Original Article

ISSN: 2349 - 4891
International
Journal of Recent Research and Applied Studies
(Multidisciplinary Open Access Refereed e-Journal)

Copper (II) complex as precursor for copper oxide synthesize acting as catalyst to study the catalytic decomposition of hydrogen peroxide

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Received 11th January 2021, Accepted 9th August 2021

Abstract

In this study, thecopper oxide was prepared via solid-state thermal decomposition technique using the copper complex as a precursor. The prepared copper oxide was used as a catalyst for catalytic decomposition of hydrogen peroxide in comparison to the copper complex.The catalytic activity of copper oxide in comparison with copper complex was investigated for the catalytic decomposition of hydrogen peroxide as a model reaction.The data reveal that both copper oxide, and copper complex are effective in catalyzing the hydrogen peroxide decomposition and the decomposition percentage increased with time. Moreover, the decomposition efficiency followed the order:copper oxide (62.00) >Cu(II) complex (45.00).The decomposition reaction is a first order reaction and the values of k ($t_{½}$) was found to be 0.030 min^{-1}(22.57min) and 0.014min^{-1}(49.50 min) for copperoxide, and Cu(II) complex, respectively.

Keywords:*Copper complex; copper oxide; hydrogen peroxide; decomposition efficiency, rate constant.*

Introduction

Hydrogen peroxide (H_2O_2) is an important chemical compound as an oxidizing agent and has a broad applications in various fields. It is used in many important applications such as in textile production, dye decomposition, pulp and paper bleaching, mining, food manufacturing, and laboratory practice. Importantly, it is used for wastewater treatment, and refereed as an environmentally-friendly oxidizing agent. In the presence of an appropriate catalyst, it is easy decompose to water and oxygen only. Moreover, Catalytic decomposition of H_2O_2 is studied duet oitsvast applicability in water treatment technologies. Various organic water and soil pollutant scanbe successfully oxidized and degraded by hydro genperoxide[1-3].

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On the other hand, catalysts are among the most important technologicalmaterials used in the manufacture of the fine chemicals,fuels, foods, and pharmaceuticals materials and are classified as homogeneous, heterogeneous or biological catalysts. The catalytic decomposition of H_2O_2 has beenperformed both in homogeneous and heterogeneoussystems [4,5].Homogeneous catalysts are characterize with high selectivity and activity but have severallimitations such as purification of the final products, recoveringand reusing of the catalyst. These limitations canbe overcome by using heterogeneous catalysts [6].

Catalysts based on metal ions and transition metal complexeshave been shown to be useful in the oxidation oforganic pollutants present in wastewater. Additionally, transition metal oxides have received an increasing attention due to their specialstructural features such as surface area, morphology, andinterior void. Among them, copper oxide has been extensivelystudied, due to their novel physicochemical properties andwide applications in many fields, such as heterogeneous catalysts,

electrochemical sensor, and lithium-ion battery, antimicrobialmaterials and adsorbents [7,8].
In this regard, we decide to synthesize copper complex and its corresponding copper oxide to be act as catalysts to hydrogen peroxide decomposition.

1. Experimental section

1.1. Chemicals used

All used materials were bought from Fluka, Prolabo and Sigma Aldrich Companies and are used without further purification.

1.2. Apparatus

Elemental analyses (Elemen. Analy. -Vario EL Fab. CHNS Nr.- 11042023) was used to determine the content of carbon, hydrogen, and nitrogen, Infrared spectra were recorded as KBr disc use a FTIR-IR prestige 21 covering the frequency range 400-4000 cm^{-1}. Perkin Elmer analyzer equipment's-Shimadzu was used for thermal study from 50 to 1000 ^{O}C under a nitrogen air flow of 50 mL min^{-1} and a heating rate of 10 ^{O}C min^{-1}. Melting point measurements were recorded using GALLENKAMP melting point apparatus.Molar conductance measurement ($1x10^{-3}$ M in DMF solvent) was measured at ambient temperature by JENWAY 3450 pH & Conductivity meter (JCM-3450).

1.3. Synthesis of cooper oxide nanoparticles

The copper oxide was prepared via solid-state thermal decomposition technique using the copper complex as a precursor. Typically, an appropriate weightof the prepared copper complex was ground and loaded into a previously clean dry weighted ceramic crucible. The crucible was placed inside a mufflefurnace previously set to a temperature of 700 ^{O}C, and calcinedunder an air atmosphere for three hs. Thereafter, the obtained black powderwas left to cool at room temperature, collected, and washed with ethanol followed by diethyl ether repeatedly to remove any impurities then, collected for analysis. Fig.1. shows the color of the obtained copper oxide [9-11].

1.4. Catalytic decomposition of hydrogen peroxide

The catalytic decomposition of hydrogen peroxide (H_2O_2) was study to evaluate the catalytic properties of the new synthesized compounds. The synthesized Cu(II) complex, and its corresponding oxidehave been used as a representative example to catalyze H_2O_2 decomposition. The experiment was carried out at ambient temperatureand atmospheric pressure for 60 min [12]. Briefly, a series of an Erlenmeyer flasks (100 mL) wrapped with aluminum foil and containing 0.01gof Cu(II) complex / copper oxide (catalysts) together with 50 mL of distilled water were stirred for 20 min to provide sufficient dispersion of the catalyst particles. For each flask, 1mL of 10 % H_2O_2 solution was added under constant agitation and record the time. H_2O_2 decomposition can be kinetically monitored by removing aliquots of the reacting mixture from each flask at different intervals of time (each 10 min), filter and titrate the undecomposed H_2O_2 with standard $KMnO_4$ solution (0.03 M)in presence of H_2SO_4(2N). The consumed volume of $KMnO_4$ solution for each interval of time was recorded during the course of the reaction. A blank experiment (without a catalyst) has been conducted and did not show any H_2O_2 decomposition under the applied reaction conditions. In addition, a characteristic change in the reaction mixture color take place during the course of the reactions accompanied with small bubbles of oxygen.

2. Results and discussion

It is well known that, the hydrogen peroxide (H_2O_2) decomposition is greatly enhanced by many catalysts such as metalions, metal oxides, metal complexes, and other [13-15]. In our study, H_2O_2 decomposition was catalyzed by Cu(II) complex, and copper oxide (catalysts). The reaction was monitor using a standard solution of potassium permanganate as explained in the experimental part.

It is clear that Cu(II) complex, and copper oxide were found to catalyze the H_2O_2 decomposition, and the extent of H_2O_2 decomposition increased with the time as clear from Table 1, and Fig. 1. Moreover, the decomposition efficiency for H_2O_2 decomposition followed the order: copper oxide (62.00) >Cu(II)complex (45.00)as clear from Table 1.

Furthermore, the assumption that the catalytic decomposition of H_2O_2 reaction is a first order reaction has been assumed to follow the reaction [16]. Fig. 2 depicts the plots of log (a-x) as a function of reaction time. The observed resulted linearity confirms that catalyzed reaction is a first order one, furthermore the slopes of the obtained plots allow ready determination of the reaction rate constant values of the different catalysts [17]. The previous results were summarized in Table 1.

Table 1: Effect of time and temperature on reaction rate of H_2O_2 decomposition.

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Compound	**Decomposition percentage (%) of H_2O_2 at different time intervals (min) Time (0-90 min)**							**K min^{-1}**	**$t_{½}$ min**
	0	10	20	30	40	50	60		
Cu(II) complex	0	10	17	25	38	42	45	0.014	49.50
Copper oxide	0	19	28	39	50	57	62	0.031	22.57

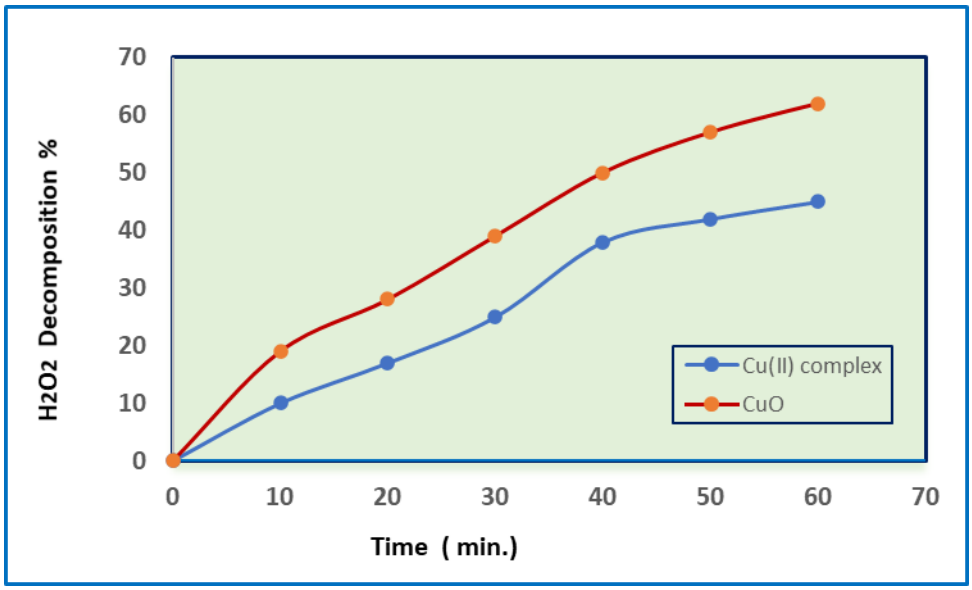

Figure 1: Influence of reaction time on H_2O_2 decomposition in presence ofcopper oxide, and Cu(II) complex as catalysts.

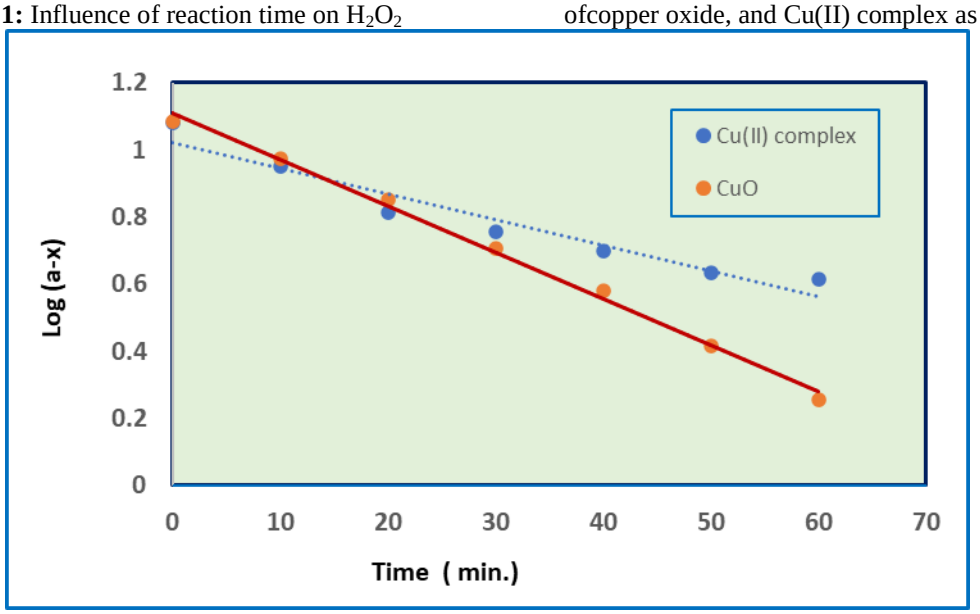

Figure 2: Effect of copper oxide, andCu(II) complexon reaction rate of H_2O_2 decomposition.

Based on the literature [18], the mechanism of the catalytic decomposition reaction of H_2O_2 by metal complexes may be proposed according to:

- At first, H_2O_2 decompose to give the anionic species $[H]^+$ and $[HO_2]^-$ (hydrogen ion and peroxo species, respectively):

$$H_2O_2 \rightarrow HO_2^- + H^+$$

- Then, the metal complexes may interact with anionic species $[HO_2]^-$ to form an intermediate complex:

$$M - L + HO_2^- \rightarrow [M - L(HO_2)]^-$$

- Finally, the intermediate complex thus formed may interact with another molecule of H_2O_2 to form the following products:

$$[M - L(HO_2)]^- + H_2O_2 \rightarrow M - L + H_2O + OH^- + O_2$$

Another similar mechanism is suggested for metal oxides catalyzed H_2O_2 as [19].

$$H_2O_2 + M_xO_y \rightarrow H_2O_2 - M_xO_y$$

$$H_2O_2 - M_xO_y \rightarrow ½O_2 + H_2O + M_xO_y$$

Conclusion

The copper oxide was prepared based on the coppercomplex as a precursor via solid-state thermal decompositiontechnique. The present investigation has demonstrated the use of the copper oxide in comparison

Please cite this article as **MarwaM. Gouda[1], Omyma A.M. Ali[2], Zeinab H. Abd EI- Wahab[3], Abeer A. Faheim[3] and Ranih H. Taha[3] (2021) Copper (II) complex as precursor for copper oxide synthesize acting as catalyst to study the catalytic decomposition of hydrogen peroxide** . *International Journal of Recent Research and Applied Studies*, 8- 8(1), 01-04

increased with time. Moreover, the decomposition efficiency followed the order:Copper oxide >Cu(II) complex.

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