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The photocatalytic degradation of direct blue 14 in the presence of synthetic cerium oxide nanoparticles

M.Dridi[1*], A.Daas [1]and Y.Hamlaoui[1]

[1]*Laboratory of physics matter and radiation, Mohamed-Cherif Messaadia-Souk Ahras, Algeria*

Email of the corresponding auth[*](ma.dridi@univ-soikahras.dz)

Abstract **–** Cerium oxide nanoparticles are considered promoter and emerging substances due to their properties such as redox, transport properties, and oxygen storage capacity. Thus, it can be effectively used in water treatment technologies. In this study, we investigate the photocatalytic activity of cerium oxide nanoparticles as a photocatalyst for direct bleu 14(organic dye) photodegradation. The influence of several parameters such as solution pH, initial concentration of dyes and bath temperature on the photocatalytic degradation was evaluated by using UV spectroscopy. Cerium oxide nanoparticles were synthesized through the chemical precipitation method; first, the experiments were conducted by varying the amount of cerium oxide nanoparticles from 1 to 12 mg for an initially fixed dye concentration of 10 ml/l, a solution pH which is about 5 and at room temperature; then the pH solution effect was studied for an optimized added amount of nanoceria of 6 mg and an ambient temperature, varying the initial pH solution studied in a range between 1.5 and 11.8. Finally, the bath temperature range was studied for 25, 30,35,40,45 and 50° C. The obtained results showed that the total degradation of the organic dye was achieved after 20 minutes in the presence of 6 mg of cerium oxide nanoparticles, for a solution pH of 1.5 and bath temperature of 50° C.

Keywords – Photodegradation, Ceo$_2$, Ph, Temperature, DB14. UV Spectroscopy

I. INTRODUCTION

cerium oxide nanoparticles have attracted much attention in recent years due to its wild application in many fields such as polishing agents; sunscreen; solid electrolytes; solar cells; gas sensors; phosphorescent/luminescent nanomaterial; oxygen storage; solid oxide fuel cells; metallurgy and heterogeneous photocatalysis.[1]

These applications take advantage of redox potential chemistry between CeIII/CeVI [2] valance state, and its oxygen storage capacity allowing the nanoparticles to act as a regenerative catalyst. The size and catalytic activity of the surface of the cerium oxide particles are strongly affected by numerous factors, namely the synthesis way, the precursor type, and particle geometry [3] Heterogeneous photocatalysis using nanoceria particles is mediated by the valance band (VB) as a hole (h+) and the conduction band (CB) as electrons (é) which are produced by the absorption of ultra-violet light (UV). The photogenerated pairs accelerate the formation of highly aggressive species such as hydroxyl (HO) or superoxide (O.2) which are sufficient to oxidize and decompose organic compounds [1-4]. For this purpose, cerium oxide nanoparticles are successfully used in water treatment. H.R. Pouretedal [5] investigated the photocatalytic activity of CeO_2 nanoparticles by the photodegradation of methylene blue under UV light. The highest degradation was obtained with 1.0 g/L CeO_2 at pH 11 within 125 min. Jibran Iqbala et al [6] studied the degradation of flumequine (FLU) under UV-C irradiation in presence of ceria nanoparticles as a photocatalyst, the results showed high photocatalytic degradation of FLU with degradation conversion of 94 %.

Laouedj Nadjia & al studied the photocatalytic activity of synthesized cerium oxide nanoparticles

calcined at different temperatures under UV light. The highest photocatalytic degradation of Congo red was achieved after 100 min using CeO2 nanoparticles calcined at 500°C [7].

This work aims to study the photocatalytic activity of synthesized cerium oxide nanoparticles as a photocatalyst for direct bleu 14 degradation. The photocatalytic degradation of DB14 in the presence of nanoceria was investigated under UV irradiations as a function of three environmental key factors (photocatalyst amount (CeO2 Nps), pH solution and bath temperature).

II. Materials and Method

All reagents were analytical grade purity and used as received without any further treatments.

Cerium oxide nanoparticles were prepared through chemical precipitation way using cerium nitrate hexahydrate as precursor with the presence of acetic acid seving as a ligand and ammonia (24%).

Photocatalytic activity of synthesized ceria nanoparticles was investigated for the degradation of 10 mg/L of Direct Blue 14 solution. Sulphuric acid and sodium hydroxide were used for adjusting the solution pH.

The solution dye/ nano ceria was stirred in the dark for 40 min to achieve adsorption/desorption equilibrium before it is exposed to UV irradiation. 2 ml samples were taken from the solution, centrifuged at 3000 rpm for 30 min then analysed using UV-Vis spectroscopy.

III. Results

A total photodegradation of Direct Blue 14 solution was achieved in the presence of 6 mg of cerium oxide nanoparticles after 20 min of UV irradiation, an initial solution pH of 1.5 and a bath temperature of 50°C.

IV. DISCUSSION

IV.1. the effect of CeO2 concentration:

In order to study the photocatalytic activity of cerium oxide 10 mg/L of DB14 were used for a variant added amount of 1, 3, 6, 8, 10 and 12 mg of cerium oxide. Figure .1.a. presents the ratios C/C0 as a function of time. It can be seen that the highest photodegradation was achieved by using 6 mg of cerium oxide nanoparticles. The obtained results presented in Fig. 1.b. shows that by the increasing added amount of ceria nanoparticles between 1 and 6 mg increases the degradation rate of the dye (DB14). This is due to the increase of the number of active sites on the surface of CeO2 particles, which increases the formation of free radicals HO° and O_2^- in the reaction medium. After this, a decrease is observed in the elimination rate of DB14 by increasing the added amount higher than 6 mg. This is mainly due to the aggregation of the photocatalyst particles, which decreases the penetration of light (the protective effect of suspended particles) and reduces the rate of photodegradation. It's noted that the increase in suspension turbidity that also decreases the photoactive volume. Moreover, the particle/particle interactions become significant as the number of particles in the solution increases which seems to reduce the density of the sites for the hole/e- pairs.

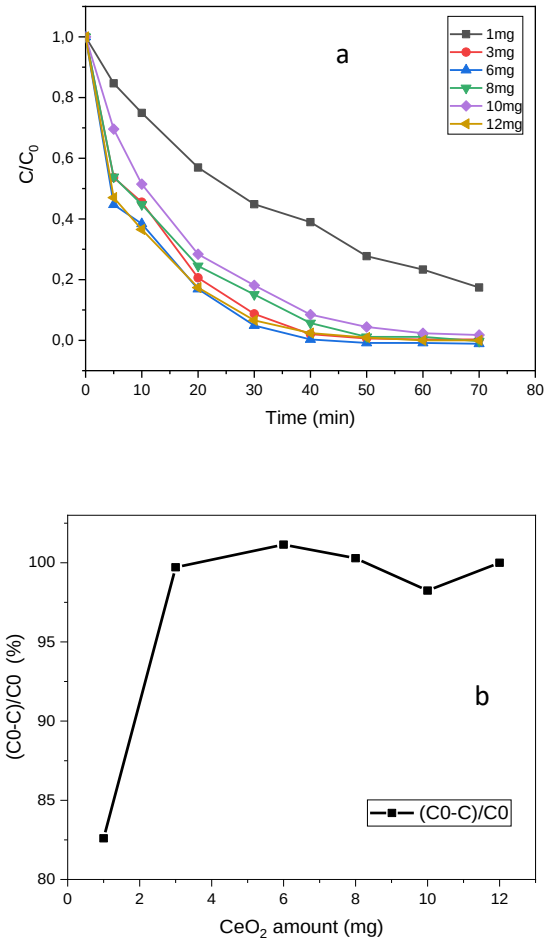


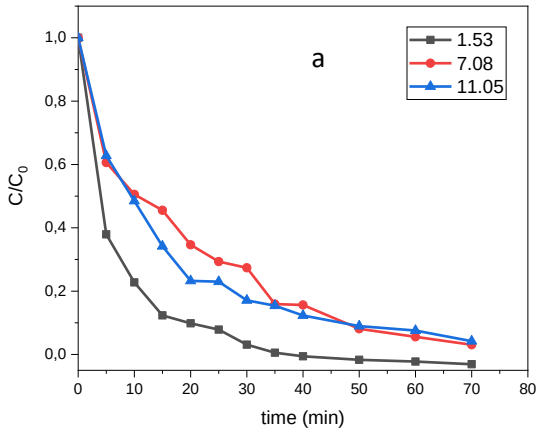
Fig.1. Effect of CeO_2 amount on the photodegration of DB14

IV.2. Effect of initial solution pH:

The effect of initial solution pH was investigated for a fixed dye concentration (10 mg/L) and ceria nanoparticles (6 mg). The reaction solution pH was varied from 1.5 to 11 by using sulphuric acid and sodium hydroxide.

Figure2.a. shows that a total degradation of the dye was obtained after 40 min in acidic medium.

The efficiency of the UV/CeO_2 system is due to both the nature of the surface charges and the concentration of the produced free radicals. It is noted that the surface charges are carried by the cerium oxide and the ionic state of the dye molecules in the aqueous solution, the adsorption of the dye. These properties depend essentially on the initial pH of the solution, which can affect the interactions between the surface charge of cerium oxide nanoparticles and the dye's molecules (DB 14), as well as the interactions between the hydroxide ions and the generated positive holes on the photocatalyst surface. Since DB14 is an anionic dye and the highest degradation was observed in acidic medium, lets us to conclude that the surface of the nanoceria is positively charged. However, the lowest degradation of the dye was observed in alkaline medium, which is due to the repulsive force between DB14 and the positive surface charge of the photocatalyst, which reduces the photogenerated hydroxyl radicals.



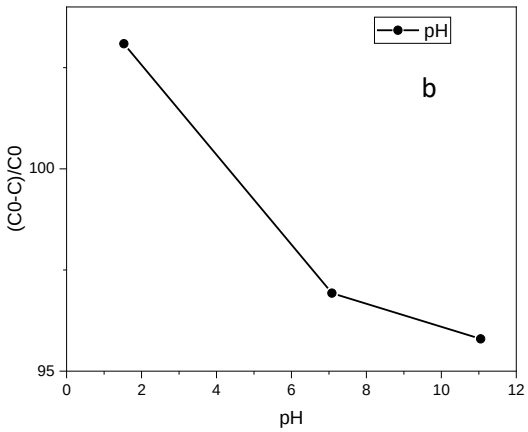


Fig.2. Effect of the initial solution pH on the photodegration of DB14 (C0= 10 mg/L; mCeO2 = 6mg)

IV.3. Effect of bath temperature:

In order to investigate the influence of bath temperature on the photodegradation of DB14, the amount of photocatalyst (CeO2) was fixed to be 6 mg, pH 1.5, and the temperature was varied from 25 to 50 °C. Figure.3. shows that a complete degradation of the dye was achieved at a bath temperature of 50 °C while only partial degradation occurred at lower temperatures. This result highlights the significant impact that bath temperature can have on the photodegradation process. The increasing bath temperature increases the conversion of the direct bleu 14 as result of the increasing concentration of hydroxyl and superoxide radicals.

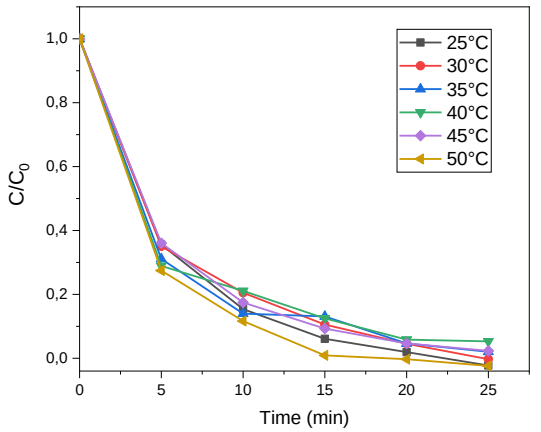


Fig.3 the influence of bath temperature on the photodegration of DB14 (C0= 10mg/L; mCeO2= 6mg; pH=1.5)

V. CONCLUSION

The photocatalytic activity of synthesized cerium oxide nanoparticles was investigated for the photodegradation of DB14 under the influence of certain parameters (solution pH, photocatalyst amount and bath temperature). The photocatalytic experiments showed that a complete degradation of the dye was achieved after 20 min of UV irradiation and for a nanoceria concentration of 6 mg, an initial pH of DB14/nanoceria mixture of 1.5 and a bath temperature of 50°C.

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