DOI: 10.24996/ijs.2020.61.8.2

ISSN: 0067-2904

Experimental Evaluation for the Inhibition of Carbon Steel Corrosion in Salt and Acid Media by New Derivative of Quinolin-2-One

Mustafa Alaa Mohammed, Rehab Majed Kubba*

Department of Chemistry, College of Science, University of Baghdad, Baghdad, Iraq

Received: 1/2/2020 Accepted: 13/4/2020

Abstract

The inhibition ability of the new derivative (quinolin-2-one), namely (1-{[5-(2-Chloro-phenylazo)-2- hydroy-benzylidene]-amino}-4,7-dimethyl -6-nitro- 1H-quinolin-2-one (CPHAQ2O)) towards carbon steel corrosion in (3.5% NaCl) and (0.5M HCl) solutions were evaluated by potentiodynamic polarization at different inhibitor concentrations. Polarization curves showed that the evaluated compound acted as mixed inhibitors, and the adsorption of the evaluated inhibitor obeys the Langmuir adsorption isotherm in both salt and acid solutions. The results revealed that the percentage inhibition efficiency (%IE) in the salty solution (90.55%) is greater than that in the acidic solution (77.62%). The surface changes of the carbon steel and the film persistency of the inhibitor were studied using SEM (Scanning Electron Microscopy).

Keywords: Quinolin; Corrosion inhibitors; Quantum chemical calculations; Thermodynamic parameters

التقييم التجريبي لتثبيط تآكل حديد الصلب الكربوني في الوسطين الملحي والحامضي بفعل مشتق جديد من الكينولين-2-اون

مصطفى علاء محمد، رحاب ماجد كبة*

قسم الكيمياء، كليةالعلوم، جامعةبغداد، بغداد، العراق

الخلاصه

تم تقييم قابلية تثبيط المشتق الجديد (كوينولين-2-اون) الذي يحمل الاسم 1-{[5-(2-Chloro-phenylazo) -2-hydroy-benzylidene]-amino}-4,7-dimethyl -6-nitro- 1H-quinolin-2-one (CPHAQ2O) نحو تآكل حديد الصلب الكربوني في محلولي (3.5NaCl%) و (0.5M HCl) بإستخدام قياسات الاستقطاب المجهادي عند تراكيز مختلفة من المثبط. أظهرت منحنيات الاستقطاب أن المركب الذي تم تقييمه كان بمثابة مثبط مختلط، وأن امتزاز المثبط الذي تم تقييمه يطيع ايزوثيرم امتزاز لنكماير Langmuir isotherm. أظهرت النتائج أن كفاءة التثبيط (%IE) في المحلول الملحي (90.55٪) أكبر من كفاءة التثبيط في المحلول الحامضي (77.62٪). تمت دراسة التغيرات السطحية لحديد الصلب الكربوني باستخدام تقنية SEM (الفحص المجهري للإلكترون).

Introduction

Corrosion is defined as the degradation of minerals as a result of chemical interaction to the surrounding environment. Corrosion causes heavy economic losses. Carbon steel is widely used in metallurgical industries because of its high strength, ease of manufacture and cost-effectiveness.

---

*Email: Rehab_mmr_kb@yahoo.com

However, it suffers from corrosion during pickling, descaling and acid cleaning. Thus it is necessary to develop some effective corrosion inhibitors [1]. The choice of a good corrosion inhibitor depends on having functional groups rich in electrons. In general, organic inhibitors prevent metallic corrosion by absorbing on the surface and thus form a protective barrier between the metal and the electrolyte (salt or acid). Organic compounds containing heterogeneous atoms including (Nitrogen, Sulfur, and/ or Oxygen) have been reported with polar functional groups and conjugate double bonds as an effective corrosion inhibitor [2-6]. Quinoline derivatives in general are known to have a variety of pharmacological and biological activities, such as immune depressant activity, antimalarial activity and antitubecular activity [7-8]. Many reports have been presented in literature on the use of quinoline and some of its derivatives as corrosion inhibitors in different media [9-13]. In this search we focused on the Quinolin-2-one derivative, a heterocyclic entity and pharmacologically important molecule.

The aim of this work was studying the inhibition efficiency of organic inhibitor (CPHAQ2O), (see Figure -1), prepared by Luma S.A. et. al. [14]; experimentally, in salty (3.5% NaCl) and acidic (0.5M HCl) solutions using potentiostat method, and theoretically, the calculations of quantum chemical parameters were done in three media (vacuum, DMSO, and water) using DFT [6-311/ B3LYP++G (2d, 2p)] method and Gaussian 09 program.

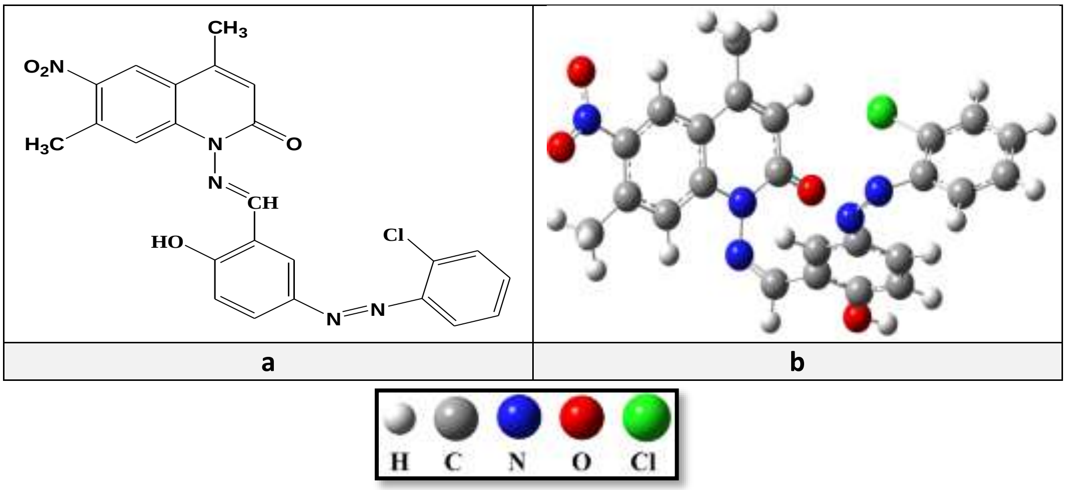


Figure 1- a. Two dimensions structure of (1-{[5-(2-Chloro-phenylazo) -2-hydroy-benzylidene]-amino}-4,7-dimethyl -6-nitro- 1H-quinolin-2-one (CPHAQ2O)). **b.** Three dimensions structure of (CPHAQ2O).

Experimental details

Preparation of carbon steel samples

The experiments were carried out using steel's rod symbolized as (C45) with composition percentage (wt %): (0.122% C, 0.206% Si, 0.641% Mn, 0.016% P, 0.031% S, 0.118% Cr, 0.02% Mo, 0.105% Ni, and 0.451% Cu) [3]. The rod was mechanically cut into pieces to form a circular sample of carbon steel with a diameter of 1.6 cm and a thickness of 3 mm. Each of these specimen was refined with emery paper (silicon carbide SiC) in different grades (80, 150, 220, 320, 400, 1000, 1200 and 2000) grades, then washed with tap water, distilled water and recent degreased with acetone, washed again with deionizer water, finally the specimen hold in a desiccators after it is dried in room temperature.

Preparation of solutions

Blank salt solution

35gm of sodium chloride (NaCl) was dissolved in (100mL) distilled water; transferred the formative solution into (1L) volumetric flask, containing 2mL of dimethyl sulfoxide (DMSO). The volume of the solution was completed to (1L) by adding distilled water. Using 3.5% NaCl is the suitable chooses in this study in order to avoid some problems related to the ohmic drop.

Blank acid solution

40 ml (0.5M) of HCl was diluted by distilled water to (1 liter) in a volumetric flask, after adding 2mL of solvent of dimethyl sulfoxide (DMSO).

Preparation of the salty solutions of (CPHAQ2O) compound

Three concentrations of the (CPHAQ2O) inhibitor (5,10, and 20ppm) were prepared by dissolving (0.005, 0.01 and 0.02gm), respectively in (2mL) of DMSO, then transferred each one to (1L) volumetric flask containing 35gm (3.5%) of NaCl dissolved in distilled water. The volume of each solution was completed to 1L with distilled water.

Preparation of the acidic solutions of (CPHAQ2O) compound

Three concentrations of the (CPHAQ2O) inhibitor (5, 10, and 20ppm) were prepared, by dissolving (0.005, 0.01 and 0.02gm), respectively in (2mL) DMSO, then transferred each one to (1L) volumetric flask containing (~44mL of 11.456M HCl). The volume for each solution was completed to (1L) with distilled water.

Electrochemical measurements

Potentiostatic polarization study

The potentiostat set up including host computer, Mat lab (Germany, 2000), magnetic stirrer, thermostat, potentiostat, and galvanostat. The main part of the apparatus is the corrosion cell; it's made of Pyrex with 1L capacity. This cell consists of two bowls external and internal. Three electrodes are mainly present in the electrochemical corrosion cell, carbon steel specimen having $1cm^2$ surface area represented as a working electrode that is used to determine the working electrode potential due to another electrode namely reference electrode was putting in a close to the working electrode. The reference electrode was (Ag/ AgCl, 3.0M KCl). The last electrode is a platinum auxiliary electrode having (10 cm) length. The starting step was represented in immersing the working electrode in the test solution for fifteen minutes (15 min.), to establish a steady-state open circuit potential (E_{ocp}). This potential was noted for starting the electrochemical measurements in the range of ±200 mV. All tests solution were done at temperatures of (293, 303, 313 and 323) K.

Results and discussion

Corrosion inhibition measurement

Potentiodynamic polarization measurements

The electrochemical corrosion parameters in salt and acid solutions are presented in Tables (1 and 2), such as corrosion potential (E_{corr}), Tafel slopes (bc, ba) and corrosion current density (I_{corr}) obtained for cathodic and anodic regions of the Tafel lines. Figures- (2and 3) present potentiodynamic polarization curves for carbon steel (C.S) in sea water and acid solutions, containing different concentrations of CPHAQ2O compound. IE%, ϴ, can be measured using equations (1-4).

$$\%\mathrm{IE} = \frac{\mathrm{I}_{\mathrm{corr(un)}} - \mathrm{I}_{\mathrm{corr(in)}}}{\mathrm{I}_{\mathrm{corr(un)}}} \times 100 \qquad \ldots.(1)$$

Where $I_{corr\ (in)}$ is the inhibited corrosion current densities; $I_{corr\ (un)}$ is the uninhibited current densities. The values of polarization resistance (Rp) can be calculated using equation 2.

$$\mathrm{Rp} = \frac{b_a \times b_c}{2.303(b_a + b_c) \times I_{\mathrm{corr}}} \qquad (2)$$

The surface coverage (ϴ) of the carbon steel immersed in 3.5% NaCl and acidic solutions containing different CPHAQ2O concentrations (C) can be estimated using equation 3.

$$\Theta = \frac{\%\mathrm{IE}}{100} \qquad (3)$$

The corrosion rate (CR) can be calculated using equation 4:

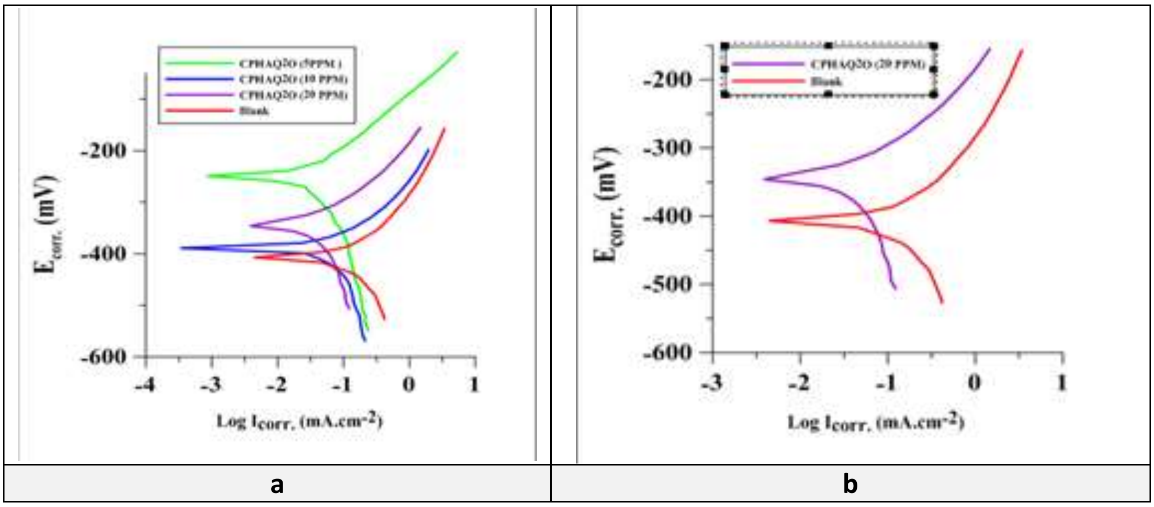
$$\mathrm{CR} = I_{\mathrm{corr}} \times 0.249 \ldots \qquad (4)$$

The addition of the quinolin-2-one derivative leads to a decrease in the corrosion rate i.e the conversion of cathodic and anode curves to lower values of the current density. Both cathode and anode corrosion reactions in C.S (carbon 45) electrode were prevented by CPHAQ2O in both 3.5% NaCl and 0.5M HCl solution. Figures- (3 and 4) show Tafel lines of anodic and cathodic polarization curves for the corrosion of carbon steel in the salty and in the acidic solution respectively, with and without the addition of various concentrations of CPHAQ2O inhibitor as well as the optimum conditions of (20ppm) inhibitor and (at 293K) temperature.

Tables-(1 and 2) list the corrosion rate values of C.S and inhibition efficiencies of various inhibitor concentrations measured at salty and acidic solutions at different temperature respectively. The tables show that increasing temperature lead to increase the corrosion current densities $I_{corr.}$. While the efficiencies IE% is enhanced with the increasing of the inhibitor concentration. The optimum conditions for CPHAQ2O in the salty and in the acidic solutions were found at 293K temperature and 20ppm inhibition concentration both corresponded to the lowest I_{corr} of (12.58 μA.cm^{-2}) and the maximum IE% of 90.55% in the salty solution and lowest I_{corr} of (37.84 μA.cm^{-2}) and the maximum IE% of 77.62% in the acidic solution respectively. The values of iron corrosion rate CR are decreased with the increase of CPHAQ2O concentration. The addition of the inhibitor to the blank solution increases the cathodic and anodic current densities without shifting the corrosion potential. The CPHAQ2O inhibitor therefore can be described as a mixed-type inhibitor in which its inhibition action is caused by the adsorption process. The inhibition action is a proportional of the reduction reaction area on the carbon steel surface [15].

Table 1-Electrochemical data of C.S corrosion in salty solution at different concentrations of CPHAQ2O compound

Soln.	T (K)	E_{corr} (mV)	I_{corr} (μA.cm^{-2})	bc (mV.dec^{-1})	ba (mV.dec^{-1})	IE%	Θ	CR (Ampere)
Blank 3.5% NaCl	293	-408.0	133.13	-230.4	138.5	------	------	33.15
	303	-446.7	172.04	-279.6	110.2	------	------	42.84
	313	-491.2	189.34	-269.0	96.5	------	------	47.15
	323	-547.7	192.99	-252.9	84.4	------	------	48.05
5ppm	293	-248.5	17.54	-125.8	74.4	86.82	0.864	4.49
	303	-421.2	27.41	-56.5	43.8	84.06	0.849	6.46
	313	-432.1	35.03	-67.6	47.1	81.49	0.819	8.54
	323	-479.4	47.74	-88.0	54.4	75.26	0.776	10.76
10ppm	293	-386.4	17.24	-63.3	38.7	87.05	0.871	4.27
	303	-420.9	23.89	-73.8	45.6	86.11	0.863	5.86
	313	-488.8	36.55	-113.0	58.1	80.69	0.836	7.73
	323	-540.3	42.23	-189.9	79.7	78.11	0.780	10.56
20ppm	293	-344.6	12.58	-66.6	53.5	**90.55**	0.950	1.66
	303	-458.3	23.27	-145.0	65.5	86.47	0.856	6.18
	313	-458.4	36.38	-219.5	68.0	80.78	0.830	7.98
	323	-487.0	43.51	-299.5	76.8	77.45	0.801	9.53

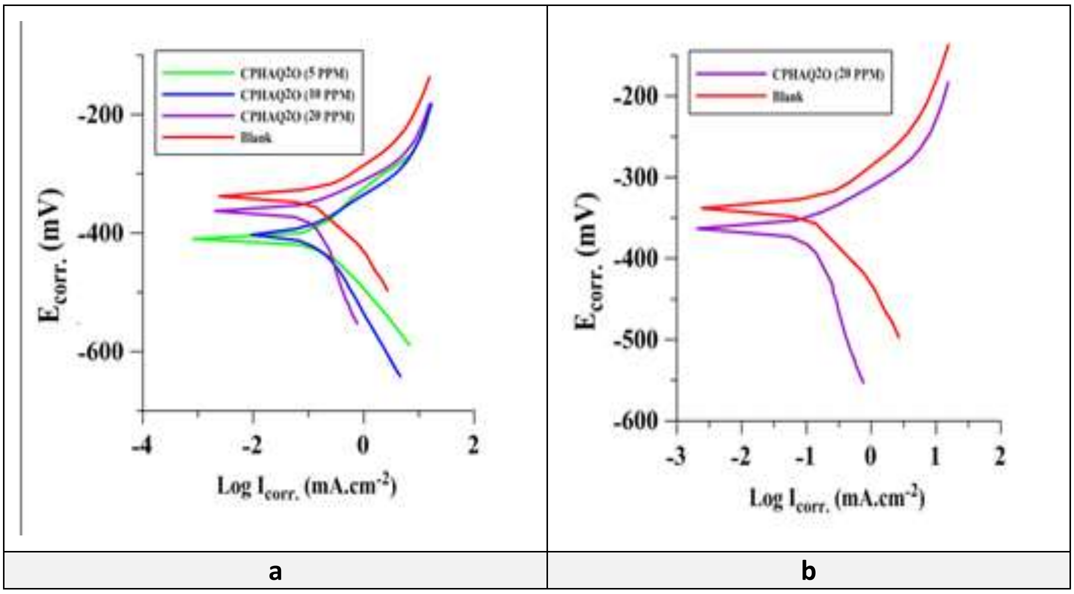


a **b**

Figure 2-Polarization curve of carbon steel in salty solution at 293 (K) for CPHAQ2O compound; (a) at different concentrations, and (b) at the optimum concentration.

Table 2-Electrochemical data of carbon steel corrosion in acidic solution at different concentrations of CPHAQ2O compound

Soln.	**T (K)**	**E_{corr} (mV)**	**I_{corr} ($\mu A.cm^{-2}$)**	**bc ($mV.dec^{-1}$)**	**ba ($mV.dec^{-1}$)**	**IE%**	**ϴ**	**CR (Ampere)**
Blank 0ppm	293	-340.2	196.59	-132.9	76.1	------	------	48.95
	303	-349.9	285.76	-129.4	87.4	------	------	71.15
	313	-336.8	383.29	-123.8	77.4	------	------	95.44
	323	-326.9	495.50	-107.5	58.6	------	------	123.38
5ppm	293	-410.3	55.85	-51.0	56.4	74.59	0.716	13.91
	303	-369.3	67.54	-67.6	50.6	73.36	0.764	16.82
	313	-381.1	86.41	-82.6	64.7	72.45	0.775	21.52
	323	-407.8	129.37	-46.5	55.7	71.59	0.739	32.21
10ppm	293	-401.6	46.40	-56.1	44.5	76.39	0.764	11.55
	303	-394.0	78.99	-71.9	70.2	72.85	0.724	19.67
	313	-402.2	104.98	-89.0	102.7	72.61	0.726	26.14
	323	-431.7	119.92	-118.6	121.4	70.79	0.758	29.86
20ppm	293	-362.7	43.98	-64.9	36.6	**77.62**	0.776	10.95
	303	-414.5	74.66	-54.1	45.9	73.87	0.739	18.59
	313	-413.6	100.70	-64.6	49.1	73.72	0.737	25.07
	323	-412.7	200.41	-52.2	48.0	59.55	0.595	49.90



a **b**

Figure 3- Polarization curve of carbon steel in acidic solution at 293 (K) for CPHAQ2O compound; (a) at different concentrations, and (b) at the optimum concentration.

Corrosion kinetic and thermodynamic activation parameters

Arrhenius law is presented as a straight line of the logarithm of the corrosion rate. The activation parameters were calculated with and without inhibitors at different concentrations Tables- (3 and 4). The activation energy of the corrosion process (E_a), and the pre-exponential factor (A), were calculating from equation 5. All E_a values in presence of CPHAQ2O inhibitor are higher than that of the blank 09.6348 **(**kJ/ mol) for the salty solution and 24.1828 **(**kJ/ mol) for the acidic solution which means that the corrosion reaction of C.S is retarded by CPHAQ2O inhibitor. These observations support the physical observation. Plot of log (CR/ T) or log (I_{corr}/ T) against (1/ T), gave a linear relationship with the slope of ($-\Delta H^*/ 2.303R$) and intercept of [log(R/ Nh)+ ($\Delta S^*/ 2.303R$)] equation 6, as shown in Figures- (4 and 6) for salty and acidic media respectively.

$$\text{Log}\,(I_{corr}) = \text{Log}\,A - E_a / 2.303RT \qquad (5)$$

$$\text{Log}\,(I_{corr}/\,T)) = \log\,(CR/\,T) = \text{Log}\,(R/\,N\,h) + \Delta S^*/\,2.303R - \Delta H^*/\,2.303RT \qquad (6)$$

Where (I_{corr}) is the corrosion current density which is equal to the corrosion rate (CR), (R) is the universal gas constant (8.314 J mol^{-1} K^{-1}), (T) is the absolute temperature in K, (h) is Planck's constant (6.626 x 10^{-34} J s), (N) is Avogadro's number (6.022 x 10^{23} mol^{-1}), ΔH* is the enthalpy of activation and (ΔS*) is the entropy of activation.

Accordingly, the activation thermodynamic parameters (ΔH* and ΔS*) were calculated in salty and acidic media, respectively, as shown in Tables-(6 and 7). Positive values of (ΔH*) for the corrosion reaction in 3.5% NaCl and in acidic media at the temperature range of (293-323) K and different concentration support the endothermic nature of this reaction [16]. Whereas negative values of (ΔS*) for the corrosion reaction indicate a decrease in the degree of freedom and consequently the inhibition action [17]. The values of ΔG* for corrosion reaction were calculated from equation 7. The positive values of ΔG* indicating that the transition state of the adsorption process is not spontaneous[18].

$$\Delta G^* = \Delta H^* - T\Delta S^* \qquad (7)$$

Table 3- Corrosion kinetic parameters for carbon steel in (3.5% NaCl) for blank and with various concentrations of CPHAQ2O inhibitor.

Conc. (ppm)	**ΔG* (kJ/ mol)**				**ΔH* kJ/ mol**	**ΔS* kJ/ mol K**	**Ea* kJ/ mol**	**A Molecule/ cm^2 S**
	293K	**303K**	**313K**	**323K**				
Blank	62.189	63.574	64.959	66.344	21.617	-0.1385	09.6348	1.10E+27
5	68.044	69.579	71.114	72.649	23.068	-0.1574	24.5734	6.30E+28
10	68.138	69.712	71.286	72.649	22.017	-0.1535	25.6246	1.01E+29
20	68.730	70.036	71.343	72.860	30.457	-0.1306	33.0135	1.58E+30

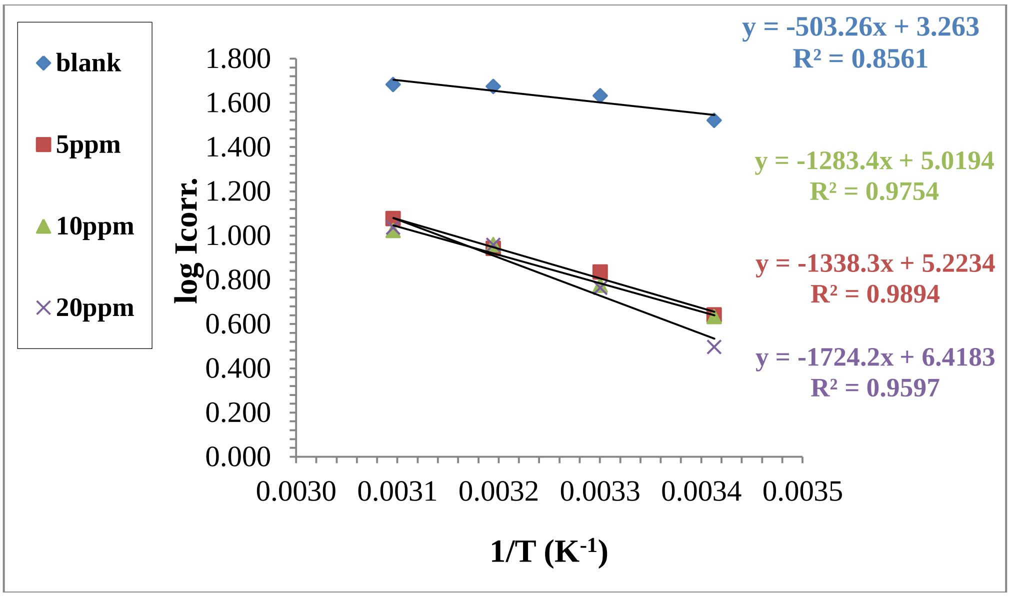


Figure 4- Plotting log (I_{corr}) vs (1/ T) for carbon steel in salty solution in absence (blank) and in presence of different concentrations of CPHAQ2O inhibitor.

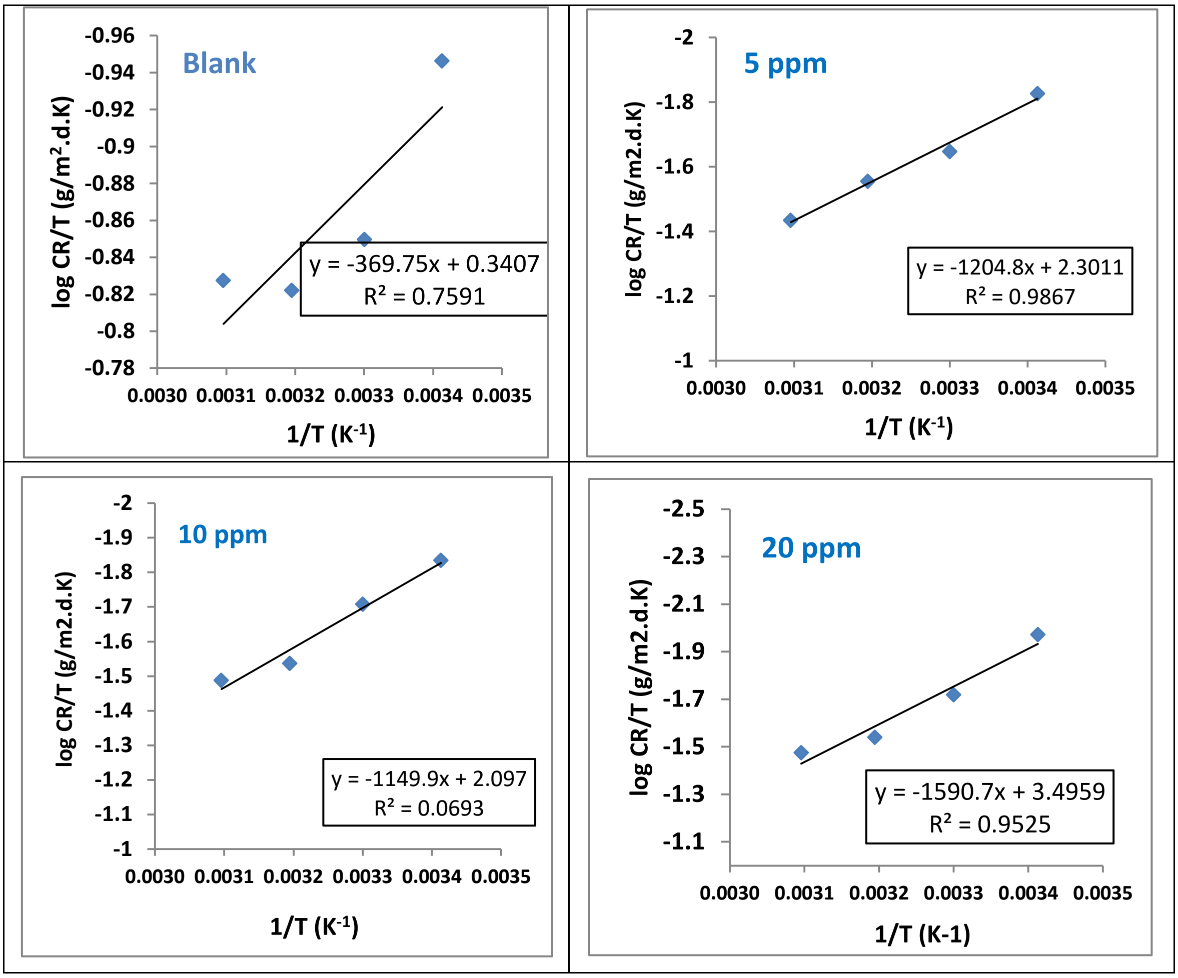


Figure 5- Plotting log (CR/ T) vs (1/ T) of carbon steel in salty solution for absence (blank) and in presence of different concentrations of CPHAQ2O inhibitor.

Table 4- Corrosion kinetic parameters for carbon steel in acidic medium for blank and with various concentrations of CPHAQ2O inhibitor.

Conc. (ppm)	**ΔG* (kJ/ mol)**				**ΔH* kJ/ mol**	**ΔS* kJ/ mol K**	**Ea kJ/ mol**	***A* Molecule/ cm^2 S**
	293K	**303K**	**313K**	**323K**				
Blank 0	62.193	63.582	64.967	66.351	21.625	-0.1385	24.1828	6.15E+29
5	65.443	67.025	68.607	70.189	19.092	-0.1582	21.6478	5.73E+28
10	65.541	67.018	68.494	69.970	22.289	-0.1476	24.8453	2.04E+29
20	65.947	66.986	68.025	69.064	35.503	-0.1039	38.0588	3.92E+31

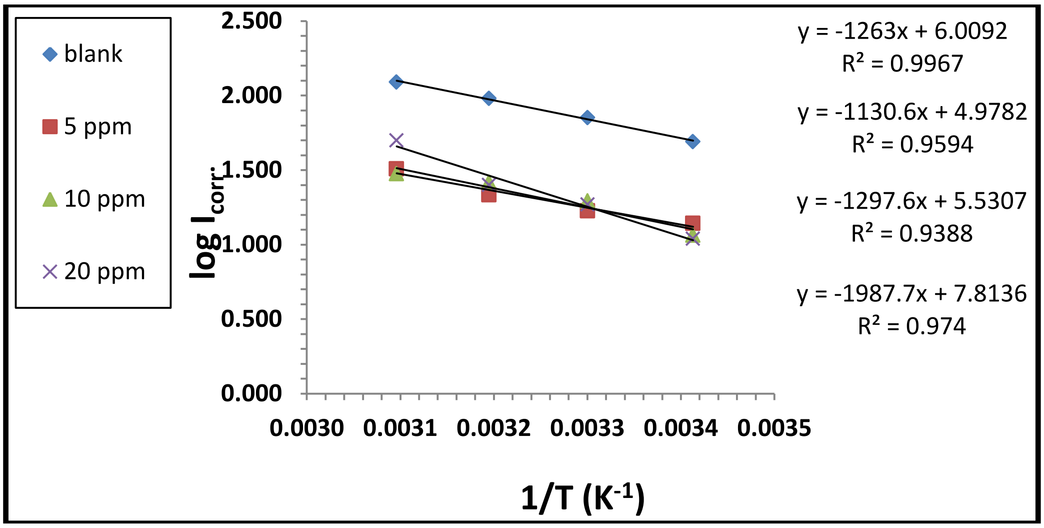
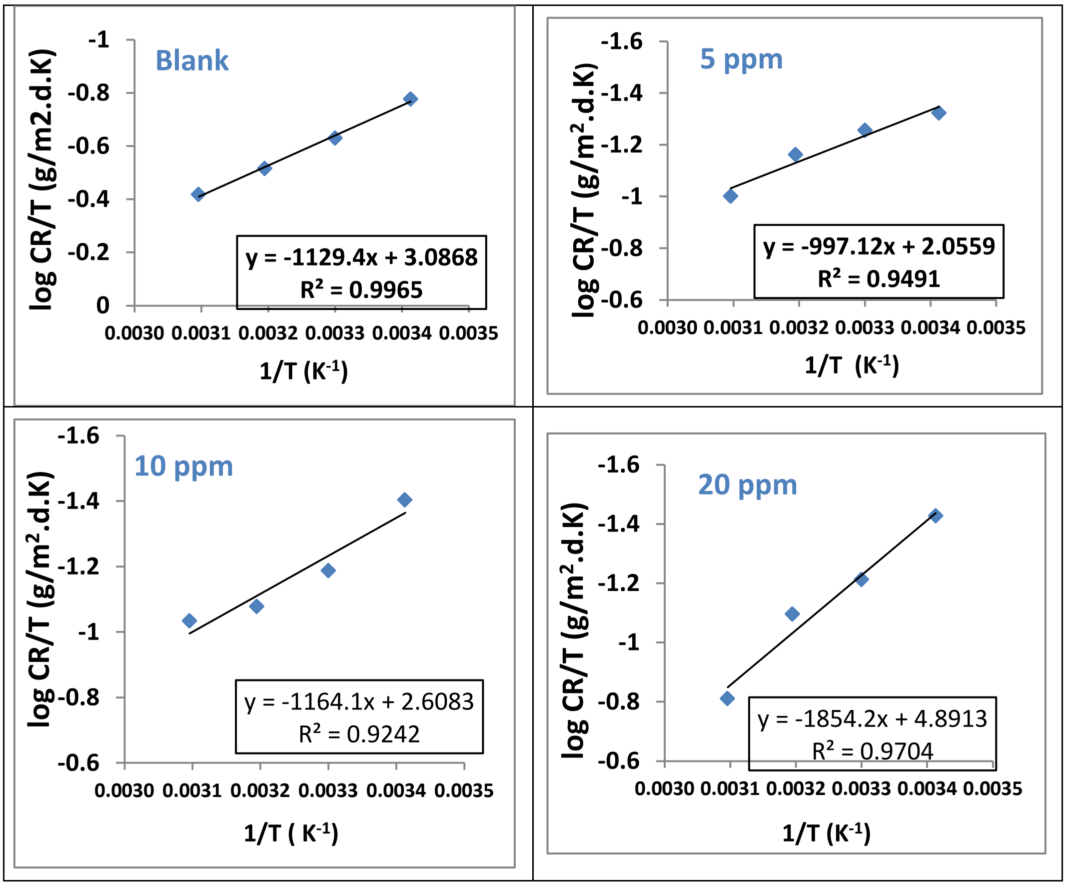


Figure 6- Plotting log (I_{corr}) against (1/ T) for carbon steel in acidic solution in absence (blank) and in presence of different concentrations of the CPHAQ2O inhibitor.



Figgure 7- Plotting log (CR/ T) against (1/ T) of carbon steel in acidic solution for in absence (blank) and in presence of different concentrations of the CPHAQ2O inhibitor.

Adsorption isotherm

The adsorption isotherms are essential in characterizing the reaction between carbon steel surface and inhibitor molecules. Langmuir adsorption isotherm is the most frequently used isotherms. It can be described by the following equation:

$$C/ \Theta = (1/ K_{ads}) + C \qquad (8)$$

Whereas C is the inhibitor concentration in 3.5% NaCl and 0.5M HCl, K_{ads} is the adsorption equilibrium constant and Θ is the surface coverage. The dependence of the (C/ Θ) fraction as a function of (C) for CPHAQ2O in salty and acidic solutions is shown in Figures- (8 and 10). It can be used to determine K_{ads}. The adsorption equilibrium constant has a relation with the free energy of adsorption (ΔG_{ads}) through the following equation [16]:

$$K_{ads}= (1/55.55) \exp (\Delta G_{ads}/ RT) \quad (9)$$

Here R is the gas constant (J K^{-1} mol^{-1}), T is the absolute temperature (K) and 55.5 is the molar concentration of water in the solution (mol L^{-1}), So the values of ΔG_{ads} at different temperature were obtained from equation 10. Enthalpy value of adsorption ($\Delta H°_{ads}$) was obtained from the slope of Vant Hoff equation expressed by equation 11, and entropy value of adsorption ($\Delta S°_{ads}$) was obtained from the intercept of the same equation.

$$\Delta G°_{ads}= -2.303RT \log K_{ads} \quad (10)$$

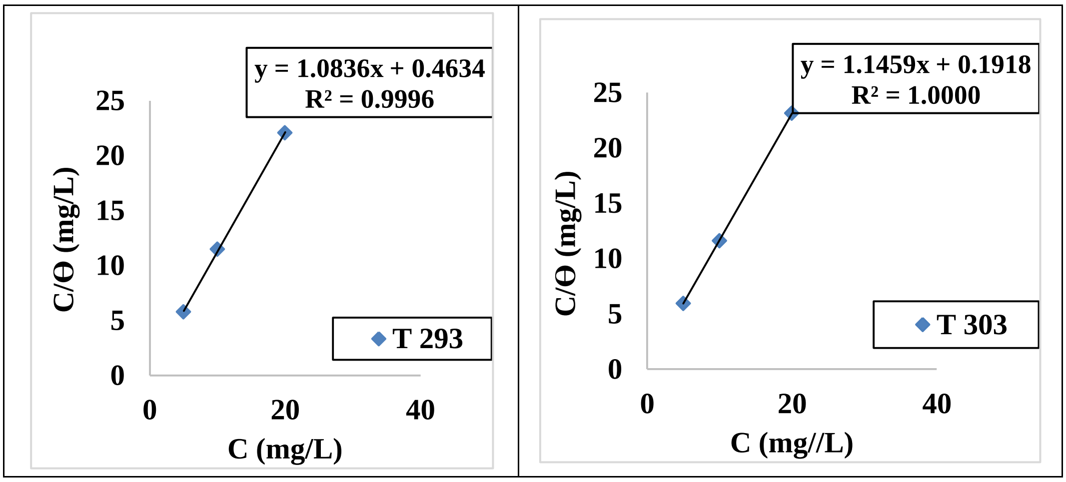
$$\Delta G°_{ads}= \Delta H°_{ads}-T\Delta S°_{ads}$$

$$\log K_{ads}= - \Delta H°_{ads}/ 2.303RT+ \Delta S°_{ads}/ 2.303R \quad (11)$$

Tables-(5 and 6) listed the thermodynamic functions of CPHAQ2O inhibitor on C.S surface in 3.5% NaCl and 0.5M HCl at various temperatures respectivily. Higher values of K_{ads} which obtained from Langmuir isotherm for CPHAQ2O indicate strong adsorption on the carbon steel in 3.5% NaCl and 0.5M HCl. Negative values of $\Delta G°_{ads}$ indicate spontaneous adsorption process. The values of $\Delta G°_{ads}$ around -20 (kJ/mol) or less negative consisted with the electrostatic interaction (physic-sorption); While those values of -40 (kJ/mol) or more negative involve electron transfer which leads to form a chemical bond (chemisorptions) [16]. The calculated values for $\Delta G°_{ads}$ were found in the range of (-11.860 to -16.893 kJ mol^{-1}) at different temperatures (293-323K) in the salty medium, while, $\Delta G°_{ads}$ were found in the range of (-9.996to -7.809 kJ mol^{-1}) at different temperatures (293-323K) in the acidic medium. These values indicate that the adsorption of CPHAQ2O follows physisorption processing. The obtained entropy $\Delta S°_{ads}$ value is positive which confirming that the corrosion process is entropically favorable [19]. The negative value of $\Delta H°_{ads}$ in the salt and acidic media indicates an exothermic process for the adsorption of inhibitory molecules on the C.S surface. For CPHAQ2O compound, $\Delta H°_{ads}$ is equal to (-41.262 kJ mol^{-1}) in the salt medium, and equal to (-45.413 kJ mol^{-1}) in acidic medium see Tables-(8 and 9).

Table 5- Thermodynamic parameters for adsorption of CPHAQ2O compound on C.S surface in 3.5% NaCl solution at various temperatures.

T (K)	K_{ads} (L mol^{-1})	$\Delta G°_{ads}$ (kJ. mol^{-1})	$\Delta H°_{ads}$ (kJ.mol^{-1})	$\Delta S°_{ads}$ (kJ.mol^{-1})	R^2
293	$7.827*10^5$	-11.860	-41.262	0.291	0.9996
303	$3.891*10^5$	-14.046			1.0000
313	$2.481*10^5$	-15.161			1.0000
323	$1.026*10^5$	-16.893			0.9998



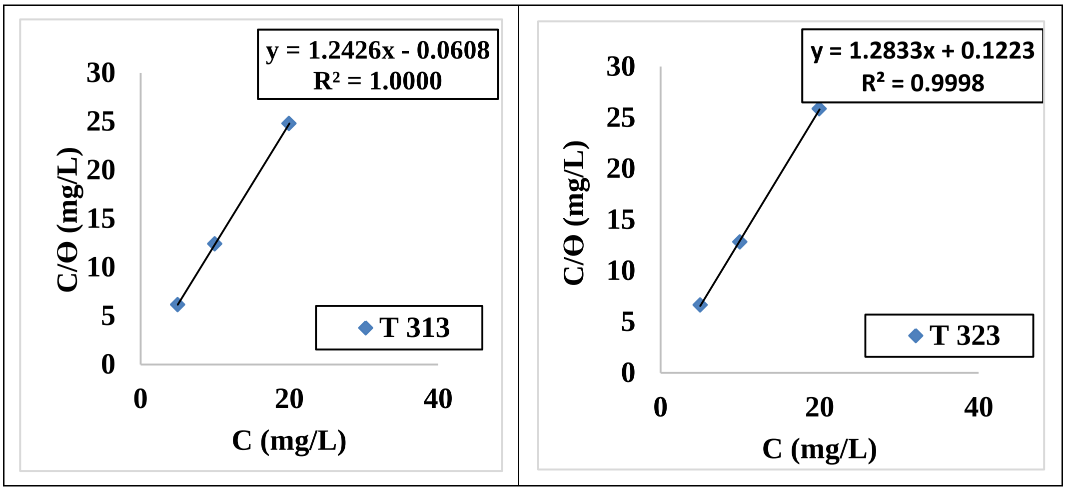


Figure 8- Langmuir isotherms plot for the adsorption of CPHAQ2O compound on carbon steel in salty medium at temperatures of (293, 303, 313 and 323) K

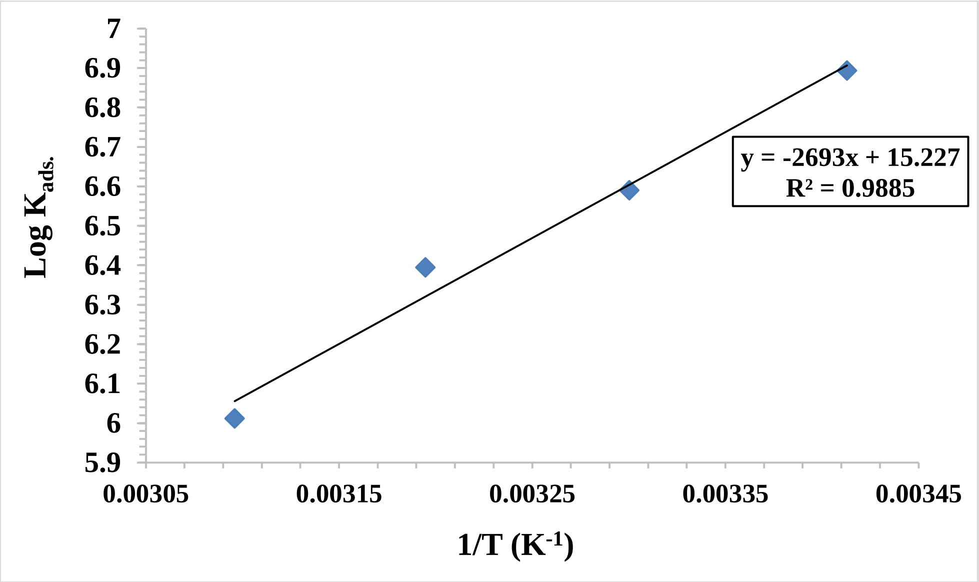


Figure 9- Plotting log K_{ads} vs (1/ T) for CPHAQ2O compound in the salty medium.

Table 6-Langmuir parameters for adsorption of CPHAQ2O compound on carbon steel surface in 0.5M HCl solution at different temperatures

T (K)	K_{ads} (L mol^{-1})	$\Delta G°_{ads}$ (kJ. mol^{-1})	$\Delta H°_{ads}$ (kJ. mol^{-1})	$\Delta S°_{ads}$ (kJ. mol^{-1})	R^2
293	$7.423*10^5$	-11.056	-45.413	0.065	0.9999
303	$5.860*10^5$	-16.176			0.9995
313	$2.069*10^5$	-13.597			0.9995
323	$1.381*10^5$	-6.889			0.9896

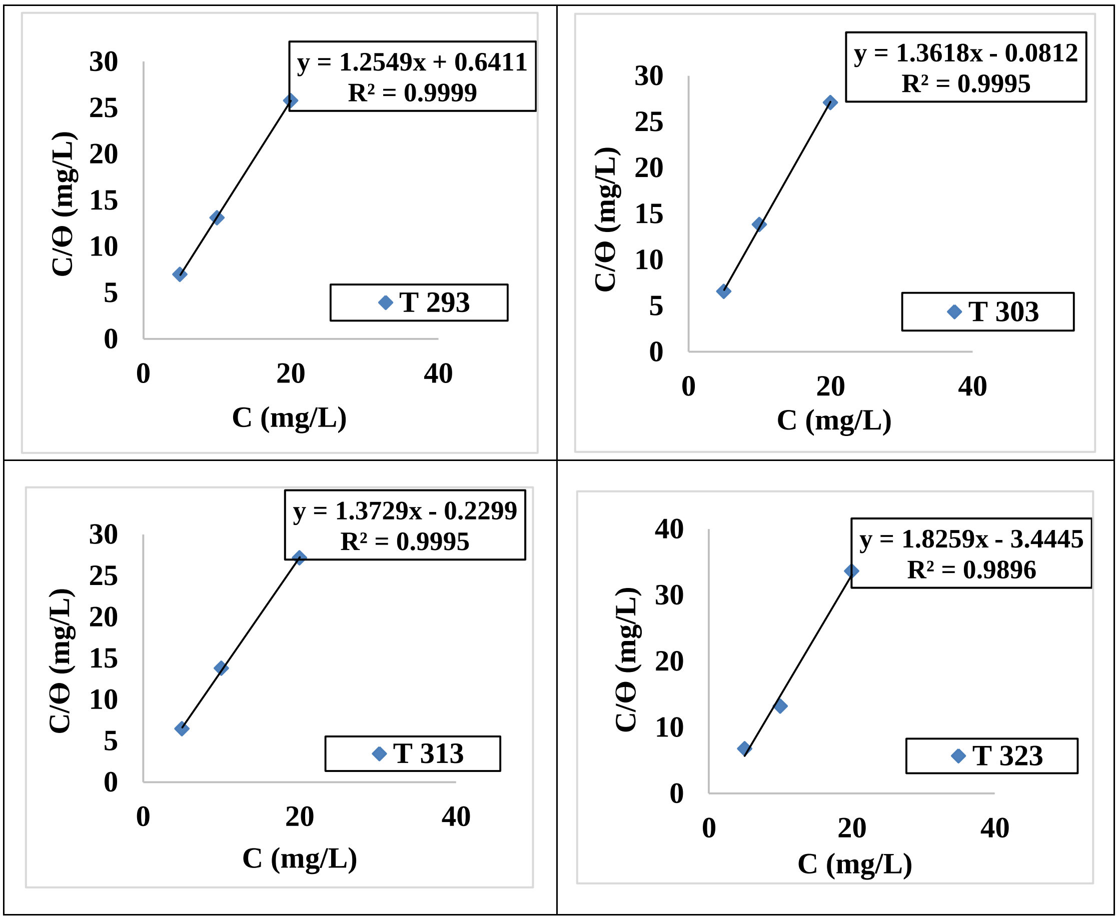


Figure 10- Langmuir isotherms plot for the adsorption of CPHAQ2O compound on carbon steel in acidic medium at temperatures of (293, 303, 313 and 323) K.

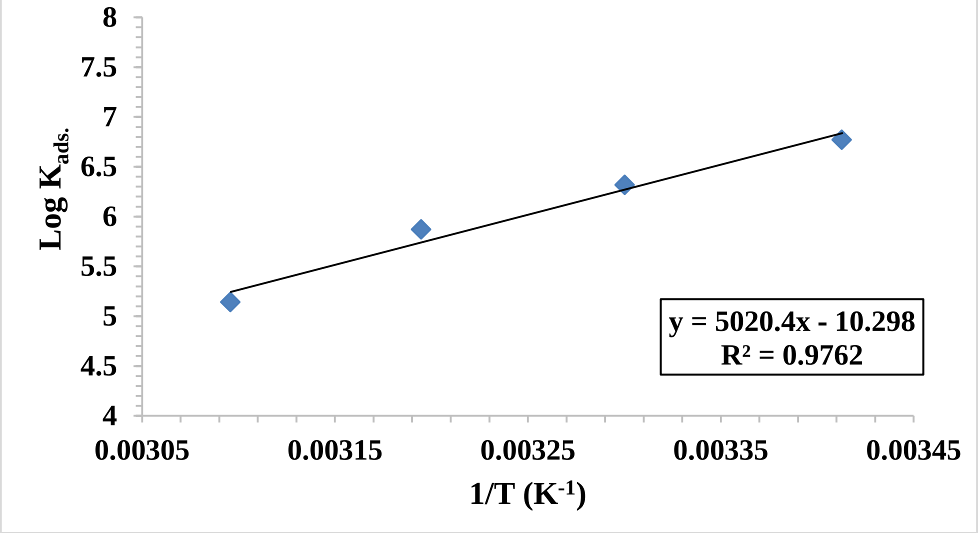
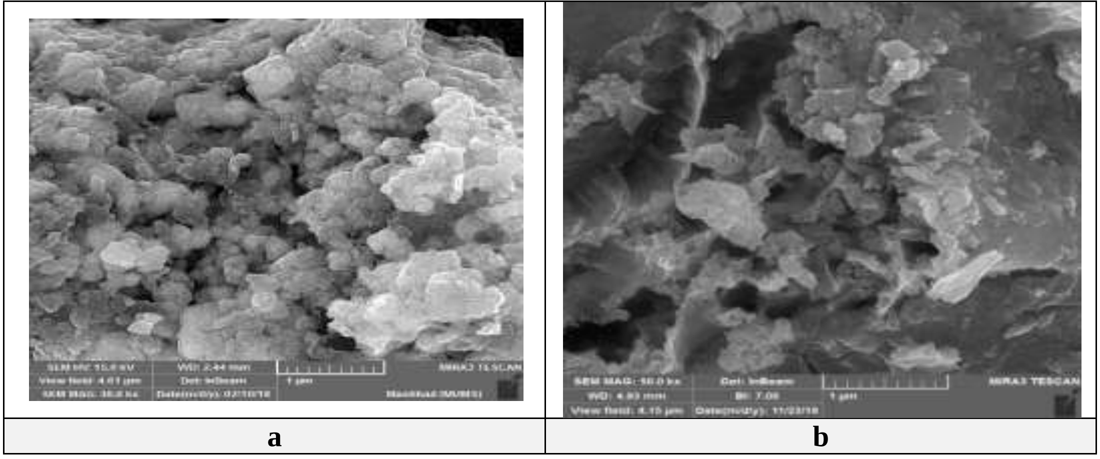


Figure 11- Plotting log K_{ads} against (1/ T) for CPHAQ2O compound in acid solution.

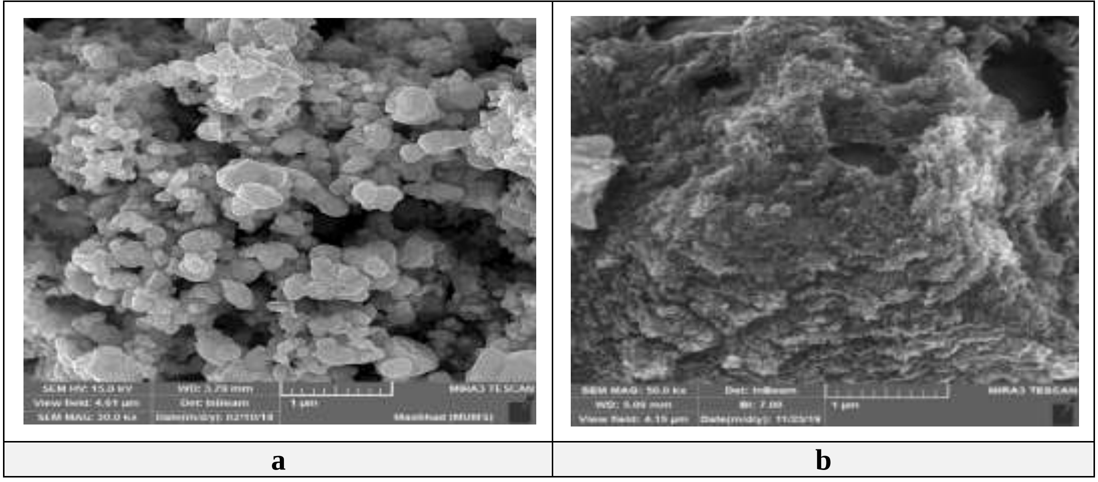
Scanning Electron Microscopy (SEM)

The SEM micrographs of the corroded carbon steel in 3.5% NaCl and 0.5M HCl solutions in the presence and absence of CPHAQ2O inhibitor are shown in Figures- (12 and 13) respectively. In images (a) of these Figures (absence of inhibitor of carbon steel surface) notches and defects were observed, while a layer of closely packed film was obtained in Figures- (12b and 13b), and the surface was free from pits and it was smooth. It was concluded from Figures- 12 and 13 (a-b) that corrosion does not occur in presence of CPHAQ2O and consequently corrosion was strongly prevented when the inhibitor was present in the solution. The electronic microscopic observation, confirmed the presence of a condensation protective film on the carbon steel surface, which is responsible for inhibiting corrosion. It can be shown that the surface coverage increases, which in turn leads to the formation of an insoluble compound on the surface of the metal (Fe^{2+}-CPHAQ2O complex), and the surface is covered with a thin layer of inhibitors that control the dissolution of solid carbon [19-21].



a b

Figure 12-SEM of carbon steel surface (a) in 3.5% NaCl solution in absence of CPHAQ2O inhibitor (blank), (b) in presence of 20 ppm of CPHAQ2O inhibitor.



a b

Figure 13-SEM of carbon steel surface (a) in acidic solution in absence of CPHAQ2O inhibitor (blank), (b) in presence of 20 ppm of CPHAQ2O inhibitor.

Conclusions

It has been observed that the corrosion rates of the carbon steel in the corroding mediums were reduced on addition of different concentrations of the studied inhibitor and decreasing temperature. A comparison of the inhibition efficiency of CPHAQ2O inhibitor in the salt solution (90.55%) is more electron deficient than in acid solution (77.62%). However the thermodynamic and kinetic parameters suggest that CPHAQ2O inhibitor has greater tendency to interact with the metal surface in (3.5% NaCl) solution than in (0.5M HCl) solution, and it is a very good inhibitor in both of them.

References

1. David, A. **2017.** Predicting the performance of organic corrosion inhibitors. *Metals*, **7**(553): 1-8.
2. El Bakri, Y., Boudalia, M., Echihi, S., Harmaoui, A., Sebhaoui, J., Elmsellem, H., Ramli, Y., Guenbour, A., Bellaouchou, A. and Essassi, E. **2017**. Performance and theoretical study on corrosion inhibition of new Triazolopyrimidine derivative for carbon steel in hydrochloric acid. *J. Mat. Envir. Sci.*, **8**(2): 378-388.
3. Louadi, Y.E., Abrigach, F., Bouyanzer, A., Touzani, R., El Assyry, A., Zarrouk, A. and Hammoutia, B. **2017**. Theoretical and Experimental Studies on the Corrosion Inhibition Potentials of Two Tetrakis Pyrazole Derivatives for Mild Steel in 1.0M HCl. *Portug. Electrochim. Acta,* **35**(3): 159-178.

4. Louadi, Y.E., Abrigach, F., Bouyanzer, A., Touzani, R., El Assyry, A., Zarrouk, A. and Hammoutia, B. **2017**. Theoretical and Experimental Studies on the Corrosion Inhibition Potentials of Two Tetrakis Pyrazole Derivatives for Mild Steel in 1.0M HCl. *Portugaliae Electrochimica Acta,* **35**(3): 159-178.

5. Kitagawa,W. Tamura,T. A. **2008**. Quinoline. antibiotic from rhodococcus erythropolis JCM 6824. *J. Antibiot*., **61**(11): 680–682.

6. Kubba, R.M., Challoob, D.A. and Hussen, S.M. **2017**. Quantum mechanical and electrochemical study of new isatin derivative as corrosion inhibitor for carbon steel in 3.5 % NaCl. *Int. J. Sci. Res.*, **6**(7): 1656-1669.

7. GneDy, P.O. PALMER, R. RoocEne, H. and Svrrn, P. **1987**. Isolation of aeromonass almonicidaS trains resistant to the Quinoline antibiotics. *Bull. Eur. Ass. Fish parhol*., **7**(2): 43.

8. Fu, H.-G.; Li, Z.-W.; Hu, X.-X.; Si, S.-Y.; You, X.-F.; Tang, S.; Wang, Y.-X.; Song, D.-Q. **2019**. Synthesis and biological evaluation of quinoline derivatives as a novel class of broad-spectrum antibacterial agents. *Molecules,* **24**: 548.

9. Singh P, Srivastava V. 2**016**. Quraishi MA. Novel quinoline derivatives as green corrosion inhibitors for mild steel in acidic medium: electrochemical, SEM, AFM, and XPS studies. *J Molliq*. **216**: 164–173.

10. Elyoussfi1, A. Dafali1, A. Elmsellem1, H. Bouzian, Y. bouhfid, R. Zarrouk1, A. Cherrak, K. Essassi, E.M. Aouniti, A. and Hammouti, B. **2016**. Some quinoline derivatives: Synthesis and comparative study towards corrosion of mild steel in 0.5M H_2SO_4. *Der Pharma Chemica,* **8**(4): 226-236.

11. Naik, UJ. Jha, PC. Lone, MY. Shah, RR. and Shah, NK. **2016**. Electrochemical and theoretical investigation of the inhibitory effect of two Schiff bases of benzaldehyde for the corrosion of aluminium in hydrochloric acid. *J. Mol. Str.,* **1125**: 63–72.

12. Saha, S.K, Ghosh, P., Hens A, Murmu NC, Banerjee P. **2015**. Density functional theory and molecular dynamics simulation study on corrosion inhibition performance of mild steel by mercapto-quinoline Schiff base corrosion inhibitor. *Physica E.,* **66**: 332–341.

13. Sundaram, R.G. and Sundaravadivelu, M. **2016**. Electrochemical and surface Investigation of quinoline-8-sulphonyl chloride as corrosion inhibitor for mild steel in acidic medium. *Int J Chem Tech Res*., **9**: 527–539.

14. Luma, S.A. Rana, A.A. Rana S.A. Mohammed R.A. and Redha I. A. **2017**. Synthesis of new 7-Ethyl- 4-methy l-1-[(4-nitrophenyl)- amino]- 1H- quinolin- 2-one quinoline derivatives. *Scientific International Conference , College of Science, AL-Nahrain Univesity*. **357**: 30–37.

15. Kubba, R.M., Al-Majidi S.M.H. and Ahmed A.H. **2019**. Synthesis, characterization and quantum chemical studies of inhibition ability of novel 5-nitro isatin derivatives on the corrosion of carbon steel in sea water. *Iraqi Journal of Science,* **60**(4): 688-705.

16. Ahamad, I., Prasad, R., Quraishi, M.A. **2010**. Thermodynamic, electrochemical and quantum chemical investigation of some Schiff bases as corrosion inhibitors for mild steel in hydrochloric acid solutions. *Corrosion science,* **52**: 933–942

17. Duboscq, J., Sabot, R., Jeannin, M. and Refait, Ph. **2019**.Localized corrosion of carbon steel in seawater: Processes occurring in cathodic zones. *Mat. Corr.,* **70**(6): 941-1140.

18. Kubba, R.M. and Al-Joborry, N.M. **2020**. Theoretical and experimental study of a new imidazo (1,2-a) pyridine derivative as a corrosion inhibitor for the carbon steel surface in the saline media. *ANJS,* **23**(1): 13–26.

19. Singh, A., Ansari, K.R., Lin, Y., Quraishi, M.A., Lgaz, H. and Chung. Ill-M. **2019**. Corrosion inhibition performance of imidazolidine derivatives for J55 pipeline steel in acidic oilfield formation water: Electrochemical, surface and theoretical studies. *J. Taiw. Inst. Chem. Eng.,* **95**: 341-356.

20. Ben Hmamou, D., Aouad, M., Salghi, R., Zarrouk, A., Assouag, M., Benali, O., Messali, M., Zarrok, H. and Hammouti, B. **2012**. Inhibition of C38 steel corrosion in hydrochloric acid solution by 4,5- diphenyl-1H-imidazole-2-thiol:gravimetric and temperature effects treatments. *Int. J. Sci. Res.,* **4**(7): 3498-3504.

21. Anbarasi, C.M. and Rajendran, S. **2012**. Surface protection of carbon steel by butane sulphonic acid-zinc ion system”, *Research Journal of Chemical Sciences*. **2**(12): 21-26.