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## The Study of *Aloe-Vera* gel Extract as Green Corrosion Inhibitor for Mild Steel in Acetic acid.

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**ABSTRACT:** *Aloe vera* (Aloe Vera) gel extract was investigated as green corrosion inhibitor of mild steel in acetic acid solution using weight-loss and electrochemical techniques like potentiodynamic polarization and electrochemical impedance spectroscopy (EIS). The experimental result shows that the *Aloe vera* gel extract is good corrosion inhibitor and inhibition efficiency increase with the extract concentration. *Aloe vera* extract shows maximum I.E. of 82.35 % at an optimum concentration of 1.0 g/L. The value of activation energy shows that the *Aloe vera* gel extract is better inhibitor at lower temperature. The negative value of  $Q_{ads}$  supports spontaneous adsorption of the inhibitor. The adsorption characteristic of the *Aloe vera* gel extract on mild steel surface obeys Langmuir adsorption isotherm. The potentiodynamic polarization study shows that it is a mixed type inhibitor. The result obtained from weight-loss and electrochemical techniques are reasonably in agreement

**KEYWORDS:** Mild steel, Acetic acid, Corrosion, inhibition, *Aloe vera*, Weight loss, Polarization, EIS.

### I. INTRODUCTION

Corrosion of metal/alloy defined as the deterioration of materials due to their reaction with the environment. It is a common problem in industry and it has received a considerable amount of attention. Mild steel is widely used as constitutional material in many industries due to its good mechanical property and low cost. However, the main problem of using mild steel is its dissolution in acidic medium. Acid solutions are widely used for removal of undesirable scale and rust in many industrial process. The use of inhibitor is one of the most important methods for protection of mild steel against corrosion in acid media. Large numbers of organic compounds [1-4] have been studied to investigate their corrosion inhibition effect. All these studies reveals that organic compounds especially those contains N, S and O showed inhibition efficiency. But a major disadvantage of these inhibitors is their toxicity. Thus attention have been shifted towards investigating the eco-friendly inhibitors. Numerous naturally occurring plants organ extract, like *Psidium guajava* (guava) leaf extract[5], *Aspilia africana* leaves extract [6], Rubber leaf Extract [7], *Piper nigrum* [8], *Dodonaea viscosa* (L.) leaves extract[9] and fig leaves extract [10] have been evaluated as effective corrosion inhibitors. The main aim of present work is to find out corrosion inhibition efficiency (IE) of aqueous extract of *Aloevera* gel as green inhibitor for mild steel in acetic acid solution.

### II. EXPERIMENTAL

#### 2.1. Preparation of sample and solution

Mild steel specimens with a chemical composition of C = 0.25%, Mn = 0.50%, Si = 0.35%, P = 0.09%, S = 0.07% and Fe = 98.74% are used in the present study. The metal sheet, test specimens of size 4.5×2.0×0.2cm having an effective area of 0.2097 dm<sup>2</sup> are used. The specimens are cleaned by washing with distilled water, degreased by acetone, washed

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again with doubled distilled water and finally dried and weighted by using electronic balance. Acetic acid was used as corrosive solution having concentration of 0.5, 1.0, 1.5 and 2.0 M prepared by diluting analytical grade of acetic acid purchased from Merck using double distilled water.

## 2.2. Preparation of Aloe vera gel extract

For preparation of the aqueous extract of *Aloe vera* gel, aloe leaves was cut and open with a clean cutting material. The gel was squeezed out from the aloe leaves. Then the aqueous extract of gel content was prepared by grinding 10 g of fresh *Aloe vera* gel, filtering and making up to 100 ml using double distilled water. From 100 ml *Aloe vera* gel extract, required concentration of gel extract was prepared [11 - 12].

## 2.3. Weight-loss measurement

For weight-loss measurement, the mild steel specimen having an area of 0.2097 dm<sup>2</sup> were each completely suspended in 230 ml of 0.5, 1.0, 1.5 and 2.0 M acetic acid solution with and without *Aloe vera* gel extract having concentration of 0.1, 0.25, 0.50 and 1.00 g/L at room temperature of 303±1 K, for 24 h.

## 2.4. Surface cleaning of test specimens

After exposure period, test specimens were cleaned by Clark's solution [13- 14] to remove the rust from mild-steel. After that the test specimens were washed with distilled water followed by acetone and then dried with air dryer. From the weight loss data, corrosion rate (CR) was calculated.

## 2.5. Temperature effect

To study the effect of temperature on corrosion rate, mild steel specimens were completely immersed in 230 ml of 1.0 M acetic acid solution without and with different concentrations of *Aloe vera* gel extract at 313, 323 and 333K for 2h. After exposure period, the test specimens were weighed to determine corrosion rate. From the weight-loss data Inhibition efficiency (I.E.), Energy of activation (E<sub>a</sub>), Heat of adsorption (Q<sub>ads</sub>), Free energy of adsorption (ΔG<sup>o</sup><sub>ads</sub>), Enthalpy of adsorption (ΔH<sup>o</sup><sub>ads</sub>) and Entropy of adsorption (ΔS<sup>o</sup><sub>ads</sub>) were calculated.

## 2.6. Electrochemical measurements

To study the mechanism of inhibition action and to evaluate the inhibition efficiency of *Aloe vera* gel extract in 0.5 M acetic acid on mild steel, Polarization study and Electrochemical Impedance Spectroscopy (EIS) measurements has been carried out without and with 1.0 g/L of *Aloe vera* gel extract. The volume of corrosive medium was kept 200 ml. The test specimen of area 1cm<sup>2</sup> was immersed in corrosive environment act as working electrode. A platinum electrode and saturated calomel electrode (SCE) were used as auxiliary and reference electrode respectively. All the experiments were carried out at constant temperature of 298 K. Initially open circuit potential (OCP) was measured as a function of time. The measurement was carried out after stabilization of electrode at OCP at room temperature. The change in potential was measured by potentiostat/ galvanostat (CH instrument model- CHI608C, made in USA). EIS was carried out in frequency range 1 to 100 KHz and AC amplitude of 5.0 mV. A graph was drawn by plotting real impedance (Z') versus imaginary impedance (Z''). The typical Nyquist plots of mild steel in the absence and presence of the inhibitor in acetic acid solution was obtained. The value of charge transfer resistance (R<sub>ct</sub>) and double layer capacitance (C<sub>dl</sub>) were calculated in absence and presence of inhibitor.

## III. RESULTS AND DISCUSSION

### 3.1. Weight-loss measurement

From the weight-loss measurement data the corrosion rate has been calculated as following equation (1),

$$\text{Corrosion rate (mg dm}^{-2}\text{d}^{-1}) = \frac{(\text{Weight loss in gram} \times 1000)}{\text{dm}^2 \cdot \text{day}} \text{-----(1)}$$

Percentage inhibition efficiency (I.E.%) has been calculated by using following equation,

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$$I.E. (\%) = \frac{W_u - W_i}{W_u} \times 100 \quad \text{-----}(2)$$

Where,  $w_u$  and  $w_i$  are the weight-loss of the metal in uninhibited and inhibited acid respectively.

**Table 1:** Effect of acid and inhibitor concentration on corrosion rate ( $\text{mg dm}^{-2}\text{d}^{-1}$ ) and inhibition efficiency (I.E. %) of different concentration of *Aloe vera* gel extract on mild steel in acetic acid environment at room temperature of  $303 \pm 1$  K.

Inhibitor	Inhibitor concentration (g/L)	Acid concentration							
		0.5 M		1.0 M		1.5 M		2.0 M	
		CR ( $\text{mg dm}^{-2}\text{d}^{-1}$ )	I.E. (%)	CR ( $\text{mg dm}^{-2}\text{d}^{-1}$ )	I.E. (%)	CR ( $\text{mg dm}^{-2}\text{d}^{-1}$ )	I.E. (%)	CR ( $\text{mg dm}^{-2}\text{d}^{-1}$ )	I.E. (%)
Blank		486.41		629.47		767.76		891.75	
<i>Aloe vera</i>	0.10	200.29	58.82	281.35	55.30	357.65	53.42	433.95	51.34
	0.25	166.91	65.68	228.90	63.64	290.89	62.11	338.58	62.03
	0.50	95.37	80.39	152.60	75.76	195.52	74.53	224.13	74.87
	1.00	85.84	82.35	119.22	81.06	152.60	80.12	171.67	80.75

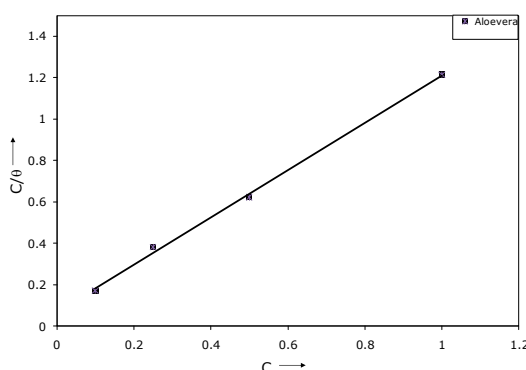
As data given in the Table-1, the corrosion rate increases as concentration of acid increase. The corrosion rate was found as 486.41, 629.47, 767.47 and 891.75  $\text{mg dm}^{-2}\text{d}^{-1}$  with respect to 0.5, 1.0, 1.5 and 2.0 M acetic acid respectively without inhibitor. The I.E.% increases with increase inhibitor concentration, while I.E.% decreases as acid concentration increase from 0.5 to 2.0 M.

### 3.2. Adsorption isotherm

The value of surface coverage  $\theta$  ( $\theta = W_u - W_i / W_u$ ) were calculated directly from the I.E.% of the inhibitor by weight-loss method. The plot of  $C/\theta$  versus  $C$  yield a straight line with a slope nearest to one (Figure-1). This suggests that the inhibitor was adsorbed on metal surface following Langmuir adsorption isotherm [15]. This isotherm can be represented as,

$$\frac{C_{inh}}{\theta} = \frac{1}{K_{ads}} + C_{inh} \quad \text{-----}(3)$$

Where,  $K_{ads}$  is the equilibrium constant of the adsorption process and  $C_{inh}$  is the inhibitor concentration.



**Figure 1:** Langmuir adsorption isotherm for corrosion of mild steel in 0.5 N acetic acid solution Containing *Aloe vera* gel extract.

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### 3.3. Effect of temperature

Results of Table 2 indicates that, as temperature increases rate of corrosion increase while percentage of I.E. decreases. The value of activation energy ( $E_a$ ) has been calculated with the help of Arrhenius equation [16].

$$\log \frac{\rho_2}{\rho_1} = \frac{E_a}{2.303R} \left( \frac{1}{T_1} - \frac{1}{T_2} \right) \quad \text{-----(4)}$$

Where,  $\rho_1$  and  $\rho_2$  are the corrosion rate at temperature  $T_1$  and  $T_2$  respectively.

Results given in Table 2 indicates that the mean values of  $E_a$  were found higher in inhibited acid ranging from 52.71 to 73.78  $\text{kJ mol}^{-1}$  than the  $E_a$  values for uninhibited acid 42.50  $\text{kJ mol}^{-1}$  in 1.0 M acetic acid. The increase in  $E_a$  in presence of inhibitor has been associated with physisorption of the adsorptive film onto the metal surface. Higher values of  $E_a$  in the presence of inhibitor compared to its absence are generally consistent with a physisorption [17- 19]. However the increase in the  $E_a$  in inhibited system compare to uninhibited system indicates that the extract of *Aloe vera* gel was performs as a good inhibitor at ordinary temperature with considerable loss in I.E. at elevated temperature. The value of  $E_a$  were also calculated from the slope of the Arrhenius plot of  $\log p$  versus  $1/T \times 1000$  (Figure 2). The mean value of  $E_a$  calculated from equation and from the slope of the Arrhenius plot was found almost similar value ( $\pm 0.1 \text{ kJ mol}^{-1}$ ).

**Table 2:** Temperature effect on corrosion rate (CR), activation energy ( $E_a$ ) and heat of adsorption ( $Q_{\text{ads}}$ ) for brass in 0.1M  $\text{HNO}_3$  in absence and presence of *Aloe vera* extract for an immersion period of 2h.

Inhibitor concentration (g/L)	Temperature						Mean ( $E_a$ ) From Equation (4) ( $\text{kJmol}^{-1}$ )	$E_a$ From Arrhenius Plot	$Q_{\text{ads}}$ ( $\text{kJ mol}^{-1}$ )	
	313 K		323 K		333 K				313-323 K	323-333 K
	CR $\text{mg dm}^{-2}\text{d}^{-1}$	I. E. (%)	CR $\text{mg dm}^{-2}\text{d}^{-1}$	I. E. (%)	CR $\text{mg dm}^{-2}\text{d}^{-1}$	I. E. (%)				
Blank	858.37	-	1430.62	-	2288.98	-	42.50	42.47	-	-
0.10	457.79	46.67	858.37	40.00	1545.06	32.50	52.71	52.67	-22.87	-101.63
0.25	286.12	66.67	515.02	64.00	858.37	62.50	47.55	47.60	-9.91	-5.77
0.50	171.67	80.00	400.57	72.00	686.70	70.00	59.72	60.16	-37.15	-8.69
1.00	114.45	86.66	286.12	80.00	629.47	72.50	73.78	73.85	-40.77	-37.30

The values of heat of adsorption ( $Q_{\text{ads}}$ ) were calculated by following equation [20].

$$Q_{\text{ads}} = 2.303R \left[ \log \left( \frac{\theta_2}{1-\theta_2} \right) - \log \left( \frac{\theta_1}{1-\theta_1} \right) \right] \left[ \frac{T_1 T_2}{T_2 - T_1} \right] \quad \text{-----(5)}$$

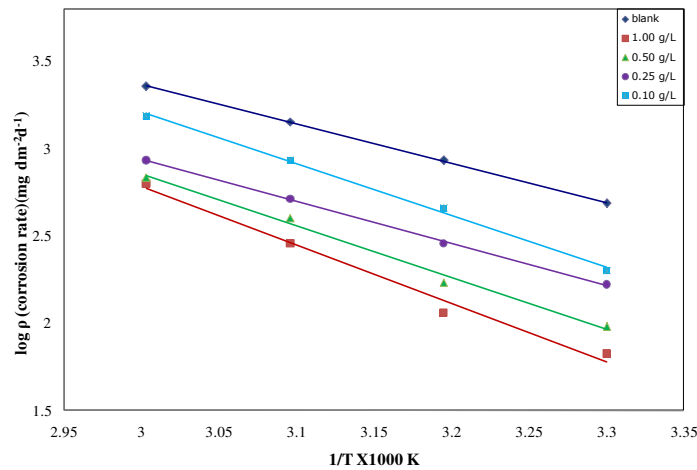
Where,  $\theta_1$  and  $\theta_2$  are the fraction of the metal surface covered by the inhibitor at temperature  $T_1$  and  $T_2$  respectively. From Table 2, it was evident that in all cases, the  $Q_{\text{ads}}$  values were negative and ranging from -5.77 to -101.63  $\text{kJmol}^{-1}$ . The negative value of  $Q_{\text{ads}}$  indicates that the inhibitor was physically adsorbed on mild steel surface, and the I.E. of the inhibitor was decrease with increase in temperature [21]. The lower value of the  $Q_{\text{ads}}$  (less than 40  $\text{kJ mol}^{-1}$ ) was associated with physical adsorption of the inhibitor on the mild steel surface [22].

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**Figure 2:** Arrhenius plot for corrosion of mild steel in 1.0 M acetic acid in presence and absence of *Aloe vera* gel extract.

The standard free energy of adsorption  $\Delta G^\circ_{ads}$  was calculated according to equation mentioned by Sobhiet al. [23] as follow,

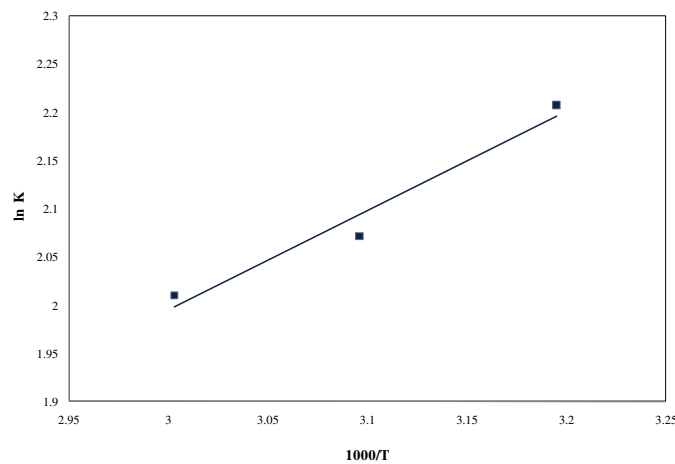
$$K_{ads} = \frac{1}{C_{solvent}} \exp\left(\frac{-\Delta G^\circ_{ads}}{RT}\right) \quad \text{-----(6)}$$

Where,  $K_{ads}$  obtained from intercept of the plot of  $C$  versus  $C/\theta$  for each temperature. ‘R’ is gas constant and ‘T’ is the absolute temperature.

The enthalpy of adsorption  $\Delta H^\circ_{ads}$  was calculated according to the Van’t Hoff equation [24].

$$\ln K_{ads} = \frac{-\Delta H^\circ_{ads}}{RT} + \text{constant} \quad \text{-----(7)}$$

Where,  $K_{ads}$  is adsorption equilibrium constant. The enthalpy of adsorption was obtained by plotting  $\ln K_{ads}$  versus  $1/T$  (Figure 3) with slope of  $(-\Delta H^\circ_{ads}/RT)$  [23].



**Figure 3:** Van’t Hoff plot

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The entropy of adsorption  $\Delta S^{\circ}_{ads}$  was calculated according to thermodynamic basic equation as follow [25].

$$\Delta S^{\circ}_{ads} = \Delta H^{\circ}_{ads} - \Delta G^{\circ}_{ads}/T \quad \text{-----(8)}$$

**Table3:** Thermodynamic parameters: Enthalpy of adsorption ( $\Delta H^{\circ}_{ads}$ ) and Entropy of adsorption ( $\Delta S^{\circ}_{ads}$ ) for the adsorption of *Aloe vera* gel extract on mild steel surface.

Inhibitor	Temperature (K)	Free energy of adsorption ( $\Delta G^{\circ}_{ads}$ ) (kJ mol <sup>-1</sup> )	$\Delta H^{\circ}_{ads}$ (kJ mol <sup>-1</sup> )	$\Delta S^{\circ}_{ads}$ (J mol <sup>-1</sup> K <sup>-1</sup> )
<i>Aloe vera</i>	313	-16.41	-8.57	24.35
	323			24.71
	333			24.36

Table 3 shows that the value of  $\Delta G^{\circ}_{ads}$  is negative. The negative and low values of  $\Delta G^{\circ}_{ads}$  indicates the spontaneous adsorption of the inhibitor on the mild steel surface [26]. Average value of  $\Delta G^{\circ}_{ads}$  at higher temperature was near to -16.0 kJ mol<sup>-1</sup> indicating the physical adsorption of the inhibitor on the metal surface. Generally, values of  $\Delta G^{\circ}_{ads}$  up to -20 kJ mol<sup>-1</sup> are consistent with electrostatic interaction between charged molecules and a charged metal (physical adsorption) while those more negative than -40 kJ mol<sup>-1</sup> involves charge sharing or transfer from the inhibitor components to the metal surface to form a coordinate type of bond (chemisorption) [27, 28]. Table- 3 shows the negative value of  $\Delta H^{\circ}_{ads}$  which suggest the process of adsorption of inhibitor on mild steel surface is exothermic, which means that I.E. decreases with rise in temperature. It can be assumed that the increase in temperature leads to the increase in desorption of the adsorbed inhibitor molecule from the mild steel surface [29].

*Aloe vera* gel gives the positive value of  $\Delta S^{\circ}_{ads}$ , which is opposite to the usual expectation that the adsorption is an exothermic process and always accompanied by a decrease of entropy. That can be explain as, the process of adsorption of inhibitor molecule was accompanied by desorption of water molecule from the mild steel surface. The adsorption occurs as the result of substitution adsorption process between inhibitor molecule present in solution and the water molecule previously adsorbed on the metallic surface [30] and the thermodynamic values obtained were algebraic sum of the adsorption of inhibitor molecule and desorption of water molecule [31].

### 3.4. Polarization measurement

The various electrochemical parameters such as corrosion potential ( $E_{corr}$ ), corrosion current density ( $i_{corr}$ ), the value of Tafel parameters ( $\beta_a$ ,  $\beta_c$ ,  $\beta$ ) are evaluated from Tafel plot and are given in Table 4.

The percentage I.E. from  $i_{corr}$  was calculated by using the following equation [32]:

$$I. E. (\%) = \frac{i_{corr,u} - i_{corr,i}}{i_{corr,u}} \times 100 \quad \text{-----(9)}$$

Where,  $i_{corr,u}$  = corrosion current in uninhibited acid and  $i_{corr,i}$  = corrosion current in inhibited acid.

**Table 4:** Polarization measurements of mild steel in absence and presence of 1.0 g/L *Aloe vera* leaves extract in 0.5 M acetic acid at 298 K.

System	$E_{corr}$ (V)	$I_{corr}$ ( $\mu A/cm^2$ )	Tafel slope (V / decade)			IE (%) Calculated from	
			Anodic (+ $\beta_a$ )	Cathodic (- $\beta_c$ )	$\beta$ (V)	Polarization method	Weight loss method
Blank	-0.610	244	5.195	4.659	1.068	-	-
<i>Aloe vera</i>	-0.630	65.50	5.612	4.245	1.051	73.15	82.35

The values of  $I_{corr}$  was found to be decrease in presence of the inhibitor. The decrease in  $I_{corr}$  values can be due to the adsorption of the component of extract on the mild steel surface. It was found that the  $E_{corr}$  value for uninhibited system was -0.610 V, while in the presence of inhibitor the value of  $E_{corr}$  is -0.630 V. In general, an inhibitor is consider as

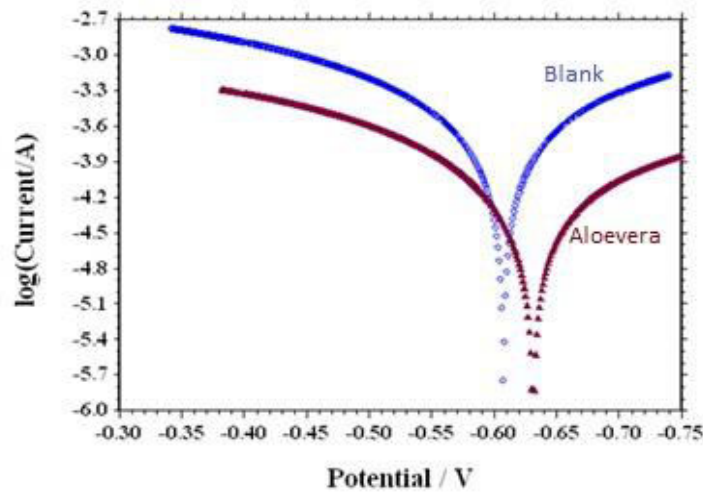
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anodic or a cathodic type if the variation  $E_{corr}$  against the blank is higher or above 85 mV [33]. In this study, the displacement of  $E_{corr}$  was 20 mV which is less than a 85 mV (Table 4), which suggest that the *Aloe vera* gel extract function as a mixed-type of inhibitor. The anodic and cathodic polarization curves (Tafel plot) of the mild steel in 0.5 M acetic acid solution without and with the addition of inhibitor was presented in Figure 4. The anodic and cathodic Tafel slope ( $\beta_a$ , and  $\beta_c$ ) changed with respect to uninhibited system in presence of inhibitor. As shown in figure 4, curves show polarization of both the anodes as well as the cathodes.



**Figure 4:** Potentiodynamic polarisation curves for mild Steel in 0.5 M acetic acid solution in absence (Blank) and in presence of 1.0 g/L *Aloe vera* extract.

### 3.5. Electrochemical Impedance Spectroscopy (EIS) measurements

Nyquist plots for the corrosion of mild steel in 0.5 M acetic acid solution in absence and presence of *Aloe vera* gel extract was obtained by EIS method at room temperature was shown in Figure 5. It is observed from Figure 5 that the impedance diagram is almost semicircular in appearance, but not perfect semicircle. The difference has been attributed to frequency dispersion. The semicircle nature of the plots indicates that the corrosion of mild steel is mainly controlled by charge transfer process [34]. The diameter of capacitive loop in the presence of inhibitor is bigger than that in the absence of inhibitor. The high frequency capacitive loop is related to the charge transfer resistance ( $R_{ct}$ ). The double layer capacitance ( $C_{dl}$ ) was calculated from the frequency at which the imaginary component of impedance ( $-Z''_{max}$ ) is maximum using following equation [35].

$$C_{dl} = \frac{1}{2\pi f_{max} R_{ct}} \quad \text{-----(10)}$$

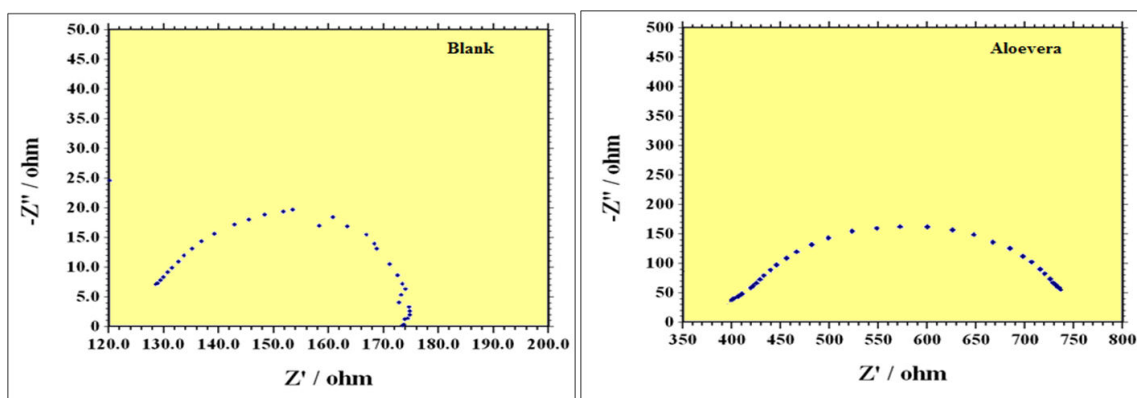
Where, ' $f_{max}$ ' is the frequency at the maximum height of the semicircle on the imaginary axis.

The I.E. of the inhibitor from  $R_{ct}$  value was calculated from the following equation.

$$I.E. (\%) = \frac{R_{ct,i} - R_{ct,u}}{R_{ct,i}} \times 100 \quad \text{-----(11)}$$

Where,  $R_{ct,u}$  = Charge transfer resistance for uninhibited acid and  $R_{ct,i}$  = Charge transfer resistance for inhibited acid.





**Figure 5:** Nyquist plot of mild steel in 0.5 M acetic acid (Blank) and in presence of 1.0 g/L *Aloe vera* gel extract at 298 K.

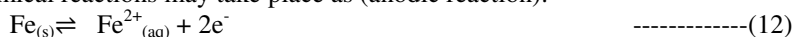
**Table 5:** EIS measurements of mild steel in absence and presence of 1.0 g/L *Aloe vera* gel extract in 0.5M acetic acid at 298 K.

System	R <sub>ct</sub> (Ω cm <sup>2</sup> )	C <sub>dl</sub> (μF cm <sup>-2</sup> )	I.E. (%) Calculated from	
			EIS method	Weight loss method
Blank	56.22	145	-	-
<i>Aloe vera</i>	456.98	3.308	87.70	82.35

The value of R<sub>ct</sub> increase with addition of the extract to the acid solution, while the value of C<sub>dl</sub> tend to decrease. A large R<sub>ct</sub> value is associated with lower corroding system. Furthermore, a better protection provided by an inhibitor is associated with a decrease in C<sub>dl</sub>. As the data given in Table 5, the R<sub>ct</sub> value was increase from 56.22 ohm cm<sup>2</sup>(for uninhibited system) to 456.98 ohm cm<sup>2</sup> (in presence of *Aloe vera* gel extract) at 1.0 g/L inhibitor concentration. The values of C<sub>dl</sub> decrease from 145 μF cm<sup>-2</sup>(for uninhibited system) to 3.3080 μF cm<sup>-2</sup> ( in presence of *Aloe vera* gel extract). This may be due to the adsorption of the components of the extract at the metal/solution interface. The decrease in C<sub>dl</sub> values, caused by a decrease in local dielectric constant and/or an increase in the thickness of the electrical double layer, suggests that the water molecules are replaced by inhibitor molecules [36].

### 3.6. Mechanism of corrosion

In mild steel corrosion, electrochemical reactions may take place as (anodic reaction):



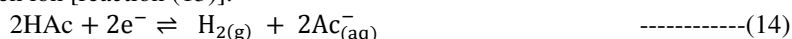
When iron corrodes, the rate is usually controlled by the cathodic reaction. The most common cathodic reaction that is frequently encountered in metallic corrosion in acidic media is hydrogen evolution.



The exact mechanism of corrosion of mild steel by acetic acid is controversial and it is not clear whether the adsorbed acetic acid molecule is reduced at the surface in addition to any reduction of hydrogen ions or it dissociates and provides an additional source of hydrogen ions near the mild steel surface. The previous is called “direct reduction”, and later is referred to as “buffering effect”, in which cathodic reaction is reduction of hydrogen ions. These two mechanisms are reviewed in detail below [37].

#### Direct reduction

In order to explain the high corrosion rate of mild steel in acetic acid, many authors [38] has proposed this mechanism. According to this mechanism acetic acid is reduced at the metal surface according to reaction (14), in addition to the reduction of hydrogen ion [reaction (13)].





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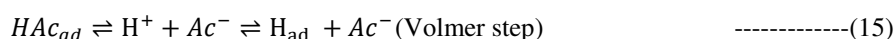
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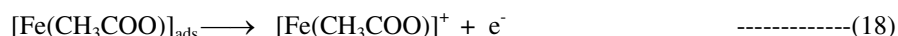
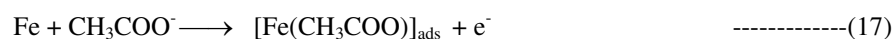
At the same time anodic reaction occurs at the metal surface, in order to balance the charge is the dissolution of iron [reaction (12)].

### Buffering effect

Another possible and simpler pathway is to consider acetic acid only as a source of hydrogen ions which are then reduced at the steel surface. In this scenario, the role of acetic acid is to act as a “buffer,” which provides more hydrogen ions when the latter are consumed by the corrosion reaction at the surface, reaction (13). This mechanism is termed the “buffering effect.” Similar results and conclusions were made by Amri [39]. He proposed a mechanism where the dissociation of adsorbed acetic acid is followed by a Volmer-Heyrovsky step, reactions (15) and (16).

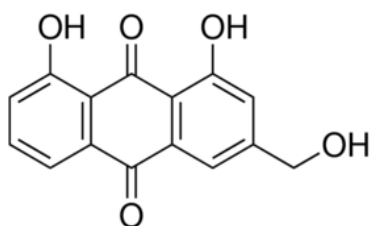


The corrosion of mild steel in aqueous acetic acid solution has been described [40] to occur in following stages:

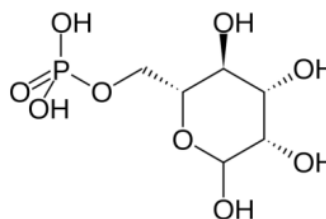


### 3.7. Mechanism of inhibition

According to Cang et al. [41] *Aloe vera* have abundant organic components in which N, S, O atoms are the main constituent atoms like aloe-emodin, aloin-barbaloin, anthranol, chrysophanol glucoside, rutin etc. Availability of lone pairs and  $\pi$  electrons in these inhibitor molecules facilitate electron transfer from the inhibitor to the metal, forming a coordinate covalent bond [42]. The inhibition effect of *Aloe vera* may be due to the presence of these organic compounds in the extract. Organic compounds having centres for  $\pi$  electrons and functional groups of O, S or N or combination have been reported as corrosion inhibitors in acid solutions [43-45].



**Figure 6:** Structure of Aloe emodin



**Figure 7:** Structure of Mannose -6- phosphate

Hart and James [46] also find that components like folic acid (vitamin A) and aloe emodin (an anthraquinone) (Figure 6) with structures contain electron rich oxygen and nitrogen that could serve as good active ingredients which are responsible for corrosion I.E. of *Aloe vera*. According to investigation carried out by Sriharathy et al. [12] the active constituent of *Aloe vera* extract is mannose-6-phosphate [47]. The structure of mannose-6-phosphate is shown in Figure-7 contain phosphate group, hydroxyl group and ring oxygen. Mannose-6-phosphate was coordinated with through the oxygen atom of P-O groups, OH group and ring oxygen resulting in the formation of  $Fe^{2+}$ -mannose – 6 – phosphate complex.

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## IV. CONCLUSION

1. The corrosion rate of mild steel increase with increase in acetic acid concentration.
2. The *Aloe vera* extract found to be effective inhibitor for mild steel in acetic acid, and their I.E. increase with increase in its concentrations.
3. *Aloe vera* extract shows maximum I.E. of 82.35 % at an optimum concentration of 1.0 g/L.
4. The higher values of activation energy indicate that electrostatic interaction between charged inhibitor molecule and the metal surface occurred.
5. The values of  $\Delta G_{ads}^{\circ}$  are negative, which reveals the spontaneous adsorption of inhibitor onto the metal surface.
6. Plot of  $C/\theta$  versus  $C$  shows straight line with almost unit slope, which suggest that the inhibitor cover both anodic and cathodic regions through general adsorption following Langmuir isotherm.
7. The potentiodynamic polarization study revealed that the *Aloe vera* extract act as mixed type inhibitor.
8. The results obtained from polarization and electrochemical impedance technique are in good agreement with weight loss data with marginal variation due to limitations of the technique itself.

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