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Abstract: Background: Au-catalyzed selective oxidation of benzyl alcohol to benzaldehyde was investigated over Au/γ-Al₂O₃ nanocatalysts under aerobic conditions. The homogeneous deposition-precipitation method was used to prepare these catalysts. In the present work, varying Au content over γ-Al₂O₃ support has been used as heterogeneous catalysts to investigate the vapor phase oxidation of benzyl alcohol to benzaldehyde. In this study, it was observed that an Au/γ-Al₂O₃ catalyst shows an optimum conversion of benzyl alcohol to benzaldehyde at Au loading of 2 wt%. The catalytic activity of Au/γ-Al₂O₃ was interrelated with Au particle size supported by Au on γ-Al₂O₃ support. The catalytic activity depends on the size of the gold nanoparticles, as well as on the interaction between gold nanoparticles and various support materials. We have optimized various parameters such as Au nanoparticles loading, reaction temperature, and reaction time for efficient conversion as well as product selectivity.

Methods: The Au nanocatalysts supported on γ-Al₂O₃ were prepared with by homogeneous deposition-precipitation (HDP) method by varying the loading of Au nanoparticles and using urea as the precipitating agent.

Results: A varying Au loading has been employed over γ-Al₂O₃ support material after their structural investigation. The vapor phase oxidation of PhCH₂OH to PhCHO was investigated over Au/γ-Al₂O₃ catalysts under air. Only a few percent of benzyl alcohol were found to convert in the absence of as-synthesized catalysts. Moreover, bare support also showed a very poor catalytic activity towards benzyl alcohol conversion. Hence, the synergistic effect of Au nanoparticles over support materials facilitated as an excellent catalyst for efficient conversion of benzyl alcohol to benzaldehyde. The 2 wt% of Au/γ-Al₂O₃ catalysts after 2 h of reaction time showed the maximum conversion of 33%.

Conclusion: Au/γ-Al₂O₃ catalyst prepared by HDP method exhibits a high catalytic activity as well as stability for the vapor phase conversion of benzyl alcohol to benzaldehyde. The optimum condition for efficient conversion of benzyl alcohol is observed to be 2 wt% Au loading, 2 hr reaction time and 320 °C of reaction time for all cases.

Keywords: Gold nanoparticles, benzyl alcohol, oxidation, benzaldehyde, aerobic condition, HDP.

1. INTRODUCTION

Bulk gold (Au) shows poor catalytic performance due to its stable and inert nature compared to other transition metals. After various studies it has been observed that Au in the form of nanoparticles (NPs) shows significant catalytic performance [1]. Moreover, supported Au NPs shows much higher catalytic activity than Au alone. Hence, supported Au NPs received major attention in catalytic science today. Au shows excellent catalytic characteristics towards the oxidation reactions at lower temperatures [2, 3], which allow excellent control over the selectivity for specific selective oxidation reactions. The alcohol oxidation process produces very valuable by-products which could be utilized as intermediates for the synthesis of other compounds and as end products for chemical industries. Further, benzyl alcohol (PhCH₂OH) selective oxidation acts as a fundamental reaction for both laboratory and industry procedures. Au is one of the catalysts, which is very famous for the selective oxidation of benzyl alcohol (PhCH₂OH) to benzaldehyde (PhCHO) [4-10]. The selective oxidation of alcohol is usually carried out under base, which acts as a promoter or a co-catalyst [2, 5, 6, 8, 9, 11-14]. During alcohol oxidation, the presence of base increases alcohol deprotonation which...
clearly confirms that catalytic oxidation is the rate limiting step [2-14]. Moreover, it has also been reported that alkaline conditions can significantly enhance the selectivity towards benzoic acid (PhCOOH) [1, 8]. Furthermore, alkaline conditions have also been reported to enhance the selectivity towards PhCOOH; however, turn over frequency (TOF) was the main focused parameter [3, 5, 9]. The issues of catalyst deactivation, which arise due to catalysts poisoning or degradation [15] and reusability were also studied [2, 4, 7, 8, 13]. Catalyst deactivation during selective oxidation can also arise due to over-oxidation of Pt [13] and Pd [16] in the presence of excess of (molecular) oxygen. The excess amount of atomic oxygen blocks the catalytic sites which hindered further adsorption of hydrocarbons. It is known that Au based catalysts are highly resistant towards over-oxidation [2, 8, 12], which makes them very encouraging as catalytic materials for the oxidation reactions.

The present study is concerned with the Au-catalyzed selective oxidation of PhCH₂OH to PhCHO and benzyl benzoate over the commercial support in Au/γ-Al₂O₃ catalysts. The support plays an important role in supported Au catalysts employed for the vapor phase PhCH₂OH oxidation. This could be related to the nature of the catalyst and the active phase support interactions. From the past decades, the silica-supported Au catalysts are widely used for many industrial reactions. PhCH₂OH, which is a primary alcohol, is oxidized to PhCHO and subsequently to PhCOOH, while forming benzyl benzoate [17]. However, the deactivation of this catalytic system is the main concerned here, which is observed when the catalyst was reused in the batch process. In the present work, our main focus was to investigate the deactivation process, classify the probable inhibiting species, and clarify the deactivation mechanism. Hence, in order to that, we carried out the oxidation reaction under different conditions.

Various metal supported catalysts including Pt, Pd, Au with/without promoters have been studied for alcohols oxidation in the liquid phase [8]. However, the difficult separation of catalysts from the reaction mixture is the main disadvantage of liquid phase oxidation of alcohols. Nowadays, the use of molecular oxygen as oxidant, heterogeneous catalyst, and water as a solvent are the main interest in the oxidation of alcohols. Au is a very distinguished catalytic material and its catalytic activity highly depends on its particles’ size. It was observed that the catalytic performance of Au enhanced significantly, when its particles size was reduced to 1-10 nm [18, 19]. In the 1980s, Au in the form of nanoparticles was first used as catalytic material CO oxidation [20]. After that Au has been investigated widely as a catalytic material for various oxidation reactions including oxidation of alkanes [21], alcohols [22, 23], lactose [24], epoxides [25] and in the direct synthesis of hydrogen peroxide [26]. Different support materials have been investigated and employed to disperse Au nanoparticles, which modify the catalytic properties of Au significantly via metal-support interactions [18, 23, 24, 27-33].

Recently, the vapor-phase catalytic oxidation of PhCH₂OH to PhCHO has received great attention as per both economical as well as environmental point of views [34-40]. Due to solvent-free, vapor phase, and continuous system conditions, the system can deliver chloride-less good quality PhCHO for its application in flavouring and pharmaceutical industries without the requirement of separating the catalysts from reaction mixture.

In the present work, Au supported on macro porous support γ-Al₂O₃ has been prepared using HDP method. These catalysts have been used in vapor phase oxidation of PhCH₂OH to PhCHO in aerobic conditions. The effects of the Au loading on γ-Al₂O₃ support, the temperature, and time on the catalytic activity of supported Au catalysts for the PhCH₂OH to PhCHO have been studied.

2. EXPERIMENTAL SECTION

2.1. Synthesis of Supported Nano Au Catalysts

The support employed for Au nanocatalysts were γ-Al₂O₃ (produced from Engelhard Corporation, Al-3996, BET surface area = 192 m²/g). The Au nanocatalysts supported on γ-Al₂O₃ were prepared with by homogeneous deposition-precipitation (HDP) method by varying the loading of Au nanoparticles and using urea as precipitating agent [41-43]. First, the mixture of an aqueous solution containing HAuCl₄.3H₂O and urea was stirred with a slight increase in temperature up to 95°C for 6 h. The urea in the mixture decomposes to ammonia on heating whereby the precipitation happens in a regular way in the solution as the pH shift towards basic conditions (pH ~ 6-8). Then, the support materials were introduced to the solution while maintaining homogeneous stirring. The required quantity of 0.1 M NaBH₄ solution [44] was introduced to the above solution, which reduces and precipitates the Au nanoparticles on catalytic support. After that, the solid product produced was filtered and washed thoroughly with DI water ensuring no chloride ions (confirmed with AgNO₃ test). Finally, the solid product was dried 100°C for 5 h in an oven and then calcined at 400°C for 3 h in N₂ atmosphere. The EDAX-analysis confirms a very minute amount of sodium (<0.01%) in the prepared catalysts.

2.2. Characterization of Catalysts

X-ray powder diffraction (XRD) analysis of the catalysts was done using a Rigaku MiniFlex (M/s. Rigaku Corporation, Japan). X-ray diffractometer using Ni filtered Cu Kα radiation (λ = 0.15406 nm) with a scan speed of 2º min⁻¹ in the scan range of 10-80º. The crystallite size of Au was investigated with the help of Debye-Scherrer formulae. The CO-chemisorption study was done on AutoChem 2910 (Micromeritics, USA) instrument, where a 100 mg amount of the catalyst was pre-treated in the presence of He gas for 1 h at 150°C and then cooled upto a temperature of 50°C. CO uptake was determined by injecting pulses of 10% CO/He from a calibrated online sampling valve into the He gas stream passing over the samples at 80°C. Inductively coupled plasma optical emission spectrometer (ICP-OES, Varian 720-ES instrument) was utilized to determine the Au content. Surface area of the catalysts was determined by the BET surface areas from N₂ adsorption-desorption isotherm (Autosorb I / Quantachrome instruments, USA at -196°C). Morphological investigation of the catalysts was done using transmission electron microscope (Technai-12, FEI). The XPS spectra of the catalysts were measured on a XPS spec-
Table 1. The physico-chemical properties of various supported nano Au catalysts.

<table>
<thead>
<tr>
<th>Au (wt%)</th>
<th>CO_{irr} (μmol/g)</th>
<th>Au Dispersion (%)</th>
<th>d_{Au} (nm)</th>
<th>d_{m} (nm)</th>
<th>d_{a} (nm)</th>
<th>TOF x 10^{-3} (h^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>18.82</td>
<td>37</td>
<td>0.98</td>
<td>98.59</td>
<td>3.15</td>
<td>5.41</td>
</tr>
<tr>
<td>2.0</td>
<td>23.34</td>
<td>23</td>
<td>1.22</td>
<td>61.13</td>
<td>5.08</td>
<td>5.46</td>
</tr>
<tr>
<td>3.0</td>
<td>28.45</td>
<td>19</td>
<td>1.53</td>
<td>51.41</td>
<td>6.04</td>
<td>7.19</td>
</tr>
<tr>
<td>4.0</td>
<td>29.28</td>
<td>14</td>
<td>1.54</td>
<td>38.34</td>
<td>8.10</td>
<td>9.28</td>
</tr>
</tbody>
</table>

*Au dispersion, *Metal area (catalyst), *Metal area (Au), *Metal area (Au) and *Au Particle size determined from CO_{irr} uptake values; *Au Crystallite size determined from XRD; *Au Particle size determined from TEM; *TOF (h^{-1}): TOF were calculated on the basis of CO uptake.

The vapor phase oxidation of PhCH_{2}OH was conducted at 320°C reaction temperature under atmospheric pressure in a fixed-bed vertical down-flow glass reactor (length = 520 mm, inner diameter = 12 mm) using 1.0 g catalyst. The top portion of the reactor was occupied with glass beads that act as a preheater for the reactant. The catalyst was activated at 250°C for 2 h prior to the oxidation reaction in the presence of N_{2} flow (50 mL/min). Then, the PhCH_{2}OH was introduced into the reactor via a syringe pump along with air in a stoichiometric quantity (WHSV = 2.84 h^{-1}). The reaction products were collected at the bottom of the reactor in an ice-cold trap for every 1 h, which were analysed by means of gas chromatography (GC) equipped with a HP-5 capillary column having flame-ionization detector (FID). The products were further confirmed through HP-5973 quadruple GC-MSD system with an HP-1MS capillary column using helium as a carrier gas. The gaseous products were introduced to a 1 cm³ gas sampler and analyzed by a GC-2014 (Shimadzu, Japan) equipped with thermal conductivity detector (TCD) and Carboxen 1000 column with helium as a carrier gas.

### 3. RESULTS AND DISCUSSION

#### 3.1. X-Ray Diffraction (XRD) Analysis

The XRD patterns of Au/γ-Al_{2}O_{3} catalysts with varying Au wt.% are shown in Fig. (1), where it can be seen that the spectra for γ-Al_{2}O_{3} exhibit three reflections at 2θ ~ 37.2°, 45.6°, and 66.9° which is in agreement with database standard (JCPDS No: 10-0425) [42, 43].

A varying Au loading has been employed over γ-Al_{2}O_{3} support material after their structural investigation. The presence of Au content and its structural features over γ-Al_{2}O_{3} was successfully confirmed by XRD. The XRD patterns of Au/γ-Al_{2}O_{3} are shown in Fig. (1). Au has been also found to be present in the face centered cubic lattice over γ-Al_{2}O_{3} support as evidence by the four characteristic peaks located at the 20 values of 38.2°, 44.5°, 46.6°, and 77.6° which are indexed to (1 1 1), (2 0 0), (2 2 0), and (3 1 1) reflection planes, respectively, of metallic Au (JCPDS 01-1172) [44-46]. Here, all catalysts having lower content of Au does now show XRD reflections at 38.2° and 44.3° due to smaller size of Au nanoparticles (2-5 nm). The XRD patterns showed no characteristic peaks of mixed phase produced by interaction between Au and supports, which confirms the formation of Au⁶ phase. Moreover, sharp and intense XRD peaks further confirm the excellent crystallinity of metallic Au nanoparticles. The crystallite sizes for all the Au catalysts were calculated, which are reported in Table 1.

![Powder XRD patterns of bare γ-Al_{2}O_{3} and γ-Al_{2}O_{3} supported nano Au catalysts.](image)

### 3.2. CO-Chemisorption Analysis

The parameters including dispersion, metal area, and particle size of Au, evaluated from CO-chemisorption analysis of γ-Al_{2}O_{3} supported Au catalysts are reported in Table 1. A significant increase in particle size of Au nanoparticles due to increase in CO uptake and in metal loading can be observed. The higher metal loading causes the agglomeration of Au nanoparticles, which results to significantly decrease metal dispersion and increase in Au particle size. This affects the catalytic activity of Au catalysts in terms TOF (Table 1). On the other hand, the better dispersion of Au (for 2wt% loading) towards lower loadings might be due to strong interaction of Au with the support materials [3].

It is likely that as Au content increases the deposition may be more on the external surface of the supports. This will reduce the distance between metallic species, thereby...
promoting sintering (agglomeration) leading to the decrease of dispersion. These are in good agreement with the results of XRD and TEM.

Table 2. Textural properties of bare γ-Al$_2$O$_3$ and γ-Al$_2$O$_3$ supported nano Au catalysts.

<table>
<thead>
<tr>
<th>Au/γ-Al$_2$O$_3$ Catalysts</th>
<th>Au (wt %)</th>
<th>Au Content (wt %)*</th>
<th>$S_{BET}$ (m$^2$/g)</th>
<th>$V_t$ (cc/g)</th>
<th>$D_{BJH}$ (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>0.00</td>
<td>192</td>
<td>0.68</td>
<td>6.46</td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td>0.82</td>
<td>188</td>
<td>0.66</td>
<td>5.81</td>
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<tr>
<td>2.0</td>
<td>1.76</td>
<td>173</td>
<td>0.62</td>
<td>5.69</td>
<td></td>
</tr>
<tr>
<td>3.0</td>
<td>2.58</td>
<td>162</td>
<td>0.59</td>
<td>5.61</td>
<td></td>
</tr>
<tr>
<td>4.0</td>
<td>3.54</td>
<td>154</td>
<td>0.51</td>
<td>4.52</td>
<td></td>
</tr>
</tbody>
</table>

*Au content measured by ICP-OES; $S_{BET}$: BET surface area; $V_t$: total pore volume; $D_{BJH}$: average pore diameter calculated by BJH method.

3.3. Transmission Electron Microscopy (TEM)

TEM analysis was used to investigate the size of Au nanoparticles over the catalytic supports. The highly dispersed spherical shaped Au nanoparticles over the catalytic support can be observed in Fig. (2a). Further, the Au nanoparticles have a mean diameter of ~5-10 nm (histogram of Fig. (2a); whereas, the crystallite size of these particles are to be ~4-11 nm (XRD patterns) (Table 1). Here, the average particle size of Au is bigger than the average pore diameter of catalytic support. The homogeneous distribution of the Au particles over the support indicates the formation of strong interactions between the Au and the supports [47]. The TEM investigations were found to be in good agreement with XRD and CO-chemisorption studies.

3.4. Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES) Analysis

The results of ICP-OES analysis of the catalysts are given in Table 2, which indicate about ~ 80-85% of the expected Au loading.

3.5. BET Surface Area and Pore Size Distribution (PSD) Measurements

The N$_2$ adsorption/desorption is a very usual process to investigate the physical properties such as surface area, the average pore diameter and pore volume of porous materials. Table 2 details the BET surface areas of pure γ-Al$_2$O$_3$ and γ-Al$_2$O$_3$ supported Au nanoparticles. Here, the BET surface areas were found to be decrease with increase in Au content. This might be due to blocking of pores of the supports by crystallites of Au particles as evidenced from pore size distribution measurements. Pore size distribution measurements of bare γ-Al$_2$O$_3$ and Au/γ-Al$_2$O$_3$ catalysts have been carried out using N$_2$ adsorption-desorption method. Fig. (3) shows the N$_2$ adsorption/desorption isotherms & Barrett Joyner Halenda (BJH) pore size distribution of bare γ-Al$_2$O$_3$ and Au/γ-Al$_2$O$_3$ catalysts, respectively. The details of average pore diameter, total pore area, and total pore volume of bare γ-Al$_2$O$_3$ and Au/γ-Al$_2$O$_3$ catalysts are reported in Table 2.
The total pore area, pore volume and average pore diameter of the catalysts were found to be decreased with the increase of Au loading. This might be due to the same reason as discussed above.

![Fig. (3). (a) N2 adsorption-desorption isotherms and (b) BJH pore size distribution of bare γ-Al2O3 and γ-Al2O3 supported nano Au catalysts.](image)

**3.6. X-Ray Photoelectron Spectroscopy (XPS)**

XPS analysis has been used to investigate the oxidation states of Au element in as-synthesized Au/γ-Al2O3 catalysts. In Fig. (4), the high resolution XPS spectrum shows binding energy of Au⁰ 4f/2 at 84.25 and Au⁰ 4f/2 at 87.75 eV. The XPS analysis result suggested that the Au species present in the catalysts are in the metallic state [48] and their binding energy values correspond to the metallic Au particles [49, 50].

![Fig. (4). XPS spectrum of 2 wt% Au/γ-Al2O3 catalysts.](image)

**3.7. Catalytic Activity Studies (Vapor Phase Oxidation of PhCH₂OH)**

The vapor phase oxidation of PhCH₂OH to PhCHO was investigated over Au/γ-Al2O3 catalysts under air. Scheme 1 gives the feel of the proposed mechanism for the oxidation of PhCH₂OH over supported Au catalysts [49, 51, 52]. Only a few percent of PhCH₂OH were found to convert in the absence of as-synthesized catalysts. Moreover, bare support also showed a very poor catalytic activity towards PhCH₂OH conversion. Hence, the synergistic effect of Au nanoparticles over support materials facilitated as an excellent catalyst for efficient conversion of PhCH₂OH to PhCHO. Moreover, this work did in solvent-free, vapor phase, and continuous system conditions shows efficient conversion and selectivity of PhCH₂OH to PhCHO in comparison to liquid phase systems [53]. Further, the vapour system can deliver chloride-less good quality PhCHO for its application in flavouring and pharmaceutical industries without the requirement of separating the catalysts from reaction mixture, which is difficult in case liquid phase oxidation.

![Scheme 1. Reaction pathway for the catalytic oxidation of PhCH₂OH to PhCHO over supported nano Au catalysts.](image)

**3.8. Effect of Au Loading**

The effect of Au loading in Au/γ-Al2O3 catalyst towards PhCH₂OH conversion and selectivity for PhCHO has been investigated as shown in Fig. (5a). The reaction was carried out at 320°C under similar reaction conditions (WHSV = 2.84 h⁻¹). It can be seen that as Au loading increased from 1-4 wt%, initially the conversion and selectivity of PhCH₂OH and PhCHO, increased up to 2 wt%, respectively, which started decreasing on further increase in loading. The decrease in PhCH₂OH conversion at higher Au loading might be due to availability of less number of active metal sites of Au on the supports surface due to agglomeration of Au nanoparticles as evidenced from XRD and TEM results.
on PhCH\textsubscript{2}OH conversion, selectivity for PhCHO and (Fig. 5).

Turnover frequency (TOF) was investigated to understand the effect on catalysts activity with increase in Au loading towards PhCH\textsubscript{2}OH conversion, as shown in Fig. (5b). Catalysts with 2wt\% loading of Au/\gamma-Al\textsubscript{2}O\textsubscript{3} showed higher value of TOF, which was due to better dispersion of smaller sized Au nanoparticles over the supports which facilitates more active sites for the reaction to take place.

3.9. Effect of Reaction Temperature

The effect of reaction temperature on conversion of PhCH\textsubscript{2}OH was evaluated within the temperature range of 280-360°C (Fig. 6a). The results confirm that no oxidation reaction of PhCH\textsubscript{2}OH was observed below 280°C, whereas beyond 360°C, the product underwent severe thermal degradation along with agglomeration of Au particles. However, at 320°C of temperature and 2 wt\% of Au nanoparticles loading, Au/\gamma-Al\textsubscript{2}O\textsubscript{3} catalysts showed a maximum conversion of PhCH\textsubscript{2}OH i.e. 33%. It is the fact that higher reaction temperature favours complete oxidation of PhCH\textsubscript{2}OH to benzoic acid (PhCOOH), a minute amount of benzene, and toluene as a by-product [35, 54]. Hence, 320°C was chosen to be the optimum reaction temperature.

3.10. Time on Stream (TOS) Analysis

TOS analysis of catalysts was done to understand the stability of the catalysts during oxidation of PhCH\textsubscript{2}OH as shown in Fig. (6b). The conversion and the selectivity were checked at different reaction intervals. To estimate the life of the catalyst in the present study, TOS analysis was done at optimum reaction temperature of 320°C. The gas analysis confirms that CO and CO\textsubscript{2} were not detected under the reaction conditions. As illustrated in Fig. (6b), an optimum conversion of PhCH\textsubscript{2}OH was observed after a reaction time of 2 h for all catalysts. Further increase in the reaction time beyond 2 h, showed a significant decrease in PhCH\textsubscript{2}OH conversion, which became stable slowly upon further increase in reaction time. Hence, the supported Au catalysts required 2 h of contact time to reach its optimal catalytic activity. The 2 wt\% of Au/\gamma-Al\textsubscript{2}O\textsubscript{3} catalysts after 2 h of reaction time showed the maximum conversion of 33%. The contact time signifies that Au nanoparticles on the support surface were required to be activated at the initial stage, so that sufficient oxygen molecules can absorb Au. Fig. (2b) shows the TEM analysis of fresh and spent catalysts (2 wt\% of Au/\gamma-Al\textsubscript{2}O\textsubscript{3}), which offer easy understanding of the catalyst deactivation. The TEM analysis of spent catalysts showed slightly larger Au particles compared to the size of Au particles in fresh catalysts. This could be due course of the reaction causing
deactivation or due to carbon deposition over the Au/γ-Al2O3 catalysts. Hence, in order to ensure the reason, an experiment was carried out on the spent catalyst which had undergone a reaction at 360°C and followed by re-calcination at 400°C for 4 h in air. This catalyst was now subjected to the oxidation reaction at 320°C under similar reaction conditions (WHSV = 2.84 h⁻¹). Interestingly, the catalytic activity of spent catalyst was found much lower than the reaction carried out on the fresh catalyst under the same conditions. This confirms that poor catalytic activity of spend catalysts is not due to coke formation but it might be due to agglomeration of smaller Au nanoparticles to larger size Au nanoparticles. The vapor phase conversion of PhCH₂OH results suggest that 2 wt% of Au loading, 2 hr reaction time, and 320°C of reaction temperature are advantageous for efficient conversion of PhCH₂OH has been observed to be 2 wt% Au loading, 2 hr reaction time, and 320°C of reaction temperature for the vapor phase conversion of PhCH₂OH. The vapor phase conversion of PhCH₂OH results suggest that Au nanoparticles are present in the metallic state. The deposition of Au nanoparticles. XPS results reveal that the Au dispersion, metal area, and the oxidation activity of Au/γ-Al2O3 act as highly efficient and suitable catalytic system this particular conversion.

CONCLUSION

Au/γ-Al2O3 catalyst prepared by HDP method exhibits a high catalytic activity as well as stability for the vapor phase conversion of PhCH₂OH to PhCHO. The optimum condition for efficient conversion of PhCH₂OH has been observed to be 2 wt% Au loading, 2 hr reaction time, 320°C of reaction temperature for all cases. The conversion of PhCH₂OH beyond 2 wt% of Au loading decreased, which might be due to reduction in the number of active sites caused by agglomeration of Au nanoparticles that significantly affects the catalytic activity. XRD and pore size distribution confirmed that the pore structure of support materials remains intact even after the deposition of Au nanoparticles. XPS results reveal that the Au nanoparticles are present in the metallic state. The studies on CO-chemisorption and PhCH₂OH activity infer that the Au dispersion, metal area, and the oxidation activity of PhCH₂OH are related to one another.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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REFERENCES


Wang, F.; Ueda, W.; Xu, J. Detection and measurement of surface electron transfer on reduced molybdenum oxides (MoOx) and catalytic activities of Au/MoOx. Angew. Chem. Int. Ed., 2012, 51, 3883-3887.


