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## Photocatalytic Degradation of Aquatic Rhodamine B Solution Using Ultraviolet Light and Zinc Oxide.

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### ABSTRACT

This research include study of Photocatalytic degradation of Rohdamine b using zinc oxide , which is achieved by the irradiation of suspended solution consists of 10ppm of Rohdamine b with 0.10 gm/100 ml of ZnO metal oxide semiconductor by using 125Watts mercury lamp from external source inside a pyrex photoreaction cell of 100 ml at room temperature 298 K . In order to study the effect of zinc oxide semiconductor in Photocatalytic degradation of Rohdamine b, several experiments were carried out in various conditions to attain the best Photocatalytic degradation of Rohdamine b. These experiments include effect of mass of zinc oxide , concentration of Rohdamine b, effect of hydrogen per oxide, and the effect of light intensity. The products was studied by using UV-Vis spectrophotometer.

**Keywords:** Photocatalytic degradation , Rohdamine b .Zinc oxide , decolonization.

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### INTRODUCTION

Photocatalytic degradation process include irradiation zinc oxide semiconductor in suspension solution of dye. This technology used to treated waste water ,and other application. In the past few years zinc oxide have drawn much attention for degrade organic pollutants such as dyes , pesticides, and volatile organic compounds using ultraviolet light irradiation [1] .Zinc oxide is n-type metal oxide semiconductor with band gap ( 3.37 eV) [2,3].Zinc oxide used extensively in rubber, paint, cosmetics and textile industry[4].

Different ways used to wastewater treatment, one of them advanced oxide processes (AOP) method. It has attracted public concern for its ability to convert the pollutants into the harmless substances directly in the waste water [5].

Basically these method starting with generation of strong oxidizing agents such as hydroxyl radicals ( $\cdot\text{OH}$ ) ( $E = 2.8 \text{ V}$ ) ,this reactive radical capable of mineralizing organic pollutants [6].

Heterogeneous photo-catalytic oxidation, one of the Advanced Oxidation Processes, used to treated the organic pollutants to  $\text{CO}_2$  and inorganic acids [7].

When zinc oxide semiconductor irradiated using uv light with energy equal to or greater than the band gap( 3.2 eV) [8] , electrons are promoted from the valence band to the conduction band of the zinc oxide semiconducting oxide to give electron–hole pairs. The valence band hole ( $\text{h}^+$ ) potential is positive enough to generate hydroxyl radicals at the surface. Also, the conduction band electron ( $\text{e}^-$ ) is negative enough to reduce the oxygen molecules, present in the solution, which in turn leads to the generation of another series of hydroxyl radicals [9, 10].

As shown in figure (1):

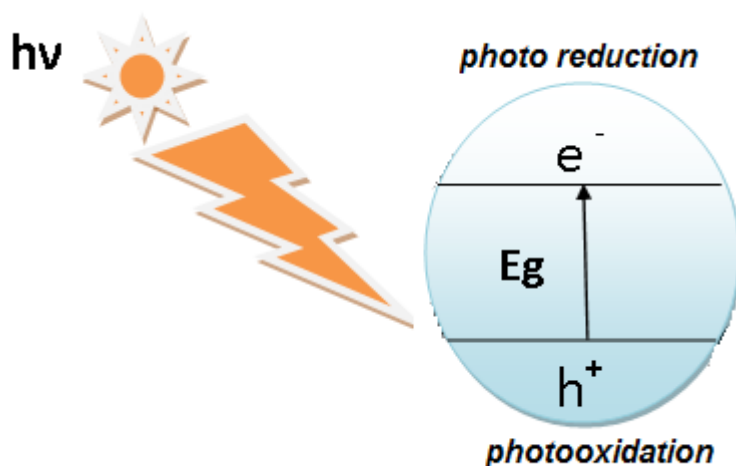
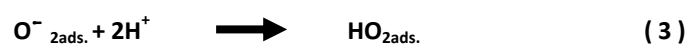
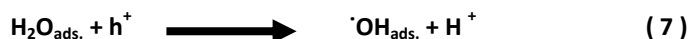
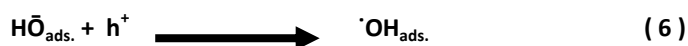


Figure 1: General mechanism of the photocatalysis on ZnO particle.

The photocatalytic degradation mechanism illustrated below [ 11 ] :





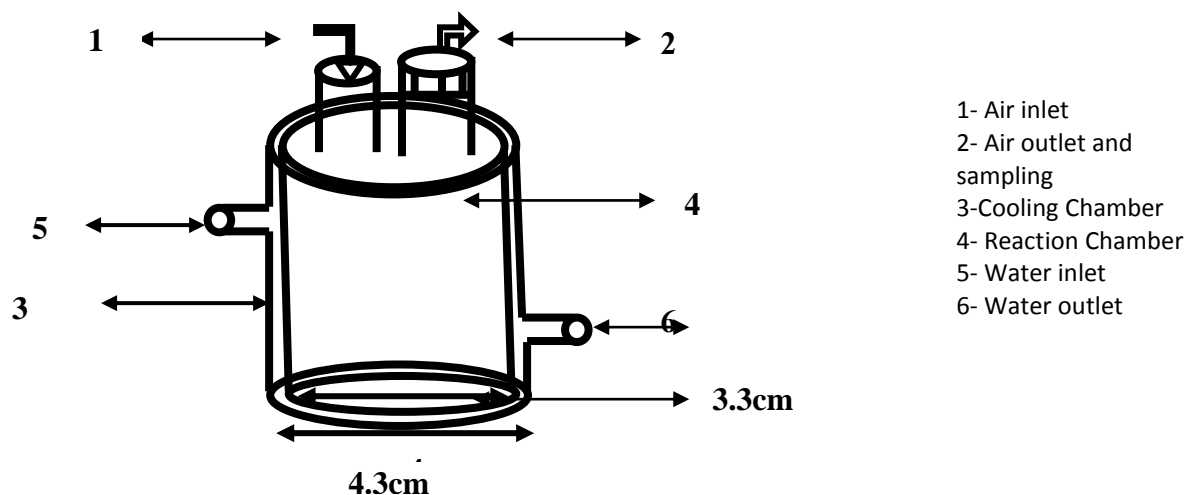
### MATERIALS AND METHODS

#### A-Chemicals:

- 1-Zinc oxide ( ZnO ) : purity ( 98% ) , supplied by Fluka AG.
- 2 – Rhodamine b supplied by sigma – Aldrich .
- 3- Hydrogen peroxide supplied by sigma-Aldrich.

#### B - Photo reactor and Procedure:

Experiments were carried out in glass photochemical reactor. The cylindrical annular – type reactor consisted of two parts. The first part was an outside thimble , Running water was passed through the thimble to cool the reaction solution . Owing to the continues cooling , the temperature of the reaction solution was maintained of room temperature . The second part was an inside thimble and the reaction solution ( volume 100 ml ) was put in the reaction chamber [12] .



Schematic diagram of photochemical reaction as shown in figure ( 2 ) :

Figure 2: Main parts of the photocatalytic cell used in Photocatalytic degradation of Rohdamine b .

#### C- Irradiation System :

A block diagram of photolysis apparatus is shown in figure ( 3 ) a 125Watts mercury lamp source is a focusing fitted with a focusing lens to ensure parallel beam of light [13].

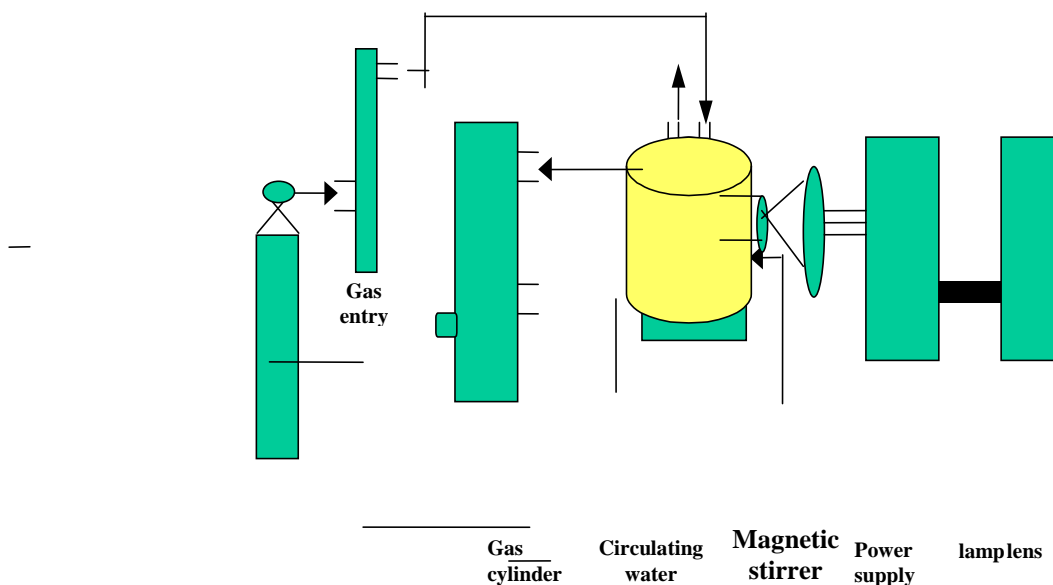


Figure 3: Schematic diagram of the experimental apparatus.

### RESULT AND DISCUSSION

#### 1 - Effect of mass catalyst of zinc oxide on photo catalytic degradation of Rohdamine b :

These experiments were carried out by using different masses of zinc oxide rang (0.02 – 0.50 g/100ml) was studied Photocatalytic degradation of Rohdamine b using 10 ppm of Rohdamine b, flow rate of air 10 ml/min, and room temperature 298 K .

Table (1) and Figure (4) represent photo catalytic degradation processes of Rohdamine b at different loaded mass of zinc oxide. Photocatalytic degradation of Rohdamine b, gradually increases as the masses of zinc oxide increases until reach to the optimum photocatalytic activity 0.10 gm/100ml , then gradually decreases . When the mass of zinc oxide equal 0.10 gm /100ml the semiconductor zinc oxide can be provide the highest absorption of light . The decrease in the efficiency of phtocatalytic degradation process at the masses of zinc oxide higher than 0.10 gm /100ml due to the light absorption will be limited only to the first layers of Rohdamine b and the other layers of solution do not receive light photons. Moreover light scattering at high zinc oxide loading , this lead to decrease the photon intensity, so the strong absorption of light through the first successive layers of solution and prevent light from passing through all other layers in the reaction vessel .Many workers studied this effect [14 , 15]. At the loading mass of zinc oxide below the optimum value 0.10 gm /100 ml the rate of photodegradation of Rohdamine b also decrease due to the quantity of mass of zinc oxide decrease that mean the surface area decrease which lead to decrease of light absorption of light by zinc oxide which cause lower photodegradation rate of Rohdamine b .

The mass of zinc oxide 0.10 gm/100 ml gives the optimum photodegradation efficiency which is equal to 97.29 % . The results of the change in photodegradation efficiency (P.D.E) with catalyst concentration plotted in figure 5.

Table 1- The change of  $A_t / A_0$  with irradiation time using different masses of zinc oxide.

Catalyst mass gm /100 ml	0.02	0.05	0.10	0.35	0.50
Irradiation Time/min	$A_t / A_0$				
0	1.00	1.00	1.00	1.00	1.00
10	0.64	0.55	0.39	0.73	0.81
20	0.44	0.32	0.18	0.54	0.70

30	0.32	0.21	0.10	0.43	0.60
40	0.30	0.19	0.06	0.40	0.49
50	0.28	0.16	0.03	0.36	0.47
60	0.26	0.14	0.03	0.34	0.45

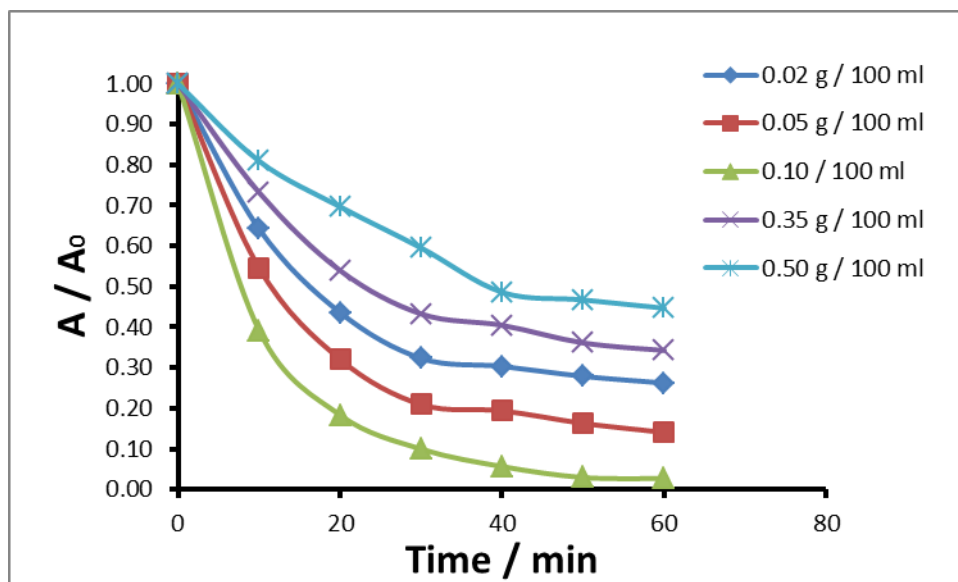


Figure 4: The effect masses of zinc oxide on Photocatalytic degradation of Rohdamine b.

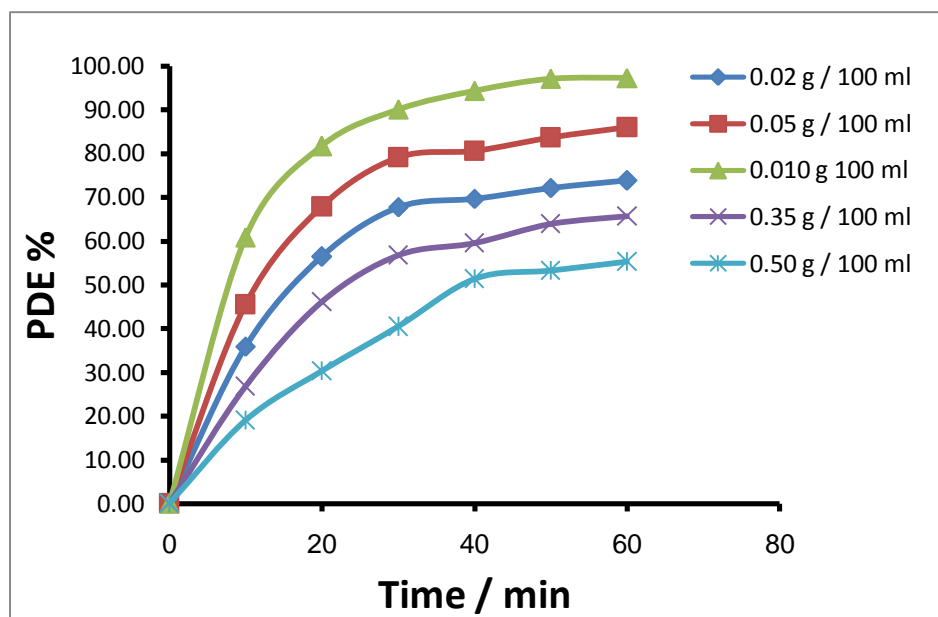


Figure 5: The change of Photocatalytic Degradation Efficiency with irradiation time of different types of catalyst.

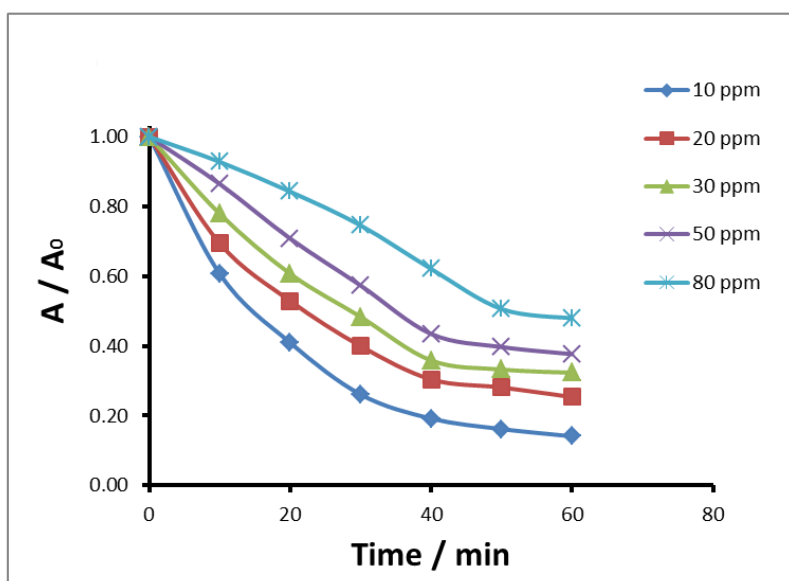
**2- The Effect of initial Rohdamine b concentration on photo catalytic degradation processes:**

A different experiments have been done , the effect of change initial rang ( 10 – 80 ppm ) on photocatalytic degradation process of Rohdamine b was studied using the optimum mass of zinc oxide 0.10gm / 100 ml , the light intensity equal to 8.5 mW/cm<sup>2</sup>, and temperature equal to 298 K . The results are listed in Table 2 and plotted in figure 6 . It has been observed that the rate of photocatalytic degradation

gradually decreases with the increasing of initial Rhodamine b concentration. This behavior could be explained, the concentration 1ppm was the optimum concentration to cover the largest area of the zinc oxide particles, therefore absorbed maximum exciting photons to generate higher concentration of the activated zinc oxide semiconductor. Another reason for this behavior is the strong absorption of light by the Rhodamine b in the sample which contain high concentration that 10 ppm, Rhodamine b on 0.10 gm /100ml of titanium dioxide. The excess of Rhodamine b prevent the penetration of light through the successive layers of Rhodamine b on the zinc oxide surface is weak to generate the required excited state of the Rhodamine b adsorbed on zinc oxide [16, 17]. The concentration of Rhodamine b 10 ppm gives the optimum photodegradation efficiency which is equal to 85.89 %. The results of the change in photocatalytic degradation efficiency (P.D.E) with concentration of Rhodamine b plotted in figure 7.

**Table2. The change of  $A_t/A_0$  with irradiation time using different concentration of Rhodamine b.**

Concentration of Rhodamine b / ppm	10	20	30	50	80
Irradiation Time/min	$A_t/A_0$				
0	1.00	1.00	1.00	1.00	1.00
10	0.61	0.69	0.78	0.86	0.93
20	0.41	0.53	0.61	0.71	0.84
30	0.26	0.40	0.48	0.57	0.75
40	0.19	0.30	0.36	0.43	0.62
50	0.16	0.28	0.33	0.40	0.51
60	0.14	0.25	0.32	0.38	0.48



**Figure 6: The change of  $(A / A_0)$  with irradiation time at concentration of Rhodamine b.**

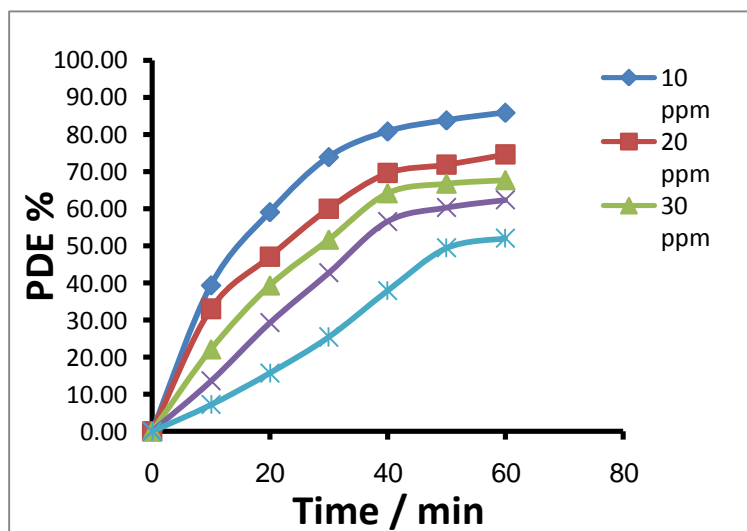


Figure 7: The change of Photocatalytic Degradation Efficiency with irradiation time of different types of concentration of Rhodamine b.

3 – Effect of light intensity on photocatalytic degradation process of Rohdamine b.

A series of experiments were carried out to study the effect of light intensity range (2.3 – 8.5) mW/cm<sup>2</sup> from a high mercury lamp (125 watts). All experiments were studied using optimum conditions, the weight of loaded zinc oxide 0.10 gm / 100 ml and the initial concentration of Rhodamine B 10 ppm, with a flow rate of air bubbling kept constant at 10 ml/min, at room temperature 298K.

Table 3 and Figure 8 illustrate the effect of light intensity on the photocatalytic degradation of Rhodamine B. The results indicate that the photocatalytic degradation of Rhodamine B increases with the increase of light intensity, the maximum value of light intensity 8.5 mW/cm<sup>2</sup>. In general, the used lamp produces photons, these photons increase electron transfer from the valence band to the conduction band in the zinc oxide. This process leads to an increase in the photocatalytic process of Rhodamine B [18,19]. The light intensity 8.5 mW/cm<sup>2</sup> gives the optimum photodegradation efficiency which is equal to 97.87%. The results of the change in photocatalytic degradation efficiency (P.D.E) with light intensity are plotted in Figure 9.

Table 3 The change of A<sub>t</sub> / A<sub>0</sub> with irradiation time using different light intensity.

light intensity/ mW/cm <sup>2</sup>	2.30	3.00	4.30	8.50
Irradiation Time/min	A <sub>t</sub> / A <sub>0</sub>			
0	1	1	1	1
10	0.64	0.54	0.44	0.29
20	0.44	0.36	0.23	0.11
30	0.30	0.19	0.10	0.04
40	0.22	0.12	0.07	0.03
50	0.14	0.11	0.05	0.03
60	0.12	0.09	0.05	0.02

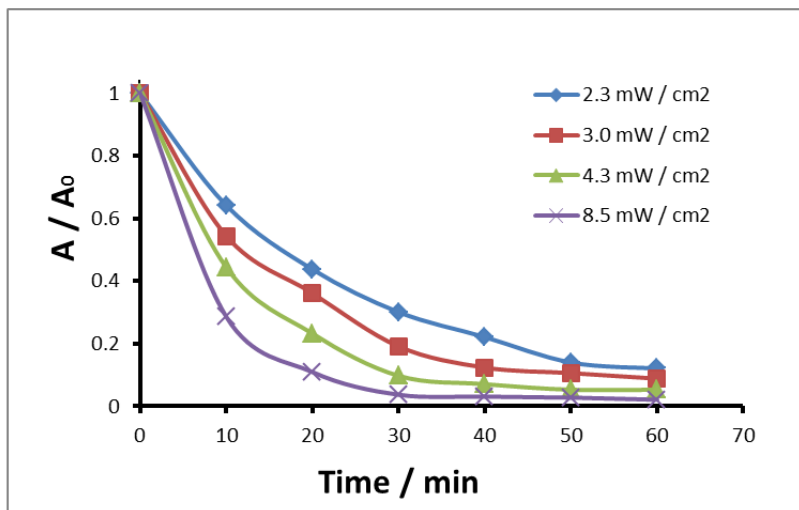


Figure 8: The change of (A / A<sub>0</sub>) with irradiation time at different light intensity with 0.10 gm/100ml zinc oxide on photocatalytic degradation of Rhodamine b .

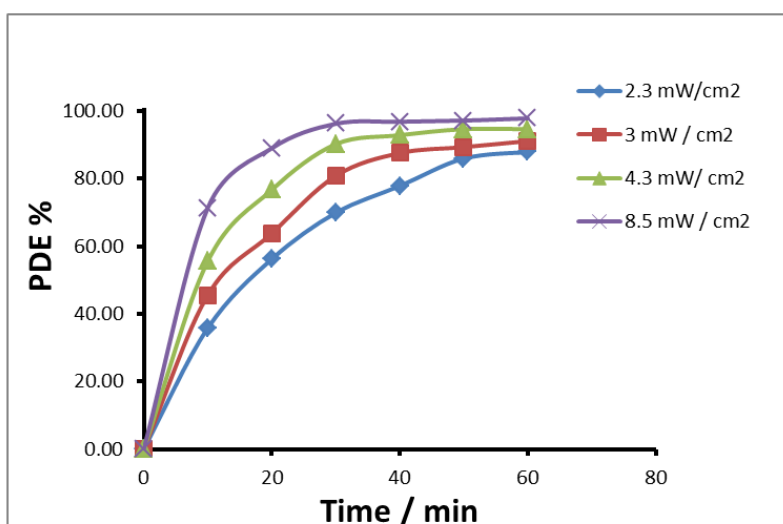
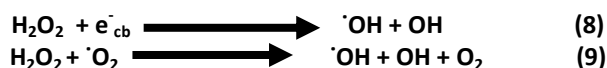


Figure 9: The change of Photocatalytic Degradation Efficiency with irradiation time of different light intensity.

**4 – Effect of added hydrogen peroxide on photocatalytic degradation of Rohdamine b.**

A series of experiments were carried out to study the effect of added hydrogen peroxide on Photocatalytic degradation rate of Rohdamine b using zinc oxide suspension at different concentration of added hydrogen peroxide rang ( 0.1 – 1.4 mmole ) [20 ]. Table 4 and figure 10 , shows the effect of added hydrogen peroxide on the photo catalytic degradation rate of Rohdamine b at fixed initial concentration 10 ppm and 0.10 gm/100ml of zinc oxide as catalyst . Figure 10 indicate that the photo catalytic degradation rate of Rohdamine b increases with increase of concentration added hydrogen peroxide lead to increase photocatalytic degradation of Rohdamine b because the increasing the concentration of hydroxyl radical this lead to inhibits the recombination peecess between holes and photoelectrons as shown in the following equations :





At high concentration of hydrogen peroxide the photocatalytic degradation processes decrease because of its hydroxyl radical scavenging effect according to the following equation :



Temperature cause to increase generate free radicals and this lead to decrease recombination process. Figure 11 indicate that the percentage efficiency of degradation rohdamine b dye increases with increase of temperature equal (96.73 %).

Table 4- The change of  $A_t / A_0$  with irradiation time using different Temperature.

Concentration of $\text{H}_2\text{O}_2$ mmole	0.1	0.2	0.4	1.4
Irradiation Time/min	$A_t / A_0$			
0	1	1	1	1
10	0.66	0.59	0.43	0.76
20	0.37	0.26	0.17	0.50
30	0.21	0.13	0.06	0.40
40	0.17	0.09	0.04	0.36
50	0.16	0.07	0.02	0.31
60	0.14	0.06	0.03	0.26

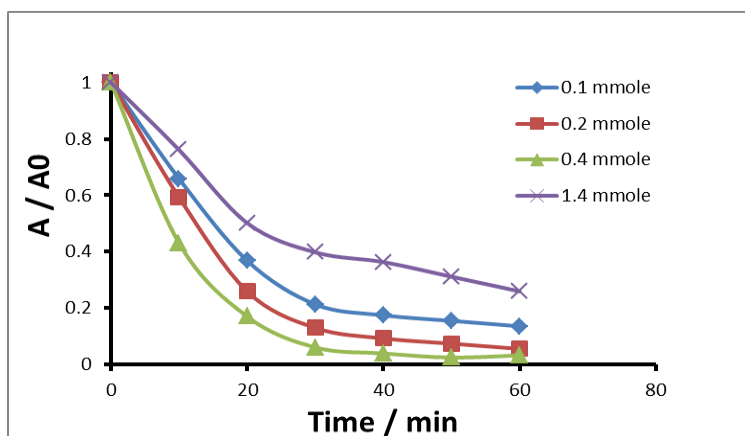


Figure 10: The change of  $( A / A_0 )$  with irradiation time at different concentration of added hydrogen peroxide for photo catalytic degradation rate of Rohdamine b by using zinc oxide .

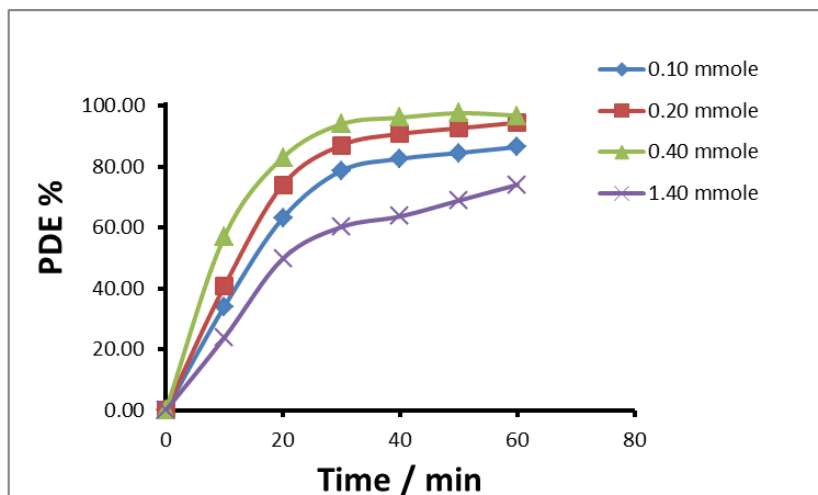


Figure 11: The change of P.D.E with irradiation time of different concentration of added hydrogen peroxide.

### CONCLUSION

- 1 – The compound has been not degraded in case of absent of catalyst.
- 2 – The compound has been successfully degraded when used the catalyst with the light.
- 3 – The optimum condition for the Photocatalytic degradation of Rhodamine b equal 0.10 gm / 100ml mass of titanium dioxide and 10 ppm concentration of Rhodamine b and 8.5 mW/cm<sup>2</sup>.
- 4 – The hydrogen peroxide increases photocatalytic degradation of Rhodamine b and the best at 0.4 mmole of H<sub>2</sub>O<sub>2</sub>.

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