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Appraisal of Adsorption and Inhibition Effect of Expired Micardis Drug on Aluminum Corrosion in Hydrochloric Acid Solution

M.Abdallah[1,2,*], *H. Hawsawi*[3], *Arej S Al-Gorair*[4,*], *Mohamed T.Alotaibi*[5], *Salih S. Al-Juaid*[6], *R.S. Abdel Hameed*[7,8]

[1] Chem. Depart. Faculty of Appl. Sci., Umm Al-Qura University, Makkah, Saudi Arabia.
[2] Chem. Depart. Faculty of Sci., Benha University, Benha, Egypt.
[3] University College of Alwajh, Alwajh, Tabuk University, Tabuk, Saudi Arabia
[4] Chem. Depart., College of Science, Princess Nourah bint Abdulrahman University, P.Box 84428, Riyadh11671, Saudi Arabia.
[5] Chem. Depart., Turabah University College, Taif University, Saudi Arabia.
[6] Chem. Depart., Faculty of Sci., King Abdulaziz University, Jeddah, Saudi Arabia
[7] Chem. Depart., Faculty of Sci., Al-Azhar Univ., 11884 Egypt
[8] Basic Sci., Depart. Prepar. Year, Hail Univ., Hail, 1560 KSA
[*]E-mail: metwally555@yahoo.com, asalgorir@pnu.edu.sa

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Expired micardis (MIC) drug was investigated as an inhibitor for the corrosion of the aluminum electrode in 1.0 M HCl solution. The anticorrosive efficacy was determined by chemical and electrochemical techniques. The outcomes indicated that the efficacy of inhibition raised with the increasing doses of expired MIC and with lowering temperature. The anticorrosive efficacy values reached to 99.93% at 300 mg/L using electrochemical impedance technique. The anticorrosion was elucidated by the vigor adsorption of expired MIC on the surface of Al through the reaction centers present in its chemical structure. The adsorption obeys Langmuir isotherm. Potentiodynamic polarization classified an expired MIC as a mixed inhibitor. The impact of temperature on the corrosion rate of Al in 1M HCl was studied and when certain concentrations of expired MIC were included. Some thermodynamic variables of activation and absorption were calculated and explained.

Keywords: Expired Micardis, Inhibitors, Aluminum, Polarization, Adsorption

1. INTRODUCTION

Aluminum (Al) has great resistance to corrosion in many environments, and therefore, it is used in many important industrial applications such as reaction vessels, pipes, machinery, chemical batteries and many other industries. The resistance of aluminum to corrosion is due to the construction of adhesive layer of oxide on its surface. Hydrochloric acid solutions are utilized for pickling, chemical, and electrical etching of Al, but unfortunately, chloride ions cause the devastation of the oxide layer and cause aluminum corrosion [1]. There are some tools to diminish aluminum corrosion in these circumstances. The most important and most effective of these methods is the use of corrosion inhibitors where it has many advantages, it has a high efficiency in reducing corrosion and has a profitable economic feasibility and is applied vastly in different fields.

Many organic compounds, nonionic surfactants molecules, natural extracts of some plants and pharmaceutical compounds have been applied to the acidic corrosive to inhibit the corrosion of Al in HCl solutions [2-16].These compounds inhibits the corrosion by forming adsorbed layer adhere to the surface of Al [17-18].This layer protect the Al from corrosive solution. The anticorrosive efficacy depends on some factors such as nature of the metal, concentration and type of the acidic solution, temperature, chemical structure of the inhibitor applied and the interaction between the additives and metal ion. Previous studies indicated that the presence of heteroatoms, aromatic ring, conjugated π bonds in the chemical structures of the additives affects the vigor of inhibitor, as it increases in the presence of these factors [19-20].

The main goal of this manuscript is to overcome the problem of aluminum corrosion in hydrochloric acid by using simple economical inhibitors such as expired micardis drug. Micardis is a medicine used to treat the symptoms of high blood pressure (hypertension) .Instead of getting rid of it or destroying it, which leads to polluting the environment and affecting human health. Recently, scientists have used expired drugs as inhibitors of metal corrosion in different media, and they have given excellent results [21-25]. The anticorrosion efficacy of expired micardis drug were measured using chemical measurement such as mass loss (ML) and hydrogen evolution reaction (HER) and electrochemical measurements such as potentiodynamic polarization (PDP)and electrochemical impedance spectroscopy(EIS).The activation thermodynamic were estimated and clarified. The adsorption isotherm was studies and determination of the adsorption isotherm.

2. EXPERIMENTAL METHODS

2.1. Chemical and electrochemical methods

Aluminum (Al) with a purity of 99.999% was supplied from the aluminum factory in Nag Hammadi – Egypt applied in the current work. Al coupons with dimension $1.1\times 2.8 \times 0.15$ cm were utilized in mass loss (ML) experiments and H_2 evolution reactions (H_2ER). A cylindrical rod immersed in araldite with exposed surface area of 1.0 cm^2 was employed in GSP and EIS experiment. Prior to any experiment, the surface of Al coupon or rod were scraped with various grades of sand papers, degreased with acetone and washed with distilled water.

The methods of Mass loss were performed using abraded Al coupons [26].The coupons are weighed before and after inundation in the 50 ml of the examined solution for time reached to 6 hours. The experiment were repeated and the mean ML are taken. The desired temperature was adjusted to ±

0.1 °C using air thermostat. The method of H_2ER reactions were performed as previously explained [27]. The difference in Mass loss (ΔW) can be computed ($\Delta W = W_x - W_y$) where W_x and W_y are weight of Al coupons before and after the exposed to the corrosive solution.

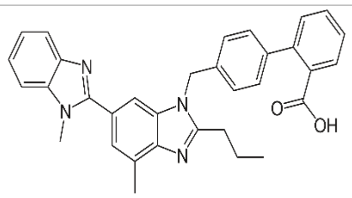
The electrochemical techniques such as PDP and EIS were performed using cell containing three electrodes, working electrode (Al), saturated calomel reference electrode (SCE) and auxiliary electrode Pt electrode. The Al electrode immersed in Araldite with appeared surface area of $0.54 cm^2$**.** The potential was measured against a reference SCE. All the chemicals utilized in this work were of A.R. quality**.**

The PDP measurements were carried out using a PS remote potentiostat with PS6 software to compute the corrosion parameters at a scanning rate $2 mV sec^{-1}$. EIS technique was performed at a frequency range from 10 kHz to 100 mHz and signal amplitude perturbation of 5 mV by using a computer- controlled potentiostate (Auto Lab 30, Metrohm).

2.2. Anticorrosive used

The chemical structure, chemical formula and IUPAC name of expired micardis used as an anticorrosive, in this manuscript are recorded in Table 1.

Table 1. The chemical structure,chemical formula and IUPAC name of expired micardis drug

Name	Chemical structure	Chemical formula	IUPAC name
Micardis (MIC)		$C_{33}H_{30}N_4O_2$	2-[4-[[4-methyl-2-propyl-6-[1-(trideuterio(1^{13}C)methyl)benzimidazol-2-yl]benzimidazol-1yl]methyl]phenyl] benzoic acid

3. RESULTS AND DISCUSSION

3.1. PDP technique

PDP technique was applied in the current manuscript to determine the adsorption characteristics of the expired MIC drug. Fig. 1 displays the PDP technique for Al electrode in 1M HCl solution without and with various concentrations of expired MIC drug. Various important parameters were achieved from this figure such as cathodic, anodic Tafel slopes (β_c and β_c), corrosion potential (E_{corr}), corrosion current density($I_{corr.}$) and anticorrosive efficacy (% AE) and collected in Table 2. The AE% were determined from this equation:

$$\% AE = [1 - \frac{I_{in}}{I_f}]100 \qquad (1)$$

Where, I_f and I_{in} are the corrosion current densities in the free 1M HCl solution and in the presence of expired MIC drug

From Table 2, it is evident that, with increasing doses of expired MIC drug, there is little difference in the values of β_a and β_c or almost constant and there is no significant shift in E_{corr} values. The E_{corr} shif equal to 25mV, respectively. These values demonstrate that expired MIC drug is a mixed inhibitor. This means that expired MIC drug blocked both the cathodic and anodic sites without variation the corrosion mechanism. The I_{corr}. values are reduced and therefore, the %AE values are increased. These data confirm the stellar inhibiting impact of expired MIC drug compounds. The %AE values reaching at 300 mgl^{-1} of expired MIC drug is 97.17% . The efficacious of inhibition action is due to the blocking of the active sites of the Al surface by MIC molecule.

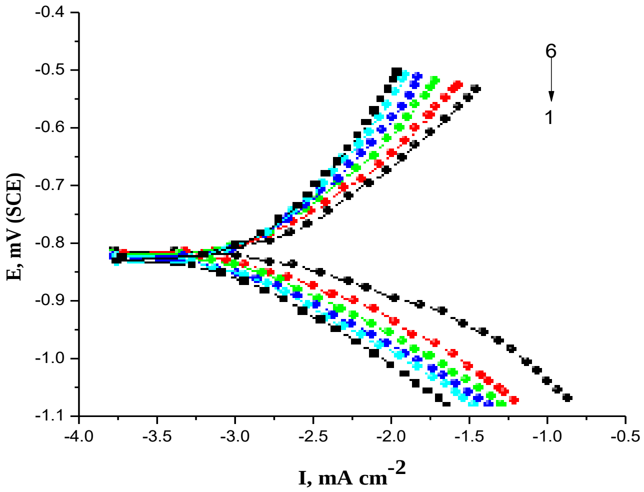


Figure 1. PDP plots of Al electrode in1M HCl solution without and with various concentrations of expired MIC drug. 1)0.00 2)100 3) 150 4)200 5)250 6)300 mgl^{-1}MIC

Table 2. Electrochemical parameters acquired from the PDP curves

Inh.	Inh. Conc. (mg l-1)	-βc, mV dec.-1	βa , mVdec-1	-Ecorr mV,(SCE)	Icorr (µA/cm2)	%AE
Blank	0.0	322	662	820	212	-
MIC	100	312	655	828	98	53.77
	150	316	658	832	68	67.92
	200	320	668	836	58	72.64
	250	328	665	840	17	91.98
	300	335	672	845	6	97.17

3.2. EIS technique

The impact of certain doses of expired MIC drug on the Nyquist and Bode plots impedance behavior of Al electrode in 1 M HCl solution at 278 K is displayed in Fig.2 (A& B). The behavior of

Nyquist plots obtained in Fig 2A not show perfect semicircle. These deviations are due to the frequency scattering of interfacial impedance which arises due to surface roughness, impurities, and inhomogeneity of electrode surface [28-29]. The results donates that each impedance diagram consists of a large capacitive loop with a single capacitive time constant in the Bode–phase plots (Fig.2b). In this way, the mass transfer process on the Al surface was prevented by the adsorption of the MIC drug showing the single capacitance ring. Moreover, the corrosion mechanism of Al in 1.0 MHCl solution in the devoid of and existence of the MIC drug was enhanced by a single maximum in the Bode plots (Fig. 2b).

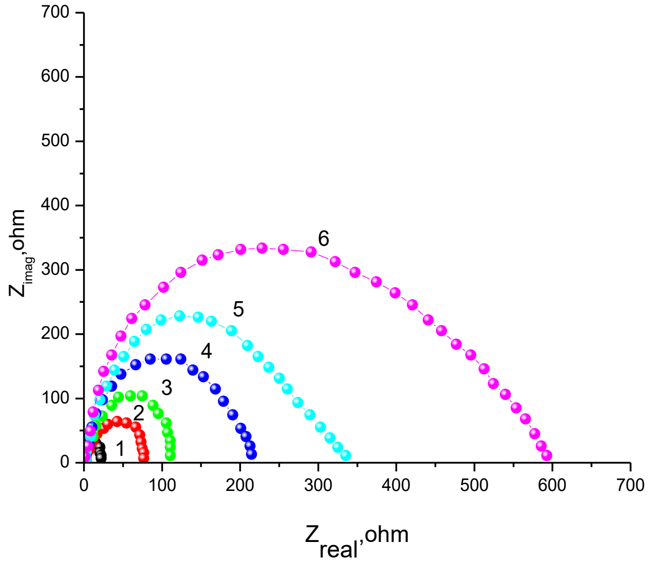


Figure 2 a. Nyquist plots of Al in 1.0M HCl solution and with some doses of expired MIC drug; 1) 0.00 2)100 3) 150 4)200 5)250 6)300 mgl^{-1}MIC

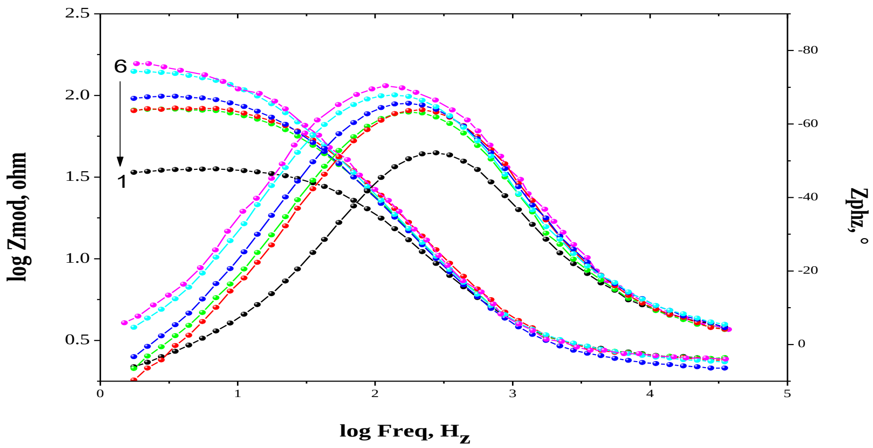


Figure 2b. Bode plots of Al in 1.0M HCl solution and with some doses of expired MIC drug; 1) 0.00 2)100 3) 150 4)200 5)250 6)300 mgl^{-1}MIC

The EIS diagrams were analyzed by fitting the experimental results to equivalent circuit as shown in Fig.3. which contains the solution resistance R_s and the double layer capacitance C_{dl} which is placed in parallel to the charge transfer resistance R_{ct}.

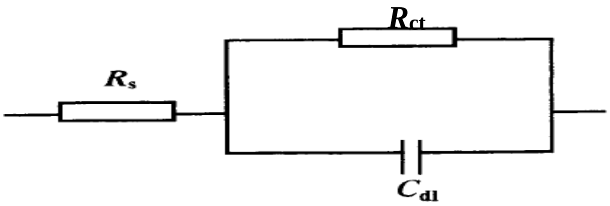


Figure 3. The equivalent circuit applied to fit the experimental results.

The EIS parameters obtained from the analysis of Nyquist plots are the resistance of charge transfer R_{ct} (diameter of the high frequency loop) and the capacity of double layer C_{dl} which is defined as:

$$C_{dl} = 1/ 2\pi f_{max} R_{ct} \quad (2)$$

Where, f_{max} is maximum frequency.

The anticorrosion efficacy obtained from the EIS measurements from the next equation:

$$\% AE = [1- \frac{R_{ct,in}}{R_{ct,f}}] 100 \quad (3)$$

Where, $R_{ct,f}$ and $R_{ct,in}$ are the charge transfer resistance in the free1.0MHCl solution and when containing the MIC drug ,respectively. The impedance parameters such as C_{dl} , R_{ct} and %AE determined and registered in Table 2. The diameter of capacitive loop rises with rising doses of MIC drug resulting in an increase in R_{ct}. This increase is due to the adsorption of the MIC drug, which leads to the construction of an adhesive film on the surface of Al. It is observed from Table 2, as the concentration of the MIC drug increases, the R_{ct} values increase and thus, the %AE values increase due to the construction of coated film on the Al surface. The C_{dl} values decrease due to the gradual substitution of water molecule by the adsorption of MIC drug on the surface of Al to form adhesive film on its surface and led to the reduce in local dielectric constant of the Al solution interface.

Table 3. EIS parameters for the corrosion of Al in 1 M HCl at certain concentrations of expired MIC drug

Inhibitor	Inh. Conc. (mg l^{-1})	C_{dl}, μF cm^{-2}	R_{ct}, ohm cm^2	%*AE*
MIC	0.0	70.22	35.5	----
	100	64.23	75.4	52.91
	150	58.47	114.6	69.02
	200	54.73	212.5	83.29
	250	50.28	335.6	89.42
	300	47.02	591.2	93.99

3.3. Hydrogen evolution reaction (HER)

The HER during the corrosion of Al coupons in a 1.0 M HCl solution is utilized to measure anticorrosion efficacy of the expired MIC. Fig.4 presents the relationship between the volume of H2 evolution during Al corrosion and the reaction time in the blank 1.0 M HCl solution and with containing some doses of expired MIC. It is evident that from this Fig. in the absence of expired MIC, the dissolution of Al is slow and thus the volume H_2 evolution is low until a certain time is reached, the evolution of H_2 increases due to the collapse of the pre-immersion of oxide film on the Al surface.

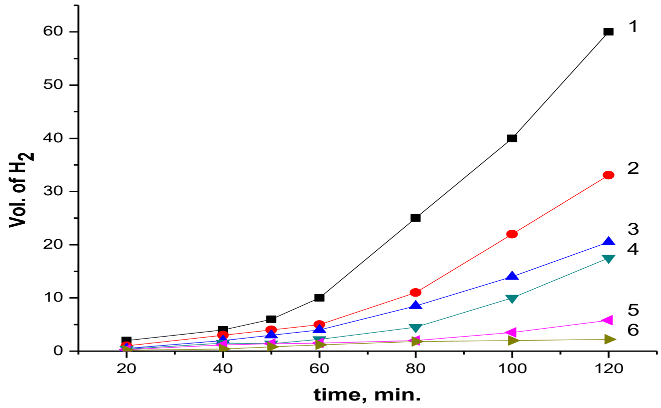


Figure 4. The relation of H_2 during the corrosion of Al in free 1.0 M HCl solution and with certain concentrations of expired MIC drug. 1) 0.00 2)100 3) 150 4)200 5)250 6)300 mgl^{-1}MIC

Table 4. Parameters obtained from the H_2 evolution reaction

Inh.	Inh. Conc. ($mg\ l^{-1}$)	*R*c (ml/min.)	%AE_{HER}
Blank	0.0	0.952	-
MIC	100	0.484	50.84
	150	0.298	68.69
	200	0.155	83.48
	250	0.062	93.97
	300	0.006	99.37

This time is known as the induction time. After this time the H_2 evolution increases rapidly with time. Dissolution of Al to $AlCl_3$according to the next reaction [30]:

$$Al + 3HCl = AlCl_3 + 3/2H_2 \quad (4)$$

The volume change of H_2 (V_{H2}) with reaction time (t) after induction time increases rapidly according to the subsequent equation:

$$V_{H2} = X\,t \quad (5)$$

Where X is the specific rate constant of the dissolution reaction.

In the presence of expired MIC drug, the induction time increases and this time increases with increasing the doses of it, due to the increase in the stability of the film formed on the surface of Al. The corrosion rate (R_C) can be determined from the slope of the straight line occurred after the induction time. The anticorrosive efficacy from HER (% AE_{HER}) are computed from the next equation and collected in Table 2:

$$\% AE_{HER} = [1- \frac{R_{c,in}}{R_{c,f}}] 100 \qquad (6)$$

The computed values of the R_C and the % AE_{HER} are recorded in Table 3. Clearly from tis table with increasing the doses of expired MIC the volume of evolved hydrogen and the rate of corrosion diminished leading to increase the %AE.

3.4. Mass loss measurements (ML)

The ML- inundation time curves for the dissolving Al coupons in 1.0M HCl solution without and with various concentrations of expired MIC are contained at 300°K is displayed in Fig.5. A rise in ML is observed in the free 1MHCl solution but when the expired MIC is added, the ML reduces and the amount of reduction increases with higher concentrations of expired MIC. This indicates that the expired MIC diminishes the corrosion rate of the Al in M HCl solution or in the or in other words the expired MIC act as inhibitor. Linear relationships are observed in Fig.5 which demonstrates the devoid of the insoluble surface film during corrosion. This indicates the expired MIC are initially absorbed on the Al surface and then hinders corrosion by covering the anodic and cathodic sites

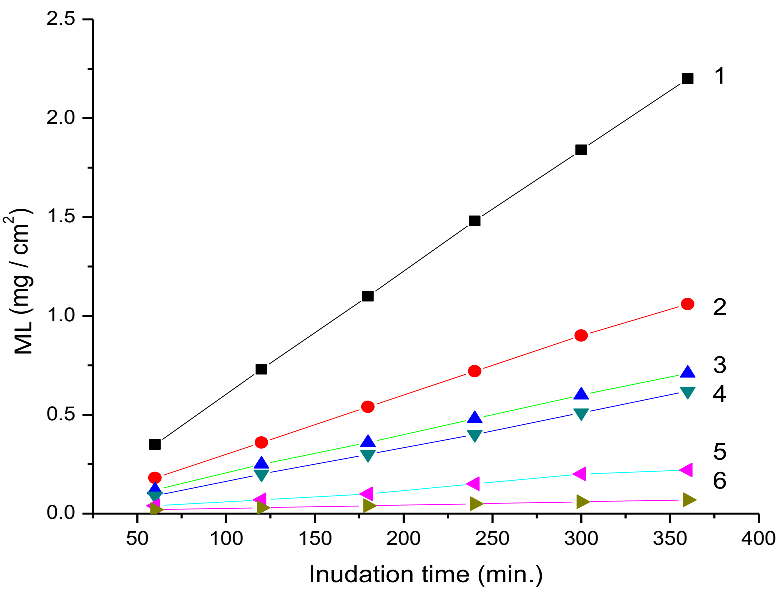


Figure 5. ML-time curves for Al coupons in free 1.0 M HCl solution and with various doses of expired MIC drug. 1) 0.00 2)100 3) 150 4)200 5)250 6)300 mgl^{-1}MIC

The rate of corrosion (R_C)is determined as $mg.cm^{-1}.min^{-1}$using the next equation [31-32].

$$R_C = \frac{\Delta w}{S.t} \qquad (7)$$

where, S is the surface area of Al coupon and t in the inundation time.

The anticorrosive efficacy (%AE_{ML}) and parameter(θ) which signifies the part of metal surface covered by the polymer molecules were calculated from the mass loss data using the flowing equations:

$$\% AE_{ML} = [1- \frac{R_{c,in}}{R_{c,f}}] 100 \quad (8)$$

$$\theta = [1- \frac{R_{c,in}}{R_{c,f}}] 100 \quad (9)$$

Where, $R_{c,in}$ and $R_{ct,un}$ are the corrosion rate obtained from ML measurements in the blank 1.0MHCl solution and when containing the MIC drug ,respectively.

The computed values of ΔW, R_C, % *AE* and θ at 300 K are recorded in Table 5.

Clearly from Table 4, with increasing the concentration of expired MIC the mass loss and the R_C of Al coupons lowered than in free 1MHCl solution and the % AE and θ increases. Theses indicate the expired MIC act as an excellent inhibitor for the corrosion of Al in 1MHCl solution. The % AE reached to 96.81 at 300 mg l^{-1} of expired MIC

3.4.1. Influence of temperature

Influence of temperature rise on the ML of Al coupons in free 1M HCl solution and when certain concentrations of 100 to 300 mg^{-1} of expired MIC are contained. Chemical parameters such as the difference in ML, R_C, %AE and θ at certain temperatures ranging from 100K to300K are computed and recorded in Table 5. From this table, it is evident that, with altitude of temperature the values of ML, R_C increases and thus %AE, θ are reduced. These outcomes demonstrate the adsorption of MIC on the Al surface is physical. The altitude of temperature led to desorption of some adsorbed expired MIC on the surface of the Al. Hence the covered area of Al was reduced resulting in lower %AE.

3.4.2. Activation of kinetic parameters

The activation energy (Ea) for dissolving the Al coupon in 1M free HCl solution and when containing different concentrations of expired MIC was determined using the Arrhenius equation [33,34].

The activation energy (E_a) for dissolving the Al coupon in free 1M HCl solution and when containing various concentrations of expired MIC drug was determined using the Arrhenius equation [33,34].

$$\log R_C = \log A - \frac{Ea}{2.303\, RT} \quad (10)$$

where A,R and T are the Arrhenius constant, the gas constant and the T temperature represents an Arrhenius diagram (log R_C vs 1/T) for dissolving the Al coupon in 1M HCl solution with and without various concentrations of expired MIC.

Table 4. Corrosion parameters acquired from ML measurements.

Temperature °K	Inh.Conc. ($mg.l^{-1}$)	R_C, $mg.cm^{-2}.h.^{-1}$	% AE_{ML}	$\theta_{(ML)}$ %
300	0.0	0.595	-	-
	100	0.286	51.93	0.519
	150	0.192	67.73	0.677
	200	0.168	71.76	0.718
	250	0.059	90.08	0.901
	300	0.019	96.81	0.968
310	0.0	0.841	-	-
	100	0.435	48.27	0.483
	150	0.330	60.76	0.608
	200	0.295	64.92	0.650
	250	0.151	82.04	0.820
	300	0.114	86.44	0.864
320	0.0	1.049	-	-
	100	0.579	44.80	0.448
	150	0.473	54.91	0.549
	200	0.411	60.82	0.608
	250	0.292	72.16	0.722
	300	0.176	83.22	0.832
330	0.0	1.168	-	-
	100	0.708	39.38	0.394
	150	0.589	49.57	0.496
	200	0.524	55.14	0.551
	250	0.397	66.01	0.660
	300	0.273	76.63	0.766

These relationships gave straight lines with linear regression coefficients very close to 1. E_a values can be computed from the slope of the straight lines and recorded in Table 5.

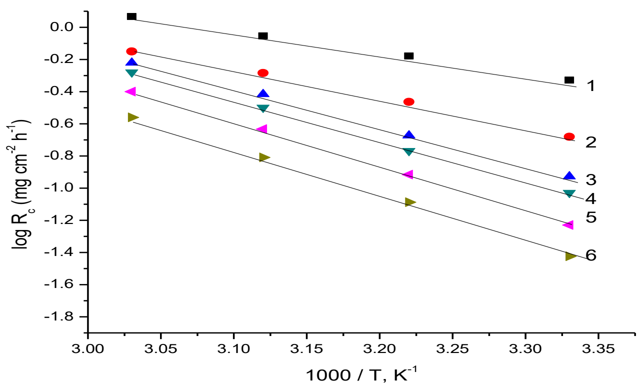


Figure 6. Arrhenius plots for the corrosion of Al coupons in free 1M HCl solution and including certain concentration of expired MIC. 1) 0.00 2)100 3) 150 4)200 5)250 6)300 mgl^{-1}MIC

Obviously from this table the E_a values in the presence of expired MIC drug are more than in free 1M HCl solution. The rise in E_a values is owing to the formation of adherent film on the Al surface. These outcomes demonstrate the physical adsorption of an expired MIC on the Al surface.

The enthalpy (ΔH°) and entropy (ΔS°) of activation were computed utilizing the transition state equation [33,34].

$$\ln \frac{Rc}{T} + \frac{\Delta H^o}{RT} = [\ln \frac{R}{N_A\, h} + \frac{\Delta S^o}{R}] \quad (11)$$

where, h is the Plank constant (6.626×10^{-34} j.s) and N_A is the Avogadro's number (6.02×10^{23} mol^{-1}),

Figure7 displays the plots between log R_c/T and 1/T for the corrosion of the Al coupon in free 1M HCl solution and when certain concentrations of expired MIC are included. Straight lines were acquired with slope equal to (-ΔH°/R) and intercept equal to ($\ln \frac{R}{N_A\, h} + \frac{\Delta S^o}{R}$). The values of ΔH° and ΔS° are computed and recorded in Table 5.

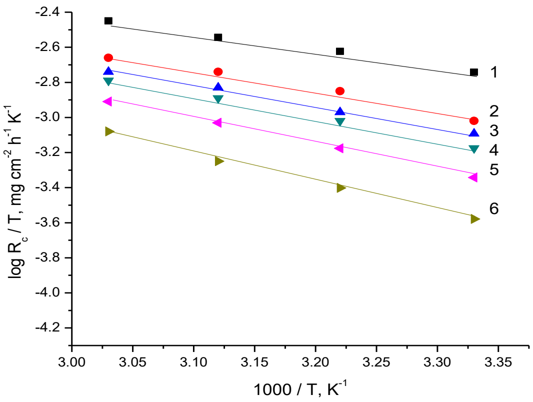


Figure 7. The relation between log R_c/T and 1/T for the corrosion of the Al coupons in free 1M HCl solution

Table 5. Activation parameters for Al in 1MH_2SO_4 solution with and without various doses of expired MIC

Conc. of expired MIC(mgl^{-1})	E_a kJ mol^{-1}	Δ*H** kJ mol^{-1}	Δ*S**- J mol^{-1} K^{-1}
0.00	15.31	10.42	312.52
100	16.63	12.05	335.13
150	18.63	14.31	352.27
200	19.12	15.38	370.95
250	20.78	16.63	384.88
300	21.62	18.29	398.64

It is evident from this table that the values of ΔH^o are positive demonstrating that the endothermic nature of the activated complex formation during corrosion operation. ΔH^o values increase with increasing doses of the expired MIC indicating that the existence of this drug makes it difficult to corrode Al in 1MHCl solution. Negative values of ΔS^o show that the active complex in the rate -determining step represents an assembly rather than disengagement demonstrating a reduction in the stochastic transition from reactants to activating complex.

3.5 Adsorption isotherm and mechanism of inhibition

Expired MIC drug inhibits the corrosion of Al in 1MHCl solution through the adsorption on its surface. The strength of the adsorption depends on the type of the interaction and the bond formed between the expired MIC and the Al surface, the concentration of the aggressive HCl and the expired MIC, temperature and other factors, The adsorption can be considered as replacement operation between the expired MIC in the aqueous solution(MIC $_{(aq).}$) and the number of H_2O molecule adsorbed on the Al surface (z H2O)$_{ads}$. to form MIC adsorbed on the Al surface MIC $_{(ads)}$.

$$MIC_{(aq)} + zH_2O_{(ads)} \rightarrow MIC_{(ads)} + z\,H_2O_{(aq)} \quad (12)$$

where z is defined as the volume ratio equal to the number of adsorbed water molecules substituted by the expired MIC molecule.

Adsorption gives knowledge about the reaction between the MIC molecule themselves as well as their reaction with the Al surface. In fact, one adsorbed MIC molecule may make the surface more or less difficult for another molecule to adhere to an adjacent site and multilayer adsorption may occur. There may be more or less than one expired MIC molecule per surface site. Finally, different surface sites can have varying degrees of activation. Therefore, Trials were performed to select the preferred for the adsorption isotherm of expired MIC on the surface of Al by applying the values of $\theta_{(ML)}$ in various isotherm. We find that the experimental data match with Langmuir isotherm by applying this equation:

$$\frac{C_{inh}}{\theta} = \frac{1}{K_{\mathrm{ads}}} + C_{inh} \quad (13)$$

where C_{inh} is the concentration of expired, K_{ads} is the equilibrium constant of adsorption

Fig. 8 represents the plots of Langmuir isotherm (C_{inh}/θ vs C_{inh}) for the corrosion of Al in 1M HCl including certain doses of expired MIC at different temperatures ranged from 300K to 330K.A straight lines were acquired with slope nearly equal one. The correlation coefficient equal 0.997. This confirm that the Langmuir isotherm is the preferable isotherm for adsorption of expired MIC on the Al surface. This means that there is no interaction between adsorbing species [35].

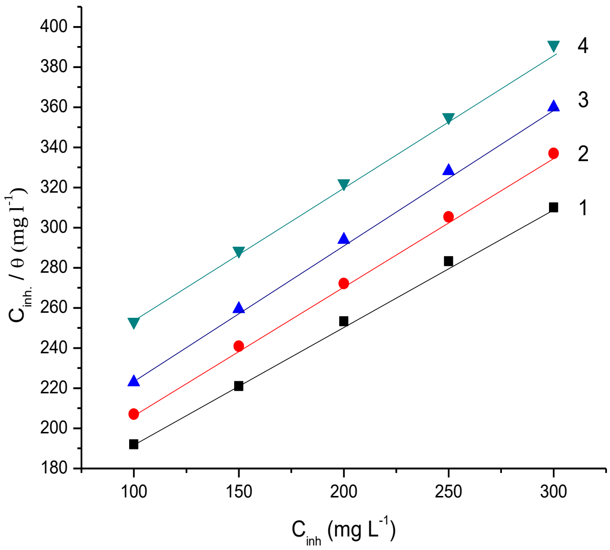


Figure 8. Plots of Langmuir isotherm for adsorption o expired MIC on the AL surface at certain temperatures. 1) 300K 2) 310 K 3) 320K 4) 330K

From intercept of the Fig 8. The Values of K_{ads} can determined and equal to(5.55,5,12, 4.72and 4.21) X10^{-3}. From these values, we can determine the free energy for adsorption ($\Delta G_{ads.}$) according to the next equation:

$$55.5\ K= e^{(-\ \Delta Goads\ /RT)} \quad (14)$$

where 55.5 of water molecule in mol. L^{-1}.

The determined values of ΔG_{ads} are equal to - 24.45, - 20.79, -18.62 and -15.02 kJ. mol^{-1} at 300,310,320 and 330 K, respectively. The negative marks of ΔG_{ads} demonstrates the spontaneous physical adsorption of expired MIC onto the Al surface. These values are lowered with increasing temperature. This results are coincides with the values of the %AE are also decreased with increasing temperature.

The enthalpy of adsorption (ΔH_{ads}) can be determined from Van't Hoff equation [36]

$$\log K_{ads.} = \frac{\Delta H_{ads}}{2.303\ RT} + K \quad (15)$$

where K is constant

Fig.9 displays the Van't Hoff plots (relationship between log K_{ads}. versus 1000/T) for the adsorption of the expired MIC on the Al surface. The value of $\Delta H°_{ads}$ was computed from the slope of the straight line obtained and equal to 3.325 kJ mol^{-1}. The positive values of $\Delta H°_{ads}$ reflect that the adsorption of expired MIC on the Al surface is endothermic in nature.

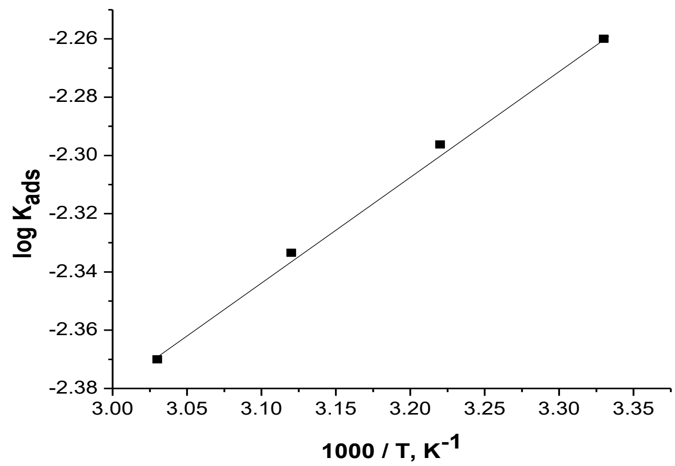


Figure 9. The relationship between log K_{ads}. versus 1000/T for the adsorption of expired MIC on the Al surface

The entropy of adsorption (ΔS_{ads}) can de determined from the next equation

$$T\Delta S_{ads} = \Delta H_{ads} - \Delta G_{ads} \quad (16)$$

The determined values of ΔS_{ads} are equal to -0.092, -0.077, -0.068 and -0.055 kJ mol^{-1}. The negative signs of ΔS_{ads} elucidate that the disturbance reduces when moving from the reactant to the adsorbed surface. This denotes the adsorption vigor of the expired MIC on the Al surfacer. The values of thermodynamic parameters of adsorption coincide with the higher values of %AE at lower temperatures.

4. CONCLUSIONS

1. Expired MIC act as excellent inhibitor for corrosion of Al in 1.0 M HCl solution.
2. The anticorrosive efficacy increases with increasing the concentrations of expired MIC.
3. The inhibition process was explained due to the vigor adsorption of expired MIC on the Al surface
4. The adsorption is subjected to Langmuir isotherm.
5. Expired MIC act as mixed inhibitor.
6. Electrochemical impedance data demonstrates that the corrosion reaction is controlled by charge transfer process.

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