Sudan-III Dye as a Novel Corrosion Inhibitor for Zinc Metal in Acidic Solutions

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Abstract- The anticorrosion property of sudan-III dye was evaluated for zinc metal in 0.5N HCl using weight loss, gasometric and thermometric methods. Parameters such as inhibition efficiency and corrosion rates were evaluated to assess the performance of the dye as a corrosion inhibitor. The inhibition efficiency was found to increase with increase in the inhibitor concentration. To study the adsorption of the inhibitor on the metal surface, adsorption isotherm was plotted.

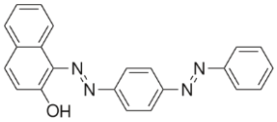
Index Terms- Sudan-III, acidic solutions, zinc corrosion, weight loss, gasometry, thermometry.

I. Introduction

In our day-to-day life, the role of metals and alloys is significant. Metals and alloys find numerous applications in various fields. When they are exposed to different environments, most of them have a strong tendency to undergo oxidation to form their stable compounds, which is termed as corrosion. Due to corrosion of metals and alloys, many important properties such as malleability, ductility and conductance are lost. In order to prevent this corrosion process many synthetic organic compounds with hetero atoms, multiple bonds and aromatic rings, called corrosion inhibitors, are added in small quantities to the corrosive environment. 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[1-18]. In this work, we have examined sudan-III 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, sudan-III dye was obtained from the Loba chemicals, India. 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 were carried out as reported earlier[19-23]. 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 five different concentrations of the inhibitor and the inhibition efficiency(IE) values were calculated. Values of inhibition efficiency obtained from these experiments 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 sudan-III inhibitor				
	10	20	30	40	50
Weight loss	40.6	57.0	67.4	76.2	81.5
Gasometry	40.9	57.6	67.9	75.8	81.6
Thermometry	41.3	58.4	68.2	76.6	82.8

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

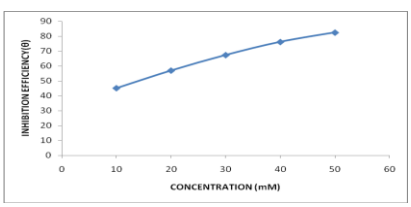


Figure 1 Variation of inhibition efficiency with concentration of the inhibitor.

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 sudan-III inhibitor				
10	20	30	40	50
83.1	60.2	45.6	33.3	25.9

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.

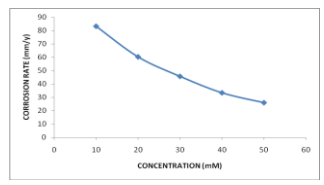


Figure 2 Variation of corrosion rates with concentration of the inhibitor.

The inhibitor molecule contains four nitrogen atoms, two double bonds, one oxygen atom in its molecular structure. All these are potential adsorption centres, through which the inhibitor molecule can 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 azo groups present in the molecule 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 resulting in the enhanced 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.

IV. ADSORPTION ISOTHERMS

Adsorption of inhibitor molecules on the metal surface is characterized by various adsorption isotherms such as Langmuir, Temkin, Freundlich 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.

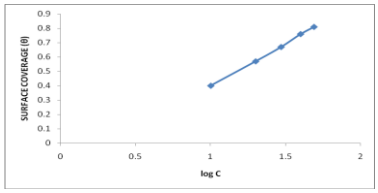


Figure 3 Temkin adsorption isotherm plot for zinc in 0.5N HCl containing different concentrations of the inhibitor

V. CONCLUSIONS

The sudan-III 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 81.5 % at 50mM concentration. The inhibition efficiency of the inhibitor increased with the increase in the concentration of the inhibitor. The adsorption of the inhibitor on zinc surface obeyed Temkin adsorption isotherm.

REFERENCES

[1] Kawai,S., Kato,H., Hatoushika, Y., and Yasumasa,M., Denki Kagaku, 43, (1975) 127.

[2] Cavallaro, L., Felloni, L., and Trabanelli, G., 1st Euro.Symp.Corro. Inhibition, University of Ferrara, Ferrara, Italy, (1960) p 129.

[3] Antropov, L.I., Zasch. Metal. 6, (1970) 440.

[4] Biallazo, S., Elektrokhimiya, 1, (19651137).

[5] Aziz, K., and Shams El din A.M., Corros.Sci, 5, (1965)489.

[6] Ramamani, R., and Shanmuganadhan, S.P., Current Science, 37, (1968)39.

[7] Machu, W., and Gouda, V.K., Werkst.Korro. 13, (1962)745.

[8] Antropov, L.I., Zasch. Metal. 6, (1970)440.

[9] Leroy, R.L., Corrosion, 34, (1978)98.

[10] Elkhar Abo, B., Mostafa, K.M., Kamal,I.A., and Abdel Hamid, K., Ind.J.Chem, 15A, 0 (1977)1010.

[11] Abdel Aal, M.S., Abdel Wahab, A.A., and El Saeed, A., Corrosion, 37, (1981)557.

[12] Stupnisek – Lisac, E., Podbrscek, S., and Soric, T., J. Appl. Electrochem, 24, (1994)779.

[13] Stupnisek – Lisac, E., Kasumic, D., and Varkapic – Furae, Corrosion, 51, (1997)767.

[14] Fouda, A.S., Madkour, L.H., Elshafei, A.A., and Elmaksoud, S.A.A., Bull. Korean. chem.soc., 16, (1995)454.

[15] Mourad, M.Y., Saliman, S.A., and Elmetaal, Bull . Soc. Chim, France, 6, (1991)832.

[16] Mani, N., Venkatakrishna Iyer, S., and Lal Bahadur, Bull.Electrochem, 19, (2003)53.

[17] Mani, N., Venkatakrishna Iyer, S., and Lal Bahadur, Trans. SAEST, 38, (2003)67.

[18] Agarwal, Y.K., Talati, J.D., Shah, M.D., Desai, M.N., and Shah, N.K., Corros.Soc, 46, (2003)633.

[19] S.Muralidharan, M.A.Quraishi and Venkatakrishna Iyer, Corros.Sci.,37(1995) 1739.

[20] S.Rengamani, S.Muralidharan and Venkatakrishna Iyer, Ind.Jour.Chem.Tech, 1 (1995) 168

[21] 15. B.N.Oza and R.S.Sinha, Trans.SAEST, 17(1982) 281.

[22] 16.R.K.Upadhyay and S.P.Mathur, E.J.Chem 4(2007)408.

[23] 17. A.Y.El-Etre, Corros.Sci.43(2001)1031

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