Inhibition of Carbon Steel Corrosion in HCl Media by Lipid Oil Melia

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Abstract

The inhibition effect of the novel Lipid Oil Melia (LOM) on the corrosion of carbon steel in 1.0 M HCl solution was investigated using weight loss and electrochemical measurements. The inhibition efficiency of this inhibitor increases with increase in concentrations. The maximum inhibition efficiency of LOM was achieved at 3 g/L concentration. The inhibition efficiency of the inhibitor decreases on increasing the temperature from 298 to 328K. The Tafel polarization studies indicate that this compound acts as a mixed type inhibitor. As the inhibitor concentration increased, the charge transfer resistance of carbon steel increased and double layer capacitance decreased. The adsorption of LOM on the surface on carbon steel has been found to obey the Langmuir adsorption isotherm, and the values of free energy of adsorption are calculated. Kinetic parameters (activation energy, pre-exponential factor, enthalpy of activation and entropy of activation) were calculated and discussed.

Keywords: Carbon steel, Corrosion inhibitor, Acid, Potentiodynamic polarisation, EIS.

1. Introduction

Inhibitors are frequently used for controlling corrosion of metals and alloys in acidic media for removing scales and rusts in metal finishing industries, cleaning of boilers, and heat exchangers. Use of inhibitors is one of the most practical methods for protection against corrosion especially in acid solutions to prevent unexpected metal dissolution and acid consumption [1-4]. The known hazardous effect of most synthetic corrosion inhibitors have motivated scientists to use naturally occurring products as corrosion inhibitors as they are inexpensive, readily available and renewable sources of materials, environmentally friendly, and ecologically acceptable [5,6].
Over the past couple of decades, studies have focused on the application of non-toxic inhibitors called green or eco-friendly environmental inhibitors. Natural plants in the form of extracts, oils or pure compounds may play major roles in keeping the environment more healthy, safe, and under pollution control. Among the various natural products, such as Ginger [7], eugenol, acetyl-eugenol [8] Argan [9,10], prickly pear seed oil [11], Pennyroyal Mint Oil [12], Lavender oil [13] and Fennel (Foeniculum Vulgare) Essential oil [14], all of which have been reported to be good inhibitors for steel in acidic solutions.

In continuation of our work on development of green corrosion inhibitors [15], the present study investigates the inhibiting effect of Lipid Oil Melia (LOM). Inhibition effect of Lipid Oil Melia (LOM) on the corrosion of carbon steel in 1.0 M HCl solution by weight loss, potentiodynamic polarization, and electrochemical impedance spectroscopy (EIS) methods. Effect of temperature is also studied and Kinetic parameters data are deduced.

2. Experimental

2.1. Materials and reagents

The steel used in this study is a carbon steel (Euronorm: C35E carbon steel and US specification: SAE 1035) with a chemical composition (in wt%) of 0.370 % C, 0.230 % Si, 0.680 % Mn, 0.016 % S, 0.077 % Cr, 0.011 % Ti, 0.059 % Ni, 0.009 % Co, 0.160 % Cu and the remainder iron (Fe). The carbon steel samples were pre-treated prior to the experiments by grinding with emery paper SiC (120, 600 and 1200); rinsed with distilled water, degreased in acetone in an ultrasonic bath immersion for 5 min, washed again with bidistilled water and then dried at room temperature before use. The acid solutions (1.0 M HCl) were prepared by dilution of an analytical reagent grade 37 % HCl with double-distilled water.

2.2. Plant collection and essential oil extraction

The fruits of Melia azedarach. L used in our experiments is harvested from trees grown in Meknes (Morocco). The plant organ almonds in fruits of the plant are dried in the shade in the laboratory at ambient temperature and stored until ready for experimentation. The almond’s Melia azedarach. L were weighed using a balance type Sertorius (1000g max ± 0.001), although crushed and then ground in mortar, until the dough is black, then subjected to defatting by soxhlet apparatus, which is as following:

100 g of powder are introduced into the cartridges, which are themselves placed in a Soxhlet apparatus. The ball used is a 500 mL flask, placed in a heating mantles suited and connected to a refrigeration system. 250 mL of petroleum ether are added to the flask. The total extraction time is about 6 hours at the boiling temperature of petroleum ether. The organic extracts were dried over anhydrous sodium sulfate and then concentrated using a rotary evaporator. The obtained lipid oil is stored away from light and at 4°C. We obtained an average yield of about 38%.

2.3. Measurements

2.3.1. Weight loss measurements

The gravimetric measurements were carried out at the definite time interval of 6 h at room temperature using an analytical balance (precision ± 0.1 mg). The carbon steel specimens used have a rectangular form (length = 1.6 cm, width = 1.6 cm, thickness = 0.07 cm). Gravimetric experiments were carried out in a double
glass cell equipped with a thermostated cooling condenser containing 50 mL of non-de-aerated test solution. After immersion period, the steel specimens were withdrawn, carefully rinsed with bidistilled water, ultrasonic cleaning in acetone, dried at room temperature and then weighted. Triplicate experiments were performed in each case and the mean value of the weight loss is calculated.

### 2.3.2. Electrochemical measurements

#### Electrochemical cell

The electrolysis cell was Pyrex of cylinder closed by cap containing five openings. Three of them were used for the electrodes. The working electrode was carbon steel with the surface area of 1 cm². Before each experiment, the electrode was polished using emery paper until 1200 grade. After this, the electrode was cleaned ultrasonically with distillate water. A saturated calomel electrode (SCE) was used as a reference. All potentials were given with reference to this electrode. The counter electrode was a platinum plate of surface area of 1 cm². The aggressive medium used here is 1.0 M HCl solution was prepared with concentrated HCl and distilled water. The concentration range of this inhibitor was 3 g /L to 1 g /L.

#### Polarisation measurements

The working electrode was immersed in test solution during 30 minutes until a steady state open circuit potential (Eocp) was obtained. The polarization curve was recorded by polarization from -800 mV to -400 mV under potentiodynamic conditions corresponding to 1 mV/s (sweep rate), at frequencies between 100 kHz and 10 mHz was superimposed on the rest potential. The potentiodynamic measurements were carried out using Tacussel Radiometer PGZ 100, which was controlled by a personal computer.

### 3. Results and discussion

#### 3.1. Weight loss tests

#### 3.1.1. Effect of concentration

Gravimetric measurements of carbon steel (CS) were investigated in 1.0 M HCl in the absence and presence of various concentrations of Lipid Oil Melia (LOM) at 6 h of immersion and at 298 K. The corrosion rate \(C_R\) and inhibition efficiency \(\eta_{WL}(\%)\) were calculated according to the Eqs. 1 and 2 [16,17], respectively:

\[
C_R = \frac{W_b - W_a}{At}
\]

\[
\eta_{WL}(\%) = \left(1 - \frac{W_i}{W_0}\right) \times 100
\]

where \(W_b\) and \(W_a\) are the specimen weight before and after immersion in the tested solution, \(W_0\) and \(W_i\) are the values of corrosion weight losses of carbon steel in uninhibited and inhibited solutions, respectively, \(A\) the total area of the carbon steel specimen (cm²) and \(t\) is the exposure time (h). The fractional surface coverage \(\theta\) can be easily determined from weight loss measurements by the ratio \(\eta_{WL}(\%)/100\) if one assumes that the values of \(\eta_{WL}(\%)\) do no differ substantially from \(\theta\).

Table 1 gathers the corrosion rates and the inhibition efficiencies evaluated from weight loss measurements for different LOM concentrations in 1.0 M HCl. The corrosion rate decreases with the concentration of LOM and in turn the inhibition efficiency \(\eta_{WL}(\%)\) increases to reach 94.5%. The decrease in the corrosion rate in the
inhibiting range may be explained by the blockage of the sites of the surface of steel by this compound. Accordingly, we can conclude that LOM is an efficient inhibitor.

Table 1. Corrosion rate of steel in 1.0 M HCl with and without LOM at various concentrations, and the corresponding inhibition efficiency.

<table>
<thead>
<tr>
<th>Inhibitor</th>
<th>C (g /L)</th>
<th>C_R (mg cm^2 h^-1)</th>
<th>ηWL (%)</th>
<th>θ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blank</td>
<td>0.0</td>
<td>0.951</td>
<td>-------</td>
<td>----</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>0.198</td>
<td>79.1</td>
<td>0.791</td>
</tr>
<tr>
<td>LOM</td>
<td>1.5</td>
<td>0.163</td>
<td>82.7</td>
<td>0.827</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>0.134</td>
<td>85.9</td>
<td>0.859</td>
</tr>
<tr>
<td></td>
<td>2.5</td>
<td>0.082</td>
<td>91.4</td>
<td>0.914</td>
</tr>
<tr>
<td></td>
<td>3.0</td>
<td>0.030</td>
<td>94.5</td>
<td>0.945</td>
</tr>
</tbody>
</table>

3.1.2. Effect of temperature

The effect of temperature on the anti-corrosion effectiveness of LOM studied at 3 g/L in the temperature domain (298-328 K) during 1 hour of immersion is summarized in Table 2. The collected data in Table 2 show an increase of corrosion rate (W) in the absence and presence of LOM at different temperatures. The increase is more pronounced in non inhibited acid than in inhibited one. The values of inhibition efficiency obtained from the weight loss at various temperatures show that the inhibition efficiency decreases rapidly with increasing temperature indicating that higher temperature dissolution of steel predominates on adsorption of LOM at the surface.

Table 2. Various corrosion parameters for CS in 1.0 M HCl in absence and presence of optimum concentration of LOM at different temperatures.

<table>
<thead>
<tr>
<th>Temp (K)</th>
<th>Inhibitor</th>
<th>CR (mg cm^2 h^-1)</th>
<th>ηWL (%)</th>
<th>θ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Blank</td>
<td>0.547</td>
<td>-------</td>
<td>----</td>
</tr>
<tr>
<td>298</td>
<td>LOM</td>
<td>0.030</td>
<td>94.5</td>
<td>0.945</td>
</tr>
<tr>
<td></td>
<td>Blank</td>
<td>1.070</td>
<td>-------</td>
<td>----</td>
</tr>
<tr>
<td>308</td>
<td>LOM</td>
<td>0.083</td>
<td>92.2</td>
<td>0.922</td>
</tr>
<tr>
<td></td>
<td>Blank</td>
<td>2.350</td>
<td>-------</td>
<td>----</td>
</tr>
<tr>
<td>318</td>
<td>LOM</td>
<td>0.266</td>
<td>88.7</td>
<td>0.887</td>
</tr>
<tr>
<td></td>
<td>Blank</td>
<td>4.730</td>
<td>-------</td>
<td>----</td>
</tr>
<tr>
<td>328</td>
<td>LOM</td>
<td>0.847</td>
<td>82.1</td>
<td>0.821</td>
</tr>
</tbody>
</table>

The activation kinetic parameters such as energy (E_a), enthalpy (∆H_a) and entropy (∆S_a) may be evaluated from the effect of temperature using Arrhenius law (eq. 3) and its alternative formulation (eq. 4) [18]:

\[ C_R = A \exp \left( \frac{-E_a}{RT} \right) \]  

(3)
\[ C_R = \frac{RT}{Nh} \exp \left( \frac{\Delta S_a}{R} \right) \exp \left( -\frac{\Delta H_a}{RT} \right) \]  

(4)

where \( C_R \) refers to the corrosion rate, \( R \) the gas constant, \( T \) the absolute temperature, \( A \) the pre-exponential factor, \( h \) is Plank’s constant and \( N \) is Avogadro’s number.

Figs. 1 and 2 show the plots of \( \ln (C_R) \) and \( \ln (C_R/T) \) against \( 1/T \), respectively. Straight lines are obtained with a slope of \((-\Delta H_a/R)\) and an intercept of \((\ln (R/Nh)+\Delta S_a/R))\) from which the values of \( \Delta H_a \) and \( \Delta S_a \) are calculated (Table 3).

**Figure 1.** Arrhenius plots of \( \ln C_R \) vs. \( 1/T \) for steel in 1.0 M HCl in the absence and the presence of LOM at optimum concentration.

**Figure 2.** Arrhenius plots of \( \ln C_R/T \) vs. \( 1/T \) for steel in 1.0 M HCl in the absence and the presence of LOM at optimum concentration.
Literature [19,20] show that compared with the activation energy in the absence of inhibitor, higher values for $E_a$ were found in the presence of inhibitor. Other studies [21,22] indicated that in the presence of inhibitor the activation energy was lower than that in its absence. It was clear that (Table 3) the value of $E_a$ (90.77 kJ mol$^{-1}$) in the presence of the LOM are higher than that in the uninhibited acid solution (58.93 kJ mol$^{-1}$). The decrease in inhibition efficiencies with increasing temperature and the increase of $E_a$ in the presence of the inhibitor indicate the physical adsorption mechanism [23].

Table 3. The values of activation parameters for CS in 1.0 M HCl in the absence and the presence of different concentrations of LOM.

<table>
<thead>
<tr>
<th>Inhibitor</th>
<th>$A$ (mg/cm$^2$ h)</th>
<th>Linear regression coefficient ($r$)</th>
<th>$E_a$ (kJ/mol)</th>
<th>$\Delta H_a$ (kJ/mol)</th>
<th>$\Delta S_a$ (J/mol K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blank</td>
<td>1.1247×10$^{10}$</td>
<td>0.99889</td>
<td>58.93</td>
<td>56.33</td>
<td>-61.20</td>
</tr>
<tr>
<td>LOM</td>
<td>2.2694×10$^{14}$</td>
<td>0.99829</td>
<td>90.77</td>
<td>88.45</td>
<td>21.20</td>
</tr>
</tbody>
</table>

Table 4 indicates that both the activation energy and the pre-exponential factor increase in the presence of LOM. The variation in pre-exponential factor, as a whole, is just like that of the activation energy. From Eq. (3), it can be seen that at a given temperature, the value of the steel corrosion rate is jointly decided by the activation energy and pre-exponential factor. The CS corrosion rate basically decreases with an increase in concentration of LOM [24].

The positive values of $\Delta H_a$ for both corrosion processes with and without the inhibitor reveal the endothermic nature of the steel dissolution process and indicate that the dissolution of steel is difficult [25,26]. The large negative value of $\Delta S_a$ for C38 steel in 1.0 M HCl implies that the activated complex is the rate-determining step, rather than the dissociation step. In the presence of the inhibitor, the value of $\Delta S_a$ increases and is generally interpreted as an increase in disorder as the reactants are converted to the activated complexes [25]. The positive values of $\Delta S_a$ reflect the fact that the adsorption process is accompanied by an increase in entropy, which is the driving force for the adsorption of the inhibitor onto the steel surface.

3.2. Electrochemical impedance spectroscopy measurements

The corrosion behaviour of carbon steel (CS), in acidic solution in the absence and presence of LOM, is also investigated by EIS method at $E_{corr}$ and 298K after 30min of immersion (Fig. 3). The charge-transfer resistance ($R_{ct}$) values are calculated from the difference in impedance at lower and higher frequencies. Inhibition efficiency values were calculated using equation (5).

$$E_{Rct}^{(\%)} = \frac{R_{ct}^{(inh)}}{R_{ct}^{(inh)}} \times 100$$

where $R_{ct}$ and $R_{ct}^{(inh)}$ are charge transfer resistances in presence and absence of inhibitor. The double layer capacitance ($C_{dl}$) and the frequency at which the imaginary component of the impedance is maximal ($-Z_{max}$) are found as represented in equation:

$$C_{dl} = \frac{1}{2\pi f_{max} R_{ct}}$$
The impedance spectra (Fig. 3) exhibit a single semicircle for a particular concentration, and the diameter of semicircle increases with increase in inhibitor concentration. The single semicircle indicates that the charge transfer takes place at electrode/solution interface, and the corrosion reaction of CS is controlled by the charge transfer process. These impedance diagrams are not perfect semicircles, which are related to the frequency dispersion as a result of the roughness and inhomogeneity of the CS electrode surface. Moreover, the impedance response of CS in HCl medium alone has changed significantly after addition of the inhibitor.

![Nyquist plots of CS in 1.0 M HCl containing various concentrations of LOM at E_{corr} after 30 min of immersion.](image)

**Figure 3.** Nyquist plots of CS in 1.0 M HCl containing various concentrations of LOM at E_{corr} after 30 min of immersion.

**Table 4.** Impedance parameters for corrosion of CS in 1.0 M HCl in the absence and presence of different concentrations of LOM at 298 K.

<table>
<thead>
<tr>
<th>Inhibitor</th>
<th>C (g/L)</th>
<th>R_{ct} (Ω cm^2)</th>
<th>f_{max} (Hz)</th>
<th>C_{dl} (µF cm^2)</th>
<th>η_I (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blank</td>
<td>0.0</td>
<td>31.04</td>
<td>63.34</td>
<td>80.86</td>
<td>-----</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>158.7</td>
<td>40.00</td>
<td>25.08</td>
<td>80.2</td>
</tr>
<tr>
<td>LOM</td>
<td>2.0</td>
<td>355.6</td>
<td>25.00</td>
<td>17.91</td>
<td>91.1</td>
</tr>
<tr>
<td></td>
<td>3.0</td>
<td>897.6</td>
<td>23.22</td>
<td>7.94</td>
<td>96.5</td>
</tr>
</tbody>
</table>

The value of C_{dl} (Table 4) decrease from the blank value as the concentration of the inhibitor is increased, which confirms the increased level of adsorption of the inhibitor on the metal surface [27]. The R_{ct} values increase from the blank value as the inhibitor concentration is raised. This indicates the resistance toward charge transfer reactions responsible for corrosion process. These observations clearly prove the dependence of inhibitor concentration on corrosion control. The inhibition efficiency obtained from weight loss and electrochemical measurements are in good agreement at all concentrations. Fig. 4 shows the equivalent circuit
based on the EIS data. The different elements are described as follows. $R_s$ is the resistance of the electrolyte between the working and reference electrode, $R_{ct}$ is the charge transfer resistance and CPE is a constant phase element. Generally, a CPE is used instead of pure capacitance because of the relaxation time induced by the inhomogeneities on the microscopic level at the electrode/electrolyte interface [28]. Excellent fit with this model was obtained with our experimental data. It is observed that the fitted data match the experimental, with an average error of about 0.1%. $R_{ct}$ values were simultaneously determined by analysis of the complex-plane impedance plots and the equivalent circuit model and the result are very similar with insignificant changes.

![Electrical equivalent circuit](image)

**Figure 4.** Electrical equivalent circuit used to fit the EIS data of the interface CS/1.0 M HCl solution without and with LOM inhibitor.

### 3.3. Polarisation study

The typical Tafel polarization curves of CS in 1.0 M HCl in the presence and absence of LOM at different concentrations are shown in Fig. 5. It could be observed that both the cathodic and anodic reactions were suppressed with the addition of LOM, which suggests that the LOM reduced anodic dissolution and also retarded the hydrogen evolution reaction effectively.

Various corrosion kinetics parameters, i.e. corrosion potential ($E_{corr}$), cathodic Tafel slope ($\beta_c$) and corrosion current density ($I_{corr}$) obtained from the Tafel extrapolation of the polarization curves, are given in Table 5. The ($\eta_{Tafel} \text{ (%)}$) is calculated using the following equation [29]:

$$\eta_{Tafel} \text{ (%) } = \left( \frac{I_{corr} - I'_{corr}}{I_{corr}} \right) \times 100$$ (7)

Where $I_{corr}$ and $I'_{corr}$ are uninhibited and inhibited corrosion current densities, respectively.

From the potentiodynamic polarisation curves, it can be seen that the extract caused a decrease in both anodic and cathodic current densities, most likely due to the adsorption of the organic compounds present in the at the active sites of the electrode surface. This also slowed both metallic dissolution and hydrogen evolution and consequently slowed down the corrosion process. Table 5 indicates that, in the presence of this extract, both stable OCP and $E_{corr}$ (derived from the Tafel plots) shifted cathodically with respect to the blank (10-25 mV). An inhibitor can be classified as cathodic or anodic if the difference in corrosion potential is more than 85 mV with respect to the corrosion potential of the blank [30]. Such results will indicate that this extract act as a mixed-type inhibitor. This result show that the extract can retard both anodic and cathodic reactions under open-circuit and polarised conditions. The corrosion current density ($I_{corr}$) decreased as the amount of the inhibitor increased. The cathodic Tafel slopes ($\beta_c$) did not change significantly with the addition of the extract (Table 5), indicating that the adsorbed inhibitor molecules do not affect hydrogen evolution: i.e., hydrogen evolution is diminished exclusively by the surface-blocking effect.
Figure 5. Polarisation curves of CS in 1.0 M HCl at different concentrations of LOM.

Table 5. Electrochemical parameters of CS in 1.0 M HCl solution without and with LOM at different concentrations.

<table>
<thead>
<tr>
<th>Inhibitor</th>
<th>Conc (g/L)</th>
<th>(-E_{corr}) (mV/SCE)</th>
<th>(I_{corr}) (µA cm(^{-2}))</th>
<th>(-b_c) (mV/dec)</th>
<th>(\eta_{Tafel}) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blank</td>
<td>0.0</td>
<td>508</td>
<td>1076</td>
<td>175</td>
<td>----</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>498</td>
<td>216</td>
<td>170</td>
<td>79.9</td>
</tr>
<tr>
<td>LOM</td>
<td>2.0</td>
<td>533</td>
<td>94</td>
<td>168</td>
<td>91.3</td>
</tr>
<tr>
<td></td>
<td>3.0</td>
<td>518</td>
<td>40</td>
<td>167</td>
<td>96.3</td>
</tr>
</tbody>
</table>

3.4. Adsorption isotherm

The mechanism of corrosion inhibition may be explained on the basis of adsorption behavior. The degrees of surface coverage (\(\theta\)) for different inhibitor concentrations were evaluated by weight loss data. Data were tested graphically by fitting to various isotherms. It is observed that these plots obey Langmuir adsorption isotherms through surface coverage of adsorbed inhibitor on carbon steel surface and consequently, there is no interaction between the molecules adsorbed at the metal surface. The higher inhibitive property of the inhibitor is attributed to the presence of \(\pi\)-electrons, in oxygen and the larger molecular size, which insures greater coverage across the metallic surface. For weight loss method used in this study, plotting of \(C_{inh}/\theta\) against the \(C_{inh}\) gave straight lines with the slope of the unit (Fig. 6). This means that the adsorption of inhibitor on the carbon steel surface obeys the Langmuir isotherm. LOM shows the expected linear relationship, well approximated in the Langmuir isotherm (correlation coefficient \(R^2\) around unity), and the lines have a slope around 0.98567. The deviation of the slope from unity is often interpreted as a sign that the adsorbing species occupies a more or less typical adsorption site at the metal/solution interface. Adsorption of the inhibitor molecule occurs because of the
favorable interaction energy between the inhibitor and the metal surface. Basic information on the interaction between the inhibitor molecules and the surface of carbon steel can be provided by an adsorption isotherm. A correlation between surface coverage ($\theta$) defined and the concentration of inhibitor ($C_{inh}$) in electrolyte can be represented by the Langmuir adsorption isotherm,

$$\frac{C_{inh}}{\theta} = \frac{1}{K_{ads}} + C_{inh}$$  \hspace{1cm} (8)

where $C_{inh}$ is the concentration of inhibitor, $K_{ads}$ is the adsorptive equilibrium constant, and $\theta$ is the surface coverage. It is very important to note that discussion of the adsorption isotherm behaviour using natural product extracts as inhibitors in terms of thermodynamic parameters (such as the standard free energy of adsorption value ($\Delta G_{ads}$)) is not possible because the molecular mass of the extract components is not known. For example, there are several phenolic compounds in the aqueous extract. Valek and Martinez [31], in their study on acid corrosion with Azadirachta indica leaf extract, noted the same limitation.

![Figure 6. The relationship between $C_{inh}/\theta$ and $C_{inh}$ of LOM.](image)

4. Conclusions

From the above results and discussion, the following conclusions are drawn:

- LOM inhibits the corrosion of carbon steel in 1.0 M HCl. The inhibition efficiency increases with the inhibitor concentration.
- The adsorption of LOM on the carbon steel surface from 1.0 M HCl follows the Langmuir adsorption isotherm. The adsorption process is a spontaneous process.
- The inhibition efficiency of LOM decreases in the temperature range 308-328 K.
- LOM acted as a mixed type inhibitor.
- EIS results showed that as the inhibitor concentration increased the charge transfer resistance increased and the double layer capacity decreased.
References