Corrosion inhibition behavior and adsorption characteristics of Quinoxaline Derived on Mild Steel C38 in Acid sulfuric 0.5 M

HASSAN EL ATTARI[a*], SALIM MENGOUCH[a] and HOUSSINE AIT SIR [b]

[a] Department of Chemistry, Laboratory de Chimie de Coordination et d'Analytique, Faculty of Science, University of Chouaib Doukkali, 24 000 El Jadida, Morocco

[b] Department of Chemistry, Laboratoire de Chimie BioOrganique, Faculty of Science, University of Chouaib Doukkali, 24 000 El Jadida, Morocco

Abstract— The effect of a compound, namely 1,4-dihydroquinoxaline-2, 3-Dione (HQD) on the corrosion of C-steel in 0.5 H_2SO_4 solutions has been studied using the potentiodynamic polarization and electrochemical impedance spectroscopy (EIS) techniques. The measurements were carried out in a temperature range of 298-308 K in the absence and in the presence of the distinct concentrations ranging from 10^{-3} to 5.10^{-3} M. The maximum effectiveness of the corrosion inhibition reached 83.5% with a concentration of 5.10^{-3} M. Impedance measurements indicated that the capacity of the double layer decreases by increasing the inhibitor concentration. While the charge transfer resistence increases by increasing the concentration. The polarization study indicates that1,4-dihydroquinoxaline-2, 3-Dionehas has a mixed behaviour. Activation energy E_a, entropy change ΔS_a and enthalpy change ΔH_a were obtained from the Arrhenius plot. Nyquist and Bode plots were obtained to discuss the mode of inhibition and the inhibition efficiency was calculated from the electrochemical kinetic parameters.

Index Terms— Acid inhibition, carbon steel, Corrosion inhibit, electrochemical impedance spectroscopy, 1, 4-dihydroquinoxaline-2, 3-Dione.

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1 INTRODUCTION

Corrosion is a complex natural phenomenon that has always been a preponderant industrial concern. This phenomenon is still causing considerable losses despite the technological and scientific advances that have accumulated over the last few years. One of areas most affected by corrosion is the petroleum industry. Pipelines are the safest and most economical hydrocarbon transportation tools. However, their burial causes systematic and accidental damage. Losses caused by corrosion represent an alert to the pipeline transportation process. The use of mineral acids for cleaning produces degradation of the steel in the form of corrosion. Hydrochloric acid and sulphuric acid are two more mineral acids used in industry. The main areas of application are acid cleaning, pickling and removal of localized deposits; these acids are also frequently used in a variety of industrial synthesis processes. Since the use of these acids is aggressive towards metal, the use of the inhibitors has become essential to reduce the degradation of the material. These methods used to inhibit corrosion are evaluated according to the particularity of the system, because the preventive measures used successfully under conditions can be harmful under other conditions. This work aims to study the action of sulfuric acid on steel without and with the addition of corrosion inhibitors. These substances must meet these requirements: limitation of the dissolution of the metal, do not delay the effect of acid on steel, less toxic and low concentrations in use. In the literature, it is widely described that the application of organic compounds as corrosion retarders, a large part of the organic compounds, heterocycles are classically considered to be effective against

corrosion. The protective action is often attributed to the physical or chemical adsorption that results from the transfer of charge from one phase to another. It is observed that adsorption depends on the structure of the molecule and the chemical structure of the solution. [1,13]

Heterocyclic compounds adsorb on to active sites on the surface without altering the mechanism of the partial electrochemical reactions. They block sites and reduce the rate of cathodic, anodic or mixed corrosion in relation to the percentage of active sites coated with the inhibitor. Their effectiveness depends, among other things, their molecular structure and their concentration. Organic molecules used as inhibitors contain a polar, hydrophobic and relatively voluminous, consisting mainly of atoms of carbon and hydrogen, and a hydrophilic polar portion consisting of one or more groups functional groups such as $-NH_2$ $-SH$ $-OH$, $-PO_3^{2-}$ [14,19] In the present study, the effect of HQD has been investigated for examining its efficacy as an inhibitor for the corrosion of mild steel in acidic solution sulfuric using three different techniques: weight loss, potentiodynamic polarization and electrochemical impedance spectroscopy. The corrosion inhibition of HQD towards carbon steel in 0.5 M H_2SO_4 was studied using chemical and electrochemical techniques and the effect of temperature on the corrosion rate in order to calculate some thermodynamic parameters related to corrosion process.In many literatures [20,22], it is reported that organic compounds, plant extracts and pharmaceutical intermediates are used as inhibitors .In the present study investigator, the inhibition properties of Quinoxaline. H_2SO_4 is tested and

discussed by various methods.

2 EXPERIMENTAL PROCEDURES

2.1 Mass loss measurement

Carbon steel samples with the following composition: 0.38 per cent (C), 0.23 per cent (Si), 0.68 per cent (Mn), 0.01 per cent (P), 0.02 per cent (S) and the remainder iron, were used in the studies. The samples were polished with emery papers from grade 120 to 1200, washed with distilled water, cleaned with acetone, and dried. After being weighed accurately by a balance with high sensitivity the specimens were immersed in 30 mL 0.5 M H_2SO_4 with and without various concentrations of the studied inhibitor at different temperatures. After 6 h of immersion, the specimens were taken out, rinsed thoroughly with distilled water, dried and weighed accurately again. Then the tests were repeated at different temperature immersion time. In order to get good reproducibility, experiments were carried out in duplicate. The corrosion rate (C_R) was calculated from the following equation:
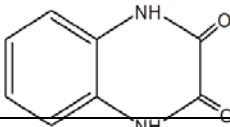
$$C_R = \frac{M1 - M2}{S.t} \qquad (1)$$

Where M1 is the initial weight before immersion, M2 the final weight after the corrosion test A the geometrical surface area (4 cm^2), and the period of corrosion test (6 h). The inhibition efficiency IE (%) has assessed using a known relation [23]:

$$IE(\%) = \frac{C_R^0 - C_R^{inh}}{C_R^0} \times 100 \qquad (2)$$

Where C_R^0 and C_R^{inh} are the values of corrosion rate without and with inhibitor, respectively.

TABLE 1
NAME AND STRUCTURE OF THE ORGANIC COMPOUND.

The structural formula	Designation and abreviation
	quinoxaline-2,3(1H,4H)-dione HQD

2.2. Electrochemical measurement:

The Electrochemical experiments were carried out in the conventional three-electrode cell with a platinum counter electrode (CE) and a saturated calomel electrode (SCE) the working electrode (WE) which was in the form of a square embedded in PVC holder using epoxy resin so that the flat surface was the only surface in the electrode. The working surface area was 1.0 x 1.0 cm^2, and prepared as described above (Section Weight loss determination). Used materiel is EC-Lab SP 200 Research Grad model potentiostat/galvanostat/FRA. Data were analyzed using an EC-Lab V10.40 software. The polarization curves were recorded by using three-electrode system. The working electrode

was first immersed into the test solution for 30 minutes to establish a steady state open circuit potential (Eocp). After measuring the open circuit potential, potentiodynamic polarization curves were obtained with a scan rate of 1 mV/s in the potential range between ±10 V relative to the Eocp. Corrosion current densities values were obtained by extrapolation of the anodic and cathodic Tafel lines to the corrosion potential. Inhibition efficiency IE (%) is defined as:

$$IE(\%) = \frac{i_{corr}^0 - i_{corr}^{inh}}{i_{corr}^0} \times 100 \qquad (3)$$

Where i_{corr}^0 and i_{corr}^{inh} represent corrosion current density values without and with inhibitor, respectively.

Electrochemical impedance spectroscopy (EIS) experiments were performed at potential open circuit in the frequency range from 100 kHz to a 10 mHz, with a signal amplitude perturbation of 10 mV. Inhibition efficiency $IE(\%)$ is estimated using the following relation:

$$IE(\%) = \frac{R_{ct}^{inh} - R_{ct}^0}{R_{ct}^{inh}} \times 100 \qquad (4)$$

Where R_{ct}^0 and R_{ct}^{inh} are charge transfer resistance in the absence and presence of the inhibitor, respectively.

3 RESULTS AND DISCUSSION

3.1. A.Electrochemical Measurements:

a. Electrochemical impedance spectroscopy (EIS):

In the field of corrosion, S.I.E. has several advantages. It allows precise determination of the corrosion rate even in the case where the metal is covered of a protective layer. The S.I.E. Evaluation of the rate of inhibition, the characterization of the various corrosion phenomena (dissolution, passivation, Pitting, etc.) and the study of the reaction mechanisms at the electrochemical interface.
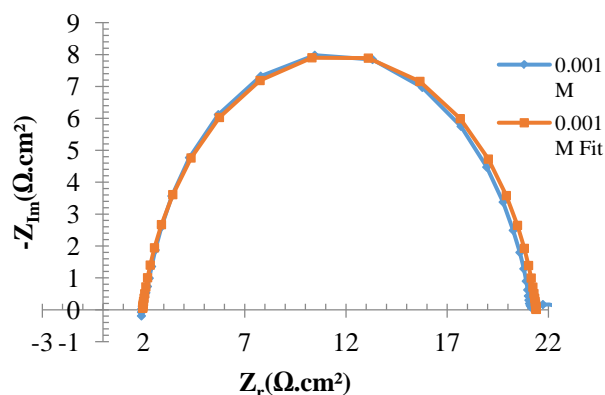

Fig.1: The Nyquist plots for corrosion of carbon steel in 0.5 H_2SO4 and his fit plot at 298 K

The diameters of the capacitive half loops increase with increasing concentration of inhibitor, indicating that the inhibitor efficiency is a function of the concentration of the inhibitor. These graphs consist of a single capacitive loop. This type of diagram generally indicates that the corrosion reaction is con-

trolled by a process of transfer of charges on a heterogeneous and irregular solid surface electrode. Indeed, a single time constant is detected on the Bode diagrams (Figures 3-4) (this behavior is observed for all concentrations) [36].

ble layer formed at the electrode-solution interface is considered as an electrical capacitor whose capacity decreases due to the displacement of the water molecules present in the electrolyte in favor of the molecules naturally adsorbed on the surface of the steel, forming a protective layer which reduces the number of active sites necessary for corrosion. The increase in the coefficient n with the concentration of the inhibitor reflects the decrease in the heterogeneity of the surface of the steel which is the result of the adsorption of DHQD molecules on the surface of the steel. [37,38].
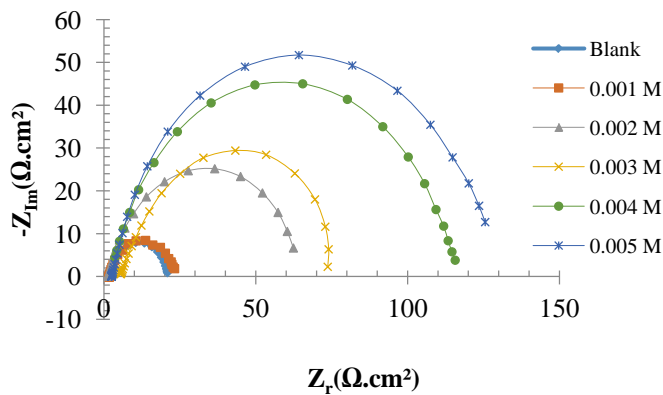

Fig.2: The Nyquist plots for corrosion of carbon steel in 0.5 M H_2SO_4 in the absence and presence of different concentrations of HQD at 298 K.

The values of the electrochemical parameters and the inhibitor efficiency IE(%) for different inhibitor concentrations obtained by electrochemical impedance spectroscopy and using the equivalent circuit are shown in Table 2.
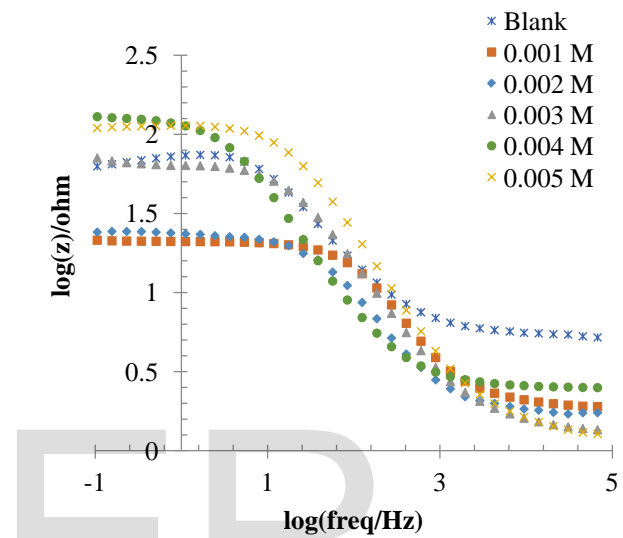

$$C_{dl} = (AR^{1-n})^{1/n} \quad (5)$$

TABLE 2

ELECTROCHEMICAL PARAMETERS OF IMPEDANCE FOR CARBON STEEL IN 0.5 M H_2SO_4 WITHOUT AND WITH OF DIFFERENT CONCENTRATIONS OF HQD AT 298 K.

C (mol/L)	R_{ct} (Ω cm²)	C_{dl} (10^{-6}F cm^{-2})	A(Sn Ω^{-1}cm^{-2}10^4)	n	IE(%)
Blank	19,25	378,5	10,69	0,789	
0.001	22,14	273,3	6,74	0,823	13,0
0.002	65,71	229,5	4,27	0,817	70,7
0.003	97,30	192,0	4,22	0,802	80,2
0.004	117,30	124,7	2,31	0,854	83,5
0.005	129,10	81,0	1,65	0,843	85,0

According to the parameters obtained, the addition of the inhibitor decreases the value of the double layer capacitance Cdl (calculated from equation 5) and increases that of the charge transfer resistance. The decrease in C_{dl} can be attributed to the adsorption of inhibitor molecules to the surface of the protective layer forming steel.

The impedance spectra obtained from a single capacitive loop, which also means that the adsorption of the inhibitor is achieved simply by covering the surface of the steel. The dou-
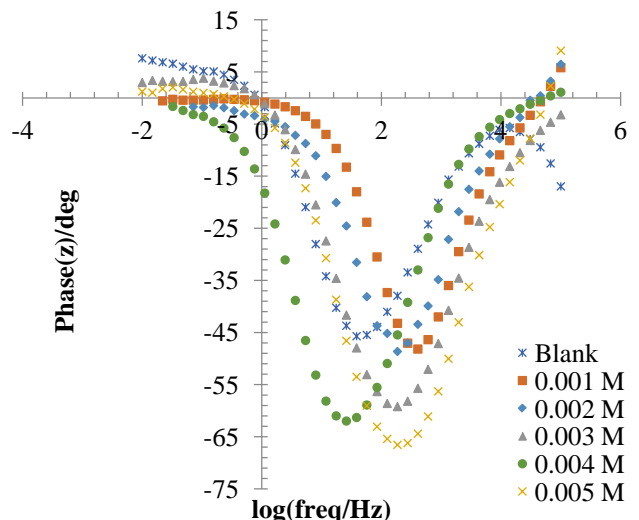

Fig.3.4. Bode plots in the absence and presence of different concentrations of HQD ofMild steel after immersion in the reference solution and with HQD at 298K.

Other authors still attribute this phase shift to impurities or dislocations, the adsorption of the inhibitor the formation of a porous layer, variations thickness or composition of a film or coating on the surface of the electrode. It is by a constant phase element (CPE) that we account for the inhomogeneity of

by means of the coefficient n. Such an element is described by the following equation [37,40]:

$$Z_{cpe} = A^{-1}(i\omega)^{-n}$$

Where A is a coefficient of proportionality, ω is the angular frequency (in rad s^{-1}) and $i^2 = -1$ is An imaginary number and n is linked to the phase shift [41]. For integers of n = 1, 0, -1 the CPE is reduced respectively to a planar capacitor (C), a resistor (R) and a inductance (L). When n = 0.5, this is the Warburg impedance (W).
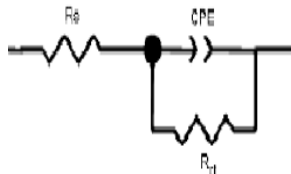

Fig. 5: Suggested equivalent circuit model for the studied systems.

B. Potentiodynamic polarization

The polarization curve of the metal-solution interface is a characteristic of electrochemical kinetics, but only accounts for the most process at the electrochemical interface. Electrochemical polarization measurements were performed to understand the process of anodic and cathodic partial
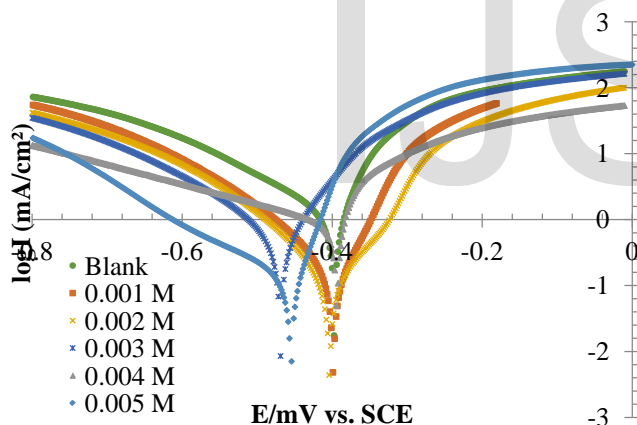

Fig. 6: Potentiodynamic polarization curves for carbon steel in 0.5 M H_2SO_4 in the absenceand presence of different concentrations of HQD at 298 K

From Table 3 and Figure 6, it is noted that the values of corrosion current density for steel in an acidic environment with the presence of the inhibitor are lower than those without inhibitor. It is noted that the addition of the inhibitor to a sulfuric environment causes the decrease in the density of the corrosion current and also the slopes of Tafel β_c and β_a [24-26]. In our case, the cathodic curves showing a linear part indicate that the reduction reaction of H_2 on the metal surface is carried out according to a pure activation mechanism. The anode curves show that the inhibition mode depends on the potential of the electrode. Indeed, for an overvoltage greater than -300mV / SCE, the presence of the inhibitors in the solution does not affect the anodic curves, which suggests the desorption of the inhibitor and thus the dissolution dominates the

anodic reaction. The marked decrease in cathodic current density and negative potentials greater than -300mV / SCE in the anodic domains plus the slight shift of the potential towards the lower values shows that the inhibitors studied are of mixed type with a cathodic predominance [27].

TABLE 3:

ELECTROCHEMICAL PARAMETERS OF STEEL SAMPLES AFTER IMMERSION IN 0.5 M H_2SO_4 IN THE ABSENCE AND PRESENCE OF HQD AT VARIOUS CONCENTRATIONS.

| C (mol/L)	E_{corr}(mV vs SCE)	I_{corr}(µA cm^{-2})	β_a(mV dec^{-1})	β_c(mV dec^{-1})	IE(%)
Blank	-397,14	1175,37	56,3	169,2	
0.001	-393,95	848,86	52,8	139,1	27,7
0.002	-468,28	700,07	86,7	165,2	40,4
0.003	-425,11	448,36	96,1	135,5	61,8
0.004	-404,79	269,87	93,9	137,2	77,0
0.005	-499,29	215,56	72,3	169,7	81,6

Indeed, in addition to the slight displacement of the free potential towards less noble values, the addition of the inhibitor in 0.5 M H_2SO_4 solution induces the reduction of the anodic partial current corresponding to the dissolution of the metal described by the reaction [28]:

$$Fe \leftrightarrow Fe^{2+} + 2e^-$$
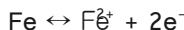
And also the reduction of the cathodic current corresponding to the reduction of the proton:

$$2H^+ + 2e^- \leftrightarrow H_2$$
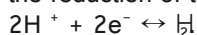
It is generally accepted that this reaction requires two successive steps; the first is the so-called discharge reaction (or Volmer reaction): [29-35]

$$2H_{ads}^+ + 2e^- \longrightarrow H_2$$
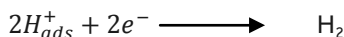
- Either purely chemical: $H_{ads} + H_{ads} \longrightarrow H_2$ (Tafel)
- Or electrochemical: $H_{ads} + H^+ + e^- \longrightarrow H_2$ (Heyrovsky)

In our case, the cathode curves have a linear part (Tafel straight line) indicating that the reduction reaction of hydrogen at the surface of the steel takes place according to a pure activation mechanism.

C. Gravimetric experiment:

In this section, gravimetric measurements of C38 steel were performed in H_2SO_4 medium (0.5M) in the absence and presence of different concentrations of HQD. The immersion time was 6 hours at different temperatures. Table 4 gives the values of the corrosion rate (C_R) and the percent inhibitory efficiency IE (%) calculated

by gravimetric for different concentrations of HQD in sulfuric medium. The value of the inhibitory efficiency given is the average of three tests carried out under the same conditions for each concentration.

TABLE 4

EFFECT OF HQD CONCENTRATION ON CORROSION DATA OF MILD STEEL IN 0.5 M H_2SO_4

C(mol/L)	Δm			C_R(mg.cm^{-2}.h^{-1})		
	298 K	303 K	308 K	298 K	303 K	308 K
Blank	0,1057	0,1182	0,1304	0,0066	0,0074	0,0082
0,001	0,0569	0,0640	0,0749	0,0035	0,0040	0,0046
0,002	0,0429	0,0562	0,0635	0,0026	0,0035	0,0040
0,003	0,0384	0,0461	0,0561	0,0024	0,0029	0,0035
0,004	0,0276	0,0417	0,0559	0,0017	0,0026	0,0034
0,005	0,0174	0,0306	0,0345	0,0010	0,0019	0,0022

TABLE 5

CORROSION PARAMETERS OBTAINED OF MILD STEEL IN 0.5 M H_2SO_4 SOLUTIONS WITH AND WITHOUT ADDITION OF VARIOUS CONCENTRATIONS OF HQD AT DIFFERENT TEMPERATURES

C(mol/L)	θ			IE(%)		
	298 K	303 K	308 K	298 K	303 K	308 K
Blank						
0,001	0,4617	0,4585	0,4256	46,1	45,8	42,5
0,002	0,5941	0,5245	0,5130	59,4	52,4	51,3
0,003	0,6367	0,6099	0,5698	63,6	60,9	56,9
0,004	0,7389	0,6472	0,5713	73,8	64,7	57,1
0,005	0,8353	0,7411	0,7354	83,5	74,1	73,5

Analysis of the results of Table 5 clearly shows that this molecule possesses good corrosion-inhibiting properties of C38 steel in 0.5 M H_2SO_4 medium. The variation of the inhibitory efficacy of HQD as a function of the concentration of the inhibitor is illustrated in Figure 8 We note that for this inhibitor, at each temperature, the rate of corrosion decreases while the inhibition efficiency increases with the inhibitor concentration and reaches a maximum value of 83.5% at 298 K. It is clear As well as by increasing the temperature, the rate of corrosion increases, decreasing the inhibitor's efficiency and decreasing from 83.5% to 298 K to 73.5% at 308 K, suggesting that the inhibitor acts on the metal by a physisorption mechanism. The decrease in inhibition efficiency with temperature may be attributed to desorption of the inhibitor. Corrosion rate of cooper, aluminum and zinc have been the subject of many investigators [42,43]. Recent studies show that a strong coordination bond causes higher inhibition efficiency, the inhibition increasing in the sequence O < N < S < P [44].
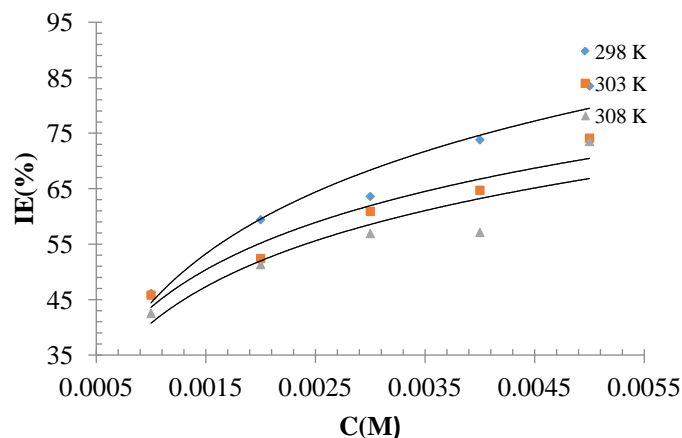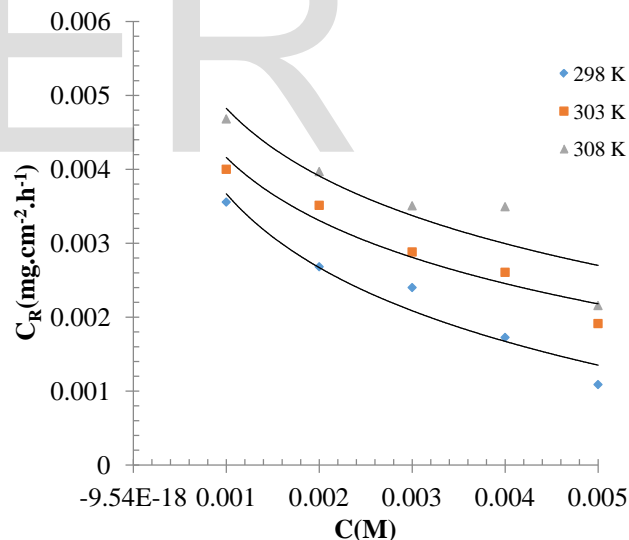

Fig. 7.8: Dependence of the percentage inhibition efficiency IE (%) and corrosion rate on the inhibitor concentration

Due to the acidity of the medium, the HQD molecules can exist in neutral form or in cationic form. Thus, the adsorption of HQD neutral molecules could occur due to the formation of bonds between the iron orbitals d, involving the displacement of water molecules from the metal surface, and the electron Alone sp2 present on the O and N atoms and π-orbitals, blocking the active sites in the surface of the steel and therefore a reduction in the corrosion rate.

D.Adsorption isotherm

The inhibition of corrosion of metals by organic compounds is explained by their adsorption. The latter is described by two main types of adsorption, namely, physical adsorption and

chemisorption. It depends on the load of the metal, its nature, the Chemical structure of the organic product and the type of electrolyte. During this study and in order to find the most significant adsorption isotherm, different types of isotherm were tested namely: Langmuir, Temkin and. These adsorption isotherms have been used for other inhibitors [45]. According to Langmuir isotherms, the recovery rate (Θ) is related to the concentration of inhibitor C by the following equations:

$$\log C / \Theta = \log C - \log K_{ads} \quad (6)$$

In a sulfurique medium, the C / Θ curves as a function of the concentration of DHQD at different temperatures are linear (Figure 9), this shows that the adsorption of DHQD to the surface of the steel in a sulfurique medium obeys the Langmuir adsorption isotherm. The adsorption constant K_{ads} is related to the standard free energy of adsorption ΔGads by the following equation:
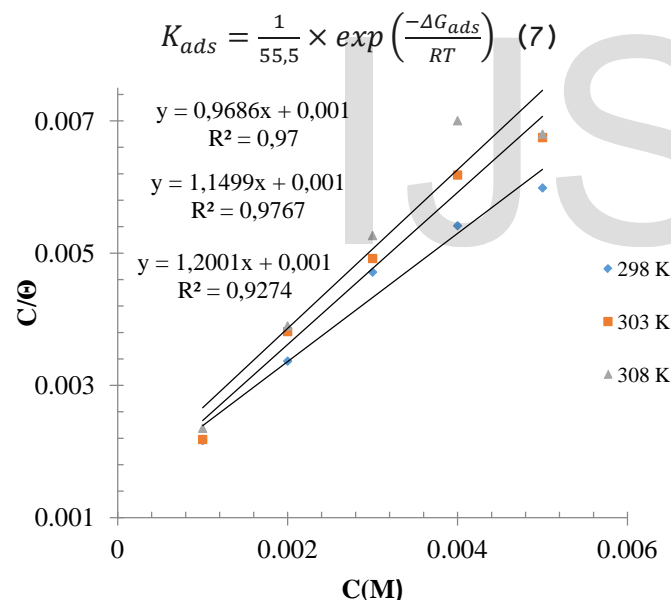
$$K_{ads} = \frac{1}{55,5} \times exp\left(\frac{-\Delta G_{ads}}{RT}\right) \quad (7)$$

FIG.9: CURVE FITTING OF THE DATA OF MILD STEEL IN 0.5 M H_2SO_4 IN THE PRESENCE OF HQD TO THERMODYNAMIC–KINETIC LANGUIMIR MODEL ISOTHERM AT DIFFERENT TEMPERATURE.

The value 55.5 is the concentration of water in solution (mol/l) [46], from the relation the value of ΔG_{ads} adsorption is found to be in the order of -27 kJ mol^{-1}.The negative value of ΔG_{ads} indicates the spontaneity of the adsorption process and the stability of the adsorbed double layer on the metal surface. Generally, the absolute values from ΔG_{ads} close to 20 kJ / mol or lower, are linked to electrostatic interactions between The charged molecules and the charged metal (physical adsorption), whereas those close to 40 kJ mol^{-1} or higher implies charge transfer between organic molecules and metal surface
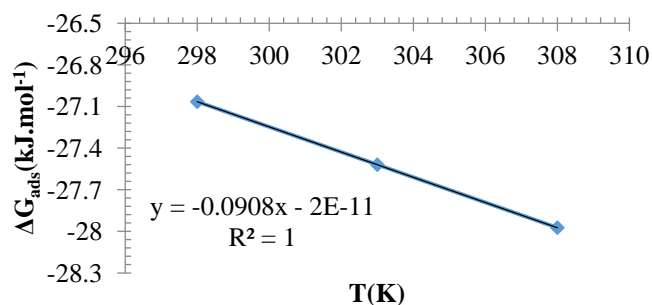
(chemisorption) [47].The negative value of ΔG_{ads} value is an indication of spontaneity and stability of the adsorbed

Fig.10: Graphic representation of ΔG_{ads} (kJ.mol^{-1}VS T (K))

inhibitor layer on the metal surface. Generally the ΔG_{ads} value are less negative or equal to −20 kJ/mol is considered for the physisorption and those more negative or

equal to −40 kJ/mol are considered as chemisorption. ΔG_{ads} values obtained is approximately equal to -27 kJ/mol.
Therefore, the Quinoxaline adsorbed on the mild steel surface predominately by a physisorption method because of the ΔG_{ads} values were closer towards-27 kJ/mol [48]. The graph of ΔG_{ads} v/s T is provided in Figure 10, with the slope equal to the standard enthalpy of adsorption ΔH_{ads}.

TABLE 6
ADSORPTION PARAMETERS FOR MILD STEEL CORROSION IN THE PRESENCE OF HQD IN 0.5 M H_2SO_4

T(K)	K_{ads}	intercept	R^2	ΔG_{ads}(kJ.mol^{-1})	ΔS_{ads} (J.mol^{-1}.K^{-1})	R^2
298	1000	0,968	0,970	-27,06	0,09	1
303	1000	1,149	0,976	-27,51	0,09	1
308	1000	1,200	0,927	-27,97	0,09	1

3. Effect of temperature

It is found that the efficiency increases by increasing the inhibitor concentration and decreases by increasing the temperature, this can be explained by the competition between adsorption and desorption and that the balance between these two processes is established at an optimum temperature when the inhibitory molecule is regularly adsorbed on the surface of the metal, The fact of increasing the temperature gives rise to a desorption rate greater than the adsorption speed until the equilibrium is again equalized. To calculate the thermodynamic activation parameters, the Arrhenius equations were used [52,54].

$$C_R = k \, exp\left(-\frac{E_a}{RT}\right) \quad (8)$$

$$C_R = \frac{RT}{Nh} \exp\left(\frac{\Delta S_a}{R}\right) \exp\left(-\frac{\Delta H_a}{RT}\right)$$

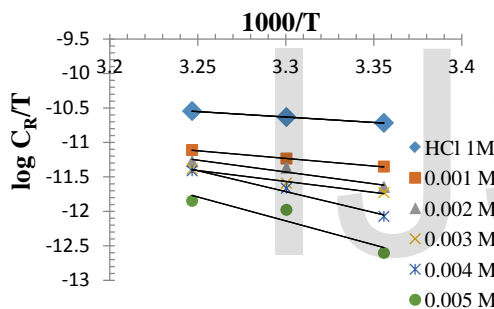| C(mol /L)	ΔS_a (J.mol^{-1}.K^{-1})	ΔH_a (kJ.mol^{-1})	k (g.m^{-2}.h^{-1})	E_a (kJ.mol^{-1})	$E_a - \Delta H_a$
Blank	-0,09	13,10	3,61	15,62	2,52
0.001	-0,10	18,32	16,11	20,84	2,52
0.002	-0,13	28,49	732,16	31,01	2,52
0.003	-0,13	26,23	260,60	28,75	2,52
0.004	-0,07	50,43	3335055,90	52,95	2,52
0.005	-0,05	57,84	41037630	60,36	2,52

Fig.11-12: Arrhenius plot for mild steel corrosion in 0.5M H_2SO_4 in the absence and presence of HQD

TABLE 7
THERMODYNAMICS PARAMETERS FOR MILD STEEL IN 0.5 M H_2SO_4 IN ABSENCE AND PRESENCE OF HQD

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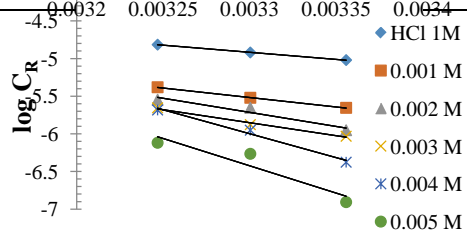
E_a is the gy of rosion parent vation, R universal gas constant, k is the Arrhenius preexponential factor, T is the absolute temperature, h is Plank's constant, N is the number of Avogadro, and ΔS_a, ΔH_a successively are entropy and enthalpy of the activation.The linear regression between $\ln(C_R)$ and $1/T$ to calculate the values of the apparent activation energy of corrosion E_a of mild steel in 0.5 M H_2SO_4 in the presence of (HQD) at various concentrations, the results are given in table 7. Arrhenius plots of the rate of mild steel ($\ln(C_R)$ versus $1/T$) to corrosion are given in figure 11.

In general, the temperature has an important effect on the corrosion phenomena corrosion rate increases as the test temperature increases, and this increase of temperature induced, in fact, changes on the action of inhibitors. Putilova and all. [56] consider that the increase in protective power with the increase in temperature is due to the change in the nature of the adsorption: Low temperatures, the inhibitor are physically adsorbed while chemisorption is Favored at high temperature. The inhibition efficiency of quinoxaline in H_2SO_4 decreases with temperature and these results in the increase in the apparent activation corrosion energy. This trend probably was attributed to physisorption of Quinoxaline on the metal surface [57]. The positive signs of enthalpies ΔH_a reflect the endothermic nature of dissolution process. The shift towards negative values of entropies ΔS_a implies that the activated complex in the rate-determining step represents association rather than dissociation, meaning that disordering increases on going from reactants to the activated complex [58,59]. Activation energy of blank we found as 15, 62 kJ/mol, same that of the inhibited solution ranging of 20,84 kJ/mol to 56,83 kJ/mol. This adsorption process leads to increase of activation energy and Arrhenius pre exponential (k) factor in presence of Quinoxaline, which retards the corrosion rate due to the increase of thickness of the double layer [60]. Arrhenius pre exponential constant k of inhibited solution is lesser than that of the uninhibited solution and also, theses parameter goes on increasing with the increasing the inhibitor concentration.

4 CONCLUSION:

- The addition of the inhibitor decreases the value of the double layer capacitance and increases that of the charge transfer resistance which can be attributed to the adsorption of HQD molecules to the surface of the protective layer forming steel.

- The marked decrease in cathodic current density the slight shift of the potential towards the lower values shows that the inhibitor studied is of mixed type with a cathodic predominance.

- The rate of corrosion is increasing by the increase of temperature while the inhibitor's efficiency is decreasing from 83.5% at 298 K to 73.5% at 308 K, suggesting that the inhibitor acts on the metal by a physisorption mechanism.

- The positive signs of enthalpies ΔH_a reflect the endothermic nature of dissolution process. The shift towards negative values of entropies ΔS_a implies that the activated complex in the rate-determining step represents association rather than dissociation, meaning that disordering increases on going from reactants to the activated complexe.

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