Decolourization of Acid Chrome Blue K by Persulfate

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Abstract

The decolourization of dye wastewater by persulfate was studied using acid chrome blue K as a model dye wastewater. Effects of several parameters, such as dose of oxidant, ionic strength, pH, temperature and UV irradiation, were investigated in detail. The results showed that the decolourization reaction of acid chrome blue K by persulfate could be fitted to a pseudo-first order kinetics model. In addition, no degradation products were observed during the decolourization of acid chrome blue K by persulfate. The results are useful for the treatment of dye wastewater.

Keywords: Acid chrome blue K; Decolourization; Persulfate

With the development of dye industry, there are greatly increased dyes in categories and varieties on the market for different applications. At the same time, dye wastewater will cause extremely damages to the environment if improperly disposed. Azo dyes have been widely used because of their chemical stability and versatility. Effluents from dye wastewater are often characterized by very high COD and TOC values and they are non-biodegradable, toxic and potentially carcinogenic in nature. At present dye wastewater is abated by some non-destructive processes such as coagulation, activated carbon adsorption and membrane filtration, electrochemistry and advanced oxidation processes (AOPs). Dye wastewater has low biodegradability due to its complexity in composition and toxic intermediates produced during some treatment processes. Persulfate, as a powerful oxidant, has been tested for the degradation of many persistent pollutants and achieved satisfied results. It has a higher potential than those of H2O2, KMnO4, and O3 which are known oxidants widely used. It offers some advantages over other oxidants as a solid chemical at ambient temperature with the ease of storage and transport, high stability, high aqueous solubility and relatively low cost. These features let it to be a promising choice for cleanup applications in wastewater treatment.

In this paper, the decolourization of Acid Chrome Blue K (ACBK) was studied by potassium persulfate under the irradiation of ultraviolet light. Effects of several parameters, such as dose of oxidant, ionic strength, pH, temperature and UV irradiation on the decolourization of A CBK, were investigated in detail. The results showed that the decolourization reaction of A CBK by persulfate could be fitted to a pseudo-first order kinetics model. In addition, no degradation products were observed during the decolourization of A CBK by persulfate. The results might be potentially useful for the treatment of dye wastewater.

Apparatus and reagents
1.1 apparatus and reagents

UV-VIS spectrophotometer (TU-1901, Beijing Purkinje General Instrument Co., Ltd), Medical UV germicidal lamp (30 W, Philips, main wavelength at 254 nm), Electric thermostatically water bath (HH-S, Jiangsu Hongqi Medical Instrument Co., Ltd), Precision pH meter (PHS-3D, Shanghai Dapu Instrument Co., Ltd), electrical balance (AR1140, Mettler-Toledo Instrument Co., Ltd)

All reagents with analytical reagent grade were bought from Chengdu Kelong Chemical Reagents Factory).

2. Experimental

2.1 Dye stock solution

Aqueous solutions were prepared in the deionized water obtained from a Millipore Milli-Q system. The ACBK stock solution was prepared at 1 mM. The K$_2$S$_2$O$_8$ solution (200mM) was prepared and stored at 4 ºC.

2.2 Buffer solutions

Buffer solutions with pH at 2.98 and 4.37 are prepared by acetic acid and acetic sodium. Buffer solutions with pH at 6.48, 8.46, 10.35 were prepared by phosphoric acid and sodium dihydrogen phosphate solutions. Their total concentrations were 0.2 M.

2.3 Effects of factors on the decolourization of ACBK

Keeping the concentration and dosage of ACBK constant, effects of the pHs of solutions, the dosages of the oxidant, temperatures and the presence of ions were investigated to the decolourization of ACBK. Then the utilization of UV irradiation was carried out to investigate the improved removal efficiency of SCBK decolourization.

2.4 Calculation of ACBK decolourization efficiency

The ACBK decolourization efficiency was calculated by the following equation:

\[ \eta_t = \frac{(A_0 - A)}{A_0} \times 100\% \]

where

- \( \eta_t \)——ACBK decolourization efficiency at time t;
- \( A_0 \)——the initial absorbance of ACBK;
- A——absorbance of ACBK at time t.

3 Results and discussion

3.1 Effect of pH

In 6 test tubes, reaction mixtures were obtained by taking 2 ml of 1 mM dye solution and adding 4 ml of 0.1 M potassium permanganate. Then five tubes of the 6 tubes were adjusted pH value with 5 buffer solutions to 2.98, 4.37, 6.48, 8.46 and 10.5 and only one test tube without pH adjustment. The final volume of the reaction mixture was 10 ml with DI water dilution. The absorbances were determined at 546 nm after reaction at ambient temperature. The results are presented in Fig. 1.
Fig. 1 Effect of pH

From Fig. 1, it is obvious that the decolourization of ACBK could be carried out at different pH values studied. Even in a higher pH value such as 10.35, the decolourization of ACBK could achieve a satisfied result after 90 min. The results are significant especially to practical application in wastewater treatment. Generally, the pH range of wastewater varies greatly. Furthermore, most of oxidants have no good removal efficiencies when in alkaline solutions. Therefore, it is potential that persulfate can be used in a wide pH range in wastewater treatment.

3.2 Effect of temperature on the decolourization of ACBK

Reaction mixtures were obtained by taking 2 ml of 1 mM dye solution and adding 2 ml of buffer solutions at pH 9.8. Different amounts of potassium persulfate were added to the final volume of 10 ml with DI water dilution. The absorbances were determined at 546 nm after reaction at three temperatures ranged from 55 to 75 °C. The results are presented in Fig. 2.
Seen from the Figs 2, 3 and 4, it is found that the dosage of oxidant gradually decreased and the decolourization time was shortened with the increase of temperature. At the same time, the dosage of oxidant is only 1% at maximum which is reasonable by treatment price.

3.3 Effect of concurrence of ions

In 6 test tubes, reaction mixtures were obtained by taking 2 ml buffer solutions at pH 2.98, 2 ml of 1 mM dye solution, and adding 2 ml of 0.1 M potassium permanganate. The first tube was then directly added with DI water to the total volume of 10 ml, while the other five tubes were added with 12% of sodium phosphate, sodium sulfate, sodium chloride, sodium nitrate. The results indicated that the ions often occur in wastewater have no significance effect on the decolourization of ACBK which is beneficial to the practical application.

3.4 Effect of UV light

Reaction mixtures were obtained by taking 2 ml buffer solutions at pH 2.98, 2 ml of 1 mM dye
solution, and adding different amounts of 0.1 M potassium persulfate. The absorbance at 546 nm was determined after the irradiation of UV light. The results in Fig. 5 indicated that the UV light is beneficial to the color removal of ACBK and shorten the time for the decolourization of ACBK.

Fig. 5 Effect of UV light

![Graph showing the effect of UV light on color removal.](image)

3.5 Degradation pathway

In a test tube, 10 ml of reaction mixture containing of 2 ml of 1 mM dye solution and 2 ml of 0.1 M potassium persulfate was irradiated under UV light at 65 °C. The spectrophotometry was scanned in UV-VIS wavelength. Fig. 6 presented that the absorbance peak at 546 nm disappeared after 30 reaction
time which means that the decolourization process has finished. The peak produced in 290 nm increased firstly and then decreased, showing that the conjugated π system was firstly destroyed to produce an aromatic ring, which was gradually opened by degradation. After 110 min of reaction time, there is no new compound produced which indicated that the degradation of ACBK is completely.

3.6 Reaction kinetics

Fig. 7 shows the plot of ln(C/C₀) versus time for the decolourization of ACBK. It indicated the decolourization reaction of ACBK by persulfate could be fitted to a pseudo-first order kinetics model with a rate constant at 0.7776 min⁻¹.

4. Conclusions

The decolourization of dye ACBK by persulfate was studied. The decolourization of ACBK was found to increase with an increase of oxidant dose and pH. It should be pointed out that the decolourization of ACBK can be carried out in a wide pH range even in alkaline solutions. The presence of ions has no significant effect on the decolourization of dye solution. The experimental results showed that the decolourization reaction of acid chrome blue K by persulfate could be fitted to a pseudo-first order kinetics model. In addition, no degradation products were observed during the decolourization of ACBK by persulfate. The results are useful for the treatment of dye wastewater.

References


