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Congo Red Dye As A Novel Corrosion Inhibitor for Zinc in Hydrochloric Acid Solution

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Abstract: The inhibitive effect of congo red was examined as corrosion inhibitor for the corrosion of zinc in 1N HCl by conventional weight loss and gasometric methods. Results obtained show that congo red exhibited high inhibition efficiencies. 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: Congo red, acidic solutions, zinc corrosion, weight loss

I. Introduction

Because of its immense use in various industries, the protection of zinc metal against corrosion has gained much importance. In order to remove the undesirable scale and rust from the surface of the metals several acids are used[1-4] in many industrial processes which may involve metal dissolution and excess acid consumption. Among the various methods available for the protection of metals against corrosion, use of inhibitors is an important one. Inhibitors are compounds when added in small amounts to a corrosive medium, control the reaction between the metal and the medium. A survey of the literature reveals the fact that organic compounds containing oxygen, nitrogen and sulphur atoms are widely used as corrosion inhibitors for zinc metal corrosion in various acidic environments[5-14]. The effectiveness of these compounds in bringing down the corrosion of metals largely depends on their ability to get adsorbed on the metal surface through the polar groups present in their molecular structure acting as active adsorption centres.

Nowadays much attention is focused on organic dyes because of the existence some desirable characteristics such as possessing hetero atoms like oxygen, nitrogen and sulphur, triple bonds, conjugated double bonds and aromatic rings in their molecular structures which are rich sources of electrons essential for the adsorption process. Because of these characteristics organic dyes are expected to perform as efficient corrosion inhibitors for a wide variety of metals.

In the present work, we have evaluated Congo red as a corrosion inhibitor for zinc in 1N HCl medium employing the conventional weight loss and gasometry methods.

II. Experimental

2.1 Material

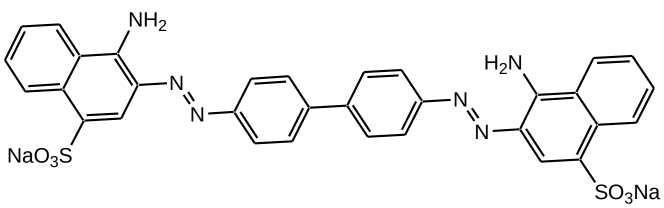
The zinc metal specimens used in this work has the following composition: lead 1.03%, cadmium 0.04%, iron 0.001% and the remainder being zinc. Zinc metal specimens were pretreated before the experiments by polishing with a series of emery papers of various grades from 400- 1200, degreased with absolute ethanol and air dried. For weight loss and gasometric experiments zinc metal specimens of size 4cm*2cm* 0.08cm with a small hole of approximately 3mm near the end of the specimen were used.

2.2 Solutions

The corrosion medium used was 1N HCl prepared from A.R grade HCl and deionised water.

2.3 Inhibitor

The organic dye, Congo red was imported from Alfa Aesar company of England. Fig 1 presents the molecular structure of Congo red.



2.4 Weight loss experiments

In the weight loss experiments, the pre-weighed zinc metal specimens were suspended in a 200ml beaker containing 100ml of acidic solutions for two hours. Then the metal specimens were removed from the acid solution, washed with deionised water, cleaned, dried and reweighed. From this the metal weight loss was determined as the difference between the initial weight and weight after 2 hours immersion in acid solutions. The experiments were repeated in the absence and in the presence inhibitor of different concentrations. Each experiment was repeated thrice and the average of the three values was taken as the final value.

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 in the absence and presence of the inhibitors 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).

2.5 Gasometry Experiments

The procedure for gasometry method for evaluation of inhibition efficiency of the inhibitors of various concentrations is described elsewhere[15]. 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 inhibitors respectively.

III. Results and discussion

Weight loss and gasometry 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 the weight loss and gasometry experiments for the inhibitor for the corrosion of zinc in 1N 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 and gasometry experiments for the corrosion of zinc in 1N HCl in the presence of different concentrations of the inhibitor.

Method employed	Values of I.E(%) for different concentrations (mM) of congo red inhibitor						
	1	5	10	20	30	40	50
Weight loss	21.7	45.5	58.4	68.2	74.4	80.7	84.6
Gasometry	22.1	46.3	57.8	67.5	74.9	81.1	83.9

It can be observed from the table 1 that there is very good agreement between the values of inhibition efficiency obtained from both weight loss and gasometric 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-2

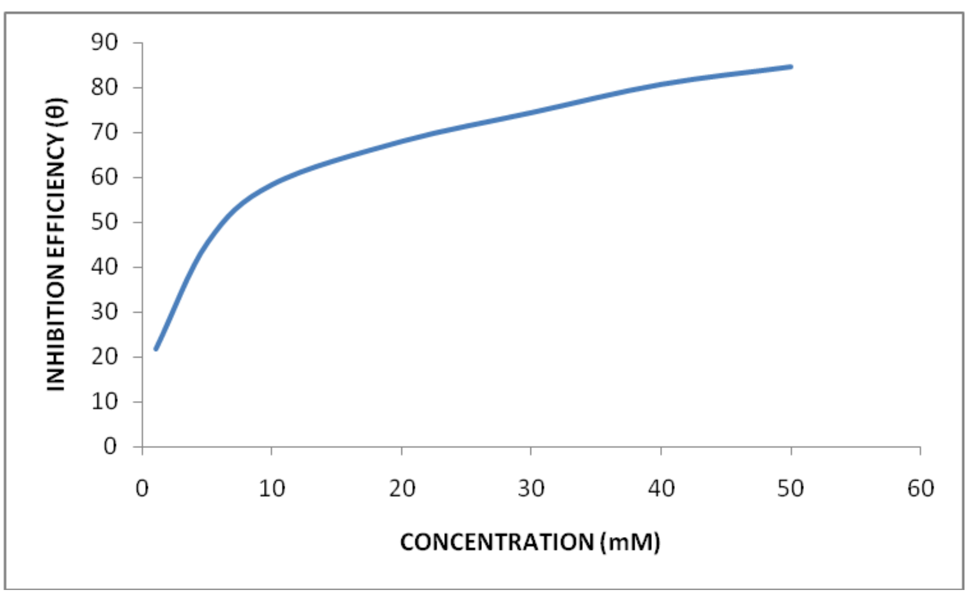


Figure 2 Variation of inhibition efficiency with concentration of the inhibitor.

Values of corrosion rates obtained from the weight loss and gasometry experiments for the inhibitor for the corrosion of zinc in 1N 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 and gasometry experiments for the corrosion of zinc in 1N HCl in the presence of different concentrations of the inhibitor.

Method employed	Values of corrosion rates for different concentrations (mM) of congo red inhibitor						
	1	5	10	20	30	40	50
Weight loss	109.6	76.3	58.2	44.5	35.8	27.0	21.6
Gasometry	109.1	75.2	59.1	45.5	35.1	26.5	22.5

From the table it can be seen that the corrosion rates for the corrosion of zinc in 1N HCl decreases with increasing concentration of the inhibitor. The effect of inhibitor concentration on the corrosion rates is shown in figure-3.

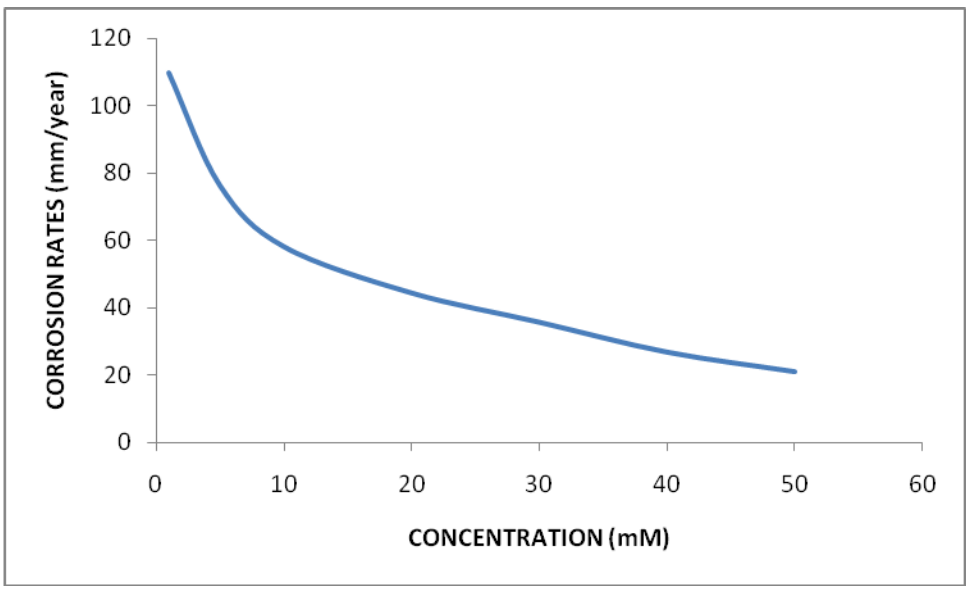


Figure 3 Variation of corrosion rate with concentration of the inhibitor

From the chemical structure of congo red dye we can observe the presence of two-NH_2 groups, two-SO_3Na groups, two azo groups and six aromatic rings. All these groups are rich sources of electrons and can act as active adsorption centers. The inhibitor molecules can get adsorbed via these groups.

Apart from this, the amino group in the molecule can get protonated in acid medium to form the cationic form of the inhibitor. As the chloride ions present in the medium which posses lesser degree of hydration gets adsorbed specifically on the positively charged metal surface resulting in the creation of excess negative charge on the metal surface. In this situation the adsorption of the cationic form of the inhibitor is favoured. This leads to more adsorption and hence more inhibition efficiency.

IV. Adsorption isotherms

Adsorption isotherms are very important in the understanding of the mechanism of inhibition of corrosion of metals. 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 for all concentrations. No straight line was obtained which indicated that the adsorption of the inhibitor on the surface of the zinc from 1N 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 1N HCl obeys Temkin's adsorption isotherm. Figure -4 shows the Temkin adsorption isotherm plot for zinc in 1N HCl containing different concentrations of the inhibitor.

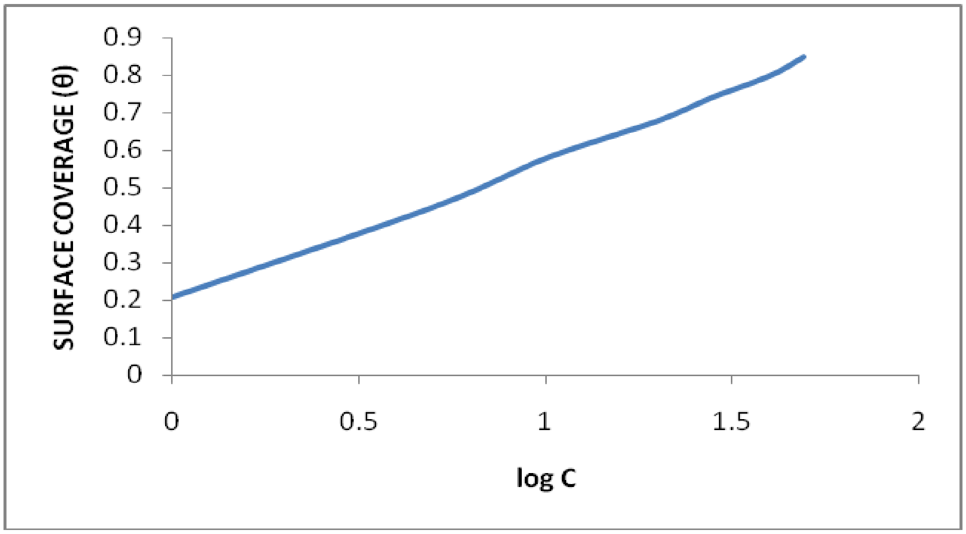


Figure 4 Temkin adsorption isotherm plot for zinc in 1N HCl containing different concentrations of the inhibitor

V. Conclusions

The congo red dye used as a corrosion inhibitor for zinc in 1NHCl performed well and gave high percentage of inhibition efficiency. It exhibited a maximum inhibition efficiency of 84.6% at 50mM concentration. The adsorption of the inhibitor on zinc surface obeyed Temkin adsorption isotherm.

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