Corrosion Inhibition of Carbon Steel by Cefotaxime Sodium in Acidic Medium

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Abstract -The present study is undertaken to create awareness among the methods of corrosion prevention and control the use of organic inhibitors is one of the most practiced one. The majority of organic inhibitors act by the adsorption on the metal surface. The adsorption is influenced by the chemical structure of the inhibitors. Most of the well-known acid inhibitors are organic compounds containing nitrogen, sulphur and oxygen atoms. The influence of nitrogen containing organic compounds as amines and hetrocyclic compounds on the corrosion of steel in acidic solution have investigate. In this paper deals with the experimental results from weight loss method on corrosion behavior of carbon steel in 0.5N, 1N HCl and 0.5N, 1N H_2SO_4 acids and its inhibition by the antibiotic inhibitor namely cefotaxime Sodium. As a result, the inhibitor produced high efficiency even with very low concentration of the order 1mM.

Key words- Corrosion, Organic Inhibitor, Adsorption, Cefotaxime Sodium.

I. INTRODUCTION

The corrosion cell has four components, the aqueous phase which act as an electrolyte, an anode on the metal surface, a cathode [1]. Now-a-days more attention paid to the study of metallic due to increasing awareness of the need to conserve the world metallic resources, increasing the use of the metals in all fields of technology, use of high strength alloys which are usually more susceptible to certain types of corrosive attack, increasing pollution of air and water resulting in more corrosive environment, strict safety standards of operating equipment, which may fail in a catastrophic manner due to corrosion and slender dimension used in metallic construction, which do not tolerate corrosive attacks [2]. Corrosion inhibitor is a substance, when it is added to a small concentration to an environment reduces the corrosion rate of a metal exposed to that environment. An inhibitor function by adsorption as a film on the corroding medium, inducing the formation of thick product and changing the characteristics of the environment either by producing protonating   precipitates or by inactivating an aggressive constituent [3]. The aim of this investigation is to examine the inhibitory effect of antibiotic Cefotaxime sodium toward the corrosion of mild steel corrosion in hydrochloric acid and sulphuric acid solution.

Weight loss techniques were used in this work to evaluate the inhibition efficiency of the compound.
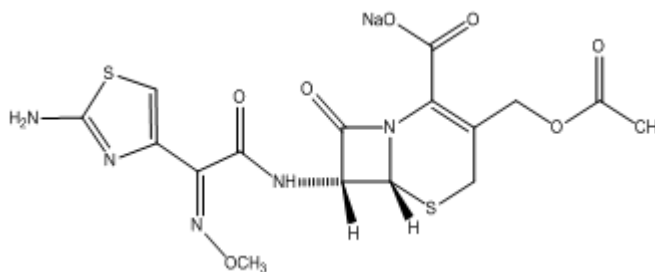
II. EXPERIMENTAL METHODS

The antibiotic Cefotaxime Sodium was procured in the market and used as such.

Molecular formula: $C_{16}H_{16}N_5NaO_7S_2$

Molecular weight   : 477.4

Molecular structure:

Carbon steel specimens of size 2*2.5 cm were employed for weight loss measurements. A hole of diameter 0.05 cm was drilled near the upper edge of the specimen in order to hook it in the glass rod for immersion. The specimens were polished successively with emery of 400,1/0,2/0,3/0 and 4/0 grades and degreased with acetone. The of 5N HCl and 2.5 N H_2SO_4 were prepared with doubly distilled water and were diluted to the required concentrations. From this, diluted acids of required concentrations (1N and 0.5N) were prepared by proper dilution. Inhibitor solutions of different concentration were prepared in the respective acids by properly diluting the bulk solution of the inhibitors (10mM) prepared in conductivity water.

The corrosion of carbon steel was studied by weight-loss method. The temperature was maintained constant throughout these experiments at 300C +_10C. After specified period of immersion, the samples were removed, washed and dried. Weights of the specimen were taken before and after

immersion in inhibited and uninhibited acids at the end of 1 hour.

2.1. Evaluation of inhibition efficiency (%):

Inhibition efficiency of the inhibitor is calculated using the following formula,

Inhibition efficiency (%) = [W_A – W_B/W_A] x 100

Where W_A, W_B are weight loss of specimen with in unit time and unit area prior to end posterior to addition of inhibitors to medium respectively.

2.2. Evaluation of corrosion rate (mmpy):

The corrosion rate is calculated by measuring the loss in weight of specimen of a known area to a particular environment for specified period using formula

Corrosion rate (mmpy) = Weight loss (mg) x 87.6 / Area (cm2) x time (hrs) x density (g cm-3)

2.3. Measurement of surface coverage (θ):

The surface coverage (θ) is calculated using the formula,

Surface coverage (θ)= W_A – W_B / W_A

2. 4. Determination of activation energy:

Activation energy (Ea) is calculate from the formula

Ea (J/mol) =2.303 x R x T_1 x T_2 x log (ρ_2/ ρ_1) / (T_1-T_2)

Where ρ_2,ρ_1 are the corrosion rates at temperatures T_1 and T_2, R respectively is gas constant.

2.5. Free energy of adsorption (ΔGads):

The free energy of adsorption is calculated using formula,

ΔGads = -RT ln (55.5 k)

K = θ/C (1- θ)

Where θ is the degree of coverage on the metal surface, C is the concentration of inhibitor in mole /liter, k is equilibrium constant, R is a gas constant and T temperature in Kelvin scale.

III. RESULTS AND DISCUSSION

3.1. Weight Loss Method

The weight loss experiments were carried with 1N, 0.5N HCl and 1N,0.5N H_2SO_4 acids using various concentration of inhibitor namely cefotaxime sodium. The effect of temperature was also studied by varying the temperature from 30ºC to 60ºC. In this study, the parameters are like inhibition efficiency (%), corrosion rate (mmpy), activation energy(Ea) and free energy of adsorption (ΔG ads)were determined.

3.2 Effect of Nature of Acids

The effect of nature of acids was studied with 1N, 0.5N HCl and 1N, 0.5N H_2SO_4 acids using inhibitor cefotaxime sodium. The corrosion rate and inhibition efficiency were calculated and are given in the tables 1&2 and are shown figures 1,2, 3, & 4. The inhibition efficiency was found to be high and hence corrosion rate was low in HCl than in H_2SO_4. For example, the maximum inhibition efficiency was found to be 70.62%, 75.01% and 44.12%, 42.17% in HCl and H_2SO_4 acids respectively with inhibitor cefotaxime sodium. This likely due to the lesser surface coverage of inhibitor H_2SO_4 media.

3.3 Effect of concentration of the inhibitor

The effect of concentration of inhibitor cefotoxime sodium on inhibition efficiency and corrosion rate was studied by varying the concentration of the inhibitor from 1nM to 3mM with 0.5N, 1.0N of HCl and H_2SO_4 acids concentration. The results given in the Table 1& 2 and are depicted in Figures 1,2, & 4. The values in the table shows that inhibition efficiency increases with increase in concentration of the inhibitor and corresponding there is degrease in the corrosion rate.

Increase in inhibition efficiency with increase in inhibitor concentration indicates that these compounds act as adsorption inhibitor. The inhibitor cefotoxime sodium gave highest efficiency in 0.5 and 1.0N HCl medium.

Table 1. Inhibition Efficiency (%) of carbon steel in varying concentration of the inhibitor in HCl and H_2SO_4 acids

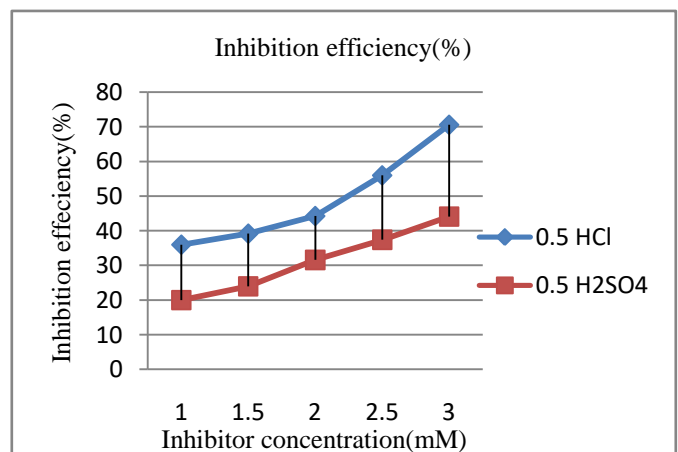| Inhibitor Concentration in mM	Concentration of HCl		Concentration of H_2SO_4	
	0.5N	1N	0.5N	1N
1.0	36.00	30.35	20.01	18.12
1.5	39.19	41.09	23.98	24.02
2.0	44.28	52.47	31.61	29.06
2.5	56.01	69.27	37.42	34.35
3.0	70.62	75.01	44.12	42.17

Fig. 1.Inhibition Efficiency (%) of carbon steel in varying concentration of the inhibitor in 0.5N HCl and 0.5N H_2SO_4 acids.
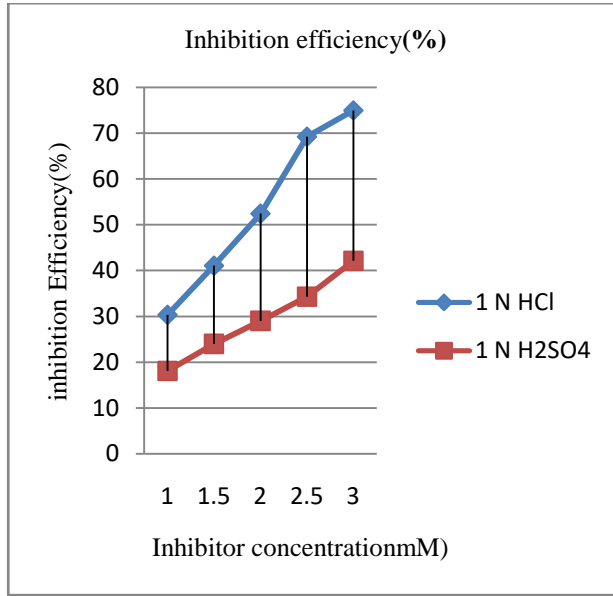
Fig. 2. Inhibition Efficiency (%) of carbon steel in varying concentration of the inhibitor in 1N HCl and 1N H₂SO₄ acids.
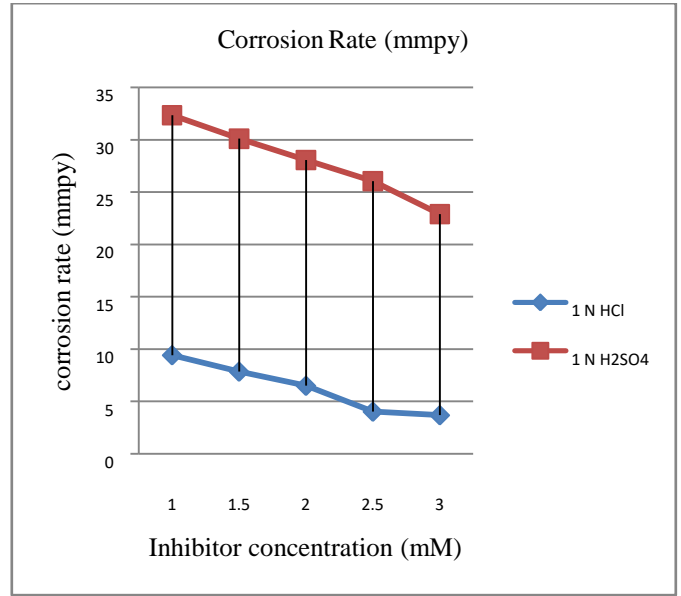
Inhibitor Concentration in mM	Concentration of HCl		Concentration of H₂SO₄	
	0.5N	1N	0.5N	1N
Blank	11.45	13.48	21.34	39.77
1.0	7.41	9.43	16.91	32.35
1.5	6.96	7.86	16.40	30.11
2.0	6.23	6.51	14.60	28.08
2.5	4.94	4.04	13.25	26.06
3.0	3.37	3.70	11.90	22.91

Table 2. Corrosion rate (mmpy) for Carbon steel in varying concentration of the inhibitor in HCl and H₂SO₄ acids.

Fig. 3. Corrosion rate of Carbon steel in varying concentration of inhibitor in 0.5N HCl and 0.5N H₂SO₄ acids.

Fig. 4. Corrosion rate of Carbon steel in varying concentration of inhibitor in 1N HCl and 1N H₂SO₄ acids.

3.4 Effect of concentration of the inhibitor on surface coverage adsorption isotherm.

The surface coverage(θ) values calculated from weight loss measurements for different inhibitor concentrations of cefotaxime sodium are tabulated in the table 3. The surface coverage values were employed to find out the suitable adsorption isotherm. Of all the isotherm tested, Langmuir adsorption isotherm gave the best fit with maximum correlation coffficient (0.9998) nearly unity.

Table 3. Surface Coverage(θ) for Carbon steel in varying concentration of the inhibitor Cefotaxime in HCl and H₂SO₄ acids.

Inhibitor Concentration in mM	Concentration of HCl		Concentration of H₂SO₄	
	0.5N	1N	0.5N	1N
1.0	0.360	0.303	0.200	0.181
1.5	0.391	0.410	0.239	0.240
2.0	0.442	0.524	0.316	0.290
2.5	0.560	0.692	0.374	0.343
3.0	0.706	0.750	0.441	0.421

3.5 Activation energy –Influence of Temperature

To understand the effect of temperature on corrosion rate and inhibition efficiency, the weight loss measurements were carried out at various temperatures ranging from 30º to 60º with 2.5mM of cefotaxime sodium and without inhibitor in 1N,0.5 N HCl and H₂SO₄ acids. From table 6,7 it is clear that in both acids, increases in temperature the inhibition efficiency decreases, suggesting that the inhibitor inhibits corrosion by physisorption. The decrease in efficiency with
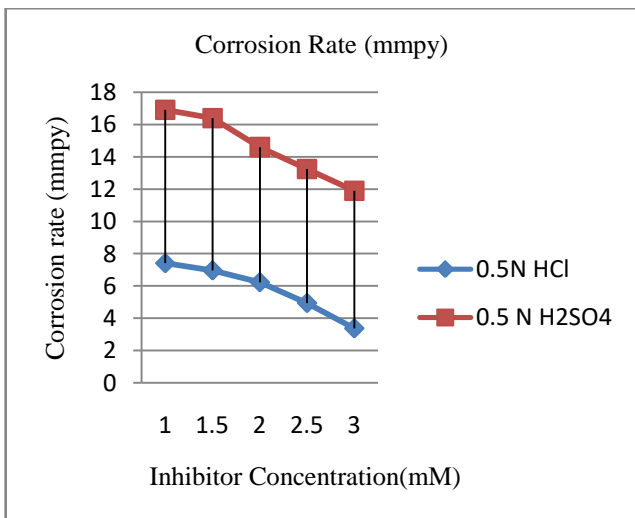
increase in temperature is probably due to the desorption of the inhibitor molecules at higher temperature.

The activation energy is found that Ea values for inhibited systems are higher than for uninhibited acid, indicating that adsorption of these inhibitors occurs through physical mechanism. The values of free energy of adsorption $\Delta Gads$ were calculated from(θ) values at various temperatures and are given Table 4&5. The low more negative values of $\Delta Gads$ indicate the spontaneous adsorption of inhibition on the surface of carbon steel. The more negative values $\Delta Gads$ also suggest that the strong interaction of the inhibitor molecules on to the carbon steel surface. In HCl medium the $\Delta Gads$ values are higher than that in H_2SO_4 medium supporting the fact that the inhibitor functions well in HCl medium.

Table 4. free energy adsorption – $\Delta Gads$ (J mol-1) for the corrosion of carbon steel in the presence of inhibitor in 0.5N and H_2SO_4 acids.

Inhibitor (2.5mM)	Temperature in K			
	303	313	323	333
0.5N HCl	25939.72	26168.11	26720.57	26586.65
0.5N H_2SO_4	24285.97	24559.52	24748.02	25217.63

Table 5. free energy adsorption – $\Delta Gads$ (J mol^{-1}) for the corrosion of carbon steel in the presence of inhibitor in 1N and H_2SO_4 acids.

Inhibitor (2.5mM)	Temperature in K			
	303	313	323	333
1N HCl	27258.84	26650.87	26876.47	27533.69
1N H_2SO_4	18976.83	25754.71	25982.03	26379.08

Table 6. Inhibition efficiency (%), corrosion (mmpy), and activation energy (Ea) for corrosion of carbon steel in 0.5N HCl and H_2SO_4 with 2.5mM concentration of inhibitor cefotaxime sodium at different temperatures

Electrolyte composition	Corrosion rate (mmpy)				Inhibition efficiency (%)				Activation energy
	Temperature in K				Temperature in K				
	303	313	323	333	303	313	323	333	
Blank	23.8	27.6	53.7	88.53	-	-	-	-	50333.25
0.5N HCl+ 2.5 mM inhibitor	2.2	4.0	4.5	9.9	57.18	51.20	48.56	40.02	49997.21
Blank	21.3	176.8	177.8	174.2	-	-	-	-	17236.14
0.5N H_2SO_4+ 2.5 mM inhibitor	13.25	66.6	43.2	142.4	40.92	36.12	31.17	28.92	13186.79

Table 7. Inhibition efficiency (%) , corrosion (mmpy), and activation energy (Ea) for corrosion of carbon steel in 1N HCl and H_2SO_4 with 2.5mM concentration of inhibitor cefotaxime sodium at different temperatures

Electrolyte composition	Corrosion rate (mmpy)				Inhibition efficiency (%)				Activation energy
	Temperature in K				Temperature in K				
	303	313	323	333	303	313	323	333	
Blank	26.51	146.5	177.96	196.8	-	-	-	-	55707.85
1N HCl+ 2.5 mM inhibitor	40.12	41.3	42.4	104.2	69.27	55.81	50.01	48.17	52788.20
Blank	39.77	282.2	295.7	319.5	-	-	-	-	36544.74
1N H_2SO_4+ 2.5 mM inhibitor	26.06	134.82	112.35	127.4	45.23	47.23	41.76	38.23	15285.69

IV. CONCLUSION

Antibiotic cefotaxime sodium is found to be efficient inhibitor which produced high efficiency even with very low concentration of the order 1mM. The inhibitor perform well in both acids (namely 0.5N, 1N HCl and 0.5N, 1N H_2SO_4). However, they have shown better results in HCl media. The inhibitor inhibits corrosion by adsorption on the metal surface and it also obeys Langmuir adsorption isotherm .

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