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Anticorrosion potential of a pharmaceutical intermediate Floctafenine for zinc in 0.1 M HCl solution

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Abstract Corrosion inhibition of Floctafenine for zinc in 0.1 M HCl solution was studied using empirical and theoretical methods. Quantum studies have been utilized for studying the interaction between metal and inhibitor. Empirical methods like potentiodynamic polarization and electrochemical impedance spectroscopy were adopted to verify the inhibition efficiency of the inhibitor. Adsorption of the inhibitor follows the Langmuir isotherm. Thermodynamic values show the physical adsorption mechanism of the inhibitor. Activation and thermodynamic parameters explain the corrosion mechanism. The effect of temperature on the corrosion behavior of zinc in the given temperature range 303–333 K was studied and discussed.

Keywords Floctafenine · Adsorption · Polarization · Quantum chemical studies · Zinc

Introduction

Zinc is widely used in the industry, especially for galvanizing process and it is employed as a galvanizing material for steel piping, fencing, nails, electronic goods and many types of machinery. It is also used as bars, plates, slabs to protect ship hulls, pipelines and other structural materials. Zinc is a very active metal and it gives white rust in the presence of moisture and air [1–4]. Corrosion is a big challenge and many corrosion control methods have been adopted all over the world. Among these methods, using corrosion inhibitors is a very prominent method [5, 6]. Various types of chemical inhibitors—organic and inorganic compounds, pharmaceuticals drugs, dyes and even plant extracts are developed to control corrosion. Few years back, corrosion inhibition of zinc could be achieved by the chromate treatment. The effluents obtained from this treatment result in more adverse effect on the environment [7–9]. Therefore, the environment-friendly corrosion inhibitors have been discovered [10–13]. In the present study, investigator studied the corrosion inhibition effect of environment-friendly corrosion inhibitor Floctafenine on zinc in 0.1 M HCl solution.

Floctafenine is a class of non-steroidal anti-inflammatory drug used for the treatment of inflammatory disorders. The presence of electron-rich N, O, F atoms and π -bonds in its structure might be in favor of its adsorption on the metal surface which gives a scope for its study as a potential corrosion inhibitor. Not only the structure but also the eco-friendly nature is the main criterion to select the potential inhibitor. The significance of the present work is to develop new inhibitor for zinc corrosion. For this purpose corrosion of zinc has been investigated using various chemical and electrochemical techniques. A number of attempts have been made to understand different aspects of corrosion,

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such as mechanism of corrosion, kinetics of corrosion, thermodynamics of corrosion, etc.

Experimental

Material

Zinc metal sheet of pure grade (Cu 0.17 %, Ti 0.075 %, Al <0.05 %, Pb–Cd <0.003 %, Fe 0.002 %, Sn 0.001 % and Mg 0.0005 %) material were used for the measurement of the corrosion rate. Electrodes were prepared from a rectangular zinc metal sheet and isolated with an insulator so that only a 1 cm² area was exposed for the electrochemical measurements. Prior to every experiment, the electrode was polished with silicon carbide emery paper (grade no.:80, 120, 220, 320, 1200, 1500) and washed with distilled water.

Test solution

The Floctafenine is procured from Sequent Scientific Limited. This inhibitor is soluble in 0.1 M HCl. The different concentrations of Floctafenine are prepared in 0.1 M HCl solution. The molecular structure of Floctafenine is as shown in the Fig. 1. The IUPAC name of Floctafenine is 1-*N*-[8-(trifluoromethyl)-4-quinolyl] anthranilate.

Methods

Quantum chemical studies

Quantum chemical calculations for Floctafenine were carried out in gas phase using parametric method 3 (PM3). The Polak–Rieberre algorithm which is fast and accurate has been used for computation. The energy parameters in the form of root mean square gradient were kept at 0.05 kcal^{−1} Å mol and convergence limit at 0.05. These calculations were performed using Hyperchem 7.5 package program (Hypercube Inc., Florida, 2003).

Fig. 1 Structure of Floctafenine

Adsorption isotherm and thermodynamic parameters

To gain more information about mode of adsorption of Floctafenine on zinc surface in 0.1 M HCl at different temperature, attempts were made to fit experimental data with several adsorption isotherms like Temkin, Langmuir and Freundlich.

Activation parameters

Effect of temperature on the corrosion and its inhibition in the presence of inhibitor in 0.1 M HCl solution is studied using Arrhenius plots and transition state plots. The change in apparent enthalpy and change in apparent entropy are calculated.

Electrochemical measurements

The electrochemical measurements were carried out in Ivium electrochemical analyser at 303–333 K. The cell consists of three electrodes namely, the working electrode (zinc), counter electrode (platinum) and reference electrode (Ag/AgCl electrode). Before each electrochemical measurement, the working electrode was allowed to stand for 30 min in test solution to establish steady-state open circuit potential (OCP). All reported potentials were with respect to Ag/AgCl electrode. For Tafel measurements, potential–current curves were recorded at a scan rate of 0.01 V s^{−1} in the potential range obtained by adding −0.2 to +0.2 V to the open circuit potential (OCP) value. The corrosion parameters such as corrosion potential (E_{corr}), corrosion current (I_{corr}) cathodic Tafel slope (bc) and anodic Tafel slope (ba) were calculated from the software installed in the instrument. Impedance measurements were carried out using AC signal with amplitude of 5 mV at OCP in the frequency range from 0.1 Hz to 1 kHz. The impedance data were fitted to most appropriate equivalent circuit using ZSimp Win 3.21 software. The impedance parameters were obtained from Nyquist plots.

Results and discussion

Quantum chemical studies

The design and development of organic corrosion inhibitors in corrosion field can be performed by computational method. The corrosion inhibition efficiency theoretically calculated using very powerful tool is called as quantum chemical calculations [14]. The inhibition effect of inhibitor is related to its functional groups, steric effect, orbital character of donating electrons and electronic density of donor atoms [15, 16]. The investigator uses the PM3

method to calculate the theoretical aspects of the inhibitor and metal interactions. This semi empirical method is based on the neglect of differential diatomic overlap integral approximation. PM3 uses two Gaussian functions for the core repulsion function, the method was developed by Stewart and first reported in 1989 [17, 18].

The parameters such as E_{HOMO} , E_{LUMO} , ΔE , dipole moment, number of electrons transferred from inhibitor to metal orbitals, total energy, binding energy are evaluated. All parameters are depicted in Table 1.

E_{HOMO} , E_{LUMO} and ΔE

The ability of the molecules to donate the electrons to appropriate molecular orbitals is indicated by E_{HOMO} , whereas the E_{LUMO} indicates its ability to accept electrons. This could be simply donating electron density to form a bond (act as a Lewis base) or it could be oxidation. As the value of E_{HOMO} is higher, the easier is its ability to offer electrons to the unoccupied d-orbital of metal surface, and it results in maximum efficiency [19, 20]. The difference between E_{HOMO} and E_{LUMO} results ΔE , i.e., $E_{\text{HOMO}} - E_{\text{LUMO}} = \Delta E$. The value of ΔE indicates the extent of inhibition efficiency. E_{HOMO} and E_{LUMO} structure is as shown in the Figs. 2 and 3. The smaller value of ΔE facilitates adsorption of the molecule and thus will cause higher inhibition efficiency, because the energy to remove an electron from the last occupied orbital will be low [21, 22]. Mahendra Yadav et al. [23] reported the ΔE value in the range of 7.9–8.05 for three inhibitors and experimental %IE is in the range of 85–90 %, respectively. Mistry et al. [24] compared the ΔE values of two inhibitors and the inhibition efficiency and correlated with the experimental

findings. In the present study, investigators obtained the ΔE value of 7.731 eV and the experimental percentage efficiency is 85 %.

Dipole moment

The dipole moment (μ) is an important parameter to find out the electronic distribution in a molecule and is used to rationalize the structure. Dipole moment can be defined as the product of magnitude of charges and the distance of separation between the charges [25]. But many literatures explain the lack of agreement on the correlation between the dipole moment and inhibition efficiency [26, 27].

Despite lack of correlation, many literatures [28–30] reported that the molecule with lowest dipole moment has better inhibition efficiency. In the present study, investigators obtained the dipole moment of 6.018 Debye.

Binding energy

Binding energy is the energy required to disassemble a whole system into separate parts. The negative value of binding energy suggests that the inhibitor is very stable and less prone to split apart. In this study, investigator got negative value and it is concluded that the inhibitor is stable [31].

The number of transferred electrons (ΔN)

To support the above observations, the number of transferred electrons (ΔN) was calculated using following equation [32]

Table 1 The different quantum parameters for the Floctafenine molecule

E_{HOMO} (eV)	E_{LUMO} (eV)	ΔE (eV)	μ (debye)	Total energy (Kcal mol ⁻¹)	Binding energy (Kcal mol ⁻¹)	ΔN
-9.015	-1.245	-7.7	6.018	-125726.4	-5071.605	0.22

Fig. 2 HOMO structure of Floctafenine

Fig. 3 LUMO structure of Floctafenine

$$\Delta N = \frac{\chi_{\text{Fe}} - \chi_{\text{inh}}}{2(\eta_{\text{Fe}} + \eta_{\text{inh}})} \quad (1)$$

Electron donating ability of inhibitor can be determined by ΔN . The inhibition efficiency of the inhibitor directly related to donating ability of the electrons of the inhibitor to the metal surface [33]. Many literatures reported that the inhibition efficiency increases with the electron donating ability of the inhibitor at the metal surface, when the ΔN value is less than the 3.6 [34–36].

Adsorption isotherm

Basic information on the interaction between metal surface and the inhibitor can be determined from several adsorption isotherms. Many adsorption isotherms such as, Langmuir–Freundlich, Temkin, are examined as shown in the Figs. 3, 4 and 5, respectively. Figure 5 represents a straight line with linear correlation coefficient (R^2) in the range of 0.995–0.999 at all temperatures, indicating (Fig. 6) that adsorption of the inhibitor on the zinc surface obeys the

Langmuir adsorption isotherm. According to Langmuir adsorption isotherm, θ is related to equilibrium adsorption constant (K_{ads}) and C by the equation:

$$\frac{C}{\theta} = \frac{1}{K} + C \quad (2)$$

where C is the inhibitor concentration and K is the equilibrium constant for adsorption–desorption process. The strong adsorption of inhibitor on the zinc surface obeys Langmuir's adsorption isotherm. The K_{ads} values were calculated from the intercept of the straight line obtained from the plot of C/θ versus C . This is related to the standard free energy of adsorption (ΔG_{ads}^0) with the following equation.

$$K_{\text{ads}} = \frac{1}{55.5} \exp(-\Delta G_{\text{ads}}^0/RT) \quad (3)$$

where R is the gas constant and T is the absolute temperature. The constant value of 55.5 is the concentration of water in solution in mol L^{-1} .

Fig. 4 Langmuir adsorption plots of zinc in 0.1 M HCl solution containing different concentrations of Floctafenine at different temperatures

Fig. 5 Freundlich adsorption plots of zinc in 0.1 M HCl solution containing different concentrations of Floctafenine at different temperatures

Fig. 6 Temkin adsorption plots of zinc in 0.1 M HCl solution containing different concentrations of Floctafenine at different temperatures

If it is assumed that the inhibitor is adsorbed on the metal surface in the form of a monolayer film, covering at any instant a fraction, θ , of the metal surface in a uniform random manner then the heat of adsorption, (Q_{ads}), of the inhibitors can be calculated from the equation:

$$Q_{\text{ads}} = 2.303R \left\{ \log \frac{\theta_2}{1 - \theta_2} - \log \frac{\theta_1}{1 - \theta_1} \right\} \frac{T_1 T_2}{T_1 - T_2} \quad (4)$$

The values of K_{ads} and ΔG_{ads}^0 are listed in Table 2a.

The ΔH_{ads}^0 and ΔS_{ads}^0 are also calculated from the Gibbs–Helmholtz equation. The Gibbs–Helmholtz equation can be written as

$$\left\{ \partial(\Delta G_{\text{ads}}^0/T) / \partial T \right\}_p = \frac{-\Delta H_{\text{ads}}^0}{T^2} \quad (5)$$

By integrating the above equation, we get

$$\frac{\Delta G_{\text{ads}}^0}{T} = \frac{\Delta H_{\text{ads}}^0}{T} + K \quad (6)$$

The higher value of K_{ads} shows that the adsorption of inhibitor is a spontaneous process [37, 38]. In some systems adsorption is accompanied by absorption, where the adsorbed species penetrates into the solid through chemical bond. This process is governed by the laws of diffusion and can be readily differentiated from adsorption by experimental means. In the absence of chemical adsorption (chemisorption) and penetration into the bulk of the solid phase (absorption), only the weak physical adsorption (physisorption) case remains [39].

The forces that bring about physisorption are predominantly the attractive “dispersion forces” and short-range repulsive forces. In addition, electrostatic (Coulombic) forces are responsible for the adsorption of polar molecules, or by surfaces with a permanent dipole. Altogether, these forces are called “van der Waals forces” [40].

The efficiency of the inhibitor is generally attributed to the adsorption of the inhibitor molecules at the metal/solution interface, forming a protective film. Adsorption process can occur through the replacement of solvent

Table 2 Thermodynamic parameters for the corrosion of zinc in 0.1 M HCl in the presence of different concentrations of Floctafenine at different temperatures

Temperature (K)	K_{ads} (M^{-1})	ΔG_{ads}^0 (kJ mol^{-1})	$-\Delta H_{\text{ads}}^0$ (kJ mol^{-1})	$-\Delta S_{\text{ads}}^0$ ($\text{J mol}^{-1} \text{K}^{-1}$)
303	86730	−7.13	8.2	1.53
313	167220	−7.79	8.2	1.30
323	107870	−7.74	8.2	1.42
333	97560	−7.91	8.2	1.48

molecules from metal surface by ions and molecules accumulated in the vicinity of metal/solution interface. Aromatic compounds (which contain the benzene ring) undergo particularly strong adsorption on many electrode surfaces. The bonding can occur between metal surface atoms and the aromatic ring of the adsorbate molecules or ligands and substituent groups. The exact nature of the interactions between a metal surface and an aromatic molecule depends on the relative coordinating strength towards the given metal of the particular groups present [41].

The negative value of ΔG_{ads}^0 shows the spontaneity of the adsorption process and generally, values of ΔG_{ads}^0 around -20 kJ mol^{-1} or lower show that the electrostatic interaction between the charged molecules and the charged metal is physical adsorption; those around -40 kJ mol^{-1} or higher involves the coordinate type of bond (chemisorption) between the inhibitor and metal surface [42].

The calculated ΔG_{ads}^0 values approaching to -8.0 kJ mol^{-1} indicate that the adsorption mechanism of the inhibitors on zinc in 0.1 M HCl solution is typical physical adsorption [43]. The negative values of (Q_{ads}) indicated that the adsorption of used inhibitor on zinc surface is exothermic [44]. Q_{ads} values are as shown in Table 2b.

Relationship between $-\Delta G_{\text{ads}}^0/T$ v/s $1000/T$ is as shown in the Fig. 7. The slope of straight line (from Fig. 7) gives the ΔH_{ads}^0 value with $R^2 = 0.976$. The negative sign of ΔH_{ads}^0 shows that the adsorption process is exothermic [45]. The numeric value of ΔH_{ads}^0 approaches to -10 kJ mol^{-1} which shows the adsorption mechanism involves the physisorption [46].

Activation parameters

The corrosion inhibition efficiency and rate of corrosion is depending on the temperature. As we increase the temperature, corrosion current also increases. The effect of temperature on the corrosion and corrosion inhibition is studied using Arrhenius equation and transition state plots.

The Arrhenius equation can be written as,

$$\ln v_{\text{corr}} = \ln A - E_a^*/RT \quad (7)$$

where v_{corr} is the corrosion rate, E_a^* is the apparent activation energy (J mol^{-1}), R is the gas constant

Fig. 7 Relationship between $-\Delta G_{\text{ads}}^0/T$ v/s $1000/T$ (using Gibbs–Helmholtz equation)

($8.314 \text{ J mol}^{-1} \text{K}^{-1}$), T is the absolute temperature (K) and A is the Arrhenius pre-exponential factor. Figure 8 presents the Arrhenius plot of $\ln v_{\text{corr}}$ against $1/T$ for the corrosion of zinc in 0.1 M HCl solution in the presence and absence of inhibitor at concentrations ranging from 5 to 25 ppm. From the Fig. 8, the slope ($-E_a/R$) of each individual straight line was determined and the apparent activation energy (E_a) was calculated using the expression $E_a = \text{slope} \times R$ ($8.314 \text{ J mol}^{-1} \text{K}^{-1}$). The calculated apparent activation energy (E_a) values and Arrhenius pre-exponential factors can be reported in Table 3.

The values of the standard enthalpy (ΔH^*) and standard entropy (ΔS^*) of activation were calculated by the following equation

$$\frac{\ln v_{\text{corr}}}{T} = \left[\ln \frac{R}{Nh} + \frac{\Delta S^*}{R} \right] - \frac{\Delta H^*}{R} \quad (8)$$

where h is plank's constant ($6.626 \times 10^{-34} \text{ m}^2 \text{ kg s}^{-1}$) and Avogadro's number (6.022×10^{23}).

A transition plot of $\ln (v_{\text{corr}}/T)$ Vs $1/T$ gave straight lines which are depicted in Fig. 9. ΔH^* value was calculated using slope with an expression: $\Delta H^* = -\text{slope} \times R$ (8.314) and ΔS^* was calculated by the help of intercept with an expression $\Delta S^* = \text{intercept} - \ln \frac{R}{Nh}$. The calculated values of ΔH^* and ΔS^* are listed in Table 3. The values of E_a determined from the Arrhenius plots are 2.19 kJ mol^{-1} and 25.8 kJ mol^{-1} in absence and presence of inhibitor, respectively. The value of E_a shows that the presence of the inhibitor increased the activation energy values and

Fig. 8 Arrhenius plot for zinc in 0.1 M HCl solution containing different concentrations of Floctafenine at different temperatures

Table 3 Heat of adsorption values for the corrosion of zinc in 0.1 M HCl in the presence of different concentrations of Floctafenine at different temperatures

Temperature (K)	Q_{ads} (303–313 K)	Q_{ads} (313–323 K)	Q_{ads} (323–333 K)
1 M HCl	−7.13	−7.86	−8.03
5	−6.09	−6.52	−7.26
10	−4.13	−4.01	−5.20
15	−3.21	−3.51	−4.38
20	−2.51	−2.09	−3.33
25	−1.60	−1.47	−2.58

Fig. 9 Transition plot for zinc in 0.1 M HCl solution containing different concentrations of Floctafenine at different temperatures

consequently decreased the metal corrosion rate. These observations show that inhibitor compound acted as protective layer and decreases the corrosion rate through increasing the activation energy of metal dissolution by making a barrier to charge and mass transfer by their

adsorption on metal surface [47, 48]. Positive value of ΔH^* shows the zinc dissolution process is endothermic in nature. The negative values of entropy of activation in the absence and presence of inhibitor implies that the rate-determining step for the activated complex is an association step rather than a dissociation step, meaning that during adsorption process the decrease in disordering takes place on moving from reactants to the activated complex [49].

Polarization studies

This method is very important and useful to find the corrosion inhibition properties of inhibitor. The parameters such as corrosion potential (E_{corr}), corrosion current density (i_{corr}), cathodic Tafel slope (β_c), anodic Tafel slope (β_a) and percentage inhibition efficiency according to polarization studies (η_p) are listed in Table 4. The η_p was calculated from the following relation:

$$\eta_p = \frac{i_{\text{corr}}^o - i_{\text{corr}}}{i_{\text{corr}}^o} \times 100 \quad (9)$$

where i_{corr}^o and i_{corr} are corrosion current densities in absence and presence of inhibitor, respectively. From Fig. 10, it is clear that both rate of cathodic reactions and rate of anodic reactions have decreased. This is confirmed by the E_{corr} values in the presence and absence of inhibitors. There is no significant change in the E_{corr} values [50]. The presence of H_2 shifts both anodic and cathodic branches to the lower values of current densities and thus causes a remarkable decrease in the corrosion rate. Oxygen is reduced in low cathodic potentials, but the main cathodic reaction in acidic solution is the discharge of hydrogen ions to produce hydrogen gas. It can be clearly seen from Fig. 10 that both anodic metal dissolution of zinc and cathodic reactions were inhibited after the addition of

Table 4 Activation parameters for zinc

Concentration of inhibitor (ppm)	E_a^* (kJ mol ⁻¹)	A (kJ mol ⁻¹)	ΔH^* (kJ mol ⁻¹)	ΔS^* (J mol ⁻¹ K ⁻¹)
Blank	2.19	0.092	4.88	-18.56
5	5.88	0.253	8.57	-18.07
10	6.72	0.317	9.62	-17.81
15	7.88	0.374	10.24	-17.52
20	20.1	7.52	22.07	-12.58
25	25.8	16.2	30.08	-8.48

inhibitor to the aggressive solution [51]. Hence, the inhibitor behaves as the mixed-type inhibitor. We can observe the decrease in the corrosion rate and current density with the increase in the concentration of Floctafenine.

AC impedance method

Electrochemical impedance spectra for zinc in 0.1 M HCl without and with different concentrations of inhibitor at different temperatures are presented as Nyquist plot in Fig. 11. An equivalent circuit model (Fig. 12) was proposed to fit and analyze EIS data. EIS parameters

calculated in accordance with equivalent circuit are listed in Table 4, the sum of charge transfer resistance (R_{ct}) and adsorption resistance (R_{ad}) is equivalent to polarization resistance (R_p). Inhibition efficiency (η_z) was calculated using following equation:

$$\eta_z = \frac{R_p - R_{p0}}{R_p} \times 100 \quad (10)$$

The data indicate that increasing charge transfer resistance is associated with a decrease in the double-layer capacitance. It has been reported that the adsorption of organic inhibitor on the metal surface is characterized by a decrease in C_{dl} and increase in the R_p value. The decreased values of C_{dl} and increase in the R_p value may be due to the replacement of water molecules at the electrode interface by organic inhibitor of lower dielectric constant through adsorption (Table 5), suggesting that inhibitor was taken up by adsorption at the metal–solution interface [52].

The value of C_{dl} determines the characterization of the adsorption, desorption and film formation on the metal surface [53]. The results described above can be interpreted in terms of equivalent circuit of the electrical double layer shown in Fig. 12. Nyquist plots are depressed into the Z' (real axis) and not perfect semi-circles as a result of the

Fig. 10 Tafel plots for zinc in 0.1 M HCl in presence of different concentration of Floctafenine at **a** 303 K, **b** 313 K, **c** 323 K, **d** 333 K

Fig. 11 Nyquist plots for zinc in 0.1 M HCl in the absence and presence of different concentrations of Floctafenine at **a** 303 K, **b** 313 K, **c** 323 K, **d** 333 K temperature

Fig. 12 Electrical equivalent circuit model used to fit impedance data

roughness and other inhomogeneities of the metal surface [54]. This kind of phenomenon is known as “the dispersing effect”.

SEM analysis

Figure 13 shows the micrographs of the zinc surface before and after immersion in 0.1 M HCl solution with and without corrosion inhibitor. Figure 13a shows surface of the zinc specimen after immersion in 0.1 M HCl solution for 2 h in the absence of inhibitor. Figure 13b shows the

surface of the zinc specimen after immersion in the corrosive solution in the presence of 25 ppm inhibitor for the same period of time. SEM micrograph revealed that the surface morphology was strongly damaged in the absence of the inhibitor, but in the presence of 25 ppm inhibitor damage was considerably diminished, which confirmed the high efficiency of Floctafenine at this concentration.

Conclusions

- A small amount of inhibitor shows inhibition efficiency.
- The maximum %IE of Floctafenine for the zinc metal in acidic media is 85.8 %.
- Polarization curves reveal the Floctafenine is a mixed-type inhibitor.

Table 5 Tafel and AC impedance results for the corrosion of zinc in 0.1 M HCl in the presence of different concentrations of Floctafenine at different temperatures

Temperature (K)	Inhibitor con ⁿ (mg L ⁻¹)	E_{corr} (V)	I_{corr} A cm ⁻²	Corrosion rate (mpy)	$-\beta_c$ (mV/decade)	$-\beta_a$ (mV/decade)	η_p (%)	R_p (Ωcm^2)	C_{dl} (F cm ⁻²)	η_p (%)
303	0.1 M HCl	-0.943	0.078	17.21	0.142	0.074	–	120	0.049	–
	5	-0.936	0.0478	11.49	0.165	0.078	38.7	235	0.042	48.9
	10	-0.934	0.0372	10.66	0.109	0.069	52.3	287	0.031	58.1
	15	-0.947	0.0362	8.065	0.135	0.071	53.5	331	0.022	63.6
	20	-0.927	0.0292	6.513	0.117	0.063	62.5	390	0.010	69.2
	25	-0.930	0.0251	5.591	0.115	0.061	67.8	428	0.0075	71.96
313	0.1 M HCl	-0.876	0.125	19.16	0.146	0.071	–	51.41	0.092	–
	5	-0.883	0.059	13.25	0.151	0.06	52.8	137.0	0.075	65
	10	-0.888	0.0481	11.76	0.124	0.056	61.52	213.3	0.064	75.8
	15	-0.892	0.0401	8.52	0.111	0.054	67.9	270.0	0.055	80.9
	20	-0.890	0.0316	7.21	0.133	0.047	74.7	333.1	0.032	84.5
	25	-0.892	0.0275	5.79	0.141	0.046	78.0	362.32	0.014	85.8
323	0.1 M HCl	-0.916	0.161	28.85	0.139	0.084	–	22.67	0.111	–
	5	-0.921	0.078	22.28	0.125	0.072	51.5	58.5	0.090	61.2
	10	-0.931	0.063	12.37	0.137	0.0762	60.8	76.2	0.081	70.2
	15	-0.914	0.056	10.03	0.126	0.073	65.2	101.0	0.080	77.5
	20	-0.927	0.043	8.36	0.128	0.061	73.2	116.5	0.077	80.5
	25	-0.923	0.031	7.045	0.124	0.055	80.7	205.5	0.069	88.9
333	0.1 M HCl	-0.876	0.186	48.02	0.122	0.082	–	21.6	0.129	–
	5	-0.885	0.099	23.04	0.116	0.077	46.7	42.87	0.099	49.6
	10	-0.881	0.067	12.75	0.118	0.075	63.9	86.59	0.078	75.0
	15	-0.878	0.060	10.77	0.135	0.079	67.7	101.2	0.062	78.6
	20	-0.873	0.045	9.05	0.124	0.083	75.8	112.3	0.051	80.7
	25	-0.879	0.036	7.89	0.111	0.085	80.6	136.0	0.036	84.1

Fig. 13 SEM photographs of zinc surface in absence of inhibitor (0.1 M HCl) (*left*) and, in presence of inhibitor Floctafenine in 0.1 M HCl solution (*right*)

- Adsorption of the inhibitor follows the Langmuir isotherm.
- The adsorption of this inhibitor on the zinc surface takes place through physical adsorption.
- Activation parameters explain the corrosion process.
- Quantum chemical studies support the experimental results.

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