.3	Yes	ND	NA	NA	H2	ND	393
5.2	Yes	ND	NA	NA	H2	ND	393
4.6	Yes	ND	NA	NA	H2	ND	393
5.2	Yes	ND	NA	NA	H2	ND	393
4.1	Yes	ND	NA	NA	H2	ND	393
5.5	Yes	ND	NA	NA	H2	ND	393
4.4	Yes	ND	NA	NA	H2	ND	393
5.1	Yes	ND	NA	NA	H2	ND	393
4.5	Yes	ND	NA	NA	H2	ND	393

5.4	Yes	ND	NA	NA	H2	ND	393
4.7	Yes	ND	NA	NA	H2	ND	393
5.5	Yes	ND	NA	NA	H2	ND	393
4.8	Yes	ND	NA	NA	H2	ND	393
5.5	Yes	ND	NA	NA	H2	ND	393
4.8	Yes	ND	NA	NA	H2	ND	393
5.3	Yes	ND	NA	NA	H2	ND	393
ND	No	ND	ND	ND	H2	2	573
ND	No	ND	ND	ND	H2	2	573
ND	No	ND	ND	ND	H2	2	573
ND	No	ND	ND	ND	H2	2	573
ND	No	10.5	3	1173	H2	ND	353
ND	No	ND	ND	ND	ND	4	673
ND	No	ND	ND	ND	ND	4	673
ND	No	ND	ND	ND	ND	4	673
ND	No	ND	ND	ND	ND	4	673
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	7.7	ND	ND	H2	2	573
ND	No	6.1	ND	ND	H2	2	573
ND	No	7.7	ND	ND	H2	2	573
ND	No	8.7	3	823	H2	2	573
ND	Yes	7.5	ND	673	H2	ND	423
ND	No	11	ND	ND	NaBH4	1	298
ND	No	11	ND	ND	CH2O	1	353
ND	No	11	ND	ND	H2	1	363
ND	No	11	ND	ND	H2	1	363
ND	No	11	ND	ND	H2	1	363
ND	No	11	ND	ND	H2	1	363
ND	No	11	ND	ND	H2	1	363
ND	No	11	ND	ND	H2	1	363
ND	No	11	ND	ND	H2	1	363
ND	No	11	ND	ND	H2	1	363
ND	No	11	ND	ND	H2	1	363
ND	No	11	ND	ND	H2	1	363
ND	No	11	ND	ND	H2	1	363
ND	No	11	ND	ND	H2	1	363
ND	No	8.5	2	773	H2	2	773
ND	No	8.5	2	923	H2	2	773
ND	No	8.5	2	1073	H2	2	773
ND	No	8.5	2	1173	H2	2	773
ND	No	8.5	2	773	H2	2	773
ND	No	ND	ND	ND	H2	1	473
ND	No	ND	ND	ND	H2	1	473
ND	No	ND	ND	ND	H2	1	473
ND	No	ND	ND	ND	H2	1	473
ND	No	ND	ND	ND	H2	1	473
ND	No	ND	ND	ND	H2	1	473
ND	No	8.5	4	823	ND	ND	ND

ND	No	8.5	4	823	ND	ND	ND
9	Yes	8.5	4	823	ND	ND	ND
8.9	Yes	6	4	873	ND	ND	ND
8.9	Yes	6	4	1173	ND	ND	ND
8.9	Yes	6	4	1223	ND	ND	ND
8.9	Yes	6	4	1273	ND	ND	ND
8.9	Yes	6	4	1373	ND	ND	ND
8.9	Yes	6	4	1473	ND	ND	ND
ND	No	6	4	873	ND	ND	ND
ND	No	6	4	1173	ND	ND	ND
ND	No	6	4	1223	ND	ND	ND
ND	No	6	4	1273	ND	ND	ND
ND	No	8.5	ND	ND	H2	2	423
ND	No	8.5	ND	ND	H2	2	573
ND	No	8.5	ND	ND	H2	2	673
ND	No	8.5	ND	ND	H2	2	773
ND	No	8.5	ND	ND	H2	2	873
ND	No	8.5	ND	ND	H2	2	423
ND	No	8.5	ND	ND	H2	2	573
ND	No	8.5	ND	ND	H2	2	673
ND	No	8.5	ND	ND	H2	2	773
ND	No	8.5	ND	ND	H2	2	873
11	Yes	3	ND	ND	H2	2	523
11	Yes	8.5	ND	ND	H2	2	523
ND	No	ND	ND	ND	H2	1	323
ND	No	ND	ND	ND	H2	1	323
ND	No	ND	ND	ND	H2	1	323
ND	No	ND	ND	ND	H2	1	323
ND	No	ND	ND	ND	H2	1	323
ND	No	ND	ND	ND	H2	1	323
ND	No	ND	ND	ND	H2	1	323
ND	No	ND	ND	ND	H2	1	323
ND	No	ND	ND	ND	H2	1	323
ND	No	7.5	2	823	H2	0.5	573
ND	No	7.5	2	823	H2	0.5	573

7	Yes	8.5	ND	ND	NaBH4	2	273
7	Yes	3	ND	ND	NaBH4	2	273
7	Yes	6	ND	ND	NaBH4	2	273
7	Yes	6.1	ND	ND	NaBH4	2	273
7	Yes	6	ND	ND	NaBH4	2	273
ND	No	6	2	823	H2	1	573
ND	No	ND	2	823	H2	1	573
ND	No	ND	3	773	H2	1	673
ND	No	ND	3	773	H2	1	673
10.5	Yes	6.81	4	573	H2	2	573
10.5	Yes	6.81	4	573	H2	2	573
10.5	Yes	6.81	4	573	H2	2	573
10.5	Yes	6.81	4	573	H2	2	573
10.5	Yes	8.45	4	573	H2	2	573
10.5	Yes	2.54	4	573	H2	2	573
10.5	Yes	2.06	4	573	H2	2	573
ND	No	6	5	773	H2	0.5	473
ND	No	ND	5	773	H2	0.5	473
ND	No	ND	5	773	H2	0.5	473
ND	No	3	ND	ND	H2	2	753
ND	No	3	ND	ND	H2	2	753
1	Yes	8.5	3	723	H2	ND	673
1	Yes	8.5	3	723	H2	ND	673
1.4	Yes	8.5	3	723	H2	ND	673
1.4	Yes	8.5	3	723	H2	ND	673
1.4	Yes	8.5	3	723	H2	ND	673
1.4	Yes	8.5	3	723	H2	ND	673
2.2	Yes	8.5	3	723	H2	ND	673
2.2	Yes	8.5	3	723	H2	ND	673
2.2	Yes	8.5	3	723	H2	ND	673
2.2	Yes	8.5	3	723	H2	ND	673
ND	No	6	2	673	H2	1	623
ND	No	6	NA	NA	NA	NA	NA
ND	No	6	2	673	H2	1	623
ND	No	6	NA	NA	NA	NA	NA
ND	No	6	2	673	H2	1	623
ND	No	6	2	673	H2	1	623

ND	No	7.5	4	723	ND	ND	ND
ND	No	6	4	673	H2	1	473
ND	No	6	4	673	H2	1	473
ND	No	6	4	673	H2	1	473
ND	No	4	2	573	H2	2	573
ND	No	8.5	2	773	H2	1	773
ND	No	8.5	2	773	H2	1	773
ND	No	8.5	2	773	H2	1	773
ND	No	8.5	2	773	H2	1	773
ND	No	8.5	2	773	H2	1	773
ND	No	8.5	7	973	H2	1	773
ND	No	8.5	3.5	1123	H2	1	773
ND	No	8.5	4	1173	H2	1	773
ND	No	8.5	6	1173	H2	1	773
ND	No	9.5	2	773	H2	2	773
ND	No	ND	2	673	H2	0.5	673
ND	No	ND	2	673	H2	0.5	673
ND	No	ND	2	673	H2	0.5	673
ND	No	ND	2	673	H2	0.5	673
ND	No	ND	2	673	H2	0.5	673
ND	No	ND	3	773	H2	1	673
ND	No	ND	3	773	H2	1	673
ND	No	ND	3	773	H2	1	673
ND	Yes	8.2	ND	773	H2	4	473
ND	Yes	8.2	ND	773	H2	4	473
ND	Yes	8.2	ND	773	H2	4	473
ND	Yes	8.2	ND	773	H2	4	473
ND	Yes	8.2	ND	773	H2	4	473
ND	Yes	8.2	ND	773	H2	4	473
ND	Yes	ND	ND	ND	H2	4	473
ND	Yes	ND	ND	ND	H2	4	473
ND	No	ND	ND	ND	H2	4	473
ND	No	ND	ND	ND	H2	0.0833333	298
ND	No	ND	ND	ND	H2	0.0833333	298
ND	No	ND	ND	ND	H2	0.0833333	298
ND	No	ND	ND	ND	H2	0.0833333	298
ND	No	ND	ND	ND	H2	0.0833333	298
ND	No	7.5	2	773	H2	1	473
ND	No	7.5	2	773	H2	1	473
ND	No	7.5	2	773	H2	1	473
ND	No	7.5	2	773	H2	1	473
ND	No	7.5	2	773	H2	1	473
10	Yes	7.5	5	773	H2	1	573
10	Yes	3	5	773	H2	1	573

10	Yes	6	5	773	H2	1	573
10	Yes	6.1	5	773	H2	1	573
ND	No	6.7	ND	ND	H2	4	573
ND	No	6.7	ND	ND	H2	4	573
ND	No	8.5	5	823	H2	0.33	593
ND	No	ND	5	823	H2	0.33	593
ND	No	ND	5	823	H2	0.33	593
ND	No	ND	5	823	H2	0.33	593
ND	No	ND	5	823	H2	0.33	593
ND	No	ND	5	823	H2	0.33	593
ND	No	8.5	5	823	H2	1	593
ND	No	ND	5	823	H2	1	593
ND	No	ND	5	823	H2	1	593
10	Yes	ND	3	673	H2	1	573
10	Yes	ND	3	673	H2	1	573
10	Yes	ND	3	673	H2	1	573
10	Yes	ND	3	673	H2	1	573
10	Yes	ND	3	673	H2	1	573
10	Yes	ND	3	673	H2	1	573

10	Yes	ND	3	673	H2	1	573
10	Yes	ND	3	673	H2	1	573
10	Yes	6	5	773	H2	28.5	523
10	Yes	6	5	773	H2	28.5	523
10	Yes	6	5	773	H2	28.5	523
ND	No	8.5	ND	ND	H2	1	673
ND	No	8.5	ND	ND	H2	1	673
ND	No	6	ND	ND	H2	1	673
ND	No	6	ND	ND	H2	1	673
ND	No	9	ND	ND	H2	1	673
ND	No	9	ND	ND	H2	1	673
ND	No	8.5	4	773	H2	1	773
ND	No	ND	4	773	H2	1	773
ND	No	ND	4	773	H2	1	773
ND	No	ND	4	773	H2	1	773
ND	No	ND	4	773	H2	1	773
ND	No	ND	4	773	H2	1	773
ND	No	ND	4	773	H2	1	773
ND	No	ND	4	773	H2	1	773
ND	No	ND	4	773	H2	1	773
ND	No	ND	4	773	H2	1	773
ND	No	8.9	4	773	H2	1	573
ND	No	8.9	4	773	H2	1	573
ND	No	8.9	4	773	H2	1	573
ND	No	8.9	4	773	H2	1	573
ND	No	8.9	4	773	H2	1	573
ND	No	5.5	4	773	H2	1	423
ND	No	5.5	4	773	H2	1	423
ND	No	5.5	4	773	H2	1	423
ND	No	ND	4	773	H2	1	423
ND	No	ND	4	773	H2	1	423
ND	No	ND	4	773	H2	1	423
ND	No	6	4	673	H2	1	673
ND	No	9.5	4	673	H2	1	673
ND	No	ND	4	873	H2	1	423
ND	No	ND	4	873	H2	1	423

ND	No	ND	4	873	H2	1	423
ND	No	ND	4	873	H2	1	423
1.5	Yes	7.5	4	673	H2	1	573
1.5	Yes	ND	4	673	H2	1	573
1.5	Yes	7.5	4	673	H2	1	573
ND	No	6	2	673	H2	1	573
ND	No	6	2	673	H2	1	723
11	Yes	ND	ND	ND	HCOONa	0.5	298
11	Yes	ND	ND	ND	H2	1	623
ND	No	8.5	2	623	H2	3.5	573
ND	No	6.1	5	773	H2	0.5	573
ND	No	6.1	5	773	H2	0.5	573
10.5	Yes	6.1	5	773	H2	0.5	573
10.5	Yes	6.1	5	773	H2	0.5	573
ND	No	ND	5	573	ND	ND	ND
ND	No	ND	5	573	ND	ND	ND
ND	No	6.7	2	773	ND	ND	ND
ND	No	8.6	2	773	ND	ND	ND
ND	No	7.5	2	873	H2	2	723
ND	No	7.5	2	873	H2	2	723
ND	No	7.5	2	873	H2	2	723
ND	No	7.5	2	873	H2	2	723
ND	No	7.5	2	473	H2	2	723
ND	No	7.5	2	673	H2	2	723
ND	No	7.5	2	1073	H2	2	723
ND	No	6.1	4	673	H2	2	473
ND	No	6.1	4	673	H2	2	473
ND	No	6.1	4	673	H2	2	473
ND	No	6.1	4	673	H2	2	473
ND	No	5.9	4	673	H2	2	473
ND	No	8	ND	673	H2	ND	923
ND	No	6	ND	673	H2	ND	923
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	8.5	1	823	H2	ND	773
ND	No	ND	1	823	H2	ND	773
ND	No	ND	1	823	H2	ND	773
ND	No	8.5	ND	ND	H2	0.5	393
ND	No	8.5	ND	ND	H2	0.5	393
ND	No	8.5	ND	ND	H2	0.5	393
ND	No	ND	4	573	H2	3	573

ND	No	6	2	823	H2	1	623
ND	No	6	2	823	H2	1	773
ND	No	6	2	823	H2	1	623
5.5	No	6.7	NA	NA	H2	2	573
5.5	No	6.7	NA	NA	H2	2	573
5.5	No	6.7	4	723	H2	2	573
ND	No	6	3	773	H2	0.25	673
ND	No	6	3	773	H2	0.25	673
ND	No	9.5	3	773	H2	0.25	673
ND	No	6.1	3	773	H2	0.25	673
ND	No	2	3	773	H2	0.25	673
ND	No	5.8	4	573	H2	2	573
10.5	Yes	5.8	ND	ND	H2	2	573
10.5	Yes	5.8	ND	ND	H2	2	573
10.5	Yes	5.8	ND	ND	H2	2	573
10.5	Yes	5.8	ND	ND	H2	2	573
11	Yes	5.5	ND	ND	CH2O	1	353
11	Yes	5.9	ND	ND	CH2O	1	353
11	Yes	6	ND	ND	CH2O	1	353
11	Yes	ND	ND	ND	CH2O	1	353
11	Yes	ND	ND	ND	CH2O	1	353
ND	Yes	8.5	3	673	ND	ND	ND
ND	Yes	8.5	3	673	ND	ND	ND
ND	Yes	8.5	3	873	ND	ND	ND
ND	No	8.5	ND	ND	NaBH4	0.5	298
ND	No	8.5	ND	ND	NaBH4	0.5	298
ND	No	3	ND	ND	NaBH4	0.5	298
ND	No	3	ND	ND	NaBH4	0.5	298
ND	No	ND	2	1073	H2	0.5	873
ND	No	ND	2	1073	H2	0.5	873
ND	No	ND	2	1073	H2	0.5	873
ND	No	8.5	5	923	H2	0.08	313
ND	No	8.5	5	923	H2	0.08	313
ND	No	8.5	5	923	H2	0.08	313
ND	No	8.5	5	923	H2	0.08	313
ND	No	ND	ND	ND	H2	11	673
ND	No	ND	ND	ND	H2	11	673
ND	No	ND	ND	ND	H2	11	673
ND	No	ND	4	773	ND	ND	ND
ND	No	8.5	5	823	H2	2	673
ND	No	ND	5	823	H2	2	673
ND	No	ND	3	673	H2	5	573
ND	No	ND	3	673	H2	5	573
ND	No	ND	3	673	H2	5	573

ND	No	ND	3	673	H2	5	573
ND	No	ND	3	673	H2	5	573
ND	No	ND	1	673	H2	1	573
ND	No	ND	1	673	H2	1	573
ND	No	ND	1	673	H2	1	573
ND	No	ND	1	673	H2	1	573
ND	No	ND	1	673	H2	1	573
ND	No	ND	1	573	H2	17	873
ND	No	ND	1	573	H2	17	873
ND	No	ND	1	573	H2	17	873
ND	No	ND	1	573	H2	17	873
ND	No	ND	1	573	H2	17	873
ND	No	ND	NA	NA	NA	NA	NA
ND	No	ND	ND	ND	H2	2	573
ND	No	5.5	ND	ND	H2	2	673
ND	No	5.9	ND	ND	H2	2	673
ND	No	6	ND	ND	H2	2	673
ND	No	6	ND	ND	H2	1	623
ND	No	ND	ND	ND	H2	1	623
ND	No	ND	ND	ND	H2	1	623
ND	No	ND	ND	ND	H2	1	623
ND	No	8.5	5	423	H2	ND	723
ND	No	8.5	5	523	H2	ND	723
ND	No	8.5	5	773	H2	ND	723
ND	No	ND	ND	ND	H2	2	723
ND	No	ND	ND	ND	H2	2	723
ND	No	ND	ND	ND	H2	2	723
ND	No	ND	ND	ND	H2	2	723
ND	No	8.5	5	823	H2	0.5	673
ND	No	10	5	823	H2	0.5	673
ND	No	3	5	823	H2	0.5	673
ND	No	ND	ND	ND	w Discharge	1.5	ND
ND	No	ND	ND	ND	w Discharge	1.5	ND
ND	No	ND	ND	ND	w Discharge	1.5	ND
ND	No	ND	ND	ND	w Discharge	1.5	ND
10.5	Yes	6	4	573	H2	2	573
10.5	Yes	6	4	573	H2	2	573
10.5	Yes	6	4	573	H2	2	573
10.5	Yes	7.5	4	573	H2	2	573

10.5	Yes	3	4	573	H2	2	573
10.25	Yes	ND	ND	ND	CH2O	0.5	353
10.25	Yes	ND	ND	ND	CH2O	0.5	353
10.25	Yes	ND	ND	ND	CH2O	0.5	353
10.25	Yes	ND	ND	ND	CH2O	0.5	353
ND	No	ND	3	873	ND	ND	ND
ND	No	6.1	3	873	ND	ND	ND
1.6	No	ND	2	573	H2	1	573
8.8	No	ND	2	573	H2	1	573
ND	No	3.5	3	673	H2	2	673
ND	No	ND	3	673	H2	2	673
ND	No	6.1	3	673	H2	2	673
ND	No	7.5	ND	ND	H2	4	673
ND	No	7.5	ND	ND	H2	4	673
ND	No	7.5	ND	ND	H2	4	673
ND	No	ND	4	773	H2	1	773
ND	No	ND	4	773	H2	1	773
ND	No	ND	4	773	H2	1	773
ND	No	8.5	3	573	H2	0.16	573
ND	No	8.5	3	573	H2	0.16	573
ND	No	8.5	3	773	H2	0.16	573
ND	No	8.5	3	773	H2	0.16	573
ND	No	8.5	3	773	H2	0.16	573
ND	No	8.5	10	1073	H2	0.16	573
ND	No	8.5	10	1123	H2	0.16	573
ND	No	8.5	10	1173	H2	0.16	573
ND	No	7.5	3	573	H2	0.16	573
ND	No	7.5	3	573	H2	0.16	573
ND	No	7.5	3	773	H2	0.16	573
ND	No	7.5	3	773	H2	0.16	573
ND	No	7.5	3	773	H2	0.16	573
ND	No	7.5	10	1073	H2	0.16	573
ND	No	7.5	10	1123	H2	0.16	573
ND	No	7.5	10	1173	H2	0.16	573
ND	No	ND	2	773	H2	ND	573
ND	No	ND	2	773	H2	ND	573

ND	No	ND	2	773	H2	ND	573
ND	No	ND	2	773	H2	ND	573
ND	No	ND	2	773	H2	ND	573
ND	No	ND	2	973	H2	ND	573
ND	No	ND	2	973	H2	ND	573
ND	No	ND	2	973	H2	ND	573
ND	No	ND	2	973	H2	ND	573
ND	No	ND	2	973	H2	ND	573
ND	No	ND	ND	ND	H2	1	473
ND	No	ND	ND	ND	H2	1	473
ND	No	ND	ND	ND	H2	1	673
ND	No	ND	ND	ND	H2	1	873
ND	No	ND	ND	ND	H2	1	473
ND	No	ND	ND	ND	H2	1	473
ND	No	ND	ND	ND	H2	1	473
ND	No	ND	ND	ND	H2	2	523
ND	No	ND	ND	ND	H2	2	523
ND	No	ND	ND	ND	H2	2	523
ND	No	ND	ND	ND	H2	2	523
ND	No	ND	ND	ND	H2	2	523
1.1	Yes	2.5	ND	ND	NaBH4	2	273
2.5	No	2.5	ND	ND	NaBH4	2	273
2.5	No	2.5	ND	ND	NaBH4	2	273
10	Yes	2.5	ND	ND	NaBH4	2	273
1.1	Yes	2.5	ND	ND	NaBH4	2	273
2.5	No	2.5	ND	ND	NaBH4	2	273
10	Yes	2.5	ND	ND	NaBH4	2	273
ND	No	7.5	ND	ND	H2	3	673
ND	No	7.5	ND	ND	H2	5	673
ND	No	7.5	ND	ND	H2	5	773
ND	No	7.5	ND	ND	H2	5	873
ND	No	7.5	ND	ND	H2	5	973
ND	No	7.5	ND	ND	H2	5	1073
7.5	Yes	8.5	ND	ND	H2	1	473
7.5	Yes	8.5	ND	ND	H2	1	473
7.5	Yes	8.5	ND	ND	H2	1	473
7.5	Yes	8.5	ND	ND	H2	1	473
7.5	Yes	8.5	ND	ND	H2	1	473
ND	No	7.5	3	773	H2	NA	NA
ND	No	7.5	3	773	H2	1	373
ND	No	7.5	3	773	H2	1	473
ND	No	7.5	3	773	H2	1	573
ND	No	7.5	3	773	H2	1	673

3	No	10	5	723	H2	3	723
ND	No	10	5	723	H2	3	723
9	No	10	5	723	H2	3	723
ND	No	ND	5	723	H2	3	723
ND	No	ND	5	723	H2	3	723
ND	No	8.5	3	773	H2	1	773
ND	No	8.5	3	773	H2	1	773
ND	No	ND	3	773	H2	1	773
ND	No	ND	3	773	H2	1	773
ND	No	11	6	823	H2	1	1173
ND	No	11	6	823	H2	1	1173
8	Yes	ND	4	823	H2	1	573
8	Yes	ND	4	823	H2	1	573
8	Yes	ND	4	823	H2	1	573
8	Yes	ND	4	823	H2	1	573
8	Yes	ND	4	823	H2	1	573
8	Yes	ND	4	823	H2	1	573
8	Yes	ND	4	823	H2	1	573
8	Yes	ND	NA	NA	H2	1	573
8	Yes	ND	4	823	H2	1	573
8	Yes	ND	4	823	H2	1	573
8	Yes	ND	4	823	H2	1	573
8	Yes	ND	4	823	H2	1	573
8	Yes	ND	4	823	H2	1	573
ND	No	ND	2	773	H2	2	298
ND	No	ND	2	773	H2	2	298
ND	No	ND	2	773	H2	2	298
ND	No	ND	3	573	H2	1	573
ND	No	ND	4	773	ND	ND	ND
ND	No	ND	4	773	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	H2	1	673
ND	No	ND	ND	ND	H2	1	673
ND	No	ND	ND	ND	H2	1	673
ND	No	ND	ND	ND	H2	1	673

ND	No	ND	ND	ND	H2	1	673
ND	No	ND	ND	ND	H2	1	673
ND	No	ND	ND	ND	H2	1	673
ND	No	ND	ND	ND	H2	1	673
ND	No	ND	ND	ND	H2	1	673
ND	No	ND	ND	ND	H2	1	673
ND	No	ND	5	823	H2	2	673
ND	No	ND	5	823	H2	2	673
ND	No	ND	5	823	H2	2	673
ND	No	ND	ND	ND	H2	1	773
ND	No	ND	4	573	H2	ND	623
ND	No	ND	4	573	H2	ND	723
ND	No	ND	4	773	H2	ND	623
ND	No	ND	4	773	H2	ND	723
ND	No	ND	4	673	H2	ND	623
ND	No	ND	4	673	H2	ND	723
ND	No	ND	4	773	H2	ND	723
ND	No	ND	4	573	H2	ND	723
ND	No	ND	4	573	H2	ND	723
ND	No	ND	4	573	H2	ND	723
ND	No	ND	4	673	H2	ND	723
ND	No	ND	4	673	H2	ND	723
ND	No	ND	4	673	H2	ND	723
ND	No	ND	ND	723	H2	ND	723
ND	No	ND	ND	723	H2	ND	723
ND	No	ND	ND	723	H2	ND	723
ND	No	ND	ND	723	H2	ND	723
ND	No	ND	ND	723	H2	ND	723
ND	No	ND	ND	723	H2	ND	723
ND	No	ND	ND	723	H2	ND	723
ND	No	ND	ND	723	H2	ND	723
ND	No	ND	ND	723	H2	ND	723
ND	No	ND	ND	723	H2	ND	723
ND	No	ND	ND	723	H2	ND	723
ND	No	ND	ND	723	H2	ND	723
ND	No	ND	ND	723	H2	ND	723
ND	No	ND	ND	723	H2	ND	723
ND	No	ND	ND	723	H2	ND	723
ND	No	ND	ND	723	H2	ND	723
ND	No	ND	4	673	H2	4	723
ND	No	ND	4	673	H2	4	723
ND	No	ND	4	673	H2	4	723
ND	No	ND	4	673	H2	4	723
ND	No	ND	4	673	H2	1	573

ND	No	ND	5	813	H2	2	300
ND	No	ND	5	813	H2	2	300
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	1	573	H2	1	573
ND	Yes	4	ND	773	ND	ND	473
ND	Yes	4	ND	773	ND	ND	473
ND	Yes	4	NA	773	ND	ND	473
ND	Yes	4	NA	773	ND	ND	473
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	2	773	H2	2	298
ND	No	ND	2	773	H2	2	298
ND	Yes	ND	6	673	H2	2	573
ND	Yes	ND	6	673	H2	2	573
ND	No	ND	ND	573	ND	ND	ND
ND	No	ND	ND	573	ND	ND	ND
ND	No	ND	4	773	H2	2	753
ND	No	ND	4	773	H2	2	753
ND	No	ND	4	773	H2	2	753
ND	No	ND	4	773	H2	2	753
ND	No	ND	4	773	H2	2	753
ND	No	ND	3	773	H2	1	298
ND	No	ND	3	773	H2	1	298
ND	No	ND	3	773	H2	1	298
ND	No	ND	3	773	H2	1	298
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
8	Yes	ND	2	773	ND	ND	ND
8	Yes	ND	2	773	ND	ND	ND
ND	No	ND	3	673	ND	ND	ND
ND	No	ND	3	853	H2	3	623
ND	No	ND	3	853	H2	3	623
ND	No	ND	6	813	H2	3	623
ND	No	ND	6	813	H2	3	623
ND	No	ND	1	673	ND	ND	ND
ND	Yes	ND	4	773	ND	4	573
ND	Yes	ND	4	773	ND	4	573
ND	Yes	ND	4	773	ND	4	573
ND	Yes	ND	4	773	ND	4	573
ND	Yes	ND	4	773	ND	4	573
7	Yes	ND	2	723	ND	ND	ND
7	Yes	ND	2	723	ND	ND	ND
7	Yes	ND	2	723	ND	ND	ND
7	Yes	ND	2	723	ND	ND	ND
ND	No	3.1	5	773	ND	ND	ND
ND	No	ND	ND	773	ND	ND	ND
ND	No	ND	NA	NA	H2	1	298
ND	No	ND	3	773	H2	4	773

ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	393	H2	ND	573
ND	No	ND	ND	473	H2	ND	573
ND	No	ND	ND	523	H2	ND	573
ND	No	ND	ND	573	H2	ND	573
ND	No	ND	ND	673	H2	ND	573
ND	No	ND	ND	773	H2	ND	573
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	H2	2	573
ND	No	ND	ND	ND	H2	2	473
ND	No	ND	ND	ND	H2	2	473
ND	No	ND	ND	ND	H2	2	473
ND	No	ND	ND	ND	H2	2	473
ND	No	ND	4	673	H2	2	473
ND	No	ND	ND	ND	ND	ND	ND
ND	Yes	ND	ND	673	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	H2	1	573
ND	No	ND	ND	ND	H2	1	773
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	H2	1	573
ND	No	ND	ND	ND	H2	1	773
ND	Yes	ND	ND	ND	ND	ND	ND

ND	No	ND	3	673	H2	2	673
ND	No	ND	ND	ND	H2	4	298
ND	No	ND	ND	ND	H2	1	338
ND	No	ND	4	1273	ND	ND	ND
ND	No	ND	4	1273	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	H2	2	298
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
2	Yes	ND	ND	ND	ND	ND	ND
2	Yes	ND	ND	ND	ND	ND	ND
ND	No	ND	NA	NA	NA	NA	NA
ND	No	ND	1	573	NA	NA	NA
ND	No	ND	1	573	H2	1	473
ND	No	ND	NA	NA	H2	1	473
ND	No	ND	1	573	CH2O	24	298
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	H2	2	573
ND	No	ND	ND	ND	H2	2	573
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	1	723	ND	ND	ND
ND	No	ND	1	723	ND	ND	ND
ND	No	ND	1	723	ND	ND	ND
ND	No	ND	1	723	ND	ND	ND

3	No	ND	ND	ND	ND	ND	ND
3	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	2.5	773	ND	ND	ND
ND	No	ND	2.5	773	ND	ND	ND
ND	No	ND	2.5	773	ND	ND	ND
ND	No	ND	2.5	773	ND	ND	ND
ND	No	ND	2.5	773	ND	ND	ND
ND	No	ND	ND	ND	H2	ND	353
9	No	ND	1	823	H2	1	773
1	No	ND	2	673	H2	1	673
ND	No	ND	3	823	H2	0.5	623
9	Yes	ND	ND	ND	ND	ND	ND
9	Yes	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	H2	ND	298
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	H2	1	298
ND	No	ND	ND	ND	H2	2	298
11	Yes	ND	NA	NA	H2	ND	373
11	Yes	ND	NA	NA	H2	ND	473
11	Yes	ND	NA	NA	H2	ND	573
10	Yes	ND	NA	NA	H2	12	298
10	Yes	ND	NA	NA	H2	12	298
ND	no	ND	ND	ND	ND	ND	ND
ND	no	ND	ND	ND	H2	ND	298
ND	No	ND	ND	ND	ND	ND	ND
ND	No	ND	ND	ND	ND	ND	ND
ND	No	11	2	823	H2	0.167	773
ND	Yes	ND	3	623	H2	ND	443
1.5	Yes	ND	4	673	H2	1	573
ND	No	ND	3	573	H2	ND	873
ND	No	ND	3	773	H2	ND	873

method for dispersion/size determination	Dispersion (%)	std dev	Size (Å) (Chemisorp.)	std dev	Size (Å) XRD	std dev	Size (Å) (S)TEM	std dev
H2 Chemisorption	71	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	62	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	43	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	17	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	19	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	22	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	9	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	79.00	ND	11	ND	ND	ND	ND	ND
H2 Chemisorption	59.00	ND	15	ND	ND	ND	ND	ND
H2 Chemisorption	18.00	ND	45	ND	ND	ND	ND	ND
H2 Chemisorption	100.00	ND	10	ND	ND	ND	ND	ND
H2 Chemisorption	46.00	ND	20	ND	ND	ND	ND	ND
H2 Chemisorption	10.00	ND	90	ND	ND	ND	ND	ND
CO Chemisorption	43	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	44	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	53	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	58	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	61	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	40	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	38	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	47	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	52	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	59	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	29	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	10	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	12	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	14	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	20	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	43	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	33	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	40	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	39	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	44	ND	ND	ND	ND	ND	ND	ND
H2-O2 Titration	42.44	ND	ND	ND	ND	ND	ND	ND
H2-O2 Titration	12.23	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	36	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	5	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	37	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	28	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	15	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	7	ND	ND	ND	ND	ND	ND	ND
CO Desorption	31.00	ND	ND	ND	ND	ND	ND	ND
CO Desorption	19.00	ND	ND	ND	ND	ND	ND	ND
CO Desorption	16.00	ND	ND	ND	ND	ND	ND	ND
CO Desorption	20.00	ND	ND	ND	ND	ND	ND	ND
CO Desorption	16.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	23.80	ND	47	ND	ND	ND	ND	ND

CO Chemisorption	26	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	25	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	25	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	26	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	30	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	36	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	30	ND	35	ND	ND	ND	48	ND
CO Chemisorption	10	ND	105	ND	ND	ND	86	ND
CO Chemisorption	7	ND	163	ND	ND	ND	102	ND
CO Chemisorption	8	ND	143	ND	ND	ND	115	ND
XRD	ND	ND	140	ND	140	ND	ND	ND
XRD	ND	ND	130	ND	50	ND	ND	ND
CO Methanation	46.8	ND	ND	ND	ND	ND	ND	ND
CO Methanation	49.9	ND	ND	ND	ND	ND	ND	ND
CO Methanation	54.00	ND	ND	ND	ND	ND	ND	ND
CO Methanation	37.5	ND	ND	ND	ND	ND	ND	ND
CO Methanation	11.30	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	4.45	ND	247	ND	ND	ND	ND	ND
H2 Chemisorption	4.56	ND	241.1	ND	ND	ND	ND	ND
H2 Chemisorption	0.92	ND	1192.2	ND	ND	ND	ND	ND
H2 Chemisorption	1.30	ND	845.3	ND	ND	ND	ND	ND
CO Chemisorption	32	ND	39	ND	30	ND	ND	ND
CO Chemisorption	86	ND	13	ND	20	ND	ND	ND
CO Chemisorption	19	ND	55	ND	60	ND	ND	ND
CO Chemisorption	25	ND	49	ND	41	ND	ND	ND
H2 Chemisorption	30.80	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	34.00	ND	33	ND	ND	ND	ND	ND
H2 Chemisorption	31.00	ND	36	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	20	ND
TEM	ND	ND	ND	ND	20	ND	25	ND
TEM	ND	ND	ND	ND	20	ND	90	ND
TEM	ND	ND	ND	ND	ND	ND	30	ND
TEM	ND	ND	ND	ND	ND	ND	30	ND
TEM	ND	ND	ND	ND	80	ND	50	ND
TEM	ND	ND	ND	ND	300	ND	90	ND
CO Pulse Adsorption	27	ND	ND	ND	ND	ND	ND	ND
CO Pulse Adsorption	15	ND	ND	ND	ND	ND	ND	ND
CO Pulse Adsorption	12	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	77	ND	14	ND	ND	ND	ND	ND
H2 Chemisorption	62	ND	21	ND	ND	ND	ND	ND
H2 Chemisorption	41	ND	30	ND	ND	ND	ND	ND
H2 Chemisorption	23	ND	55	ND	ND	ND	ND	ND
H2 Chemisorption	73	ND	15	ND	ND	ND	ND	ND
H2 Chemisorption	41	ND	35	ND	ND	ND	ND	ND
H2 Chemisorption	23	ND	62	ND	ND	ND	ND	ND

H2 Chemisorption	21	ND	68	ND	ND	ND	ND	ND
H2-O2 Titration	37.00	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	26.40	ND	36.8	ND	ND	ND	ND	ND
CO Chemisorption	57.8	ND	16.80	ND	ND	ND	ND	ND
CO Chemisorption	75.5	ND	12.80	ND	ND	ND	ND	ND
CO Chemisorption	58.9	ND	16.60	ND	ND	ND	ND	ND
H2 Chemisorption	45	ND	30	ND	25	ND	ND	ND
H2 Chemisorption	37	ND	40	ND	30	ND	ND	ND
H2 Chemisorption	10	ND	150	ND	112	ND	ND	ND
H2 Chemisorption	12	ND	100	ND	93	ND	ND	ND
TEM	ND	ND	ND	ND	180	ND	550	ND
H2 Chemisorption	4	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	3	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	21	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	5	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	6	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	22	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	9	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	18	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	11	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	10	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	40	ND	28	ND	ND	ND	ND	ND
H2 Chemisorption	34	ND	33	ND	ND	ND	ND	ND

H2 Chemisorption	23	ND	49	ND	ND	ND	ND	ND
H2 Chemisorption	19	ND	59	ND	ND	ND	ND	ND
H2 Chemisorption	12	ND	94	ND	ND	ND	ND	ND
H2 Chemisorption	10	ND	113	ND	ND	ND	ND	ND
TEM	30.00	ND	ND	ND	38	ND	42	ND
TEM	ND	ND	ND	ND	155	ND	157	ND
H2 Chemisorption	24.50	ND	46	ND	ND	ND	ND	ND
H2 Chemisorption	0.16	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	18.10	ND	62	ND	ND	ND	ND	ND
H2 Chemisorption	10.70	ND	105	ND	ND	ND	ND	ND
H2 Chemisorption	23	ND	49	ND	ND	ND	ND	ND
H2 Chemisorption	0.2	ND	5600	ND	ND	ND	ND	ND
H2 Chemisorption	39	ND	29	ND	ND	ND	ND	ND
H2 Chemisorption	1.7	ND	660	ND	35	ND	46	ND
H2 Chemisorption	29	ND	39	ND	33	ND	ND	ND
H2 Chemisorption	10	ND	118	ND	39	ND	ND	ND
H2 Chemisorption	30	ND	37	ND	28	ND	48	ND
H2 Chemisorption	19	ND	59	ND	40	ND	48	ND
CO Chemisorption	6.50	ND	172	ND	ND	ND	ND	ND
CO Chemisorption	7.30	ND	153	ND	ND	ND	ND	ND
CO Chemisorption	58	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	8	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	8	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	4.2	ND	278	ND	ND	ND	182	ND
CO Chemisorption	4.1	ND	283	ND	ND	ND	216	ND
CO Chemisorption	3.8	ND	306	ND	ND	ND	269	ND
CO Chemisorption	3.5	ND	333	ND	ND	ND	287	ND
CO Chemisorption	3.0	ND	396	ND	ND	ND	381	ND
CO Chemisorption	26.1	ND	43	ND	ND	ND	48	ND
CO Chemisorption	17.7	ND	63	ND	100	ND	101	ND
CO Chemisorption	22.0	ND	51	ND	120	ND	115	ND
CO Chemisorption	9.3	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	6.6	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	6.0	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	8.6	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	6.2	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	5.4	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	48	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	34	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	25	ND	ND	ND	ND	ND	ND	ND

H2 Chemisorption	8.6	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	2.9	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	3.3	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	38.0	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	13.0	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	65.1	ND	14	ND	ND	ND	ND	ND
CO Chemisorption	42.1	ND	22	ND	ND	ND	ND	ND
CO Chemisorption	10.0	ND	112	ND	ND	ND	ND	ND
CO Chemisorption	8.3	ND	135	ND	ND	ND	ND	ND
H2-O2 Titration	31	ND	ND	ND	98	ND	ND	ND
H2-O2 Titration	2	ND	ND	ND	103	ND	ND	ND
H2-O2 Titration	38	ND	ND	ND	82	ND	ND	ND
H2-O2 Titration	ND	ND	ND	ND	81	ND	ND	ND
H2-O2 Titration	30	ND	ND	ND	ND	ND	ND	ND
H2-O2 Titration	34	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	48	8	23	ND	ND	ND	25	10
CO Chemisorption	46	3	25	ND	ND	ND	ND	ND
CO Chemisorption	79	1	14	ND	ND	ND	ND	ND
CO Chemisorption	97	2	12	ND	ND	ND	ND	ND
H2 Chemisorption	ND	ND	34	ND	ND	ND	ND	ND
H2 Chemisorption	ND	ND	18	ND	ND	ND	ND	ND
H2 Chemisorption	ND	ND	42	ND	ND	ND	ND	ND
H2 Chemisorption	ND	ND	39	ND	ND	ND	ND	ND
H2 Chemisorption	55.00	ND	17	ND	ND	ND	ND	ND
H2 Chemisorption	53.00	ND	18	ND	ND	ND	ND	ND
H2 Chemisorption	47.00	ND	20	ND	ND	ND	ND	ND
H2 Chemisorption	28.00	ND	35	ND	ND	ND	ND	ND
H2 Chemisorption	12.00	ND	78	ND	ND	ND	ND	ND
H2 Chemisorption	59.00	ND	16	ND	ND	ND	ND	ND
H2 Chemisorption	70.00	ND	13	ND	ND	ND	ND	ND
TEM	47.00	ND	ND	ND	ND	ND	20	ND
TEM	38.00	ND	ND	ND	ND	ND	24	ND
H2 Chemisorption	26.00	ND	35	ND	ND	ND	ND	ND
TEM	26.00	ND	ND	ND	ND	ND	36	ND
TEM	29.00	ND	ND	ND	ND	ND	32	ND
H2 Chemisorption	46.80	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	31.70	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	30.10	ND	ND	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	200	ND	100	ND
TEM	ND	ND	ND	ND	250	ND	80	ND
TEM	ND	ND	ND	ND	230	ND	130	ND
H2 Chemisorption	ND	ND	67	ND	ND	ND	40	ND
CO Chemisorption	19.70	ND	57	ND	ND	ND	ND	ND
CO Chemisorption	16.30	ND	69	ND	ND	ND	ND	ND

CO Chemisorption	12.50	ND	90	ND	ND	ND	ND	ND
CO Chemisorption	41.10	ND	27	ND	ND	ND	ND	ND
CO Chemisorption	12.00	ND	93	ND	ND	ND	ND	ND
CO Chemisorption	4.30	ND	260	ND	ND	ND	ND	ND
CO Chemisorption	10.00	ND	105	ND	ND	ND	ND	ND
CO Chemisorption	0.50	ND	2110	ND	ND	ND	ND	ND
CO Chemisorption	20.50	ND	51	ND	ND	ND	ND	ND
CO Chemisorption	2.50	ND	422	ND	ND	ND	ND	ND
XRD	ND	ND	ND	ND	472.9112	ND	ND	ND
H2 Chemisorption	10.30	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	24.80	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	35.50	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	41.80	ND	ND	ND	ND	ND	ND	ND
H2 titration	18.70	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	25.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	25.00	ND	ND	ND	ND	ND	ND	ND
TEM	30.00	ND	ND	ND	38	ND	42	ND
TEM	40.00	ND	ND	ND	28	ND	25	ND
TEM	ND	ND	ND	ND	ND	ND	80	ND
TEM	ND	ND	ND	ND	ND	ND	240	ND
CO Chemisorption	17.00	ND	64	ND	ND	ND	ND	ND
CO Chemisorption	31.00	ND	36	ND	ND	ND	ND	ND
CO Chemisorption	53.00	ND	21	ND	ND	ND	ND	ND
CO Chemisorption	54.00	ND	21	ND	ND	ND	ND	ND
CO Chemisorption	29.00	ND	39	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	121	ND	90	ND
CO Chemisorption	27.30	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	29.40	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	19.20	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	26.70	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	7.30	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	8.70	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	15.60	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	18.10	ND	ND	ND	ND	ND	ND	ND
XRD	ND	ND	ND	ND	15.3	ND	ND	ND
CO Chemisorption	2.73	ND	410	ND	ND	ND	ND	ND
CO Chemisorption	2.10	ND	533	ND	ND	ND	ND	ND
CO Chemisorption	0.86	ND	1302	ND	ND	ND	ND	ND
CO Chemisorption	3.93	ND	285	ND	ND	ND	ND	ND
CO Chemisorption	58	ND	21	ND	ND	ND	ND	ND
CO Chemisorption	46	ND	27	ND	ND	ND	ND	ND
CO Chemisorption	31	ND	41	ND	ND	ND	ND	ND
CO Chemisorption	20	ND	63	ND	ND	ND	ND	ND
CO Chemisorption	12.5	ND	104	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	43	ND
TEM	ND	ND	ND	ND	ND	ND	56	ND
TEM	ND	ND	ND	ND	ND	ND	29	ND

TEM	ND	ND	ND	ND	ND	ND	32	ND
TEM	ND	ND	ND	ND	ND	ND	49	ND
TEM	ND	ND	ND	ND	ND	ND	50	ND
H2 Chemisorption	60	ND	19	ND	NA	ND	32	ND
H2 Chemisorption	29	ND	39	ND	66	ND	74	ND
H2 Chemisorption	38	ND	29	ND	36	ND	NA	ND
H2 Chemisorption	26	ND	42	ND	78	ND	NA	ND
H2 Chemisorption	9	ND	121	ND	106	ND	145	ND
CO Chemisorption	7.1	ND	158	ND	ND	ND	ND	ND
CO Chemisorption	4.4	ND	254	ND	ND	ND	ND	ND
H2 Chemisorption	25.00	ND	45	ND	ND	ND	ND	ND
H2 Chemisorption	32.00	ND	35	ND	ND	ND	ND	ND
H2 Chemisorption	23.00	ND	48	ND	ND	ND	ND	ND
CO Pulse Adsorption	52.2	ND	ND	ND	ND	ND	ND	ND
CO Pulse Adsorption	32.5	ND	ND	ND	ND	ND	ND	ND
CO Pulse Adsorption	44.3	ND	ND	ND	ND	ND	ND	ND
CO Pulse Adsorption	10.4	ND	ND	ND	ND	ND	ND	ND
CO Pulse Adsorption	17.9	ND	ND	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	160	ND	120	ND
TEM	ND	ND	ND	ND	180	ND	160	ND
TEM	ND	ND	ND	ND	150	ND	140	ND
TEM	ND	ND	ND	ND	120	ND	150	ND
TEM	ND	ND	ND	ND	150	ND	ND	ND
TEM	ND	ND	ND	ND	140	ND	150	ND
TEM	ND	ND	ND	ND	160	ND	ND	ND
XRD	ND	ND	ND	ND	190	ND	ND	ND
H2 Chemisorption	40.00	ND	27	9	ND	ND	ND	ND
H2 Chemisorption	40.00	ND	28	6	ND	ND	ND	ND
H2 Chemisorption	51.00	ND	22	6	ND	ND	ND	ND
H2 Chemisorption	31.00	ND	36	6	ND	ND	ND	ND
H2 Chemisorption	24.00	ND	46	5	60	5	ND	ND
H2 Chemisorption	26.00	ND	42	4	ND	ND	ND	ND
H2 Chemisorption	14.20	ND	78	4	90	5	ND	ND
CO Chemisorption	5.81	ND	190	ND	ND	ND	ND	ND
H2 Chemisorption	25	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	19	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	39	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	47	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	8.40	ND	88	ND	ND	ND	ND	ND
CO Chemisorption	7.60	ND	147	ND	ND	ND	ND	ND
CO Chemisorption	3.90	ND	284	ND	ND	ND	ND	ND
CO Chemisorption	12.70	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	2.60	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	4.60	ND	ND	ND	ND	ND	ND	ND

H2 Chemisorption	20.01	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	20.0	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	24.9	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	23.4	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	24.1	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	15.0	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	10.4	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	10.0	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	12.0	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	12.0	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	86.00	ND	19.70	ND	ND	ND	ND	ND
CO Chemisorption	72.00	ND	25.42	ND	ND	ND	ND	ND
CO Chemisorption	49.00	ND	32	ND	ND	ND	ND	ND
CO Chemisorption	30.00	ND	47.14	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	41	ND	39	8
TEM	ND	ND	ND	ND	52	ND	51	7
TEM	ND	ND	ND	ND	ND	ND	40	ND
TEM	ND	ND	ND	ND	ND	ND	26	ND
XRD	ND	ND	ND	ND	33	ND	ND	ND
TEM	ND	ND	ND	ND	46	ND	47	ND
TEM	ND	ND	ND	ND	60	ND	61	ND
XRD	ND	ND	ND	ND	77	ND	ND	ND
XRD	ND	ND	ND	ND	92	ND	ND	ND
CO Chemisorption	12.50	ND	89	ND	ND	ND	ND	ND
CO Chemisorption	18.50	ND	61	ND	ND	ND	ND	ND
CO Chemisorption	42.90	ND	26	ND	ND	ND	ND	ND
CO Chemisorption	53.50	ND	21	ND	ND	ND	ND	ND
CO Chemisorption	59.20	ND	19	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	90	ND
TEM	ND	ND	ND	ND	ND	ND	96	ND
TEM	ND	ND	ND	ND	ND	ND	91	ND
TEM	ND	ND	ND	ND	ND	ND	100	ND
TEM	ND	ND	ND	ND	ND	ND	125	ND
TEM	ND	ND	ND	ND	ND	ND	193	ND
TEM	ND	ND	ND	ND	ND	ND	55	34
TEM	ND	ND	ND	ND	ND	ND	44	25
TEM	ND	ND	ND	ND	ND	ND	37	20
CO Chemisorption	ND	ND	25	ND	ND	ND	ND	ND
CO Chemisorption	ND	ND	19	ND	ND	ND	ND	ND
CO Chemisorption	ND	ND	18	ND	ND	ND	ND	ND
CO Chemisorption	ND	ND	24	ND	ND	ND	ND	ND
CO Chemisorption	ND	ND	20	ND	ND	ND	ND	ND

CO Chemisorption	ND	ND	16	ND	ND	ND	ND	ND
CO Chemisorption	ND	ND	32	ND	ND	ND	ND	ND
CO Chemisorption	ND	ND	37	ND	ND	ND	ND	ND
CO Chemisorption	ND	ND	35	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	300	ND	140	ND
TEM	ND	ND	ND	ND	300	ND	160	ND
TEM	ND	ND	ND	ND	38	ND	39	9
TEM	ND	ND	ND	ND	50	ND	52	18
TEM	ND	ND	ND	ND	61	ND	61	21
TEM	ND	ND	ND	ND	68	ND	75	29
TEM	ND	ND	ND	ND	49	ND	50	ND
TEM	ND	ND	ND	ND	50	ND	51	ND
TEM	ND	ND	ND	ND	51	ND	52	ND
TEM	ND	ND	ND	ND	53	ND	54	ND
TEM	ND	ND	ND	ND	55	ND	56	ND
TEM	ND	ND	ND	ND	ND	ND	58	ND
TEM	ND	ND	ND	ND	ND	ND	63	ND
TEM	ND	ND	ND	ND	ND	ND	48	ND
CO Chemisorption	23.00	ND	40	ND	ND	ND	ND	ND
CO Chemisorption	44.00	ND	20	ND	ND	ND	ND	ND
CO Chemisorption	22.00	ND	40	ND	ND	ND	ND	ND
CO Chemisorption	39.00	ND	25	ND	ND	ND	ND	ND
CO Chemisorption	14.00	ND	70	ND	ND	ND	ND	ND
CO Chemisorption	3.00	ND	300	ND	ND	ND	ND	ND
CO Chemisorption	1.00	ND	680	ND	ND	ND	ND	ND
CO Chemisorption	4.00	ND	220	ND	ND	ND	ND	ND
CO Chemisorption	41.00	ND	20	ND	ND	ND	ND	ND
CO Chemisorption	16.00	ND	60	ND	ND	ND	ND	ND
CO Chemisorption	52.00	ND	20	ND	ND	ND	ND	ND
CO Chemisorption	31.00	ND	30	ND	ND	ND	ND	ND
CO Chemisorption	5.00	ND	180	ND	ND	ND	ND	ND
CO Chemisorption	20.00	ND	45	ND	ND	ND	ND	ND
CO Chemisorption	3.00	ND	290	ND	ND	ND	ND	ND
CO Chemisorption	0.20	ND	4400	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	28	9
TEM	ND	ND	ND	ND	ND	ND	28	9
TEM	ND	ND	ND	ND	ND	ND	30	15
TEM	ND	ND	ND	ND	ND	ND	30	8

TEM	ND	ND	ND	ND	ND	ND	32	10
TEM	ND	ND	ND	ND	ND	ND	36	15
TEM	ND	ND	ND	ND	ND	ND	27	6
TEM	ND	ND	ND	ND	ND	ND	33	13
TEM	ND	ND	ND	ND	ND	ND	37	14
TEM	ND	ND	ND	ND	ND	ND	20	ND
TEM	ND	ND	ND	ND	ND	ND	40	ND
TEM	ND	ND	ND	ND	ND	ND	58	ND
TEM	ND	ND	ND	ND	ND	ND	63	ND
TEM	ND	ND	ND	ND	ND	ND	36	ND
TEM	ND	ND	ND	ND	ND	ND	52	ND
TEM	ND	ND	ND	ND	ND	ND	57	ND
TEM	ND	ND	ND	ND	ND	ND	58	ND
TEM	ND	ND	ND	ND	ND	ND	60	ND
H2 Chemisorption	23.00	ND	40	ND	ND	ND	ND	ND
H2 Chemisorption	11.00	ND	82	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	36	9
TEM	ND	ND	ND	ND	ND	ND	40	9
XRD	ND	ND	ND	ND	60	ND	ND	ND
CO Chemisorption	13.80	ND	81	ND	ND	ND	ND	ND
CO Chemisorption	68.40	ND	16	ND	ND	ND	ND	ND
CO Chemisorption	ND	ND	31	ND	ND	ND	ND	ND
CO Chemisorption	ND	ND	54	ND	ND	ND	ND	ND
CO Chemisorption	30.00	ND	35	ND	ND	ND	ND	ND
CO Chemisorption	18.00	ND	58	ND	ND	ND	ND	ND
CO Chemisorption	17.00	ND	60	ND	ND	ND	ND	ND
XRD	ND	ND	ND	ND	48	ND	ND	ND
H2 Chemisorption	26.00	ND	ND	ND	ND	ND	109	ND
H2 Chemisorption	29.00	ND	ND	ND	ND	ND	48	ND
H2 Chemisorption	38.00	ND	ND	ND	ND	ND	89	ND

H2 Chemisorption	60.00	ND	ND	ND	ND	ND	29	ND
H2-O2 Titration	57.00	ND	ND	ND	ND	ND	ND	ND
H2-O2 Titration	36.00	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	67.00	ND	17	ND	ND	ND	ND	ND
CO Chemisorption	47.00	ND	24	ND	ND	ND	ND	ND
CO Chemisorption	54.00	ND	21	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	25	ND
TEM	ND	ND	ND	ND	ND	ND	70	ND
TEM	ND	ND	ND	ND	ND	ND	75	ND
TEM	ND	ND	ND	ND	ND	ND	26	ND
CO Chemisorption	15.00	ND	ND	ND	ND	ND	36	3
CO Chemisorption	85.00	ND	ND	ND	ND	ND	15	ND
CO Chemisorption	69.00	ND	ND	ND	ND	ND	25	ND
CO Chemisorption	30.00	ND	ND	ND	ND	ND	150	ND
CO Chemisorption	17.30	ND	ND	ND	ND	ND	30	ND
CO Chemisorption	15.10	ND	ND	ND	ND	ND	30	ND
TEM	ND	ND	ND	ND	ND	ND	100	20
TEM	ND	ND	ND	ND	ND	ND	50	20
TEM	ND	ND	ND	ND	ND	ND	90	20
TEM	ND	ND	ND	ND	ND	ND	110	40
TEM	ND	ND	ND	ND	ND	ND	120	20
TEM	ND	ND	ND	ND	ND	ND	80	30
TEM	ND	ND	ND	ND	ND	ND	50	7
TEM	ND	ND	ND	ND	ND	ND	110	30
CO Chemisorption	13.00	ND	ND	ND	ND	ND	105	ND
CO Chemisorption	55.00	ND	ND	ND	ND	ND	28	ND
CO Chemisorption	37.00	ND	ND	ND	ND	ND	36	ND
CO Chemisorption	74.00	ND	ND	ND	ND	ND	13	ND
XRD	ND	ND	ND	ND	300	ND	ND	ND
CO Chemisorption	ND	ND	310	ND	300	ND	270	ND
XRD	ND	ND	ND	ND	300	ND	ND	ND
CO Chemisorption	ND	ND	330	ND	300	ND	260	ND
XRD	ND	ND	ND	ND	230	ND	ND	ND
CO Chemisorption	ND	ND	280	ND	280	ND	240	ND
XRD	ND	ND	ND	ND	290	ND	ND	ND
CO Chemisorption	ND	ND	300	ND	300	ND	290	ND
XRD	ND	ND	ND	ND	210	ND	ND	ND
XRD	ND	ND	ND	ND	260	ND	ND	ND
TEM	ND	ND	ND	ND	221	ND	157.5	ND
TEM	ND	ND	ND	ND	176	ND	117.5	ND
TEM	ND	ND	ND	ND	68	ND	42.5	ND
TEM	ND	ND	ND	ND	80	ND	75	ND
TEM	ND	ND	ND	ND	57	ND	45	ND
TEM	ND	ND	ND	ND	78	ND	71	ND
TEM	ND	ND	ND	ND	69	ND	65	ND
TEM	ND	ND	ND	ND	69	ND	53	ND
TEM	ND	ND	ND	ND	79	ND	80	ND
TEM	ND	ND	ND	ND	58	ND	56	ND
XRD	ND	ND	ND	ND	94	ND	ND	ND

XRD	ND	ND	ND	ND	152	ND	ND	ND
TEM	ND	ND	ND	ND	39	ND	40	ND
TEM	ND	ND	ND	ND	79	ND	81	ND
TEM	24.80	ND	ND	ND	ND	ND	45	18
TEM	12.60	ND	ND	ND	ND	ND	97	34
TEM	9.60	ND	ND	ND	ND	ND	117	33
H2 Chemisorption	ND	ND	89	ND	68	ND	ND	ND
H2 Chemisorption	ND	ND	121	ND	110	ND	ND	ND
H2 Chemisorption	ND	ND	245	ND	226	ND	ND	ND
H2 Chemisorption	ND	ND	298	ND	284	ND	ND	ND
H2 Chemisorption	ND	ND	19	ND	ND	ND	ND	ND
H2 Chemisorption	48.00	ND	20	ND	ND	ND	ND	ND
H2 Chemisorption	21.00	ND	50	ND	70	ND	ND	ND
H2 Chemisorption	19.00	ND	50	ND	60	ND	ND	ND
CO Chemisorption	11.50	0.5	90	ND	ND	ND	ND	ND
CO Chemisorption	11.95	0.2	90	ND	ND	ND	ND	ND
CO Chemisorption	6.50	0.5	170	ND	ND	ND	ND	ND
CO Chemisorption	7.80	0.8	140	ND	ND	ND	ND	ND
CO Chemisorption	8.30	0.8	130	ND	ND	ND	ND	ND
CO Chemisorption	12.40	0.3	90	ND	ND	ND	ND	ND
CO Chemisorption	5.30	0.1	210	ND	ND	ND	ND	ND
CO Chemisorption	5.50	0.1	200	ND	ND	ND	ND	ND
CO Chemisorption	ND	ND	44	ND	ND	ND	30	10
CO Chemisorption	ND	ND	51	ND	ND	ND	32	15
CO Chemisorption	ND	ND	55	ND	ND	ND	33	13
CO Chemisorption	ND	ND	114	ND	ND	ND	63	32
H2-O2 Titration	25.00	ND	ND	ND	ND	ND	ND	ND
H2-O2 Titration	31.00	ND	ND	ND	ND	ND	ND	ND
H2-O2 Titration	34.00	ND	ND	ND	ND	ND	ND	ND
H2-O2 Titration	42.00	ND	ND	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	24	10
TEM	ND	ND	ND	ND	ND	ND	49	13
TEM	ND	ND	ND	ND	ND	ND	80	34
TEM	ND	ND	ND	ND	ND	ND	57	20
TEM	ND	ND	ND	ND	ND	ND	58	20
TEM	ND	ND	ND	ND	ND	ND	52	16
TEM	ND	ND	ND	ND	ND	ND	51	16
TEM	ND	ND	ND	ND	ND	ND	71	32
TEM	ND	ND	ND	ND	ND	ND	65	29
TEM	ND	ND	ND	ND	ND	ND	20	ND
CO Chemisorption	20.94	ND	53.518	ND	ND	ND	ND	ND
CO Chemisorption	7.90	ND	141.856	ND	ND	ND	ND	ND
H2 Chemisorption	16.00	ND	72	ND	ND	ND	80	ND
H2 Chemisorption	28.00	ND	40	ND	ND	ND	30	ND
TEM	ND	ND	ND	ND	ND	ND	34	13
TEM	ND	ND	ND	ND	ND	ND	59	ND
TEM	ND	ND	ND	ND	26	ND	29	ND
TEM	ND	ND	ND	ND	36	ND	45	ND
TEM	ND	ND	ND	ND	ND	ND	31.7	4.2

TEM	ND	ND	ND	ND	ND	ND	24.8	4.7
TEM	ND	ND	ND	ND	ND	ND	21	2
TEM	ND	ND	ND	ND	ND	ND	34.9	10.4
TEM	ND	ND	ND	ND	202	ND	178	ND
TEM	ND	ND	ND	ND	197	ND	169	ND
TEM	ND	ND	ND	ND	115	ND	94	ND
TEM	ND	ND	ND	ND	148	ND	134	ND
TEM	ND	ND	ND	ND	182	ND	161	ND
H2 chemisorption	39.00	ND	28	ND	ND	ND	34	18
CO Chemisorption	44.30	ND	25	ND	ND	ND	ND	ND
CO Chemisorption	18.60	ND	60	ND	ND	ND	ND	ND
CO Chemisorption	27.70	ND	41	ND	ND	ND	ND	ND
CO Chemisorption	43.10	ND	26	ND	ND	ND	ND	ND
H2 chemisorption	54.00	ND	20	ND	ND	ND	23	ND
H2 chemisorption	10.10	ND	113	ND	ND	ND	122	ND
H2 chemisorption	8.40	ND	134	ND	ND	ND	164	ND
XRD	ND	ND	ND	ND	97	ND	ND	ND
CO Chemisorption	21.40	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	39.60	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	44.70	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	12.30	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	11.70	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	16.80	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	44.10	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	25.70	ND	ND	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	30	ND	20	4
H2 Chemisorption	17.20	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	17.40	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	26.00	ND	43	ND	ND	ND	62	3
CO Chemisorption	35.00	ND	32	ND	ND	ND	35	2
CO Chemisorption	38.00	ND	29	ND	ND	ND	30	1
TEM	ND	ND	ND	ND	ND	ND	50	ND
TEM	ND	ND	ND	ND	ND	ND	45	ND
TEM	ND	ND	ND	ND	ND	ND	45	ND
TEM	ND	ND	ND	ND	ND	ND	45	ND
CO Chemisorption	23.00	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	22.00	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	12.00	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	4.00	ND	ND	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	27	ND
TEM	ND	ND	ND	ND	74	ND	68	ND

TEM	ND	ND	ND	ND	98	ND	91	ND
TEM	ND	ND	ND	ND	135	ND	136	ND
TEM	ND	ND	ND	ND	220	ND	200	ND
TEM	ND	ND	ND	ND	234	ND	218	ND
TEM	ND	ND	ND	ND	ND	ND	33	ND
SEM	ND	ND	ND	ND	133	ND	132	ND
XRD	ND	ND	ND	ND	72	ND	ND	ND
XRD	ND	ND	ND	ND	87	ND	ND	ND
XRD	ND	ND	ND	ND	101	ND	ND	ND
XRD	ND	ND	ND	ND	116	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	38	ND
TEM	ND	ND	ND	ND	ND	ND	47	ND
TEM	ND	ND	ND	ND	ND	ND	54	ND
H2 chemisorption	17.70	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	21.00	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	39.00	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	44.00	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	66.00	ND	ND	ND	ND	ND	ND	ND
H2 chemisorption	ND	ND	80	ND	ND	ND	ND	ND
H2 chemisorption	ND	ND	136	ND	ND	ND	ND	ND
CO Chemisorption	54.00	ND	ND	ND	21	ND	ND	ND
CO Chemisorption	9.00	ND	ND	ND	117	ND	ND	ND
CO Chemisorption	27.00	ND	ND	ND	42	ND	ND	ND
CO Chemisorption	86.00	ND	ND	ND	13	ND	ND	ND
CO Chemisorption	98.00	ND	ND	ND	11	ND	ND	ND
CO Chemisorption	22.00	ND	ND	ND	50	ND	ND	ND
TEM	ND	ND	ND	ND	164	ND	56	ND
CO Chemisorption	18.00	ND	ND	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	35	ND
TEM	ND	ND	ND	ND	ND	ND	34	ND
O2 chemisorption	1.30	ND	431	ND	468	ND	548	101
O2 chemisorption	3.70	ND	151	ND	132	ND	158	35
O2 chemisorption	15.50	ND	36	ND	21	ND	30	15
O2 chemisorption	15.20	ND	37	ND	21	ND	28	16
O2 chemisorption	17.10	ND	33	ND	21	ND	31	20
O2 chemisorption	16.10	ND	35	ND	22	ND	33	18
O2 chemisorption	13.90	ND	40	ND	25	ND	41	15
TEM	ND	ND	ND	ND	ND	ND	80	ND

CO Chemisorption	ND	ND	340	ND	400	ND	ND	ND
CO Chemisorption	ND	ND	150	ND	100	ND	ND	ND
CO Chemisorption	ND	ND	50	ND	70	ND	ND	ND
CO Chemisorption	ND	ND	80	ND	100	ND	ND	ND
H2 Chemisorption	13.00	ND	80	ND	ND	ND	ND	ND
CO Chemisorption	5.60	ND	200	ND	ND	ND	100	ND
TEM	ND	ND	ND	ND	ND	ND	100	ND
CO Chemisorption	12.90	ND	86	ND	ND	ND	30	ND
CO Chemisorption	8.20	ND	137	ND	ND	ND	30	ND
TEM	ND	ND	ND	ND	ND	ND	66.5	ND
TEM	ND	ND	ND	ND	ND	ND	83	ND
TEM	ND	ND	ND	ND	ND	ND	40	ND
TEM	ND	ND	ND	ND	ND	ND	30	ND
TEM	ND	ND	ND	ND	ND	ND	25	ND
H2 Chemisorption	12.00	ND	94	ND	ND	ND	92	ND
H2 Chemisorption	10.40	ND	108	ND	ND	ND	107	ND
H2 Chemisorption	9.40	ND	119	ND	ND	ND	113	ND
H2 Chemisorption	8.90	ND	126	ND	ND	ND	120	ND
H2 Chemisorption	36.40	ND	31	ND	ND	ND	30	ND
H2 Chemisorption	26.60	ND	42	ND	ND	ND	43	ND
H2 Chemisorption	18.40	ND	61	ND	ND	ND	61	ND
H2 Chemisorption	15.60	ND	65	ND	ND	ND	65	ND
TEM	ND	ND	ND	ND	ND	ND	75	ND
CO Chemisorption	ND	ND	85	ND	ND	ND	ND	ND
CO Chemisorption	ND	ND	25	ND	ND	ND	ND	ND
CO Chemisorption	ND	ND	23	ND	ND	ND	ND	ND
CO Chemisorption	ND	ND	14	ND	ND	ND	ND	ND
CO Chemisorption	ND	ND	12	ND	ND	ND	ND	ND
H2 Chemisorption	63.70	ND	ND	ND	ND	ND	50	ND
H2 Chemisorption	43.90	ND	ND	ND	ND	ND	45	ND
H2 Chemisorption	18.50	ND	ND	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	188	ND
CO Chemisorption	32.50	ND	34	ND	ND	ND	36	ND
TEM	ND	ND	ND	ND	ND	ND	42	ND
TEM	ND	ND	ND	ND	ND	ND	32	ND
TEM	ND	ND	ND	ND	ND	ND	39	ND
TEM	ND	ND	ND	ND	ND	ND	28	ND
H2 Chemisorption	38.00	ND	29	ND	ND	ND	ND	ND
H2 Chemisorption	37.00	ND	30	ND	ND	ND	ND	ND
H2 Chemisorption	26.00	ND	43	ND	ND	ND	ND	ND
H2 Chemisorption	7.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	25.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	24.00	ND	ND	ND	ND	ND	ND	ND

TEM	56.00	ND	ND	ND	ND	ND	20	ND
TEM	20.00	ND	ND	ND	ND	ND	55	ND
TEM	56.00	ND	ND	ND	ND	ND	20	ND
TEM	25.00	ND	ND	ND	ND	ND	45	ND
TEM	22.00	ND	ND	ND	ND	ND	50	ND
TEM	17.00	ND	ND	ND	ND	ND	65	15
TEM	10.00	ND	ND	ND	ND	ND	115	5
TEM	16.00	ND	ND	ND	ND	ND	70	ND
TEM	ND	ND	ND	ND	ND	ND	32	ND
TEM	ND	ND	ND	ND	ND	ND	22	ND
TEM	ND	ND	ND	ND	ND	ND	30	ND
TEM	ND	ND	ND	ND	ND	ND	100	ND
TEM	ND	ND	ND	ND	ND	ND	120	ND
TEM	ND	ND	ND	ND	ND	ND	25	ND
TEM	ND	ND	ND	ND	ND	ND	45	ND
H2 Chemisorption	5.40	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	14.70	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	12.60	ND	ND	ND	ND	ND	ND	ND
XRD	ND	ND	ND	ND	66	ND	ND	ND
TEM	20.00	ND	ND	ND	ND	ND	57	ND
CO Chemisorption	4.00	ND	ND	ND	ND	ND	10	ND
TEM	43.00	ND	ND	ND	ND	ND	26	ND
CO Chemisorption	69.00	ND	ND	ND	ND	ND	22	ND
TEM	22.00	ND	ND	ND	ND	ND	51	ND
TEM	27.00	ND	ND	ND	ND	ND	42	ND
TEM	32.00	ND	ND	ND	ND	ND	32	ND
CO Chemisorption	27.00	ND	ND	ND	ND	ND	43	ND
CO Chemisorption	34.00	ND	ND	ND	ND	ND	36	ND
CO Chemisorption	39.00	ND	ND	ND	ND	ND	31	ND
CO Chemisorption	37.00	ND	ND	ND	ND	ND	31	ND
CO Chemisorption	43.00	ND	ND	ND	ND	ND	29	ND
CO Chemisorption	48.00	ND	ND	ND	ND	ND	30	ND
H2 Chemisorption	51.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	55.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	12.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	24.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	40.00	ND	ND	ND	ND	ND	ND	ND
TEM	70.00	ND	ND	ND	ND	ND	15.9	3.9
TEM	65.00	ND	ND	ND	ND	ND	17.2	4.7
TEM	43.00	ND	ND	ND	ND	ND	26	7.7
TEM	ND	ND	ND	ND	28	2	14	7
TEM	ND	ND	ND	ND	37	1	31	14
TEM	ND	ND	ND	ND	124	3	96	35
CO Chemisorption	ND	ND	72	ND	48	2	43	22
TEM	ND	ND	ND	ND	39	3	25	13
CO Chemisorption	ND	ND	51	ND	ND	ND	20	4
CO Chemisorption	ND	ND	31	ND	ND	ND	31	8

TEM	ND	ND	ND	ND	ND	ND	49	ND
TEM	ND	ND	ND	ND	ND	ND	41	ND
TEM	ND	ND	ND	ND	ND	ND	38	ND
TEM	ND	ND	ND	ND	ND	ND	43	ND
TEM	ND	ND	ND	ND	ND	ND	62	ND
CO Chemisorption	ND	ND	58	ND	ND	ND	47	ND
CO Chemisorption	24.40	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	23.50	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	23.20	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	18.00	ND	62	ND	ND	ND	ND	ND
CO Chemisorption	30.00	ND	37	ND	ND	ND	ND	ND
CO Chemisorption	27.00	ND	41	ND	ND	ND	ND	ND
CO Chemisorption	35.00	ND	32	ND	ND	ND	ND	ND
CO Chemisorption	28.00	ND	40	ND	ND	ND	43	ND
CO Chemisorption	20.00	ND	56	ND	ND	ND	59	ND
CO Chemisorption	27.00	ND	41	ND	ND	ND	43	ND
CO Chemisorption	24.00	ND	47	ND	ND	ND	50	ND
CO Chemisorption	20.00	ND	56	ND	ND	ND	58	ND
CO Chemisorption	26	ND	43	ND	ND	ND	47	ND
CO Chemisorption	22	ND	51	ND	ND	ND	58	ND
CO Chemisorption	37	ND	30	ND	ND	ND	30	ND
CO Chemisorption	24	ND	47	ND	ND	ND	52	ND
CO Chemisorption	24	ND	47	ND	ND	ND	44	ND
CO Chemisorption	26	ND	43	ND	ND	ND	42	ND
CO Chemisorption	27.00	ND	41	ND	ND	ND	48	ND
CO Chemisorption	16.00	ND	70	ND	ND	ND	85	ND
CO Chemisorption	27.00	ND	41	ND	ND	ND	43	ND
CO Chemisorption	24.00	ND	47	ND	ND	ND	48	ND
CO Chemisorption	26.00	ND	43	ND	ND	ND	46	ND
CO Chemisorption	27.00	ND	41	ND	ND	ND	43	ND
TEM	ND	ND	ND	ND	ND	ND	41	ND
TEM	ND	ND	ND	ND	ND	ND	64	ND
TEM	ND	ND	ND	ND	ND	ND	73	ND
TEM	ND	ND	ND	ND	ND	ND	85	ND
TEM	ND	ND	ND	ND	ND	ND	94	ND
TEM	ND	ND	ND	ND	ND	ND	104	ND
TEM	ND	ND	ND	ND	ND	ND	133	ND
TEM	ND	ND	ND	ND	ND	ND	200	ND

TEM	ND	ND	ND	ND	ND	ND	159.3	54.2
TEM	ND	ND	ND	ND	ND	ND	7	ND
TEM	ND	ND	ND	ND	ND	ND	10	ND
TEM	ND	ND	ND	ND	ND	ND	8	ND
O2 Chemisorption	0.34	ND	ND	ND	ND	ND	ND	ND
O2 Chemisorption	0.37	ND	ND	ND	ND	ND	ND	ND
O2 Chemisorption	0.27	ND	ND	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	15	ND
TEM	ND	ND	ND	ND	ND	ND	20	ND
TEM	ND	ND	ND	ND	ND	ND	100	ND
TEM	ND	ND	ND	ND	ND	ND	200	ND
TEM	ND	ND	ND	ND	ND	ND	250	ND
CO Chemisorption	85.4	ND	13.1	ND	ND	ND	ND	ND
CO Chemisorption	60.8	ND	18.4	ND	ND	ND	ND	ND
CO Chemisorption	70.7	ND	15.9	ND	ND	ND	ND	ND
CO Chemisorption	81.2	ND	13.8	ND	ND	ND	ND	ND
CO Chemisorption	96	ND	11.7	ND	ND	ND	ND	ND
CO Chemisorption	90.5	ND	12.4	ND	ND	ND	ND	ND
CO Chemisorption	84.9	ND	13.2	ND	ND	ND	ND	ND
CO Chemisorption	64.2	ND	17.5	ND	ND	ND	ND	ND
CO Chemisorption	26	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	23.3	ND	ND	ND	ND	ND	30	ND
H2 Chemisorption	ND	ND	24	ND	ND	ND	30	13
H2 Chemisorption	ND	ND	22	ND	ND	ND	25	11
CO Chemisorption	5.7	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	4.8	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	4.2	ND	ND	ND	ND	ND	ND	ND
TEM	51	ND	ND	ND	ND	ND	22	ND
TEM	51	ND	ND	ND	ND	ND	22	ND
TEM	48	ND	ND	ND	ND	ND	23	ND
TEM	45	ND	ND	ND	ND	ND	25	ND
CO Chemisorption	36	ND	ND	ND	ND	ND	23	ND
CO Chemisorption	16	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	23	ND	48	ND	ND	ND	ND	ND
CO Chemisorption	21	ND	53	ND	ND	ND	ND	ND
CO Chemisorption	32	ND	36	ND	ND	ND	ND	ND
CO Chemisorption	20	ND	57	ND	ND	ND	ND	ND
CO Chemisorption	41	ND	27	ND	ND	ND	ND	ND
CO Chemisorption	10	ND	111	ND	ND	ND	ND	ND
TEM	24.1	ND	30	ND	58	ND	40	ND
TEM	19.8	ND	ND	ND	81	ND	48	ND
TEM	17.8	ND	ND	ND	78	ND	55	ND
TEM	ND	ND	ND	ND	ND	ND	70	10
TEM	ND	ND	ND	ND	ND	ND	70	10
TEM	ND	ND	ND	ND	ND	ND	70	10
TEM	ND	ND	ND	ND	ND	ND	70	10

TEM	ND	ND	ND	ND	ND	ND	70	10
TEM	ND	ND	ND	ND	ND	ND	70	10
TEM	ND	ND	ND	ND	ND	ND	70	10
CO Chemisorption	20.1	ND	55	ND	ND	ND	ND	ND
CO Chemisorption	24.5	ND	45	ND	ND	ND	ND	ND
CO Chemisorption	39.8	ND	28	ND	ND	ND	ND	ND
CO Chemisorption	36	ND	30	ND	30	ND	40	ND
CO Chemisorption	34.6	ND	25	ND	ND	ND	43	14
CO Chemisorption	5.9	ND	149	ND	ND	ND	62	32
CO Chemisorption	4	ND	220	ND	ND	ND	87	43
CO Chemisorption	100	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	11	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	18	ND	ND	ND	213	ND	152	ND
CO Chemisorption	16	ND	ND	ND	213	ND	167	ND
CO Chemisorption	20	ND	ND	ND	213	ND	142	ND
CO Chemisorption	ND	ND	26	ND	ND	ND	48	11
CO Chemisorption	ND	ND	96	ND	ND	ND	160	70
CO Chemisorption	ND	ND	1250	ND	ND	ND	750	ND
CO Chemisorption	18.2	ND	65	ND	ND	ND	60	ND
CO Chemisorption	23.8	ND	49	ND	ND	ND	30	ND
XRD	ND	ND	ND	ND	90	ND	ND	ND
XRD	ND	ND	ND	ND	160	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	62	ND
TEM	ND	ND	ND	ND	ND	ND	56	ND
TEM	ND	ND	ND	ND	ND	ND	56	ND
TEM	ND	ND	ND	ND	ND	ND	64	ND
TEM	ND	ND	ND	ND	ND	ND	56	ND
TEM	ND	ND	ND	ND	ND	ND	18	4
TEM	ND	ND	ND	ND	ND	ND	13	4
TEM	ND	ND	ND	ND	ND	ND	25	10
TEM	ND	ND	ND	ND	ND	ND	57	18
TEM	ND	ND	ND	ND	ND	ND	23	7
TEM	ND	ND	ND	ND	ND	ND	28	8
TEM	ND	ND	ND	ND	ND	ND	38	9
CO Chemisorption	52.2	ND	21	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	111	ND	157	ND
TEM	ND	ND	ND	ND	134	ND	165	ND
TEM	ND	ND	ND	ND	32	ND	51	ND
TEM	ND	ND	ND	ND	14	ND	16	ND
CO Chemisorption	32	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	38	ND	ND	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	113	40
TEM	ND	ND	ND	ND	ND	ND	104	40
TEM	ND	ND	ND	ND	ND	ND	14	ND
TEM	ND	ND	ND	ND	ND	ND	32	ND
TEM	ND	ND	ND	ND	ND	ND	63	ND
TEM	ND	ND	ND	ND	ND	ND	88	ND
TEM	ND	ND	ND	ND	ND	ND	93	ND
TEM	ND	ND	ND	ND	ND	ND	283	ND
TEM	ND	ND	ND	ND	ND	ND	31	ND
TEM	ND	ND	ND	ND	ND	ND	28	ND
TEM	ND	ND	ND	ND	ND	ND	43	ND

TEM	ND	ND	ND	ND	ND	ND	49	ND
TEM	ND	ND	ND	ND	ND	ND	54	ND
TEM	ND	ND	ND	ND	ND	ND	73	ND
CO Chemisorption	3	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	10	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	7	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	6	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	4	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	18	ND	ND	ND	ND	ND	ND	ND
XRD	ND	ND	ND	ND	90	ND	ND	ND
XRD	ND	ND	ND	ND	90	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	15	ND
TEM	ND	ND	ND	ND	ND	ND	38	12.5
TEM	ND	ND	ND	ND	ND	ND	9	3.5
CO Chemisorption	57.9	ND	19	ND	ND	ND	ND	ND
CO Chemisorption	30.2	ND	37	ND	ND	ND	ND	ND
CO Chemisorption	20.8	ND	54	ND	ND	ND	49	27
CO Chemisorption	14.5	ND	77	ND	ND	ND	ND	ND
CO Chemisorption	5.9	ND	191	ND	ND	ND	ND	ND
CO Chemisorption	72.7	ND	15	ND	ND	ND	11	10
CO Chemisorption	29.2	ND	38	ND	ND	ND	41	9
CO Chemisorption	21	ND	54	ND	ND	ND	52	25
CO Chemisorption	15.4	ND	73	ND	ND	ND	64	20
CO Chemisorption	7.8	ND	144	ND	ND	ND	99	55
CO Chemisorption	5.8	ND	192	ND	ND	ND	226	120
CO Chemisorption	32.2	ND	35	ND	ND	ND	ND	ND
CO Chemisorption	27	ND	41	ND	ND	ND	ND	ND
CO Chemisorption	21.1	ND	53	ND	ND	ND	44	23
CO Chemisorption	12	ND	93	ND	ND	ND	ND	ND
CO Chemisorption	5.8	ND	192	ND	ND	ND	ND	ND
H2 Chemisorption	23.3	ND	469	ND	ND	ND	ND	ND
H2 Chemisorption	11.4	ND	865	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	15	ND
TEM	ND	ND	ND	ND	ND	ND	35	ND
CO Chemisorption	4	ND	278	ND	ND	ND	77	ND
CO Chemisorption	14	ND	79	ND	ND	ND	59	ND
TEM	ND	ND	ND	ND	ND	ND	10	ND
TEM	ND	ND	ND	ND	ND	ND	25	ND
TEM	ND	ND	ND	ND	ND	ND	40	ND
TEM	ND	ND	ND	ND	ND	ND	55	ND
TEM	ND	ND	ND	ND	ND	ND	70	ND
H2 Chemisorption	25.9	ND	46	ND	54	ND	ND	ND
H2 Chemisorption	13.1	ND	89	ND	73	ND	ND	ND

H2 Chemisorption	6.5	ND	182	ND	157	ND	ND	ND
H2 Chemisorption	13.8	ND	81	ND	ND	ND	ND	ND
H2 Chemisorption	34.5	ND	32	ND	ND	ND	ND	ND
H2 Chemisorption	26.4	ND	43	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	30	ND
TEM	ND	ND	ND	ND	ND	ND	25	ND
TEM	ND	ND	ND	ND	ND	ND	32	ND
TEM	ND	ND	ND	ND	ND	ND	14	ND
TEM	ND	ND	ND	ND	ND	ND	37	ND
TEM	ND	ND	ND	ND	ND	ND	71	ND
TEM	ND	ND	ND	ND	ND	ND	19	ND
TEM	ND	ND	ND	ND	ND	ND	25	ND
TEM	ND	ND	ND	ND	ND	ND	27	ND
TEM	ND	ND	ND	ND	34	ND	40	ND
TEM	ND	ND	ND	ND	29	ND	32	ND
H2 Chemisorption	ND	ND	36	ND	26	ND	32	ND
H2 Chemisorption	ND	ND	36	ND	41	ND	ND	ND
H2 Chemisorption	ND	ND	6	ND	ND	ND	10	ND
H2 Chemisorption	ND	ND	18	ND	33	ND	ND	ND
H2 Chemisorption	ND	ND	6	ND	ND	ND	10	ND
TEM	ND	ND	ND	ND	ND	ND	21	5
TEM	ND	ND	ND	ND	ND	ND	29	8
TEM	ND	ND	ND	ND	ND	ND	63	14
TEM	ND	ND	ND	ND	ND	ND	46	12
CO Chemisorption	57	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	47	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	33	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	15	ND	ND	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	33.2	10.6
TEM	ND	ND	ND	ND	ND	ND	29.7	9.6
TEM	ND	ND	ND	ND	ND	ND	40	ND
TEM	ND	ND	ND	ND	ND	ND	60	ND
TEM	ND	ND	ND	ND	ND	ND	150	ND
CO Chemisorption	29	ND	38	ND	ND	ND	ND	ND
CO Chemisorption	21	ND	53	ND	ND	ND	74	ND
CO Chemisorption	27	ND	41	ND	ND	ND	ND	ND
CO Chemisorption	21	ND	53	ND	ND	ND	107	ND
CO Chemisorption	19	ND	58	ND	ND	ND	ND	ND
CO Chemisorption	16	ND	69	ND	ND	ND	ND	ND
CO Chemisorption	32	ND	35	ND	ND	ND	57	ND
CO Chemisorption	17	ND	65	ND	ND	ND	102	ND
CO Chemisorption	15	ND	74	ND	ND	ND	ND	ND

CO Chemisorption	7	ND	159	ND	ND	ND	ND	ND
CO Chemisorption	21	ND	53	ND	ND	ND	ND	ND
CO Chemisorption	12	ND	93	ND	ND	ND	ND	ND
CO Chemisorption	21	ND	53	ND	ND	ND	ND	ND
CO Chemisorption	14	ND	79	ND	ND	ND	163	ND
CO Chemisorption	14	ND	79	ND	ND	ND	ND	ND
CO Chemisorption	8	ND	139	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	22.5	11.6
TEM	ND	ND	ND	ND	ND	ND	21.1	8
TEM	ND	ND	ND	ND	ND	ND	17.8	7.8
TEM	ND	ND	ND	ND	ND	ND	21.7	11
CO Chemisorption	42	ND	ND	ND	ND	ND	27	3
TEM	ND	ND	ND	ND	ND	ND	47	ND
TEM	ND	ND	ND	ND	ND	ND	61	ND
TEM	ND	ND	ND	ND	ND	ND	43	ND
TEM	ND	ND	ND	ND	ND	ND	59	ND
CO Chemisorption	13	ND	85	ND	ND	ND	ND	ND
CO Chemisorption	17	ND	67	ND	ND	ND	ND	ND
CO Chemisorption	17	ND	66	ND	ND	ND	ND	ND
CO Chemisorption	60	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	34	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	57	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	4	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	4.9	ND	180	ND	130	ND	174	39
TEM	ND	ND	ND	ND	29	ND	60	ND
TEM	ND	ND	ND	ND	40	ND	30	ND
H2 Chemisorption	ND	ND	7	ND	ND	ND	9	2
H2 Chemisorption	ND	ND	8	ND	ND	ND	14	3
H2 Chemisorption	ND	ND	6	ND	ND	ND	8	3
H2 Chemisorption	ND	ND	8	ND	ND	ND	14	3
H2 Chemisorption	ND	ND	8	ND	ND	ND	10	2
H2 Chemisorption	ND	ND	14	ND	ND	ND	15	4
H2 Chemisorption	ND	ND	10	ND	ND	ND	8	2
H2 Chemisorption	ND	ND	20	ND	29	ND	11	3
H2 Chemisorption	ND	ND	18	ND	52	ND	6	2
H2 Chemisorption	ND	ND	29	ND	48	ND	10	3
H2 Chemisorption	ND	ND	3	ND	ND	ND	7	2
H2 Chemisorption	ND	ND	8	ND	ND	ND	8	2
H2 Chemisorption	ND	ND	9	ND	95	ND	9	2
CO Chemisorption	33	ND	34	ND	ND	ND	ND	ND
CO Chemisorption	26	ND	43	ND	ND	ND	ND	ND
CO Chemisorption	25	ND	45	ND	ND	ND	ND	ND
CO Chemisorption	10	ND	110	ND	ND	ND	ND	ND
CO Chemisorption	23	ND	49	ND	ND	ND	ND	ND
CO Chemisorption	33.5	ND	ND	ND	ND	ND	9	4
CO Chemisorption	25	ND	ND	ND	ND	ND	18	4
CO Chemisorption	21.1	ND	ND	ND	ND	ND	13	4
CO Chemisorption	15	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	38	ND	ND	ND	ND	ND	11	2
CO Chemisorption	36	ND	ND	ND	ND	ND	13	2
TEM	ND	ND	ND	ND	ND	ND	45	ND

TEM	ND	ND	ND	ND	ND	ND	45	ND
TEM	ND	ND	ND	ND	ND	ND	45	ND
TEM	ND	ND	ND	ND	ND	ND	75	ND
XRD	ND	ND	ND	ND	230	20	ND	ND
XRD	ND	ND	ND	ND	210	20	ND	ND
XRD	ND	ND	ND	ND	180	10	ND	ND
XRD	ND	ND	ND	ND	190	10	ND	ND
XRD	ND	ND	ND	ND	170	10	ND	ND
TEM	ND	ND	ND	ND	ND	ND	125	ND
XRD	ND	ND	ND	ND	110	20	ND	ND
XRD	ND	ND	ND	ND	180	20	ND	ND
XRD	ND	ND	ND	ND	350	20	ND	ND
CO Chemisorption	35.4	ND	32	ND	ND	ND	ND	ND
CO Chemisorption	38.2	ND	29	ND	ND	ND	ND	ND
CO Chemisorption	41.3	ND	27	ND	ND	ND	ND	ND
CO Chemisorption	29.3	ND	38	ND	ND	ND	ND	ND
CO Chemisorption	25.4	ND	44	ND	ND	ND	ND	ND
CO Chemisorption	46.7	ND	24	ND	ND	ND	ND	ND
CO Chemisorption	54.7	ND	20	ND	ND	ND	ND	ND
CO Chemisorption	57.7	ND	19	ND	ND	ND	ND	ND
CO Chemisorption	50.5	ND	22	ND	ND	ND	ND	ND
CO Chemisorption	38	ND	29	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	50.4	11.1
TEM	ND	ND	ND	ND	ND	ND	62.2	12.2
CO Chemisorption	13.07	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	17.37	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	17.40	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	23.60	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	22.65	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	18.76	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	17.97	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	17.51	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	17.17	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	8.53	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	22.22	ND	ND	ND	ND	ND	ND	ND

CO Chemisorption	26.00	ND	ND	ND	ND	ND	29	ND
CO Chemisorption	5.00	ND	ND	ND	ND	ND	92	ND
CO Chemisorption	32.00	ND	ND	ND	ND	ND	27	ND
CO Chemisorption	8.00	ND	ND	ND	ND	ND	52	ND
CO Chemisorption	10.00	ND	ND	ND	ND	ND	43	ND
CO Chemisorption	23.90	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	44.20	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	36.20	ND	ND	ND	ND	ND	55	ND
CO Chemisorption	21.30	ND	ND	ND	ND	ND	74	ND
CO Chemisorption	81.80	ND	13.6	ND	ND	ND	18.1	ND
CO Chemisorption	69.10	ND	15.3	ND	ND	ND	19.3	ND
CO Chemisorption	56.20	ND	17.7	ND	ND	ND	22.6	ND
CO Chemisorption	41.60	ND	26.9	ND	ND	ND	29.4	ND
CO Chemisorption	28.30	ND	37.6	ND	ND	ND	32.1	ND
CO Chemisorption	10.30	ND	103.3	ND	ND	ND	114.6	ND
CO Chemisorption	ND	ND	ND	ND	ND	ND	71.3	ND
CO Chemisorption	87.00	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	83.00	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	75.00	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	19.80	ND	ND	ND	ND	ND	57.7	26.84
CO Chemisorption	30.60	ND	ND	ND	ND	ND	48.4	33.06
CO Chemisorption	32.20	ND	35	ND	ND	ND	ND	ND
CO Chemisorption	40.60	ND	28	ND	ND	ND	ND	ND
CO Chemisorption	43.00	ND	26	ND	ND	ND	ND	ND
CO Chemisorption	29.20	ND	38	ND	ND	ND	ND	ND
CO Chemisorption	27.00	ND	41	ND	ND	ND	ND	ND
CO Chemisorption	24.10	ND	46	ND	ND	ND	ND	ND
CO Chemisorption	36.20	ND	32	ND	ND	ND	ND	ND
CO Chemisorption	35.80	ND	31	ND	ND	ND	ND	ND
CO Chemisorption	36.50	ND	31	ND	ND	ND	ND	ND
CO Chemisorption	36.90	ND	30	ND	ND	ND	ND	ND
CO Chemisorption	5.40	ND	ND	ND	ND	ND	41.6	ND
TEM	ND	ND	ND	ND	ND	ND	27.2	ND
CO Chemisorption	5.30	ND	ND	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	30.9	ND
CO Chemisorption	19.40	ND	ND	ND	ND	ND	21.5	ND
CO Chemisorption	7.30	ND	ND	ND	ND	ND	ND	ND

CO Chemisorption	15.00	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	59.40	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	41.50	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	32.40	ND	ND	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	47	13
CO Chemisorption	93.00	ND	12	ND	ND	ND	ND	ND
CO Chemisorption	73.00	ND	15	ND	ND	ND	ND	ND
CO Chemisorption	54.00	ND	21	ND	ND	ND	ND	ND
CO Chemisorption	34.00	ND	33	ND	ND	ND	ND	ND
CO Chemisorption	21.00	ND	53	ND	ND	ND	ND	ND
CO Chemisorption	47.00	ND	26	ND	ND	ND	ND	ND
CO Chemisorption	32.00	ND	35	ND	ND	ND	ND	ND
CO Chemisorption	14.00	ND	83	ND	ND	ND	ND	ND
CO Chemisorption	8.50	ND	130	ND	ND	ND	ND	ND
CO Chemisorption	36.00	ND	30	ND	ND	ND	33	ND
TEM	ND	ND	ND	ND	ND	ND	22.5	6.5
TEM	ND	ND	ND	ND	ND	ND	19.9	5.1
TEM	ND	ND	ND	ND	ND	ND	17.1	4
TEM	ND	ND	ND	ND	ND	ND	17.5	2.9
TEM	ND	ND	ND	ND	ND	ND	25.2	8
CO Chemisorption	19.60	ND	67	ND	ND	ND	ND	ND
CO Chemisorption	22.60	ND	58	ND	ND	ND	ND	ND
CO Chemisorption	10.00	ND	128	ND	ND	ND	ND	ND
CO Chemisorption	45.50	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	28.30	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	19.00	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	13.70	ND	ND	ND	ND	ND	80	ND
TEM	ND	ND	ND	ND	ND	ND	70	ND
TEM	ND	ND	ND	ND	ND	ND	84	ND
TEM	ND	ND	ND	ND	ND	ND	45	ND
TEM	ND	ND	ND	ND	ND	ND	93	ND
TEM	ND	ND	ND	ND	ND	ND	46	ND
CO Chemisorption	23.00	ND	48.8	ND	ND	ND	ND	ND
CO Chemisorption	20.90	ND	53.7	ND	ND	ND	ND	ND
CO Chemisorption	11.90	ND	94	ND	ND	ND	ND	ND
CO Chemisorption	8.90	ND	126.7	ND	ND	ND	ND	ND
CO Chemisorption	6.30	ND	178.2	ND	ND	ND	ND	ND
CO Chemisorption	83.80	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	72.60	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	61.10	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	56.90	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	40.60	ND	ND	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	40	ND
TEM	ND	ND	ND	ND	ND	ND	40	ND

TEM	ND	ND	ND	ND	ND	ND	100	ND
XRD	ND	ND	ND	ND	30	ND	NA	ND
H2 Chemisorption	5.00	ND	180	ND	ND	ND	ND	ND
H2 Chemisorption	0.00	ND	1000	ND	ND	ND	ND	ND
CO Pulse Adsorption	11.70	ND	161	ND	ND	ND	ND	ND
CO Pulse Adsorption	12.10	ND	155	ND	ND	ND	ND	ND
CO Pulse Adsorption	12.80	ND	142	ND	ND	ND	ND	ND
CO Pulse Adsorption	13.20	ND	133	ND	ND	ND	ND	ND
CO Pulse Adsorption	16.10	ND	118	ND	ND	ND	ND	ND
CO Pulse Adsorption	17.10	ND	108	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	80	ND
TEM	ND	ND	ND	ND	ND	ND	63	ND
TEM	ND	ND	ND	ND	ND	ND	52	ND
H2 Adsorption	ND	ND	22.7	ND	ND	ND	ND	ND
H2 Adsorption	ND	ND	34.5	ND	ND	ND	ND	ND
H2 Adsorption	ND	ND	22.2	ND	ND	ND	ND	ND
H2 Adsorption	ND	ND	21.6	ND	ND	ND	ND	ND
H2 Adsorption	ND	ND	23.5	ND	ND	ND	ND	ND
H2 Adsorption	ND	ND	32.6	ND	ND	ND	ND	ND

H2 Adsorption	ND	ND	60.4	ND	ND	ND	ND	ND
H2 Adsorption	ND	ND	67.5	ND	ND	ND	ND	ND
XRD	ND	ND	ND	ND	30	ND	ND	ND
XRD	ND	ND	ND	ND	30	ND	ND	ND
XRD	ND	ND	ND	ND	30	ND	ND	ND
CO Chemisorption	22.00	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	29.00	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	8.00	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	25.00	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	7.00	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	16.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	31.10	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	28.30	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	21.70	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	17.10	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	13.20	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	37.70	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	39.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	46.10	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	45.30	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	43.90	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	14.00	ND	79	ND	ND	ND	ND	ND
H2 Chemisorption	21.00	ND	52	ND	ND	ND	ND	ND
H2 Chemisorption	38.00	ND	29	ND	ND	ND	ND	ND
H2 Chemisorption	52.00	ND	21	ND	ND	ND	ND	ND
H2 Chemisorption	80.00	ND	14	ND	ND	ND	ND	ND
H2 Chemisorption	20.00	ND	55	ND	ND	ND	ND	ND
H2 Chemisorption	33.00	ND	33	ND	ND	ND	ND	ND
H2 Chemisorption	50.00	ND	22	ND	ND	ND	ND	ND
H2 Chemisorption	60.00	ND	18	ND	ND	ND	ND	ND
H2 Chemisorption	75.00	ND	15	ND	ND	ND	ND	ND
H2 Chemisorption	80.00	ND	14	ND	ND	ND	ND	ND
H2 Chemisorption	70.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	13.00	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	33.60	ND	33	ND	ND	ND	ND	ND
CO Chemisorption	20.80	ND	53	ND	ND	ND	ND	ND

CO Chemisorption	16.10	ND	68	ND	ND	ND	ND	ND
CO Chemisorption	15.70	ND	70	ND	ND	ND	ND	ND
CO Chemisorption	37.40	ND	30	ND	ND	ND	35	12
CO Chemisorption	13.60	ND	85	ND	ND	ND	80	30
CO Chemisorption	3.00	ND	369	ND	ND	ND	320	180
CO Chemisorption	21.40	ND	ND	ND	ND	ND	49	NND
CO Chemisorption	16.90	ND	ND	ND	ND	ND	38	ND
H2 Chemisorption	8.40	ND	ND	ND	ND	ND	5000	ND
H2 Chemisorption	30.58	ND	ND	ND	ND	ND	500	ND
H2 Chemisorption	47.00	ND	24	ND	ND	ND	31	ND
CO Chemisorption	47.00	ND	20	ND	ND	ND	ND	ND
CO Chemisorption	7.00	ND	127	ND	ND	ND	ND	ND
CO Chemisorption	72.00	ND	13.4	ND	ND	ND	ND	ND
CO Chemisorption	8.00	ND	117	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	23	ND
TEM	ND	ND	ND	ND	ND	ND	31	ND
CO Chemisorption	2.30	ND	486	ND	ND	ND	ND	ND
CO Chemisorption	8.20	ND	137	ND	ND	ND	ND	ND
CO Pulse Adsorption	70.29	ND	ND	ND	ND	ND	ND	ND
CO Pulse Adsorption	53.82	ND	ND	ND	ND	ND	ND	ND
CO Pulse Adsorption	47.90	ND	ND	ND	ND	ND	83.4	ND
CO Pulse Adsorption	42.63	ND	ND	ND	ND	ND	ND	ND
CO Pulse Adsorption	87.83	ND	ND	ND	ND	ND	21.6	ND
CO Pulse Adsorption	68.70	ND	ND	ND	ND	ND	45.9	ND
CO Pulse Adsorption	36.22	ND	ND	ND	ND	ND	137.3	ND
H2 Chemisorption	64.00	ND	17	ND	ND	ND	ND	ND
H2 Chemisorption	40.00	ND	28	ND	ND	ND	ND	ND
H2 Chemisorption	50.00	ND	22	ND	ND	ND	ND	ND
H2 Chemisorption	38.00	ND	29	ND	ND	ND	ND	ND
H2 Chemisorption	14.00	ND	84	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	40	ND
TEM	ND	ND	ND	ND	ND	ND	25	ND
TEM	ND	ND	ND	ND	ND	ND	100	ND
TEM	ND	ND	ND	ND	ND	ND	80	ND
H2 Chemisorption	62.20	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	52.50	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	39.00	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	24.00	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	23.00	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	25.00	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	19.70	ND	57	ND	ND	ND	ND	ND

HREM	37.00	ND	ND	ND	ND	ND	31	1
HREM	35.00	ND	ND	ND	ND	ND	33	1
HREM	ND	ND	ND	ND	80	ND	72	ND
CO Chemisorption	17.33	ND	65	ND	ND	ND	ND	ND
CO Chemisorption	25.35	ND	44	ND	ND	ND	ND	ND
CO Chemisorption	23.47	ND	48	ND	ND	ND	ND	ND
CO Chemisorption	25.00	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	8.90	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	54.00	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	10.00	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	16.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	43.50	ND	25.8	ND	ND	ND	22.6	ND
H2 Chemisorption	72.60	ND	15.4	ND	ND	ND	11.7	ND
H2 Chemisorption	68.40	ND	16.4	ND	ND	ND	12.5	ND
H2 Chemisorption	52.80	ND	21.3	ND	ND	ND	19.1	ND
H2 Chemisorption	38.10	ND	33.6	ND	ND	ND	27.4	ND
TEM	ND	ND	ND	ND	ND	ND	36	ND
TEM	ND	ND	ND	ND	ND	ND	72	ND
TEM	ND	ND	ND	ND	ND	ND	32	ND
TEM	ND	ND	ND	ND	ND	ND	44	ND
TEM	ND	ND	ND	ND	ND	ND	46	ND
TEM	ND	ND	ND	ND	34	ND	35	ND
TEM	ND	ND	ND	ND	43	ND	50	ND
TEM	ND	ND	ND	ND	57	ND	61	ND
H2 Chemisorption	11.00	ND	ND	ND	ND	ND	130	ND
H2 Chemisorption	44.00	ND	ND	ND	ND	ND	30	ND
H2 Chemisorption	13.00	ND	ND	ND	ND	ND	100	ND
H2 Chemisorption	44.00	ND	ND	ND	ND	ND	30	ND
CO Chemisorption	6.80	ND	ND	ND	ND	ND	213	ND
CO Chemisorption	11.00	ND	ND	ND	ND	ND	158	ND
CO Chemisorption	31.80	ND	ND	ND	ND	ND	40	ND
CO Pulse Adsorption	33.00	ND	ND	ND	ND	ND	ND	ND
CO Pulse Adsorption	12.00	ND	ND	ND	ND	ND	ND	ND
CO Pulse Adsorption	11.00	ND	ND	ND	ND	ND	ND	ND
CO Pulse Adsorption	3.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	ND	ND	92	ND	82	ND	76	ND
TEM	ND	ND	ND	ND	127	ND	108	ND
H2 Chemisorption	ND	ND	94	ND	77	ND	60	ND
H2 Chemisorption	47.00	ND	28	ND	ND	ND	ND	ND
CO Chemisorption	6.50	ND	ND	ND	ND	ND	90	ND
CO Chemisorption	9.70	ND	ND	ND	ND	ND	40	ND
CO Pulse Adsorption	49.20	ND	ND	ND	ND	ND	ND	ND
CO Pulse Adsorption	21.30	ND	ND	ND	ND	ND	ND	ND
CO Pulse Adsorption	49.80	ND	ND	ND	ND	ND	ND	ND

CO Pulse Adsorption	31.30	ND	ND	ND	ND	ND	ND	ND
CO Pulse Adsorption	29.50	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	23.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	39.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	29.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	30.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	35.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	0.20	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	0.20	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	1.70	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	9.50	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	19.00	ND	ND	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	31	ND
TEM	ND	ND	ND	ND	ND	ND	27	11
CO Chemisorption	2.30	ND	490	ND	ND	ND	ND	ND
CO Chemisorption	1.10	ND	1000	ND	ND	ND	ND	ND
CO Chemisorption	8.90	ND	130	ND	ND	ND	ND	ND
CO Chemisorption	13.90	ND	ND	ND	ND	ND	33.2	ND
CO Chemisorption	14.30	ND	ND	ND	ND	ND	30.4	ND
CO Chemisorption	18.00	ND	ND	ND	ND	ND	21.7	ND
CO Chemisorption	21.30	ND	ND	ND	ND	ND	17.4	ND
CO Chemisorption	11.90	ND	94	ND	ND	ND	ND	ND
CO Chemisorption	32.90	ND	28	ND	ND	ND	ND	ND
CO Chemisorption	5.60	ND	168	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	147.2	27.6
TEM	ND	ND	ND	ND	ND	ND	219.3	11.5
TEM	ND	ND	ND	ND	ND	ND	91	4.2
TEM	ND	ND	ND	ND	ND	ND	213.5	4.2
CO Chemisorption	24.00	ND	ND	ND	ND	ND	35	11
CO Chemisorption	19.00	ND	ND	ND	ND	ND	35	12
CO Chemisorption	22.00	ND	ND	ND	ND	ND	33	11
H2 Chemisorption	34.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	20.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	14.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	12.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	52.00	ND	19	ND	ND	ND	ND	ND
H2 Chemisorption	46.00	ND	22	ND	ND	ND	25	ND
H2 Chemisorption	39.00	ND	27	ND	ND	ND	30	ND
H2 Chemisorption	59.00	ND	18	ND	ND	ND	ND	ND

H2 Chemisorption	62.00	ND	17	ND	ND	ND	ND	ND
CO Chemisorption	7.91	ND	142	ND	ND	ND	158	ND
CO Chemisorption	36.30	ND	30.9	ND	ND	ND	28	ND
CO Chemisorption	17.30	ND	64.7	ND	ND	ND	61	ND
CO Chemisorption	33.90	ND	33	ND	ND	ND	32	ND
CO Chemisorption	6.73	ND	129	ND	ND	ND	ND	ND
CO Chemisorption	6.37	ND	147	ND	ND	ND	ND	ND
CO Chemisorption	5.80	ND	83	ND	ND	ND	84	15
CO Chemisorption	59.00	ND	8	ND	ND	ND	27	8
CO Chemisorption	12.00	ND	90	ND	150	ND	66	ND
CO Chemisorption	19.00	ND	59	ND	ND	ND	63	ND
CO Chemisorption	88.00	ND	13	ND	ND	ND	39	ND
CO Chemisorption	21.80	ND	ND	ND	ND	ND	46	ND
CO Chemisorption	15.90	ND	ND	ND	ND	ND	40	ND
CO Chemisorption	22.20	ND	ND	ND	ND	ND	49	ND
CO Chemisorption	54.50	ND	20.6	ND	ND	ND	ND	ND
CO Chemisorption	42.50	ND	26.3	ND	ND	ND	ND	ND
CO Chemisorption	46.00	ND	24.4	ND	ND	ND	ND	ND
CO Chemisorption	71.00	7	15	1	ND	ND	ND	ND
CO Chemisorption	71.00	1	16	1	ND	ND	ND	ND
CO Chemisorption	54.00	11	22	1	ND	ND	ND	ND
CO Chemisorption	45.00	9	26	5	ND	ND	ND	ND
CO Chemisorption	27.00	3	41	4	ND	ND	ND	ND
CO Chemisorption	24.00	9	52	11	ND	ND	ND	ND
CO Chemisorption	13.00	2	90	11	ND	ND	ND	ND
CO Chemisorption	6.00	ND	191	ND	ND	ND	ND	ND
CO Chemisorption	97.00	ND	12	ND	ND	ND	ND	ND
CO Chemisorption	83.00	ND	14	ND	ND	ND	ND	ND
CO Chemisorption	73.00	ND	15	ND	ND	ND	ND	ND
CO Chemisorption	29.00	ND	38	ND	ND	ND	ND	ND
CO Chemisorption	21.00	ND	54	ND	ND	ND	ND	ND
CO Chemisorption	15.00	ND	73	ND	ND	ND	ND	ND
CO Chemisorption	8.00	ND	144	ND	ND	ND	ND	ND
CO Chemisorption	6.00	ND	192	ND	ND	ND	ND	ND
H2 Chemisorption	22.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	5.00	ND	ND	ND	ND	ND	ND	ND

H2 Chemisorption	8.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	10.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	10.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	21.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	10.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	16.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	16.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	24.00	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	16.00	ND	72	ND	ND	ND	65	ND
CO Chemisorption	17.00	ND	66	ND	ND	ND	73	ND
CO Chemisorption	13.00	ND	84	ND	ND	ND	101	ND
CO Chemisorption	1.00	ND	1070	ND	ND	ND	530	ND
CO Chemisorption	31.00	ND	36	ND	ND	ND	39	ND
CO Chemisorption	27.00	ND	41	ND	ND	ND	40	ND
CO Chemisorption	38.00	ND	30	ND	ND	ND	32	ND
H2 Chemisorption	ND	ND	97	ND	ND	ND	83	ND
H2 Chemisorption	ND	ND	93	ND	ND	ND	78	ND
H2 Chemisorption	ND	ND	129	ND	ND	ND	116	ND
H2 Chemisorption	ND	ND	159	ND	ND	ND	167	ND
H2 Chemisorption	ND	ND	173	ND	ND	ND	160	ND
TEM	ND	ND	ND	ND	ND	ND	70	30
TEM	ND	ND	ND	ND	ND	ND	41	14
TEM	ND	ND	ND	ND	ND	ND	67	34
TEM	ND	ND	ND	ND	ND	ND	210	ND
TEM	ND	ND	ND	ND	ND	ND	160	ND
TEM	ND	ND	ND	ND	ND	ND	135	ND
TEM	ND	ND	ND	ND	ND	ND	340	ND
CO Chemisorption	41.00	ND	40	ND	ND	ND	50	ND
CO Chemisorption	36.00	ND	50	ND	ND	ND	50	ND
CO Chemisorption	29.00	ND	50	ND	ND	ND	60	ND
CO Chemisorption	26.00	ND	60	ND	ND	ND	70	ND
CO Chemisorption	17.00	ND	90	ND	ND	ND	80	ND
CO Chemisorption	11.00	ND	140	ND	ND	ND	100	ND
CO Chemisorption	20.60	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	20.80	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	29.80	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	11.00	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	2.90	ND	ND	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	80	ND
TEM	ND	ND	ND	ND	ND	ND	78	ND
CO Chemisorption	16.60	ND	ND	ND	ND	ND	67.5	ND
CO Chemisorption	14.60	ND	ND	ND	ND	ND	76.8	ND
CO Chemisorption	13.30	ND	ND	ND	ND	ND	84.5	ND

CO Chemisorption	56.00	ND	20	ND	ND	ND	62	ND
CO Chemisorption	51.00	ND	22	ND	ND	ND	71	ND
CO Chemisorption	37.00	ND	30	ND	ND	ND	76	ND
CO Chemisorption	55.00	ND	21	ND	ND	ND	ND	ND
CO Chemisorption	36.00	ND	31	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	37	25
TEM	ND	ND	ND	ND	ND	ND	31	25
TEM	ND	ND	ND	ND	ND	ND	45	30
TEM	ND	ND	ND	ND	ND	ND	25	21
CO Pulse Adsorption	35.9	ND	ND	ND	ND	ND	ND	ND
CO Pulse Adsorption	27.2	ND	ND	ND	ND	ND	ND	ND
CO Pulse Adsorption	14	ND	80	ND	ND	ND	ND	ND
CO Pulse Adsorption	13	ND	88	ND	ND	ND	ND	ND
CO Pulse Adsorption	100	ND	9	ND	ND	ND	ND	ND
CO Pulse Adsorption	68	ND	17	ND	ND	ND	ND	ND
CO Pulse Adsorption	57	ND	19	ND	ND	ND	ND	ND
CO Pulse Adsorption	32	ND	36	ND	ND	ND	ND	ND
CO Pulse Adsorption	34	ND	35	ND	ND	ND	30	ND
CO Pulse Adsorption	100	ND	10	ND	ND	ND	ND	ND
CO Pulse Adsorption	96	ND	12	ND	ND	ND	ND	ND
CO Pulse Adsorption	57	ND	19	ND	ND	ND	ND	ND
CO Pulse Adsorption	64	ND	18	ND	ND	ND	ND	ND
CO Pulse Adsorption	82	ND	14	ND	ND	ND	ND	ND
CO Pulse Adsorption	68	ND	17	ND	ND	ND	ND	ND
CO Chemisorption	30.2	ND	37	ND	ND	ND	51	ND
CO Chemisorption	18.2	ND	62	ND	112	ND	102	ND
CO Chemisorption	17.7	ND	63	ND	130	ND	120	ND
CO Pulse Adsorption	60.8	ND	15	ND	ND	ND	ND	ND
H2 Chemisorption	4.57	ND	245	ND	210	ND	ND	ND
H2 Chemisorption	5.92	ND	189	ND	160	ND	ND	ND
H2 Chemisorption	45.3	5	ND	ND	ND	ND	ND	ND
H2 Chemisorption	41.9	5	ND	ND	ND	ND	ND	ND
H2 Chemisorption	50.2	5	ND	ND	ND	ND	ND	ND
H2 Chemisorption	22.9	5	ND	ND	ND	ND	ND	ND
H2 Chemisorption	21.3	5	ND	ND	ND	ND	ND	ND
H2 Chemisorption	24.1	5	ND	ND	ND	ND	ND	ND
H2 Chemisorption	20.01	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	20.0	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	24.9	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	23.4	ND	ND	ND	ND	ND	ND	ND

H2 Chemisorption	24.1	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	15.0	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	10.4	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	10.0	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	12.0	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	12.0	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	79.5	ND	10.80	ND	ND	ND	ND	ND
H2 Chemisorption	59.4	ND	15.20	ND	ND	ND	ND	ND
H2 Chemisorption	28.20	ND	36.1	ND	ND	ND	ND	ND
CO Adsorption	37.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	98.4	5	ND	ND	ND	ND	ND	ND
H2 Chemisorption	71.6	5	ND	ND	ND	ND	ND	ND
H2 Chemisorption	75.1	5	ND	ND	ND	ND	ND	ND
H2 Chemisorption	66.2	5	ND	ND	ND	ND	ND	ND
H2 Chemisorption	73.7	5	ND	ND	ND	ND	ND	ND
H2 Chemisorption	63.1	5	ND	ND	ND	ND	10	ND
H2 Chemisorption	63.5	5	ND	ND	ND	ND	ND	ND
H2 Chemisorption	71.6	5	ND	ND	ND	ND	ND	ND
H2 Chemisorption	68.4	5	ND	ND	ND	ND	ND	ND
H2 Chemisorption	66.5	5	ND	ND	ND	ND	ND	ND
H2 Chemisorption	53.4	5	ND	ND	ND	ND	ND	ND
H2 Chemisorption	52.6	5	ND	ND	ND	ND	ND	ND
H2 Chemisorption	51.4	5	ND	ND	ND	ND	ND	ND
H2 Adsorption	7.0	ND	225	ND	ND	ND	ND	ND
H2 Adsorption	7.0	ND	225	ND	ND	ND	ND	ND
H2 Adsorption	8.0	ND	225	ND	ND	ND	ND	ND
H2 Adsorption	39.0	ND	225	ND	ND	ND	ND	ND
H2 Adsorption	17.5	ND	225	ND	ND	ND	ND	ND
H2 Adsorption	10.5	ND	225	ND	ND	ND	ND	ND
H2 Adsorption	8.0	ND	225	ND	ND	ND	ND	ND
H2 Adsorption	7.0	ND	225	ND	ND	ND	ND	ND
H2 Adsorption	33.0	ND	225	ND	ND	ND	ND	ND
H2 Adsorption	15.5	ND	225	ND	ND	ND	ND	ND
H2 Adsorption	10.0	ND	225	ND	ND	ND	ND	ND
H2 Adsorption	8.0	ND	225	ND	ND	ND	ND	ND
H2 Adsorption	7.0	ND	225	ND	ND	ND	ND	ND
H2 Adsorption	8.0	ND	225	ND	ND	ND	ND	ND
H2 Adsorption	9.0	ND	225	ND	ND	ND	ND	ND
H2 Chemisorption	32.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	35.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	26.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	25.00	ND	ND	ND	ND	ND	ND	ND
H2 Chemisorption	ND	ND	45	ND	ND	ND	32	ND

H2 Chemisorption	8.20	ND	ND	ND	ND	ND	230	ND
H2 Chemisorption	13.60	ND	ND	ND	ND	ND	100	ND
TEM	1.70	ND	ND	ND	ND	ND	510	ND
CO Chemisorption	28.00	ND	40	ND	ND	ND	47	ND
TEM	ND	ND	ND	ND	ND	ND	13.00	4.3
TEM	ND	ND	ND	ND	ND	ND	13.00	3.2
TEM	ND	ND	ND	ND	ND	ND	110.00	52
TEM	ND	ND	ND	ND	ND	ND	110.00	53
CO Chemisorption	30.00	ND	30	ND	ND	ND	24	5
CO Chemisorption	32.00	ND	28.1	ND	ND	ND	25	7
CO Chemisorption	4.40	ND	249	ND	ND	ND	ND	ND
CO Chemisorption	12.00	ND	94	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	30	ND	30	ND
TEM	ND	ND	ND	ND	35	ND	35	ND
TEM	ND	ND	ND	ND	ND	ND	34	ND
TEM	ND	ND	ND	ND	ND	ND	41	ND
H2 Chemisorption	ND	ND	16.6	ND	ND	ND	105	ND
H2 Chemisorption	ND	ND	25.1	ND	ND	ND	ND	ND
H2 Chemisorption	ND	ND	21.9	ND	ND	ND	ND	ND
H2 Chemisorption	ND	ND	29.5	ND	ND	ND	56	ND
H2 Chemisorption	ND	ND	28.8	ND	ND	ND	ND	ND
CO Chemisorption	42.00	ND	ND	ND	ND	ND	45	ND
CO Chemisorption	49.00	ND	ND	ND	ND	ND	29	ND
CO Chemisorption	32.00	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	34.00	ND	ND	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	81	ND
TEM	ND	ND	ND	ND	ND	ND	65	ND
TEM	ND	ND	ND	ND	ND	ND	53	ND
TEM	ND	ND	ND	ND	ND	ND	72	ND
XRD	ND	ND	ND	ND	100.39	ND	ND	ND
XRD	ND	ND	ND	ND	92.02	ND	ND	ND
H2 Chemisorption	26.00	ND	25	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	110	10
TEM	ND	ND	ND	ND	ND	ND	90	10
TEM	ND	ND	ND	ND	ND	ND	120	10
TEM	ND	ND	ND	ND	ND	ND	80	10
XRD	ND	ND	ND	ND	64	ND	ND	ND
TEM	ND	ND	ND	ND	109	ND	57	ND
TEM	ND	ND	ND	ND	110	ND	61	ND
TEM	ND	ND	ND	ND	119	ND	64	ND
TEM	ND	ND	ND	ND	108	ND	58	ND
TEM	ND	ND	ND	ND	103	ND	60	ND
TEM	ND	ND	ND	ND	ND	ND	110	ND
TEM	ND	ND	ND	ND	ND	ND	100	ND
TEM	ND	ND	ND	ND	ND	ND	70	ND
TEM	ND	ND	ND	ND	ND	ND	170	ND
TEM	ND	ND	ND	ND	ND	ND	45	15
TEM	ND	ND	ND	ND	ND	ND	40	ND
TEM	ND	ND	NA	NA	96	ND	78.3	ND
TEM	ND	ND	NA	NA	120	ND	82.4	ND

TEM	ND	ND	ND	ND	ND	ND	50	ND
CO Chemisorption	6.00	ND	ND	ND	ND	ND	105	ND
CO Chemisorption	18.00	ND	ND	ND	ND	ND	54	ND
CO Chemisorption	31.00	ND	ND	ND	ND	ND	29	ND
CO Chemisorption	31.00	ND	ND	ND	ND	ND	28	ND
CO Chemisorption	35.00	ND	ND	ND	ND	ND	26	ND
CO Chemisorption	57.00	ND	ND	ND	ND	ND	20	ND
TEM	ND	ND	ND	ND	ND	ND	25	ND
TEM	ND	ND	ND	ND	ND	ND	17	ND
TEM	ND	ND	ND	ND	ND	ND	28.2	ND
ND	ND	ND	ND	ND	ND	ND	ND	ND
ND	ND	ND	ND	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	34.4	ND
H2 Chemisorption	62.7	ND	18	ND	ND	ND	ND	ND
TEM	ND	ND	ND	ND	70	ND	50	ND
H2 Chemisorption	3.42	ND	270	ND	190	ND	196	73
The model developed by Fristsche et al. and Montejano-Carrizales et al.	44	ND	ND	ND	20	ND	25	6
The model developed by Fristsche et al. and Montejano-Carrizales et al.	51	ND	ND	ND	ND	ND	25	6
The model developed by Fristsche et al. and Montejano-Carrizales et al.	46	ND	ND	ND	ND	ND	25	6
The model developed by Fristsche et al. and Montejano-Carrizales et al.	53	ND	ND	ND	20	ND	19	6
The model developed by Fristsche et al. and Montejano-Carrizales et al.	57	ND	ND	ND	ND	ND	19	6
The model developed by Fristsche et al. and Montejano-Carrizales et al.	51	ND	ND	ND	ND	ND	19	6
TEM	ND	ND	ND	ND	ND	ND	31	ND

H2 Chemisorption	23	ND	ND	ND	ND	ND	73.6	ND
CO Chemisorption	13.60	ND	82	ND	ND	ND	70	24
CO Chemisorption	9.60	ND	116	ND	96	ND	88	23
TEM	ND	ND	ND	ND	500	ND	5500	ND
TEM	ND	ND	ND	ND	270	ND	1400	ND
CO Chemisorption	3.42	ND	330	ND	ND	ND	ND	ND
CO Chemisorption	3.53	ND	320	ND	ND	ND	ND	ND
CO Chemisorption	3.40	ND	330	ND	ND	ND	ND	ND
CO Chemisorption	2.88	ND	390	ND	ND	ND	ND	ND
CO Chemisorption	4.71	ND	240	ND	ND	ND	ND	ND
CO Chemisorption	4.55	ND	250	ND	ND	ND	ND	ND
SEM	ND	ND	ND	ND	ND	ND	960	ND
SEM	ND	ND	ND	ND	ND	ND	1690	ND
TEM	ND	ND	ND	ND	95	ND	114	ND
TEM	ND	ND	ND	ND	126	ND	140	ND
TEM	ND	ND	ND	ND	125	ND	158	ND
TEM	ND	ND	ND	ND	97	ND	142	ND
TEM	ND	ND	ND	ND	105	ND	102	ND
TEM	ND	ND	ND	ND	ND	ND	60	ND
TEM	ND	ND	ND	ND	ND	ND	19.2	7.5
TEM	ND	ND	ND	ND	ND	ND	69.5	19.3
TEM	ND	ND	ND	ND	46.1	ND	34.5	ND
TEM	ND	ND	ND	ND	55.3	ND	41.1	ND
TEM	ND	ND	ND	ND	60.4	ND	60.1	ND
XRD	ND	ND	ND	ND	66.7	ND	ND	ND
TEM	ND	ND	ND	ND	63.3	ND	66.2	ND
TEM	ND	ND	ND	ND	ND	ND	74	3
TEM	ND	ND	ND	ND	ND	ND	71	5
TEM	ND	ND	ND	ND	ND	ND	76	4
TEM	ND	ND	ND	ND	ND	ND	34	ND
TEM	ND	ND	ND	ND	ND	ND	31	ND
TEM	ND	ND	ND	ND	ND	ND	51	ND
TEM	16.8	ND	ND	ND	ND	ND	77	ND
TEM	54	ND	ND	ND	ND	ND	24	ND
TEM	28.2	ND	ND	ND	ND	ND	46	ND
XRD	ND	ND	ND	ND	100	ND	ND	ND
XRD	ND	ND	ND	ND	110	ND	ND	ND
XRD	ND	ND	ND	ND	100	ND	ND	ND
XRD	ND	ND	ND	ND	110	ND	ND	ND

TEM	ND	ND	ND	ND	ND	ND	26	ND
TEM	ND	ND	ND	ND	ND	ND	37	ND
TEM	ND	ND	ND	ND	ND	ND	55	ND
TEM	ND	ND	ND	ND	ND	ND	50	ND
TEM	ND	ND	ND	ND	ND	ND	21	5
TEM	ND	ND	ND	ND	ND	ND	11	3
TEM	ND	ND	ND	ND	ND	ND	19	3
TEM	ND	ND	ND	ND	ND	ND	26	5
TEM	ND	ND	ND	ND	ND	ND	21	5
CO Chemisorption	27.3	ND	ND	ND	ND	ND	41	3
CO Chemisorption	7.3	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	20.50	ND	51	ND	ND	ND	ND	ND
CO Chemisorption	ND	ND	34	ND	ND	ND	83	ND
TEM	ND	ND	ND	ND	20	ND	21	ND
TEM	ND	ND	ND	ND	48	ND	57	ND
XRD	ND	ND	ND	ND	43	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	30	ND
TEM	ND	ND	ND	ND	ND	ND	42	ND
TEM	ND	ND	ND	ND	ND	ND	42	ND
TEM	ND	ND	ND	ND	35	ND	40	ND
STEM	ND	ND	ND	ND	ND	ND	76	30
TEM	ND	ND	ND	ND	ND	ND	112	ND
TEM	ND	ND	ND	ND	ND	ND	141	ND
TEM	ND	ND	ND	ND	ND	ND	165	ND
TEM	ND	ND	ND	ND	ND	ND	23	ND
TEM	ND	ND	ND	ND	ND	ND	42	ND
XRD	NA	NA	ND	ND	30	ND	ND	ND
TEM	ND	ND	ND	ND	ND	ND	23	5
TEM	ND	ND	ND	ND	ND	ND	500	ND
ND	ND	ND	ND	ND	ND	ND	ND	ND
N2O Dissociation	12.00	ND	ND	ND	ND	ND	ND	ND
CO Chemisorption	1.00	ND	980	ND	ND	ND	ND	ND
CO Chemisorption	21.10	ND	53	ND	ND	ND	48	16
TEM	21.00	ND	ND	ND	41.00	ND	54	ND
TEM	NA	ND	ND	ND	54.00	ND	62	ND

Reaction	Year	First author	Country
Hydrogenolysis of methylcyclopentane	2000	Gaspar, A.B.	Brazil
Hydrogenolysis of methylcyclopentane	2000	Gaspar, A.B.	Brazil
Hydrogenolysis of methylcyclopentane	2000	Gaspar, A.B.	Brazil
Hydrogenolysis of methylcyclopentane	2000	Gaspar, A.B.	Brazil
Hydrogenolysis of methylcyclopentane	2000	Gaspar, A.B.	Brazil
Oxidation of methane	2000	Roth, D.	France
Oxidation of methane	2000	Roth, D.	France
Reduction of NO with CO	2000	Holles, J.H.	USA
Reduction of NO with CO	2000	Holles, J.H.	USA
Reduction of NO with CO	2000	Holles, J.H.	USA
Reduction of NO with CO	2000	Holles, J.H.	USA
Reduction of NO with CO	2000	Holles, J.H.	USA
Reduction of NO with CO	2000	Holles, J.H.	USA
Hydrogenation of phenol	2000	Narayanan, S.	India
Hydrogenation of phenol	2000	Narayanan, S.	India
Hydrogenation of phenol	2000	Narayanan, S.	India
Hydrogenation of phenol	2000	Narayanan, S.	India
Hydrogenation of phenol	2000	Narayanan, S.	India
Hydrogenation of phenol	2000	Narayanan, S.	India
Hydrogenation of phenol	2000	Narayanan, S.	India
Hydrogenation of phenol	2000	Narayanan, S.	India
Hydrogenation of phenol	2000	Narayanan, S.	India
Hydrogenation of phenol	2000	Narayanan, S.	India
Hydrogenation of phenol	2000	Narayanan, S.	India
Hydrogenation of phenol	2000	Narayanan, S.	India
Hydrogenation of phenol	2000	Narayanan, S.	India
Hydrogenation of phenol	2000	Narayanan, S.	India
Hydrogenation of phenol	2000	Narayanan, S.	India
Hydrogenation of phenol	2000	Narayanan, S.	India
Hydrogenation of phenol	2000	Narayanan, S.	India
Hydrogenation of phenol	2000	Narayanan, S.	India
Hydrogenation of phenol	2000	Narayanan, S.	India
Hydrogenation of phenol	2000	Narayanan, S.	India
Hydrogenation of phenol	2000	Narayanan, S.	India
Three-way catalytic reaction	2000	Kim, D.H.	South Korea
Three-way catalytic reaction	2000	Kim, D.H.	South Korea
Oxidation of propane	2000	Noronha, F.B.	Brazil
Oxidation of propane	2000	Noronha, F.B.	Brazil
Oxidation of propane	2000	Noronha, F.B.	Brazil
Oxidation of propane	2000	Noronha, F.B.	Brazil
Oxidation of propane	2000	Noronha, F.B.	Brazil
Oxidation of propane	2000	Noronha, F.B.	Brazil
Selective oxidative decomposition of ammonia	2000	Taguchi, J.	Japan
Selective oxidative decomposition of ammonia	2000	Taguchi, J.	Japan
Selective oxidative decomposition of ammonia	2000	Taguchi, J.	Japan
Selective oxidative decomposition of ammonia	2000	Taguchi, J.	Japan
Selective oxidative decomposition of ammonia	2000	Taguchi, J.	Japan
Hydrodechlorination of CCl2F2 to CH2F2	2000	Prasad, P.S.S.	India, UK

Hydrogenation of cyclohexene	2000	Simonov, P.A.	Russia
Hydrogenation of cyclohexene	2000	Simonov, P.A.	Russia
Hydrogenation of cyclohexene	2000	Simonov, P.A.	Russia
Hydrogenation of cyclohexene	2000	Simonov, P.A.	Russia
Hydrogenation of cyclohexene	2000	Simonov, P.A.	Russia
Hydrogenation of cyclohexene	2000	Simonov, P.A.	Russia
Hydrodechlorination of chlorobenzene	2000	Benitez, J.L.	Mexico
Hydrodechlorination of chlorobenzene	2000	Benitez, J.L.	Mexico
Hydrodechlorination of chlorobenzene	2000	Benitez, J.L.	Mexico
Hydrodechlorination of chlorobenzene	2000	Benitez, J.L.	Mexico
Hydrodechlorination of CF3–CFCl2	2000	Rioux, R.M.	USA
Hydrodechlorination of CF3–CFCl2	2000	Rioux, R.M.	USA
Oxidation of propene	2001	Macleod, N.	UK
Oxidation of propene	2001	Macleod, N.	UK
Oxidation of propene	2001	Macleod, N.	UK
Oxidation of propene	2001	Macleod, N.	UK
Oxidation of propene	2001	Macleod, N.	UK
Oxidation of ethanol	2001	Greca, M.C.	Brazil, Portugal
Oxidation of ethanol	2001	Greca, M.C.	Brazil, Portugal
Oxidation of ethanol	2001	Greca, M.C.	Brazil, Portugal
Oxidation of ethanol	2001	Greca, M.C.	Brazil, Portugal
Hydrogenation of benzaldehyde	2001	Pinna, F.	Italy
Hydrogenation of benzaldehyde	2001	Pinna, F.	Italy
Hydrogenation of benzaldehyde	2001	Pinna, F.	Italy
Hydrogenation of benzaldehyde	2001	Pinna, F.	Italy
Hydrodechlorination of tetrachloroethylene	2001	Ordóñez, S.	Spain
Reduction of NO with CO	2002	Di Monte, R.	Italy
Reduction of NO with CO	2002	Di Monte, R.	Italy
Decomposition of nitric oxide	2002	Naito, S.	Japan
Decomposition of nitric oxide	2002	Naito, S.	Japan
Decomposition of nitric oxide	2002	Naito, S.	Japan
Decomposition of nitric oxide	2002	Naito, S.	Japan
Decomposition of nitric oxide	2002	Naito, S.	Japan
Decomposition of nitric oxide	2002	Naito, S.	Japan
Decomposition of nitric oxide	2002	Naito, S.	Japan
Hydrodechlorination of polychlorinated dibenzo-p-dioxins and dibenzofurans	2003	Ukisu, Y.	Japan
Hydrodechlorination of polychlorinated dibenzo-p-dioxins and dibenzofurans	2003	Ukisu, Y.	Japan
Hydrodechlorination of polychlorinated dibenzo-p-dioxins and dibenzofurans	2003	Ukisu, Y.	Japan
Hydrogenation of phenol	2003	Velu, S.	Japan
Hydrogenation of phenol	2003	Velu, S.	Japan
Hydrogenation of phenol	2003	Velu, S.	Japan
Hydrogenation of phenol	2003	Velu, S.	Japan
Hydrogenation of phenol	2003	Velu, S.	Japan
Hydrogenation of phenol	2003	Velu, S.	Japan
Hydrogenation of phenol	2003	Velu, S.	Japan

Hydrogenation of phenol	2003	Velu, S.	Japan
Hydrogenation of o-xylene	2003	Arcoya, A.	Spain
Hydrodechlorination of chlorobenzene	2003	Gopinath, R.	India, Japan
Hydrodechlorination of chlorobenzene	2003	Gopinath, R.	India, Japan
Hydrodechlorination of chlorobenzene	2003	Gopinath, R.	India, Japan
Hydrodechlorination of chlorobenzene	2003	Gopinath, R.	India, Japan
Combustion of methane	2003	Liotta, L.F.	Italy
Combustion of methane	2003	Liotta, L.F.	Italy
Combustion of methane	2003	Liotta, L.F.	Italy
Combustion of methane	2003	Liotta, L.F.	Italy
Combustion of methane	2003	Persson, K.	Sweden
Combustion of methane	2003	Fessi, S.	Tunisie
Combustion of methane	2003	Fessi, S.	Tunisie
Combustion of methane	2003	Fessi, S.	Tunisie
Combustion of methane	2003	Fessi, S.	Tunisie
Combustion of methane	2003	Fessi, S.	Tunisie
Combustion of methane	2003	Fessi, S.	Tunisie
Combustion of methane	2003	Fessi, S.	Tunisie
Combustion of methane	2003	Fessi, S.	Tunisie
Combustion of methane	2003	Fessi, S.	Tunisie
Combustion of methane	2003	Fessi, S.	Tunisie
Combustion of methane	2003	Fessi, S.	Tunisie

Combustion of methane	2003	Fessi, S.	Tunisie
Combustion of methane	2003	Fessi, S.	Tunisie
Combustion of methane	2003	Fessi, S.	Tunisie
Combustion of methane	2003	Fessi, S.	Tunisie
Combustion of ethylene	2004	Han, Y.-F.	USA
Methanol steam reforming	2004	Suwa, Y.	Japan
Hydrodechlorination of dichloromethane	2004	Aristizábal, B.	Colombia, Spain
Hydrodechlorination of dichloromethane	2004	Aristizábal, B.	Colombia, Spain
Hydrodechlorination of dichloromethane	2004	Aristizábal, B.	Colombia, Spain
Hydrodechlorination of dichloromethane	2004	Aristizábal, B.	Colombia, Spain
Hydroconversion of n-hexane and 2,2-dimethylbutane	2004	Skotak, M.	Poland, USA
Hydroconversion of n-hexane and 2,2-dimethylbutane	2004	Skotak, M.	Poland, USA
Hydroconversion of n-hexane and 2,2-dimethylbutane	2004	Skotak, M.	Poland, USA
Hydroconversion of n-hexane and 2,2-dimethylbutane	2004	Skotak, M.	Poland, USA
Hydroconversion of n-hexane and 2,2-dimethylbutane	2004	Skotak, M.	Poland, USA
Hydroconversion of n-hexane and 2,2-dimethylbutane	2004	Skotak, M.	Poland, USA
Hydroconversion of n-hexane and 2,2-dimethylbutane	2004	Skotak, M.	Poland, USA
Hydroconversion of n-hexane and 2,2-dimethylbutane	2004	Skotak, M.	Poland, USA
Hydrogenation of 1-hexene	2004	Panpranot, J.	Thailand, USA
Hydrogenation of 1-hexene	2004	Panpranot, J.	Thailand, USA
Decomposition of methanol	2005	Collins, S.E.	Argentina
Decomposition of methanol	2005	Collins, S.E.	Argentina
Decomposition of methanol	2005	Collins, S.E.	Argentina
Hydrodechlorination of CCl2F2	2005	Shekar, S.C.	India, USA
Hydrodechlorination of CCl2F2	2005	Shekar, S.C.	India, USA
Hydrodechlorination of CCl2F2	2005	Shekar, S.C.	India, USA
Hydrodechlorination of CCl2F2	2005	Shekar, S.C.	India, USA
Hydrodechlorination of CCl2F2	2005	Shekar, S.C.	India, USA
Hydrogenation of 1-hexene	2005	Panpranot, J.	Thailand, USA
Hydrogenation of 1-hexene	2005	Panpranot, J.	Thailand, USA
Hydrogenation of 1-hexene	2005	Panpranot, J.	Thailand, USA
Oxidation of methane	2005	Ferrer, V.	Venezuela, Spain
Oxidation of methane	2005	Ferrer, V.	Venezuela, Spain
Oxidation of methane	2005	Ferrer, V.	Venezuela, Spain
Methanol steam reforming	2005	Ranganathan, E.S.	USA
Methanol steam reforming	2005	Ranganathan, E.S.	USA
Methanol steam reforming	2005	Ranganathan, E.S.	USA
Methanol steam reforming	2005	Ranganathan, E.S.	USA
Methanol steam reforming	2005	Ranganathan, E.S.	USA
Methanol steam reforming	2005	Ranganathan, E.S.	USA

Methanol steam reforming	2005	Ranganathan, E.S.	USA
Methanol steam reforming	2005	Ranganathan, E.S.	USA
Methanol steam reforming	2005	Ranganathan, E.S.	USA
Methanol steam reforming	2005	Ranganathan, E.S.	USA
Methanol steam reforming	2005	Ranganathan, E.S.	USA
Hydrogenation of tetralin	2005	Matsui, T.	Japan
Hydrogenation of tetralin	2005	Matsui, T.	Japan
Hydrogenation of acetylene	2005	Panpranot, J.	Thailand
Hydrogenation of acetylene	2005	Panpranot, J.	Thailand
Oxidation of CO	2005	Zhu, H.	China
Oxidation of CO	2005	Zhu, H.	China
Oxidation of CO	2005	Zhu, H.	China
Oxidation of CO	2005	Zhu, H.	China
Oxidation of CO	2005	Zhu, H.	China
Oxidation of CO	2005	Zhu, H.	China
Hydrogenation of propene	2005	Lear, T.	UK, Germany
Hydrogenation of propene	2005	Lear, T.	UK, Germany
Hydrogenation of propene	2005	Lear, T.	UK, Germany
Hydrogenation of propene	2005	Lear, T.	UK, Germany
Hydrogenation of sunflower oil	2005	Fernández, M.B.	Argentina
Hydrogenation of sunflower oil	2005	Fernández, M.B.	Argentina
Hydrogenation of sunflower oil	2005	Fernández, M.B.	Argentina
Hydrogenation of sunflower oil	2005	Fernández, M.B.	Argentina
Hydrogenation of sunflower oil	2005	Nohair, B.	France
Hydrogenation of sunflower oil	2005	Nohair, B.	France
Hydrogenation of sunflower oil	2005	Nohair, B.	France
Hydrogenation of sunflower oil	2005	Nohair, B.	France
Hydrogenation of sunflower oil	2005	Nohair, B.	France
Hydrogenation of sunflower oil	2005	Nohair, B.	France
Hydrogenation of sunflower oil	2005	Nohair, B.	France
Hydrogenation of sunflower oil	2005	Nohair, B.	France
Hydrogenation of sunflower oil	2005	Nohair, B.	France
Hydrogenation of sunflower oil	2005	Nohair, B.	France
Hydrogenation of sunflower oil	2005	Nohair, B.	France
Combustion of methane	2005	Araya, P.	Chile
Combustion of methane	2005	Araya, P.	Chile
Combustion of methane	2005	Araya, P.	Chile
Hydrodechlorination of chlorobenzene	2005	Amorim, C.	USA
Hydrodechlorination of chlorobenzene	2005	Amorim, C.	USA
Hydrodechlorination of chlorobenzene	2005	Amorim, C.	USA
Hydrogenation of phenyl alkyl acetylenes mixtures	2005	Marín-Astorga, N.	Spain, Chile
Combustion of methane	2005	Demoulin, O.	Belgium, Germany
Combustion of methane	2005	Demoulin, O.	Belgium, Germany

Combustion of methane	2005	Demoulin, O.	Belgium, Germany
Combustion of methane	2005	Demoulin, O.	Belgium, Germany
Combustion of methane	2005	Demoulin, O.	Belgium, Germany
Combustion of methane	2005	Demoulin, O.	Belgium, Germany
Methanol reforming	2005	Gómez-Sainero, L.M.	Spain, UK
Methanol reforming	2005	Gómez-Sainero, L.M.	Spain, UK
Methanol reforming	2005	Gómez-Sainero, L.M.	Spain, UK
Methanol reforming	2005	Gómez-Sainero, L.M.	Spain, UK
Oxidation of glucose	2005	Karski, S.	Poland
Hydrogenation of styrene oxide	2005	Kirm, I.	Spain
Hydrogenation of styrene oxide	2005	Kirm, I.	Spain
Hydrogenation of styrene oxide	2005	Kirm, I.	Spain
Hydrogenation of styrene oxide	2005	Kirm, I.	Spain
Hydrogenation of terminal and internal alkynes	2005	Papp, A.	Hungary
Wet air oxidation of nitrogen and oxygen containing compounds	2005	Barbier Jr, J.	France
Wet air oxidation of nitrogen and oxygen containing compounds	2005	Barbier Jr, J.	France
Synthesis of vinyl acetate	2005	Han, Y.-F.	USA
Synthesis of vinyl acetate	2005	Han, Y.-F.	USA
Methanol reforming	2005	Schulz, P.G.	Argentina
Methanol reforming	2005	Schulz, P.G.	Argentina
Hydrogenation of acetylene	2005	Tribolet, P.	Switzerland
Hydrogenation of acetylene	2005	Tribolet, P.	Switzerland
Hydrogenation of acetylene	2005	Tribolet, P.	Switzerland
Hydrogenation of acetylene	2005	Tribolet, P.	Switzerland
Hydrogenation of acetylene	2005	Tribolet, P.	Switzerland
Hydrogenation of CO	2006	Song, J.-R.	China
Oxidation of methane	2006	Schmal, M.	Brazil
Oxidation of methane	2006	Schmal, M.	Brazil
Oxidation of methane	2006	Schmal, M.	Brazil
Oxidation of methane	2006	Schmal, M.	Brazil
Oxidation of methane	2006	Schmal, M.	Brazil
Oxidation of methane	2006	Schmal, M.	Brazil
Oxidation of methane	2006	Schmal, M.	Brazil
Oxidation of methane	2006	Schmal, M.	Brazil
Methane reforming	2006	Rezaei, M.	China, Iran
Hydrogenation of acetylene	2006	Panpranot, J.	Thailand
Hydrogenation of acetylene	2006	Panpranot, J.	Thailand
Hydrogenation of acetylene	2006	Panpranot, J.	Thailand
Hydrogenation of acetylene	2006	Panpranot, J.	Thailand
Hydrogenation of NADPME	2006	Coulston, N.J.	UK
Hydrogenation of NADPME	2006	Coulston, N.J.	UK
Hydrogenation of NADPME	2006	Coulston, N.J.	UK
Hydrogenation of NADPME	2006	Coulston, N.J.	UK
Hydrogenation of NADPME	2006	Coulston, N.J.	UK
Oxidation of methane	2006	Aries, F.J.C.S.	France
Oxidation of methane	2006	Aries, F.J.C.S.	France
Oxidation of methane	2006	Aries, F.J.C.S.	France

Oxidation of methane	2006	Aries, F.J.C.S.	France
Oxidation of methane	2006	Aries, F.J.C.S.	France
Oxidation of methane	2006	Aries, F.J.C.S.	France
Hydrogenation of sunflower oil	2006	Piqueras, C.	Argentina
Hydrogenation of sunflower oil	2006	Piqueras, C.	Argentina
Hydrogenation of sunflower oil	2006	Piqueras, C.	Argentina
Hydrogenation of sunflower oil	2006	Piqueras, C.	Argentina
Hydrogenation of sunflower oil	2006	Piqueras, C.	Argentina
Combustion of xylenes	2006	Pérez-Cadenas, A.F.	Netherlands, Spain
Combustion of xylenes	2006	Pérez-Cadenas, A.F.	Netherlands, Spain
Oxidation of VOCs	2006	Tidahy, H.L.	France, Belgium
Oxidation of VOCs	2006	Tidahy, H.L.	France, Belgium
Oxidation of VOCs	2006	Tidahy, H.L.	France, Belgium
Hydrodechlorination of aryl chlorides	2006	Kawabata, T.	Japan
Hydrodechlorination of aryl chlorides	2006	Kawabata, T.	Japan
Hydrodechlorination of aryl chlorides	2006	Kawabata, T.	Japan
Hydrodechlorination of aryl chlorides	2006	Kawabata, T.	Japan
Hydrodechlorination of aryl chlorides	2006	Kawabata, T.	Japan
Oxidation of methane	2006	Postole, G.	Italy, France
Oxidation of methane	2006	Postole, G.	Italy, France
Oxidation of methane	2006	Postole, G.	Italy, France
Oxidation of methane	2006	Postole, G.	Italy, France
Oxidation of methane	2006	Postole, G.	Italy, France
Oxidation of methane	2006	Postole, G.	Italy, France
Oxidation of methane	2006	Postole, G.	Italy, France
Oxidation of CO	2006	Iwasa, N.	Japan
Oxidation of allylic alcohol	2006	Lee, A.F.	UK
Oxidation of allylic alcohol	2006	Lee, A.F.	UK
Oxidation of allylic alcohol	2006	Lee, A.F.	UK
Oxidation of allylic alcohol	2006	Lee, A.F.	UK
Oxidation of allylic alcohol	2006	Lee, A.F.	UK
Oxidation of allylic alcohol	2006	Lee, A.F.	UK
Oxidation of allylic alcohol	2006	Lee, A.F.	UK
Hydrogenation of 1-heptyne	2007	Somboonthanakij, S.	Thailand, Switzerland
Hydrodechlorination of 2-chloro and 3- chloropyridine	2007	Moreno, J.M.	Spain
Hydrodechlorination of 2-chloro and 3- chloropyridine	2007	Moreno, J.M.	Spain
Hydrodechlorination of 2-chloro and 3- chloropyridine	2007	Moreno, J.M.	Spain
Hydrodechlorination of 2-chloro and 3- chloropyridine	2007	Moreno, J.M.	Spain
Hydrogenation of styrene oxide	2007	Lin, Q.	China
Hydrogenation of styrene oxide	2007	Lin, Q.	China
Hydrogenation of styrene oxide	2007	Lin, Q.	China
Hydrogenation of styrene oxide	2007	Lin, Q.	China
Hydrogenation of styrene oxide	2007	Lin, Q.	China
Hydrogenation of styrene oxide	2007	Lin, Q.	China

Reduction of NO by propene or CO	2007	Konsolakis, M.	Greece
Reduction of NO by propene or CO	2007	Konsolakis, M.	Greece
Reduction of NO by propene or CO	2007	Konsolakis, M.	Greece
Reduction of NO by propene or CO	2007	Konsolakis, M.	Greece
Reduction of NO by propene or CO	2007	Konsolakis, M.	Greece
Reduction of NO by propene or CO	2007	Konsolakis, M.	Greece
Reduction of NO by propene or CO	2007	Konsolakis, M.	Greece
Reduction of NO by propene or CO	2007	Konsolakis, M.	Greece
Reduction of NO by propene or CO	2007	Konsolakis, M.	Greece
Reduction of NO by propene or CO	2007	Konsolakis, M.	Greece
Hydrogenation of nitrobenzene	2007	Sangeetha, P.	India
Hydrogenation of nitrobenzene	2007	Sangeetha, P.	India
Hydrogenation of nitrobenzene	2007	Sangeetha, P.	India
Hydrogenation of nitrobenzene	2007	Sangeetha, P.	India
Electrochemical degradation of 4-chlorophenol	2007	Wang, H.	China
Electrochemical degradation of 4-chlorophenol	2007	Wang, H.	China
Electro-reduction of nitrate	2007	Pronkin, S.N.	Russia
Electro-reduction of nitrate	2007	Pronkin, S.N.	Russia
Electro-oxidation of formic acid	2008	Zhu, Y.	China
Electro-oxidation of formic acid	2008	Zhu, Y.	China
Electro-oxidation of formic acid	2008	Zhu, Y.	China
Electro-oxidation of formic acid	2008	Zhu, Y.	China
Electro-oxidation of formic acid	2008	Zhu, Y.	China
Hydrogenation of acetylene	2008	Komhom, S.	Thailand
Hydrogenation of acetylene	2008	Komhom, S.	Thailand
Hydrogenation of acetylene	2008	Komhom, S.	Thailand
Hydrogenation of acetylene	2008	Komhom, S.	Thailand
Hydrogenation of acetylene	2008	Komhom, S.	Thailand
Oxidation of o-xylene	2008	Huang, S.	China
Oxidation of o-xylene	2008	Huang, S.	China
Oxidation of o-xylene	2008	Huang, S.	China
Oxidation of o-xylene	2008	Huang, S.	China
Oxidation of o-xylene	2008	Huang, S.	China
Oxidation of o-xylene	2008	Huang, S.	China
NA	2008	Jiao, L.	USA
NA	2008	Jiao, L.	USA
NA	2008	Jiao, L.	USA
Hydrogenation of rapeseed oil	2008	Simakova, O.A.	Russia
Hydrogenation of rapeseed oil	2008	Simakova, O.A.	Russia
Hydrogenation of rapeseed oil	2008	Simakova, O.A.	Russia
Hydrogenation of rapeseed oil	2008	Simakova, O.A.	Russia
Hydrogenation of rapeseed oil	2008	Simakova, O.A.	Russia

Hydrogenation of rapeseed oil	2008	Simakova, O.A.	Russia
Hydrogenation of rapeseed oil	2008	Simakova, O.A.	Russia
Hydrogenation of rapeseed oil	2008	Simakova, O.A.	Russia
Hydrogenation of rapeseed oil	2008	Simakova, O.A.	Russia
Hydrodechlorination of tetrachloroethylene	2008	Bueres, R.F.	Spain
Hydrodechlorination of tetrachloroethylene	2008	Bueres, R.F.	Spain
Electro-oxidation of formic acid	2009	Suo, Y.	China
Electro-oxidation of formic acid	2009	Suo, Y.	China
Electro-oxidation of formic acid	2009	Suo, Y.	China
Electro-oxidation of formic acid	2009	Suo, Y.	China
Electro-oxidation of formic acid	2009	Sun, Z.-P.	China, Germany
Electro-oxidation of formic acid	2009	Sun, Z.-P.	China, Germany
Electro-oxidation of formic acid	2009	Sun, Z.-P.	China, Germany
Electro-oxidation of formic acid	2009	Sun, Z.-P.	China, Germany
Electro-oxidation of formic acid	2009	Sun, Z.-P.	China, Germany
Adsorption of hydrogen	2009	Suttisawat, Y.	Thailand, South Africa, USA
Oxidation of glycerol	2009	Dimitratos, N.	USA, UK
Oxidation of glycerol	2009	Dimitratos, N.	USA, UK
Oxidative coupling of 4-methylpyridine	2009	Neal, L.M.	USA
Oxidative coupling of 4-methylpyridine	2009	Neal, L.M.	USA
Oxidative coupling of 4-methylpyridine	2009	Neal, L.M.	USA
Oxidative coupling of 4-methylpyridine	2009	Neal, L.M.	USA
Oxidative coupling of 4-methylpyridine	2009	Neal, L.M.	USA
Oxidative coupling of 4-methylpyridine	2009	Neal, L.M.	USA
Oxidative coupling of 4-methylpyridine	2009	Neal, L.M.	USA
Oxidative coupling of 4-methylpyridine	2009	Neal, L.M.	USA
Oxidative coupling of 4-methylpyridine	2009	Neal, L.M.	USA
Oxidative coupling of 4-methylpyridine	2009	Neal, L.M.	USA
Oxidative coupling of 4-methylpyridine	2009	Neal, L.M.	USA
Oxidative coupling of 4-methylpyridine	2009	Neal, L.M.	USA
Oxidative coupling of 4-methylpyridine	2009	Neal, L.M.	USA
Oxidative coupling of 4-methylpyridine	2009	Neal, L.M.	USA
Oxidative coupling of 4-methylpyridine	2009	Neal, L.M.	USA
Oxidative coupling of 4-methylpyridine	2009	Neal, L.M.	USA
Oxidative coupling of 4-methylpyridine	2009	Neal, L.M.	USA
NA	2009	Pellegrini, R.	Italy
NA	2009	Pellegrini, R.	Italy
NA	2009	Pellegrini, R.	Italy
NA	2009	Pellegrini, R.	Italy

NA	2009	Pellegrini, R.	Italy
NA	2009	Pellegrini, R.	Italy
NA	2009	Pellegrini, R.	Italy
NA	2009	Pellegrini, R.	Italy
NA	2009	Pellegrini, R.	Italy
Heck Reaction	2009	Martra, G.	Italy
Heck Reaction	2009	Martra, G.	Italy
Heck Reaction	2009	Martra, G.	Italy
Heck Reaction	2009	Martra, G.	Italy
Heck Reaction	2009	Martra, G.	Italy
Heck Reaction	2009	Martra, G.	Italy
Heck Reaction	2009	Martra, G.	Italy
Heck Reaction	2009	Martra, G.	Italy
Heck Reaction	2009	Martra, G.	Italy
Dry reforming of methane	2022	Romano, P.N.	Brazil
Dry reforming of methane	2022	Romano, P.N.	Brazil
Hydorgenation of CO2	2022	Zhang, J.	China
Hydorgenation of CO2	2022	Zhang, J.	China
Decomposition and Reduction of NO with H2	2009	Miller, D.D.	USA
Hydrogenation of 2-pentyne	2009	Bennett, J.A.	UK
Hydrogenation of 2-pentyne	2009	Bennett, J.A.	UK
Hydrogenation of β-sitosterol	2009	Mäki-Arvela, P.	Finland, Russia
Hydrogenation of β-sitosterol	2009	Mäki-Arvela, P.	Finland, Russia
Hydrodechlorination of industrial transformer oil	2009	Benitez A., J.L.	Mexico
Hydrodechlorination of industrial transformer oil	2009	Benitez A., J.L.	Mexico
Hydrodechlorination of industrial transformer oil	2009	Benitez A., J.L.	Mexico
Heck Reaction	2009	Fan, X.	UK
Hydrogenation of sunflower oil	2009	Fernández, M.B.	Argentina
Hydrogenation of sunflower oil	2009	Fernández, M.B.	Argentina
Hydrogenation of sunflower oil	2009	Fernández, M.B.	Argentina

Hydrogenation of sunflower oil	2009	Fernández, M.B.	Argentina
Oxidation of CO	2009	Hinokuma, S.	Japan
Oxidation of CO	2009	Hinokuma, S.	Japan
Water-gas shift reaction	2009	Panagiotopoulou, P.	Greece
Water-gas shift reaction	2009	Panagiotopoulou, P.	Greece
Water-gas shift reaction	2009	Panagiotopoulou, P.	Greece
Electro-oxidation of borohydride	2009	Yang, J.Q.	China
Direct synthesis of H2O2	2009	Liu, Q.	USA
Oxidation of CO	2009	Meng, M.	China
Electro-oxidation of ethanol	2009	Nguyen, S.T.	Singapore
Hydrogenation and hydrodeoxygenation of 2-methyl-2-pentenal	2009	Pham, T.T.	USA
Hydrogenation of tetralin	2009	Sheu, H.-S.	Taiwan
Hydrogenation of tetralin	2009	Sheu, H.-S.	Taiwan
Hydrogenation of tetralin	2009	Sheu, H.-S.	Taiwan
Hydrogenation of styrene	2009	Zeng, T.-Y.	China
Hydrogenation of styrene	2009	Zeng, T.-Y.	China
Racemization of chiral benzylic amines	2009	Parvulescu, A.N.	Belgium
Racemization of chiral benzylic amines	2009	Parvulescu, A.N.	Belgium
Racemization of chiral benzylic amines	2009	Parvulescu, A.N.	Belgium
Racemization of chiral benzylic amines	2009	Parvulescu, A.N.	Belgium
Racemization of chiral benzylic amines	2009	Parvulescu, A.N.	Belgium
Racemization of chiral benzylic amines	2009	Parvulescu, A.N.	Belgium
Racemization of chiral benzylic amines	2009	Parvulescu, A.N.	Belgium
Racemization of chiral benzylic amines	2009	Parvulescu, A.N.	Belgium
NA	2009	Tew, M.W.	Switzerland, USA
NA	2009	Tew, M.W.	Switzerland, USA
NA	2009	Tew, M.W.	Switzerland, USA
NA	2009	Tew, M.W.	Switzerland, USA
Hydrodechlorination of tetrachloroethylene	2010	Ordóñez, S.	Spain
Hydrodechlorination of tetrachloroethylene	2010	Ordóñez, S.	Spain
Hydrodechlorination of tetrachloroethylene	2010	Ordóñez, S.	Spain
Hydrodechlorination of tetrachloroethylene	2010	Ordóñez, S.	Spain
Hydrodechlorination of tetrachloroethylene	2010	Ordóñez, S.	Spain
Hydrodechlorination of tetrachloroethylene	2010	Ordóñez, S.	Spain
Hydrodechlorination of tetrachloroethylene	2010	Ordóñez, S.	Spain
Hydrodechlorination of tetrachloroethylene	2010	Ordóñez, S.	Spain
Hydrodechlorination of tetrachloroethylene	2010	Ordóñez, S.	Spain
Oxidation of glucose	2010	Chen, K.	China
Oxidation of glucose	2010	Chen, K.	China
Oxidation of glucose	2010	Chen, K.	China
Electro-reduction of oxygen	2010	Kumar, S.M.S	UK, Spain
Electro-reduction of oxygen	2010	Kumar, S.M.S	UK, Spain
Electro-reduction of oxygen	2010	Kumar, S.M.S	UK, Spain
Electro-reduction of oxygen	2010	Kumar, S.M.S	UK, Spain
Electro-oxidation of formic acid	2010	Wang, Z.-B.	China
Electro-oxidation of formic acid	2010	Wang, Z.-B.	China
Electro-oxidation of formic acid	2010	Wang, Z.-B.	China

Electro-oxidation of formic acid	2010	Wang, Z.-B.	China
Electro-oxidation of formic acid	2010	Chen, M.	China
Electro-oxidation of formic acid	2010	Chen, M.	China
Oxidation of toluene	2010	Bedia, J.	Spain
Oxidation of toluene	2010	Bedia, J.	Spain
Oxidation of toluene	2010	Bedia, J.	Spain
Hydrogenation of benzene	2010	Boudjahem, A.-G.	Algeria, France
Hydrogenation of benzene	2010	Boudjahem, A.-G.	Algeria, France
Hydrogenation of benzene	2010	Boudjahem, A.-G.	Algeria, France
Hydrogenation of benzene	2010	Boudjahem, A.-G.	Algeria, France
Hydrogenation of benzene	2010	Boudjahem, A.-G.	Algeria, France
Combustion of methane	2010	Castellazzi, P.	Italy
Combustion of methane	2010	Castellazzi, P.	Italy
Combustion of methane	2010	Castellazzi, P.	Italy
Hydrogenation of nitrite	2010	Chinthaginjala, J.K.	Netherlands
Hydrogenation of nitrite	2010	Chinthaginjala, J.K.	Netherlands
Hydrogenation of nitrite	2010	Chinthaginjala, J.K.	Netherlands
Hydrogenation of nitrite	2010	Chinthaginjala, J.K.	Netherlands
Hydrogenation of nitrite	2010	Chinthaginjala, J.K.	Netherlands
Hydrogenation of nitrite	2010	Chinthaginjala, J.K.	Netherlands
Hydrogenation of nitrite	2010	Chinthaginjala, J.K.	Netherlands
Hydrogenation of nitrite	2010	Chinthaginjala, J.K.	Netherlands
Oxidation of glucose	2010	Delidovich, I.V.	Russia
Oxidation of glucose	2010	Delidovich, I.V.	Russia
Oxidation of glucose	2010	Delidovich, I.V.	Russia
Oxidation of glucose	2010	Delidovich, I.V.	Russia
Hydrogenation of ethylanthraquinone	2010	Feng, J.-T.	China
Hydrogenation of ethylanthraquinone	2010	Feng, J.-T.	China
Hydrogenation of ethylanthraquinone	2010	Feng, J.-T.	China
Hydrogenation of ethylanthraquinone	2010	Feng, J.-T.	China
Hydrogenation of cinnamaldehyde	2010	Galletti, A.M.R.	Italy
Hydrogenation of cinnamaldehyde	2010	Galletti, A.M.R.	Italy
Hydrogenation of cinnamaldehyde	2010	Galletti, A.M.R.	Italy
Hydrogenation of cinnamaldehyde	2010	Galletti, A.M.R.	Italy
Hydrogenation of cinnamaldehyde	2010	Galletti, A.M.R.	Italy
Hydrogenation of cinnamaldehyde	2010	Galletti, A.M.R.	Italy
Hydrogenation of cinnamaldehyde	2010	Galletti, A.M.R.	Italy
Hydrogenation of cinnamaldehyde	2010	Galletti, A.M.R.	Italy
Direct synthesis of H2O2	2010	Ghedini, E.	Italy
Hydrodechlorination of chlorotrifluoroethylene	2010	Meng, B.-C.	China
Hydrodechlorination of chlorotrifluoroethylene	2010	Meng, B.-C.	China
Oxidation of CO, ethanol, toluene	2010	Santos, V.P.	Portugal
Oxidation of CO, ethanol, toluene	2010	Santos, V.P.	Portugal
Oxidation of alcohol	2011	Rikkinen, E.	Finland
Electro-oxidation of formic acid	2011	Ma, J.	China
Electro-oxidation of hydrazine	2011	Liang, Y.	China
Electro-oxidation of hydrazine	2011	Liang, Y.	China
NA	2011	Albers, P.W.	Germany, UK

NA	2011	Albers, P.W.	Germany, UK
NA	2011	Albers, P.W.	Germany, UK
NA	2011	Albers, P.W.	Germany, UK
Decomposition of 4-phenoxyphenol to aromatics	2011	Park, H.W.	South Korea
Decomposition of 4-phenoxyphenol to aromatics	2011	Park, H.W.	South Korea
Decomposition of 4-phenoxyphenol to aromatics	2011	Park, H.W.	South Korea
Decomposition of 4-phenoxyphenol to aromatics	2011	Park, H.W.	South Korea
Decomposition of 4-phenoxyphenol to aromatics	2011	Park, H.W.	South Korea
Reduction of nitrate	2011	Trawczyński, J.	Poland, Spain
Hydrogenation of β-sitosterol	2011	Chen, H.	China
Hydrogenation of β-sitosterol	2011	Chen, H.	China
Hydrogenation of β-sitosterol	2011	Chen, H.	China
Hydrogenation of β-sitosterol	2011	Chen, H.	China
Hydrogenation of sunflower oil	2011	McArdle, S.	Ireland
Hydrogenation of sunflower oil	2011	McArdle, S.	Ireland
Hydrogenation of sunflower oil	2011	McArdle, S.	Ireland
Electro-reduction of H2O2	2011	Sun, L.	China
Hydrogenation of acetophenone	2011	Xiang, Y.Z.	China
Hydrogenation of acetophenone	2011	Xiang, Y.Z.	China
Conversion of biomass-derived butanal	2011	Kim, S.M.	Republic of Korea
Conversion of biomass-derived butanal	2011	Kim, S.M.	Republic of Korea
Conversion of biomass-derived butanal	2011	Kim, S.M.	Republic of Korea
Conversion of biomass-derived butanal	2011	Kim, S.M.	Republic of Korea
Conversion of biomass-derived butanal	2011	Kim, S.M.	Republic of Korea
Conversion of biomass-derived butanal	2011	Kim, S.M.	Republic of Korea
NA	2011	Choi, S.M.	Republic of Korea
Hydrodechlorination of trichloroethylene	2011	Cobo, M.	Colombia
Hydrodechlorination of trichloroethylene	2011	Cobo, M.	Colombia
Hydrodechlorination of 2,4-dichlorophenol	2011	Diaz, E.	Spain
Hydrodechlorination of 2,4-dichlorophenol	2011	Diaz, E.	Spain
Hydrodechlorination of 2,4-dichlorophenol	2011	Diaz, E.	Spain
Reductive amination of carbonyl compounds	2011	Domine, M.E.	Spain
Reductive amination of carbonyl compounds	2011	Domine, M.E.	Spain
Reductive amination of carbonyl compounds	2011	Domine, M.E.	Spain
Reductive amination of carbonyl compounds	2011	Domine, M.E.	Spain
Combustion of methane	2011	Eyssler, A.	Switzerland
Combustion of methane	2011	Eyssler, A.	Switzerland
Combustion of methane	2011	Eyssler, A.	Switzerland
Combustion of methane	2011	Eyssler, A.	Switzerland
Hydrogenation of 3,4-dichloronitrobenzene	2011	Ma, L.	China
Hydrogenation of 3,4-dichloronitrobenzene	2011	Ma, L.	China

Hydrogenation of 3,4-dichloronitrobenzene	2011	Ma, L.	China
Hydrogenation of 3,4-dichloronitrobenzene	2011	Ma, L.	China
Hydrogenation of 3,4-dichloronitrobenzene	2011	Ma, L.	China
Hydrogenation of 3,4-dichloronitrobenzene	2011	Ma, L.	China
Hydrodechlorination of chlorofluorocarbons	2011	Zheng, X.	China
Electro-oxidation of formic acid	2011	Morgan, R.D.	USA
Electro-oxidation of ethanol	2011	Li, G.	China
Electro-oxidation of ethanol	2011	Li, G.	China
Electro-oxidation of ethanol	2011	Li, G.	China
Electro-oxidation of ethanol	2011	Li, G.	China
Hydrodechlorination of 2,4-dichlorophenol	2011	Shao, Y.	China
Hydrodechlorination of 2,4-dichlorophenol	2011	Shao, Y.	China
Hydrodechlorination of 2,4-dichlorophenol	2011	Shao, Y.	China
Dechlorination of 1,2-dichloroethane	2011	Śrębowata, A.	Poland
Oxidation of CO	2011	Tanikawa, K.	Japan
Oxidation of CO	2011	Tanikawa, K.	Japan
Oxidation of CO	2011	Tanikawa, K.	Japan
Oxidation of CO	2011	Tanikawa, K.	Japan
Hydrogenation of citral	2011	Vicente, A.	France, USA
Hydrogenation of citral	2011	Vicente, A.	France, USA
HDS of thiophene and benzothiophene	2011	Vít, Z.	Czech Republic, Italy
HDS of thiophene and benzothiophene	2011	Vít, Z.	Czech Republic, Italy
HDS of thiophene and benzothiophene	2011	Vít, Z.	Czech Republic, Italy
HDS of thiophene and benzothiophene	2011	Vít, Z.	Czech Republic, Italy
HDS of thiophene and benzothiophene	2011	Vít, Z.	Czech Republic, Italy
HDS of thiophene and benzothiophene	2011	Vít, Z.	Czech Republic, Italy
Hydrogenation–esterification of furfural and acetic acid	2011	Yu, W.	China
Decomposition of methanol	2011	Zhao, M.	China
Reduction of oxygen	2011	Alvarez, G.F.	UK
Reduction of oxygen	2011	Alvarez, G.F.	UK
Oxidation of benxyl alcohol	2011	Li, B.	China
Oxidation of benxyl alcohol	2011	Li, B.	China
Oxidation of benxyl alcohol	2011	Li, B.	China
Oxidation of benxyl alcohol	2011	Li, B.	China
Oxidation of benxyl alcohol	2011	Li, B.	China
Oxidation of benxyl alcohol	2011	Li, B.	China
Oxidation of benxyl alcohol	2011	Li, B.	China
Hydrocracking of light cycle oil	2011	Gutiérrez, A.	Spain

Reduction of nitrate	2011	Krawczyk, N.	Poland
Reduction of nitrate	2011	Krawczyk, N.	Poland
Reduction of nitrate	2011	Krawczyk, N.	Poland
Reduction of nitrate	2011	Krawczyk, N.	Poland
Decomposition of aromatic hydrocarbon	2011	Rönkkönen, H.	Finland
Hydrogenation of 1,3-butadiene	2011	Pattamakomsan, K.	Thailand, France
Hydrogenation of 1,3-butadiene	2011	Pattamakomsan, K.	Thailand, France
Hydrogenation of 1,3-butadiene	2011	Pattamakomsan, K.	Thailand, France
Hydrogenation of 1,3-butadiene	2011	Pattamakomsan, K.	Thailand, France
Hydrodesulfurization of thiophene	2011	Suo, Z.	China
Electro-oxidation of formic acid	2011	Woo, S.	Republic of Korea
Direct synthesis of H2O2	2011	Abate, S.	Italy
Direct synthesis of H2O2	2011	Abate, S.	Italy
Direct synthesis of H2O2	2011	Abate, S.	Italy
Reduction of Cr(VI)	2011	Chen, H.	China
Reduction of Cr(VI)	2011	Chen, H.	China
Reduction of Cr(VI)	2011	Chen, H.	China
Reduction of Cr(VI)	2011	Chen, H.	China
Reduction of Cr(VI)	2011	Chen, H.	China
Reduction of Cr(VI)	2011	Chen, H.	China
Reduction of Cr(VI)	2011	Chen, H.	China
Reduction of Cr(VI)	2011	Chen, H.	China
Heck Reaction	2011	Janowska, I.	France
Hydrogenation of crotonaldehyde	2011	McInroy, A.R.	UK, Germany, Austria
Hydrogenation of crotonaldehyde	2011	McInroy, A.R.	UK, Germany, Austria
Hydrogenation of crotonaldehyde	2011	McInroy, A.R.	UK, Germany, Austria
Hydrogenation of crotonaldehyde	2011	McInroy, A.R.	UK, Germany, Austria
Hydrogenation of crotonaldehyde	2011	McInroy, A.R.	UK, Germany, Austria
Hydrogenation of phenol	2011	Pérez, Y.	Spain
Hydrogenation of phenol	2011	Pérez, Y.	Spain
Hydrogenation of phenol	2011	Pérez, Y.	Spain
Reduction of potassium hexacyanoferrate(III)	2011	He, H.	China
Hydrogenation of pyrolysis gasoline	2011	Zhou, Z.	China
Hydrogenation of 3,4-(10,30-dibenzyl-20-oxoimidazolido)-2-(4-carboxybutylidene) thiophane	2018	An, N.	China
Hydrogenation of 3,4-(10,30-dibenzyl-20-oxoimidazolido)-2-(4-carboxybutylidene) thiophane	2018	An, N.	China
Hydrogenation of 3,4-(10,30-dibenzyl-20-oxoimidazolido)-2-(4-carboxybutylidene) thiophane	2018	An, N.	China
Hydrogenation of 3,4-(10,30-dibenzyl-20-oxoimidazolido)-2-(4-carboxybutylidene) thiophane	2018	An, N.	China
Hydrogenation of styrene	2011	Badano, J.M.	Argentina, Spain
Hydrogenation of styrene	2011	Badano, J.M.	Argentina, Spain
Hydrogenation of styrene	2011	Badano, J.M.	Argentina, Spain
Oxidation of methane	2011	Amairia, C.	France
Oxidation of methane	2011	Amairia, C.	France
Oxidation of methane	2011	Amairia, C.	France

Steam reforming of dimethyl ether	2011	Ledesma, C.	Spain, USA
Steam reforming of dimethyl ether	2011	Ledesma, C.	Spain, USA
Steam reforming of dimethyl ether	2011	Ledesma, C.	Spain, USA
Steam reforming of dimethyl ether	2011	Ledesma, C.	Spain, USA
Steam reforming of dimethyl ether	2011	Ledesma, C.	Spain, USA
Steam reforming of dimethyl ether	2011	Ledesma, C.	Spain, USA
Steam reforming of dimethyl ether	2011	Ledesma, C.	Spain, USA
Steam reforming of dimethyl ether	2011	Ledesma, C.	Spain, USA
Electro-oxidation of formic acid	2011	Yang, J.	China
Electro-oxidation of formic acid	2011	Yang, J.	China
Electro-oxidation of formic acid	2011	Yang, J.	China
Electro-oxidation of formic acid	2011	Yang, J.	China
Electro-oxidation of formic acid	2011	Yang, J.	China
Suzuki-Miyaura cross coupling	2011	Sreedhar, B.	India
Direct synthesis of H2O2	2011	Abate, S.	Italy
Capture of toxic components from fuel gas	2011	Baltrus, J.P.	USA
Capture of toxic components from fuel gas	2011	Baltrus, J.P.	USA
Hydrogenation–dehydration of aromatic ketones	2011	Bertero, N.M.	Argentina
NA	2011	Parambhath, V.B.	India
Dehydrogenation of alcohols	2011	Zhang, Q.	China
Dehydrogenation of alcohols	2011	Zhang, Q.	China
Dehydrogenation of alcohols	2011	Zhang, Q.	China
Dehydrogenation of alcohols	2011	Zhang, Q.	China
Dehydrogenation of alcohols	2011	Zhang, Q.	China
Dehydrogenation of alcohols	2011	Zhang, Q.	China
Dehydrogenation of alcohols	2011	Zhang, Q.	China
Dehydrogenation of alcohols	2011	Zhang, Q.	China
Dehydrogenation of alcohols	2011	Zhang, Q.	China
Dehydrogenation of alcohols	2011	Zhang, Q.	China
Dehydrogenation of alcohols	2011	Zhang, Q.	China
Dehydrogenation of alcohols	2011	Zhang, Q.	China
Dehydrogenation of alcohols	2011	Zhang, Q.	China
Hydrodeoxygenation of bio-derived phenols	2011	Zhao, C.	Germany
Hydrodeoxygenation of bio-derived phenols	2011	Zhao, C.	Germany
Hydrodeoxygenation of bio-derived phenols	2011	Zhao, C.	Germany
Hydrodeoxygenation of bio-derived phenols	2011	Zhao, C.	Germany
Hydrodeoxygenation of bio-derived phenols	2011	Zhao, C.	Germany
Oxidation of CO	2012	Li, Y.	China, Denmark
Oxidation of CO	2012	Li, Y.	China, Denmark
Oxidation of CO	2012	Li, Y.	China, Denmark
Reduction of nitrite	2012	Shuai, D.	USA
Reduction of nitrite	2012	Shuai, D.	USA
Reduction of nitrite	2012	Shuai, D.	USA
Reduction of nitrite	2012	Shuai, D.	USA
Reduction of nitrite	2012	Shuai, D.	USA
Reduction of nitrite	2012	Shuai, D.	USA
Reduction of nitrite	2012	Shuai, D.	USA

Oxidation of aromatic alcohols	2013	Wu, G.	China
Oxidation of aromatic alcohols	2013	Wu, G.	China
Oxidation of aromatic alcohols	2013	Wu, G.	China
Oxidation of aromatic alcohols	2013	Wu, G.	China
Oxidation of aromatic alcohols	2013	Wu, G.	China
Oxidation of CO	2013	Cao, Y.	China
Debenzylation of 4-benzyloxyphenol	2014	Agostini, G.	Italy, France
Debenzylation of 4-benzyloxyphenol	2014	Agostini, G.	Italy, France
Debenzylation of 4-benzyloxyphenol	2014	Agostini, G.	Italy, France
Oxidation of CO	2014	Wang, L.	China
Oxidation of CO	2014	Wang, L.	China
Oxidation of CO	2014	Wang, L.	China
Oxidation of CO	2014	Wang, L.	China
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium

Oxidation of CO	2014	Qi, B.	China
Hydrogenation of acetylene	2014	Benavidez, A.D.	USA
Hydrogenation of acetylene	2014	Benavidez, A.D.	USA
Hydrogenation of acetylene	2014	Benavidez, A.D.	USA
Isomerization of n-hexane	2015	Dzhikiya, O.V.	Russia
Isomerization of n-hexane	2015	Dzhikiya, O.V.	Russia
Isomerization of n-hexane	2015	Dzhikiya, O.V.	Russia
Hydrogenation of nitrocompounds	2015	Eremenko, N.K.	Russia
Hydrogenation of nitrocompounds	2015	Eremenko, N.K.	Russia
Hydrogenation of nitrocompounds	2015	Eremenko, N.K.	Russia
Hydrogenation of nitrocompounds	2015	Eremenko, N.K.	Russia
Hydrogenation of nitrocompounds	2015	Eremenko, N.K.	Russia
Hydrogenation for reduction of MCAA and bromate	2015	Zhou, J.	China
Hydrogenation for reduction of MCAA and bromate	2015	Zhou, J.	China
Hydrogenation for reduction of MCAA and bromate	2015	Zhou, J.	China
Hydrogenation for reduction of MCAA and bromate	2015	Zhou, J.	China
Hydrogenation for reduction of MCAA and bromate	2015	Zhou, J.	China
Hydrogenation for reduction of MCAA and bromate	2015	Zhou, J.	China
Hydrogenation for reduction of MCAA and bromate	2015	Zhou, J.	China
Hydrodechlorination of chloromethanes	2015	Martin-Martinez, M.	Spain, UK, USA
Dehydrogenation of biomass	2015	Su, J.	USA
Hydrogenation of butyronitrile	2015	Hao, Y.	Scotland
Hydrogenation of butyronitrile	2015	Hao, Y.	Scotland
Oxidation of methane	2015	Lee, H.	Republic of Korea
Oxidation of methane	2015	Lee, H.	Republic of Korea
Oxidation of methane	2015	Lee, H.	Republic of Korea
Direct synthesis of H2O2	2015	Ouyang, L.	China
Direct synthesis of H2O2	2015	Ouyang, L.	China
Direct synthesis of H2O2	2015	Ouyang, L.	China
Direct synthesis of H2O2	2015	Ouyang, L.	China
Hydrogenation of furfural	2015	Mironenko, R.M.	Russia
Hydrogenation of furfural	2015	Mironenko, R.M.	Russia
Oxidation of methane	2015	Miller, J.B.	USA
Oxidation of methane	2015	Miller, J.B.	USA
Oxidation of methane	2015	Miller, J.B.	USA
Oxidation of methane	2015	Miller, J.B.	USA
Oxidation of methane	2015	Miller, J.B.	USA
Oxidation of methane	2015	Miller, J.B.	USA
Hydrogenation of furfural	2015	Bhogeswararao, S.	India
Hydrogenation of furfural	2015	Bhogeswararao, S.	India
Hydrogenation of furfural	2015	Bhogeswararao, S.	India
Oxidation of propene	2015	Gil, S.	France, Italy
Oxidation of propene	2015	Gil, S.	France, Italy
Oxidation of propene	2015	Gil, S.	France, Italy
Oxidation of propene	2015	Gil, S.	France, Italy

Oxidation of propene	2015	Gil, S.	France, Italy
Oxidation of propene	2015	Gil, S.	France, Italy
Oxidation of propene	2015	Gil, S.	France, Italy
Elimination of HC, CO, NOx	2015	Lin, S.	China
Elimination of HC, CO, NOx	2015	Lin, S.	China
Elimination of HC, CO, NOx	2015	Lin, S.	China
Heck Reaction	2015	Wang, P.	China
Hydrogenation of acetylene	2015	He, Y.	China
Hydrogenation of acetylene	2015	He, Y.	China
Hydrogenation of acetylene	2015	He, Y.	China
Hydrogenation of CO2	2015	Wang, X.	USA, Korea
Hydrogenation of CO2	2015	Wang, X.	USA, Korea
Oxidation of alcohols	2015	Liu, K.	China
Oxidation of alcohols	2015	Liu, K.	China
Oxidation of alcohols	2015	Liu, K.	China
Oxidation of methane	2016	Bychkov, V. Y.	Russia, Germany
Oxidation of methane	2016	Bychkov, V. Y.	Russia, Germany
Oxidation of methane	2016	Bychkov, V. Y.	Russia, Germany
Oxidation of CO	2016	Soni, K.C.	India
Oxidation of CO	2016	Soni, K.C.	India
Hydrogenation of lignin-derived monophenols	2016	Yi, J.	China
Hydrogenation of lignin-derived monophenols	2016	Yi, J.	China
Hydrogenation of paracetamol	2016	Song, W.	China, Spain
Hydrogenation of paracetamol	2016	Song, W.	China, Spain
Hydrogenation of paracetamol	2016	Song, W.	China, Spain
Hydrogenation of paracetamol	2016	Song, W.	China, Spain
Hydrogenation of paracetamol	2016	Song, W.	China, Spain
Hydrogenation of cinnamaldehyde	2016	Jiang, F.	China
Hydrogenation of cinnamaldehyde	2016	Jiang, F.	China
Hydrogenation of cinnamaldehyde	2016	Jiang, F.	China
Hydrogenation of cinnamaldehyde	2016	Jiang, F.	China
Hydrogenation of cinnamaldehyde	2016	Jiang, F.	China
Hydrogenation of cinnamaldehyde	2016	Jiang, F.	China
Hydrogenation of cinnamaldehyde	2016	Jiang, F.	China
Hydrodeoxygenation of 5-hydroxymethylfurfural	2016	Duarte, D.P.	Colombia
Hydrogenation of C=C bond	2016	Nie, R.	China
Hydrogenation of C=C bond	2016	Nie, R.	China
Hydrogenation of C=C bond	2016	Nie, R.	China
Hydrogenation of C=C bond	2016	Nie, R.	China
Hydrodechlorination of the MCPA herbicide	2016	Diaz, E.	Spain
Hydrodechlorination of the MCPA herbicide	2016	Diaz, E.	Spain
Hydrogenation of methanol	2016	Bahruji, H.	UK
Hydrogenation of methanol	2016	Bahruji, H.	UK
Hydrogenation of methanol	2016	Bahruji, H.	UK
Hydrogenation of methanol	2016	Bahruji, H.	UK
Hydrogenation of methanol	2016	Bahruji, H.	UK
Hydrogenation of methanol	2016	Bahruji, H.	UK
Hydrogenation of methanol	2016	Bahruji, H.	UK
Hydrogenation of methanol	2016	Bahruji, H.	UK
Hydrogenation of methanol	2016	Bahruji, H.	UK
Hydrogenation of methanol	2016	Bahruji, H.	UK
Hydrogenation of methanol	2016	Bahruji, H.	UK

Hydrogenation of methanol	2016	Bahruji, H.	UK
Hydrogenation of methanol	2016	Bahruji, H.	UK
Hydrogenation of methanol	2016	Bahruji, H.	UK
Suzuki cross-coupling reaction	2016	Jacquemin, M.	Belgium
Suzuki cross-coupling reaction	2016	Jacquemin, M.	Belgium
Suzuki cross-coupling reaction	2016	Jacquemin, M.	Belgium
Suzuki cross-coupling reaction	2016	Jacquemin, M.	Belgium
Suzuki cross-coupling reaction	2016	Jacquemin, M.	Belgium
Suzuki cross-coupling reaction	2016	Jacquemin, M.	Belgium
Oxidation of CO	2016	Vasilchenko, D.B.	Russia
Oxidation of CO	2016	Vasilchenko, D.B.	Russia
Oxidation of CO	2016	Vedyagin, A.A.	Russia
Hydrogenation of acetylene	2016	Zhou, H.	China
Hydrogenation of acetylene	2016	Zhou, H.	China
Combustion of methane	2017	Murata, K.	Japan
Combustion of methane	2017	Murata, K.	Japan
Combustion of methane	2017	Murata, K.	Japan
Combustion of methane	2017	Murata, K.	Japan
Combustion of methane	2017	Murata, K.	Japan
Combustion of methane	2017	Murata, K.	Japan
Combustion of methane	2017	Murata, K.	Japan
Combustion of methane	2017	Murata, K.	Japan
Combustion of methane	2017	Murata, K.	Japan
Combustion of methane	2017	Murata, K.	Japan
Combustion of methane	2017	Murata, K.	Japan
Combustion of methane	2017	Murata, K.	Japan
Combustion of methane	2017	Murata, K.	Japan
Combustion of methane	2017	Murata, K.	Japan
Combustion of methane	2017	Murata, K.	Japan
Combustion of methane	2017	Murata, K.	Japan
Combustion of methane	2017	Murata, K.	Japan
Oxidation of CO	2017	Lang, W.	USA
Oxidation of CO	2017	Lang, W.	USA
Hydrogenation of alkynes	2018	Ellis, P.R.	UK
Hydrogenation of alkynes	2018	Ellis, P.R.	UK
Hydrogenation of sodium 2,4,6-trinitrobenzoate	2018	Belskaya, O. B.	Russia
Hydrogenation of sodium 2,4,6-trinitrobenzoate	2018	Belskaya, O. B.	Russia
Suzuki-Miyaura cross coupling	2018	Martínez-Klimov, M.E.	Mexico
Suzuki-Miyaura cross coupling	2018	Martínez-Klimov, M.E.	Mexico
Suzuki-Miyaura cross coupling	2018	Martínez-Klimov, M.E.	Mexico
Suzuki-Miyaura cross coupling	2018	Martínez-Klimov, M.E.	Mexico
Suzuki-Miyaura cross coupling	2018	Martínez-Klimov, M.E.	Mexico
Hydrogenation of benzene	2018	Redjel, A.	France
Hydrogenation of benzene	2018	Redjel, A.	France

Hydrogenation of benzene	2018	Redjel, A.	France
Oxidation of Industrial VOC	2018	Brunet, J.	Belgium, France
Oxidation of Industrial VOC	2018	Brunet, J.	Belgium, France
Oxidation of Industrial VOC	2018	Brunet, J.	Belgium, France
Hydrogenation of 1,3-butadiene	2018	Castillejos, E.	Spain
Hydrogenation of 1,3-butadiene	2018	Castillejos, E.	Spain
Hydrogenation of 1,3-butadiene	2018	Castillejos, E.	Spain
Hydrogenation of 1,3-butadiene	2018	Castillejos, E.	Spain
Hydrogenation of 1,3-butadiene	2018	Castillejos, E.	Spain
Hydrogenation of 1,3-butadiene	2018	Castillejos, E.	Spain
Hydrogenation of 1,3-butadiene	2018	Castillejos, E.	Spain
Hydrogenation of 1,3-butadiene	2018	Castillejos, E.	Spain
Hydrogenation of 1,3-butadiene	2018	Castillejos, E.	Spain
Hydrogenation of cinnamaldehyde	2018	Lamme, W.S.	Netherlands
Hydrogenation of cinnamaldehyde	2018	Lamme, W.S.	Netherlands
Hydrogenation of cinnamaldehyde	2018	Lamme, W.S.	Netherlands
Hydrogenation of cinnamaldehyde	2018	Lamme, W.S.	Netherlands
Hydrogenation of cinnamaldehyde	2018	Lamme, W.S.	Netherlands
Hydrogenation of cinnamaldehyde	2018	Lamme, W.S.	Netherlands
Hydrogenation of cinnamaldehyde	2018	Lamme, W.S.	Netherlands
Amination of halogenated aldehydes	2018	Villa, A.	Italy, Belgium
Amination of halogenated aldehydes	2018	Villa, A.	Italy, Belgium
Amination of halogenated aldehydes	2018	Villa, A.	Italy, Belgium
Amination of halogenated aldehydes	2018	Villa, A.	Italy, Belgium
Hydrogenation of long chain alkadienes	2004	Li, Y.	China
Hydrogenation of long chain alkadienes	2004	Li, Y.	China
Hydrogenation of long chain alkadienes	2004	Li, Y.	China
Hydrogenation of long chain alkadienes	2004	Li, Y.	China
Hydrogenation of furfural	2018	Albilali, R.	UK, Saudi Arabia
Hydrogenation of furfural	2018	Albilali, R.	UK, Saudi Arabia
Hydrogen production from hydrogen iodide	2018	Singhania, A.	India
Hydrogen production from hydrogen iodide	2018	Singhania, A.	India
Hydrogen production from hydrogen iodide	2018	Singhania, A.	India
Hydrogenation of 2,4,6-trinitrobenzoic acid	2018	Belskaya, O. B.	Russia
Hydrogenation of 2,4,6-trinitrobenzoic acid	2018	Belskaya, O. B.	Russia
Hydrogenation of 2,4,6-trinitrobenzoic acid	2018	Belskaya, O. B.	Russia
Hydrogenation of 2,4,6-trinitrobenzoic acid	2018	Belskaya, O. B.	Russia
Hydrogenation of 2,4,6-trinitrobenzoic acid	2018	Belskaya, O. B.	Russia
Hydrogenation of 2,4,6-trinitrobenzoic acid	2018	Belskaya, O. B.	Russia
Hydrogenation of 2,4,6-trinitrobenzoic acid	2018	Belskaya, O. B.	Russia
Hydrogenation of 2,4,6-trinitrobenzoic acid	2018	Belskaya, O. B.	Russia

Hydrogenation of 2,4,6-trinitrobenzoic acid	2018	Belskaya, O. B.	Russia
Hydrogenation of 2,4,6-trinitrobenzoic acid	2018	Belskaya, O. B.	Russia
Hydrogenation of 2,4,6-trinitrobenzoic acid	2018	Belskaya, O. B.	Russia
Hydrogenation of 2,4,6-trinitrobenzoic acid	2018	Belskaya, O. B.	Russia
Hydrogenation of 2,4,6-trinitrobenzoic acid	2018	Belskaya, O. B.	Russia
Hydrogenation of 2,4,6-trinitrobenzoic acid	2018	Belskaya, O. B.	Russia
Hydrogenation of 2,4,6-trinitrobenzoic acid	2018	Belskaya, O. B.	Russia
Oxidation of ethanol	2018	Louisia, S.	France
Oxidation of ethanol	2018	Louisia, S.	France
Oxidation of ethanol	2018	Louisia, S.	France
Oxidation of ethanol	2018	Louisia, S.	France
Combustion of methane	2018	Toso, A.	Italy
Hydrogenation of the carbon support	2018	lost, KN	Russia
Hydrogenation of the carbon support	2018	lost, KN	Russia
Hydrogenation of the carbon support	2018	lost, KN	Russia
Hydrogenation of the carbon support	2018	lost, KN	Russia
Oxidation of CO	2018	Burange, A.S.	India
Oxidation of CO	2018	Burange, A.S.	India
Oxidation of CO	2018	Burange, A.S.	India
Hydrogenation of furfural	2019	Mironenko, R.M.	Russia
Hydrogenation of furfural	2019	Mironenko, R.M.	Russia
Hydrogenation of furfural	2019	Mironenko, R.M.	Russia
Hydrogenation of furfural	2019	Mironenko, R.M.	Russia
Hydrogenation of 4-chloronitrobenzenes	2019	Králik, M.	Slovakia
Hydrogenation of cinnamaldehyde	2019	Lamme, W.S.	Netherlands, Belgium
Hydrogenation of cinnamaldehyde	2019	Lamme, W.S.	Netherlands, Belgium
Hydrogenation of cinnamaldehyde	2019	Lamme, W.S.	Netherlands, Belgium
Hydrogenation of cinnamaldehyde	2019	Lamme, W.S.	Netherlands, Belgium
Hydrogenation of cinnamaldehyde	2019	Lamme, W.S.	Netherlands, Belgium
Hydrogenation of cinnamaldehyde	2019	Lamme, W.S.	Netherlands, Belgium
Hydrogenation of cinnamaldehyde	2019	Lamme, W.S.	Netherlands, Belgium
Hydrogenation of cinnamaldehyde	2019	Lamme, W.S.	Netherlands, Belgium
Hydrogenation of cinnamaldehyde	2019	Lamme, W.S.	Netherlands, Belgium
Hydrogenation of cinnamaldehyde	2019	Lamme, W.S.	Netherlands, Belgium
Hydrogenation of cinnamaldehyde	2019	Lamme, W.S.	Netherlands, Belgium
Hydrogenation of cinnamaldehyde	2019	Lamme, W.S.	Netherlands, Belgium
Hydrogenation of cinnamaldehyde	2019	Lamme, W.S.	Netherlands, Belgium
Hydrogenation of cinnamaldehyde	2019	Lamme, W.S.	Netherlands, Belgium
Oxidation of methane	2019	Velin, P.	Sweden, UK
Oxidation of methane	2019	Velin, P.	Sweden, UK
Oxidation of methane	2019	Velin, P.	Sweden, UK
Oxidation of methane	2019	Velin, P.	Sweden, UK
Oxidation of methane	2019	Velin, P.	Sweden, UK
Hydrogenation of nitrobenzene	2019	Matus, E.V.	Russia, Spain
Hydrogenation of nitrobenzene	2019	Matus, E.V.	Russia, Spain
Hydrogenation of nitrobenzene	2019	Matus, E.V.	Russia, Spain
Hydrogenation of nitrobenzene	2019	Matus, E.V.	Russia, Spain
Hydrogenation of nitrobenzene	2019	Matus, E.V.	Russia, Spain
Hydrogenation of nitrobenzene	2019	Matus, E.V.	Russia, Spain
Oxidation of toluene	2019	Pham, T.H.	Vietnam

Oxidation of toluene	2019	Pham, T.H.	Vietnam
Oxidation of toluene	2019	Pham, T.H.	Vietnam
Oxidation of CO	2019	Stonkus, O.A.	Russia
Oxidation of CO	2019	Stonkus, O.A.	Russia
Oxidation of CO	2019	Stonkus, O.A.	Russia
Oxidation of CO	2019	Stonkus, O.A.	Russia
Oxidation of CO	2019	Stonkus, O.A.	Russia
Oxidation of CO	2019	Stonkus, O.A.	Russia
Oxidation of CO	2019	Stonkus, O.A.	Russia
Oxidation of CO	2019	Stonkus, O.A.	Russia
Oxidation of CO	2019	Stonkus, O.A.	Russia
Oxidation of CO	2019	Stonkus, O.A.	Russia
Hydrogenation of propylene	2019	Laskin, A.I.	Russia
Hydrogenation of propylene	2019	Laskin, A.I.	Russia
Hydrogenation of propylene	2019	Laskin, A.I.	Russia
Hydrogenation of propylene	2019	Laskin, A.I.	Russia
Hydrogenation of propylene	2019	Laskin, A.I.	Russia
Hydrogenation of propylene	2019	Laskin, A.I.	Russia
Hydrogenation of propylene	2019	Laskin, A.I.	Russia
Hydrogenation of propylene	2019	Laskin, A.I.	Russia
Hydrogenation of propylene	2019	Laskin, A.I.	Russia
Hydrogenation of propylene	2019	Laskin, A.I.	Russia
Hydrogenation of acetylene	2019	Kang, L.	China
Hydrogenation of acetylene	2019	Kang, L.	China
Rosin disproportionation	2020	Gu, Y.	China, USA
Rosin disproportionation	2020	Gu, Y.	China, USA
Rosin disproportionation	2020	Gu, Y.	China, USA
Rosin disproportionation	2020	Gu, Y.	China, USA
Rosin disproportionation	2020	Gu, Y.	China, USA
Rosin disproportionation	2020	Gu, Y.	China, USA
Rosin disproportionation	2020	Gu, Y.	China, USA
Rosin disproportionation	2020	Gu, Y.	China, USA
Rosin disproportionation	2020	Gu, Y.	China, USA
Oxidation of HCHO	2020	Xiang, N.	China
Oxidation of HCHO	2020	Xiang, N.	China

Hydrogenation of furfural	2020	Byun, M.Y.	Korea
Hydrogenation of furfural	2020	Byun, M.Y.	Korea
Hydrogenation of furfural	2020	Byun, M.Y.	Korea
Hydrogenation of furfural	2020	Byun, M.Y.	Korea
Hydrogenation of furfural	2020	Byun, M.Y.	Korea
Combustion of methane	2020	Ding, Y.	China
Combustion of methane	2020	Ding, Y.	China
Combustion of methane	2020	Ding, Y.	China
Combustion of methane	2020	Ding, Y.	China
Dehalogenation of bromochloroacetic acid	2020	Zheng, C.	China
Dehalogenation of bromochloroacetic acid	2020	Zheng, C.	China
Dehalogenation of bromochloroacetic acid	2020	Zheng, C.	China
Dehalogenation of bromochloroacetic acid	2020	Zheng, C.	China
Dehalogenation of bromochloroacetic acid	2020	Zheng, C.	China
Dehalogenation of bromochloroacetic acid	2020	Zheng, C.	China
Dehalogenation of bromochloroacetic acid	2020	Zheng, C.	China
Oxidation of CO	2020	Li, H.	China
Oxidation of CO	2020	Li, H.	China
Oxidation of CO	2020	Li, H.	China
Combustion of n-butylamine	2020	Ma, M.	China
Combustion of n-butylamine	2020	Ma, M.	China
Hydrogenation of olefins	2020	Howeizi, J.	Hungary
Hydrogenation of olefins	2020	Howeizi, J.	Hungary
Hydrogenation of olefins	2020	Howeizi, J.	Hungary
Hydrogenation of olefins	2020	Howeizi, J.	Hungary
Hydrogenation of olefins	2020	Howeizi, J.	Hungary
Hydrogenation of olefins	2020	Howeizi, J.	Hungary
Hydrogenation of olefins	2020	Howeizi, J.	Hungary
Hydrogenation of olefins	2020	Howeizi, J.	Hungary
Hydrogenation of olefins	2020	Howeizi, J.	Hungary
Hydrogenation of olefins	2020	Howeizi, J.	Hungary
Direct synthesis of H2O2	2020	Cho, Y.-H.	Republic of Korea
Direct synthesis of H2O2	2020	Cho, Y.-H.	Republic of Korea
Direct synthesis of H2O2	2020	Cho, Y.-H.	Republic of Korea
Direct synthesis of H2O2	2020	Cho, Y.-H.	Republic of Korea
Direct synthesis of H2O2	2020	Cho, Y.-H.	Republic of Korea
Direct synthesis of H2O2	2020	Cho, Y.-H.	Republic of Korea

Oxidation of CO	2020	Zhou, G.-F.	China
Oxidation of CO	2020	Song, S.	China
Oxidation of CO	2020	Song, S.	China
Oxidation of CO	2020	Song, S.	China
Oxidation of NH3	2020	Lin, M.	Japan, China
Oxidation of methane	2020	Velin, P.	UK, Sweden
Oxidation of methane	2020	Velin, P.	UK, Sweden
Oxidation of methane	2020	Velin, P.	UK, Sweden
Oxidation of methane	2020	Velin, P.	UK, Sweden
Oxidation of methane	2020	Velin, P.	UK, Sweden
Oxidation of methane	2020	Velin, P.	UK, Sweden
Oxidation of methane	2020	Velin, P.	UK, Sweden
Oxidation of methane	2020	Velin, P.	UK, Sweden
Oxidation of methane	2020	Velin, P.	UK, Sweden
Decomposition of acetic acid	2020	Brijaldo, M.H.	Colombia, Brazil
Oxidative coupling of CO	2021	Yang, L.	China
Oxidative coupling of CO	2021	Yang, L.	China
Oxidative coupling of CO	2021	Yang, L.	China
Oxidative coupling of CO	2021	Yang, L.	China
Oxidative coupling of CO	2021	Yang, L.	China
Combustion of methane	2021	Ding, Y.	China, Vietnam
Combustion of methane	2021	Ding, Y.	China, Vietnam
Combustion of methane	2021	Ding, Y.	China, Vietnam
Reduction of bromate	2021	Cerrillo, J.L.	Spain, Brazil
Reduction of bromate	2021	Cerrillo, J.L.	Spain, Brazil
Reduction of bromate	2021	Cerrillo, J.L.	Spain, Brazil
Reduction of bromate	2021	Cerrillo, J.L.	Spain, Brazil
Reduction of bromate	2021	Cerrillo, J.L.	Spain, Brazil
Reduction of bromate	2021	Cerrillo, J.L.	Spain, Brazil
Reduction of bromate	2021	Cerrillo, J.L.	Spain, Brazil
Reduction of bromate	2021	Cerrillo, J.L.	Spain, Brazil
Reduction of bromate	2021	Cerrillo, J.L.	Spain, Brazil
Reduction of oxyanion	2021	Gao, J.	USA
Reduction of oxyanion	2021	Gao, J.	USA
Reduction of oxyanion	2021	Gao, J.	USA
Reduction of oxyanion	2021	Gao, J.	USA
Reduction of oxyanion	2021	Gao, J.	USA
Hydrogenation of benzene	2021	Zhou, G.	China
Hydrogenation of benzene	2021	Zhou, G.	China
Hydrogenation of benzene	2021	Zhou, G.	China
Hydrogenation of benzene	2021	Zhou, G.	China
Hydrogenation of benzene	2021	Zhou, G.	China
Hydrogenation of CO	2001	Shen, W.-J.	Japan
Hydrogenation of CO	2001	Shen, W.-J.	Japan

Hydrogenation of CO	2001	Shen, W.-J.	Japan
Hydrogenation of CO	2001	Shen, W.-J.	Japan
Synthesis of diethyl oxalate	2001	Jiang, X.Z.	China, Taiwan
Synthesis of diethyl oxalate	2001	Jiang, X.Z.	China, Taiwan
Hydrogenation of CO	2002	Imamura, S.	Japan
Hydrogenation of CO	2002	Imamura, S.	Japan
Hydrogenation of CO	2002	Imamura, S.	Japan
Hydrogenation of CO	2002	Imamura, S.	Japan
Hydrogenation of CO	2002	Imamura, S.	Japan
Hydrogenation of CO	2002	Imamura, S.	Japan
Hydrogenation of CO	2002	Imamura, S.	Japan
Hydrogenation of CO	2002	Imamura, S.	Japan
Hydrogenation of CO	2002	Imamura, S.	Japan
Decomposition of methanol	2001	Kapoor, M.P.	Japan
Decomposition of methanol	2001	Kapoor, M.P.	Japan
Decomposition of methanol	2001	Kapoor, M.P.	Japan
Decomposition of methanol	2001	Kapoor, M.P.	Japan
Decomposition of methanol	2001	Kapoor, M.P.	Japan
Decomposition of methanol	2001	Kapoor, M.P.	Japan

Decomposition of methanol	2001	Kapoor, M.P.	Japan
Decomposition of methanol	2001	Kapoor, M.P.	Japan
Hydrogenation of CO	2001	Shen, W.-J.	Japan
Hydrogenation of CO	2001	Shen, W.-J.	Japan
Hydrogenation of CO	2001	Shen, W.-J.	Japan
Hydrogenation of phenol	2002	Scirè, S.	Italy
Hydrogenation of phenol	2002	Scirè, S.	Italy
Hydrogenation of phenol	2002	Scirè, S.	Italy
Hydrogenation of phenol	2002	Scirè, S.	Italy
Hydrogenation of phenol	2002	Scirè, S.	Italy
Hydrogenation of phenol	2002	Scirè, S.	Italy
Decomposition of methanol	2002	Yang, C.	China
Decomposition of methanol	2002	Yang, C.	China
Decomposition of methanol	2002	Yang, C.	China
Decomposition of methanol	2002	Yang, C.	China
Decomposition of methanol	2002	Yang, C.	China
Decomposition of methanol	2002	Yang, C.	China
Decomposition of methanol	2002	Yang, C.	China
Decomposition of methanol	2002	Yang, C.	China
Decomposition of methanol	2002	Yang, C.	China
Decomposition of methanol	2002	Yang, C.	China
ND	2002	Wang, C.-B.	Republic of China
ND	2002	Wang, C.-B.	Republic of China
ND	2002	Wang, C.-B.	Republic of China
ND	2002	Wang, C.-B.	Republic of China
ND	2002	Wang, C.-B.	Republic of China
ND	2002	Wang, C.-B.	Republic of China
ND	2002	Wang, C.-B.	Republic of China
ND	2002	Wang, C.-B.	Republic of China
ND	2002	Wang, C.-B.	Republic of China
ND	2002	Wang, C.-B.	Republic of China
Reduction of Nitrate	2002	Epron, F.	France
Reduction of Nitrate	2002	Epron, F.	France
Combustion of methane	2017	Zhao, Z.	China
Combustion of methane	2017	Zhao, Z.	China

Combustion of methane	2017	Zhao, Z.	China
Combustion of methane	2017	Zhao, Z.	China
Hydrogenation of benzonitrile	2017	Dai, C.	China
Hydrogenation of benzonitrile	2017	Dai, C.	China
Hydrogenation of benzonitrile	2017	Dai, C.	China
Oxidation of formaldehyde	2017	Li, Y.	China
Oxidation of formaldehyde	2017	Li, Y.	China
Hydrogenation of isophorone and 2-benzylidene-1-benzosuberone	2004	Sípos, É	Hungary, Portugal
Hydrogenation of isophorone and 2-benzylidene-1-benzosuberone	2004	Sípos, É	Hungary, Portugal
Combustion of methane	2004	Neyertz, C.	Argentina
Hydrodechlorination of chlorobenzene	2004	Gopinath, R.	India, Japan
Hydrodechlorination of chlorobenzene	2004	Gopinath, R.	India, Japan
Hydrodechlorination of chlorobenzene	2004	Gopinath, R.	India, Japan
Hydrodechlorination of chlorobenzene	2004	Gopinath, R.	India, Japan
Hydrogenation of o-chloronitrobenzene	2007	Sikhwivhilu, L.M.	South Africa, India
Hydrogenation of o-chloronitrobenzene	2007	Sikhwivhilu, L.M.	South Africa, India
Hydrogenation of acetylene	2008	Komhom, S.	Thailand
Hydrogenation of acetylene	2008	Komhom, S.	Thailand
Combustion of methane	2008	Gao, D.	China
Combustion of methane	2008	Gao, D.	China
Combustion of methane	2008	Gao, D.	China
Combustion of methane	2008	Gao, D.	China
Combustion of methane	2008	Gao, D.	China
Combustion of methane	2008	Gao, D.	China
Combustion of methane	2008	Gao, D.	China
Oxidation of chlorobenzene	2008	Giraudon, J.-M.	France, Belgium
Oxidation of chlorobenzene	2008	Giraudon, J.-M.	France, Belgium
Oxidation of chlorobenzene	2008	Giraudon, J.-M.	France, Belgium
Oxidation of chlorobenzene	2008	Giraudon, J.-M.	France, Belgium
Oxidation of chlorobenzene	2008	Giraudon, J.-M.	France, Belgium
Oxidation of ethanol	2008	Costa, L.O.O.	Brazil
Oxidation of ethanol	2008	Costa, L.O.O.	Brazil
Hydrodechlorination of chlorobenzene	2008	Amorim, C.	USA, Scotland
Hydrodechlorination of chlorobenzene	2008	Amorim, C.	USA, Scotland
Hydrogenation of a model mixture (toluene, 1,7-octadiene, 1-octene, DCPD)	2008	Gaspar, A.B.	Brazil
Hydrogenation of a model mixture (toluene, 1,7-octadiene, 1-octene, DCPD)	2008	Gaspar, A.B.	Brazil
Hydrogenation of a model mixture (toluene, 1,7-octadiene, 1-octene, DCPD)	2008	Gaspar, A.B.	Brazil
Debenzylation of 4-benzyloxyphenol	2012	Groppo, E.	Italy, France
Debenzylation of 4-benzyloxyphenol	2012	Groppo, E.	Italy, France
Debenzylation of 4-benzyloxyphenol	2012	Groppo, E.	Italy, France
Hydrodeoxygenation of benzofuran	2012	Liu, C.	China

ND	2012	Mira, C.	Spain
ND	2012	Mira, C.	Spain
ND	2012	Mira, C.	Spain
Hydrogenation of methylacetylene	2012	Yu, H.	China
Hydrogenation of methylacetylene	2012	Yu, H.	China
Hydrogenation of methylacetylene	2012	Yu, H.	China
Oxidation of CO	2013	Satsuma, A.	Japan
Oxidation of CO	2013	Satsuma, A.	Japan
Oxidation of CO	2013	Satsuma, A.	Japan
Oxidation of CO	2013	Satsuma, A.	Japan
Oxidation of CO	2013	Satsuma, A.	Japan
Hydrodechlorination of chloroacetic acids	2013	Zhou, J.	China
Hydrodechlorination of chloroacetic acids	2013	Zhou, J.	China
Hydrodechlorination of chloroacetic acids	2013	Zhou, J.	China
Hydrodechlorination of chloroacetic acids	2013	Zhou, J.	China
Hydrodechlorination of chloroacetic acids	2013	Zhou, J.	China
Hydrodeoxygenation of guaiacol	2017	Lu, M.	China, USA
Hydrodeoxygenation of guaiacol	2017	Lu, M.	China, USA
Hydrodeoxygenation of guaiacol	2017	Lu, M.	China, USA
Hydrodeoxygenation of guaiacol	2017	Lu, M.	China, USA
Hydrodeoxygenation of guaiacol	2017	Lu, M.	China, USA
Oxidation of propane	2017	Khudorozhkov, A.K.	Russia
Oxidation of propane	2017	Khudorozhkov, A.K.	Russia
Oxidation of propane	2017	Khudorozhkov, A.K.	Russia
Hydrogenation of phenol and derivatives	2014	Cheng, L.	China
Hydrogenation of phenol and derivatives	2014	Cheng, L.	China
Hydrogenation of phenol and derivatives	2014	Cheng, L.	China
Hydrogenation of phenol and derivatives	2014	Cheng, L.	China
Oxidation of methane	2013	Li, B.	China
Oxidation of methane	2013	Li, B.	China
Oxidation of methane	2013	Li, B.	China
NO-CO reaction	2013	Tou, A.	Japan
NO-CO reaction	2013	Tou, A.	Japan
NO-CO reaction	2013	Tou, A.	Japan
NO-CO reaction	2013	Tou, A.	Japan
Oxidation of methanol	2007	Ubago-Pérez, R.	Spain
Oxidation of methanol	2007	Ubago-Pérez, R.	Spain
Oxidation of methanol	2007	Ubago-Pérez, R.	Spain
Hydrodesulfurization of 4,6-dimethyldibenzothiophene	2007	Niquille-Röthlisberger, A.	Switzerland
Combustion of methane	2013	Na, H.	China
Combustion of methane	2013	Na, H.	China
Hydrogenation of toluene	2014	Gonda, M.	Japan
Hydrogenation of toluene	2014	Gonda, M.	Japan
Hydrogenation of toluene	2014	Gonda, M.	Japan

Hydrogenation of toluene	2014	Gonda, M.	Japan
Hydrogenation of toluene	2014	Gonda, M.	Japan
Conversion of C6- alkanes	2002	Skotak, M.	Poland
Conversion of C6- alkanes	2002	Skotak, M.	Poland
Conversion of C6- alkanes	2002	Skotak, M.	Poland
Conversion of C6- alkanes	2002	Skotak, M.	Poland
Conversion of C6- alkanes	2002	Skotak, M.	Poland
Conversion of C6- alkanes	2002	Skotak, M.	Poland
Conversion of C6- alkanes	2002	Skotak, M.	Poland
Conversion of C6- alkanes	2002	Skotak, M.	Poland
Conversion of C6- alkanes	2002	Skotak, M.	Poland
Dehydrogenation of HCOOH	2021	Di, L.	China
Dehydrogenation of HCOOH	2019	Di, L.	China, UK
Hydrotreatment of model mixture of tar-type compounds	2021	Raad, Z.	Spain, Lebanon, Netherlands
Hydrotreatment of model mixture of tar-type compounds	2021	Raad, Z.	Spain, Lebanon, Netherlands
Hydrotreatment of model mixture of tar-type compounds	2021	Raad, Z.	Spain, Lebanon, Netherlands
Oxidation of formaldehyde	2021	Wang, C.	China
Oxidation of formaldehyde	2021	Wang, C.	China
Oxidation of formaldehyde	2021	Wang, C.	China
Oxidation of formaldehyde	2021	Wang, C.	China
Combustion of methane	2021	Fertal, D.R.	USA, Netherlands
Combustion of methane	2021	Fertal, D.R.	USA, Netherlands
Combustion of methane	2021	Fertal, D.R.	USA, Netherlands
Reduction of NO	2021	Patel, V.K.	India
Reduction of NO	2021	Patel, V.K.	India
Reduction of NO	2021	Patel, V.K.	India
Reduction of NO	2021	Patel, V.K.	India
Hydrogenation of guaiacol	2021	Fraga, G.	Australia, France
Hydrogenation of guaiacol	2021	Fraga, G.	Australia, France
Hydrogenation of guaiacol	2021	Fraga, G.	Australia, France
Dehydrogenation of Dodecahydro-N-ethylcarbazole	2021	Feng, Z.	China
Dehydrogenation of Dodecahydro-N-ethylcarbazole	2021	Feng, Z.	China
Dehydrogenation of Dodecahydro-N-ethylcarbazole	2021	Feng, Z.	China
Dehydrogenation of Dodecahydro-N-ethylcarbazole	2021	Feng, Z.	China
Hydrogenation of Microcystin-LR	2022	Sun, J.	China, USA
Hydrogenation of Microcystin-LR	2022	Sun, J.	China, USA
Hydrogenation of Microcystin-LR	2022	Sun, J.	China, USA
Hydrogenation of Microcystin-LR	2022	Sun, J.	China, USA

Hydrogenation of Microcystin-LR	2022	Sun, J.	China, USA
Hydrogenation synthesis of meropenem	2022	Li, Y.	China
Hydrogenation synthesis of meropenem	2022	Li, Y.	China
Hydrogenation synthesis of meropenem	2022	Li, Y.	China
Hydrogenation synthesis of meropenem	2022	Li, Y.	China
Oxidation of methane	2021	Khan, H.A.	Saudi Arabia
Oxidation of methane	2021	Khan, H.A.	Saudi Arabia
Hydrogenation of palm biodiesel	2021	Udomsap, P.	Thailand, Japan
Hydrogenation of palm biodiesel	2021	Udomsap, P.	Thailand, Japan
Oxidation of methane	2022	Ghampson, I.T	Japan, USA, Republic of Korea
Oxidation of methane	2022	Ghampson, I.T	Japan, USA, Republic of Korea
Oxidation of methane	2022	Ghampson, I.T	Japan, USA, Republic of Korea
Hydrogenation of acetylene	2022	Yang, T.	China
Hydrogenation of acetylene	2022	Yang, T.	China
Hydrogenation of acetylene	2022	Yang, T.	China
CO direct esterification	2022	Hu, C.	China
CO direct esterification	2022	Hu, C.	China
CO direct esterification	2022	Hu, C.	China
CO oxidation	2019	Murata, K.	Japan
CO oxidation	2019	Murata, K.	Japan
CO oxidation	2019	Murata, K.	Japan
CO oxidation	2019	Murata, K.	Japan
CO oxidation	2019	Murata, K.	Japan
CO oxidation	2019	Murata, K.	Japan
CO oxidation	2019	Murata, K.	Japan
CO oxidation	2019	Murata, K.	Japan
CO oxidation	2019	Murata, K.	Japan
CO oxidation	2019	Murata, K.	Japan
CO oxidation	2019	Murata, K.	Japan
CO oxidation	2019	Murata, K.	Japan
CO oxidation	2019	Murata, K.	Japan
CO oxidation	2019	Murata, K.	Japan
CO oxidation	2019	Murata, K.	Japan
Combustion of methane	2010	Amairia, C.	Tunisie
Combustion of methane	2010	Amairia, C.	Tunisie

Combustion of methane	2010	Amairia, C.	Tunisie
Combustion of methane	2010	Amairia, C.	Tunisie
Combustion of methane	2010	Amairia, C.	Tunisie
Combustion of methane	2010	Amairia, C.	Tunisie
Combustion of methane	2010	Amairia, C.	Tunisie
Combustion of methane	2010	Amairia, C.	Tunisie
Combustion of methane	2010	Amairia, C.	Tunisie
Combustion of methane	2010	Amairia, C.	Tunisie
Hydrogenation of 2,4-dinitrotoluene	2001	Neri, G.	Italy
Hydrogenation of 2,4-dinitrotoluene	2001	Neri, G.	Italy
Hydrogenation of 2,4-dinitrotoluene	2001	Neri, G.	Italy
Hydrogenation of 2,4-dinitrotoluene	2001	Neri, G.	Italy
Hydrogenation of 2,4-dinitrotoluene	2001	Neri, G.	Italy
Hydrogenation of 2,4-dinitrotoluene	2001	Neri, G.	Italy
Hydrogenation of 2,4-dinitrotoluene	2001	Neri, G.	Italy
Hydrogenation of phenol	2003	Park, C.	USA
Hydrogenation of phenol	2003	Park, C.	USA
Hydrogenation of phenol	2003	Park, C.	USA
Hydrogenation of phenol	2003	Park, C.	USA
Hydrogenation of phenol	2003	Park, C.	USA
Decomposition of formic acid	2023	Arzac, G.M.	Spain
Decomposition of formic acid	2023	Arzac, G.M.	Spain
Decomposition of formic acid	2023	Arzac, G.M.	Spain
Decomposition of formic acid	2023	Arzac, G.M.	Spain
Decomposition of formic acid	2023	Arzac, G.M.	Spain
Decomposition of formic acid	2023	Arzac, G.M.	Spain
Decomposition of formic acid	2023	Arzac, G.M.	Spain
CO oxidation	2017	Haneda, M.	Japan
CO oxidation	2017	Haneda, M.	Japan
CO oxidation	2017	Haneda, M.	Japan
CO oxidation	2017	Haneda, M.	Japan
CO oxidation	2017	Haneda, M.	Japan
CO oxidation	2017	Haneda, M.	Japan
ND	2018	Byun, M.Y.	Canada, Korea
ND	2018	Byun, M.Y.	Canada, Korea
ND	2018	Byun, M.Y.	Canada, Korea
ND	2018	Byun, M.Y.	Canada, Korea
ND	2018	Byun, M.Y.	Canada, Korea
Oxidation of xylene	2013	Huang, S.	China
Oxidation of xylene	2013	Huang, S.	China
Oxidation of xylene	2013	Huang, S.	China
Oxidation of xylene	2013	Huang, S.	China
Oxidation of xylene	2013	Huang, S.	China

Hydrogenation of phenol	2001	Mahata, N.	India, UK, USA
Hydrogenation of phenol	2001	Mahata, N.	India, UK, USA
Hydrogenation of phenol	2001	Mahata, N.	India, UK, USA
Hydrogenation of phenol	2001	Mahata, N.	India, UK, USA
Hydrogenation of phenol	2001	Mahata, N.	India, UK, USA
Methane steam reforming	2014	Cassinelli, W.H.	Brazil, Bulgaria
Methane steam reforming	2014	Cassinelli, W.H.	Brazil, Bulgaria
Methane steam reforming	2014	Cassinelli, W.H.	Brazil, Bulgaria
Methane steam reforming	2014	Cassinelli, W.H.	Brazil, Bulgaria
Hydrodechlorination of aryl chlorides	2006	Kawabata, T.	Japan
Hydrodechlorination of aryl chlorides	2006	Kawabata, T.	Japan
Oxidation of methane	2003	Yuranov, I.	Switzerland
Oxidation of methane	2003	Yuranov, I.	Switzerland
Oxidation of methane	2003	Yuranov, I.	Switzerland
Oxidation of methane	2003	Yuranov, I.	Switzerland
Oxidation of methane	2003	Yuranov, I.	Switzerland
Oxidation of methane	2003	Yuranov, I.	Switzerland
Oxidation of methane	2003	Yuranov, I.	Switzerland
Oxidation of methane	2003	Yuranov, I.	Switzerland
Oxidation of methane	2003	Yuranov, I.	Switzerland
Oxidation of methane	2003	Yuranov, I.	Switzerland
Oxidation of methane	2003	Yuranov, I.	Switzerland
Oxidation of methane	2003	Yuranov, I.	Switzerland
Oxidation of methane	2003	Yuranov, I.	Switzerland
Hydrogenation of 1-hexene	2005	Panpranot, J.	Thailand, USA
Hydrogenation of 1-hexene	2005	Panpranot, J.	Thailand, USA
Hydrogenation of 1-hexene	2005	Panpranot, J.	Thailand, USA
Sulfidation behavior of Pd catalyst	2005	Matsui, T.	Japan
Combustion of methane	2004	Liu, C.-J.	China, Switzerland
Combustion of methane	2004	Liu, C.-J.	China, Switzerland
Hydroisomerization of n-butane	2002	Dorado, F.	Spain
Hydroisomerization of n-butane	2002	Dorado, F.	Spain
Hydroisomerization of n-butane	2002	Dorado, F.	Spain
Hydroisomerization of n-butane	2002	Dorado, F.	Spain
Hydroisomerization of n-butane	2002	Dorado, F.	Spain
Hydroisomerization of n-butane	2002	Dorado, F.	Spain
Reduction of NO	2007	Konsolakis, M.	Greece
Reduction of NO	2007	Konsolakis, M.	Greece
Reduction of NO	2007	Konsolakis, M.	Greece
Reduction of NO	2007	Konsolakis, M.	Greece

Reduction of NO	2007	Konsolakis, M.	Greece
Reduction of NO	2007	Konsolakis, M.	Greece
Reduction of NO	2007	Konsolakis, M.	Greece
Reduction of NO	2007	Konsolakis, M.	Greece
Reduction of NO	2007	Konsolakis, M.	Greece
Reduction of NO	2007	Konsolakis, M.	Greece
Synthesis of methyl isobutyl ketone	2007	Yang, P.	China
Synthesis of methyl isobutyl ketone	2007	Yang, P.	China
Synthesis of methyl isobutyl ketone	2007	Yang, P.	China
Decompostion of NO	2007	de Oliveira, A.M.	Brazil
Hydroisomerization of n-butane	2001	Cañizares, P.	Spain
Hydroisomerization of n-butane	2001	Cañizares, P.	Spain
Hydroisomerization of n-butane	2001	Cañizares, P.	Spain
Hydroisomerization of n-butane	2001	Cañizares, P.	Spain
Hydroisomerization of n-butane	2001	Cañizares, P.	Spain
Hydroisomerization of n-butane	2001	Cañizares, P.	Spain
Hydroisomerization of n-butane	2001	Cañizares, P.	Spain
Hydroisomerization of n-butane	2001	Cañizares, P.	Spain
Hydroisomerization of n-butane	2001	Cañizares, P.	Spain
Hydroisomerization of n-butane	2001	Cañizares, P.	Spain
Hydroisomerization of n-butane	2001	Cañizares, P.	Spain
Hydroisomerization of n-butane	2001	Cañizares, P.	Spain
Hydroisomerization of n-butane	2001	Cañizares, P.	Spain
Hydroisomerization of heptane	2000	Höchtl, M.	Austria, Germany
Hydroisomerization of heptane	2000	Höchtl, M.	Austria, Germany
Hydroisomerization of heptane	2000	Höchtl, M.	Austria, Germany
Hydroisomerization of heptane	2000	Höchtl, M.	Austria, Germany
Hydroisomerization of heptane	2000	Höchtl, M.	Austria, Germany
Hydroisomerization of heptane	2000	Höchtl, M.	Austria, Germany
Hydroisomerization of heptane	2000	Höchtl, M.	Austria, Germany
Hydroisomerization of heptane	2000	Höchtl, M.	Austria, Germany
Hydroisomerization of heptane	2000	Höchtl, M.	Austria, Germany
Hydroisomerization of heptane	2000	Höchtl, M.	Austria, Germany
Hydroisomerization of heptane	2000	Höchtl, M.	Austria, Germany
Hydroisomerization of heptane	2000	Höchtl, M.	Austria, Germany
Hydroisomerization of heptane	2000	Höchtl, M.	Austria, Germany
Hydroisomerization of heptane	2000	Höchtl, M.	Austria, Germany
Hydroisomerization of n-octane	2006	De Lucas, A.	Spain
Hydroisomerization of n-octane	2006	De Lucas, A.	Spain
Hydroisomerization of n-octane	2006	De Lucas, A.	Spain
Hydroisomerization of n-octane	2006	De Lucas, A.	Spain
Hydrogenation of phenyl alkyl acetylenes mixtures	2005	Marín-Astorga, N.	Spain, Chile

Hydrogenation of terminal and internal alkynes	2005	Papp, A.	Hungary
Hydrogenation of terminal and internal alkynes	2005	Papp, A.	Hungary
Hydrogenation of terminal and internal alkynes	2005	Papp, A.	Hungary
Direct synthesis of H2O2	2014	Hu, B.	China, Belgium
NA	2008	Jiao, L.	USA
NA	2008	Jiao, L.	USA
NA	2008	Jiao, L.	USA
NA	2008	Jiao, L.	USA
Hydrogenation of phenylacetylene	2008	Domínguez-Domínguez, S.	Spain
Hydrogenation of phenylacetylene	2008	Domínguez-Domínguez, S.	Spain
Hydrogenation of 1-hexene	2004	Panpranot, J.	Thailand, USA
Hydrogenation of 1-hexene	2004	Panpranot, J.	Thailand, USA
NA	2009	Wang, P.	China
NA	2009	Wang, P.	China
Hydrogenation of sunflower oil	2009	Fernández, M.B.	Argentina
Hydrogenation of sunflower oil	2009	Fernández, M.B.	Argentina
Oxidation of benzene, toluene, and ethyl acetate	2009	He, C.	China, Australia
Oxidation of benzene, toluene, and ethyl acetate	2009	He, C.	China, Australia
Oxidation of benzene, toluene, and ethyl acetate	2009	He, C.	China, Australia
Oxidation of benzene, toluene, and ethyl acetate	2009	He, C.	China, Australia
Oxidation of benzene, toluene, and ethyl acetate	2009	He, C.	China, Australia
Direct synthesis of H2O2	2010	Ghedini, E.	Italy
Direct synthesis of H2O2	2010	Ghedini, E.	Italy
Direct synthesis of H2O2	2010	Ghedini, E.	Italy
Direct synthesis of H2O2	2010	Ghedini, E.	Italy
C–C Bond Forming Reactions	2011	Huang, J.	China
C–C Bond Forming Reactions	2011	Huang, J.	China
C–C Bond Forming Reactions	2011	Huang, J.	China
C–C Bond Forming Reactions	2011	Huang, J.	China
Combustion of methane	2011	Bassil, J.	Lebanon, France
Combustion of methane	2011	Bassil, J.	Lebanon, France
Hydroisomerization of n-pentane	2011	Belandria, L.	Venezuela
Reductive amination of carbonyl compounds	2011	Domine, M.E.	Spain
Reductive amination of carbonyl compounds	2011	Domine, M.E.	Spain
Reductive amination of carbonyl compounds	2011	Domine, M.E.	Spain
Reductive amination of carbonyl compounds	2011	Domine, M.E.	Spain
Oxidation of toluene	2011	Wang, F.	China
Hydrogenation–esterification of furfural and acetic acid	2011	Yu, W.	China
Hydrogenation–esterification of furfural and acetic acid	2011	Yu, W.	China
Hydrogenation–esterification of furfural and acetic acid	2011	Yu, W.	China
Hydrogenation–esterification of furfural and acetic acid	2011	Yu, W.	China
Hydrogenation–esterification of furfural and acetic acid	2011	Yu, W.	China
Hydroconversion of Light Cycle Oil	2011	Gutiérrez, A.	Spain
Hydroconversion of Light Cycle Oil	2011	Gutiérrez, A.	Spain
Hydroconversion of Light Cycle Oil	2011	Gutiérrez, A.	Spain
Hydroconversion of Light Cycle Oil	2011	Gutiérrez, A.	Spain
Direct synthesis of H2O2	2011	Abate, S.	Italy
Direct synthesis of H2O2	2011	Abate, S.	Italy
Oxidation of CO	2011	Wang, H.	China
Oxidation of CO	2011	Wang, H.	China

Suzuki reaction	2011	Zhang, W.	China
Dehydrogenation of alcohols	2011	Zhang, Q.	China
Dehydrogenation of alcohols	2011	Zhang, Q.	China
Dehydrogenation of alcohols	2011	Zhang, Q.	China
Dehydrogenation of alcohols	2011	Zhang, Q.	China
Dehydrogenation of alcohols	2011	Zhang, Q.	China
Dehydrogenation of alcohols	2011	Zhang, Q.	China
Dehydrogenation of ammonia borane and nitro compound hydrogenation	2015	Yang, Q.	China, USA, Japan
Hydrogenation of olefins	2015	Zhou, W.	China
Hydrodeoxygenation	2016	Ren, H.	China
Hydrodeoxygenation	2016	Ren, H.	China
Hydrodeoxygenation	2016	Ren, H.	China
Hydrodeoxygenation	2016	Ren, H.	China
Oxidation of Industrial VOC	2018	Brunet, J.	Belgium, France
Suzuki-Miyaura coupling	2018	Tadjarodi, A.	Iran
Hydrogenation of 4-chloronitrobenzenes	2019	Králik, M.	Slovakia
Selective hydrogenation of acetylene	2019	Gong, T.	China
Hydrogenation of acetylene	2019	Gong, T.	China
Hydrogenation of acetylene	2019	Gong, T.	China
Hydrogenation of acetylene	2019	Gong, T.	China
Hydrogenation of acetylene	2019	Gong, T.	China
Hydrogenation of acetylene	2019	Gong, T.	China
Hydrogenation of acetylene	2019	Kang, L.	China

Hydroisomerization of n-hexane	2015	Dao, T.K.T.	Vietnam
Hydrogenation of benzene	2001	Horváth, A.	Hungary
Hydrogenation of benzene	2001	Horváth, A.	Hungary
Combustion of methane	2003	Persson, K.	Sweden
Combustion of methane	2003	Persson, K.	Sweden
Hydrogenation of 1-heptyne	2007	Somboonthanakij, S.	Thailand, Switzerland
Hydrogenation of 1-heptyne	2007	Somboonthanakij, S.	Thailand, Switzerland
Hydrogenation of 1-heptyne	2007	Somboonthanakij, S.	Thailand, Switzerland
Hydrogenation of 1-heptyne	2007	Somboonthanakij, S.	Thailand, Switzerland
Hydrogenation of 1-heptyne	2007	Somboonthanakij, S.	Thailand, Switzerland
Hydrogenation of 1-heptyne	2007	Somboonthanakij, S.	Thailand, Switzerland
Reduction of nitrite	2011	Bosko, M.L.	Argentina
Reduction of nitrite	2011	Bosko, M.L.	Argentina
Electro-oxidation of formic acid	2011	Mazurkiewicz, M.	Poland, Czech Republic
Electro-oxidation of formic acid	2011	Mazurkiewicz, M.	Poland, Czech Republic
Electro-oxidation of formic acid	2011	Mazurkiewicz, M.	Poland, Czech Republic
Electro-oxidation of formic acid	2011	Mazurkiewicz, M.	Poland, Czech Republic
Electro-oxidation of formic acid	2011	Mazurkiewicz, M.	Poland, Czech Republic
Oxidation of CO	2011	Moussa, S.	USA
Oxidation of CO	2014	Qi, B.	China
Oxidation of CO	2014	Qi, B.	China
Oxidation of ethanol	2015	Wang, Y.	USA, China
Oxidation of ethanol	2015	Wang, Y.	USA, China
Oxidation of ethanol	2015	Wang, Y.	USA, China
Oxidation of ethanol	2015	Wang, Y.	USA, China
Oxidation of ethanol	2015	Wang, Y.	USA, China
Combustion of methane	2015	Zong, Y.	China
Combustion of methane	2015	Zong, Y.	China
Combustion of methane	2015	Zong, Y.	China
Suzuki reaction	2015	Yang, F.	China
Suzuki reaction	2015	Yang, F.	China
Suzuki reaction	2015	Yang, F.	China
Hydrogenation of cinnamaldehyde	2016	Nagpure, A.S.	India
Hydrogenation of cinnamaldehyde	2016	Nagpure, A.S.	India
Hydrogenation of cinnamaldehyde	2016	Nagpure, A.S.	India
Oxidation of CO	2016	Vasilchenko, D.B.	Russia
Oxidation of CO	2016	Vasilchenko, D.B.	Russia
Oxidation of CO	2016	Vasilchenko, D.B.	Russia
Oxidation of CO	2016	Vasilchenko, D.B.	Russia

Hydrodechlorination of chlorobenzene and hexachlorobenzene	2016	Klokov, S.V.	Russia
Hydrodechlorination of chlorobenzene and hexachlorobenzene	2016	Klokov, S.V.	Russia
Hydrogenation of alkynes	2018	Ellis, P.R.	UK
Hydrogenation of alkynes	2018	Ellis, P.R.	UK
Hydrogenation of 1,3-butadiene	2018	Decarolis, D.	UK
Hydrogenation of 1,3-butadiene	2018	Decarolis, D.	UK
Hydrogenation of 1,3-butadiene	2018	Decarolis, D.	UK
Hydrogenation of 1,3-butadiene	2018	Decarolis, D.	UK
Hydrogenation of 1,3-butadiene	2018	Decarolis, D.	UK
Combustion of methane	2018	Toso, A.	Italy
Oxidation of methane	2005	Ferrer, V.	Venezuela, Spain
Methanol reforming	2005	Gómez-Sainero, L.M.	Spain, UK
Oxidation of CO	2013	Cao, Y.	China
Electro-oxidation of formic acid	2009	Wang, X.-M.	China
Electro-oxidation of formic acid	2009	Wang, X.-M.	China
Electro-oxidation of formic acid	2009	Zhang, S.	China
NA	2009	Jin, J.-H.	Korea
Hydrogenation of ethene	2009	Binder, A.	Germany
Hydrogenation of ethene	2009	Binder, A.	Germany
Oxidation of formic acid	2010	Morales-Acosta, D.	Mexico
ND	2011	Alonso-Núñez, G.	Mexico
Reduction of oxygen	2011	Alvarez, G.F.	UK
Reduction of oxygen	2011	Alvarez, G.F.	UK
Reduction of oxygen	2011	Alvarez, G.F.	UK
Electro-oxidation of formic acid	2011	Bai, Z.	China
Electro-oxidation of formic acid	2011	Bai, Z.	China
Oxidation of alcohol	2011	Buchbinder, A.M.	U.S.
Mizoraki–Heck cross-coupling reactions	2011	Nabid, M.R.	Iran
Electro-oxidation of methanol	2015	Datta, A.	India
Electro-oxidation of methanol	2015	Datta, A.	India
NOx storage and reduction	2006	Abdulhamid, H.	Sweden
Oxidative coupling of 4-methylpyridine	2009	Neal, L.M.	USA
Hydrogenation of benzonitrile	2017	Dai, C.	China
Hydrogenation of biodiesel fuels	2023	Supabunnapong, T.	Thailand, Japan
Hydrogenation of biodiesel fuels	2023	Supabunnapong, T.	Thailand, Japan

Reference title
Dispersion stability and methylcyclopentane hydrogenolysis in Pd/Al2O3 catalysts
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Dispersion stability and methylcyclopentane hydrogenolysis in Pd/Al2O3 catalysts
Dispersion stability and methylcyclopentane hydrogenolysis in Pd/Al2O3 catalysts
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Catalytic behaviour of Cl-free and Cl-containing Pd/Al2O3 catalysts in the total oxidation of methane at low temperature
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NO reduction by propene or CO over alkali-promoted PD/YSZ catalyst
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Complete oxidation of o-xylene over Pd/Al2O3 catalyst at low temperature
Complete oxidation of o-xylene over Pd/Al2O3 catalyst at low temperature
The synthesis of highly dispersed noble and base metals on silica via strong electrostatic adsorption: I. Amorphous silica
The synthesis of highly dispersed noble and base metals on silica via strong electrostatic adsorption: I. Amorphous silica
The synthesis of highly dispersed noble and base metals on silica via strong electrostatic adsorption: I. Amorphous silica
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Preparation of Pd/C catalysts via deposition of palladium hydroxide onto Sibunit carbon and their application to partial hydrogenation of rapeseed oil
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Effect of pH Value and Temperatures on Performances of Pd/C Catalysts Prepared by Modified Polyol Process for Formic Acid Electrooxidation
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Role of Pd loading and dispersion on redox behaviour and CH4 combustion activity of Al2O3 supported catalysts
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Selective hydrogenation of sunflower oil over noble metal catalysts
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Highly selective hydrogenation of 3,4-dichloronitrobenzene over Pd/C catalysts without inhibitors
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High-performance palladium catalysts for the hydrogenation toward dibenzylbiotinmethylester: Effect of carbon support functionalization
High-performance palladium catalysts for the hydrogenation toward dibenzylbiotinmethylester: Effect of carbon support functionalization
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Resistance to Sulfur and Oxygenated Compounds of Supported Pd, Pt, Rh, Ru Catalysts
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Hydrogen production by steam reforming of dimethyl ether over Pd-based catalytic monoliths
Hydrogen production by steam reforming of dimethyl ether over Pd-based catalytic monoliths
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Hydrogen production by steam reforming of dimethyl ether over Pd-based catalytic monoliths
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Hydrogen production by steam reforming of dimethyl ether over Pd-based catalytic monoliths
Hydrogen production by steam reforming of dimethyl ether over Pd-based catalytic monoliths
Hydrogen production by steam reforming of dimethyl ether over Pd-based catalytic monoliths
An effective strategy for small-sized and highly-dispersed palladium nanoparticles supported on graphene with excellent performance for formic acid oxidation
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Palladium on graphene as efficient catalyst for solvent-free aerobic oxidation of aromatic alcohols: Role of graphene support
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Pd catalyst supported on activated carbon honeycomb monolith for CO oxidation and the application in air purification of vehicular tunnel
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Phenol hydrogenation over palladium supported on magnesia :Relationship between catalyst structure and performance
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Hydroisomerization of n-butane over Pd/HZSM-5 and Pd/Hbeta with and without binder
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Applied Catalysis A: General	Velu, S., 2003
Applied Catalysis A: General	Velu, S., 2003

Applied Catalysis A: General	Velu, S., 2003
Applied Surface Science	Arcoya, A., 2003
Applied Catalysis B: Environmental	Gopinath, R., 2003
Applied Catalysis B: Environmental	Gopinath, R., 2003
Applied Catalysis B: Environmental	Gopinath, R., 2003
Applied Catalysis B: Environmental	Gopinath, R., 2003
Journal of Molecular Catalysis A:Chemical	Liotta, L.F., 2003
Journal of Molecular Catalysis A:Chemical	Liotta, L.F., 2003
Journal of Molecular Catalysis A:Chemical	Liotta, L.F., 2003
Journal of Molecular Catalysis A:Chemical	Liotta, L.F., 2003
Applied Catalysis A: General	Persson, K., 2003
Journal of Sol-Gel Science and Technology	Fessi, S., 2003
Journal of Sol-Gel Science and Technology	Fessi, S., 2003
Journal of Sol-Gel Science and Technology	Fessi, S., 2003
Journal of Sol-Gel Science and Technology	Fessi, S., 2003
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Journal of Sol-Gel Science and Technology	Fessi, S., 2003
Journal of Sol-Gel Science and Technology	Fessi, S., 2003
Journal of Sol-Gel Science and Technology	Fessi, S., 2003
Journal of Catalysis	Han, Y.-F., 2004
Applied Catalysis A: General	Suwa, Y., 2004
Journal of Molecular Catalysis A: Chemical	Aristizábal, B., 2004
Journal of Molecular Catalysis A: Chemical	Aristizábal, B., 2004
Journal of Molecular Catalysis A: Chemical	Aristizábal, B., 2004
Journal of Molecular Catalysis A: Chemical	Aristizábal, B., 2004
Journal of Catalysis	Skotak, M., 2004
Journal of Catalysis	Skotak, M., 2004
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Journal of Catalysis	Skotak, M., 2004
Journal of Catalysis	Skotak, M., 2004
Journal of Catalysis	Skotak, M., 2004
Catalysis Communications	Panpranot, J., 2004
Catalysis Communications	Panpranot, J., 2004
Applied Catalysis A: General	Collins, S.E., 2005
Applied Catalysis A: General	Collins, S.E., 2005
Applied Catalysis A: General	Collins, S.E., 2005
Applied Catalysis A: General	Shekar, S.C., 2005
Applied Catalysis A: General	Shekar, S.C., 2005
Applied Catalysis A: General	Shekar, S.C., 2005
Applied Catalysis A: General	Shekar, S.C., 2005
Applied Catalysis A: General	Shekar, S.C., 2005
Applied Catalysis A: General	Panpranot, J., 2005
Applied Catalysis A: General	Panpranot, J., 2005
Applied Catalysis A: General	Panpranot, J., 2005
Catalysis Today	Ferrer, V., 2005
Catalysis Today	Ferrer, V., 2005
Catalysis Today	Ferrer, V., 2005
Applied Catalysis A: General	Ranganathan, E.S., 2005
Applied Catalysis A: General	Ranganathan, E.S., 2005
Applied Catalysis A: General	Ranganathan, E.S., 2005
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Applied Catalysis A: General	Ranganathan, E.S., 2005
Applied Catalysis A: General	Ranganathan, E.S., 2005
Applied Catalysis A: General	Matsui, T., 2005
Applied Catalysis A: General	Matsui, T., 2005
Catalysis Letters	Panpranot, J., 2005
Catalysis Letters	Panpranot, J., 2005
Journal of Catalysis	Zhu, H., 2005
Journal of Catalysis	Zhu, H., 2005
Journal of Catalysis	Zhu, H., 2005
Journal of Catalysis	Zhu, H., 2005
Journal of Catalysis	Zhu, H., 2005
Journal of Catalysis	Zhu, H., 2005
The Journal of Chemical Physics	Lear, T., 2005
The Journal of Chemical Physics	Lear, T., 2005
The Journal of Chemical Physics	Lear, T., 2005
The Journal of Chemical Physics	Lear, T., 2005
Journal of Molecular Catalysis A: Chemical	Fernández, M.B., 2005
Journal of Molecular Catalysis A: Chemical	Fernández, M.B., 2005
Journal of Molecular Catalysis A: Chemical	Fernández, M.B., 2005
Journal of Molecular Catalysis A: Chemical	Fernández, M.B., 2005
Journal of Molecular Catalysis A: Chemical	Nohair, B., 2005
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Journal of Molecular Catalysis A: Chemical	Nohair, B., 2005
Journal of Molecular Catalysis A: Chemical	Nohair, B., 2005
Journal of Molecular Catalysis A: Chemical	Nohair, B., 2005
Applied Catalysis A: General	Araya, P., 2005
Applied Catalysis A: General	Araya, P., 2005
Applied Catalysis A: General	Araya, P., 2005
Journal of Catalysis	Amorim, C., 2005
Journal of Catalysis	Amorim, C., 2005
Journal of Catalysis	Amorim, C., 2005
Journal of Molecular Catalysis A: Chemical	Marín-Astorga, N., 2005
The Journal of Physical Chemistry B	Demoulin, O., 2005
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The Journal of Physical Chemistry B	Demoulin, O., 2005
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The Journal of Physical Chemistry B	Demoulin, O., 2005
Applied Catalysis A: General	Gómez-Sainero, L.M., 2005
Applied Catalysis A: General	Gómez-Sainero, L.M., 2005
Applied Catalysis A: General	Gómez-Sainero, L.M., 2005
Applied Catalysis A: General	Gómez-Sainero, L.M., 2005
Journal of Molecular Catalysis A: Chemical	Karski, S., 2005
Journal of Molecular Catalysis A: Chemical	Kirm, I., 2005
Journal of Molecular Catalysis A: Chemical	Kirm, I., 2005
Journal of Molecular Catalysis A: Chemical	Kirm, I., 2005
Journal of Molecular Catalysis A: Chemical	Kirm, I., 2005
Applied Catalysis A: General	Papp, A., 2005
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Journal of Catalysis	Han, Y.-F., 2005
Industrial Engineering Chemical Research	Schulz, P.G., 2005
Industrial Engineering Chemical Research	Schulz, P.G., 2005
Catalysis Today	Tribolet, P., 2005
Catalysis Today	Tribolet, P., 2005
Catalysis Today	Tribolet, P., 2005
Catalysis Today	Tribolet, P., 2005
Catalysis Today	Tribolet, P., 2005
Applied Surface Science	Song, J.-R., 2006
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Catalysis Today	Schmal, M., 2006
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Catalysis Today	Schmal, M., 2006
Catalysis Today	Schmal, M., 2006
Catalysis Today	Schmal, M., 2006
Journal of Natural Gas Chemistry	Rezaei, M., 2006
Applied Catalysis A: General	Panpranot, J., 2006
Applied Catalysis A: General	Panpranot, J., 2006
Applied Catalysis A: General	Panpranot, J., 2006
Applied Catalysis A: General	Panpranot, J., 2006
Catalysis Today	Coulston, N.J., 2006
Catalysis Today	Coulston, N.J., 2006
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Catalysis Today	Coulston, N.J., 2006
Catalysis Today	Coulston, N.J., 2006
Catalysis Today	Aries, F.J.C.S., 2006
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Catalysis Today	Aries, F.J.C.S., 2006

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Catalysis Today	Aries, F.J.C.S., 2006
Applied Catalysis A: General	Piqueras, C., 2006
Applied Catalysis A: General	Piqueras, C., 2006
Applied Catalysis A: General	Piqueras, C., 2006
Applied Catalysis A: General	Piqueras, C., 2006
Applied Catalysis A: General	Piqueras, C., 2006
Carbon	Pérez-Cadenas, A.F., 2006
Carbon	Pérez-Cadenas, A.F., 2006
Applied Catalysis A: General	Tidahy, H.L., 2006
Applied Catalysis A: General	Tidahy, H.L., 2006
Applied Catalysis A: General	Tidahy, H.L., 2006
Applied Catalysis B: Environmental	Kawabata, T., 2006
Applied Catalysis B: Environmental	Kawabata, T., 2006
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Applied Catalysis B: Environmental	Kawabata, T., 2006
The Journal of Physical Chemistry B	Postole, G., 2006
The Journal of Physical Chemistry B	Postole, G., 2006
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The Journal of Physical Chemistry B	Postole, G., 2006
Catalysis Communications	Iwasa, N., 2006
Green Chemistry	Lee, A.F., 2006
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Catalysis Letters	Somboonthanakij, S., 2007
Applied Catalysis B: Environmental	Moreno, J.M., 2007
Applied Catalysis B: Environmental	Moreno, J.M., 2007
Applied Catalysis B: Environmental	Moreno, J.M., 2007
Applied Catalysis B: Environmental	Moreno, J.M., 2007
Industrial and Engineering Chemistry Research	Lin, Q., 2007
Industrial and Engineering Chemistry Research	Lin, Q., 2007
Industrial and Engineering Chemistry Research	Lin, Q., 2007
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Journal of Hazardous Materials	Konsolakis, M., 2007
Journal of Molecular Catalysis A: Chemical	Sangeetha, P., 2007
Journal of Molecular Catalysis A: Chemical	Sangeetha, P., 2007
Journal of Molecular Catalysis A: Chemical	Sangeetha, P., 2007
Journal of Molecular Catalysis A: Chemical	Sangeetha, P., 2007
Science in China Series B: Chemistry	Wang, H., 2007
Science in China Series B: Chemistry	Wang, H., 2007
Journal of Molecular Catalysis A: Chemical	Pronkin, S.N., 2007
Journal of Molecular Catalysis A: Chemical	Pronkin, S.N., 2007
Electrochemistry Communications	Zhu, Y., 2008
Electrochemistry Communications	Zhu, Y., 2008
Electrochemistry Communications	Zhu, Y., 2008
Electrochemistry Communications	Zhu, Y., 2008
Electrochemistry Communications	Zhu, Y., 2008
Catalysis Communications	Komhom, S., 2008
Catalysis Communications	Komhom, S., 2008
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Catalysis Today	Huang, S., 2008
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Journal of Catalysis	Jiao, L., 2008
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Reaction Kinetics and Catalysis Letters	Simakova, O.A., 2008
Reaction Kinetics and Catalysis Letters	Simakova, O.A., 2008
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Reaction Kinetics and Catalysis Letters	Simakova, O.A., 2008
Catalysis Communications	Bueres, R.F., 2008
Catalysis Communications	Bueres, R.F., 2008
Electrochimica Acta	Suo, Y., 2009
Electrochimica Acta	Suo, Y., 2009
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Applied Surface Science	Sun, Z.-P., 2009
Applied Surface Science	Sun, Z.-P., 2009
Applied Surface Science	Sun, Z.-P., 2009
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International Journal of Hydrogen Energy	Suttisawat, Y., 2009
Physical Chemistry Chemical Physics	Dimitratos, N., 2009
Physical Chemistry Chemical Physics	Dimitratos, N., 2009
Journal of Molecular Catalysis A: Chemical	Neal, L.M., 2009
Journal of Molecular Catalysis A: Chemical	Neal, L.M., 2009
Journal of Molecular Catalysis A: Chemical	Neal, L.M., 2009
Journal of Molecular Catalysis A: Chemical	Neal, L.M., 2009
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Journal of Molecular Catalysis A: Chemical	Neal, L.M., 2009
Journal of Molecular Catalysis A: Chemical	Neal, L.M., 2009
Journal of Molecular Catalysis A: Chemical	Neal, L.M., 2009
Journal of Molecular Catalysis A: Chemical	Neal, L.M., 2009
Journal of Catalysis	Pellegrini, R., 2009
Journal of Catalysis	Pellegrini, R., 2009
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Journal of Catalysis	Pellegrini, R., 2009
Journal of Catalysis	Pellegrini, R., 2009
Journal of Catalysis	Pellegrini, R., 2009
Catalysis Letters	Martra, G., 2009
Catalysis Letters	Martra, G., 2009
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Catalysis Letters	Martra, G., 2009
Catalysis Letters	Martra, G., 2009
Catalysis Letters	Martra, G., 2009
Catalysis Letters	Martra, G., 2009
Catalysis Letters	Martra, G., 2009
Catalysis Letters	Martra, G., 2009
Catalysis Today	Romano, P.N., 2022
Catalysis Today	Romano, P.N., 2022
Journal of Catalysis	Zhang, J., 2022
Journal of Catalysis	Zhang, J., 2022
Journal of Physical Chemistry C	Miller, D.D., 2009
Applied Catalysis A: General	Bennett, J.A., 2009
Applied Catalysis A: General	Bennett, J.A., 2009
Chemical Engineering Journal	Mäki-Arvela, P., 2009
Chemical Engineering Journal	Mäki-Arvela, P., 2009
Chemical Engineering Communications	Benitez A., J.L., 2009
Chemical Engineering Communications	Benitez A., J.L., 2009
Chemical Engineering Communications	Benitez A., J.L., 2009
Journal of Catalysis	Fan, X., 2009
Chemical Engineering Journal	Fernández, M.B., 2009
Chemical Engineering Journal	Fernández, M.B., 2009
Chemical Engineering Journal	Fernández, M.B., 2009

Chemical Engineering Journal	Fernández, M.B., 2009
Topics in Catalysis	Hinokuma, S., 2009
Topics in Catalysis	Hinokuma, S., 2009
Journal of Catalysis	Panagiotopoulou, P., 2009
Journal of Catalysis	Panagiotopoulou, P., 2009
Journal of Catalysis	Panagiotopoulou, P., 2009
Journal of Power Sources	Yang, J.Q., 2009
Catalysis Letters	Liu, Q., 2009
Catalysis Letters	Meng, M., 2009
Applied Catalysis B: Environmental	Nguyen, S.T., 2009
Journal of Catalysis	Pham, T.T., 2009
Journal of Catalysis	Sheu, H.-S., 2009
Journal of Catalysis	Sheu, H.-S., 2009
Journal of Catalysis	Sheu, H.-S., 2009
Catalysis Today	Zeng, T.-Y., 2009
Catalysis Today	Zeng, T.-Y., 2009
Applied Catalysis A: General	Parvulescu, A.N., 2009
Applied Catalysis A: General	Parvulescu, A.N., 2009
Applied Catalysis A: General	Parvulescu, A.N., 2009
Applied Catalysis A: General	Parvulescu, A.N., 2009
Applied Catalysis A: General	Parvulescu, A.N., 2009
Applied Catalysis A: General	Parvulescu, A.N., 2009
Applied Catalysis A: General	Parvulescu, A.N., 2009
Applied Catalysis A: General	Parvulescu, A.N., 2009
The Journal of Physical Chemistry C	Tew, M.W., 2009
The Journal of Physical Chemistry C	Tew, M.W., 2009
The Journal of Physical Chemistry C	Tew, M.W., 2009
The Journal of Physical Chemistry C	Tew, M.W., 2009
Journal of Catalysis	Ordóñez, S., 2010
Journal of Catalysis	Ordóñez, S., 2010
Journal of Catalysis	Ordóñez, S., 2010
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Journal of Catalysis	Ordóñez, S., 2010
Journal of Catalysis	Ordóñez, S., 2010
Science China Chemistry	Chen, K., 2010
Science China Chemistry	Chen, K., 2010
Science China Chemistry	Chen, K., 2010
Journal of Electroanalytical Chemistry	Kumar, S.M.S, 2010
Journal of Electroanalytical Chemistry	Kumar, S.M.S, 2010
Journal of Electroanalytical Chemistry	Kumar, S.M.S, 2010
Journal of Electroanalytical Chemistry	Kumar, S.M.S, 2010
Journal of Electroanalytical Chemistry	Kumar, S.M.S, 2010
Fuel Cells	Wang, Z.-B., 2010
Fuel Cells	Wang, Z.-B., 2010
Fuel Cells	Wang, Z.-B., 2010

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Fuel Cells	Chen, M., 2010
Fuel Cells	Chen, M., 2010
Applied Catalysis B: Environmental	Bedia, J., 2010
Applied Catalysis B: Environmental	Bedia, J., 2010
Applied Catalysis B: Environmental	Bedia, J., 2010
Comptes Rendus Chimie	Boudjahem, A.-G., 2010
Comptes Rendus Chimie	Boudjahem, A.-G., 2010
Comptes Rendus Chimie	Boudjahem, A.-G., 2010
Comptes Rendus Chimie	Boudjahem, A.-G., 2010
Comptes Rendus Chimie	Boudjahem, A.-G., 2010
Catalysis Today	Castellazzi, P., 2010
Catalysis Today	Castellazzi, P., 2010
Catalysis Today	Castellazzi, P., 2010
Applied Catalysis A: General	Chinthaginjala, J.K., 2010
Applied Catalysis A: General	Chinthaginjala, J.K., 2010
Applied Catalysis A: General	Chinthaginjala, J.K., 2010
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Applied Catalysis A: General	Chinthaginjala, J.K., 2010
Applied Catalysis A: General	Chinthaginjala, J.K., 2010
Applied Catalysis A: General	Chinthaginjala, J.K., 2010
Applied Catalysis A: General	Chinthaginjala, J.K., 2010
Catalysis Letters	Delidovich, I.V., 2010
Catalysis Letters	Delidovich, I.V., 2010
Catalysis Letters	Delidovich, I.V., 2010
Catalysis Letters	Delidovich, I.V., 2010
Applied Catalysis A: General	Feng, J.-T., 2010
Applied Catalysis A: General	Feng, J.-T., 2010
Applied Catalysis A: General	Feng, J.-T., 2010
Applied Catalysis A: General	Feng, J.-T., 2010
Applied Catalysis A: General	Galletti, A.M.R., 2010
Applied Catalysis A: General	Galletti, A.M.R., 2010
Applied Catalysis A: General	Galletti, A.M.R., 2010
Applied Catalysis A: General	Galletti, A.M.R., 2010
Applied Catalysis A: General	Galletti, A.M.R., 2010
Applied Catalysis A: General	Galletti, A.M.R., 2010
Applied Catalysis A: General	Galletti, A.M.R., 2010
Applied Catalysis A: General	Galletti, A.M.R., 2010
Applied Catalysis A: General	Galletti, A.M.R., 2010
Journal of Catalysis	Ghedini, E., 2010
Catalysis Letters	Meng, B.-C., 2010
Catalysis Letters	Meng, B.-C., 2010
Applied Catalysis B: Environmental	Santos, V.P., 2010
Applied Catalysis B: Environmental	Santos, V.P., 2010
The Journal of Physical Chemistry C	Rikkinen, E., 2011
Applied Surface Science	Ma, J., 2011
Applied Catalysis B: Environmental	Liang, Y., 2011
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The Journal of Physical Chemistry C	Albers, P.W., 2011

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The Journal of Physical Chemistry C	Albers, P.W., 2011
Applied Catalysis A: General	Park, H.W., 2011
Applied Catalysis A: General	Park, H.W., 2011
Applied Catalysis A: General	Park, H.W., 2011
Applied Catalysis A: General	Park, H.W., 2011
Applied Catalysis A: General	Park, H.W., 2011
Applied Catalysis A: General	Trawczyński, J., 2011
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Chinese Journal of Catalysis	Chen, H., 2011
Chinese Journal of Catalysis	Chen, H., 2011
Chinese Journal of Catalysis	Chen, H., 2011
Journal of Molecular Catalysis A: Chemical	McArdle, S., 2011
Journal of Molecular Catalysis A: Chemical	McArdle, S., 2011
Journal of Molecular Catalysis A: Chemical	McArdle, S., 2011
Journal of Applied Electrochemistry	Sun, L., 2011
Journal of Molecular Catalysis A: Chemical	Xiang, Y.Z., 2011
Journal of Molecular Catalysis A: Chemical	Xiang, Y.Z., 2011
Catalysis Communications	Kim, S.M., 2011
Catalysis Communications	Kim, S.M., 2011
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Catalysis Communications	Kim, S.M., 2011
Catalysis Communications	Kim, S.M., 2011
Synthetic Metals	Choi, S.M., 2011
Catalysis Today	Cobo, M., 2011
Catalysis Today	Cobo, M., 2011
Applied Catalysis B: Environmental	Diaz, E., 2011
Applied Catalysis B: Environmental	Diaz, E., 2011
Applied Catalysis B: Environmental	Diaz, E., 2011
Catalysis Today	Domine, M.E., 2011
Catalysis Today	Domine, M.E., 2011
Catalysis Today	Domine, M.E., 2011
Catalysis Today	Domine, M.E., 2011
Applied Catalysis B: Environmental	Eyssler, A., 2011
Applied Catalysis B: Environmental	Eyssler, A., 2011
Applied Catalysis B: Environmental	Eyssler, A., 2011
Applied Catalysis B: Environmental	Eyssler, A., 2011
Catalysis Today	Ma, L., 2011
Catalysis Today	Ma, L., 2011

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Catalysis Today	Ma, L., 2011
Catalysis Today	Ma, L., 2011
Catalysis Today	Ma, L., 2011
Catalysis Today	Zheng, X., 2011
The Journal of Physical Chemistry C	Morgan, R.D., 2011
Electrochimica Acta	Li, G., 2011
Electrochimica Acta	Li, G., 2011
Electrochimica Acta	Li, G., 2011
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Catalysis Communications	Shao, Y., 2011
Catalysis Communications	Shao, Y., 2011
Catalysis Communications	Shao, Y., 2011
Catalysis Today	Śrębowata, A., 2011
Applied Catalysis A: General	Tanikawa, K., 2011
Applied Catalysis A: General	Tanikawa, K., 2011
Applied Catalysis A: General	Tanikawa, K., 2011
Applied Catalysis A: General	Tanikawa, K., 2011
Journal of Catalysis	Vicente, A., 2011
Journal of Catalysis	Vicente, A., 2011
Applied Catalysis B: Environmental	Vít, Z., 2011
Applied Catalysis B: Environmental	Vít, Z., 2011
Applied Catalysis B: Environmental	Vít, Z., 2011
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Applied Catalysis B: Environmental	Vít, Z., 2011
Applied Catalysis B: Environmental	Vít, Z., 2011
Catalysis Communications	Yu, W., 2011
Catalysis Today	Zhao, M., 2011
Journal of Applied Electrochemistry	Alvarez, G.F., 2011
Journal of Applied Electrochemistry	Alvarez, G.F., 2011
ChemCatChem	Li, B., 2011
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ChemCatChem	Li, B., 2011
ChemCatChem	Li, B., 2011
ChemCatChem	Li, B., 2011
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ChemCatChem	Li, B., 2011
Energy & Fuels	Gutiérrez, A., 2011

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Reaction Kinetics, Mechanisms and Catalysis	Krawczyk, N., 2011
Reaction Kinetics, Mechanisms and Catalysis	Krawczyk, N., 2011
Reaction Kinetics, Mechanisms and Catalysis	Krawczyk, N., 2011
Fuel Processing Technology	Rönkkönen, H., 2011
Reaction Kinetics, Mechanisms and Catalysis	Pattamakomsan, K., 2011
Reaction Kinetics, Mechanisms and Catalysis	Pattamakomsan, K., 2011
Reaction Kinetics, Mechanisms and Catalysis	Pattamakomsan, K., 2011
Reaction Kinetics, Mechanisms and Catalysis	Pattamakomsan, K., 2011
Fuel Processing Technology	Suo, Z., 2011
Journal of Nanoscience and Nanotechnology	Woo, S., 2011
Topics in Catalysis	Abate, S., 2011
Topics in Catalysis	Abate, S., 2011
Topics in Catalysis	Abate, S., 2011
Applied Catalysis B: Environmental	Chen, H., 2011
Applied Catalysis B: Environmental	Chen, H., 2011
Applied Catalysis B: Environmental	Chen, H., 2011
Applied Catalysis B: Environmental	Chen, H., 2011
Applied Catalysis B: Environmental	Chen, H., 2011
Applied Catalysis B: Environmental	Chen, H., 2011
Applied Catalysis B: Environmental	Chen, H., 2011
Applied Catalysis B: Environmental	Chen, H., 2011
Comptes Rendus Chimie	Janowska, I., 2011
Journal of Chemical Physics	McInroy, A.R., 2011
Journal of Chemical Physics	McInroy, A.R., 2011
Journal of Chemical Physics	McInroy, A.R., 2011
Journal of Chemical Physics	McInroy, A.R., 2011
Journal of Chemical Physics	McInroy, A.R., 2011
Catalysis Communications	Pérez, Y., 2011
Catalysis Communications	Pérez, Y., 2011
Catalysis Communications	Pérez, Y., 2011
Science China Chemistry	He, H., 2011
AIChe Journal	Zhou, Z., 2011
Journal of Colloid and Interface Science	An, N., 2018
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Catalysis Letters	Badano, J.M., 2011
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Applied Catalysis B: Environmental	Ledesma, C., 2011
Applied Catalysis B: Environmental	Ledesma, C., 2011
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Applied Catalysis B: Environmental	Ledesma, C., 2011
Applied Catalysis B: Environmental	Ledesma, C., 2011
Applied Catalysis B: Environmental	Ledesma, C., 2011
Applied Catalysis B: Environmental	Ledesma, C., 2011
Journal of Materials Chemistry	Yang, J., 2011
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Advanced Synthesis & Catalysis	Sreedhar, B., 2011
Catalysis Today	Abate, S., 2011
Fuel	Baltrus, J.P., 2011
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Catalysis Today	Bertero, N.M., 2011
Journal of Physical Chemistry C	Parambhath, V.B., 2011
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Applied Catalysis B: Environmental	Wu, G., 2013
Applied Catalysis B: Environmental	Wu, G., 2013
Applied Catalysis B: Environmental	Wu, G., 2013
Applied Catalysis B: Environmental	Wu, G., 2013
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Applied Catalysis A: General	Cao, Y., 2013
ACS Catalysis	Agostini, G., 2014
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Fuel Processing Technology	Wang, L., 2014
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Journal of Catalysis	Hu, B., 2014
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Journal of Materials Chemistry A	Qi, B., 2014
Applied Catalysis A: General	Benavidez, A.D., 2014
Applied Catalysis A: General	Benavidez, A.D., 2014
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Applied Catalysis B: Environmental	Zhou, J., 2015
Applied Catalysis B: Environmental	Zhou, J., 2015
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Applied Catalysis B: Environmental	Zhou, J., 2015
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Applied Catalysis B: Environmental	Martin-Martinez, M., 2015
ACS Sustainable Chemistry & Engineering	Su, J., 2015
Catalysis, Structure & Reactivity	Hao, Y., 2015
Catalysis, Structure & Reactivity	Hao, Y., 2015
Chemical Engineering Journal	Lee, H., 2015
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Applied Catalysis A: General	Miller, J.B., 2015
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Journal of Catalysis	Bhogeswararao, S., 2015
Journal of Catalysis	Bhogeswararao, S., 2015
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Catalysts	Gil, S., 2015
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Chinese Journal of Catalysis	Lin, S., 2015
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Applied Catalysis A: General	Wang, P., 2015
Journal of Catalysis	He, Y., 2015
Journal of Catalysis	He, Y., 2015
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ACS Catalysis	Wang, X., 2015
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Catalysis Communications	Liu, K., 2015
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Catalysis Communications	Bychkov, V. Y., 2016
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Applied Nanoscience	Soni, K.C., 2016
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Catalysis Communications	Vasilchenko, D.B., 2016
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Molecules	Vedyagin, A.A., 2016
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Catalysis, Structure & Reactivity	Ellis, P.R., 2018
Catalysis, Structure & Reactivity	Ellis, P.R., 2018
Russian Chemical Bulletin	Belskaya, O. B., 2018
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Catalysis Today	Martínez-Klimov, M.E., 2018
Catalysis Today	Martínez-Klimov, M.E., 2018
Catalysis Today	Martínez-Klimov, M.E., 2018
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Catalysis Today	Castillejos, E., 2018
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Catalysis Today	Belskaya, O. B., 2018
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Catalysis Communications	Louisia, S., 2018
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International Journal of Hydrogen Energy	Iost, KN, 2018
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Molecular Catalysis	Burange, A.S., 2018
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Reaction Kinetics, Mechanisms and Catalysis	Mironenko, R.M., 2019
Chemical Papers	Králik, M., 2019
Journal of Catalysis	Lamme, W.S., 2019
Journal of Catalysis	Lamme, W.S., 2019
Journal of Catalysis	Lamme, W.S., 2019
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Journal of Catalysis	Lamme, W.S., 2019
Journal of Catalysis	Lamme, W.S., 2019
The Journal of Physical Chemistry C	Velin, P., 2019
The Journal of Physical Chemistry C	Velin, P., 2019
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Polish Journal of Chemical Technology	Pham, T.H., 2019

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Petroleum Chemistry	Laskin, A.I., 2019
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Petroleum Chemistry	Laskin, A.I., 2019
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Molecular Catalysis	Xiang, N., 2020
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Chemical Engineering Journal	Ding, Y., 2020
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Applied Catalysis B: Environmental	Ding, Y., 2020
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Chemosphere	Zheng, C., 2020
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Catalysis Today	Ma, M., 2020
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Reaction Kinetics, Mechanisms and Catalysis	Howeizi, J., 2020
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Molecular Catalysis	Cho, Y.-H., 2020
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Journal of Rare Earths	Song, S., 2020
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Journal of Catalysis	Lin, M., 2020
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International Journal of Hydrogen Energy	Brijaldo, M.H., 2020
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Applied Catalysis A: General	Shen, W.-J., 2001
Applied Catalysis A: General	Shen, W.-J., 2001
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Applied Catalysis A: General	Scirè, S., 2002
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Catalysis Letters	Yang, C., 2002
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Applied Catalysis A: General	Dai, C., 2017
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Catalysis Today	Giraudon, J.-M., 2008
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Catalysis Today	Mira, C., 2012
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Applied Catalysis A: General	Yu, H., 2012
Applied Catalysis A: General	Yu, H., 2012
Applied Catalysis A: General	Yu, H., 2012
Applied Catalysis B: Environmental	Satsuma, A., 2013
Applied Catalysis B: Environmental	Satsuma, A., 2013
Applied Catalysis B: Environmental	Satsuma, A., 2013
Applied Catalysis B: Environmental	Satsuma, A., 2013
Applied Catalysis B: Environmental	Satsuma, A., 2013
Applied Catalysis B: Environmental	Zhou, J., 2013
Applied Catalysis B: Environmental	Zhou, J., 2013
Applied Catalysis B: Environmental	Zhou, J., 2013
Applied Catalysis B: Environmental	Zhou, J., 2013
Applied Catalysis B: Environmental	Zhou, J., 2013
Energy & Fuels	Lu, M., 2017
Energy & Fuels	Lu, M., 2017
Energy & Fuels	Lu, M., 2017
Energy & Fuels	Lu, M., 2017
Energy & Fuels	Lu, M., 2017
Topics in Catalysis	Khudorozhkov, A.K., 2017
Topics in Catalysis	Khudorozhkov, A.K., 2017
Topics in Catalysis	Khudorozhkov, A.K., 2017
Catalysis Communications	Cheng, L., 2014
Catalysis Communications	Cheng, L., 2014
Catalysis Communications	Cheng, L., 2014
Catalysis Communications	Cheng, L., 2014
Fuel	Li, B., 2013
Fuel	Li, B., 2013
Fuel	Li, B., 2013
Catalysis Today	Tou, A., 2013
Catalysis Today	Tou, A., 2013
Catalysis Today	Tou, A., 2013
Catalysis Today	Tou, A., 2013
Catalysis Today	Ubago-Pérez, R., 2007
Catalysis Today	Ubago-Pérez, R., 2007
Catalysis Today	Ubago-Pérez, R., 2007
Catalysis Today	Niquille-Röthlisberger, A., 2007
Frontiers of Environmental Science & Engineering	Na, H., 2013
Frontiers of Environmental Science & Engineering	Na, H., 2013
International Journal of Hydrogen Energy	Gonda, M., 2014
International Journal of Hydrogen Energy	Gonda, M., 2014
International Journal of Hydrogen Energy	Gonda, M., 2014

International Journal of Hydrogen Energy	Gonda, M., 2014
International Journal of Hydrogen Energy	Gonda, M., 2014
Applied Catalysis A: General	Skotak, M., 2002
Applied Catalysis A: General	Skotak, M., 2002
Applied Catalysis A: General	Skotak, M., 2002
Applied Catalysis A: General	Skotak, M., 2002
Applied Catalysis A: General	Skotak, M., 2002
Applied Catalysis A: General	Skotak, M., 2002
Applied Catalysis A: General	Skotak, M., 2002
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Applied Catalysis A: General	Skotak, M., 2002
International Journal of Hydrogen Energy	Di, L., 2021
Catalysis Today	Di, L., 2019
Nanomaterials	Raad, Z., 2021
Nanomaterials	Raad, Z., 2021
Nanomaterials	Raad, Z., 2021
Applied Catalysis B: Environmental	Wang, C., 2021
Applied Catalysis B: Environmental	Wang, C., 2021
Applied Catalysis B: Environmental	Wang, C., 2021
Applied Catalysis B: Environmental	Wang, C., 2021
Catalysis Today	Fertal, D.R., 2021
Catalysis Today	Fertal, D.R., 2021
Catalysis Today	Fertal, D.R., 2021
Catalysis Today	Patel, V.K., 2021
Catalysis Today	Patel, V.K., 2021
Catalysis Today	Patel, V.K., 2021
Catalysis Today	Patel, V.K., 2021
ChemCatChem	Fraga, G., 2021
ChemCatChem	Fraga, G., 2021
ChemCatChem	Fraga, G., 2021
Environmental Science and Pollution Research	Feng, Z., 2021
Environmental Science and Pollution Research	Feng, Z., 2021
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Chemosphere	Sun, J., 2022
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Catalysis Letters	Li, Y., 2022
Catalysis Letters	Li, Y., 2022
Catalysis Letters	Li, Y., 2022
Catalysis Letters	Li, Y., 2022
RSC Advances	Khan, H.A., 2021
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International Journal of Molecular Sciences	Udomsap, P., 2021
International Journal of Molecular Sciences	Udomsap, P., 2021
ACS Catalysis	Ghampson, I.T, 2022
ACS Catalysis	Ghampson, I.T, 2022
ACS Catalysis	Ghampson, I.T, 2022
Catalysis Letters	Yang, T., 2022
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Catalysis Letters	Hu, C., 2022
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Physical Chemistry Chemical Physics	Murata, K., 2019
Physical Chemistry Chemical Physics	Murata, K., 2019
Physical Chemistry Chemical Physics	Murata, K., 2019
Physical Chemistry Chemical Physics	Murata, K., 2019
Physical Chemistry Chemical Physics	Murata, K., 2019
Physical Chemistry Chemical Physics	Murata, K., 2019
Physical Chemistry Chemical Physics	Murata, K., 2019
Physical Chemistry Chemical Physics	Murata, K., 2019
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Physical Chemistry Chemical Physics	Murata, K., 2019
Physical Chemistry Chemical Physics	Murata, K., 2019
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Physical Chemistry Chemical Physics	Murata, K., 2019
Physical Chemistry Chemical Physics	Murata, K., 2019
Physical Chemistry Chemical Physics	Murata, K., 2019
Journal of Sol-Gel Science and Technology	Amairia, C., 2010
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Journal of Sol-Gel Science and Technology	Amairia, C., 2010
Journal of Sol-Gel Science and Technology	Amairia, C., 2010
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Journal of Sol-Gel Science and Technology	Amairia, C., 2010
Journal of Sol-Gel Science and Technology	Amairia, C., 2010
Journal of Sol-Gel Science and Technology	Amairia, C., 2010
Applied Catalysis A: General	Neri, G., 2001
Applied Catalysis A: General	Neri, G., 2001
Applied Catalysis A: General	Neri, G., 2001
Applied Catalysis A: General	Neri, G., 2001
Applied Catalysis A: General	Neri, G., 2001
Applied Catalysis A: General	Neri, G., 2001
Applied Catalysis A: General	Neri, G., 2001
Colloid and Interface Science	Park, C., 2003
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Colloid and Interface Science	Park, C., 2003
Colloid and Interface Science	Park, C., 2003
Colloid and Interface Science	Park, C., 2003
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International Journal of Hydrogen Energy	Arzac, G.M., 2023
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Journal of Environmental Sciences	Huang, S., 2013
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Journal of Environmental Sciences	Huang, S., 2013
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Physical Chemistry Chemical Physics	Mahata, N., 2001
Physical Chemistry Chemical Physics	Mahata, N., 2001
Physical Chemistry Chemical Physics	Mahata, N., 2001
Physical Chemistry Chemical Physics	Mahata, N., 2001
Physical Chemistry Chemical Physics	Mahata, N., 2001
Applied Catalysis A: General	Cassinelli, W.H., 2014
Applied Catalysis A: General	Cassinelli, W.H., 2014
Applied Catalysis A: General	Cassinelli, W.H., 2014
Applied Catalysis A: General	Cassinelli, W.H., 2014
Applied Catalysis B: Environmental	Kawabata, T., 2006
Applied Catalysis B: Environmental	Kawabata, T., 2006
Journal of Molecular Catalysis A: Chemical	Yuranov, I., 2003
Journal of Molecular Catalysis A: Chemical	Yuranov, I., 2003
Journal of Molecular Catalysis A: Chemical	Yuranov, I., 2003
Journal of Molecular Catalysis A: Chemical	Yuranov, I., 2003
Journal of Molecular Catalysis A: Chemical	Yuranov, I., 2003
Journal of Molecular Catalysis A: Chemical	Yuranov, I., 2003
Journal of Molecular Catalysis A: Chemical	Yuranov, I., 2003
Journal of Molecular Catalysis A: Chemical	Yuranov, I., 2003
Journal of Molecular Catalysis A: Chemical	Yuranov, I., 2003
Journal of Molecular Catalysis A: Chemical	Yuranov, I., 2003
Journal of Molecular Catalysis A: Chemical	Yuranov, I., 2003
Applied Catalysis A: General	Panpranot, J., 2005
Applied Catalysis A: General	Panpranot, J., 2005
Applied Catalysis A: General	Panpranot, J., 2005
Applied Catalysis A: General	Matsui, T., 2005
Applied Catalysis B: Environmental	Liu, C.-J., 2004
Applied Catalysis B: Environmental	Liu, C.-J., 2004
Applied Catalysis A: General	Dorado, F., 2002
Applied Catalysis A: General	Dorado, F., 2002
Applied Catalysis A: General	Dorado, F., 2002
Applied Catalysis A: General	Dorado, F., 2002
Applied Catalysis A: General	Dorado, F., 2002
Applied Catalysis A: General	Dorado, F., 2002
Journal of Hazardous Materials	Konsolakis, M., 2007
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Journal of Hazardous Materials	Konsolakis, M., 2007
Journal of Hazardous Materials	Konsolakis, M., 2007
Journal of Hazardous Materials	Konsolakis, M., 2007
Journal of Hazardous Materials	Konsolakis, M., 2007
Journal of Molecular Catalysis A: Chemical	Yang, P., 2007
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Catalysis Communications	de Oliveira, A.M., 2007
Microporous and Mesoporous Materials	Cañizares, P., 2001
Microporous and Mesoporous Materials	Cañizares, P., 2001
Microporous and Mesoporous Materials	Cañizares, P., 2001
Microporous and Mesoporous Materials	Cañizares, P., 2001
Microporous and Mesoporous Materials	Cañizares, P., 2001
Microporous and Mesoporous Materials	Cañizares, P., 2001
Microporous and Mesoporous Materials	Cañizares, P., 2001
Microporous and Mesoporous Materials	Cañizares, P., 2001
Microporous and Mesoporous Materials	Cañizares, P., 2001
Microporous and Mesoporous Materials	Cañizares, P., 2001
Microporous and Mesoporous Materials	Cañizares, P., 2001
Microporous and Mesoporous Materials	Cañizares, P., 2001
Journal of Catalysis	Höchtl, M., 2000
Journal of Catalysis	Höchtl, M., 2000
Journal of Catalysis	Höchtl, M., 2000
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Journal of Catalysis	Höchtl, M., 2000
Journal of Catalysis	Höchtl, M., 2000
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Journal of Catalysis	Höchtl, M., 2000
Journal of Catalysis	Höchtl, M., 2000
Journal of Catalysis	Höchtl, M., 2000
Journal of Catalysis	Höchtl, M., 2000
Journal of Catalysis	Höchtl, M., 2000
Journal of Molecular Catalysis A: Chemical	De Lucas, A., 2006
Journal of Molecular Catalysis A: Chemical	De Lucas, A., 2006
Journal of Molecular Catalysis A: Chemical	De Lucas, A., 2006
Journal of Molecular Catalysis A: Chemical	De Lucas, A., 2006
Journal of Molecular Catalysis A: Chemical	Marín-Astorga, N., 2005

Applied Catalysis A: General	Papp, A., 2005
Applied Catalysis A: General	Papp, A., 2005
Applied Catalysis A: General	Papp, A., 2005
Journal of Catalysis	Hu, B., 2014
Journal of Catalysis	Jiao, L., 2008
Journal of Catalysis	Jiao, L., 2008
Journal of Catalysis	Jiao, L., 2008
Journal of Catalysis	Jiao, L., 2008
Journal of Catalysis	Domínguez-Domínguez, S., 2008
Journal of Catalysis	Domínguez-Domínguez, S., 2008
Catalysis Communications	Panpranot, J., 2004
Catalysis Communications	Panpranot, J., 2004
Catalysis Letters	Wang, P., 2009
Catalysis Letters	Wang, P., 2009
Chemical Engineering Journal	Fernández, M.B., 2009
Chemical Engineering Journal	Fernández, M.B., 2009
Industrial Engineering Chemical Research	He, C., 2009
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Catalysis Today	Belandria, L., 2011
Catalysis Today	Domine, M.E., 2011
Catalysis Today	Domine, M.E., 2011
Catalysis Today	Domine, M.E., 2011
Catalysis Today	Domine, M.E., 2011
Catalysis Communications	Wang, F., 2011
Catalysis Communications	Yu, W., 2011
Catalysis Communications	Yu, W., 2011
Catalysis Communications	Yu, W., 2011
Catalysis Communications	Yu, W., 2011
Catalysis Communications	Yu, W., 2011
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Energy & Fuels	Gutiérrez, A., 2011
Energy & Fuels	Gutiérrez, A., 2011
Energy & Fuels	Gutiérrez, A., 2011
Topics in Catalysis	Abate, S., 2011
Catalysis Today	Abate, S., 2011
Applied Catalysis B: Environmental	Wang, H., 2011
Applied Catalysis B: Environmental	Wang, H., 2011

Journal of Nanoscience and Nanotechnology	Zhang, W., 2011
Chemical Communications	Zhang, Q., 2011
Chemical Communications	Zhang, Q., 2011
Chemical Communications	Zhang, Q., 2011
Chemical Communications	Zhang, Q., 2011
Chemical Communications	Zhang, Q., 2011
Chemical Communications	Zhang, Q., 2011
Chemical Communications	Yang, Q., 2015
Nanoscale	Zhou, W., 2015
RSC Advances	Ren, H., 2016
RSC Advances	Ren, H., 2016
RSC Advances	Ren, H., 2016
RSC Advances	Ren, H., 2016
Catalysts	Brunet, J., 2018
Applied Organometallic Chemistry	Tadjarodi, A., 2018
Chemical Papers	Králik, M., 2019
Applied Surface Science	Gong, T., 2019
Applied Surface Science	Gong, T., 2019
Applied Surface Science	Gong, T., 2019
Applied Surface Science	Gong, T., 2019
Applied Surface Science	Gong, T., 2019
Applied Surface Science	Gong, T., 2019
Royal Society Open Science	Kang, L., 2019

Advances in Natural Sciences: Nanoscience and Nanotechnology	Dao, T.K.T., 2015
Solid State Ionics	Horváth, A., 2001
Solid State Ionics	Horváth, A., 2001
Applied Catalysis A: General	Persson, K., 2003
Applied Catalysis A: General	Persson, K., 2003
Catalysis Letters	Somboonthanakij, S., 2007
Catalysis Letters	Somboonthanakij, S., 2007
Catalysis Letters	Somboonthanakij, S., 2007
Catalysis Letters	Somboonthanakij, S., 2007
Catalysis Letters	Somboonthanakij, S., 2007
Catalysis Letters	Somboonthanakij, S., 2007
Catalysis Communications	Bosko, M.L., 2011
Catalysis Communications	Bosko, M.L., 2011
Physica Status Solidi B	Mazurkiewicz, M., 2011
Physica Status Solidi B	Mazurkiewicz, M., 2011
Physica Status Solidi B	Mazurkiewicz, M., 2011
Physica Status Solidi B	Mazurkiewicz, M., 2011
Physica Status Solidi B	Mazurkiewicz, M., 2011
Chemical Physics Letters	Moussa, S., 2011
Journal of Materials Chemistry A	Qi, B., 2014
Journal of Materials Chemistry A	Qi, B., 2014
Journal of The Electrochemical Society	Wang, Y., 2015
Journal of The Electrochemical Society	Wang, Y., 2015
Journal of The Electrochemical Society	Wang, Y., 2015
Journal of The Electrochemical Society	Wang, Y., 2015
Journal of The Electrochemical Society	Wang, Y., 2015
Proceedings of the Combustion Institute	Zong, Y., 2015
Proceedings of the Combustion Institute	Zong, Y., 2015
Proceedings of the Combustion Institute	Zong, Y., 2015
Catalysis Today	Yang, F., 2015
Catalysis Today	Yang, F., 2015
Catalysis Today	Yang, F., 2015
RSC Advances	Nagpure, A.S., 2016
RSC Advances	Nagpure, A.S., 2016
RSC Advances	Nagpure, A.S., 2016
Catalysis Communications	Vasilchenko, D.B., 2016
Catalysis Communications	Vasilchenko, D.B., 2016
Catalysis Communications	Vasilchenko, D.B., 2016
Catalysis Communications	Vasilchenko, D.B., 2016

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Catalysis Communications	Klokov, S.V., 2016
Catalysis, Structure & Reactivity	Ellis, P.R., 2018
Catalysis, Structure & Reactivity	Ellis, P.R., 2018
Topics in Catalysis	Decarolis, D., 2018
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Topics in Catalysis	Decarolis, D., 2018
Topics in Catalysis	Decarolis, D., 2018
Topics in Catalysis	Decarolis, D., 2018
Applied Catalysis B: Environmental	Toso, A., 2018
Catalysis Today	Ferrer, V., 2005
Applied Catalysis A: General	Gómez-Sainero, L.M., 2005
Applied Catalysis A: General	Cao, Y., 2013
Electrochimica Acta	Wang, X.-M., 2009
Electrochimica Acta	Wang, X.-M., 2009
Electrochemistry Communications	Zhang, S., 2009
Transactions of Nonferrous Metals Society of China	Jin, J.-H., 2009
Journal of Catalysis	Binder, A., 2009
Journal of Catalysis	Binder, A., 2009
Journal of Power Sources	Morales-Acosta, D., 2010
Journal of Nanoparticle Research	Alonso-Núñez, G., 2011
Journal of Applied Electrochemistry	Alvarez, G.F., 2011
Journal of Applied Electrochemistry	Alvarez, G.F., 2011
Journal of Applied Electrochemistry	Alvarez, G.F., 2011
Journal of Power Sources	Bai, Z., 2011
Journal of Power Sources	Bai, Z., 2011
Journal of the American Chemical Society	Buchbinder, A.M., 2011
Applied Catalysis A: General	Nabid, M.R., 2011
Royal Society of Chemistry	Datta, A., 2015
Royal Society of Chemistry	Datta, A., 2015
Journal of Catalysis	Abdulhamid, H., 2006
Journal of Molecular Catalysis A: Chemical	Neal, L.M., 2009
Applied Catalysis A: General	Dai, C., 2017
Biomass Conversion and Biorefinery	Supabunnapong, T., 2023
Biomass Conversion and Biorefinery	Supabunnapong, T., 2023

NOTES	Support PZC Reference
In the paper, reduction cycle was studied. Only results after 1st step of reduction were used.	gamma-Al2O3 Alfa Aesar
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	Linde A α + γ Al2O3
	Linde A α + γ Al2O3
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
Chemisorption size is given as <10.	
	Degussa Al2O3
	Anatase TiO2 Aldrich
	Anatase TiO2 Aldrich
	Anatase TiO2 Aldrich
	Anatase TiO2 Aldrich
	Anatase TiO2 Aldrich
	gamma-Al2O3 Alfa Aesar

	gamma-Al2O3 Alfa Aesar
	SiO2 Aldrich
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	Al2O3 Alcoa A 16-SG
	Al2O3 Alcoa A 16-SG
	Al2O3 from nitrate and ammonia
	Al2O3 from nitrate and ammonia
XRD is given as <20.	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	SiO2 Aldrich
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
oxidation conditions are used as calcination conditions. Dispersion is given for after reaction, thus it is not used.	SiO2 Aldrich
oxidation conditions are used as calcination conditions. Dispersion is given for after reaction, thus it is not used.	SiO2 Aldrich
oxidation conditions are used as calcination conditions. Dispersion is given for after reaction, thus it is not used.	SiO2 Aldrich
oxidation conditions are used as calcination conditions. Dispersion is given for after reaction, thus it is not used.	BeO commercial
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oxidation conditions are used as calcination conditions. Dispersion is given for after reaction, thus it is not used.	BeO commercial
NaOH was used as the agent	CeO2 Aldrich
NaOH was used as the agent	CeO2 Aldrich
NaOH was used as the agent	CeO2 Aldrich
NaOH was used as the agent	CeO2 Aldrich
NaOH was used as the agent	ZrO2 from isopropoxide
NaOH was used as the agent	ZrO2 from isopropoxide

	gamma-Al2O3 Alfa Aesar
	CeO2 0.5 HNO3 4 H2O At basic pH
	CeO2 0.5 HNO3 4 H2O At basic pH
Na2CO3 was used as basic agent	CeO2 0.5 HNO3 4 H2O At basic pH
Na2CO3 was used as basic agent	CeO2 0.5 HNO3 4 H2O At basic pH
	Al2O3 is used due to high ratio
	Al2O3 is used due to high ratio
	Al2O3 is used due to high ratio
	Al2O3 is used due to high ratio
2 steps calcination, 2nd step is written. Average values of TEM results are noted.	gamma-Al2O3 Alfa Aesar
	Al2O3 from sec-butoxide
	Al2O3 from sec-butoxide
	Al2O3 from sec-butoxide
	Al2O3 from sec-butoxide
	Al2O3 from sec-butoxide
	Al2O3 from sec-butoxide
	Al2O3 from sec-butoxide
	Al2O3 from sec-butoxide
	Al2O3 from sec-butoxide
	Al2O3 from sec-butoxide
	Al2O3 from sec-butoxide

	Al2O3 from sec-butoxide
	Al2O3 from sec-butoxide
	Al2O3 Unspecified from Aldrich
	Al2O3 Degussa
	SiO2 Aldrich
	ZnO Aldrich
	Al2O3 from isopropoxide
	TiO2 from isopropoxide
	Al2O3 from isopropoxide
	TiO2 from isopropoxide
	gamma-Al2O3 Alfa Aesar
after calcination and reduction, oxidation is done at 300 °C for 0.5 h. Then, catalyst is reduced again. Initial calcination condition and final reduction condition are used in the data.	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
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	gamma-Al2O3 Alfa Aesar
after calcination and reduction, oxidation is done at 300 °C for 0.5 h. Then, catalyst is reduced again. Initial calcination condition and final reduction condition are used in the data.	gamma-Al2O3 Alfa Aesar
	SiO2 Aldrich
	SiO2 Aldrich
	SiO2 Aldrich
	Ga2O3 alpha-precipitated from nitrate with ammonia, calcined at 500°C for 4 h
	Ga2O3 alpha-precipitated from nitrate with ammonia, calcined at 500°C for 4 h
	alpha-Al2O3 Aldrich
	alpha-Al2O3 Aldrich
	alpha-Al2O3 Aldrich
	alpha-Al2O3 Aldrich
	alpha-Al2O3 Aldrich
	SiO2 Aldrich
	SiO2 Aldrich
	SiO2 Aldrich
	Unspecified Al2O3 Aldrich
	Unspecified Al2O3 Aldrich
	CeO2 Aldrich
	ZnO Aldrich
	ZnO Aldrich
	ZnO Aldrich
	CeO2 Aldrich
	CeO2 Aldrich
	CeO2 Aldrich

	ZnO Aldrich
	ZnO Aldrich
	ZnO Aldrich
	CeO2 Aldrich
	CeO2 Aldrich
	TiO2 from butoxide
	TiO2 from butoxide
	Anatase TiO2 Aldrich
	Anatase TiO2 Aldrich
	CeO2 Aldrich
	CeO2 Aldrich
	Degussa Al2O3 Aerodisp W630
	Degussa Al2O3 Aerodisp W630
	Degussa Al2O3 Aerodisp W630
	Degussa Al2O3 Aerodisp W630
	alpha-Al2O3 Aldrich
	gamma-Al2O3 Alfa Aesar
	alpha-Al2O3 Aldrich
	gamma-Al2O3 Alfa Aesar
	SiO2 Aldrich
	SiO2 Aldrich
	SiO2 Aldrich
instead of calcination, treatment in CH3OH/H2 is done	SiO2 Aldrich
instead of calcination, treatment in H2O/H2 is done	SiO2 Aldrich
	alpha-Al2O3 Alfa Aesar %99.95 alpha-phase
	gamma-Al2O3 Alfa Aesar
	MgO Merck
	ZnO Aldrich
	CeO2 Aldrich
	ZrO2 Obtained from a solution of ZrO(NO3)
	SiO2 Aldrich
	SiO2 Aldrich
H2 chemisorption is done but size determination with chemisorption is avoided because this presumes an exclusive H:Pdstoichiometry	
H2 chemisorption is done but size determination with chemisorption is avoided because this presumes an exclusive H:Pdstoichiometry	
H2 chemisorption is done but size determination with chemisorption is avoided because this presumes an exclusive H:Pdstoichiometry	
CO Chemisorption is also done (d: 6.7 nm)	SiO2 Aldrich
Final step of calcination is noted	gamma-Al2O3 Alfa Aesar
Final step of calcination is noted	gamma-Al2O3 Alfa Aesar

Final step of calcination is noted	gamma-Al2O3 Alfa Aesar
Final step of calcination is noted	gamma-Al2O3 Alfa Aesar
Final step of calcination is noted	gamma-Al2O3 Alfa Aesar
Final step of calcination is noted	gamma-Al2O3 Alfa Aesar
	CeO2 Aldrich
	Sm2O3 Shin-etsu
	Sm2O3 Shin-etsu
	SiO2 Aldrich
	MgO Merck
	MgO Merck
	gamma-Al2O3 Alfa Aesar
	SiO2 Aldrich
	CeO2 Aldrich
	CeO2 Aldrich
	SiO2 Aldrich
	SiO2 Aldrich
	alpha-Al2O3 Alfa Aesar %99.95 alpha-phase
	alpha-Al2O3 Alfa Aesar %99.95 alpha-phase
Support SA is given as 500-1100 m2/g and average value is used as Support SA. TEM results are given as 8-10 nm and average value is used.	SiO2 Aldrich
	ZrO2 Aldrich
	gamma-Al2O3 Alfa-Aesar
	gamma-Al2O3 Alfa-Aesar
	gamma-Al2O3 Alfa-Aesar
	Monoclinic Nb2O5 calcined at 823 K
	TiO2 Anatase Aldrich
	TiO2 Rutile from Tioxide
	TiO2 from ethoxide calcined at 620°C
	TiO2 from butoxide
	TiO2 Anatase Aldrich
	TiO2 Anatase Aldrich
	TiO2 Anatase Aldrich
	TiO2 Anatase Aldrich
	TiO2 Anatase Aldrich

Before reduction, the catalysts oxidized in air at 773 K for 1 h. Calcination conditions were noted instead of this.	gamma-Al2O3 Alfa Aesar
Before reduction, the catalysts oxidized in air at 773 K for 1 h. Calcination conditions were noted instead of this.	gamma-Al2O3 Alfa Aesar
Before reduction, the catalysts oxidized in air at 773 K for 1 h. Calcination conditions were noted instead of this.	alpha-Al2O3 Aldrich
Before reduction, the catalysts oxidized in air at 773 K for 1 h. Calcination conditions were noted instead of this.	alpha-Al2O3 Aldrich
Before reduction, the catalysts oxidized in air at 773 K for 1 h. Calcination conditions were noted instead of this.	gamma-Al2O3 Alfa Aesar
	TiO2 from ethoxide calcined at 620°C
	ZrO2 Aldrich
	SiO2 Aldrich
	SiO2 Aldrich
	SiO2 Aldrich
	gamma-Al2O3 Alfa Aesar
TEM and XRD data is for after calcination, so reduction info is not used	
TEM and XRD data is for after calcination, so reduction info is not used	
TEM and XRD data is for after calcination, so reduction info is not used	
TEM and XRD data is for after calcination, so reduction info is not used	
TEM and XRD data is for after calcination, so reduction info is not used	
TEM and XRD data is for after calcination, so reduction info is not used	
TEM and XRD data is for after calcination, so reduction info is not used	
	ZnO Aldrich
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	SiO2 Aldrich
Reduction is done in two steps. Final step is noted.	ZrO2 Aldrich water washed
Reduction is done in two steps. Final step is noted.	ZrO2 Aldrich water washed
Reduction is done in two steps. Final step is noted.	ZrO2 Aldrich water washed
Reduction is done in two steps. Final step is noted.	ZrO2 Aldrich water washed
	alpha-Al2O3 Alfa Aesar %99.95 alpha-phase
	alpha-Al2O3 Alfa Aesar %99.95 alpha-phase
	alpha-Al2O3 Alfa Aesar %99.95 alpha-phase
	alpha-Al2O3 Alfa Aesar %99.95 alpha-phase
	alpha-Al2O3 Alfa Aesar %99.95 alpha-phase
	alpha-Al2O3 Alfa Aesar %99.95 alpha-phase

Method is given as hydrogen reduction due to reduction type, impregnation is written as the method	
formaldehyde was used as agent	
Na2CO3 was used as agent	
Na2CO3 was used as agent	
In the preparation, EDTA was used. Calcination was done under N2. Temperature while adding NaBH4 was assumed room temperature.	
In the preparation, EDTA was used. Calcination was done under N2. Temperature while adding NaBH4 was assumed room temperature.	
In the preparation, EDTA was used. Calcination was done under N2. Temperature while adding NaBH4 was assumed room temperature.	
In the preparation, EDTA was used. Calcination was done under N2. Temperature while adding NaBH4 was assumed room temperature.	
In the preparation, EDTA was used. Calcination was done under N2. Temperature while adding NaBH4 was assumed room temperature.	
	alpha-Al2O3 Alfa Aesar 99.95% alpha phase
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
CO/Pd was given: 0.43, Na2CO3 was used as reducing agent	
CO/Pd was given: 0.57, Na2CO3 was used as reducing agent	
CO/Pd was given: 0.60, Na2CO3 was used as reducing agent	
CO/Pd was given: 0.45, Na2CO3 was used as reducing agent	
CO/Pd was given: 0.54, Na2CO3 was used as reducing agent	

CO/Pd was given: 0.68, Na2CO3 was used as reducing agent	
CO/Pd was given: 0.34, Na2CO3 was used as reducing agent	
CO/Pd was given: 0.29, Na2CO3 was used as reducing agent	
CO/Pd was given: 0.31, Na2CO3 was used as reducing agent	
catalyst was reduced before reaction, but not before TEM.	
catalyst was reduced before reaction, but not before TEM.	
pH adjustment is done by adding 0.5 M KOH. Temperature while adding ethylene glycol was assumed room temperature.	
pH adjustment is done by adding 0.1 M KOH. Temperature while adding ethylene glycol was assumed room temperature.	
pH adjustment is done by adding 0.05 M KOH. Temperature while adding ethylene glycol was assumed room temperature.	
pH adjustment is done by adding 0.03 M KOH. Temperature while adding ethylene glycol was assumed room temperature.	
NaOH was used in the synthesis, it is assumed that it was used for pH adjustment	Unspecified Al2O3 Aldrich
NaOH was used in the synthesis, it is assumed that it was used for pH adjustment	Merck MgO
NaOH was used in the synthesis, it is assumed that it was used for pH adjustment	Anatase TiO2 Aldrich
NaOH was used in the synthesis, it is assumed that it was used for pH adjustment	Aerosil A-175 SiO2
NaOH was used in the synthesis, it is assumed that it was used for pH adjustment	Unspecified Al2O3 Aldrich
NaOH was used in the synthesis, it is assumed that it was used for pH adjustment	gamma-Al2O3 Alfa Aesar
NaOH was used in the synthesis, it is assumed that it was used for pH adjustment	Aerosil A-175 SiO2
NaOH was used in the synthesis, it is assumed that it was used for pH adjustment	Anatase TiO2 Aldrich
NaOH was used in the synthesis, it is assumed that it was used for pH adjustment	anostructured and Amorphous Materials Zn
NaOH was used in the synthesis, it is assumed that it was used for pH adjustment	Aldrich CeO2
NaOH was used in the synthesis, it is assumed that it was used for pH adjustment	
NaOH was used in the synthesis, it is assumed that it was used for pH adjustment	Hydral 705 from Alcoa Al(OH)3
NaOH was used in the synthesis, it is assumed that it was used for pH adjustment	Alfa Aesar ZrO2
NaOH was used in the synthesis, it is assumed that it was used for pH adjustment	Aldrich SnO2
NaOH was used in the synthesis, it is assumed that it was used for pH adjustment	Aldrich CuO
Na2CO3 was used as basic agent	
Na2CO3 was used as basic agent	
Na2CO3 was used as basic agent	

	TiO2 Anatase Aldrich
	TiO2 Anatase Aldrich
	alpha-Al2O3 Aldrich
	Unspecified Al2O3 Aldrich
	Unspecified Al2O3 Aldrich
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
Temperature while adding NaBH4 was not given, room temperature was assumed	
Support SA was given as support external surface area and support internal surface area, summation of these two values were used.	alpha-Al2O3 Alfa Aesar 99.95% alpha phase
Support SA was given as support external surface area only, internal surface area was NA, therefore, external was noted.	gamma-Al2O3 Alfa Aesar
Support SA was given as support external surface area and support internal surface area, summation of these two values were used.	alpha-Al2O3 Alfa Aesar 99.95% alpha phase

Support SA was given as support external surface area only, internal surface area was NA, therefore, external was noted.	gamma-Al2O3 Alfa Aesar
	SiO2 Aldrich
	CeO2 Aldrich
Temperature while adding NaBH4 was not given, room temperature was assumed. NaBH4 added before mixing with carbon support	
	SiO2 Aldrich
	SiO2 Aldrich
	TiO2 Anatase Merck
	TiO2 Degussa P-25
	TiO2 Degussa P-25
NaOH and formaldehyde were used as basic agent	
NaOH and formaldehyde were used as basic agent	
NaOH and formaldehyde were used as basic agent	
NaOH and formaldehyde were used as basic agent	
NaOH and formaldehyde were used as basic agent	SiO2 Aldrich
	SiO2 Aldrich
Reduced second time before CO chemisorption at 423 K (initial reduction step with higher temperature was noted)	SiO2 Aldrich
Reduced second time before CO chemisorption at 423 K (initial reduction step with higher temperature was noted)	SiO2 Aldrich
Reduced second time before CO chemisorption at 423 K (initial reduction step with higher temperature was noted)	gamma-Al2O3 Alfa Aesar
Reduced second time before CO chemisorption at 423 K (initial reduction step with higher temperature was noted)	gamma-Al2O3 Alfa Aesar
Temperature while adding ethylene glycol was assumed room temperature	
Temperature while adding ethylene glycol was assumed room temperature	
Temperature while adding ethylene glycol was assumed room temperature	
Temperature while adding ethylene glycol was assumed room temperature	
Temperature while adding ethylene glycol was assumed room temperature	
Ethylene glycol was used as reducing agent, Modified polyol process	
Ethylene glycol was used as reducing agent, Modified polyol process	
Ethylene glycol was used as reducing agent, Modified polyol process	

Ethylene glycol was used as reducing agent, Modified polyol process	
Ethylene glycol was used as reducing agent, Modified polyol process	
Thermal treatment after impregnation at 900 °C	
	SiO2 Aldrich
	SiO2 Aldrich
	SiO2 Aldrich
	SiO2 Aldrich
	SiO2 Aldrich
TEM particle size was given as <8 nm	Unspecified Al2O3 Aldrich
TEM particle size was given as >8 nm	Unspecified Al2O3 Aldrich
TEM particle size was given as >8 nm	Unspecified Al2O3 Aldrich
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	SiO2 Aldrich
Na2CO3 was used as basic agent	
Na2CO3 was used as basic agent	
Na2CO3 was used as basic agent	
Na2CO3 was used as basic agent	
	Unspecified Al2O3 Aldrich
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
CO Chemisorption result: 23 mlCO/g Pd	
	TiO2 Degussa P-25
	TiO2 Degussa P-25
Temperature while adding NaBH4 was not given, room temperature was assumed.	
Temperature while adding NaBH4 was not given, room temperature was assumed.	

573 K 2h N2 treatment	
	gamma-Al2O3 Alfa Aesar
	ZrO2 Aldrich
	TiO2 Degussa P-25
Temperature while adding NaBH4 was not given, room temperature was assumed.	
Reduced before catalytic tests but not before CO Chemisorption	
Reduced before catalytic tests but not before CO Chemisorption	
	CeO2 Aldrich
	MgO Merck
	ZrO2 Aldrich water washed
	gamma-Al2O3 Alfa Aesar
The actual metal loading was not given, but it was stated that it was close to nominal loading. Thus, same value was written	
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
Dispersion from TEM was also given as 18%	
Reduced again before CO chemisorption at 30 °C for 2 h in H2 flow, Dispersion from TEM was also given as 32%	
Reduced again before CO chemisorption at 30 °C for 2 h in H2 flow, Dispersion from TEM was also given as 37%	
	Al2O3 from isopropoxide
	Al2O3 from isopropoxide
	Al2O3 from isopropoxide
	Al2O3 from isopropoxide

	gamma-Al2O3 Alfa Aesar
	SiO2 Aldrich
	SiO2 Aldrich
	SiO2 Aldrich
	SiO2 Aldrich
	SiO2 Aldrich
	SiO2 Aldrich
	SiO2 Aldrich
	SiO2 Aldrich
	SiO2 Aldrich
	gamma-Al2O3 Alfa Aesar

	SiO2 Degussa
	SiO2 Degussa
	gamma-Al2O3 Alfa Aesar
	TiO2 Degussa P-25
	ZrO2 Aldrich
	Al(OH)3 Hydral 705 from Alcoa
	Al(OH)3 Hydral 705 from Alcoa
	Al(OH)3 Hydral 705 from Alcoa
	Al(OH)3 Hydral 705 from Alcoa
	SiO2 Aldrich
	TiO2 Degussa P-25
	TiO2 Degussa P-25
	TiO2 Degussa P-25
	TiO2 Degussa P-25
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	Al2O3 from AlCl3 and ammonia
	boehmite, Neftekhim
	gamma-Al2O3 Alfa Aesar
Temperature while adding ethylene glycol was assumed room temperature	
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar

	CeO2 Aldrich
	ZrO2 Aldrich
	MnO2 Alfa Aesar
	SnO2 Aldrich
	gamma-Al2O3 Alfa Aesar
	WO3 Aldrich
Temperature while adding NaBH4 was not given, room temperature was assumed.	
Temperature while adding NaBH4 was not given, room temperature was assumed.	
Temperature while adding NaBH4 was not given, room temperature was assumed.	
Temperature while adding NaBH4 was not given, room temperature was assumed.	
Temperature while adding NaBH4 was not given, room temperature was assumed.	
After adding hydrazine, mixture stirred overnight which was assumed 12 h.	
	SiO2 Aldrich
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
Modified polyol process	
	SiO2 Aldrich
	SiO2 Aldrich
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	Al2O3 Degussa
	SiO2Degussa
	Unspecified Al2O3 Aldrich

Temperature while adding KBH4 was assumed room temperature	
before reduction, treated under He flow at 573 K for 1 h	
before reduction, treated under He flow at 573 K for 1 h	
before reduction, treated under He flow at 573 K for 1 h	
	gamma-Al2O3 Alfa Aesar
Na2CO3 was used as basic agent, no pre-reduction	
Na2CO3 was used as basic agent, pre-reduced with formate	
Na2CO3 was used as basic agent, pre-reduced with hydrogen	
NaBH4 as reducing agent was also used.	
NaBH4 as reducing agent was also used.	
NaBH4 as reducing agent was also used.	
NaBH4 as reducing agent was also used.	
	SiO2 Aldrich
	gamma-Al2O3 Alfa Aesar
	TiO2 Anatase from Aldrich
	ZrO2 Aldrich
	CeO2 Aldrich

treated by dielectric barrier discharge (DBD) cold plasma	
	Merck MgO
	gamma-Al2O3 Alfa Aesar
Na2CO3 was used as basic agent	
Na2CO3 was used as basic agent	
Na2CO3 was used as basic agent	
Na2CO3 was used as basic agent	
Na2CO3 was used as basic agent	
Na2CO3 was used as basic agent	
Na2CO3 was used as basic agent	
Na2CO3 was used as basic agent	
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	SiO2 Aldrich
	TiO2 Degussa P-25
	TiO2 Degussa P-25
	TiO2 Degussa P-25
	TiO2 Degussa P-25
	TiO2 Degussa P-25
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	CeO2 Aldrich
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	TiO2 Degussa P25
	CeO2 Aldrich
	Al2O3 Unspecified Aldrich
	Al2O3 Unspecified Aldrich

	Al2O3 Unspecified Aldrich
	Al2O3 Unspecified Aldrich
	Al2O3 Unspecified Aldrich
catalyst was reduced but temperature was not given	
catalyst was reduced but temperature was not given	
catalyst was reduced but temperature was not given	
	MgO Merck
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	TiO2 Degussa P25
Na2CO3 was used as basic agent	TiO2 Degussa P25
Na2CO3 was used as basic agent	TiO2 Degussa P25
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	alpha-Al2O3 Alfa Aesar, 99.95% alpha phas
	SiO2 Aldrich
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
Silica gel surface area was given, due to difference between structure, it was not used	SiO2 Aldrich
Silica gel surface area was given, due to difference between structure, it was not used	SiO2 Aldrich
Silica gel surface area was given, due to difference between structure, it was not used	SiO2 Aldrich
Silica gel surface area was given, due to difference between structure, it was not used	SiO2 Aldrich
Silica gel surface area was given, due to difference between structure, it was not used	SiO2 Aldrich
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	Anatase TiO2 Aldrich
	Anatase TiO2 Aldrich
	Anatase TiO2 Aldrich
Support calcination time was given as overnight, it is assumed as 12 h.	gamma-Al2O3 Alfa Aesar
XRD result was given as <1.4 nm	
	ZnO Aldrich
	ZnO Aldrich
Only air-dried at 120C without calcination	ZnO Aldrich
Only air-dried at 120C without calcination	ZnO Aldrich
Only air-dried at 120C without calcination	ZnO Aldrich
Only air-dried at 120C without calcination	ZnO Aldrich
Only air-dried at 120C without calcination	ZnO Aldrich
Only air-dried at 120C without calcination	ZnO Aldrich
Polyvinyl alcohol was added (PVA/Pd = 1.2 weight ratio) as stabilizer + NaBH4 used as reducing agent + Only air-dried at 120C without calcination	ZnO Aldrich
Polyvinyl alcohol was added (PVA/Pd = 1.2 weight ratio) as stabilizer + NaBH4 used as reducing agent + Only air-dried at 120C without calcination	ZnO Aldrich
Polyvinyl alcohol was added (PVA/Pd = 1.2 weight ratio) as stabilizer + NaBH4 used as reducing agent + Only air-dried at 120C without calcination	ZnO Aldrich

Polyvinyl alcohol was added (PVA/Pd = 1.2 weight ratio) as stabilizer + NaBH4 used as reducing agent + Only air-dried at 120C without calcination	ZnO Aldrich
Polyvinyl alcohol was added (PVA/Pd = 1.2 weight ratio) as stabilizer + NaBH4 used as reducing agent + Only air-dried at 120C without calcination	ZnO Aldrich
Polyvinyl alcohol was added (PVA/Pd = 1.2 weight ratio) as stabilizer + NaBH4 used as reducing agent + Only air-dried at 120C without calcination	ZnO Aldrich
	SiO2 from ethanolic TEOS
	Al2O3 from iso-propoxide calcined at 600 C for
alyst was calcined initially for 1 h at 623K, the final one was written. ZrO2 was used in the synthesis without calcination, thus, the surface area without calcination was used.	
TEM sizes belongs to without reduction condition, thus reduction was not written	ZnO Aldrich
TEM sizes belongs to without reduction condition, thus reduction was not written	ZnO Aldrich
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
Catalyst initially calcined at 500 °C for 1 h, the final calcination step was noted	gamma-Al2O3 Alfa Aesar
Catalyst initially calcined at 500 °C for 1 h, the final calcination step was noted	gamma-Al2O3 Alfa Aesar
Catalyst initially calcined at 500 °C for 1 h, the final calcination step was noted	gamma-Al2O3 Alfa Aesar
	Al2O3 Sumitomo alpha form
	Al2O3 Sumitomo alpha form
	Al2O3 Sumitomo alpha form
Catalyst initially calcined at 500 °C for 1 h, the final calcination step was noted	Al2O3 Sumitomo alpha form
Catalyst initially calcined at 500 °C for 1 h, the final calcination step was noted	Al2O3 Sumitomo alpha form
Catalyst initially calcined at 500 °C for 1 h, the final calcination step was noted	Al2O3 Sumitomo alpha form
	Al2O3 Sumitomo alpha form
	Al2O3 Sumitomo alpha form
	Al2O3 Sumitomo alpha form
	Al2O3 Sumitomo alpha form
Catalyst initially calcined at 500 °C for 1 h, the final calcination step was noted	Al2O3 Sumitomo alpha form
	gamma-Al2O3 Alfa Aesar
	alpha Al2O3 Aldrich
	TiO2 Degussa P25
TEM result was not given, it was written from 1.2 to 6 wt% particle size increased progressively from 1 nm to 7 nm. Therefore, particle size was estimated according to this relation.	
TEM result was not given, it was written from 1.2 to 6 wt% particle size increased progressively from 1 nm to 7 nm. Therefore, particle size was estimated according to this relation.	
TEM result was not given, it was written from 1.2 to 6 wt% particle size increased progressively from 1 nm to 7 nm. Therefore, particle size was estimated according to this relation.	
	SiO2 Aldrich
	SiO2 Aldrich

	SiO2 Aldrich
	alpha-Al2O3 Aldrich
	CeO2 Aldrich
	gamma-Al2O3 Alfa Aesar
ICP results was similar to nominal loading, it said. That's why same value was written	
ICP results was similar to nominal loading, it said. That's why same value was written	
ICP results was similar to nominal loading, it said. That's why same value was written	
ICP results was similar to nominal loading, it said. That's why same value was written	
ICP results was similar to nominal loading, it said. That's why same value was written	
ICP results was similar to nominal loading, it said. That's why same value was written	
ICP results was similar to nominal loading, it said. That's why same value was written	
ICP results was similar to nominal loading, it said. That's why same value was written	
ICP results was similar to nominal loading, it said. That's why same value was written	
urea was used as agent	
Reducing agent: None.	
NaBH4 as reducing agent was also used (Added at 298 K), H2 was written due to higher operational temperature	
Formaldehyde as reducing agent was also used (Added at 298 K), H2 was written due to higher operational temperature	
NaBH4 as reducing agent was also used (Added at 275 K), H2 was written due to higher operational temperature	
Formaldehyde as reducing agent was also used (Added at 353 K), H2 was written due to higher operational temperature	
Calcined under N2 flow	
Calcined under N2 flow	
Calcined under N2 flow	
Catalyst was not dried before calcination	
CO: Pd assumed 1	TiO2 Anatase Aldrich
CO: Pd assumed 1	TiO2 Anatase Aldrich
CO: Pd assumed 1	TiO2 Rutile from Tioxide
CO: Pd assumed 1	TiO2 Rutile from Tioxide
	TiO2 P-25 Degussa
	TiO2 P-25 Degussa
K2CO3 precipitant for pH adjustment	
K2CO3 precipitant for pH adjustment	
Na2CO3 precipitant for pH adjustment	
Na2CO3 precipitant for pH adjustment	
Li2CO3 precipitant for pH adjustment	
Li2CO3 precipitant for pH adjustment	
KHCO3 precipitant for pH adjustment	
KHCO3 precipitant for pH adjustment	
NaHCO3 precipitant for pH adjustment	

NaHCO3 precipitant for pH adjustment	
KOH precipitant for pH adjustment	
KOH precipitant for pH adjustment	
NaOH precipitant for pH adjustment	
NaOH precipitant for pH adjustment	
LiOH precipitant for pH adjustment	
LiOH precipitant for pH adjustment	
Irradiation time: 20 min	
Irradiation time: 40 min	
Irradiation time: 60 min	
	Unspecified Al2O3 Aldrich
Before TEM, reduction was not performed, thus, it was not written.	
Before TEM, reduction was not performed, thus, it was not written.	
Formaldehyde as reducing agent was used	
Formaldehyde as reducing agent was used	
Formaldehyde as reducing agent was used	
Formaldehyde as reducing agent was used	
Formaldehyde as reducing agent was used	
NaBH4 as reducing agent was used	
NaBH4 as reducing agent was used	
NaBH4 as reducing agent was used	
NaBH4 as reducing agent was used	
NaBH4 as reducing agent was used	
NaBH4 as reducing agent was used	
NaBH4 as reducing agent was used	
NaBH4 as reducing agent was used	
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar

	gamma-Al2O3 Alfa Aesar
NaOH was used as precipitating agent	gamma-Al2O3 Alfa Aesar
	CeO2 Aldrich
	CeO2 Aldrich
	CeO2 Aldrich
	CeO2 Aldrich
	CeO2 Aldrich
	CeO2 Aldrich
	CeO2 Aldrich
	CeO2 Aldrich
	CeO2 Aldrich
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	SiO2 Aldrich
	gamma-Al2O3 Alfa Aesar
	Al2O3 from Aldrich
	Al2O3 from Aldrich

sodium tartrate dibasic dehydrate was used as stabilizer	gamma-Al2O3 Alfa Aesar
sodium tartrate dibasic dehydrate was used as stabilizer	SiO2 Aldrich
sodium tartrate dibasic dehydrate was used as stabilizer	CeO2 Aldrich
sodium tartrate dibasic dehydrate was used as stabilizer	ZrO2 Aldrich
sodium tartrate dibasic dehydrate was used as stabilizer	TiO2 Degussa P25
	CeO2 Aldrich
N2H4 as reducing agent was also used	
N2H4 as reducing agent was also used	
Na2CO3 was used as reducing agent	
Na2CO3 was used as reducing agent	
Na2CO3 was used as reducing agent	
Na2CO3 was used as reducing agent	
Na2CO3 was used as reducing agent	
Na2CO3 was used as reducing agent	
Na2CO3 was used as reducing agent	
	SiO2 1.5 L 0.74 M ethanolic TEOS was rapidly added to 7 L of ethanol and 0.6 L of 1.03 M ammonia
	SiO2 1.5 L 0.74 M ethanolic TEOS was rapidly added to 7 L of ethanol and 0.6 L of 1.03 M ammonia
After calcination of support, support was wetted with water	gamma-Al2O3 Alfa Aesar
After calcination of support, support was wetted with water	gamma-Al2O3 Alfa Aesar
After calcination of support, support was wetted with water	gamma-Al2O3 Alfa Aesar
After calcination of support, support was wetted with water	gamma-Al2O3 Alfa Aesar
After calcination of support, support was wetted with water	gamma-Al2O3 Alfa Aesar
After calcination of support, support was wetted with water	gamma-Al2O3 Alfa Aesar
After calcination of support, support was wetted with water	gamma-Al2O3 Alfa Aesar
After calcination of support, support was wetted with water	gamma-Al2O3 Alfa Aesar
After calcination of support, support was wetted with water	gamma-Al2O3 Alfa Aesar
After calcination of support, support was wetted with water	gamma-Al2O3 Alfa Aesar
	TiO2 Anatase Aldrich
	TiO2 Anatase Aldrich
0.3 wt% Na loading, Na promoted Pd/TiO2 catalyst	TiO2 Anatase Aldrich
0.6 wt% Na loading Na promoted Pd/TiO2 catalyst	TiO2 Anatase Aldrich
0.6 wt% Na loading Na promoted Pd/TiO2 catalyst	TiO2 Anatase Aldrich
1.2 wt% Na loading Na promoted Pd/TiO2 catalyst	TiO2 Anatase Aldrich

	Cubic, hydrolysis of Ce(IV)nitrate
	Nb2O5 value selected from the given range
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
calcination was done after initial calcination at 550C for 2 h	gamma-Al2O3 Alfa Aesar
calcination was done after initial calcination at 550C for 2 h	gamma-Al2O3 Alfa Aesar
calcination was done after initial calcination at 550C for 2 h	gamma-Al2O3 Alfa Aesar
calcination was done after initial calcination at 550C for 2 h	gamma-Al2O3 Alfa Aesar
	Boehmite, Neftekhim
Dispersion from TEM was also given as 39.7%	Al2O3 gamma- from Merck
Dispersion from TEM was also given as 23.7%	Al2O3 gamma- from Merck
Dispersion from TEM was also given as 15.7%	Al2O3 gamma- from Merck
Dispersion from TEM was also given as 10.4%	Al2O3 gamma- from Merck
	Al2O3 gamma- from Merck
	Al2O3 gamma- from Merck
	Hydrolysis of Ce(IV) nitrate
	Hydrolysis of Ce(IV) nitrate
	Hydrolysis of Ce(IV) nitrate
	Hydrolysis of Ce(IV) nitrate
	Hydrolysis of Ce(IV) nitrate
Na2CO3 was used as reducing agent	Al2O3 unspecified Aldrich
Na2CO3 was used as reducing agent	SiO2 Aldrich

Na2CO3 was used as reducing agent	TiO2 P25 (Aeroxide) Degussa
Na2CO3 was used as reducing agent	ZrO2 Aldrich
	alpha-Al2O3 Aldrich
Dispersion is given as very poor and size is given as fairly large. To add the data, dispersion is written as 0% and size is written as 1000 angstrom.	alpha-Al2O3 Aldrich
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
Na2CO3 was used as reducing agent	
Na2CO3 was used as reducing agent	
Na2CO3 was used as reducing agent	
Na2CO3 was used as reducing agent	
Na2CO3 was used as reducing agent	
Na2CO3 was used as reducing agent	

Na2CO3 was used as reducing agent	
Na2CO3 was used as reducing agent	
Particle size was given as <30 angstrom, Na2CO3 were used as reducing agent	CeO2 Aldrich
Particle size was given as <30 angstrom, Na2CO3 were used as reducing agent	CeO2 Aldrich
Particle size was given as <30 angstrom, Na2CO3 were used as reducing agent	CeO2 Aldrich
CO/Pd ratio is given, it is assumed 1 for dispersion	gamma-Al2O3 Alfa Aesar
CO/Pd ratio is given, it is assumed 1 for dispersion	gamma-Al2O3 Alfa Aesar
CO/Pd ratio is given, it is assumed 1 for dispersion	CeO2 Aldrich
CO/Pd ratio is given, it is assumed 1 for dispersion	CeO2 Aldrich
CO/Pd ratio is given, it is assumed 1 for dispersion	La2O3 Commercial, 98%
CO/Pd ratio is given, it is assumed 1 for dispersion	La2O3 Commercial, 98%
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Merck
	gamma-Al2O3 Merck
	gamma-Al2O3 Merck
	gamma-Al2O3 Merck
	gamma-Al2O3 Merck
	TiO2 Anatase Aldrich
	TiO2 Anatase Aldrich
	TiO2 Anatase Aldrich
	Al2O3 Boehmite

	Al2O3 unspecified Aldrich
	Al2O3 unspecified Aldrich
	TiO2 P25 Degussa
	TiO2 P25 Degussa
Reduction temperature is assumed room temperature, support initially treated with 5% oxygen in nitrogen which is written as support calcination	
support initially treated with 5% oxygen in nitrogen which is written as support calcination	
	gamma-Al2O3 Alfa Aesar
	ZrO2 Aldrich
	ZrO2 Aldrich
Na2CO3 was used as reducing agent	ZrO2 Aldrich
Na2CO3 was used as reducing agent	ZrO2 Aldrich
	alpha-Al2O3 Aldrich
	Al2O3 from iso-propoxide
	Al2O3 unspecified Aldrich
	Al2O3 unspecified Aldrich
	Al2O3 unspecified Aldrich
	Al2O3 unspecified Aldrich
	Al2O3 unspecified Aldrich
	Al2O3 unspecified Aldrich
	Al2O3 unspecified Aldrich
	ZrO2 Aldrich
	ZrO2 Aldrich
	TiO2 Anatase from isopropoxide
	TiO2 Anatase from isopropoxide
	TiO2 Rutile from Tioxide
average size was given as 1-7 nm	Y2O3 avg. value
average size was given as 1-4 nm	CeO2 Aldrich
	gamma-Al2O3 Alfa Aesar
reducing agent formaldehyde was used at 338 K	gamma-Al2O3 Alfa Aesar
reducing agent NaBH4 was used at 338 K	gamma-Al2O3 Alfa Aesar
reduced agent hydrogen was used at 338 K	gamma-Al2O3 Alfa Aesar

	CeO2 Aldrich
	CeO2 Aldrich
	CeO2 Aldrich
catalyst wetted by IPA solution and vacuum sealed in a polyethylene bag	alpha-Al2O3 Aldrich
catalyst was left under room temperature for 48 h after wetted by IPA solution and vacuum sealing	alpha-Al2O3 Aldrich
	alpha-Al2O3 Aldrich
	CeO2 Aldrich
	TiO2 P25 (Aeroxide) Degussa
	Boehmite, Neftekhim
	ZrO2 Aldrich
	SiO2 Fuji
	from ZrOCl2, K2SO4 and HCl
Na2CO3 was used as reducing agent	from ZrOCl2, K2SO4 and HCl
Na2CO3 was used as reducing agent	from ZrOCl2, K2SO4 and HCl
Na2CO3 was used as reducing agent	from ZrOCl2, K2SO4 and HCl
Na2CO3 was used as reducing agent	from ZrOCl2, K2SO4 and HCl
	Anatase TiO2 Aldrich
TEM particle size is estimated according to particle size distribution	Rutile from Tioxide
TEM particle size is estimated according to particle size distribution	TiO2 P25 (Aeroxide) Degussa
TEM particle size is estimated according to particle size distribution	
TEM particle size is estimated according to particle size distribution	
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	SiO2 Aldrich
	SiO2 Aldrich
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar

second step of calcination and reduction are noted	
second step of calcination and reduction are noted	
second step of calcination and reduction are noted	
second step of calcination and reduction are noted	
second step of calcination and reduction are noted	
catalyst was treated by AP plate-to-plate DBD cold plasma	
	TiO2 Anatase from Aldrich
	Rutile from Tioxide
	P25 (Aeroxide) Degussa
	P25 (Aeroxide) Degussa
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	gamma-Al2O3 Alfa Aesar
	MgO Merck
	SiO2 Aldrich
Na2CO3 was used as reducing agent	TiO2 P25 (Aeroxide) Degussa
Na2CO3 was used as reducing agent	TiO2 P25 (Aeroxide) Degussa
Na2CO3 was used as reducing agent	TiO2 P25 (Aeroxide) Degussa
Na2CO3 was used as reducing agent	Al2O3 unspecified Aldrich

Na2CO3 was used as reducing agent	SiO2 Aldrich
Pd loading calculated from given amounts	
Pd loading calculated from given amounts	
Pd loading calculated from given amounts	
Pd loading calculated from given amounts	
	ZrO2 Aldrich
Calcined under N2 flow	
Calcined under N2 flow	
	SiO2 Aerosil 380
	ZrO2 Aldrich
	Al2O3 unspecified Aldrich
	Al2O3 unspecified Aldrich
	Al2O3 unspecified Aldrich
	gamma-Al2O3 from Alfa Aesar
	gamma-Al2O3 from Alfa Aesar
	gamma-Al2O3 from Alfa Aesar
	gamma-Al2O3 from Alfa Aesar
	gamma-Al2O3 from Alfa Aesar
Second step of calcination were noted	gamma-Al2O3 from Alfa Aesar
Second step of calcination were noted	gamma-Al2O3 from Alfa Aesar
Second step of calcination were noted	gamma-Al2O3 from Alfa Aesar
	Al2O3 unspecified Aldrich
	Al2O3 unspecified Aldrich
	Al2O3 unspecified Aldrich
	Al2O3 unspecified Aldrich
	Al2O3 unspecified Aldrich
Second step of calcination were noted	Al2O3 unspecified Aldrich
Second step of calcination were noted	Al2O3 unspecified Aldrich
Second step of calcination were noted	Al2O3 unspecified Aldrich

Actual metal loading is given as ± 0.2. It is assumed 10.2	
Actual metal loading is given as ± 0.2. It is assumed 10.2	
Actual metal loading is given as ± 0.2. It is assumed 10.2	
Actual metal loading is given as ± 0.2. It is assumed 10.2	
Actual metal loading is given as ± 0.2. It is assumed 10.2	
NaBH4 was added into ice bath. It was assumed 273 K	
NaBH4 was added into ice bath. It was assumed 273 K	
NaBH4 was added into ice bath. It was assumed 273 K	
NaBH4 was added into ice bath. It was assumed 273 K	
NaBH4 was added into ice bath. It was assumed 273 K	
NaBH4 was added into ice bath. It was assumed 273 K	
	Al2O3 unspecified Aldrich
	Al2O3 unspecified Aldrich
	Al2O3 unspecified Aldrich
	Al2O3 unspecified Aldrich
	Al2O3 unspecified Aldrich
	Al2O3 unspecified Aldrich
formalin was used as reducing agent	gamma-Al2O3 Alfa Aesar
formalin was used as reducing agent	gamma-Al2O3 Alfa Aesar
formalin was used as reducing agent	gamma-Al2O3 Alfa Aesar
formalin was used as reducing agent	gamma-Al2O3 Alfa Aesar
formalin was used as reducing agent	gamma-Al2O3 Alfa Aesar
	Al2O3 unspecified Aldrich
	Al2O3 unspecified Aldrich
	Al2O3 unspecified Aldrich
	Al2O3 unspecified Aldrich
	Al2O3 unspecified Aldrich

	MgO Merck
	MgO Merck
	MgO Merck
pH adjustment is done by adding aqueous NH3	
pH adjustment is done by adding aqueous NH3	
pH adjustment is done by adding aqueous NH3, Instead of calcination extraction is done	
pH adjustment is done by adding aqueous NH3, Instead of calcination extraction is done	
pH adjustment is done by adding aqueous NH3, Instead of calcination extraction is done	
pH adjustment is done by adding aqueous NH3, Instead of calcination extraction is done	
pH adjustment is done by adding aqueous NH3, Instead of calcination extraction is done	
pH adjustment is done by adding aqueous NH3, Instead of calcination extraction is done	
pH adjustment is done by adding aqueous NH3, Instead of calcination extraction is done	
pH adjustment is done by adding aqueous NH3, Instead of calcination extraction is done	
pH adjustment is done by adding aqueous NH3, Instead of calcination extraction is done	
pH adjustment is done by adding aqueous NH3, Instead of calcination extraction is done	
PdO particle size is given	
PdO particle size is given	
PdO particle size is given	

TEM result was given as <10	
average value for size is written	
average value for size is written	
average value for size is written	
average value for size is written	
average value for size is written	
average value for size is written	
average value for size is written	
average value for size is written	
average value for size is written	
average value for size is written	
average value for size is written	
average value for size is written	
average value for size is written	
average value for size is written	
average value for size is written	
average value for size is written	
CO Chemisorption is also done (d: 7.2 nm)	

Different preparation method is used, specific name is not given	

XRD graphs are available, values are not mentioned	
ALD cycle = 1	
ALD cycle = 1, 300C treatment under H2 flow	
ALD cycle = 1, 500C treatment under H2 flow	
ALD cycle = 3	
ALD cycle = 3, 300C treatment under H2 flow	
ALD cycle = 3, 500C treatment under H2 flow	

2 steps calcination, 2nd step is written. Average values of TEM results are noted. PdO size is given.	
2 steps calcination, 2nd step is written. Average values of TEM results are noted. PdO size is given.	
treated by dielectric barrier discharge (DBD) cold plasma	
treated by dielectric barrier discharge (DBD) cold plasma	

Sample is pyrolyzed for 5.5h under N2 flow (Ramping time: 2.5h, Isothermal stage: 3h)	
Sample is pyrolyzed for 5.5h under N2 flow (Ramping time: 1.5h, Isothermal stage: 4h)	
before TEM, reduction was not performed, thus it was not written in the data. Before performance tests, the catalysts were reduced under H2 flow at 323 K for 0.5 h.	
before TEM, reduction was not performed, thus it was not written in the data. Before performance tests, the catalysts were reduced under H2 flow at 323 K for 0.5 h.	
before TEM, reduction was not performed, thus it was not written in the data. Before performance tests, the catalysts were reduced under H2 flow at 323 K for 0.5 h.	
before TEM, reduction was not performed, thus it was not written in the data. Before performance tests, the catalysts were reduced under H2 flow at 323 K for 0.5 h.	
before TEM, reduction was not performed, thus it was not written in the data. Before performance tests, the catalysts were reduced under H2 flow at 323 K for 0.5 h.	
pH adjustment is done by adding 0.1 M NaOH	
pH adjustment is done by adding 0.1 M NaOH	
PZC support value belongs to before addition of ammonium carbamate and calcination.	
NaOH was used in the synthesis, it is assumed that it was used for pH adjustment	