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# PROTECTION OF ALUMINIUM IN 0.75 M HCL SOLUTION BY ETHYLAMINE: THERMODYNAMIC, KINETIC AND ELECTRODE POTENTIAL STUDY

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# ABSTRACT

The corrosion of aluminium in 0.75 HCl containing ethylamine as an inhibitor has been studied by weight loss, temperature effect and Open Circuit Potential (OCP) methods. Inhibitor concentration increases corrosion rate decreases while Inhibition Efficiency (I.E.) of ethylamine increases at constant acid concentration. As temperature increases, corrosion rate increases while I.E. decreases. The mode of inhibitor action followed by Langmuir adsorption isotherm. The maximum I.E. of 89.25 % was observed with 20 mM ethylamine in 0.75 M HCl.Higher the inhibitor concentrations higher the half-life period and lower the corrosion rate. In presence of inhibitor, the OCP values gradually increase with time towards the positive directions.

Keywords: Corrosion, Aluminium, HCl, Ethylamine, weight loss, OCP.

## I. INTRODUCTION

Corrosion, an irreversible interfacial reaction of a material (metal, ceramic, and polymer) on exposure to aggressive environments, affects the performance efficiency of a material and also leads to reduction of its service life [1,2].

One of the methods usually employed to combat corrosion is the application of corrosion inhibitors and most of the well-known inhibitors are organic compounds. Most of the effective and efficient organic inhibitors are those hetero atoms containing elements such as oxygen, nitrogen, sulphur, and phosphorus, in their structures, which allow them to be adsorbed onto the metal surface [3,4]. Most inhibitors function by being adsorbed onto the metal surface to interact with anodic and/or cathodic reaction sites and influence the oxidation and reduction corrosion reaction, and prevent transportation of water and corrosion active species onto the metal surface [5,6].

Aluminium metal and its alloys are extensively used in automotive, aviation and aerospace, ship building, military hardware and household appliances. However, exposed of the metal to aggressive environments can lead to substantial loss due to corrosion. Industrial acid cleaning, acid descaling and acid pickling are some of the important fields of HCl applications. Various investigators [7-18] have studied ethylamine as corrosion inhibitor in different acid media. Present investigation was carried out to study the effect of ethylamine as corrosion inhibitor for Al in 0.75 M HCl solution by weight loss, temperature effect, rate constant and half-life as well as OCP methods.

## II. EXPERIMENTAL

#### Preparation of sample and solution

The Al specimens with a chemical composition of 99.54 % Al, 0.090 % Si, 0.320 % Fe, 0.0012 % Cu, 0.0034 % Mn, 0.0014 % Mg, 0.0042 % Cr, 0.0046 % Ni, 0.0020 % Zn, 0.0079 % Ti, 0.0005 % Pb, and 0.0026 % Sn were used in the present study. The metal sheet, test specimens of size 5.0 x 2.50 x 0.198cm having an effective area of 0.2797 dm<sup>2</sup>were used. Aluminium specimen was cleaned by washing with distilled water, degreased by acetone, dried and weighted by using electronic balance. HCl acid was used as corrosive solution having concentration of 0.75 M prepared by diluting analytical grade of HCl purchased from Merck using double distilled water.

#### Weight loss measurement

For weight-loss measurement, the Al coupons were completely immersed in 230 mL of 0.75 M acid concentration in without and with of 5, 10, 15 and 20 mM concentrations of ethylamine for 24 h immersion



period at 301± 1 K. After cleaning, test specimens were washed with distilled and dried in air. From the weight loss data, corrosion rate (C.R.) in mg/dm<sup>2</sup> d was calculated using the following equation:

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C.R. 
$$(mg/dm^2d) = \frac{\text{Weight loss } (gm) \times 1000}{(metal surface area)dm^2 \times day}$$
 (1)

I.E. calculated by following equation:

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I.E. (%) = 
$$\left\{\frac{(W_u - W_i)}{W_u}\right\} \times 100$$
 (2)

Where, Wu is the weight loss of aluminium in uninhibited acid and Wi is the weight loss of aluminium in inhibited acid.

The degree of surface coverage ' $\theta$ ' for different concentration of the ethylamine in acidic medium have been evaluated from weight loss experiment using the equation:

$$\theta = \frac{W_{\text{uninh}} - W_{\text{inh}}}{W_{\text{uninh}}}$$
(3)

#### **Temperature effect**

To study the effect of temperature on corrosion rate, Aluminium specimen was totally immersed in 230 ml of 0.75 M HCl solution without and with different concentrations of Ethylamine at 313, 323 and 333 K for 2 h.

#### **Open Circuit Potential (OCP) measurement**

The corrosion behavior studies of metal are the measurements of OCP with time. For OCP measurement, Al specimens having as area of 1.0 cm<sup>2</sup> were immersed to 230 mL of 0.75 M HCl with and without of 20 mM inhibitor concentration. Potential was measured immediately after the immersion of metal specimens using saturated calomel electrode (SCE) as a reference electrode as a function of time. The potential values were continuously recorded after each interval of 5 minutes till the potential attained a steady state value (E s.s.).

#### III. **RESULTS AND DISCUSSION**

#### Weight loss experiments

Corrosion rate and I.E. of ethylamine for Al in 0.75 M HCl was studied by weight loss method for an immersion period of 24h at 301 ± 1 K and results are shown in Table 1.

**Table 1.** Corrosion rate (log  $\rho$ ), Inhibition efficiency (I.E.) and Surface coverage ( $\theta$ ) of ethylamine on Al in 0.75 M HCl for an immersion period of 24h at  $301 \pm 1$  K.

Inhibitor	Inhibitor Concentration (mM)	C.R. (ρ) (mg/dm <sup>2</sup> d)	log ρ	I.E. (%)	Surface coverage (θ)	C/Ð
Blank	-	2195.20	3.34	-	-	-
Ethylamine	5	464.78	2.66	78.82	0.7882	06.345
	10	393.27	2.59	82.08	0.8208	12.195
	15	314.62	2.49	85.66	0.8566	17.523
	20	235.96	2.37	89.25	0.8925	22.421

#### Effect of inhibitor concentration

A constant acid concentration, as the inhibitor concentrations increases corrosion rate decreases (Figure 3.1) while I.E. increases (Figure 3.2). In 0.75 M HCl solution, the I.E. was 78.82, 82.08, 85.66 and 89.25 % corresponding to 5, 10, 15 and 20 mM inhibitor respectively (Table 1).



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**Figure 3.1:** Corrosion rate of Al in 0.75 M HCl solution in absence and presence of various concentration of Ethylamine for an immersion period of 24 h.



**Figure 3.2:** Inhibition efficiency (I.E.) of Al corrosion in 0.75 M HCl solution in presence of different concentration Ethylamine for an immersion period of 24 h.

#### **Temperature effect**

To investigate the influence of temperature on corrosion of Al, the weight loss experiment was carried out at 313, 323 and 333K temperatures in 0.75 M HCl in without and with of ethylamine for an immersion period of 2h. Result in Table 3 shows that corrosion rate increases with increase in temperature. Corrosion rate was 21451.44, 26642.76 and 43417.92 mg/dm<sup>2</sup>d corresponding to 313, 323 and 333K respectively. This may be due to the desorption of the adsorbed molecules inhibitor and/ or aggressive at higher temperature and thus exposing the fresh metal surface to further attack [19], which results in intensification of the kinetic of electrochemical reaction [20] and thus explains the higher corrosion rate at elevated temperature. The addition of ethylamine in corrosive media indicates that as the temperature increases I.E. of inhibitor decreases (Table 2).



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**Table 2.** Temperature effect on corrosion rate (CR), Energy of activation (Ea) and Heat of adsorption (Qads) forAl in 0.75 M HCl in without and with of Ethylamine for an immersion period of 2 h.

	Temperature							Qads	
Inhibitor	313 K		323 K		333 K		Mean (E <sub>2</sub> )	(kJ/ mol)	
conc. $(\alpha/L)$	CR	I. E.	CR	I. E.	CR	I. E.	(kJ/	313-	323-
(g/L)	mg/dm²d	(%)	mg/dm <sup>2</sup> d	(%)	mg/dm <sup>2</sup> d	(%)	mol)	323 K	333 K
Blank	21451.44	-	26642.76	-	43417.92	-	30.92	-	-
5	8323.20	61.19	10768.68	59.58	20207.28	53.45	38.97	-05.65	-22.35
10	6993.12	67.40	9524.40	64.25	17075.40	60.67	39.09	-11.77	-13.66
15	5663.16	73.60	8409.00	68.43	15573.72	64.13	44.17	-21.15	-17.22
20	4504.80	79.00	7422.12	72.14	14286.72	67.09	50.27	-31.41	-21.39

#### Energy of activation (E<sub>a</sub>)

The value of 'E<sub>a</sub>' calculated using Arrhenius equation [21].

$$\log \frac{\rho_2}{\rho_1} = \frac{E_a}{2.303R} \left( \frac{1}{T_1} - \frac{1}{T_2} \right)$$
(4)

where,  $\rho_1$  and  $\rho_2$  are the corrosion rate at temperature  $T_1$  and  $T_2$  respectively. Results given in Table 2, indicates that the mean values of  $E_a$  were higher in inhibited acid ranging from 38.97 to 50.27 kJ/mol than  $E_a$  value for uninhibited acid (30.92 kJ/mol) which indicates physical adsorption of the inhibitor on metal surface [22]. The value of  $E_a$  was also calculated from the slope of the Arrhenius plot of log  $\rho$  versus 1/T x 1000 (Figure 3.3) which is also in good agreement with the calculated values.





#### Heat of adsorption(Q<sub>ads</sub>)

The values of 'Q<sub>ads</sub>' were calculated by using the following equation [23]:



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 $Q_{ads} = 2.303 R \left[ log \left( \frac{\theta_2}{1 - \theta_2} \right) - log \left( \frac{\theta_1}{1 - \theta_1} \right) \right] \left[ \frac{T_1 T_2}{T_2 - T_1} \right]$ (5)

where,  $\theta_1$  and  $\theta_2$  are the fraction of the aluminium surface covered by the inhibitor at temperature  $T_1$  and  $T_2$ respectively. It is evidence that in all cases, the value of  $Q_{ads}$  was negative and ranging from -05.65 to -31.41 kJ/mol. The negative value of  $Q_{ads}$  shows that I.E. decreases with rise in temperature supporting the physisorption mechanism [24].

#### Adsorption isotherm

Basic information on the interaction between inhibitors and a metal surface can be provided using the adsorption isotherm [25]. Due to adsorption, inhibitor molecules block the reaction sites and reduce corrosion rate. The surface coverage ' $\theta$ ' value was calculated by using equation 3. A plot of inhibitor concentration C<sub>inh</sub> versus C<sub>inh</sub>/ $\theta$  was presented in Figure. 3.4 which gives straight line with slope values equal to unity indicates that the system follows Langmuir adsorption isotherm [26]. This isotherm can be represented as,

$$\frac{C}{\theta} = \frac{1}{K_{ads}} + C$$
 (6)

where,  $K_{ads} \, is$  the equilibrium constant and  $C_{inh} \, is$  the inhibitor concentration.



Figure 3.4: Langmuir adsorption isotherm plot for Al in 0.75 M HCl containing Ethylamine as inhibitor at 301 K.

Table 3. Thermodynamic parameters of Al in 0.75 M HCl in absence and presence of	Ethylamine
as an inhibitor.	

Inhibitor	Inhibitor	Free ene	rgy of ads	orption (Δ	G° <sub>ads</sub> )	$\Delta H^{\circ}_{ads}$		$\Delta S^{\circ}_{ads}$	
	Concent-								
	ration	313 K	323 K	333 K	Mean	313 K	323 K	313 K	323 K
	(g/L)								
Blank	00	-	-	-	-	18.18	43.61	-	-
Ethylamine	5	-07.14	-07.36	-07.60	-07.36	19.04	53.60	0.083	0.188
	10					23.36	49.52	0.097	0.176
	15					30.62	52.42	0.120	0.185
	20					39.36	55.88	0.148	0.195



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#### Free energy of adsorption ( $\Delta G^{\circ}_{ads}$ )

 $\Delta G^{\circ}_{ads}$  was determined by the Langmuir isotherm was given by a plot of C/ $\theta$  versus C (Figure 3.4). From the intercepts of the straight line on the C/ $\theta$  axis, K<sub>ads</sub> can be calculated which was related to  $\Delta G^{\circ}_{ads}$  as given by the following equation [27]:

 $\Delta G_{ads}^{\circ} = -RT \ln (55.5 K_{ads})$ (7)

where, R is the gas constant, T is the concentration of water in solution in Molar [28].  $K_{ads}$  is the equilibrium constant of the adsorption/desorption process. The mean  $\Delta G^{\circ}_{ads}$  value was negative (-07.36 kJ/mol) indicating that the adsorption mechanism of ethylamine on Al in 0.75 M HCl at the studied temperatures is physisorption with adsorptive layer having electrostatic character [29]. These are concluded on the fact that the values of  $\Delta G^{\circ}_{ads}$  -20 kJ/mol are consistent with physisorption, while those around -40 kJ/mol or higher are associated with chemisorptions [30].

#### Enthalpy of adsorption ( $\Delta H^{\circ}_{ads}$ )

 $\Delta H^{\circ}_{ads}$  was calculated using the equation (8):

 $\Delta H^{\circ}_{ads} = E_a - RT \qquad (8)$ 

A result indicates in Table 3 that values of  $\Delta H^{\circ}_{ads}$  were positive and ranging between 19.04 to 55.88 kJ/mol indicates the endothermic nature of the reaction suggests that higher temperature favors the corrosion process [31].

#### Entropy of adsorption ( $\Delta S^{\circ}_{ads}$ )

 $\Delta S^{\circ}_{ads}$  was calculated using the following equation (9):

$$\Delta S^{\circ}_{ads} = \Delta H^{\circ}_{ads} - \Delta G^{\circ}_{ads} / T$$
<sup>(9)</sup>

Positive values of  $\Delta S^{\circ}_{ads}$  ranging from 0.083 to 0.195 kJ/mol (Table 3) indicate that corrosion is entropically favourable process [32].

#### Kinetic parameters: Rate constant (k) and Half-life (t<sub>1/2</sub>)

The rate constant 'k' was calculated using the following equation [33]:

$$k = 1/t \ln (W_i/W_f)$$
 (10)

Where, ' $W_i$ ' is the initial weight of the sample, ' $W_f$ ' is the final weight of the sample: 't' is the immersion time (in hours).

The values of half-life  $(t_{1/2})$  were calculated by using the following equation [34]:

$$t_{1/2} = 0.693 / k$$
 (11)

where, 't' is time in hours and 'k' is rate constant.

As inhibitor concentration increases, rate constant 'k' decreases whereas the half-life values are increases [35]. Corrosion rate constant 'k' increases with increase in acid concentration (Table 4). A plot of Inhibitor concentration against Half-life ' $t_{1/2}$ ' is shown in figure 3.5.



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Table 4. Kinetic data for the corrosion of Al in 0.75 M HCl in absence and presence of Ethylamine.

	Inhibitor	0.75 M HCl				
Inhibitor	concentr ation. (g/L)	Rate const. (k×10 <sup>-3</sup> ) (day <sup>-1</sup> )	Half life (t <sub>1/2</sub> ) (day)			
Blank	0.0	99.48	07.00			
	0.6	20.29	34.15			
Ethylamino	0.8	17.05	40.64			
Ethylannie	1.0	13.40	51.71			
	1.2	10.14	68.34			



Figure 3.5: Plot of rate Half -life against inhibitor concentration containing Ethylamine Al in 0.75 M HCl containing Ethylamine.

#### **Open Circuit Potential (OCP) measurement**

Values of OCP immersed (Eim) and steady state (Es.s) for Al in 0.75 M in HCl containing 20 mM ethylamine at 301 K. was shown in figure 3.6. It is noted that the initial potential (Eim) value for the corrosive solution without inhibitor gradually decreases with time i.e. from -901 mV and stabilizes at -878mV (Es.s) after 40 min. of immersion time. Where as in presence of inhibitor the OCP values gradually increases (less negative direction) compared to potential of uninhibited acid with time towards the positive directions and stabilize at -725 mV (Es.s) after 40 min. of immersion suggesting polarization of local anodes. The shift of OCP in the positive direction indicates the interference of this inhibitor with the anodic partial process [36] blocking the anodic reaction sites of the metal respectively [37]. It is quite understand able that change in potential with time depends on a number of factors like area of local anodes and cathodes, kinetics of anodic and cathodic reactions, anions present, dissolved oxygen.



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**Figure 3.6:** Open Circuit Potential (OCP) values for Al in 0.75 M in HCl with time in absence and presence of 20 mM ethylamine.

#### Mechanism of corrosion inhibition by Ethylamine

The mechanism of inhibition of corrosion is believed to be due to the formation of a protective film on the metal surface. The inhibitive action of ethylamine has been attributed to the strong adsorption on the metal surface using the lone pair of electrons available on the hetero-atoms. Structure of ethylamine was shown in figure 3.7 as shown below:



Figure 3.7: Structure of Ethylamine.

#### **IV. CONCLUSION**

- 1. At constant acid concentration, as the inhibitor concentration increases corrosion rate decreases while I.E. increases.
- 2. With increase in temperature, corrosion rate increases while I.E. decreases.
- 3. Ethylamine shows maximum I.E. of 89.25 % at 20 mM concentration in 0.75 M HCl.
- 4. Inhibition of Al in HCl by Ethylamine was found to obey Langmuir adsorption isotherm.
- 5. Higher the inhibitor concentrations higher the half-life period and lower the corrosion rate.
- 6. OCP value increase (less negative direction) compared to potential of uninhibited acid with time towards the positive directions suggesting polarization of local anodes.

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# V. REFERENCES

- [1] Obot, I. B., Obi-Egbedi,N. O.,Umoren, S. A., Ebenso,E.E. (2010).Synergistic and Antagonistic Effects of Anions and Ipomoea invulcrata as Green Corrosion Inhibitor for Aluminium Dissolution in Acidic Medium, International Journal of Electrochemical Science, 5 (7), 994-1007.
- [2] Alaneme, K. K., Olusegun,S. J. (2012). Corrosion inhibition performance of lignin extract of sun flower (Tithonia diversifolia) on medium carbon low alloy steel immersed in H<sub>2</sub>SO<sub>4</sub> solution, Leonardo Journal of Sciences, 20(11), 59-70.
- [3] Singh,A.,Ebenso,E. E., Quraishi,M. A. (2012). Stem Extract of Brahmi (Bacopa monnieri) as Green Corrosion Inhibitor for Aluminum in NaOH Solution, International Journal of Electrochemical Science, 7 (1),3409-3419.
- [4] Satar, M. Z. M., Noor, M. F. M., Samsudin, M. W., Othman, M. R. (2012). Corrosion Inhibition of Aluminum by Using Nipah (NypaFruticans) Extract Solutions in Hydrochloric Acid (HCl) Media, International Journal of Electrochemical Science, 7, 1958 - 1967.
- [5] Khadom, A. A., Yaro, A. S., Abdul, A. H. (2010). Adsorption mechanism of benzotriazole for corrosion inhibition of copper-nickel alloy in hydrochloric acid, Journal of the Chilean Chemical Society, 55 (1),150-152.
- [6] Olusola, J. O., Oluseyi, A. K., Kehinde O. O., Olayinka, A. O., Oluwatosin, J.M. (2009). Adsorption behavior of [(4-hydroxy-6-methyl-2-oxo-2hpyran-3-yl)-(4-methoxy-phenyl)-1methyl]-urea on stainless steel in phosphoric media, Portugaliae Electrochimica Acta, 27 (5), 591- 598.
- [7] Vashi, R.T., and Bhajiwala, H.M. (2002). Ethylamine as corrosion inhibitors for zinc in [HNO<sub>3</sub> + HCl] binary mixtrure, Bulletin of Electrochemistry,18(6), 261-266.
- [8] Vashi, R.T., and Naik, D. (2006). Ethylamines as corrosion inhibitor for zinc in phosphoric acid, Trans. SAEST, 41, 68-73.
- [9] Zele, S.A., and Vashi, R.T. (2016). Inhibition of corrosion of zinc in sulphuric acid by ethylamines, International Journal of Chemical Studies, 4(5), 31-38.
- [10] Desai, S.A., Vashi, R.T., and Champaneri, V.A. (2018). Diethylamine as corrosion inhibitor for zinc in sulfamic acid,Ayudh,37, 51.
- [11] Onuchukwu, A.I., Akpan, I.A., and Offiong, N.O. (2013). Effects of ethanolamine and ethylamine on the entropy content of the corrosion of galvanized steel in 1 mol/l NaCl solution, Material Science, An Indian Journal, 9(3), 83-90.
- [12] Akpan, I.A. and Offiong, N.O. (2013). Effects of ethanolamine and ethylamine on the entropy content of the corrosion of aluminium in 1 mol/l HCl solution, Physical Chemistry, An Indian Journal,8(3),87-92.
- [13] Akpan, I.A., and Offiong, N.O. (2013). Effects of ethanolamine and ethylamine on the entropy content of the corrosion of mild steel in 1 mol/L solution. Physical Chemistry, An Indian Journal, 8(3), 112-117.
- [14] Vashi, R.T., Bhajiwala, H.M., and Desai, S.A. (2009). Prevention of zinc metal in (HNO<sub>3</sub> + H<sub>2</sub>SO<sub>4</sub>) binary acid mixture by ethylamines, Oriental Journal of Chemistry, 8(3), 555-560.
- [15] Vashi, R.T., Desai, S.A., and Desai, P.S. (2008).Ethylamines as corrosion inhibitors for zinc in nitric acid, Asian Journal of Chemistry, 20(6), 4553-4560.
- [16] Akpan, I.A., and Offiong, N.O. (2012). Effect of ethanolamine and ethylamine on the entropy content of the corrosion of mild steel in tetraoxosulphate (VI) acid solution, Chemistry and Materials Research, 2(7), 40-47.
- [17] Vashi, R. T., Desai, Krunal.,Naik, Diksha. (2019). Corrosion inhibitory effect of ethylamine on zinc in HCl solution, Research Journal of Recent Sciences, 8(4), 40-46.
- [18] Vashi, R. T.Bhajiwala, H., (2010).Corrosion inhibition effect of ethylamines on zinc in (HNO<sub>3</sub> + H<sub>3</sub>PO<sub>4</sub>)binary aid mixure, Der Pharma Chemica, 2(2), 272-280.
- [19] Deyas, M. A. (2015).Egyptian licorice extract as a green corrosion inhibitor for copper in hydrochloric acid solution, J. Ind. and Eng. Chem, 22, 384-389.
- [20] Halambek, J.,Zutinic, A., Berkovic, K. (2013). Ocimumbasilium L. oil as corrosion inhibitor for aluminum in hydrochloric acid solution, International Journal of Electrochemical Science,8, 11201-11214.
- [21] Bruker, G. R., Phipps, P. B. (1979). Aliphatic amines as corrosion inhibitors for zinc in hydrochloric acid, Corrosion Chemistry. ACS, 293.



[22] Hosseini, M. G., Mertens, S. F. L., Arshadi, M. R. (2003). Synergism and antagonism in mild steel corrosion inhibition by sodium dodecylbenzene sulphonate and hexamethylene tetraamine,CorrosionScience,45, 1473-1489.

**Impact Factor- 5.354** 

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- [23] Thomson, R. H.(1971). Naturally Occurring Quinone, third ed, Academic Press, London, New York, 74.
- [24] Martinez, J. S., Matikos-Hukovic, M. (2003). A nonlinear kinetic model introduced for the corrosion inhibitive properties of some organic inhibitors, Journal of Applied Electrochemistry, 33, 1137-1147.
- Khaled, K.F. (2003). The inhibition of benzimidazole derivatives on corrosion of iron in 1 M HCl [25] solutions, Electrochim. Acta, 48, 2493
- Mu,G.,Li,X.,andLiu,G. (2005). Synergistic inhibition between 60 and NaCl on the corrosion of cold rolled [26] steel in 0.5 M sulfuric acid, Corrosion Science, 47, 19-32.
- [27] Oguzie, E. E.(2008). Evaluation of the inhibitive effect of some plant extracts on the acid corrosion of mild steel, Corrosion Science, 50 (11), 2993.
- [28] Langmuir, I. (1916). The constitution and fundamental properties of solids and liquids. Part I. Solids.Journal of American Chemical Society, 38, 2221, DOI:10.1021/ja02268a002.
- [29] Donahue, F.M., and Nobe, K.(1965). Theory of organic corrosion inhibitors and linear free energy relationship, Journal of Electrochemical Society, 112, 886-891.
- [30] Yurt, A., Ulutas, S., and Dal, H.(2006). Some factors affecting the corrosion behaviour of mild steel in acidic solution, Applied Surface Science, 253, 919-925.
- [31] Yaro, A. S., Khadom, A. A., Ibraheem, H. E. (2011). Peach juice as an anti-corrosion inhibitor of mild steel, Anti corrosion Methods and Materials, 58(3), 116-124.
- [32] Issa, R. M., El-Sonbati, A. Z., El-Bindary, A. A., Kera, H. M. (2002). Polymer complexes XXXIV. Potentiometric and thermodynamic studies of monomeric and polymeric complexes containing 2acrylamidosulphadiazine, Europeain Polymer Journal, 38(3), 561-566.
- [33] Ebenso, E. E. (2003). Effect of halide ions on the corrosion inhibition of mild steel in H<sub>2</sub>SO<sub>4</sub> using methyl red, Part I, Bulletin of Electrochemistry, 19(5), 209-216.
- [34] Ebenso, E. E. (2004). Effect of methyl red and halide ions on the corrosion inhibition of aluminium in H<sub>2</sub>SO<sub>4</sub>, Part 2, Bulletinof Electrochemistry, 20, 551.
- Talati, J. D., and Modi, R. M. (1986). Inhibition of corrosion of aluminium-copper alloy in NaOH, Trans. [35] SAEST, 11, 259.
- Prasad, D., Sanyal, S. (1997). Studies on adsorption of chromate as inhibitor for mild steel in aqueous [36] solution of mixture of aggressive ions, Journal of Indian Chemical Society, 74(8), 637.
- [37] Bockris, J. O. M., and Reddy, A. K. N. (1970). Modern Electrochemistry, 2, Plenum press, New York.