

Corrosion Inhibition of Aluminum using Nonionic Surfactant Compounds with a Six Membered Heterocyclic Ring in 1.0M HCl Solution

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The inhibiting vigor of a novel synthetic two nonionic surfactant (NS) compounds containing heterocyclic six membered ring moiety toward the corrosion of pure aluminum (Al) in 1.0MHCl solutions was inspected. Electrochemical techniques like galvanstatic polarization, electrochemical impedance spectroscopy and chemical technique such as weight loss, thermometric were utilized in this study. The NS compounds were identified by IR and 1HNMR spectra. The inhibition efficiency (IE %) obtained from the four various techniques proved that the compounds performed as a good inhibitor for the corrosion of Al. The inhibition was explained by adsorption of NS compounds on the surface of Al. The IE % values surge by increasing the concentration of NS compounds. The adsorption obeys Freundlich isotherm. . The activated thermodynamic parameters were computed and assessed

Keywords: Nonionic surfactant, Adsorption; corrosion inhibitors; Interfaces

1. INTRODUCTION

Aluminum (Al) is one of the most essential elements that have multiple industrial applications due to its low cost, lightweight, high thermal and electrical conductivity. One of the most important advantages of Al is that it is good resistance to corrosion in aqueous solutions due to the formation of oxide film detaches the Al from the corrosive solutions environment. Nonetheless, the existence of destructive anions like chloride allows a corrosion attack. There are numerous methods to stifle aluminum corrosion in hydrochloric acid, but the best way is the use of corrosion inhibitors, which are generally organic compounds, which have different hetro atoms, aromatic rings, or multiple bonds [1-14].

The chemical composition of compounds as well as their functional and aromatic groups, electron density of hetro atoms and the presence of the active center of the molecule are all essential in the process of the adsorption. Normally, the organic molecules adsorbed on the Al surface act as a barrier, detaching the Al surface from a corrosive solution [15-17]. Most organic compounds are used to inhibit the corrosion of most metals and alloys in acidic solutions but unfortunately have damaging effects on human health and the atmosphere. As a result, scientists have attempted to find compounds that are successful in inhibiting corrosion and as well as human and environmentally friendly. Hence, one of these surfactant compounds which are characterized by many advantages such as its ability to adsorption on the surface of the metal and environmentally friendly and both human and ecologically friendly [18-20]. In our previous studies some types of surfactant compounds are tested to inhibit the corrosion of metals in acidic solutions [21-26].

This work aims to verify the inhibitory effect of novel synthetic two compounds of nonionic surfactant (NS) containing heterocyclic six membered ring moiety as a safe, environmentally friendly and non-toxic toward the corrosion of Al in 1.0M HCl solution using galvanostatic polarization (GP) and electrochemical impedance spectroscopy (EIS) weight loss (WL) and thermometric (TM) techniques. Adsorption isotherm and the effect of rising temperature was studied. Some activated thermodynamic parameters for the corrosion process were computed and illustrated.

2. EXPERIMENTAL METHODS

2.1. Materials

The aluminum (Al) rods and sheets used in the current manuscript having high purity reached to 99.99% provided from Aluminum Factory in Nagh Hammadi-Egypt. Al coupons with dimension 1.0 x 3.0 x 0.1 cm³ were employed For WL and TM measurements while Al cylindrical rod electrode with exposed bottom surface areas of 0.46 cm² were used for GP and EIS measurements. Before any experiment, the electrode or sheets mechanically polished with various grades of emery paper, degreased with acetone and lastly washed by bidistilled water. An air thermostat was used to control the temperature.

2.2. Corrosion measurements

The process for the WL and TM measurements were done as earlier mentioned [27-29]. For electrochemical methods such as GP and EIS, a three-compartment cell with working Al electrode, saturated calomel reference electrode (SCE) and a Pt foil was used as an auxiliary electrode. The corrosion parameters such as anodic (β_a), cathodic (β_c) Tafel slopes, corrosion potential (E_{corr}), corrosion current density (I_{corr}), the percentage inhibition efficiency (IE%) and surface coverage (Θ) were obtained from GP measurements using a PS remote potentiostat with PS6 software. GP curves were obtained by changing the electrode potential automatically at a scan rate of 2.0 mV/s at 25 °C. EIS measurements were done at a frequency range from 10 kHz to 100 mHz and signal amplitude perturbation of 5 mV by using a computer-controlled potentiostat (Auto Lab 30, Metrohm)

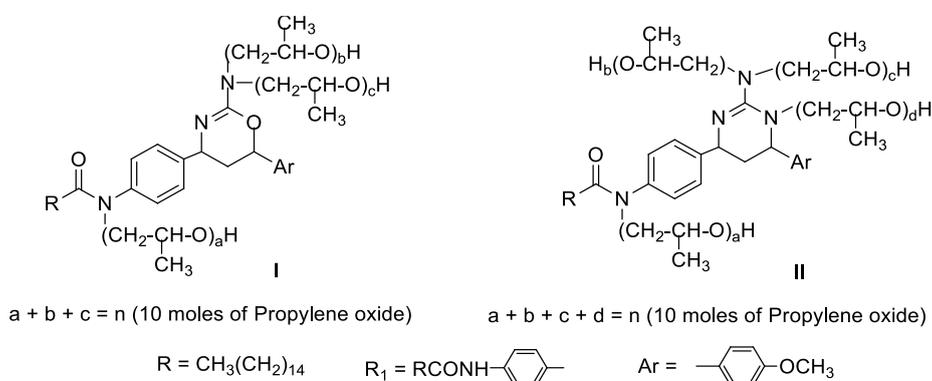
2.3. Synthesis of nonionic surfactants (NS)

The examined nonionic surfactants were branded by spectral and elemental analysis approaches. All melting points shown in open glass capillary tubes were identified using an electrothermal 9300 digital melting point apparatus (Tokyo, Japan). IR spectra of the prepared products were analyzed on FTIR-BRUKER (Switzerland). ¹HNMR was documented with Bruker AC 300 spectrometer (Fa'llanden, Switzerland) operating at 300MHz (CDCl₃) as a solvent. This happened at the Chemistry Department, Faculty of Applied Science, Umm Al-Qura University, Saudi Arabia..

2.3.1 Synthesis of nonionic surfactants containing six-membered rings as oxazine (I), and pyrimidine (III) derivatives

A solution of palmitoyl chloride (0.01 mol) and 4-aminoacetophenone (0.01 mol) was stirred on ice bath for 2hr to produce the acetyl derivative [30], thereafter refluxed with benzaldehyde in ethanol (20 ml) to form the chalcone derivative, which treatment with urea (0.01 mol) and/or guanidine hydrochloride (0.01 mol) by mixing at room temperature. The acquired solid (0.01 mol), in each case, and 0.5 % KOH was heated in exceed of its melting point, then the propylene oxide was carefully removed with the nonstop stirring to make both nonionic surfactants (I and II). The quantity of the reactivated propylene oxide, and the mean degree of propoxylate was calculated by assessing the increase in mass of the mixture after the addition of propylene oxide [31].

The quantity of the reactivated propylene oxide, and the mean degree of propoxylate was calculated by assessing the increase in the mixtures mass after adding propylene oxide [31].



(Scheme 1)

The structure of the latter products was based on the IR and ¹HNMR spectra.

Oxazine (**I**): IR (ν/cm^{-1}): Broad band at 3435 for (OH), 3045 (CH arom), 2917, 2849(CH aliphatic), 1678 (CO), 1100, 948 (C-O-C) ether of poly propoxy chain; $^1\text{H NMR}$ (δ , ppm): Multiple signals in region (3.01–3.88 ppm) for the propoxy protons besides the other signals of the compound.

Pyrimidine (**II**): IR (ν/cm^{-1}): Broad band at 3424 for (OH), 3052 (CH arom), 2917, 2850 (CH aliphatic), 1678 (CO), 1125, 938 (C-O-C) ether of poly propoxy chain; $^1\text{H NMR}$ (δ , ppm): Multiple signals in region (3.00–3.85 ppm) for the propoxy protons besides the other signals of the compound.

2.4. Surface properties

The surface properties as surface and interfacial tension measured in neutral medium to estimate the possible application of these products in the different industrial fields and were depicted in Table 1. Surface and interfacial tension characteristics of a solution of the surfactant (10 mmol) were measured using a Kruss du Nouy tensiometer, Type K6 (Kruss GmbH, Hamburg, Germany) at 25 oC and the light paraffin oil was used for interfacial tension. [32].

Table 1. Surface properties of the synthesized compounds

No.	Surface Tension (γ) (dyne/cm), 0.1 wt%	Interfacial Tension (dyne/cm), 0.1 wt%
I	32	10.7
II	29	8.9

3. RESULTS AND DISCUSSION

3.1. GP measurements

The GP measurements of the Al electrode were inspected in the 1M HCl solutions containing a variety of concentrations (100 - 500ppm) of NS compound II in Fig.1. A related figure was attained for the other compound I but not visible. The anodic and cathodic curves obtained exhibit Tafel-type behavior. The addition of NS compounds leads to the displacement of the anodic and cathodic curves towards both the positive and negative directions. The corrosion parameters were taken from these figures, such as anodic and cathodic Tafel slope (β_a and β_c), corrosion potential (E_{corr}), corrosion current density (I_{corr}), and the inhibition efficiency (IE%) was inserted in Table 2. The inhibition efficiency (IE %) was determined from the equation:

$$\text{IE \%} = (1 - i_f/i_{in}) 100 \quad (1)$$

Where, i_f and i_{in} are the current values in free and inhibitory solutions.

Table 2 shows that the increased concentration of NS compounds, the values of β_a , β_c and E_{corr} , are almost unaltered denoting that the NS compounds are termed as mixed inhibitors, meaning they inhibit the Al dissolution and H_2 evolution reactions. The values of I_{corr} are lower and hence the values

of IE % increases, which endorses the inhibitory effect of NS compounds. The arrangement of the IE % of decreases in the following: Comp. II > Comp. I

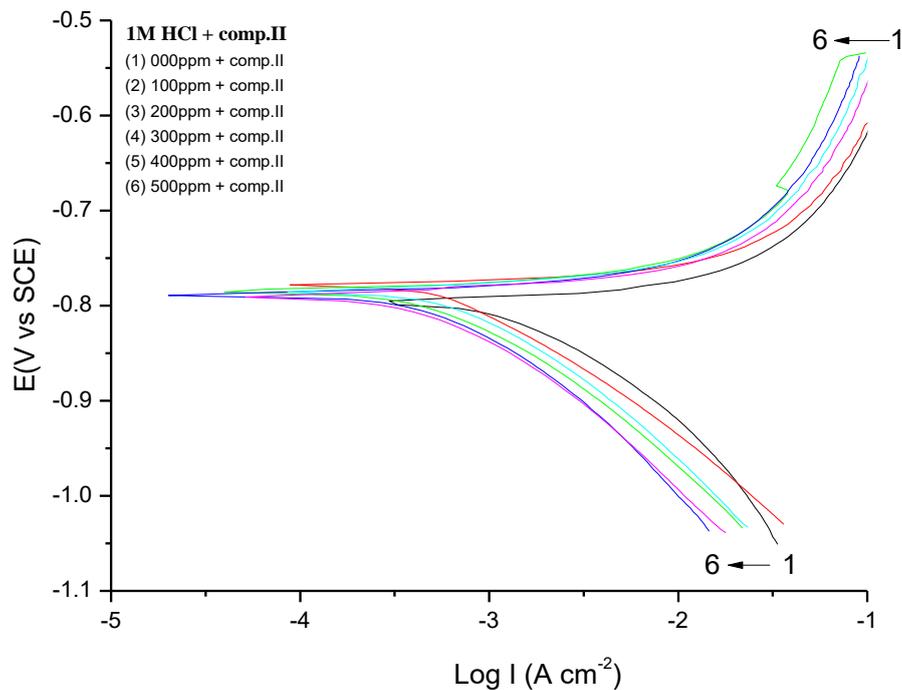


Figure 1 .Galvanostatic polarization curves for the corrosion of Al in 1.0 M HCl solution in presence and absence of various concentration of compound II. (1) 0.0 ppm (2) 100 ppm (3) 200 ppm (4) 300 ppm (5) 400 ppm (6) 500 ppm.

Table 2. Corrosion parameters obtained from GP for corrosion of Al in 1M HCl solution containing NS compounds

Inhibitor Concentration	β_a mV dec ⁻¹	β_c mV dec ⁻¹	E_{corr} mV(SCE)	I_{corr} mA cm ⁻²	%IE
1M HCl	60	-204	-795	-	-
<u>1M HCl + Comp.I</u>					
100 ppm <u>Comp.I</u>	54	-204	-793	1.78	71.1
200 ppm <u>Comp.I</u>	46	-204	-794	0.92	85.0
300 ppm <u>Comp.I</u>	53	-212	-799	0.61	90.1
400 ppm <u>Comp. I</u>	44	-195	-801	0.52	91.5
500 ppm <u>Comp.I</u>	46	-194	-799	0.33	64.6
<u>1M HCl + Comp.II</u>					
100 ppm <u>Comp.II</u>	43	-191	-778	1.56	74.6
200 ppm <u>Comp.II</u>	53	-179	-785	0.78	87.3
300 ppm <u>Comp.II</u>	58	-199	-789	0.50	91.9
400 ppm <u>Comp.II</u>	49	-190	-785	0.39	93.7
500 ppm <u>Comp.II</u>	53	-188	-791	0.28	95.4

3.2. EIS measurements

The effect of increasing concentrations of compound II on the Nyquist plots of Al in 1M HCl solution are presented in Fig.2. Similar curves were obtained for compound I but not shown. The presence of a single half-circle showed the transfer of single charge during dissolution, which is not affected by the presence of NS molecules. Deviations from the ideal circular shape mean the frequency dispersion of interfacial impedance caused by surface roughness, impurities, grain boundaries, adsorption of inhibitors, formation of porous layers and homogenates of the electrode surface [33,34]. The equivalent circuit model used to analyze the parameters obtained from EIS showed in Fig. 3. The model consists of solution resistance (R_s), charge transfer resistance (R_{ct}) and double layer capacitance (C_{dl}). Excellent compatibility with this model was found

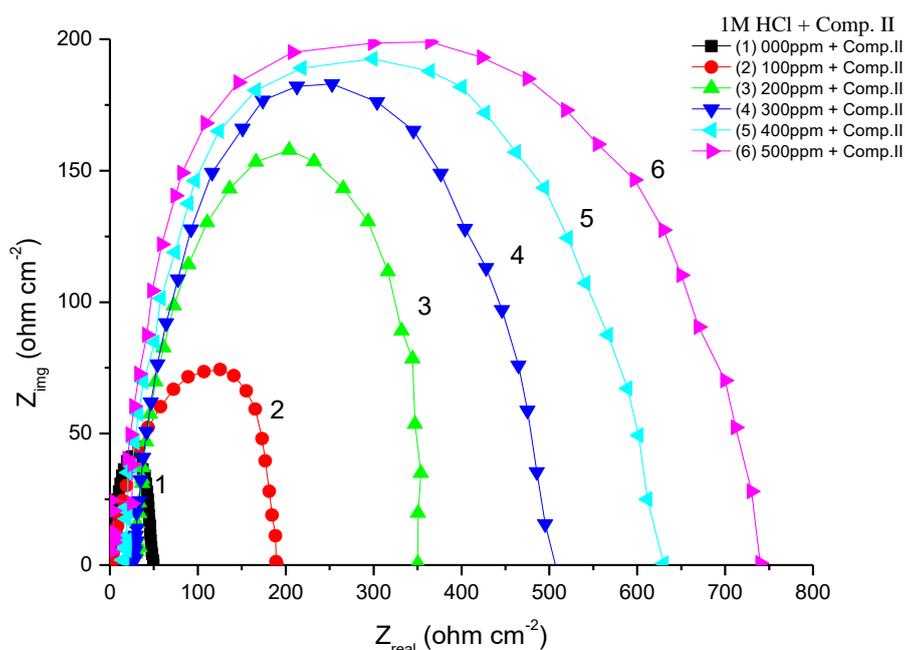


Figure 2. The Nyquist plots for the dissolution of Al electrode in 1.0 M HCl solution in the absence and presence of different concentrations of compound II.

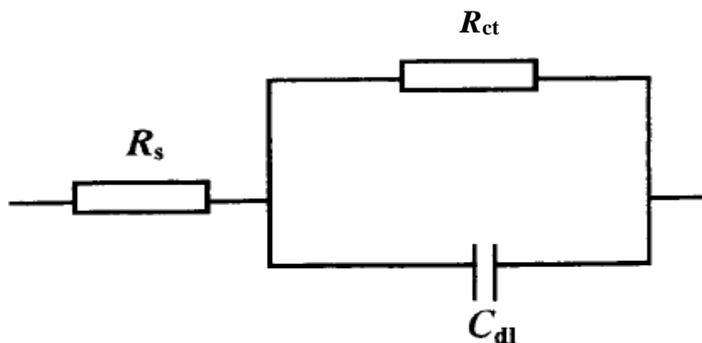


Figure 3. The equivalent circuit model used to fit the experimental results.

Table 3 lists the electrochemical parameters obtained from EIS measurements. It evident that, with the increasing of the NS concentrations the R_{ct} value increases and the C_{dl} values decrease. The increase of R_{ct} is caused by the gradual replacement of H_2O molecules by the adsorption of NS compounds on the Al surface which results in a decrease in the corrosion reaction. Higher values (R_{ct}) are normally associated with slower corroding system [35].

A decrease in C_{dl} can be because of a decrease in the dielectric constant and / or an increase in the thickness of the electrical double layer demonstrating that the inhibitor molecules are acting by absorption in the interface of the Al / solution interface [36].

IE% acquired from EIS measurements is near to those derived from polarization measurements. The effectiveness of the inhibition of EIS measurements is as follows: compound II > compound I.

Table 3. Electrochemical parameters obtained from EIS measurements for corrosion of Al in 1 M HCl solution-containing NS compounds

Inhibitor Concentration	$R_{ct}(\text{ohm cm}^{-2})$	$C_{dl} \times 10^{-5} (\mu\text{Fcm}^{-2})$	% I.E
1M HCl	50	98.5	-
1M HCl + Comp.I			
100ppm Comp.I	280	42.2	82.1
200 ppm Comp.I	340	32.8	85.3
300 ppm Comp.I	410	29.1	87.0
400 ppm Comp. I	560	26.5	89.9
500 ppm Comp.I	650	22.7	92.3
1MHCl+Comp.II			
1000ppm Comp.II	190	30.6	73.7
200 ppm Comp.II	350	27.6	85.7
300 ppm Comp.II	510	23.3	90.2
400 ppm Comp.II	630	19.4	92.6
500 ppm Comp.II	740	17.2	93.2

3.3. TM measurements

Figure 4 illustrates the variation of the temperature with time curves for Al in 1.0M HCl solution having different concentrations of NS compound II by using TM measurements. The same curves were obtained in the presence of NS compound I but not shown. It is evident that, with increasing time, the temperature value increases up to the T_{max} whereby, it then decreases. The addition of the NS compounds causes the value of T_{max} to decrease than free solution and increase the time required to reach it and thus the values of RN decrease. The reaction number (RN) is calculated from

$$RN = (T_m - T_i) / t. \quad (2)$$

Where, T_m and T_i are the maximum and the initial temperatures, respectively, t is the time taken to reach T_{max} . The percentage inhibition efficiency $IE_{TM} \%$ were calculated from the following equation:

$$IE_{TM} (\%) = (1 - RN_f / RN_{inh}) \times 100 \quad (3)$$

Where, RN_f and $RN_{inh.}$ are the reaction number in free 1M HCl and presence of NS compounds. The values R.N and $IE_{TM} \%$ are inserted in Table 4

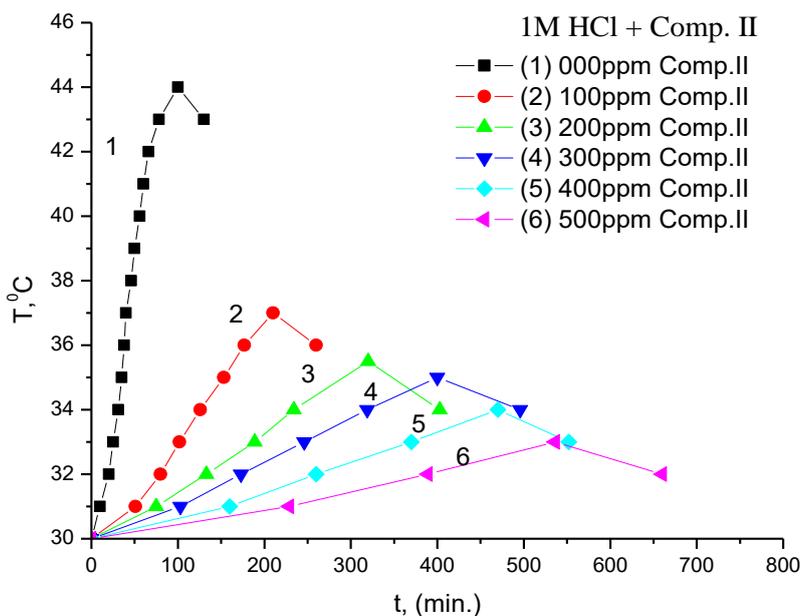


Figure 4. Thermometric curves for corrosion of Al in 1.0 M HCl solution devoid of and containing various concentrations compound II .

From the values of Table 4, as the concentration of NS compounds increases, the values of T_{max} and RN are decreased and the values of $IE_{TM} \%$ increases. This shows that the NS compounds hinder the dissolution reaction of Al in 1M HCl solution probably by its adsorption its adsorption on the Al surface. The vigor of adsorption is dependent on the chemical structure of the NS compounds. The order of the IE % of decreases in the following sequences: Comp. II > Comp. I

Table 4. Corrosion parameters obtained from TM measurements for corrosion of Al in 1M HCl solution containing NS compounds

Inhibitor	Concentration (ppm)	RN. ($^{\circ}C/min.$)	$IE_{TM} \%$
Blank 1MHCl	0	0.140	---
Compound I	100	0.041	70.7
	200	0.021	85.0
	300	0.012	91.4
	400	0.010	92.8
	500	0.008	94.3
Compound II	100	0.033	76.4
	200	0.017	87.9
	300	0.013	90.7
	400	0.008	94.3
	500	0.005	96.4

3.4. WL measurements

Figure 5 displays the weight loss versus time curves of Al coupons in 1.0M HCl solution having altered concentrations of NS compound II. Although not displayed, identical curves are obtained in the presence of NS compound I. As the concentration of NS increases the values of WL is decreased. These results show that the studied two compounds of NS act as inhibitors. The lines in Fig 1 are linear in the absence and presence of NS compounds demonstrating that, the absence of insoluble surface films during corrosion. This causes the adsorption of NS compounds on the Al surface and impedes the dissolution reaction by obstructing the reaction sites (anodic and cathodic) or by altering the mechanism of anodic and cathodic partial processes.

The corrosion rate ($R_{corr.}$) the percentage inhibition efficiency (IE %) and the surface coverage (Θ) of the NS compounds were computed from the following equations [37]:

$$R_{corr.} = \Delta W / A t \quad (4)$$

$$IE\% = (R_{un} - R_{in}) / R_{un} \times 100 \quad (5)$$

$$\Theta = 1 - (R_{im.} / R_{uin}) \quad (6)$$

Where, ΔW is the weight loss, A is the surface area of the Al sheet, t is the time, R_{un} and $R_{in.}$ are the rate of corrosion of Al in the absence and presence of the NS compounds, respectively.

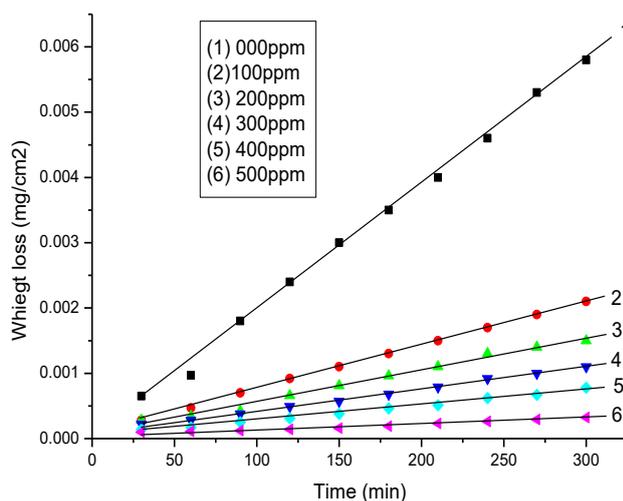


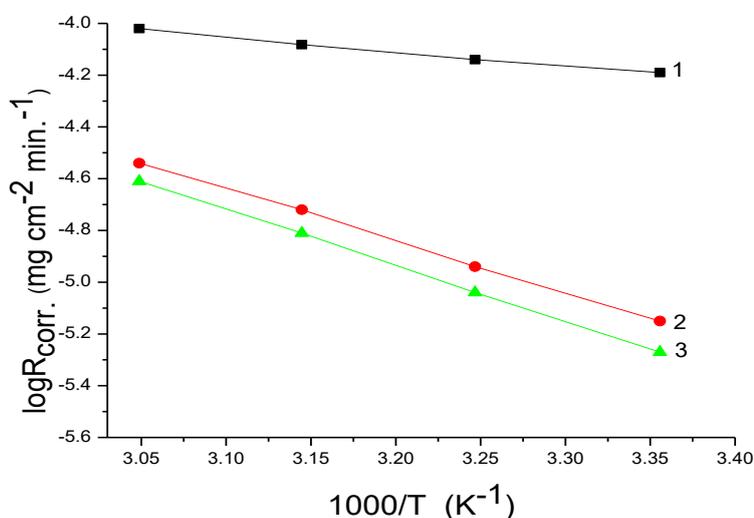
Figure 5. Weight loss-time curves for Al in 1.0 M HCl containing different concentrations of compound II

The resulting values of $R_{corr.}$, Θ and IE% of Al at 30 °C are illustrated in Table 5. It is without a doubt that with increased concentration of the two NS compounds the values of IE % and Θ are increased. The sequence of the IE % decreases in the following sequences: Comp. II > Comp. I

Table 5. Corrosion parameters obtained from Al corrosion in 1.0M HCl solution containing various concentrations of NS compounds using weight loss measurements

Inhibitors	Concentration (ppm)	R_{corr} ($\text{mg cm}^{-2} \text{min}^{-1}$)	θ	% I.E (Weight loss)
Blank	0	6.440	--	---
Compound I	100	1.880	0.708	70.8
	200	1.020	0.842	48.2
	300	0.665	0.896	89.7
	400	0.492	0.924	92.4
	500	0.386	0.940	94.0
Compound II	100	1.650	0.744	74.4
	200	0.802	0.875	87.6
	300	0.567	0.912	91.2
	400	0.462	0.928	92.8
	500	0.314	0.951	95.1

3.5. Effect of Temperatures.

**Figure 6.** Log R_{corr} vs. $1/T$ curves for Al in 1.0 M HCl in absence and presence 500ppm of NS compounds. 1) 1M HCl 2) 1M HCl+500ppm comp.I 3) 1M HCl+500ppm comp.II

The corrosion of Al in 1M HCl solution both with and without 500ppm of NS compounds was explored at a variety of temperatures stretching from 298 to 328K was studied with the use of WL measurements. Although not shown, similar curves of Figure 5 were gained. The values of IE % were computed and given in Table 6. It is obvious from this table that, as the temperature rises, the WL increases and the IE% values decrease, therefore showing that, the adsorption of NS compounds on the Al surface is physical. The increase of the temperature causes desorption of the adsorbed NS compounds from the Al surface. Furthermore, the sequence of inhibition efficiency, increase is as follows: II > I

The activation energy (E_a^*) For the corrosion of 1MHCl solution in containing and without 500ppm of NS compounds at changed temperatures was calculated from the Arrhenius equation [38, 39]:

$$R_{\text{corr}} = A \exp (-E_a^* / RT) \tag{7}$$

Where, R_{corr} , A,R and T are corrosion rate of Al , Arrhenius constant, the gas constant and the absolute temperature, respectively.

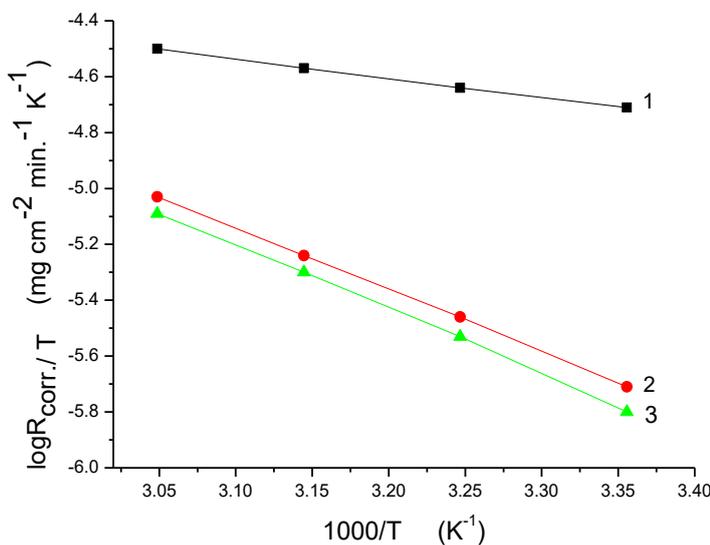


Figure 7. Log $R_{\text{corr.}}/T$ vs. $1/T$ curves for Al corrosion in 1.0 M HCl in absence and presence 500ppm of NS compounds 1) free 1M HCl 2) compound I 3) compound II

E_a^* values can be computed from the slope of straight lines when we plot the relationship between $\log R_{\text{corr}}$ vs. $1/T$ for Al corrosion in 1MHCl solution in the absence and presence of 500ppm of NS compounds (Fig 6). The values of E_a^* are equal to 18.36 ,46.67 and 50.25kJ.mol⁻¹ 1 for free 1MHCl, 1M HCl+500ppm comp.I and 1M HCl+500 ppm comp.II respectively. The values E_a^* increases in the presence of NS compounds than free solution, indicating that NS acts as inhibitors by increasing E_a^* values by making a barrier to mass and charge transfer by their adsorption on Al surface

The enthalpy (ΔH^*), and entropy (ΔS^*) of activation was determined from the following equation (8):

$$R_{\text{corr.}} = (RT/Nh) e^{(\Delta S^*/R)}. e^{(-\Delta H^*/RT)} \tag{8}$$

Where, h is Planck’s constant, N is Avogadro’s number.

Fig 7 shows the plot of $R_{\text{corr.}}/T$ vs $1/T$ for Al corrosion in 1MHCl solution in the absence and presence of 500ppm of NS compounds. Straight lines are obtained with slope equal to $-\Delta H^* /2.303R$ and the intercept equal to $\log R/ Nh + (\Delta S^* / 2.303R)$.The value of ΔH^* was calculated and equal to 17.75,43.21 and 47.64 kJ.mol⁻¹ for free 1MHCl, 1M HCl+500 ppm comp. I and 1M HCl+500 ppm comp.II respectively. The values of ΔH^* are positive reflecting the endothermic nature of the Al corrosion process. The calculated values of ΔS^* equal to -122.17,-131.12 and -132.07 J K⁻¹mol⁻¹ for

free 1M HCl, 1M HCl+500 ppm comp.I and 1M HCl+500 ppm comp.II respectively. The negative values of ΔS^* indicating that the activated complex in the rate-determining step represents an association rather than dissociation step, meaning that a reduction in disordering takes place when moving from reactants to the product. The sequence of an IE % of the NS compounds as compiled from the increase in E_a^* and ΔH^* and the decrease in ΔS^* values remains unchanged and follows the sequence: compound II > compound I

Table 6. Effect of increasing temperature on the corrosion parameters obtained from Al corrosion in 1.0M HCl solution containing 500ppm of NS compounds using weight loss measurements

Inhibitors	Temperature ($^{\circ}$ K)	$R_{\text{corr.}}$ ($\text{mg cm}^{-2} \text{min}^{-1}$)	% I.E
1M HCl	298	6.44	---
	308	7.22	---
	318	8.22	---
	328	9.44	---
Compound I	298	0.386	94.0
	308	0.582	91.9
	318	0.932	88.8
	328	1.32	86.0
Compound II	298	0.314	95.1
	308	0.436	93.2
	318	0.785	90.5
	328	1.140	87.9

3.6. Evaluation of the surface properties

The construction of surfactant molecules containing heterocyclic moiety are thought to be a significant class of organic compounds because of their double characters, one being the incompatibility between the hydrophobic and hydrophilic structure that gives a surface-active property and other one as the heterocyclic moiety mixed with aid of hydrophilic moiety (propylene oxide) that causes biological activity [40]. NS compounds are amphiphilic chemicals that improve desorption and bioavailability by increasing the solubility because of their properties, competence, cost, simplicity in using and formulating, which are used in diverse ways. [41-42]. The results listed in Table 1 shows that the pyrimidine derivative II has a maximum capability to shrink surface tension, while oxazine derivative I has an inferior effectiveness. Usually, the acquired results indicate that the synthesized products have noticeable surface activity, where, the synthesized products showed aptitude to decrease the surface and interfacial tension

3.7. Adsorption isotherm and mechanism of inhibition

NS compounds reduces the corrosion rate of Al in 1.0M HCl solutions by adsorption on the surface of Al. The adsorption procedure can be viewed as a one alternative process in which an NS molecule,

in the aqueous phase NS(aq) substitutes an "x" number of water molecules adsorbed on the Al surface vis,



where, x knows as the size ratio and basically equal to the number of adsorbed water molecules that have been replaced by one NS molecule.

The adsorption is dependent on several aspects like the chemical structure and the molecular weight of the inhibitor, the nature of the metal the medium of corrosion used and the electrochemical potential of the Al/solution interface. Also, the adsorption gives information on the interaction between the molecules themselves and their interactions with the metal. Further details on the interaction between NS compounds and Al surface, the degree of surface coverage (θ), acknowledged at different concentrations of NS compounds was found through WL measurements. Trials were carried out to determine the most convenient isotherm. We concluded that the best adsorption isotherm is Freundlich according to the following equation:

$$\theta = KC^n \quad (10)$$

Where C is the concentration of NS compounds and K is the equilibrium constant of adsorption. The values of K are related to the value of free energy of adsorption $\Delta G^{\circ}_{\text{ads}}$ using the following equation:

$$55.5 K_{\text{ads}} = \exp(-\Delta G^{\circ}_{\text{ads}}/RT) \quad (11)$$

Where R and T are the gas constant and absolute temperature. The value 55.5 is the concentration of water on the metal surface in mol/ L.

From the logarithmic form of equation (11), we can plot the relationship between $\log \theta$ and the logarithm of the concentrations of NS compounds as shown in Fig.8 .A straight line is obtained with intercept equal to $\log K_{\text{ads}}$ indicating that the adsorption of NS compounds on the Al surface is obeyed Freundlich isotherm. The computed values of K_{ads} are equal to $(73.8 \text{ and } 76.2) \times 10^{-2}$ for compounds II, respectively and I. The values of $\Delta G^{\circ}_{\text{ads}}$ are calculated and equal to -59.87 and $-62.43 \text{ KJ.mol}^{-1}$ for compound I and II, respectively. Of these values, we note that the strong spontaneous adsorption of two NS compounds on the surface of the Al. The efficiency of inhibition of NS molecules is linked to the ability of the surfactant to bind with each other in the interface and in the solution to form micelles [43]. The aggregation of NS compounds can be measured by reducing the surface tension and interfacial tension. The values IE % obtained from the four techniques used in this work are consistent with each other according the following sequence: compound II > compound I. This sequence is a good agreement with the surface and interfacial tension values in Table 1. These values in the case of compound II < compound I. The more inhibition efficiency gives lower surface and the interfacial tension values due to increase the adhesion force between the Al surface and NS compounds. Compound II also contains a high molecular size than the compound I which increases the surface area of Al covered by NS compounds i.e., increasing the values of θ and the IE% values Also, the inhibitory effect of NS compounds is associated with the presence of hetro atoms such as N and O in the chemical structure of the inhibitors which increases the electron density in the adsorption center and thus increases the values of IE%.

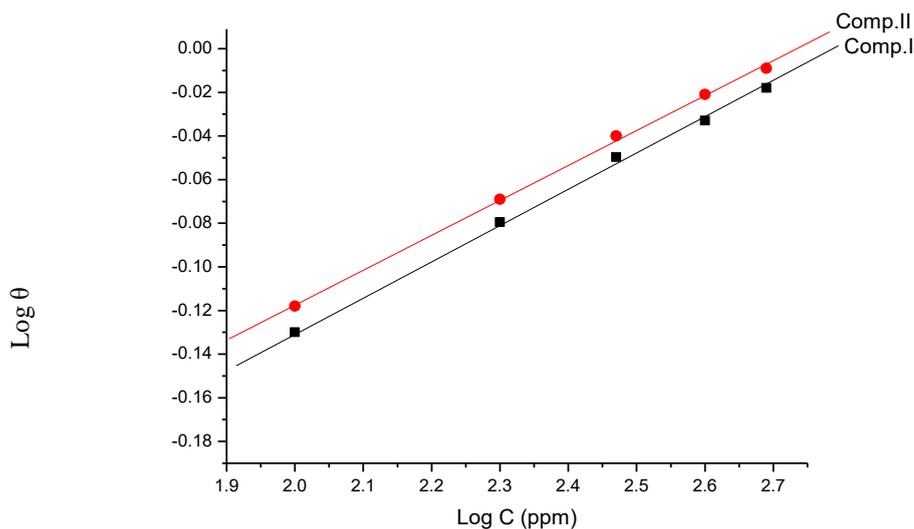


Figure 8. The relation between $\log \theta$ and $\log C$ (Freundlich isotherm)

4. CONCLUSION

1. NS compound containing heterocyclic six membered ring moiety acted as an inhibitor for corrosion of Al in 1.0M HCl
2. The inhibition was interpreted by adsorption of NS compounds on the surface of Al.
3. The adsorption obeyed Freundlich isotherm.
4. Gavanostatic polarization indicated that NS compound is a mixed-type inhibitor.

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