Materials Research Proceedings **21** (2022) 220-223 https://doi.org/10.21741/9781644901755-39

Studies of the Influence of Temperature on the Photocatalytic Activity of Tungsten Oxide

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Keywords: Tungsten Oxide, Organic Pollutants, Photocatalytic Activity, Methylene Blue

Abstract. The results of photocatalytic activity of tungsten oxide in visible light are analyzed. It was shown that tungsten oxide has photocatalytic activity under the action of visible light in the photodegradation of the dye methylene blue. It was determined that the concentration of 15 mg/L provides the highest rate of photodecomposition of methylene blue. The optimum temperature for the process was determined. The process of methylene blue decomposition is most effective at 25 °C.

Introduction

In recent years, considerable attention has been paid to obtaining materials with unique properties. Over the years, a large number of semiconductors have been developed and used as photocatalysts. Among various semiconductors, TiO_2 is considered the best photocatalyst and is widely used to detoxify water from a number of organic pollutants [1-3]. However, photocatalysis using titanium dioxide has a number of significant drawbacks. Thus, the energy-gap width of titanium dioxide is 3.0-3.2 eV; light absorption by titanium dioxide lies in the UV region of the spectrum, that is why the efficiency of photocatalysts under visible radiation is less than 10%. There is also insufficiently high quantum yield of phototransformation, which is connected with the high degree of recombination of charge carriers, low specific surface, as well as low adsorption capacity of TiO_2 [4,5]. Therefore, it became necessary to find an alternative to TiO_2. In turn, photocatalysts based on tungsten oxide WO_3 are among the best materials operating under visible light [6-8]. WO_3 has a energy-gap width of 2.6 eV, is stable under acidic and oxidizing conditions, has chemical stability in the pH range (pH <8), significant photocurrent conversion efficiency, is resistant to corrosion processes, stable in various electrolytes and, most importantly, is considered harmless.

The analysis of works of similar studies revealed that mainly the studies of photocatalytic activity of tungsten trioxide are aimed at studying and developing methods of chemical synthesis of nanodispersed tungsten oxide in forms suitable for its subsequent use [9-13]. Meanwhile, there are no studies on the photocatalytic activity of tungsten trioxide obtained by recycling tungsten carbide waste. Studying the properties of tungsten trioxide will enable the development of more effective photocatalysts for the oxidation of organic pollutants to CO_2 and H_2O.

Methodology for investigating the photocatalytic activity of tungsten oxide nanopowder

The decomposition process of methylene blue was studied by spectrophotometry and by the color change of the solution during the photocatalytic reaction. A sample of nanopowder weighing 0.2 g was placed in a round flat-bottomed flask and 200 ml of methylene blue solution (solution concentrations of 9, 13, 15, and 20 mg/L) was added.

The solution was irradiated with a standard white LED lamp with a temperature of 4000 K in the wavelength range of 380 ... 780 nm. Stirring was performed on a magnetic stirrer "Ritm-01"

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with a speed of rotation of the armature of 500 rpm. Centrifugation was performed on a "CentriFuga 80-1" centrifuge, at 3000 rpm. UV-vis spectra were recorded for aqueous solutions on spectrophotometer "Expert 003" in quartz cuvettes with a width of 1 cm.

Sampling was performed every 2 hours to control the course of the photochemical reaction and to observe changes in the concentration of the pollutant in the solution, and 10 ml of the sample was centrifuged for 15 min at 3000 rpm, separating the sediment. After that the solution was decanted and the dye concentration was evaluated on a photometer "Expert 003" by the degree of discoloration of the solution. After analysis, the sample was returned to the original solution.

From the works [14,15] it was revealed that the decomposition of solutions of methylene blue passes through the kinetics of the first order, which is expressed by the equation:

$$\ln(C_0/C) = k_{app} \cdot t$$

Where C_0 – is the initial concentration of the methylene blue solution;

C – concentration at a given time;

k_{app} – decomposition rate constant.

To determine the rate constant of decomposition in our case, we plotted $\ln(C_0/C)$ as a function of time shown in Figure 1.

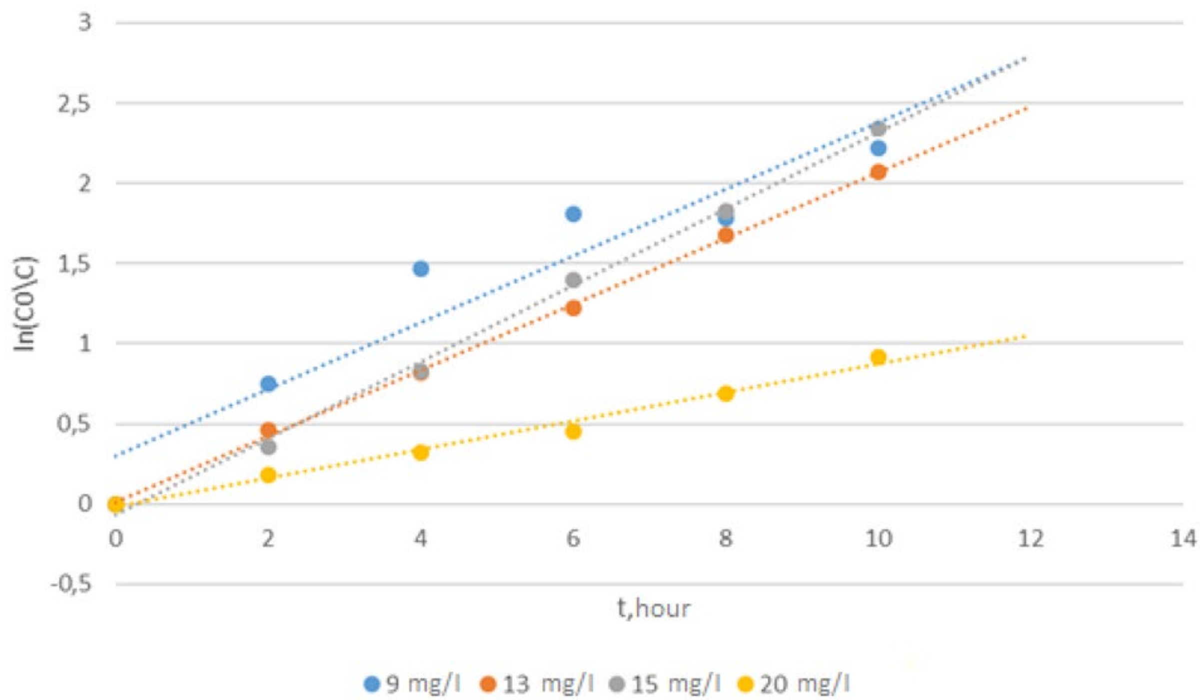

Fig. 1. *- Rate constant of decomposition at different concentrations of methylene blue*

The linear dependence of the data between $\ln(C_0/C)$ and irradiation time confirmed the applicability of this model with correlation coefficient values of 0.9489; 0.9995; 0.9984 and 0.9931. The decomposition rate constant (k_{app}) obtained from the slope of the plot was 3.7 × 103 min-1, 3.45 × 103 min-1, 3.9 × 103 min-1, and 1.53 × 103 min-1.for concentrations of 9, 13, 15, and 20 mg/L, respectively. Thus, the higher the k_{app}, the shorter the time required for complete decomposition of methylene blue.

The presented data show that the photocatalytic activity of tungsten oxide is most effective for the concentration of methylene blue 15 mg/l.

Study of photocatalytic activity at temperature exposure

We also studied the effect of temperature on the photocatalytic activity of tungsten oxide. For this purpose, aqueous solutions of methylene blue with a concentration of 15 mg/L were heated with a magnetic stirrer at constant stirring for 10 hours at temperatures 15, 25, and 30 ^{0}C. Methylene blue concentration drop was measured after 10 hours.

The results of the calculations are shown in figure 2.

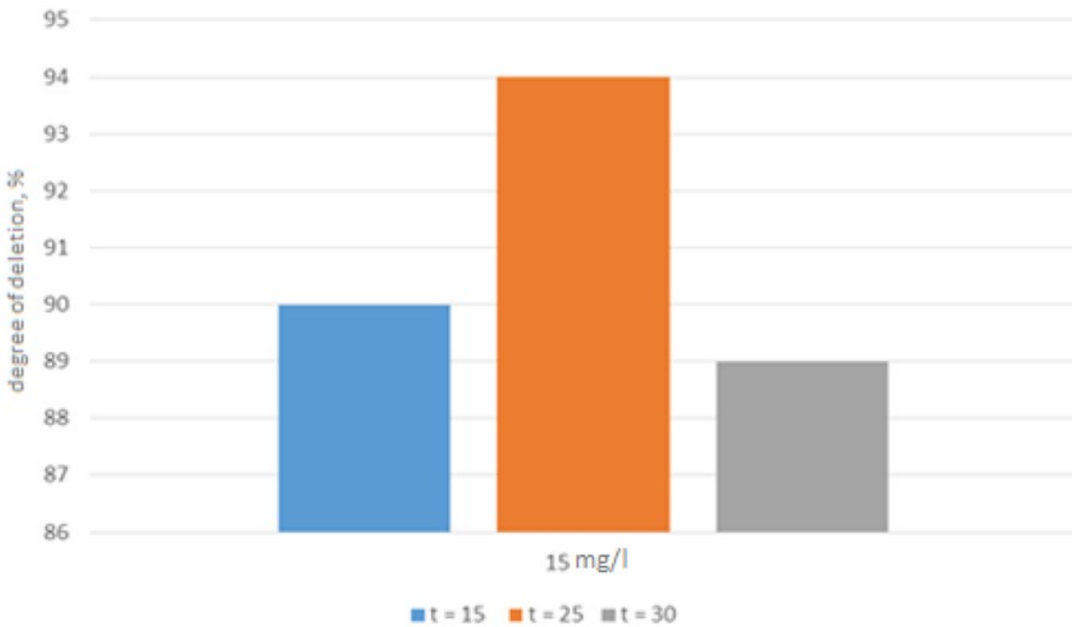

Fig. 2. *Photocatalytic activity data for different temperatures*

After 10 hours of continuous process, the dye spectrum value decreased by 90, 94 and 89%. From the analysis of the data obtained, we can conclude that the decomposition process of methylene blue is most effective at a temperature of 25 ^{0}C.

Conclusions

It was found that tungsten oxide has maximum photocatalytic activity under the action of visible light in the photodegradation of the dye methylene blue at a concentration of 15 mg/l. It was shown that the temperature optimum of the process is 25 ^{0}C.

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