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Catalytic Conversion of Isopropyl Alcohol over CuO/MgO Treated with K₂O

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Abstract

CuO/MgO system having different extent of CuO varying between 0.025 to 0.3 mol/mol MgO were prepared by impregnation method followed by calcination at 400-800 °C. The effect of CuO content, calcination temperature and doping with small amounts of K₂O (1-3 mol %) on physicochemical surface and catalytic properties of the system have been investigated using XRD, adsorption of N₂ at -196°C, and catalytic conversion of isopropyl alcohol at 150-400 °C using a flow technique. The results revealed that the solids having formula 0.2 and 0.3 CuO/MgO calcined at 400 consisted of MgO and CuO as major phases together with Cu₂O as minor phase. The degree of crystallinity and crystallite size increase by increasing the calcination temperature within 400-800 °C. The BET-surface areas of different adsorbents decreased progressively as a function of CuO loading and calcination temperature. Furthermore, K₂O-doping decreased the degree of crystallinity of CuO phase present with subsequent increase in the crystallite size of MgO from 23 to 37.5 nm in case of solid having the formula 0.2 CuO / MgO calcined at 400 °C. MgO-support material showed very small catalytic activity in isopropyl alcohol conversion. The investigated system behaved as selective catalyst for dehydrogenation of isopropyl alcohol with selectivity > 80%. The catalytic activity increases progressively as a function of extent of loading and decreases by increasing calcination temperature above 400 °C. K₂O- doping much increases the catalytic activity.

Keywords: CuO/MgO, K₂O-doping, catalytic conversion of isopropanol

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1. Introduction

One of the many catalytic material types is metal oxide, which is used in its pure form or supported on another oxide for many commercially important catalytic reactions [1,2]. To improve the catalytic activity and selectivity of metal oxides employed in some important industrial reactions the following parameters (suitable support, exposure to radiation and doping with certain foreign cations) must be considered [3,4]. The loading on a suitable support-material results in an increase in the dispersity of catalytically active constituents [5] and increase their thermal stability via hindering their grain growth [6]. The catalytic activity of most of transition metal oxides can be greatly improved by supporting on a suitable carrier such as γ -alumina, magnesia.

Magnesia is a ceramic oxide is widely used as support material for metal catalysts and high temperature superconductors [1]. The activity and selectivity of metal oxides supported on magnesia could be changed by treatment with foreign ions and by subjecting to ionizing radiations. These treatments modify the concentration and the nature of the active sites of the treated solids.

The doping of alkali metal with larger cationic radius than that of Mg^{2+} such as Li, Na, K, Cs imparted high catalytic activity to MgO in the acrylonitrile synthesis from methanol [7]. Addition of increasing amounts of potassium up to 1.8 wt.%) to a $Cr_2O_3/\gamma-Al_2O_3$ dehydrogenation catalyst can modify the surface chemistry and then the catalytic behavior[8]. Alcohol conversion was studied using various solids such as copper oxide [9], and copper – thorium oxide [10]. The simultaneous presence of Cu^{2+} , Cu^{1+} and/or Cu^0 in the thoria with a ratio of $(Cu^0 + Cu^+) / Cu^{2+}$ is required for activity toward isopropyl alcohol dehydrogenation [10]. The conversion of isopropyl alcohol over solids containing magnesia catalyst has been investigated using a pulse microcatalytic reactor [11] and flow system [12]. The activity depends on the reaction temperature, textural properties, the nature and the concentration of the dopant used [11].

The present work was devoted to study the effect of extent of CuO loading, calcination temperature, and doping with K_2O on the surface and catalytic (activity and selectivity) properties of the investigated catalysts towards isopropyl alcohol. The techniques employed were XRD, S_{BET} measurements and catalytic conversion of isopropyl alcohol using the flow method.

2. Experimental

2.1. Materials

Five specimens of CuO / MgO were prepared by wet impregnation method. A known mass of MgCO₃ was impregnated with solutions containing different proportions of copper nitrate dissolved in the least amounts of distilled water. The nominal compositions of the calcined impregnated solids were 0.025, 0.05, 0.10, 0.20 and 0.30 CuO / MgO which contained 4.7, 9.16, 16.4, 28.3 and 37.1 wt % CuO. The obtained solids were dried at 110 °C then calcined at 400- 900°C for 4h.

The solids having the formula 0.2 CuO/MgO was doped with 1, 2, 3 mol% K₂O. The doped samples were prepared by treating a known mass of MgCO₃ support material with different amounts of KNO₃ dissolved in the least amounts of distilled water dried at 110 °C till constant weight. The K₂O-treated samples will then impregnated with known amounts of Cu(NO₃)₂.6H₂O dissolved in the least amounts of distilled water sufficient to make paste, dried at 110 °C then calcined in air at 400 °C for 4h. The nominal compositions of the doped samples were 0, 1, 2 and 3 mol% K₂O/0.2CuO/MgO which contained 0, 1.65, 3.24 and 4.8 wt % K₂O. All the chemicals employed were of analytical grade supplied by BDH Ltd.

2.2. Techniques

Phase analysis of the pure and variously treated specimens preheated in air at 400 and 800 °C were performed by X-ray powder diffraction employing a BRUKER Axs D8 Advance, Germany. Patterns were run using Ni-filtered copper radiation ($\lambda = 1.5404 \text{ \AA}$) at 40 kV and 40 mA.

The specific surface areas of the pure and variously doped catalyst samples were determined from nitrogen adsorption isotherms measured at -196 °C using a quantachrome NOVA2000 automated gas sorption apparatus model 7.11. All samples were degassed at 200 °C for 2 hours under a reduced pressure of 10⁻⁵ Torr before undertaking such measurements.

The catalytic activities of the various solid catalyst samples were determined by using isopropyl alcohol conversion reaction at 150- 400 °C, the catalytic reaction being conducted in a flow reactor under atmospheric pressure. Thus, a 50 mg catalyst sample was held between two glass wool plugs in a Pyrex glass reactor tube 20 cm long and 1 cm internal diameter packed with quartz fragments 2-3 mm length. The temperature of the catalyst bed was regulated and controlled to within ± 1 °C. Argon gas was used as the diluents and the isopropyl alcohol vapor was introduced into the reactor through an evaporator/saturator containing the

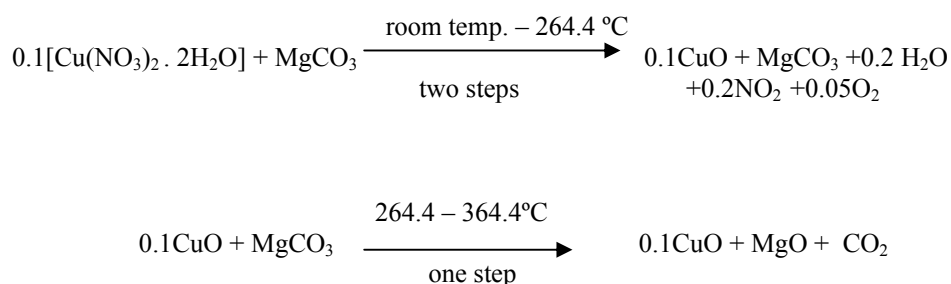
liquid reactant at constant temperature 35°C. The flow rate of the carrier gas was maintained at 25 ml/min. Before carrying out such catalytic activity measurements, each catalyst sample was activated by heating at 350 °C in a current of argon for 2 hours then cooled to the catalytic reaction temperature. The reaction products in the gaseous phase were analyzed chromatographically using Perkin-Elmer Auto System XL Gas Chromatograph fitted with a flame ionization detector. The column used was fused silica glass capillary column type PE-CW length 15 m-1.0 UM Perkin-Elmer corp.

3. Results and Discussion

3.1. Thermal analysis of different investigated solids

3.1.1. TGA of uncalcined CuO/MgO system

Figure (1) shows TGA curve of uncalcined 0.1CuO/MgO solid. It is clear from this figure that the thermal decomposition of the investigated mixed solid sample takes place via three successive weight loss processes as follows:



3.1.2. DTA of uncalcined CuO/MgO system

The DTA curve of uncalcined 0.1CuO/MgO solid was determined as shown in Figure (2). This figure consists of three sharp endothermic peaks, their maxima located at 59°C, 254°C, and 354°C together with an endothermic broad shoulder at about 200°C. These peaks characterize the removal of water of crystallization of hydrated copper nitrate, the thermal decomposition of anhydrous copper nitrate yielding copper oxide and the thermal decomposition of magnesium carbonate yielding magnesium oxide, respectively.

3.2. XRD investigation of different investigated solids

3.2.1. CuO/MgO system

X-Ray powdered diffractograms of 0.1, 0.2, and 0.3 CuO/MgO precalcined at 400°C were determined and illustrated in Figure (3). It is seen from this figure that, the diffractograms of solid samples calcined at 400°C consist of a crystalline MgO phase together with CuO phase whose degree of crystallinity increases by increasing the extent of CuO loading. The crystallite size of CuO phase present in different investigated samples calcined at 400°C measured 27, 32, 37nm for the supported solids having the compositions 0.1, 0.2, and 0.3 CuO per mol MgO, respectively. The crystallite size of MgO present in these supported solids was found to measure about 45 nm in various solids investigated. The fact that the crystallite size of CuO phase lies in the nano crystalline range might indicate the role of MgO support material in increasing the degree of dispersion of CuO phase. Preliminary experiments showed that the crystallite size of un-loaded CuO phase prepared by thermal decomposition of copper nitrate at 400°C measured about 150nm. These results justify the use of MgO as a support material for CuO in order to have finely divided nano crystalline CuO catalyst.

The fact that MgO and Cu₂O show common diffraction lines at $d = 2.43, 2.11$ and 1.48 \AA makes their distinction a difficult task. However, the brown coloration of the solids having the formulae 0.2 CuO / MgO and 0.3 CuO / MgO and being precalcined at 400°C, might suggest the possible formation of Cu₂O phase together with CuO and MgO [13].

XPS is a decisive tool to be used for detecting copper with various oxidation states. However, using the brown coloration as the first evidence, which supports our speculation for presence copper with different oxidation states (Cu⁺¹ and Cu⁺²). The additional evidence comes from the significant increase in the relative intensity of the diffraction peak at $d = 2.43 \text{ \AA}$ which corresponds to 10% in case of MgO increased to 30% in case of (0.2 CuO / MgO) solid calcined at 400°C due to a possible superposition with the main line of Cu₂O found at the same d -value [13]. The presence of zero-, mono- and divalent copper ions in CuO lattice especially when it is loaded on MgO support material have been reported [13]. So, the possible presence of Cu₂O in our case is confirmed from both works done previously and the brown coloration acquired by 0.2 and 0.3 CuO / MgO solid calcined at 400°C.

3.2.2. XRD of CuO/MgO solids precalcined at various temperatures

X-Ray powdered diffractogram of 0.1 CuO/MgO calcined at 400 and 800°C and illustrated in figure (4). This figure shows that the increase in the calcination temperature from 400 to 800°C increases the degree of crystallinity of both CuO and MgO phases as being evidenced from the effective increase in the peak area of their main diffraction lines

,from 20.5 to 44.6 a.u. of CuO and from 164 to 262 a.u. relative to MgO phase . The crystallite size of CuO increases from 24.5 to 83 nm while the increase of crystallite size was so limited in case of MgO from 46 to 49.4 nm.

3.2.3. XRD investigation of the pure and K₂O-doped 0.2 CuO / MgO solid

Figure (5) shows the diffractograms of pure and variously K₂O-doped 0.2 CuO / MgO solid samples calcined at 400°C. It is seen from figure (5) that the phases present in pure and doped solids consist of CuO, Cu₂O, MgO phases together K₃CuO₂ and K₂O in the heavily doped -K₂O samples. The treatment with 3 mol % K₂O decreased the degree of ordering of CuO phase which was evidenced from the decrease in peak area from 15.6 to 5.7 (a.u.) and the effect on degree of ordering of Cu₂O is negligible. The crystallite size of MgO increased from 23 to 37.5 nm due to treatment of 0.2 CuO/MgO solid calcined at 400 °C with 3 mol% K₂O.

3.3. Specific surface areas of different investigated solids

The SBET of CuO/MgO system having an extent of loading 0.1 and 0.2 mol CuO per mol catalyst calcined at 400°C and 800°C were determined from N₂ adsorption measurements carried out at -196. The BET-surface area of 0.2 CuO/ MgO doped with 1 and 3 mol% K₂O and being calcined at 400°C have been also determined. The results obtained are given in Table (1). It is seen from this table that the increase in CuO content from 0.1 and 0.2 mol CuO per mol catalyst calcined at 400° includes the S_{BET} values of pure and doped 0.2 CuO/MgO solid calcined at 400°C resulted in a limited decrease in its S_{BET} (7%). It can also be seen from this table that K₂O doping of 0.2 CuO/MgO solid calcined at 400°C treatment decreased the specific surface area, this decrease attained 16.5% in presence of 3 mol % K₂O.

3.4. Catalytic activity measurements of different investigated solids

3.4.1. Effect of extent of CuO loading on the activity CuO/MgO system towards isopropyl alcohol conversion

The catalytic conversion of isopropyl alcohol was carried out over 0.025, 0.05, 0.1, 0.2 and 0.3 CuO/MgO solids calcined at various calcination temperatures. The catalytic reaction was also carried over MgO support material calcined at 400°C. The reaction was also carried out over unloaded CuO obtained from the thermal decomposition of copper nitrate in air at

400°C. Figure (6) shows the effect of extent of CuO loading on the total conversion as a function of reaction temperature. It is noticed from figure (6) that: (i) MgO and un-supported CuO exhibited small catalytic activities and the activity of CuO was, however, greater than that of MgO. This finding clarifies the necessity of using a support for increasing the catalytic activity of copper oxide. (ii) increasing the extent of CuO loading resulted in an increase in the total conversion of isopropyl alcohol till certain amount of CuO (28.3 wt%) above which a limited decrease in the total conversion was found. (iii) There is a linear increase in total conversion with increasing reaction temperature from 150 to 400°C in case of CuO or MgO separately, while in CuO/MgO system, there is an increase in total conversion with increasing the CuO content linearly till 200°C then a broad maximum was formed till 275°C after that the total conversion decreases. In the range of 275 to 400°C, there is an abrupt decrease in total conversion falling to 70%.

It is well known that, the increase in the reaction temperature is followed up by an increase in reaction rate, the observed decrease in total conversion found at high reaction temperatures could not be attributed to sintering process but due to a possible formation of carbon deposits on the catalyst's surface blocking some active centers reducing thus the catalytic activity [13]. The possible formation of carbon deposits on the catalyst's surface can find experimental evidence. In fact, the color of CuO/ MgO participated in the catalytic reaction turned from brown to black. This black color can be attributed to accumulation of carbon deposits on the catalyst surface after being used in the catalytic reaction. The carbon deposits formation takes place on solids devoted with high catalytic activity [13]. So, the absence of a maximum in activity curves of unloaded CuO and MgO expressed the small catalytic activity of these solids. A conclusion that has been evidenced experimentally.

It has been shown in XRD-section in this work that increasing CuO-content loaded on MgO affected on formation nano crystallites CuO oxide phase (27-37nm). These finely divided particles may be responsible for the high conversion for isopropyl alcohol. Also, presence of copper oxide with different oxidation states may play another role for increasing the conversion of isopropyl alcohol.

3.4.2. Effect of extent of CuO loading in the products' selectivity as a function of reaction time-on-stream (decay in catalyst activity with time)

Table (2) includes the effect of extent of CuO loading on total conversion (T.C.%), products' selectivity : acetone ($S_a\%$), propene ($S_p\%$) and methyl isobutyl ketone MIBK($S_m\%$)

as a function of time-on-stream. This table shows that: (i) the selectivity of the solids as function of reaction time-on-stream suffered a limited decrease toward various products, which means that these solids have high stable catalytic selectivity through 3 hours. (ii) Increasing the amount of CuO to 28.3 wt% resists the decay in total conversion of isopropyl alcohol as function of reaction time more than the other concentrations. (iii) the catalyst having the composition 0.2 CuO/MgO (CuO is 28.3 wt%)calcined at 400°C is the most selective one to acetone and resists the decrease in $S_a\%$ with reaction time –on-stream through 3 hours. (iv)The amount of propene is negligible and there is no change in $S_p\%$ with reaction time-on-stream, while there is a so limited increase in $S_m\%$ in all cases with increasing the reaction time-on-stream through 3hours. The % of decrease in the total conversion of isopropyl alcohol was found to be 30, 27, 25, 15 and 16 % due to using catalysts samples for 3 hours containing 0.025, 0.05, 0.1, 0.2 and 0.3mol CuO per mol MgO, respectively. So, the increase in CuO content in CuO/MgO system not only increases its catalytic activity but also increase its catalytic durability.

In fact, the main function of support is to increase the degree of dispersion of catalytic active constituents, thus increasing the concentration of active constituents involved in the catalyzed reaction. However, each support material exhibits a limited capacity for dispersing the active phase, so the relationship between the catalytic activity as a function of metal oxide loading exhibits an increase of this activity reaching to a maximum limit then remains unaffected or decreases slightly upon increasing of the extent of loading above this limit [14, 15]. In our study, the catalytic activity (measured as total conversion) increases progressively with CuO content till 28.3 wt% and increasing CuO content from 28.3 wt % to 37.1 wt % resulted in a limited decrease in the catalytic activity, with other words, the catalytic activity remains unaffected. The fact that, the catalytic activity attained a maximum limit at percentage of loading 28.25 wt % CuO suggested a maximum limit for MgO support material to disperse CuO crystallites, above which some kind of grain growth or particle adhesion takes place leading to a limited decrease in the catalytic activity of heavily copper oxide loaded MgO.

3.4.3. Effect of calcination temperature on the catalytic activity and selectivity of CuO/MgO system

In order to investigate the effect of precalcination temperature on the catalytic activity of CuO/MgO system, two compositions were chosen and their catalytic activities were investigated as a function of calcination temperature as shown in Figure (7). Inspection of Figure (7) shows that (i) both of the activity and selectivity of the investigated solids suffers a

limited decrease indicating a catalytic stability. (ii) The increase in CuO content in the solid calcined at 400 not only increase the activity but increase the stability. (iii) The increase in the calcination temperature of 0.05CuO/MgO and 0.2CuO/MgO from 400 to 600 °C resulted in a limited decrease about 9%. a significant drop in the activity of this solids took place upon increase calcination temperature up to 900. In case of 0.2CuO/MgO solid the decrease in its activity due to increasing the calcination from 400 to 600°C reached 9 %, this decrease attained 39 % upon increasing the calcination up to 900°C.

The observed limited decrease in the catalytic activity of different solids due to increasing their calcination temperature above 400°C and below 900 °C could be attributed to an effective increase in the crystallite size of CuO phase (catalytically active constituent) as shown in XRD section. The reported drop in the catalytic activity due to calcination at 900 °C can be expressed as a sharp drop in concentration of active sites involved in the catalyzed reaction. In fact, MgO support material dissolved an important portion of CuO by heating at 900 °C yielding the solid solution having the formula $Cu_xMg_{1-x}O$ [16-18]. The copper oxide captured in MgO solvent lost completely its catalytic activity.

Table (3) shows the effect of calcination temperature of CuO/MgO system on products' selectivity for iso-propanol conversion. Examination of Table (3) shows the following: (i) All catalysts investigated calcined at 400-900° C are selective towards acetone formation (87 to 98%). So, these catalysts acted as dehydrogenation catalysts. (ii) The rise in precalcination temperature from 400 to 900°C brought a small increase in the selectivity towards acetone formation. (iii) The selectivity towards dehydrogenation process suffered a small decrease by increasing the reaction temperature of the catalyzed reaction carried out at 175-250°C. (iv) The selectivity towards MIBK formation increases progressively with increasing the reaction temperature for catalysts calcined at a given temperature. On the other hand, the amounts of MIBK produced at different reaction temperatures decrease by increasing the precalcination temperature of solids investigated

3.4.4. Effect of K₂O -treatment of CuO/MgO system on its activity and selectivity

The effect of K₂O-doping of 0.2CuO/MgO system calcined at 400°C on its activity and selectivity was investigated for the catalytic reaction carried out at 175 - 400°C. The results of this study are graphically illustrated in Figures (8,9). Examination of these figures shows that: (i) K₂O-doping increases the catalytic activity to an extent proportional to the amount of dopant added. (ii) The selectivity towards acetone formation increases progressively by

increasing the amount of K_2O . (iii) The selectivity towards propene and MIBK formation decreases by increasing the amount of K_2O .

The catalytic activity and selectivity of the investigated solids depend on (i) the composition of the catalyst, (ii) calcination temperature and (iii) reaction temperature, as shown in our study. The dehydrogenation of iso-propanol to acetone and the aldol condensation to MIBK both take place on (Lewis-acid – strong base pair) [19].

3.4.5 . Effect of reuse of pure and K_2O -doped 0.2 CuO/MgO solids on their activity

The decrease in the catalytic activity of 0.2CuO/MgO calcined at 400°C because of its reuse three times was investigated. The reaction was monitored at 300 °C until equilibrium was attained and the investigated solid catalyst was reused three times under the same conditions. The reuse of catalyst three times resulted in a small decrease in its activity. This finding might expect a reasonable lifetime of the pure catalyst investigated. The same effect has been studied for K_2O -doped solids. The doping process has been found to increase the resistance of catalytic activity to decrease as a function of time its reuse. In other words, K_2O -treatment increases the lifetime of the investigated catalysts. In fact, the observed decrease in catalytic activity of pure sample due to using it 3 hours working at 300°C attained 10%. The first and second reuse of pure sample decreases its activity to about 10 and 17%, respectively. These values attained 3.8 and 4.7% in case of samples doped with 3 mol % K_2O . These results support the role of K_2O -doping for enhancing the catalyst stability and durability through several times of reusing.

4. Conclusions

The following are the main conclusions that may drawn from the obtained results:

- (1) MgO acted as a convenient support for copper oxide catalyst calcined at 400 - 800°C. The possible formation of Cu^{1+} besides Cu^{2+} in the solids calcined at 400°C was confirmed.
- (2) Doping CuO/MgO system with 3 mol % K_2O calcined at 400°C decreases the degree of ordering of CuO phase while increases the degree of ordering of MgO phase.
- (3) The S_{BET} of CuO/MgO system decreases by K_2O -doping. The decrease attained 16.5 % due to treatment with 3 mol % K_2O for the solids calcined at 400 °C.
- (4) The catalytic activities have been determined by following up the conversion of isopropyl alcohol under certain conditions. This catalytic reaction yielded mainly acetone(major product) via dehydrogenation mechanism besides propene via dehydration mechanism and

methyl iso-butyl ketone via aldol condensation. The product selectivity depends on the composition of the investigated solid, calcination temperature, and reaction temperature.

(5) The catalytic activity of CuO/MgO system calcined at 400 °C increases with increasing extent for CuO loading till 28.3 wt % then remained almost constant. This treatment increases not only its catalytic activity but also the catalytic stability and durability of system investigated.

(6) The catalytic activity and durability of CuO/MgO solid calcined at 400 °C increases with increasing the amount of K₂O added. The doping process increases also the selectivity towards dehydrogenation process.

5. References

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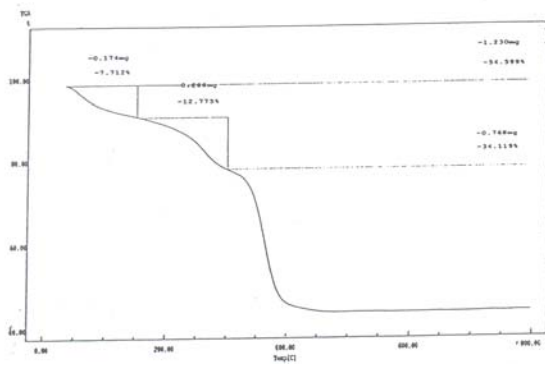


Figure (1): TGA curve of $0.1[\text{Cu}(\text{NO}_3)_2 \cdot 2\text{H}_2\text{O}] / \text{MgCO}_3$ solid.

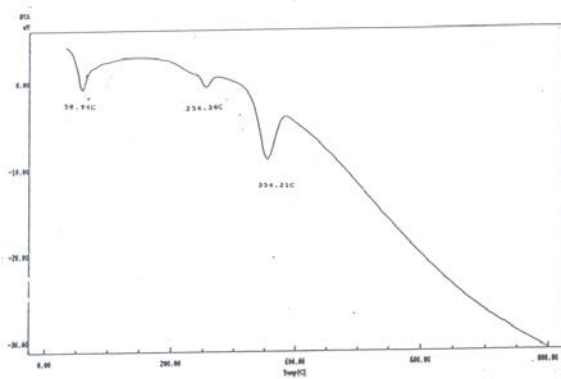


Figure (2): DTA curve of $0.1[\text{Cu}(\text{NO}_3)_2 \cdot 2\text{H}_2\text{O}] / \text{MgCO}_3$ solid.

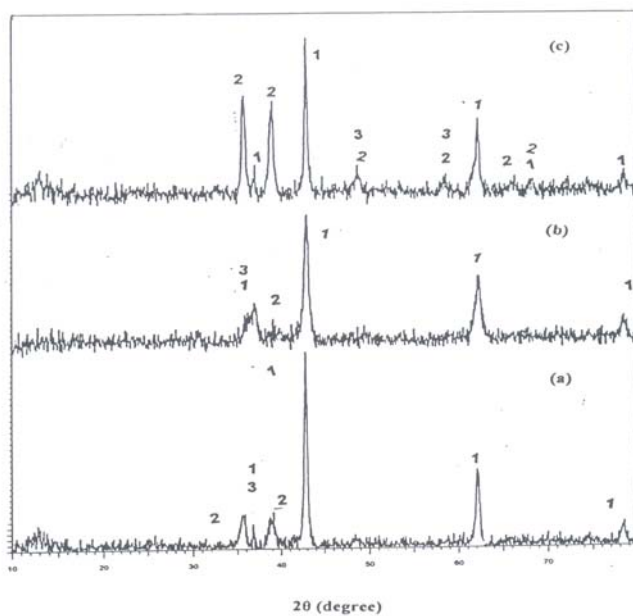


Figure (3): XRD diffractograms of: (a) 0.1 CuO/MgO, (b) 0.2 CuO/MgO and (c) 0.3 CuO/MgO solids precalcined at 400 °C. Lines (1) refer to MgO, lines (2) refer to CuO, and lines (3) refer to Cu_2O .

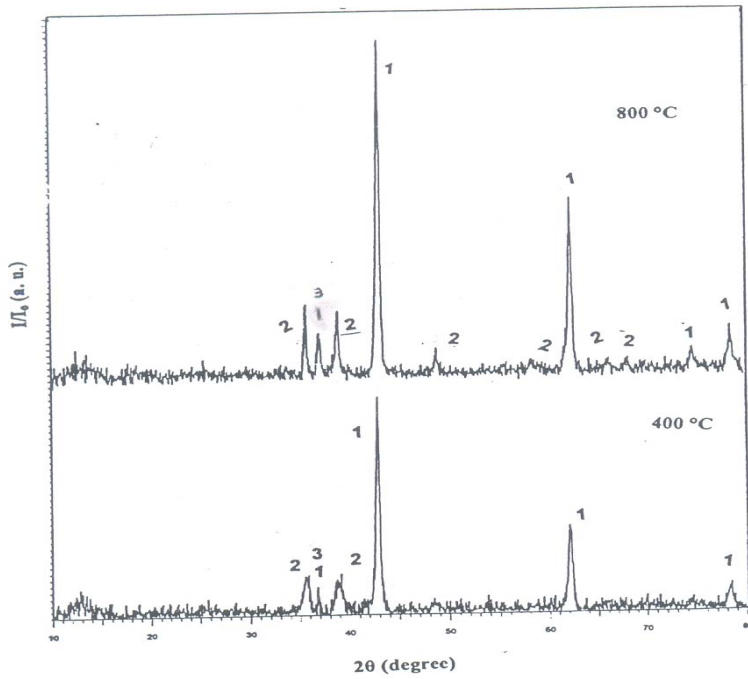


Figure (4): XRD diffractograms of 0.1CuO/MgO solid precalcined at 400 and 800°C. Lines (1) refer to MgO, lines (2) refer to CuO, and lines (3) refer to Cu₂O.

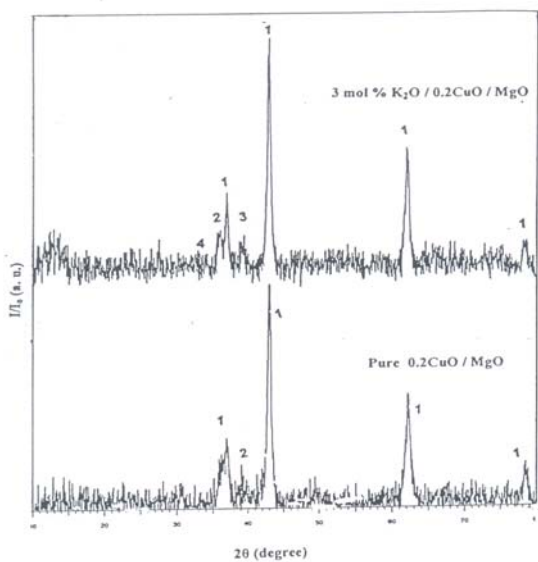


Figure (5): XRD diffractograms of pure and K₂O- treated 0.2CuO/MgO, solids precalcined at 400 °C. Lines (1) refer to MgO, lines (2) refer to CuO, lines (3) refer to K₂O and lines (4) refer to K₃CuO₂.

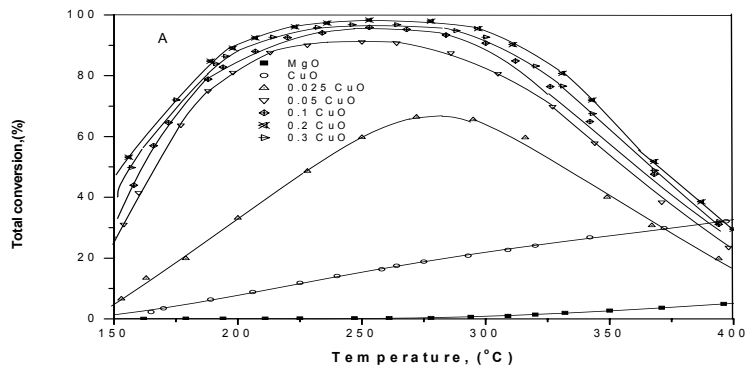


Figure (6): Total conversion of iso-propanol as a function of reaction temperature on CuO/MgO solid precalcined at 400°C using various molar ratios of CuO.

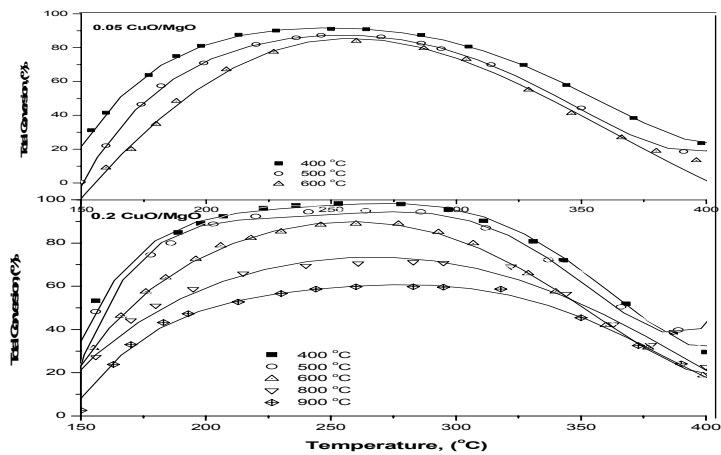


Figure (7): Total conversion of isopropyl alcohol over two different compositions of CuO/MgO system at various calcination temperatures.

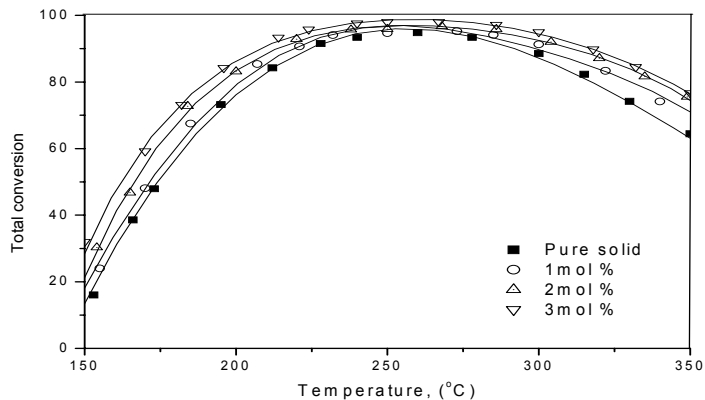


Figure (8): Total conversion of isopropyl alcohol as a function of temperature on pure and doped 0.2CuO / MgO calcined at 400°C by different amounts of K₂O.

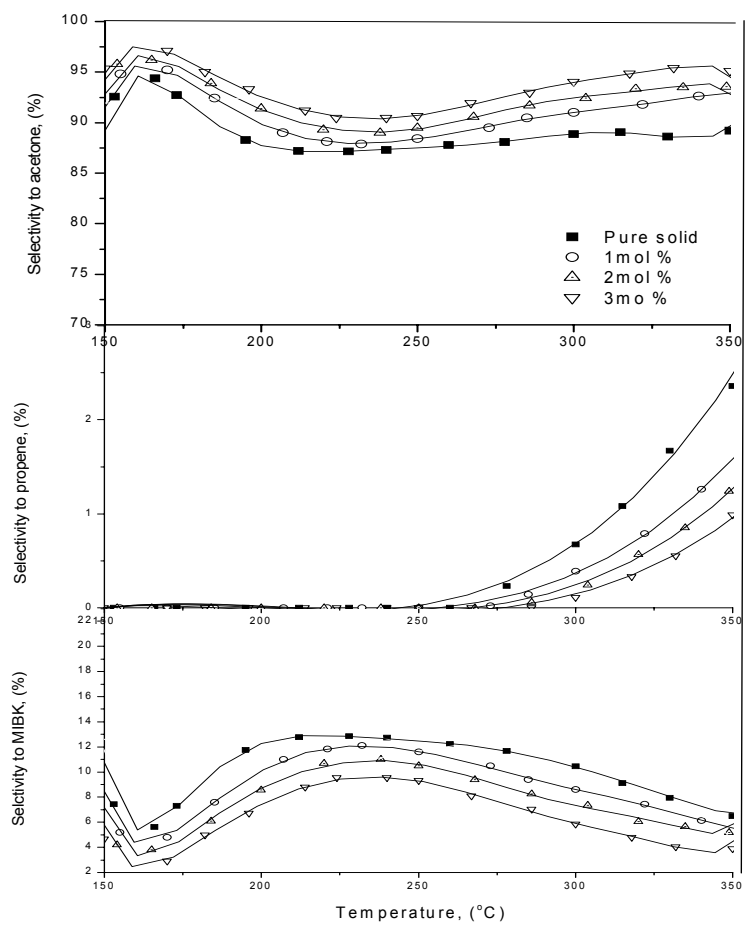


Figure (9): Effect of K₂O-doping on the selectivity of 0.2CuO/MgO solid calcined at 400°C towards acetone, propene and MIBK formation.

Table 1. The specific surface areas of different investigated adsorbents

Sample	Calcination temperature	S_{BET}, (m²/g)
0.1 CuO/MgO	400°C	58.3
0.1 CuO/MgO	800°C	30.0
0.2 CuO/MgO	400°C	54.0
1% K ₂ O /0.2 CuO/MgO	400°C	53.3
3% K ₂ O /0.2 CuO/MgO	400°C	45.1

Table 2. Total conversion of isopropyl alcohol over CuO/MgO calcined at 400 °C, the selectivity to various products at reaction temperature 300 °C, using various molar ratios as a function of reaction time-on-stream.

CuO/MgO (X mol/mol)	Time, min.	T.C.%	S_a%	S_p%	S_m%
0.025	30	82.66	97.73	0.78	1.50
0.050		85.77	98.11	0.52	1.36
0.100		89.20	98.42	0.40	1.18
0.200		95.80	98.94	0.17	0.89
0.300		91.78	98.70	0.26	1.04
0.025	60	75.75	97.47	0.82	1.7
0.050		78.81	97.89	0.60	1.52
0.100		83.07	98.21	0.46	1.33
0.200		92.58	98.68	0.20	1.12
0.300		87.61	98.50	0.29	1.21
0.025	120	65.99	97.08	0.96	1.95
0.050		69.50	97.61	0.73	1.66
0.100		73.48	97.98	0.56	1.46
0.200		86.09	98.56	0.23	1.21
0.300		81.87	98.32	0.34	1.33
0.025	180	58.22	96.57	1.30	2.13
0.050		62.93	97.22	0.96	1.82
0.100		66.62	97.74	0.71	1.56
0.200		81.19	98.45	0.23	1.32
0.300		76.86	98.16	0.40	1.43

T.C., total conversion

S_a, selectivity towards acetone (dehydrogenation).S_p, selectivity towards propene (dehydration).S_m, selectivity towards methyl iso-butyl ketone (MIBK).

Table 3. Total conversion and selectivity of (0.2CuO/MgO) calcined at different temperatures in isopropyl alcohol conversion carried out at 175-250 °C.

Reaction temperature	Activity and Selectivity	Calcination temperature				
		400°C	500°C	600°C	800°C	900°C
175°C	T.C (%)	75.80	74.00	57.50	47.00	38.89
	S _a (%)	97.70	94.75	95.01	95.74	97.70
	S _m (%)	2.31	5.25	4.99	4.26	2.31
200°C	T.C (%)	89.08	88.40	75.00	61.90	49.60
	S _a (%)	91.33	91.50	93.33	94.35	96.77
	S _m (%)	8.67	8.50	6.67	5.65	3.23
225°C	T.C.(%)	96.08	93.00	84.50	67.50	55.60
	S _a (%)	88.63	89.25	91.72	93.33	96.58
	S _m (%)	11.73	10.75	8.28	6.67	3.42
250°C	T.C (%)	98.30	94.50	88.80	70.00	59.10
	S _a (%)	87.19	87.83	89.86	92.86	95.43
	S _m (%)	12.81	12.17	10.14	7.00	4.25