ISSN NO. 2320-5407

Journal homepage: http://www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH

RESEARCH ARTICLE

Cefadroxil as Save Corrosion Inhibitor for Carbon Steel in Hydrochloric Acid Solutions

AMEENA MOHSEN AL-BONAYAN

Department of Chemistry, Faculty of Applied Science Girls, Umm Al-Qura University, Makkah Al-Mukarramah, Kingdom of Saudi Arabia

Manuscript Info

Manuscript History:

Received: 12 March 2014
Final Accepted: 22 April 2014
Published Online: May 2014

Key words:
Cefadroxil, carbon steel, corrosion inhibition, H_2SO_4, EIS, EFM

Corresponding Author

AMEENA MOHSEN AL-BONAYAN

Abstract

The effect of an antibacterial cefadroxil on the corrosion of carbon steel was studied in 0.5 M H_2SO_4 at different concentrations using weight loss, potentiodynamic polarization, electrochemical frequency modulation (EFM) and electrochemical impedance spectroscopy (EIS) measurements. The synergistic effect of KI was studied. Potentiodynamic polarization indicated that cefadroxil acted as mixed- type inhibitor. EIS measurements were also used to investigate the mechanism of corrosion inhibition. The adsorption of cefadroxil on the surface of carbon steel follows the Langmuir adsorption isotherm. Results obtained from EFM technique were in agreement with weight loss, potentiodynamic and EIS techniques.

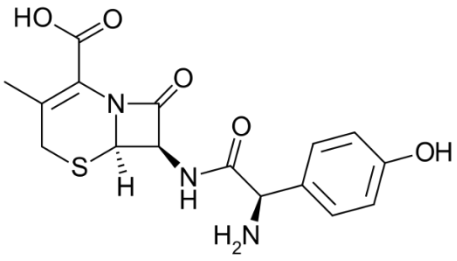
I. Introduction

Corrosion inhibitor is one of the most practical methods for protecting the corrosion of metal. Hydrochloric acid and sulphuric acid are regular aggressive solutions for acid picking, acid cleaning and acid descaling because of their special chemical properties. Accordingly, corrosion inhibitors for hydrochloric acid and sulphuric acid have attracted increasing attention due to their extended applications [1]. Some works have studied the influence of organic compounds containing nitrogen, sulphur, oxygen and phosphorus [2-12] on the corrosion of steel in acidic media. The results show that these organic compounds are good inhibitors. Nowadays, many studies indicate that nitrogen-containing organic compounds are found to behave better for the steel corrosion in hydrochloric acid than in sulphuric acid. The possible reason is that there is a synergism inhibition between chloride ion and nitrogen containing organic compound for carbon steel corrosion in hydrochloric acid. Generally speaking, organic inhibitors are found to protect carbon steel corrosion in acid solutions by adsorbing on steel surface. Because of the fact that most of the chemical compounds that prevent the corrosion of metals and alloys are toxic, and thus pose threat both for human health and environment, their usage is limited. For this reason various researchers have turned to the use of eco-friendly inhibitors, such as extracts of common plants that contain a variety of organic compounds [13]. In recent years researchers have paid attention on the development of drugs as inhibitors for metallic corrosion. In the literature, several authors have reported the influence of the drugs on the corrosion of metals in acid media [14-22].
The present study aims to investigate the inhibitory action of cefadroxil on carbon steel corrosion in 0.5M H2SO4 solution under the impact of such factors, as inhibitor concentration, solution temperature and iodide ion (I^-) addition.

2. EXPERMINTAL

2.1. Materials and Solutions

Carbon steel composed of (wt %): 0.200 C, 0.350 Mn, 0.024 P, 0.003 Si and the remainder Fe was used as the working electrode for all studies. Compound studied in this work has the structure, molecular formula and molecular weight as below:



Cefadroxil

(6*R*,7*R*)-7-{[(2*R*)-2-amino-2-(4-hydroxyphenyl)acetyl]amino}-3-methyl-8-oxo-5-thia-1-azabicyclo[4.2.0]oct-2-ene-2-carboxylic acid

Molecular formula $C_{16}H_{17}N_3O_5S$

Molar mass 363.389 g/mol`

Scheme 1. Chemical, molecular structure of cefadroxil

Appropriate concentration of acid (H_2SO_4) was prepared by using bidistilled water.

2.2. Chemical technique (weight loss method)

Six test pieces of C-steel were cut into 2 x 2 x 0.2 cm. They were abraded with emery papers (a coarse paper was used initially and then progressively finer grades were employed), degreased in acetone [23], rinsed with bidistilled water and finally dried between two filter papers and weighed. The test pieces were suspended by suitable glass hooks at the edge of the basin, and under the surface of the test solution by about 1 cm. Weight loss measurements were performed for 3 hours at the temperature range from 25 – 55 ^oC by immersing C- steel pieces into 100 ml acid solution with and without various concentrations of inhibitors. After the specified periods of time, the specimen were taken out of the test solution, rinsed with bidistilled water, dried as before and weighed again accurately. The average weight loss at a certain time for each set of the six samples was taken. The weight loss was recorded to nearest 0.0001 g.

2.3. Electrochemical techniques

Polarization experiments were carried out in a conventional three-electrode cell with a platinum counter electrode (1 cm^2) and a saturated calomel electrode (SCE) coupled to a fine Luggin capillary as the reference electrode. The working electrode was in the form of a square cut from copper embedded in epoxy resin of polytetrafluoroethylene (PTFE) so that the flat surface was the only surface in the electrode.

The electrochemical measurements were carried out using a Gamry instrument Potentiostat/Galvanostat/ZRA (PCI 300/4). This includes a Gamry Framework system based on the ESA400, Gamry applications that include DC105 for dc corrosion measurements, EIS300 for electrochemical impedance spectroscopy and EFM140 software for electrochemical frequency modulation measurements along with a computer for collecting data. Electrochemical data were analyzed by Echem Analyst 5.5 software. The working electrode was immersed in the test solution before starting the measurements, until a steady state was reached (30 min). For potentiodynamic polarization measurements, the potential was scanned at a scan rate of $1mVs^{-1}$. Potential changed automatically from -700 mV up to $+300.mV_{SCE}$. EIS measurements were performed at open-circuit potential over a frequency range of 0.1Hz to 100 kHz. The sinusoidal potential perturbation was 5 mV in amplitude. EFM carried out using two frequencies 2.0 and 5.0 Hz. The base frequency was 1.0 Hz. We use a perturbation signal with amplitude of 10 mV for both perturbation frequencies of 2.0 and 5.0 Hz.

3. Results and Discussion

3.1. Weight loss measurements

The weight loss (mg cm^{-2}) of C-steel was determined at various time intervals, in the absence and presence of different concentrations of cefadroxil. Figure (1) shows the effect of increasing concentration of cefadroxil on the weight loss of C-steel vs. time curves at 25°C. It is obvious that the weight loss of C- steel in the presence of cefadroxil varies linearly with time, and is much lower than that obtained in blank solution. The linearity obtained indicated the absence of insoluble surface film during corrosion and that the inhibitor was first adsorbed onto the metal surface and, therefore, impede the corrosion process [24]. The inhibition efficiency (% η) and the surface coverage (θ) that represents the weight of the metal surface covered by inhibitor molecules were calculated using the following equation:

$$\% \eta = \theta \times 100 = [1 - (\Delta W_{inh} / \Delta W_{free})] \times 100 \quad (1)$$

where ΔW_{free} and ΔW_{inh} are the weight losses per unit area in the absence and presence of inhibitor, respectively. The calculated values of % η are summarized in Table (1). Careful inspection of these results showed that, the increase in the inhibitor concentration was accompanied by a decrease in weight-loss and an increase in the percentage inhibition (%η). These results lead to the conclusion that, this compound under investigation is fairly efficient as inhibitors for C-steel dissolution in sulphuric acid solution. This behavior could be attributed to increase of the number of adsorbed molecules at metal surface [25].

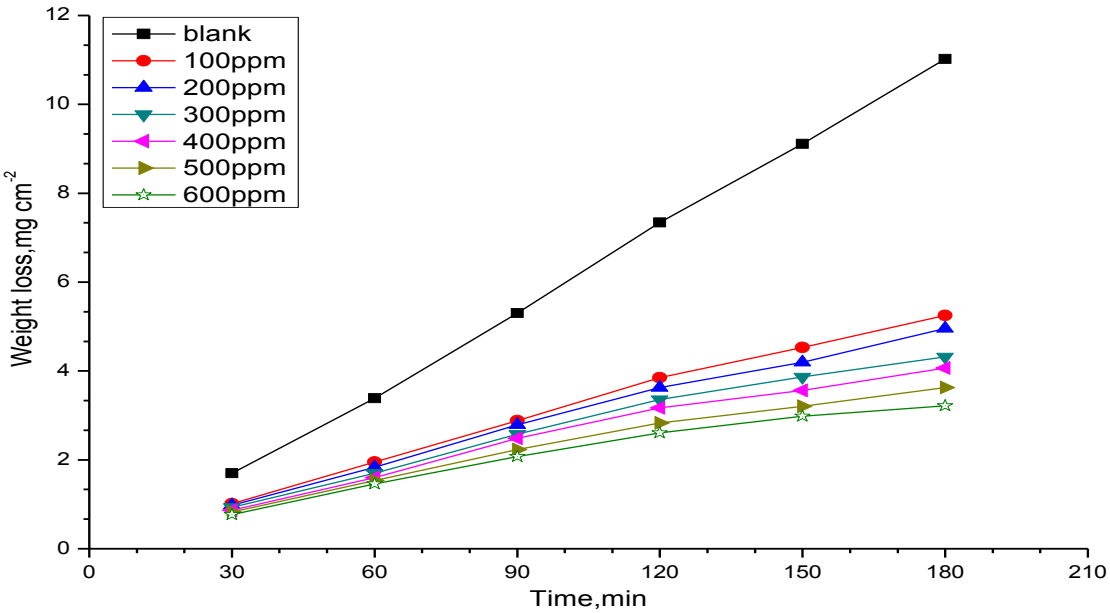


Figure (1): Weight loss- time curves for the corrosion of C- steel in 0.5 M H_2SO_4 in the absence and presence of different concentrations of cefadroxil at 25°C

3.2. Synergistic effect

Iodide ion is found to enhance the inhibitive effect of several inhibitors in acid solutions. In the present study the influence of iodide ion on the inhibitive performance of the investigated compound has been studied. Similar results have been documented elsewhere [26, 27]. Table (1) shows the influence of 0.01 M KI on inhibition efficiency of various concentrations of the investigated compound for carbon steel using weight loss technique. It can be seen from this table that the addition of KI increases the inhibition efficiency of the investigated compound for carbon steel. Figure (2) represents the weight loss-time curves of carbon steel in 0.5 M H_2SO_4 in the absence and presence of 0.01 M KI and different concentrations of cefadroxil at 25°C. The synergistic effect between iodide ions and inhibitor molecules can be explained by the fact that the addition of KI component stabilized the adsorption of the investigated compound on the steel surface. This stabilization may be caused by the interaction between inhibitor molecule and iodide ions. Thus, the interaction enhances the inhibition efficiency to a considerable extent due to the increase of the surface coverage in the presence of iodide ions.

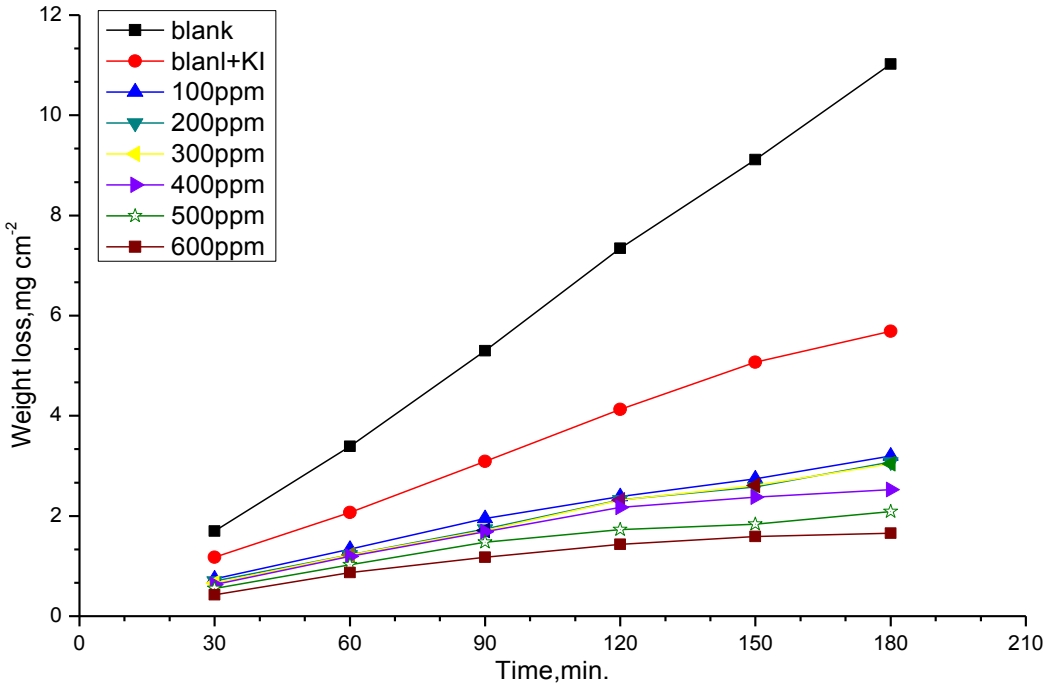


Figure (2): Weight loss- time curves for the corrosion of C- steel in 0.5 M H_2SO_4 in the absence and presence of different concentrations of cefadroxil and 0.01 M KI at 25°C

Table 1: Inhibition efficiency (%η) of the investigated compound at different concentrations for carbon steel in 0.5M H_2SO_4 in the absence and presence of 0.01 M KI as determined by weight loss method after 90 min at 25C°

[Inhibitor], ppm	Inhibition efficiency (%η)	
	In the absence of KI	In the presence of KI
100	45.7	63.2
200	47.4	67.1
300	51.4	69.8
400	53.2	71.2
500	57.8	75.1
600	60.9	78.2

3.3. Potentiodynamic Polarization

Potentiodynamic polarization curves for the corrosion of carbon steel in 0.5M H_2SO_4 in the absence and presence of different concentrations of cefadroxil at 25°C are shown in Figure 3. The corrosion current density (i_{corr}), anodic (β_a) and cathodic (β_c) Tafel slopes were calculated by extrapolation of linear parts of anodic and cathodic curves to the

corresponding corrosion potential (E_{corr}). The percentage inhibition efficiency (η_{pp} %) and the degree of surface coverage (θ), were calculated from equation (2) [28]:

$$\% \eta = \theta \times 100 = [1-(i_{cor(inh)} / i_{corr(free)})] \times 100 \quad (2)$$

where $i_{corr(free)}$ and $i_{corr(inh)}$ are the corrosion current densities of uninhibited and inhibited solutions, respectively.

The electrochemical parameters, determined from Tafel polarization curves are summarized in Table 2. The data in Table 2 showed that the current density decreased in the presence of cefadroxil than in its absence. The % inhibition efficiency increased with increasing cefadroxil concentration. This indicates that cefadroxil molecules are adsorbed on the metal surface. The inhibition was more pronounced with increasing inhibitor concentration. Tafel lines are shifted to more negative and more positive potentials with respect to the blank curve by increasing the concentration of the inhibitor (Figure 3), also there is a small changes in E_{corr} value. This behavior indicates that Septazole acts as

Conc., ppm	-E_{corr}, mV vs SCE	i_{corr}, μA cm^{-2}	-β_c, mV dec^{-1}	β_a, mV dec^{-1}	R_p ohm cm	C.R mm y^{-1}	θ	% η
0.0	488	10.402	49	180	221	896.1	0.490	49.0
100	487	5.302	83	253	203	456.7	0.556	55.6
200	459	4.614	87	137	189	397.5	0.659	65.9
300	451	3.546	115	143	187	305.5	0.695	69.5
400	458	3.177	122	133	182	273.7	0.703	70.3
500	459	3.090	127	136	182	266.2	0.743	74.3
600	460	2.989	123	123	179	257.5	0.790	79.0

Table (2): The effect of concentrations on the free corrosion potential (E_{corr}), corrosion current density (i_{corr}), Tafel slopes (β_c,β_a), corrosion rate(CR) and degree of surface coverage (θ), inhibition efficiency (% η) of carbon steel in 0.5M H_2SO_4 at 25°C

mixed-type inhibitor [29].

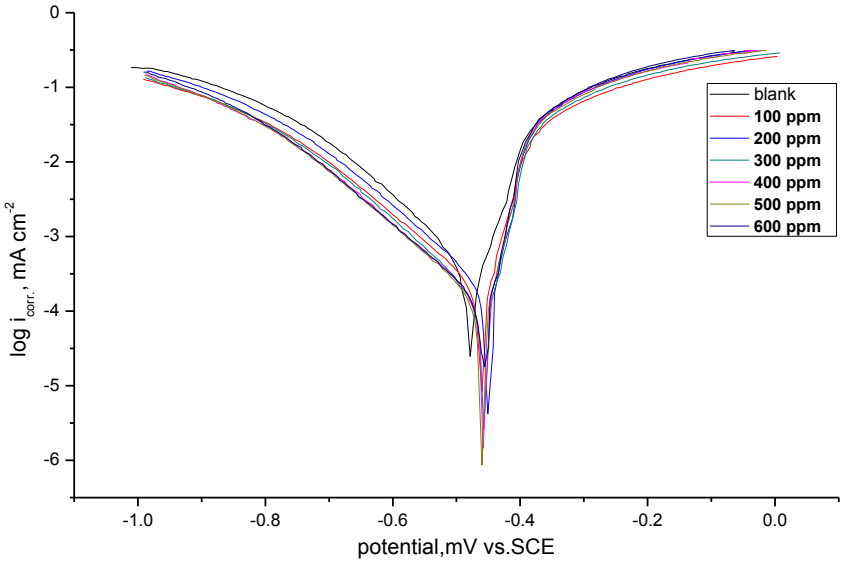


Figure 3. Potentiodynamic polarization curves for the corrosion of carbon steel in 0.5 M H_2SO_4 in the absence and presence of different concentrations of cefadroxil at 25°C

3.4. Electrochemical Impedance Spectroscopy (EIS) Measurements

Nyquist plots of carbon steel in 0.5M H_2SO_4 solution in the absence and presence of different concentrations of cefadroxil at 25°C are shown in Figure 4. The charge transfer resistance (R_{ct}) values were calculated from the difference in the Nyquist plots at low and high frequencies. Therefore, the inhibition efficiency, (η_{EIS} %) and the degree of surface coverage (θ) of cefadroxil can be calculated from the charge- transfer resistance according to Eq. (3) [30]:

$$\% \eta = \theta \times 100 = [1 - (R_{ct}^{*}/R_{ct})] \times 100 \quad (3)$$

Where, R^{*}_{ct} = The charge-transfer resistances for uninhibited solution and R_{ct} = The charge-transfer resistances for inhibited solution.

The double layer capacitance values (C_{dl}) at different cefadroxil concentrations, was calculated using equation (4) [31]:

$$C_{dl} = \frac{1}{\omega R_{ct}} = \frac{1}{2\pi \int_{max} R_{ct}} \quad (4)$$

where f_{max} = The frequency at the maximum in the Nyquist plot.

Double layer capacitance (C_{dl}) obtained from the Nyquist plots and the calculated inhibition efficiency values (η_{EIS} %) are reported in Table 3. It is apparent from this table that the value of R_{ct} increased with increasing concentration of cefadroxil. The increase in R_{ct} values is attributed to the formation of an insulating protective film at the metal/solution interface. So that. The (η_{EIS} %) increased. On the contrary, the value of C_{dl} decreased upon the addition of the inhibitor, suggesting, an increase in the local dielectric constant and/or an increase in the thickness of the electrical double layer, indicating the inhibitor molecules function by the formation of the protective layer at the metal surface [32].

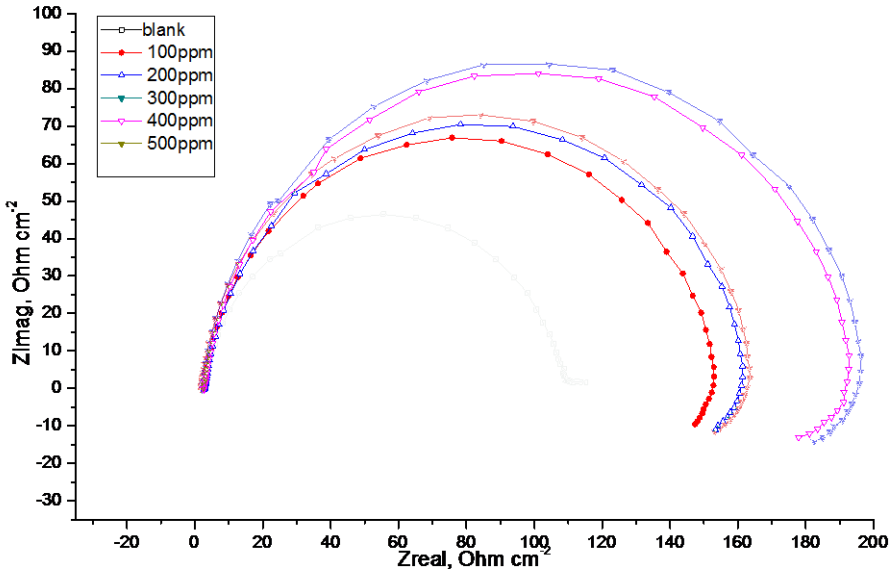


Figure 3. Nyquist plots for corrosion of carbon steel in 0.5 M H_2SO_4 in the absence and presence of different concentrations of cefadroxil at 25°C

Table (3): Electrochemical kinetic parameters obtained by EIS technique for the corrosion of carbon steel in 0.5 M H_2SO_4at different concentrations of investigated compound

Conc., ppm	C_{dl} μFcm^{-2}	R_{ct} $\Omega\ cm^2$	θ	% η
blank	62.57	107.4	-	-

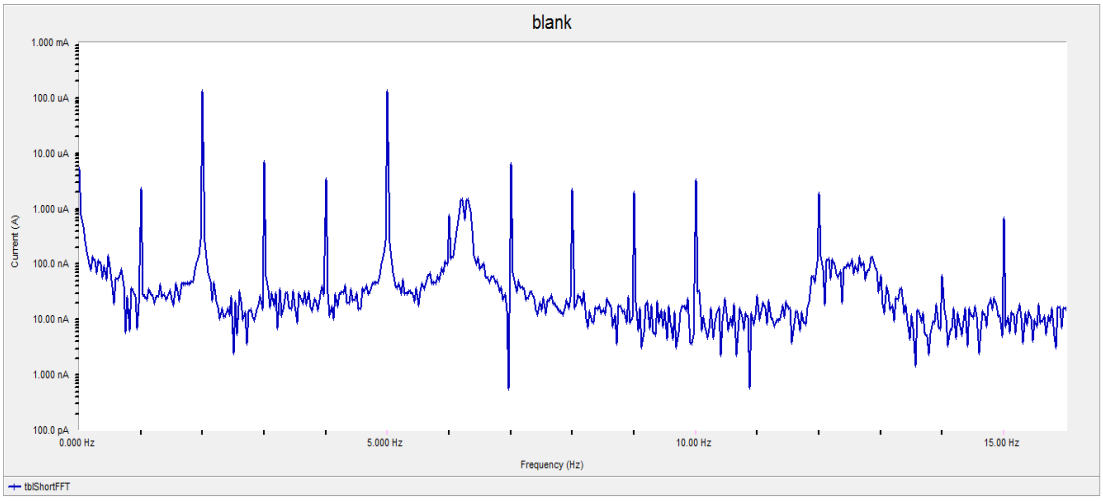
100	54.34	150.1	0.284	28.4
200	53.55	157.8	0.319	31.9
300	47.88	159.8	0.328	32.8
400	50.85	188.5	0.430	43.0
500	49.52	192.6	0.442	44.2
300	39.42	267.4	0.598	59.8
400	39.75	290.7	0.631	63.1
500	37.24	332.9	0.677	67.7

3.4. Electrochemical Frequency Modulation (EFM) Measurements

EFM is a nondestructive and a rapid test technique. Also, The EFM technique is used to calculate the anodic and cathodic Tafel slopes as well as corrosion current densities without prior knowledge of Tafel constants. Fig. 4a and b show representative examples for EFM intermodulation spectra of carbon steel in 0.5 M H_2SO_4 in the absence and presence of 500 ppm of inhibitor at 25°C. Similar results were obtained for the other concentrations (not shown). The inhibition efficiency (η_{EFM} %) and the degree of surface coverage (θ) was calculated from equation (5):

$$\% \eta_{EFM} = \theta \times 100 = [1-(i_{corr(inh)}/i_{corr(free)})] \times 100 \quad (5)$$

The electrochemical parameters obtained from spectral analysis of EFM are summarized in Table 4. It is clear that from this table, the values of i_{corr} decrease with increasing the concentration of inhibitor, this means (η_{EFM} %) increased, suggesting that cefadroxil inhibits the corrosion process by adsorption on the carbon steel surface. The values of causality factors (CF-2, CF-3) are very close to theoretical values (2) and (3) according to the EFM theory, suggesting that, the validity of Tafel slopes and corrosion current densities [33, 34].



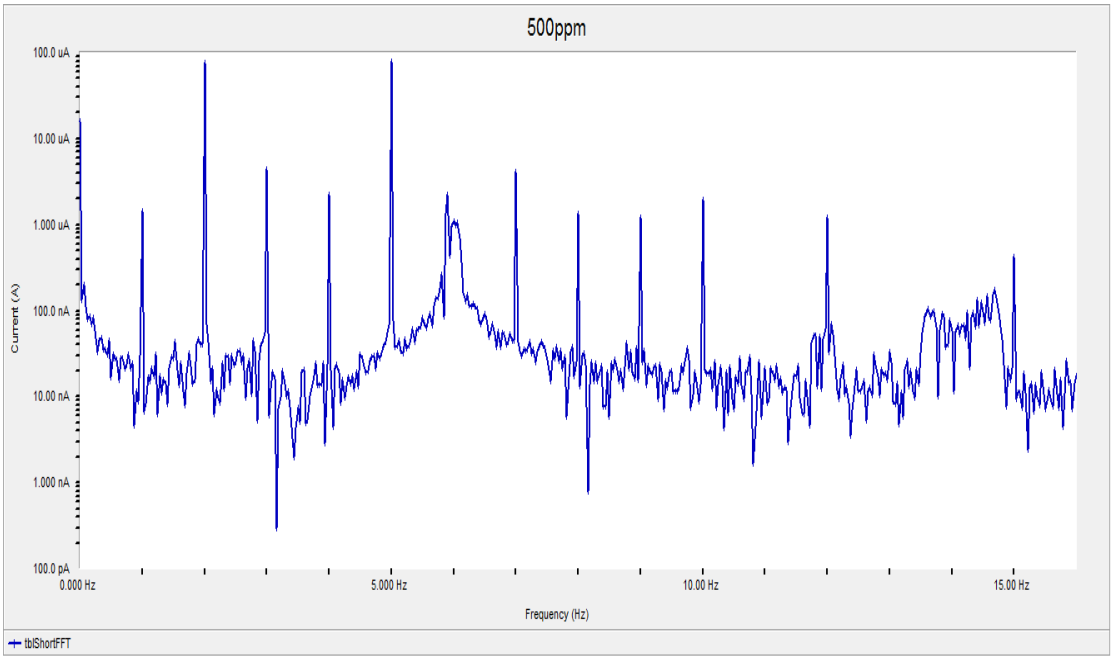


Figure 4: Intermodulation spectra of carbon steel in 0.5M H_2SO_4 solution and intermodulation spectra of carbon steel 0.5M H_2SO_4 solution in presence of 500 ppm cefadroxil at 25°C

Table 4: Data from electrochemical frequency modulation of carbon steel in 0.5 M H_2SO_4containing different concentrations of cefadroxil at 25°C

Comp.	[Inh.] ppm	i_{corr}, µA cm^{-2}	β_a, mV dec^{-1}	β_c, mV dec^{-1}	CF-2	CF-3	CR, mpy	θ	% η
blank	0.0	240.8	83	112	2.030	2.919	85.08	-	-
cefadroxil	100	139.8	78	119	1.995	3.188	62.34	0.416	41.6
	200	126.3	78	116	2.009	2.790	56.34	0.475	47.5
	300	120.2	80	106	2.018	3.139	57.46	0.501	50.1
	400	105.9	79	123	1.994	3.485	51.67	0.560	56.0
	500	85.6	79	108	2.013	1.737	48.42	0.645	64.5

3.5. Adsorption Isotherm and Thermodynamic Parameters

Basic information on the interaction between the surface of carbon steel and inhibitor can be determined from several adsorption isotherms. The common used adsorption isotherms are the Temkin, Frumkin, Langmuir and Flory–Huggins isotherm. The degree of surface coverage (θ) for different concentrations of the inhibitor (C_{inh}) has

been evaluated. The data were tested graphically to determine a suitable adsorption isotherm. A straight line with linear correlation coefficient (R^2) is almost equal to 1.0, was obtained on plotting C_{inh}/θ versus C_{inh} at all studied different temperatures as shown in Fig. 5, indicating that adsorption of the inhibitor on the carbon steel surface obeys the Langmuir adsorption isotherm. According to the Langmuir adsorption isotherm, the surface coverage (θ) is related to inhibitor concentration (C_{inh}) by equation (6) [35]:

$$\frac{C_{inh}}{\theta} = \frac{1}{K_{ads}} + C_{inh} \quad (6)$$

where, K_{ads} is the adsorption equilibrium constant. The slopes of straight lines (Fig.5) were found to be very close to unity. This means that, adsorbed molecule occupies only one site and it does not interact with other adsorbed species [36]. The K_{ads} values can be calculated from the intercept lines on the C_{inh}/θ axis in Fig.5. K_{ads} is related to the standard free energy of adsorption (ΔG^0_{ads}) by equation (7) [35]:

$$K_{ads} = \frac{1}{C_{solvent}} \exp\left(-\frac{\Delta G^\circ_{ads}}{RT}\right) \quad (7)$$

where, $C_{solvent}$ = molar concentration of the solvent, which in the case of water is 55.5 mol L^{-1}.
R is the gas constant, and T is the absolute temperature.
The calculated values of K_{ads} and ΔG^0_{ads} are given in Table 4. As shown from Table 4, the large values of K_{ads} obtained for investigated drug, imply efficient adsorption and, therefore, better inhibition efficiency. The negative value of ΔG^0_{ads}, indicated spontaneous adsorption of the inhibitor on the surface of carbon steel. Generally, the value of ΔG^0_{ads} up to - 20 kJ mol^{-1} suggests electrostatic interactions between the charged molecules of inhibitor and the charged metal surface (i.e., physisorption). On the contrary, the value of ΔG^0_{ads} above − 40 kJ mol^{-1}, involve charge sharing or transfer from the inhibitor molecules to the metal surface to form a coordinate bond (i.e., chemisorptions). In our measurement, the calculated value ΔG^0_{ads} at 25°C for carbon steel is - 28.9-28.0 kJ mol^{-1}, which suggests that adsorption of the inhibitor on the carbon steel surface, involves both physical and chemical process [37, 38]. But the inhibition efficiency decreased with increasing temperature, indicating that the inhibitor adsorbed predominantly physically on the carbon steel surface [39].

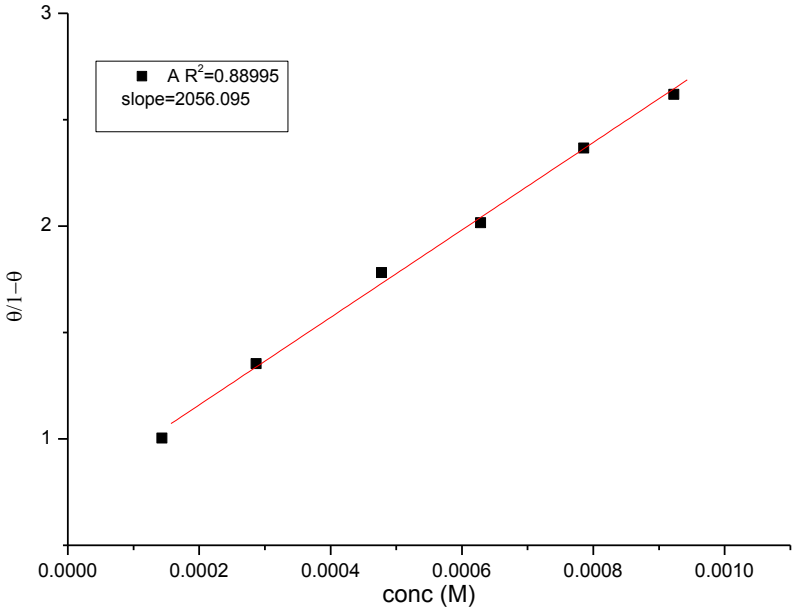


Figure 5: Langmuir adsorption isotherm of cefadroxil on carbon steel surface in 0.5 M H_2SO_4at 25°C

Table 4: Inhibitor binding constants (K_{ads}) and free energy of binding (ΔG°_{ads}, kJ mol^{-1}) for inhibitor at different temperatures

Temp, °C	K_{ads} M^{-1}	$-\Delta G^\circ_{ads}$ kJ mol^{-1}

25	2056.10	28.9
35	1598.21	28.7
45	1040.62	28.5
55	472.42	28.0

3.6. Effect of Temperature and Kinetic Parameters

To evaluate the mechanism of inhibition and to determine the kinetic parameters of the corrosion process, potentiodynamic polarization measurements were carried out at 298-328 K. The inhibition efficiency (η%) decreased with increase in temperature, and hence, protective film of inhibitor formed on the surface of carbon steel is less stable at higher temperatures, which may be due to the desorption of some adsorbed molecules from the surface of the carbon steel, due to which greater area of the metal is exposed to the acidic environment as reported [38]. The apparent activation energy (E_a) of carbon steel corrosion in 0.5 M H_2SO_4 can be expressed using the Arrhenius equation (8) [40]:

Rate (k) = A exp ($-E_a$/RT) (8)

where k is the rate constant, E_a is the apparent activation energy and A is the Arrhenius pre-exponential factor. Figure 6 shows, the Arrhenius plot of log k against 1/T for the corrosion of carbon steel in 0.5 M H_2SO_4 solution in the absence and presence of various concentrations cefadroxil. From Fig.6, the values of E_a were calculated from the slope of each individual line using the expression E_a = (slope) x 2.303R, and then, are listed in Table 5. It is clear from Table 5, that the values of E_a for the inhibited solutions were higher than that for the uninhibited solution, suggesting a physical adsorption. The increase in E_a can be attributed to an appreciable decrease in the adsorption of the inhibitor on the copper surface with increase in temperature. Similar behaviour was previously reported [41].

The values of the enthalpy of activation (ΔH^*) and entropy of activation (ΔS^*) were calculated by equation (9) [40]:

Rate (k) = RT/Nh exp (ΔS^*/R) exp $-(\Delta H^*$/ RT) (9)

where h = Planck's constant .N =the Avogadro's number.

A plot of log k/T vs. 1/T. (Fig. 8), gave straight lines with slope of ($-\Delta H^*$/2.303R) and an intercept of, [log(R/Nh) + ΔS^*/2.303R] from which the values of ΔH^* and ΔS^* were calculated and summarized in Table 5. The positive values of ΔH^* for corrosion of carbon steel in the presence and absence of the inhibitor reflect the endothermic nature of the metal dissolution process as reported [42]. The entropy of activation values are less negative for inhibited solutions than that for the uninhibited solutions. This indicates that an increase in randomness occurred while moving from reactants to the activated complex as reported [43, 44].

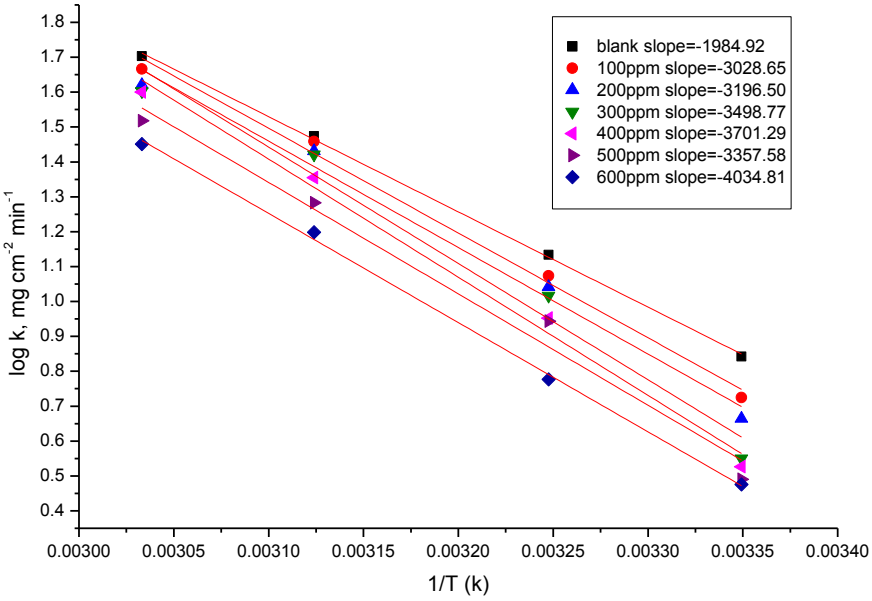


Figure 6. log k vs. (1/T) curves for the corrosion of carbon steel in 0.5 M H_2SO_4 in the absence and presence of different concentrations of cefadroxil at different temperatures

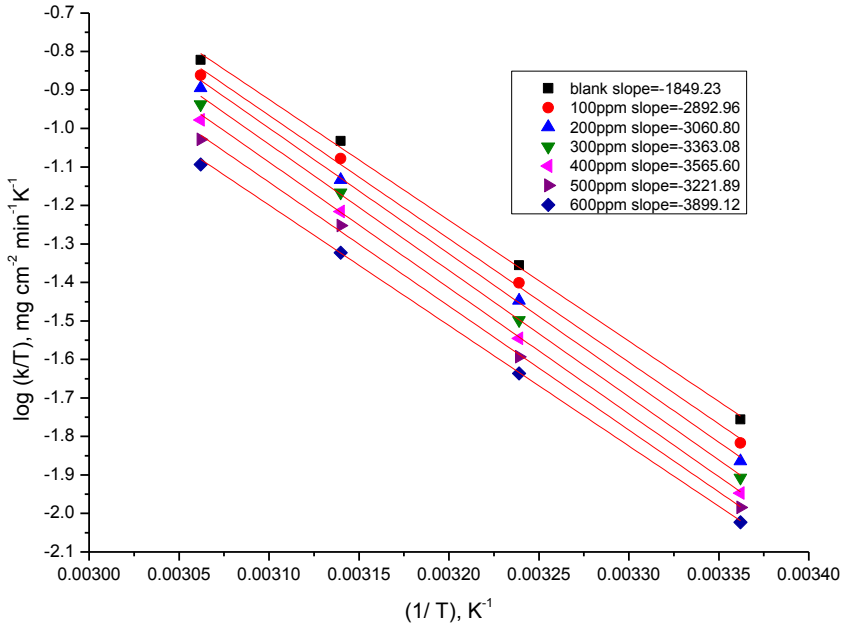


Figure 7. log k / T vs. 1/T in absence and presence of various concentrations of cefadroxil at different temperatures

Table 5: Energy E_a, enthalpy change (ΔH^*) and entropy change (ΔS^*) of activation for carbon steel in 0.5M H2SO4 in presence of different concentrations of cefadroxil

Conc.x 10^5 M	E_a kJ mol^{-1}	ΔH^* kJ mol^{-1}	$-\Delta S^*$ J $mol^{-1}K^{-1}$
0.0	38.0	35.4	106.6
16	58.0	55.4	44.8
31	61.2	58.6	35.1
47	67.0	64.3	17.4
63	70.9	68.3	15.8
79	74.3	71.7	12.7
94	77.3	74.7	10.4

3.7. Mechanism of Corrosion Inhibition

The adsorption of investigated drug can be attributed to the presence of polar unit having atoms of nitrogen, sulphur and oxygen and aromatic/heterocyclic rings. Therefore, the possible reaction centers are unshared electron pair of hetero-atoms and л-electrons of aromatic ring [45]. The adsorption and inhibition effect of cefadroxil drug in 0.5 M H_2SO_4 solution can be explained as follows: In general, two modes of adsorption are considered on the metal surface in acid media. In the first mode, the neutral molecules may be adsorbed on the surface of carbon steel through the chemisorption mechanism, involving the displacement of water molecules from the carbon steel surface and the sharing electrons between the hetero- atoms and Fe. The inhibitor molecules can also adsorb on the carbon steel surface. In the second mode, since it is well known that the carbon steel surface bears positive charge in acid solution [46], so it is difficult for the protonated molecules to approach the positively charged carbon steel surface due to the electrostatic repulsion. Since sulfate ions could bring excess negative charges in the vicinity of the interface and favor more adsorption of the positively charged cefadroxil molecules, the protonated cefadroxil adsorb

through electrostatic interactions between the positively charged molecules and the negatively charged metal surface. Thus there is a synergism between adsorbed SO_4^{--} ions and protonated cefadroxil. Thus we can conclude that inhibition of carbon steel corrosion in 2 M H_2SO_4 is mainly due to electrostatic interaction. The decrease in inhibition efficiency with rise in temperature supports electrostatic interaction.

4. Conclusions

From the overall experimental results the following conclusions can be deduced:

The investigated drug is good inhibitor and act as mixed type inhibitor for carbon steel corrosion in 2 M H_2SO_4 solution. The results obtained from electrochemical and chemical measurements showed that the inhibiting action increases with the inhibitor concentration and decreases with the increasing in temperature. Double layer capacitances decrease with respect to blank solution when the cefadroxil is added. This fact confirms the adsorption of cefadroxil molecule on the carbon steel surface. The adsorption of inhibitor on carbon steel in 2 M H_2SO_4 solution follows Langmuir isotherm.

REFERANCES

1. LB,Tang, GN Mu, G H Liu, Corros. Sci. 45 (2003) 2251.
2. J Fu, S Li, L Cao, Y Wang, L Yan, L Lu, J. Mater. Sci. 45(2010) 979.
3. SS Mahmoud, J. Mater. Sci. 42 (2007) 989.
4. L Tang, X Li , G Mu, G Liu, L Li, H Liu, Y Si, J. Mater. Sci. 41(2006) 3063.
5. Manjula P, S Manonmani, P Jayaram, S Rajendran, Anti-Corros. Methods Mater. 48(2001) 319.
6. BR Babu, R Holze, Br. Corros. J. 35 (2000) 204.
7. MA Quraishi, D Jamal, Corrosion, 56 (2000)156.
8. B Mernari, H El Attari, M Traisnel, F Bentiss, M Lagrenee, Corros. Sci. 40 (1998) 391.
9. P Li, TC Tan, JY Lee, Corrosion, 53(1997) 186.
10. G Moretti, G Quartarone, A Tassan, A Zingales, Electrochim. Acta ,41 (1996) 1971.
11. S Martinez, I Stern, Appl. Surf. Sci. 199 (2002) 83.
12. I Sekine, Y Hirakawa, Corrosion, 42 (1986)272.
13. S.Biligic, Korozyon, 13(2005)1
14. M.Abdallah, Corros.Sci., 44(2002)717
15. M.S.Morad, Corros.Sci., 50(2008)436
16. R.A.Prabhu, A.V.Shanbhag, T.V.Venkatesha, J.Appl.Electrochem., 37(2007)491
17. M.El-Naggar, Corros.Sci., 49(2007)2226
18. I.B.Obot, N.O.Obi-Egbedi, S.A.Umoren, Corros.Sci., 51(2009)1868
19. S.K.Shukla, M.A.Quraishi, Corros.Sci., 51(2009)617
20. S.K.Shukla, A.K.Singh, I.Ahamad, M.A.Quraishi, Mater.Lett., 63(2009)819
21. A.K.Singh, M.A.Quraishi, Corros.Sci., 52(2010)152
22. I.Ahamad, M.A.Quraishi, Corros.Sci., 52(2010)651
23. E.Kamis, F.Bellucci, R.M.Latanision, E.S.El-Ashry, Corrosin, 47 (1991) 677.
24.Otieno-Alego V., Hope G.A., Flitt H.J., Cash G.A and Schweinberg D.P., Corros. Sci., 33 (1992) 1719.
25. M Sahin., S Bilgic. H Ylmaz., Appl. Surf. Sci. 195 (2002) 1.
26. E. Khamis, E.S.H. El-Ashry, A.K. Ibrahim, Br. Corros. J,. 35 (2000) 150.
27. A.S. Fouda, A.A. Al-Sarawy, E.E. El-Katori Desalination, 201 (2006) 1.
28. H Ma, S Chen, L.Niu, S.Zhao, S.Li, D.Li, J. Appl. Electrochem., 32(2002) 65.
29. E.Hamed, , Mater. Chem. Phys., 21(2010) 70
30. Ahamad, I., Prasad, R., and Quraisi, M. A., Corros. Sci., 52(2010) 1472.
31. El-Haddad, M.N., 55 (2013) 142.
32. RW Bosch, J.Hubrecht, WFBogaerts, BC. Syrett, , Corrosion, 57(2001) 60.
33. M N El-Haddad, A S.Fouda, , Chem.Eng.Comm., 200(2013) 1366.
34. RS.Abdel Hameed, Port. Electrochim. Acta, 29(2011) 273.
35. XH. Li, SD.Deng, GN.Mu, H.Fu, FZ.Yang, , Corros. Sci., 50(2008) 420.
36. AK. Singh, MA.Quraishi, , Corros. Sci., 52(2010)152.
37. M.Bouklah, N. Benchat, B. Hammouti, A.Aouniti, S. Kertit, Mater. Lett., 60(2006) 1901.
38. M.Karakus, M.Sahin, S.Bilgic¸ Mater. Chem. Phys., 92(2005) 565.
39. I.Dehri, M.Ozcan, Mater. Chem. Phy., 98(2006) 316.
40. T.Szauer, A.Brandt, Electrochim. Acta, 26(1981) 1253.

41. T.Szauer, A.Brandt, Electrochim. Acta, 26(1981) 1209.
42. Marsh, J.," Advanced Organic Chemistry, 3rd ed.", Wiley, Eastern New Delhi, 1988.
43. K.Fukui, "Theory of Orientation and Stereoselection, Springer-Verlag", New York, 1975.
44. N.Khalil, Electrochim., Acta, 48(2003) 2635.
45. I. Ahamad, R.Prasad, MA.Quraishi, , Corros. Sci., 52(2010) 3033.
46. YC.Wu, P.Zhang, HW.Pickering, DL.Allara, , J.Electrochem.Soc., 140(1993)2791