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The corrosion inhibition study of Al - Pure By p-Anisidine -N-Benzylidene Schiff base in HCl solution

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Abstract

In this investigation, the inhibition effect of p-Anisidine-N-Benzylidene (p-AnNB) on the corrosion of Al-Pure in 1.0 M HCl has been studied by weight loss, galvanostatic polarization, and electrochemical impedance spectroscopy (EIS) measurements. It was found from the polarization curves that the used Schiff base is of mixed type inhibitor with predominant effect on cathode. The changes in polarization and impedance parameters values (I_{corr}, R_{ct} and C_{dl}) obtained indicate that the adsorbed protective film grows with increasing concentration of inhibitor. The adsorption of used compound on Al-Pure found to obey langmuir isotherm. Some thermodynamic parameters (ΔG_{ads} and Q_{ads}) and activation energy (E_a) were calculated to elaborate the mechanism of corrosion inhibition. The Schiff base used for investigation is an excellent inhibitor for Al-Pure in 1.0 M HCl. The optimum concentration of this inhibitor is 0.5% with around 99.78% inhibition efficiency. The obtained results from various techniques are in good agreement.

Keywords: Corrosion, Inhibitor, Aluminium, p-AnNB, Electrochemical,EIS;

1. Introduction

Aluminium and its alloys are very good corrosion resistant materials in neutral aqueous solution, due to the formation of passive film. Aluminium and its alloys have remarkable economic and attractive materials for engineering applications owing to its low cost, light weight, high thermal and electrical conductivity [1]. It is well known that pitting corrosion occurs on metals covered with passive films. The corrosion of metal is the result of two simultaneous reactions that are in electrical equilibrium, i) Oxidation of metal to metal ions, ii) Reduction of hydrogen to hydrogen gas. Hydrochloric acid and sulphuric acid solutions are used for pickling of aluminium or for its chemical or electrochemical etching. It is very important to add corrosion inhibitors to decrease the rate of metal dissolution in such solutions.

Inhibition of metal corrosion by organic compounds is a result of adsorption of organic molecules or ions at the metal surface forming a protective layer. This layer reduces or prevents corrosion of the metal. The action of such inhibitors depends on the specific interaction between the functional groups and the metal surface. The extent of adsorption depends on the nature of the metal, the metal surface condition, the mode of adsorption, the chemical structure of the inhibitor and the type of corrosion media [1, 2]. Thus, many studies concerning the inhibition of Al corrosion using organic substances are conducted in acidic and basic solutions [2-7]. In earlier work from this laboratory, the use of various Schiff bases as corrosion inhibitors for zinc in sulphuric acid [8-16] and hydrochloric acid [17-18] has been reported.

In the present work the corrosion of Al-Pure in hydrochloric acid, containing pare-Anisidene-N-benzylidene has been reported. Due to the presence of an imine >C = N- group and conjugated double bonds, these should function as good inhibitors. The effect of inhibitor concentration, exposure period and temperature on the behavior of the Schiff base has been investigated.

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2. Experimental

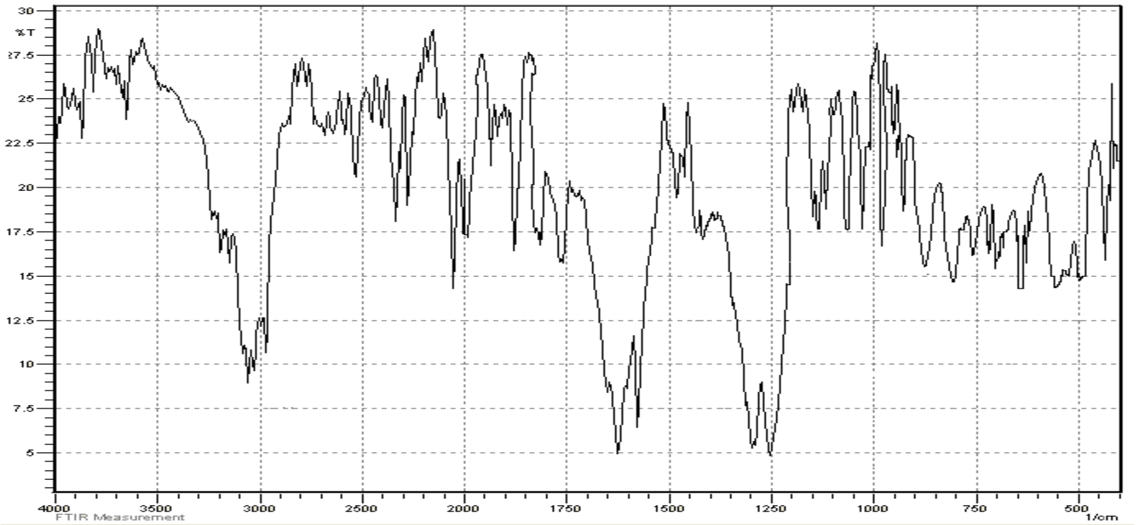
2.1. Material

Rectangular specimens of Al-Pure, of size 6.0cm × 3.0 cm (thickness = 0.050 cm), with a small hole of ~ 2mm diameter just near one end of the specimens were used for the determination of corrosion rate in weight loss method. The specimen were polished to mirror finish using successively “0” to “0000” Oakey emery followed by jeweler’s rough. The specimens were finally degreased with A.R. carbon tetrachloride (sulphur free).

The corrosive solution (1.0 M) were prepared by dilution of analytical grade 37% HCl (NICE) with double distilled water. The concentration range of employed inhibitor was 0.0001% to 0.5 % in 1.0 M HCl. The used all chemicals for preparation of Schiff’s base were AR grade (MERCK).

2.2. Synthesis of Schiff base

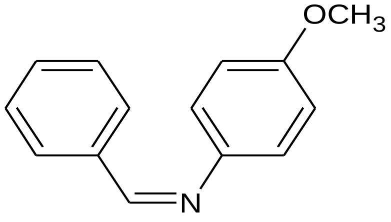
The Schiff’s base was synthesized from equimolar amount of benzaldehyde with p-Anisidine through a condensation reaction in the methanol media as per described by Shah et al.[19]. Synonym of p-Anisidine-N-benzylidene (p-AnNB) is [Benzeneamine-4-methoxy-N-phenylmethylene], which is Grey crystalline substance, m.p. 70°C, is insoluble in water but soluble in acetone. The chemical structure of used Schiff’s base is characterized by IR (fig.1), which is shown below:



aromatic ring :- 3080 cm^{-1}, >C=N- :- 1647 cm^{-1}, -C-OCH_3 :- 1258 cm^{-1}

Fig.1 : IR Spectra of p-AnNB.

Three methods namely weight loss method, impedance spectroscopy and polarization study was used to determine the corrosion inhibition efficiencies of p-AnNB.



p-AnNB

2.3. Accelerated Ageing test

- Weight loss method:

In weight loss method, the test specimens were immersed in 230 ml of 1.0 M hydrochloric acid solution containing various concentration of inhibitor of p-AnNB in the range 0 – 0.5%. One specimen only was suspended by a Pyrex glass hook in each beaker containing 230 ml of the test solution which was open to the air at 35º ± 0.5º C (unless otherwise specified) for different exposure period, to the same depth of about 1.5 cm below the surface of the solution. The weight of the specimen before and after immersion was determined using mettler balance – M5 type. The accuracy of the balance was 0.0001gm. Triplicate experiments were performed. After completing weight loss experiments the metal coupon was washed with double distilled water, dried and weighed. Experiment (the loss in weight of specimen) were carried out at 0.05%,0.1% & 0.5% concentration of inhibitor at temperature ranging from 35º ± 0.5º C to 65º ± 0.5º C.

2.4. Electrochemical measurements

Electrochemical experiments were carried out using a standard electrochemical three electrode cell assembly, Al-Pure was used as working electrode, platinum as counter electrode and saturated calomel electrode (SCE) as reference electrode. The test solution was contained in

H-type (80 ml in each limb) Pyrex glass cell with Luggin capillary as near to the electrode surface as possible and porous partition to separate the two compartments.

(a) The potential was measured against a saturated calomel electrode (SCE),in polarization study. The corrosion parameters such as corrosion potential (E_{corr}), corrosion current density (I_{corr}) and Tafel plots were measured in polarization method. In this study, the current density was varied in the range of 2×10^{-4} to 3.25×10^{-4} A cm^{-2}.

(b) Electrochemical impedance measurements were carried out in the frequency range of 20 kHz – 0.1 Hz at the open circuit potential (OCP), after 30 minutes of immersion by applying amplitude of 5 mV sine wave ac signal (AUTOLAB). Double layer capacitance ($C_{\mathbf{dl}}$) and charge transfer resistance ($R_{\mathbf{ct}}$) values were calculated from Nyquist plots as described by Hosseine [20]. EIS data were analyzed using frequency response analyzer (FRA) electrochemical setup.

3. Results and Discussion

3.1. Weight loss measurements

3.1.1 Effect of inhibitor concentration

The percentage of inhibition efficiency and surface coverage obtained from weight loss method at different concentrations of inhibitor for the corrosion of Al-Pure in 1.0 M HCl for an immersion period of 60 min. at 35°C are given in Table-1. The results show that inhibitor actually inhibited the corrosion of Al-Pure in 1.0 M HCl. At constant temperature the IE% increases with increasing inhibitor concentration. This behavior is the result of increased adsorption of the inhibitor on the metal surface. The inhibition efficiency (IE %) and degree of surface coverage (θ) were calculated using equations 1 and 2, respectively [21],

$$Inhibition\ Efficiency(IE\%) = \frac{W_u - W_i}{W_u} \times 100 \quad .... \quad (1)$$

$$Surface\ coverage\ (\theta) = \frac{W_u - W_i}{W_u} \quad ....(2)$$

Where W_u and W_i are the weight loss of Al-Pure in 1.0 M HCl in absence and presence of p-AnNB.

Table 1. (i) Corrosion parameters obtained from weight loss measurements for Al – Pure in 1.0 M HCl containing different concentrations of inhibitor at 35° ± 0.5° C for exposure period of 60 min.

Inhibitor	Concentration (%w/v)	Weight loss (mg dm^{-2})	Surface coverage (θ)	(%IE)
Blank	-	2312	-	-
p-AnNB	0.0001	1314	0.4317	43.17
	0.0005	1018	0.5597	55.97
	0.001	224	0.9031	90.31
	0.01	102	0.9559	95.59
	0.05	51	0.9779	97.79
	0.1	32	0.9859	98.59
	0.5	5	0.9978	99.78

3.1.2 Adsorption behavior

It is generally assumed that the adsorption of the inhibitor at the metal/solution interface is the first step in the mechanism of inhibition in aggressive media. Two main types of interaction can describe the adsorption of inhibition namely: 1) Physical adsorption, 2) Chemical adsorption. In view of the above discussion, two modes of adsorption, physisorption and chemisorption, should be considered. The proceeding of physical adsorption requires the presence of electrically charged metal surface and charged species in the bulk of the solution [22]. While chemical adsorption process involved charge sharing or charge transfer from the inhibitor molecules to the vacant p-orbital in Al surface [22]. According to Shreir et. al., [23] an adsorption isotherm gives the relationship between the coverage of an interface with an adsorbed species (the amount adsorbed) and the concentration of species in solution; in electrochemical reactions the coverage will depend also on the potential of the interface.

The extent of corrosion inhibition depends on the surface conditions and the mode of adsorption of the inhibitors [24], under the assumptions that the corrosion of the covered parts of the surface is equal to zero and that corrosion takes place only on the uncovered parts of the surface. Basic information on the interaction between the organic compounds and metal surface can be provided from the adsorption isotherms. So several adsorption isotherms [Langmuir isotherm, Frundlich isotherm and Temkin isotherm] were tested for the description of adsorption behavior of studied compound and it is found that adsorption of studied Schiff base on Al-Pure surface in HCl solution obey the Langmuir adsorption isotherm given by Eq.3:

$$C_{inhi} = \frac{\theta}{k(1-\theta)} \qquad ....(3)$$

where, C_{inh} is the inhibitor concentration, θ is the surface coverage values and K is the equilibrium constants of adsorption process. Typical plot of log (θ/1-θ) vs log C_{inh} for p-AnNB is given in Fig.2.

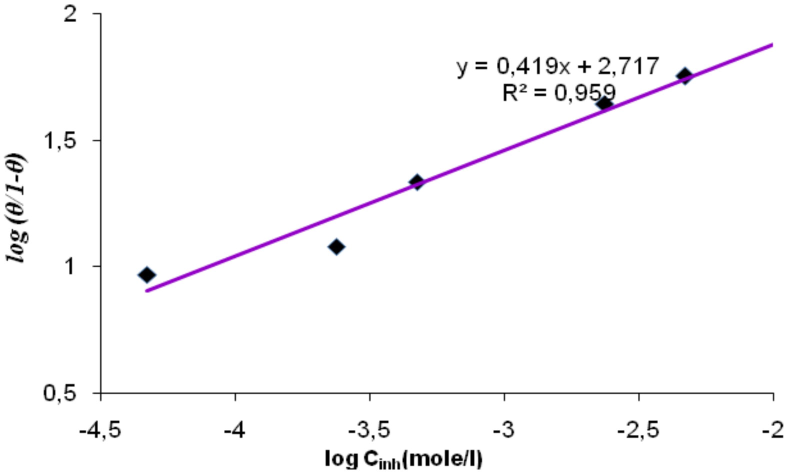


Fig.2. plot of log (θ/1-θ) vs log C_{inh} for p-AnNB

The expected linear relationship is well approximated (correlation coefficients R^2 equal 0.959, and the line has a slope of 0.419). The deviation of the slope from unity is often interpreted as a sign that the adsorbing species occupy more or less than a typical adsorption site at the metal/solution interface [25, 26].

3.1.3 Effect of temperature :

Temperature has a great effect on the corrosion phenomenon. Generally the corrosion rate increase with the rise in temperature. For this purpose, we made weight loss measurements in the temperature range of 35°C ± 0.5°C to 65°C ± 0.5°C, in the absence and presence of 0.05%, 0.1% and o.5% concentration of p-AnNB after 60 minutes of immersion. The corresponding data are shown in Table-2.

Table 2. Effect of temperature on weight loss and inhibition efficiency for Al-Pure in 1.0 M HCl.

Inhibitor	Concentration	Weight loss (mg dm^{-2}) at temperature			
		35° C	45° C	55° C	65° C
Blank	-	2312	4436	5241	5786
p-AnNB	0.05	51 (97.79%)	251 (94.32%)	1192 (77.26%)	4509 (22.07%)
	0.10	32 (98.62%)	225 (94.93%)	989 (81.13%)	2599 (55.08%)
	0.5	5 (99.78%)	8 (99.82%)	19 (99.64%)	25 (99.57%)

From the Table-2, at constant concentration of inhibitor the IE% decreases with increasing temperature. This is due to the increased effect of temperature on the dissolution process of Al-Pure and partial desorption of the inhibitor from the metal surface. But the optimum concentration of inhibitor (i.e. 0.5%) shows excellent inhibition at higher temperature (65° C)

3.1.4 Thermodynamic Parameters

The values of the energy of activation, E_a, were calculated with the help of the Arrhenius equation.

$$\rho = k\ exp^{\left(-\frac{E_a}{R\,T}\right)} \ ....(4)$$

where ρ is corrosion rate determined from the weight loss measurement, E_a is the apparent activation energy, A is the Arrhenius constant, R is the molar gas constant and T is the absolute temperature. The apparent activation energy was determined from the slopes of log ρ versus 1/T × 10^4 graph depicted in Fig.3.

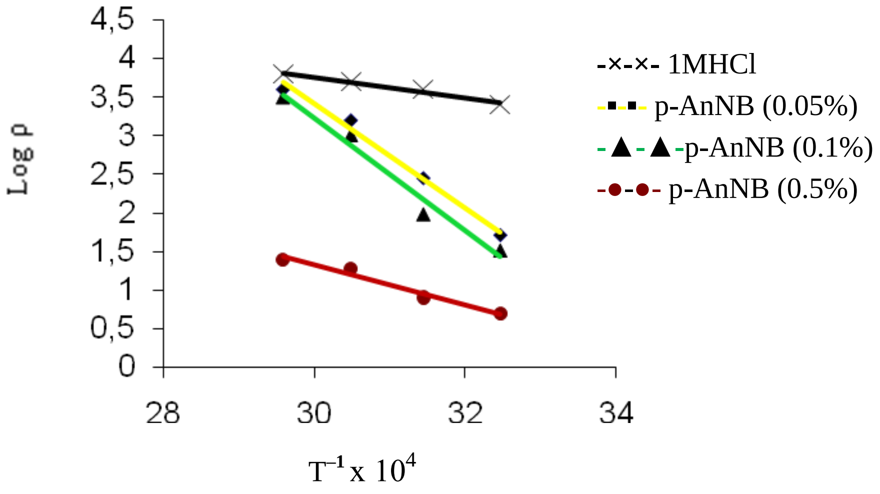


Fig.3 : Plotting log ρ vs. T^{-1} × 10^4 to calculate the activation energy of corrosion process in the presence and absence of p-AnNB

From the results (Table-3), it is apparent that for the corrosion of Al-Pure in uninhibited acid the E_a value is 26.03 kJ/mole, whereas in inhibited acid the values are higher and range from 49.97kJ/mole (0.5% of p-AnNB) to 132.29 kJ/mole (0.05% of p-AnNB). The value of Ea for all the concentration of used inhibitor shows its tendency to act as a corrosion inhibitor. From these results we can conclude that the inhibition of Al-Pure in a 1 M HCl solution occurs by the adsorption of the inhibitor.

In inhibited acid the E_a values vary and depend on the inhibitive power of the inhibitor. The E_a values are higher at the lower inhibitor concentration and it decreases rapidly for the higher inhibitor concentration. It appears that the exponential term in the Arrhenius equation appreciably changes the E_a values with a slight change in the corrosion rate. The higher values of activation energy in inhibited acid suggest that the adsorption of the inhibitor on the metal surface may be physical or weak in nature and falls off appreciably with rise in temperature [27]. The decrease in inhibitive efficiency of inhibitor at higher temperature may be due to the fact that the time longe between the process of adsorption and desorption of inhibitor molecules over metal surface is becoming shorter with increase in temperature, hence the metal surface remains exposed to a acid solution for a longer period [28]. However, for 0.5% inhibitor concentration the very high inhibitive power (>99%) and almost a constant values of the extent of inhibition in the temperature range studied suggest that the adsorption bonds are stronger and the lower rate of hydrogen evolution in inhibited acid may not be able to cause any damage to the surface film or dislodge the adsorbed protective layer. It can also be explained with the consideration of the decrease in oxygen solubility takes place with the increase in temperature of corrosive media and the fact that the increase in inhibitor concentration decreases the transport of oxygen and other reducible species. This decrease in cathodic corrosion process simultaneously and ultimately retards the anodic dissolution of metal. The formation of protective monolayer on the metal surface in presence of inhibitor decreases number of active sites. The coverage of the metal surface might have been increased with the gradual rise in the inhibitor concentration [29, 30].

If it is assumed that the inhibitor is adsorbed on the metal surface in the form of a monolayer film, covering at any instant a fraction, θ, of the metal surface in a uniform random manner, then the heat of adsorption, (Qads), of the inhibitors can be calculated from the equation :

$$(Q_{ads}) = 2.303\,R\left\{log\frac{\theta_2}{1-\theta_2} - log\frac{\theta_1}{1-\theta_1}\right\}\left[\frac{T_1T_2}{T_2-T_1}\right] \ldots\ldots\ldots(5)$$

The values of the free energy of adsorption (ΔGads) were calculated from the following equation (Desai *et al* 2008) :

$$log\,C_{inh} = log\frac{\theta}{1-\theta} - log\,B \ldots\ldots\ldots(6)$$

where, $log\,B = 1.74 - \left[{}^{\Delta G_{ads}}/_{2.303\,RT}\right] \ldots\ldots\ldots(7)$

The values of (ΔGads) and (Qads) are shown in Table-3. The negative value of (ΔGads) suggests that the inhibitor molecules are strongly adsorbed on the metal surface, the values also indicate a spontaneous adsorption of the inhibitor molecules usually characterized by the strong interactions with the metal surface. Generally, values of ΔG_{ads} around –20kJ mole^{-1} or lower are consistent with the electrostatic interaction between charged molecules and the charged metal surface (physisorption), those around –40 kJ mole^{-1} or higher involves charge sharing or transfer from organic molecules to the metal surface to form a co-ordinate type of metal bond (chemisorption) [31,32]. In the present work, the calculated ΔG_{ads} values are almost slightly less negative than –40 kJ mole^{-1} indicating that the adsorption of inhibitor molecule is not merely physisorption or chemisorptions but obeying a comprehensive adsorption (physical and chemical adsorption). It was observed, limited decrease in the absolute value of ΔG_{ads} with an increase in the temperatures, indicating that the adsorption was somewhat unfavourable with increasing experimental temperature, indicating that physisorption has the major contribution while chemisorptions has the minor contribution in the adsorption mechanism.

The negative value of the heat of adsorption (Q_{ads}) indicates that the adsorption process is exothermic in nature. This observation further confirms physical adsorption of the inhibitor on the metal surface in HCl solution.

Table 3. Thermodynamic parameters and activation energy for inhibitor adsorption for corrosion of Al-Pure in 1.0 M HCl.

Inhibitor		E_a (kJ mole^{-1})	Q_{ads} (kJ mole^{-1})	ΔG_{ads} (kJ mole^{-1})
Blank		26.0	-	-
p-AnNB	0.05	132.3	-171.6	-31.2
	0.1	127.5	-126.2	-30.8
	0.5	50.0	-23.9	-33.4

The values of the heat of adsorption (Q_A) are negative in the case of all concentration of the inhibitors but are found to be less negative in case of higher inhibitor concentration. At low concentration it is more negative when it loses its inhibitive power at higher temperatures.

3.2 *Electrochemical impedance spectroscopy (EIS)*

The corrosion of Al-Pure in 1.0 M HCl solution in the absence and presence of different concentration of p-AnNB were investigated by EIS at the open circuit potential condition. The effects of the inhibitor concentration on the impedance behavior of metal in 1.0 M HCl have been studied and the corresponding Nyquist plots are given in Fig.4.

The IE % at different inhibitor concentration were calculated by using the following equation,

$$Inhibition\ Efficiency\ (IE\ \%) = \frac{R_{ct} - R^{\circ}_{ct}}{R_{ct}} \times 100 \ldots\ldots\ldots (8)$$

Where R_{ct} and R°_{ct} are the charge transfer resistance in the HCl solution in the presence and absence of p-AnNB, respectively.

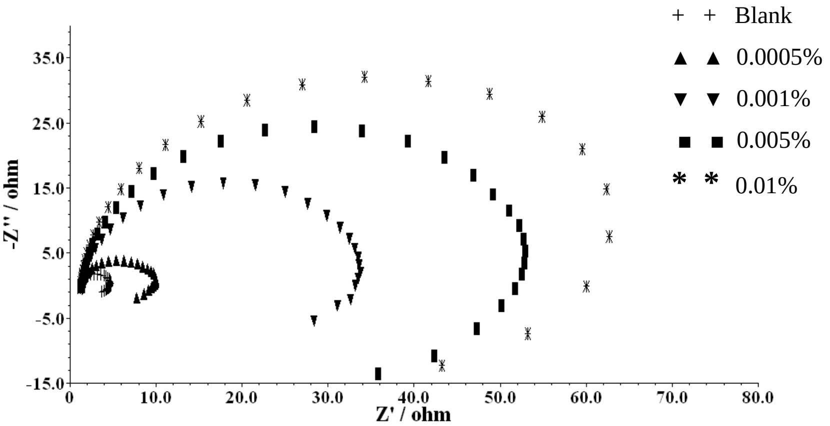


Fig.4 : Impedance plot obtained at 35ºC in 1.0 M HCl in various concentration of p-AnNB.

The Nyquist diagram obtained with 1.0 M HCl shows only one capacitive loop and the diameter of the semicircle increases on increasing the inhibitor concentration suggesting that the formed inhibitive film was strengthened by the addition of inhibitors. All the obtained plots show only one semicircle and they were fitted using one time constant equivalent model fig.5 with capacitance (C) and charge transfer resistance (R). All the impedance parameters [Double layer capacitance (C_{dl}), Charge transfer resistance (R_{ct}), Solution resistance (R_s)] are derived from Nyquist plots and the inhibition efficiency (%IE) of p-AnNB is given in Table 4.

The lower capacitance (C_{dl}) values for 1.0 M HCl medium indicates the in-homogeneity of surface of the metal roughened due to corrosion. The C_{dl} values decreases on increasing the inhibitor concentration and reaches very low value for the optimum concentration of all the studied systems indicating that the reduction of charges accumulated in the double layer due to formation of adsorbed inhibitor layer [33]. The charge transfer resistance (R_{ct}) of double layer increases on increasing the concentration of the inhibitor upto the optimum level indicating the decreased corrosion rate.

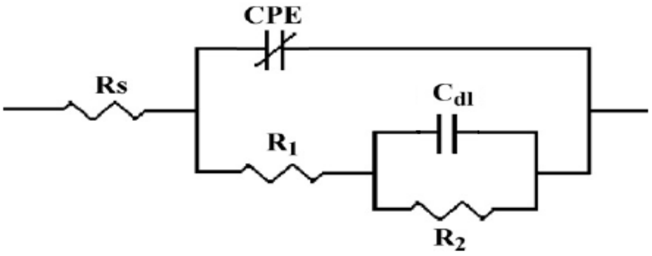


Fig.5 : The equivalent circuit model used to fit the experimental result.

Table 4. EIS parameters and corresponding inhibition efficiency for the corrosion of Al-Pure in 1.0 M HCl

Inhibitor	Concentration	R_s (ohm)	R_{ct} (ohm)	C_{dl} (μF)	(IE %)
Blank	-	1.256	3.46	113.1	-
p-AnNB	0.0005	1.409	8.12	112.2	57.39
	0.001	1.440	32.4	104.1	89.32
	0.005	1.274	56.0	95.21	93.82
	0.01	1.247	64.8	92.76	94.66

3.3 Galvanostatic polarisation

Anodic and cathodic polarization curves were obtained for Al-Pure in 1.0 M HCl with and without inhibitor. The curves were obtained by scanning from the corrosion potential (E_{corr}) in the cathodic direction and then in the anodic direction. The corrosion current densities were calculated from the polarization curves, by extrapolation of the linear logarithmic segments of the anodic and cathodic Tafel lines to the point of intersection. These values were used in calculating the IE %. The IE % obtained from the polarization method, was calculated using the following equation:

$$Inhibition\ Efficiency\ (IE\ \%) = \frac{I^{\circ}{}_{corr} - I_{corr}}{I^{\circ}{}_{corr}} \times 100 \ldots\ldots\ldots (9)$$

Where, I°corr and Icorr are uninhibited and inhibited corrosion current density, respectively [34-39]. Fig.6 show polarization curves of Al-Pure surface in 1.0 M HCl in the presence and absence of various concentration of studied Schiff base p-AnNB at 35° ± 0.5° C.

As would be expected both anodic and cathodic reactions of metal surface corrosion were inhibited with the increase of inhibitor concentration. This result suggests that the addition of p-AnNB reduces a little bit anodic dissolution and significant retards in the hydrogen evolution reaction [40]. So this inhibitor is a mixed type inhibitor with predominantly effect on the cathode.Table-5 shows the electrochemical corrosion kinetics parameters.

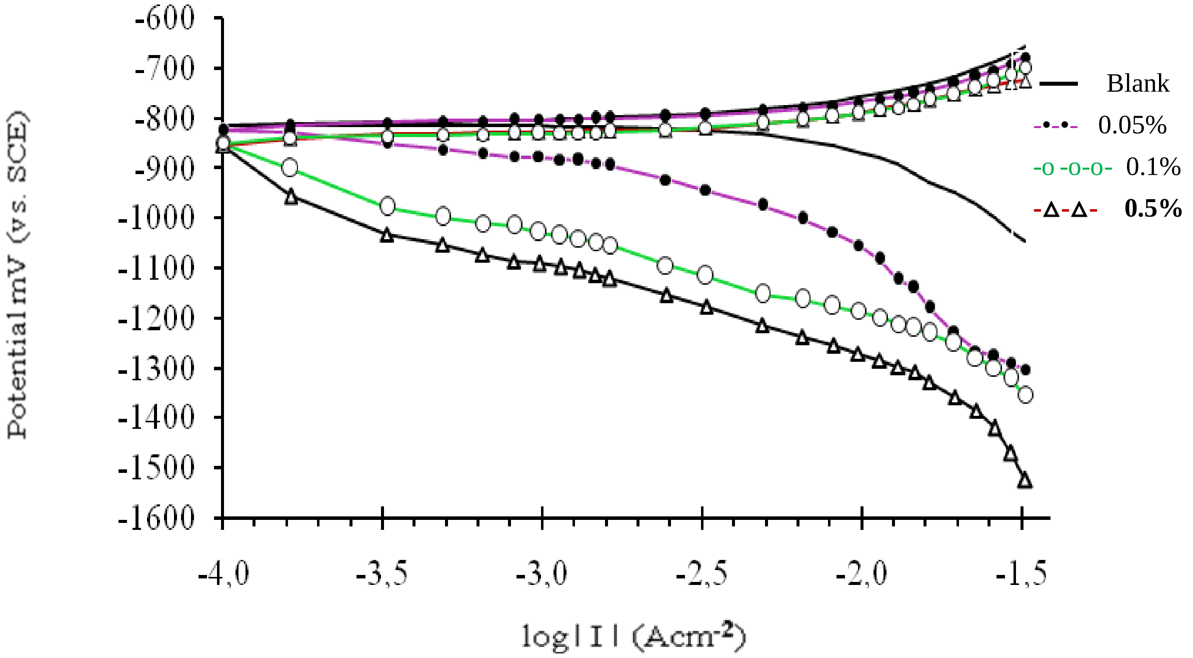


Fig. 6 : Cathodic & Anodic pollarization graph for Al Pure in 1M hydrochloric acid in the presence and absence of inhibitors

Table-5: Tafel parameters and inhibitor efficiencies at different concentrations of p-AnNB for Al/1M HCl at 35^{o}C $\pm$ 0.5^{o}C).

p-AnNB (%)	E_{corr} (mV vs SCE)	I_{corr} ($mAcm^{-2}$)	β_a (mV/decade)	β_c (mV/decade)	IE (%)
HCl Only (-)	-814	0.003715	136	124	-
0.05	-823	0.00617	100	171	83.39
0.1	-850	0.00525	103	143	98.59
0.5	-854	0.000072	120	199	98.06

3.5 Mechanism of inhibition

Many of the organic corrosion inhibitors are compounds with at least polar unit having atoms of nitrogen, sulfur, oxygen and in some cases selenium and phosphorous. The polar unit is regarded as the reaction centre for the adsorption process. In such a case the adsorption bond strength is determined by the electron density on the atom acting as the reaction centre and by the polarisability of the unit. Thus polar organic compounds acting as corrosion inhibitors are adsorbed on the surface of the bulk metal, M, forming a charge transfers from the inhibitor active sites and the metal:

$$M + RnX \leftrightarrow M : XRn$$

The size, orientation, shape and electric charge on the molecules determined the degree of adsorption and hence the effectiveness of the inhibitor.

The structure of p-AnNB has three anchoring sites (one iminic group and two aromatic rings). Schiff base confers good protection and the compound when present in sufficient amount confer almost 99.0% protection of Al-Pure in hydrochloric acid leads support this matter. The adsorption of the inhibitor obeys Langmuir adsorption isotherm (The plot of log $\theta/1-\theta$ vs log C_{inh} is linear). The increase in inhibiting efficiencies with the increase in the concentration of the studied Schiff base show that the inhibiting actions are may be due to that adsorption of the inhibitor molecules on the metal surface. It is generally assumed that the adsorption of inhibitor at the metal/solution interface is the mechanism of inhibitor through electrostatic attraction between the charged molecules and charged metal. p-AnNB has been found to give an excellent inhibition due to the presence of the electron donating groups (such as $–OCH_3$), which increases the electron density on the nitrogen of the >C=N- group [8]. Thus leads to be the strong adsorption of inhibitor on the metal surface thereby resulting in high inhibition efficiency.

The free energy of adsorption (ΔG_{ads}) and heat of adsorption (Q_{ads}) are negative, suggest that the adsorption is physisorption which further supported from Ea values. In presence of Schiff base with sufficient amount, both the cathoidc and anodic are polarized, but a tremendous polarization effect on the cathode. Thus, the Schiff base is mixed type inhibitor with a tremendous effect on the cathode. The high efficiency of inhibitor may be traced to the presence of a methoxy ($–OCH_3$) group which exhibits a (–I) (inductive) effect and activated the benzene ring.

Conclusion

The present study leads to the following conclusions in controlling the corrosion of Al-Pure by p-AnNB in 1.0 M HCl.

1. The inhibitor molecules adsorbed on the metal surface and tend to retard the rate of corrosion by reducing the number of available surface sites for corrosion.
2. The adsorption of inhibitor investigated follows the Langmuir adsorption isotherm.
3. Thermodynamic parameters (ΔG_{ads}, Q_{ads} and Ea) show that the studied compound is adsorbed on Al-Pure surface by an exothermic, spontaneous process and physical adsorption accompanied by chemisorptions and adsorbed spcies occupy more or less than a typical adsorption site at the metal/solution interface.
4. P-AnNB inhibit both cathodic and anodic reactions by adsorption but tremendous polarization effect on cathode and hence behave like mixed type inhibitors.
5. Obtained results about inhibition efficiencies from weight loss method, polarization study and EIS are in good agreement with each other.
6. It is also possible that the compounds may form onium ions in acidic medium and move to the cathodic regions and then the adsorption will take place through the iminic nitrogen and also through the delocalized π-electrons of the benzene moiety. Then molecule will lie flat on the metal surface and further cover the adjoining positions of the surface.

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