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Reactive Blue Dye as a Novel Corrosion Inhibitor for Zinc Metal in Acidic Solutions

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Abstract- Reactive blue dye was evaluated as a corrosion inhibitor for zinc in 0.5N HCl by weight loss, gasometric and thermometric methods. The inhibition efficiency was found to increase with increase in the inhibitor concentration. The adsorption of the inhibitor molecules on the zinc metal surface obeyed Temkin adsorption isotherm.

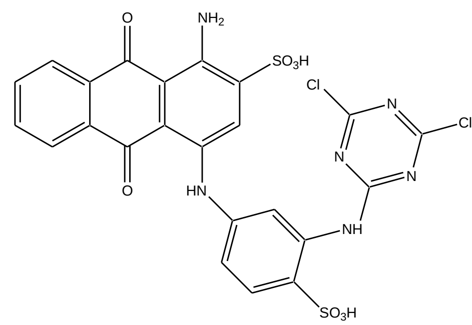
***Index Terms*-** Reactive blue, acidic solutions, zinc corrosion, weight loss, gasometry, thermometry.

I. Introduction

The attention on zinc metal corrosion has increased because of its wide applications such as electrode material in batteries, sacrificial anodes and metallic coatings. Therefore zinc metal has to be protected against corrosion from aggressive environments. In industries hydrochloric and sulphuric acids are widely used for the cleaning of metals and alloys. During this process metal loss occurs due to the dissolution of the metals in acids. In order to avoid metal loss and for reducing acid consumption many organic compounds are used as corrosion inhibitors. A review of the literature clearly brings out the fact that many organic compounds were used as corrosion inhibitors for zinc metal in various environments[1-21]. The presence of hetero atoms such as sulphur, oxygen and nitrogen, multiple bonds, aromatic rings and large surface area are some of the requirements to be satisfied by organic compounds to be employed as corrosion inhibitors. Many synthetic dyes are found to satisfy these requirements. Therefore we have selected and evaluated reactive blue dye as a corrosion inhibitor for zinc metal in 0.5N HCl acid solution by weight loss, gasometry and thermometric methods.

II. Experimental

The zinc metal specimens of composition: lead 1.03%, cadmium 0.04%, iron 0.001% and the remainder being zinc and size of 4cm*2cm* 0.08cm were used for weight loss gasometry and thermometry studies.. Zinc metal specimens were polished with a series of emery papers of various grades from 400-1200, degreased with absolute ethanol and air dried. The inhibitor compound, reactive blue dye was obtained from the Alfa-Aesar chemicals of United kingdom.. The corrosion medium was 0.5N HCl prepared from A.R grade HCl and deionised water. The structure of the inhibitor molecule is given below.



Weight loss, gasometry and thermometric studies

Weight loss, gasometry and thermometric studies were carried out as reported earlier[22-26]. From the weight loss experiments, the % inhibition efficiency (I.E) and the degree of surface coverage (θ) were calculated by using the following equations.

$$I.E = \frac{Wo - Wi}{Wo} X\, 100$$

$$\theta = \frac{Wo - Wi}{WO}$$

Where W_o and W_i are the weight loss of the metal in the absence and presence of the inhibitor respectively.

The corrosion rate (C.R) of the metal was calculated by using the following equation.

$$C.R(mmy) = \frac{87.6\, W}{A\, t\, D}$$

Where W is the weight loss of the zinc metal (mg), A is the surface area of the metal specimen(cm^2), t is the exposure time (h) and D is the density of the metal (g/cm^3).

From the gasometry experiments the inhibition efficiency is calculated by using the following equation.

$$I.E = \frac{Vo - Vi}{Vo} X\, 100$$

Where V_o and V_i are the volume of hydrogen gas evolved in the absence and presence of the inhibitor respectively.

From the thermometric studies the reaction number was first calculated by using the equation

$$RN = \frac{Tm - Ti}{t}$$

Where T_m is the maximum temperature , T_i is the initial temperature and t is the time taken to attain the maximum temperature.

The inhibition efficiency is calculated by using the following equation

$$I.E = \frac{RNo - RNi}{RNo}$$

Where RN_o is the reaction number in the absence of the inhibitor and RN_i is the reaction number in the presence of various concentrations of the inhibitor.

III. Results and Discussion

Weight loss, gasometry and thermometric studies were carried out at seven different concentrations of the inhibitor and the inhibition efficiency(IE) values were calculated. Values of inhibition efficiency obtained from these experiments for the inhibitor for the corrosion of zinc in 0.5N HCl in the presence of different concentrations of the inhibitor are presented in the table-1

Table 1 Values of inhibition efficiency(I.E(%)) obtained from the weight loss, gasometry and thermometric experiments for the corrosion of zinc in 0.5N HCl in the presence of different concentrations of the inhibitor.

Method employed	Values of I.E(%) for different concentrations (mM) of reactive blue inhibitor						
	1	5	10	20	30	40	50
Weight loss	24.2	52.4	63.1	75.6	83.5	88.7	91.2
Gasometry	23.8	51.9	63.9	74.8	83.1	88.2	90.8
Thermometry	24.8	53.1	64.6	76.2	84.6	89.4	92.5

It can be observed from the table 1 that there is very good agreement between the values of inhibition efficiency obtained from these three methods. The results also show that the inhibition efficiency increases with increase in the inhibitor concentration. The dependence of inhibition efficiency of the inhibitor on the concentration is shown in figure-1.

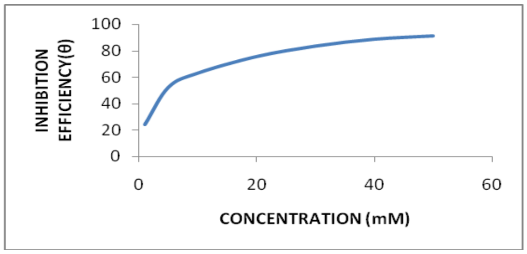


Figure 1 Variation of inhibition efficiency with concentration of the inhibitor.

The first step in the reduction of corrosion by inhibitors is the adsorption of the inhibitor molecules onto the metal surface. After the adsorption is completed, the inhibitor retards the cathodic and/ or anodic reaction at the metal surface. The inhibitor reactive blue molecule contains three hetero atoms namely sulphur, oxygen and nitrogen in its molecular structure.

All these hetero atoms possess lone pair of electrons. Through these lone pair of electrons they get adsorbed on the metal surface leading to the formation of a layer on the metal surface. This layer acts as a barrier between the metal and the corrosive media giving protection to the metal. The inhibitor also contains many aromatic rings with lot of π electrons through which also adsorption of the inhibitor molecules on the metal surface can take place leading to enhanced protection. In addition to these, the inhibitor molecule contains primary and secondary amine groups in the molecular structure. These amine groups can be easily protonated in acid medium to form the cationic form of the inhibitor. The chloride ions present in the acid medium gets adsorbed specifically on the positively charged metal surface due to its lesser degree of hydration leading to the creation of excess negative charges on the metal surface which favours the adsorption of these cationic form of the inhibitor molecules on the metal surface leading to the protection of the metal. Another important factor responsible for the higher inhibition efficiency of the inhibitor is the large surface area of the inhibitor molecules which provides higher surface coverage to the metal after getting adsorbed on the metal surface.

Values of corrosion rates obtained from the weight loss experiments for the inhibitor for the corrosion of zinc in 0.5N HCl in the presence of different concentrations of the inhibitor are presented in the table-2

Table 2 Values of corrosion rates obtained from the weight loss experiments.

Values of corrosion rates for different concentrations (mM) of reactive blue inhibitor						
1	5	10	20	30	40	50
106.1	66.6	51.7	34.2	23.1	15.8	12.3

From the table-2 it can be seen that the corrosion rates for the corrosion of zinc in 0.5N HCl decreases with increasing concentration of the inhibitor. The effect of inhibitor concentration on the corrosion rates is shown in figure-2.

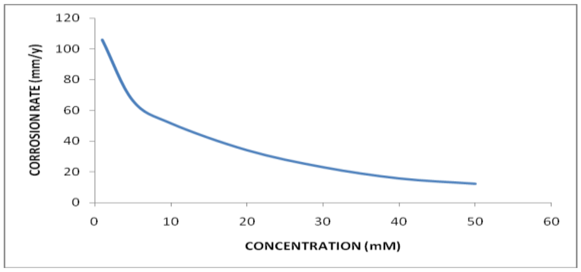


Figure 2 Variation of corrosion rates with concentration of the inhibitor.

IV. ADSORPTION ISOTHERMS

Basic information regarding the interaction between the metal surface and the inhibitor molecules can be obtained from the adsorption isotherms. Adsorption of inhibitor molecules on the metal surface is characterized by various adsorption isotherms such as Langmuir, Temkin, Freundlisch etc., From the weight loss measurements, the degree of surface coverage (θ) for various concentrations of the inhibitor were evaluated. Langmuir's isotherm was tested by plotting C/ θ vs C and no straight line was obtained which indicated that the adsorption of the inhibitor on the surface of the zinc from 0.5N HCl does not obey Langmuir's adsorption isotherm. Temkin's adsorption isotherm was tested by plotting logC vs θ which resulted in a straight line thereby showing that the adsorption of the inhibitor on the surface of zinc from 0.5N HCl obeys Temkin's adsorption isotherm. Figure -3 shows the Temkin adsorption isotherm plot for zinc in 0.5N HCl containing different concentrations of the inhibitor.

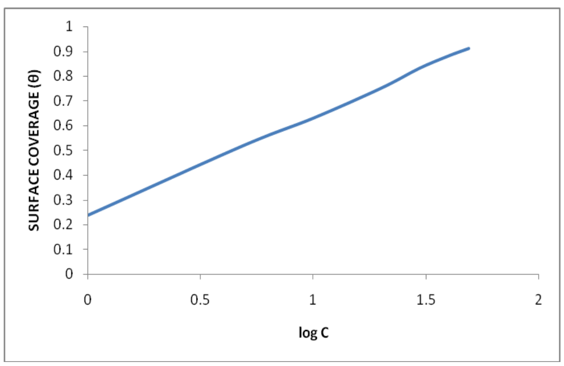


Figure 3 Temkin adsorption isotherm plot for zinc in 0.5N HCl containing different concentrations of the inhibitor

V. CONCLUSIONS

The reactive blue dye used as a corrosion inhibitor for zinc in 0.5N HCl performed well and gave high percentage of inhibition efficiency. It exhibited a maximum inhibition efficiency of 92.5 % at 50mM concentration. The inhibition efficiency of the inhibitor increases with the increase in the concentration of the inhibitor. The adsorption of the inhibitor on zinc surface obeyed Temkin adsorption isotherm.

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