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Inhibition of Aluminum Corrosion by *Salvia Judica* Extract

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Abstract

The inhibitive effect of the extract of Salvia Judica on aluminum corrosion in 1 M NaOH solutions was investigated by using the weight loss method at different temperatures. It was found that the extract play as corrosion inhibitor for aluminum corrosion in 1 M NaOH solution. The inhibition action of the extract was discussed in view of Langmuir and Temkin adsorption isotherms. It was found that the adsorption of the extract on aluminum surface is a spontaneous process. The inhibition efficiency was found to increase with increasing concentration of the extract and decreased with increasing temperature.

Keywords: Aluminum, inhibition efficiency, Langmuir adsorption isotherm, Temkin adsorption isotherms, *Salvia Judica*; weight loss method.

Introduction

Corrosion inhibitors are widely used in industry to decrease the corrosion rate of metals and alloys in contact with aggressive environment. Some investigations have in recent time been made into the corrosion inhibiting properties of natural products of plant origin, which have been found to generally exhibit good inhibition efficiencies[1–7]. This area of research is of much importance because in addition to being inexpensive, readily available and renewable sources of materials, plant products are environmentally friendly and ecologically acceptable. Plant products are organic in nature and some of the constituents including tannins, organic and amino acids, alkaloids and pigments are known to exhibit inhibiting action.

Some researchers reported the presence of some triterpenoids, diterpenoids, mono-terpenoid, caffeic acid derivative, chlorogenic derivative, rosmarinic derivative and ferulic derivative in Salvia species[8-14]. The major adsorption centers of these organic compounds are polar functions with -OH and -COOH groups as well as conjugated double bonds or aromatic rings in their molecular structures. In previous work shown that the inhibitive effect of these organic molecule is due to the adsorption of these molecules on the surface of the metal[7,15,16].

In the present study, the effect of *Salvia Judica* extracts on the corrosion of aluminum in 1 M NaOH solution using weight loss method. The Effect of the temperature on the corrosion inhibition in absence and presence of plant were fully discussed.

Material and Methods

A 10 ml of test solution were carried out in a test tube and placed in a thermostat water bath, in order to calculate the weight loss of aluminum metal. The test specimen of 99.96% aluminium (length=2cm, width = 1cm , thickness = 0.03cm), were treated by a solution containing 85% concentrated H_3PO_4 and15% concentrated HNO_3 for 30 second, then immersed in 50% HNO_3 solution at 50 °C for 20 second, rinsed well in deionized water and placed in alkaline solution (prepared by dissolving 40g NaOH in 1L deionized water). The specimens dried well on air stream and isolated from outside atmosphere.

Inhibitor material and weight loss method: A 2.0 g of dry *Salvia Judica* was refluxed in 250ml of 1M NaOH for 3 hours. The refluxed solution was allowed to stand overnight and filtered through ordinary filter paper.A10ml test solution of different concentrations were prepared by dilution different volumes from extraction 1M NaOH (volume of extract from 0-10ml). After the specified time, the coupons were removed from test solution, thoroughly washed with acetone solution and deionized water, dried well and then reweighed. The weight loss recorded to the nearest 0.0001 g.

Results and Discussion

The weight loss of the metal in the corrosive solution is given by equation 1.

$$\Delta W = W_B - W_A \quad (1)$$

Where W_B and W_A are the weights of metal before and after exposure to the corrosive solution, respectively.

The effect of temperature on the corrosion of aluminum in 1M NaOH over the temperature range of (25–50 ºC) in the absence and presence of different concentrations of the *S. Judaica* extract has been studied, figure-1. From figure-1 the result showed that weight loss increases as temperatures increases and the figure-1 showed that the weight loss values (mg) of aluminum in 1M NaOH solution containing *S. Judica* extract decreased as the concentration of the inhibitors increased, i.e. the corrosion inhibition strengthened with the increase of the surfactant concentration. This trend, it may result from the fact that adsorption amount and the coverage of surfactants on the aluminum surface increases with the increase of the concentration, thus the aluminum surface is efficiently separated from the medium[15].

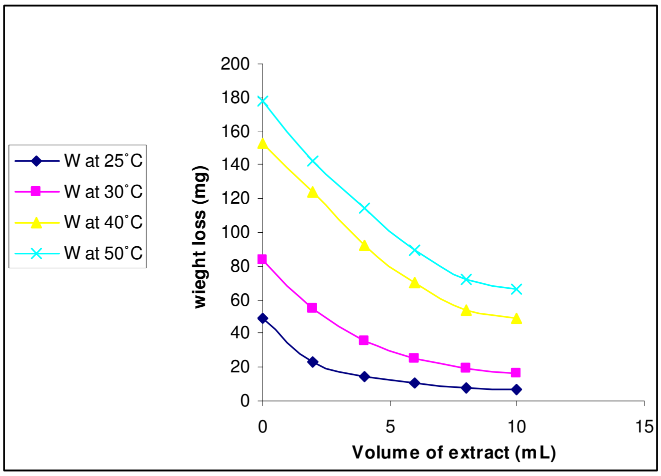

Figure-1
The weight loss (mg) curves of aluminum due to corrosion in 1M NaOH in the presence *S. Judaica* extract at various temperatures

The percentage inhibition efficiency (%I) and the degree of surface coverage (θ) of the investigated *Salvia Judaic* extract were computed from the following equations:

$$\%I = [1- \frac{\Delta W_P}{\Delta W_a}]\times 100 \quad (2)$$

$$\theta = [1- \frac{\Delta W_P}{\Delta W_a}] \quad (3)$$

Where ΔW_a and ΔW_P are weight losses of metal in the absence and presence of inhibitor respectively. From figure-2 the results showed that inhibition efficiency increased as the concentration of inhibitor increases from 20% to 100% of extract is used. The maximum inhibition efficiency was observed at 25 ℃ for 10 mL of extract. Probably due to an increase in the metal surface area covered by the exudates and it is seen that inhibition efficiency of *Salvia Judica* extract decreases with increase in temperature. Decrease in inhibition efficiency with increase in temperature is suggestive of physical adsorption mechanism.

The inhibitive effect of the *S. Judica* extract this can be attributed to the presence of some organic molecules in the extract. Therefore it could be assumed that the extract gums establish their inhibitory action via adsorption of these organic molecules on the metal surface[17-20]. This adsorption process creates a layer between the metal and the corrosive medium leading to decrease the corrosion rate. Consequently, inhibition efficiency increases as the metal surface area covered by the adsorbed molecules increases, the later is in turn increased as the extract concentration increases.

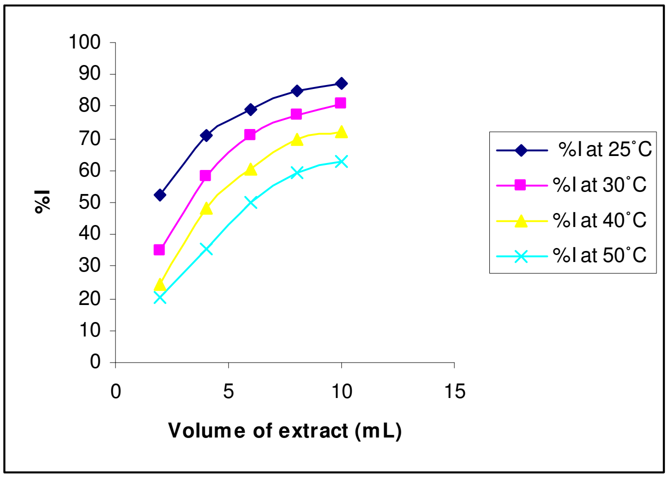

Figure-2
Inhibition efficiency of *S. Judaica* extract on aluminum in 1M NaOH for 2hr immersion period at different temperatures

Effect of temperature and activation parameters of inhibition process: The corrosion rate of aluminum is determined by using the relation:

$$R = \frac{\Delta W}{A.t} \quad (4)$$

Where ΔW is the mass loss, A the area and t the immersion period. The plot of logarithm of the corrosion rate versus the reciprocal of absolute temperature gives straight lines according to Arrhenius equation, figure-3:

$$\log R = \log A - \frac{Ea}{2.303RT} \quad (5)$$

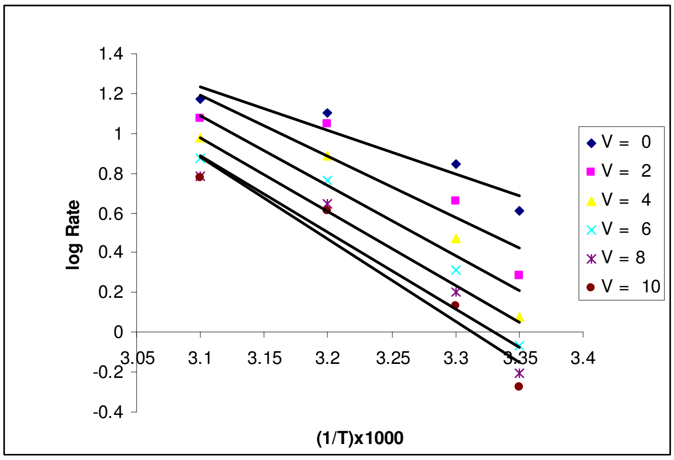

Figure-3
Arrhenius plot for aluminum corrosion in 1M NaOH in free and inhibited extract

Where R is the corrosion rate, A is the constant frequency factor and Ea is the apparent activation energy. The values of Ea were found to be 41.77 and 78.95 kJ/mol for corrosion reactions in free and inhibited extract, respectively. It is clear that, the activation energy increases in presence of *S. Judica* extract and consequently the rate of corrosion reaction is decreased, and it is responsive to temperature.

The Thermodynamic parameters like enthalpy (ΔH^*) of corrosion process and entropy (ΔS^*) were calculated using the transition state equation 6.

$$R = \frac{RT}{Nh} exp^{\frac{\Delta S^*}{R}} exp^{\frac{\Delta H^*}{RT}} \quad (6)$$

where h is Planck's constant and N is Avogadro's number.

Figure-4 shows a plot of log (Rate/T) against (1/T). Straight lines are obtained with a slope of ($-\Delta H^*/2.303R$) and an intercept of ($\log R/Nh + \Delta S^*/2.303R$) from which the values of ΔH^* and ΔS^* are calculated and tabulated in table-1. The values of ΔH^* lower than 43.2 kJmol^{-1} which attributed with physical adsorption and if the values equal 100 kJmol^{-1} this indicate adsorption is chemical adsorption[21]. The values of ΔS^* in the presence and absence of the inhibitors are negative. This implies that the activation complex is the rate determining step representing association rather than dissociation, indicating that a decrease in disorder takes place on going from reactant to the activated complex[20]. The increase in activation energy (Ea) of inhibited solutions compared to the blank suggests that inhibitor is physically adsorbed on the corroding metal surface, while either unchanged or lower energy of activation in the presence of inhibitor suggest chemisorption[21]. As reported in table-1, Ea values increased significantly after the addition of the inhibitor. Hence corrosion inhibition of *S. Judica* is occurring through physical adsorption.

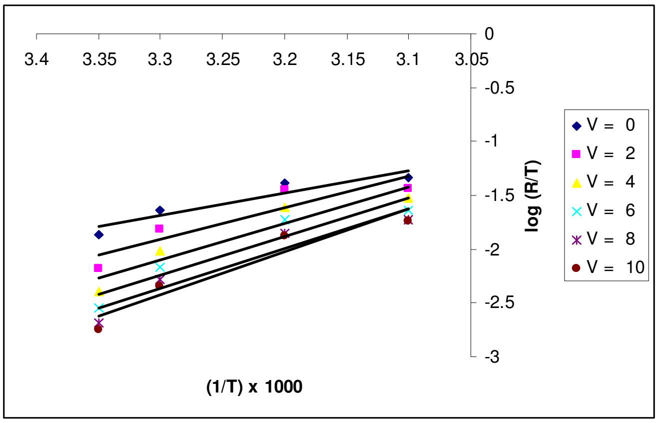

Figure-4
Log (R/T) vs. 1/T for aluminum electrode in 1 M NaOH in the absence and presence of *S. Judica* extract

The values of Q_{ads} on aluminum specimen in the presence of inhibitor is arrived by the following equation (7)

$$Q_{ads}=2.303R\left[Log\left(\frac{\theta_2}{1-\theta_2}\right)-Log\left(\frac{\theta_1}{1-\theta_1}\right)\right]\times\left(\frac{T_2T_1}{T_2-T_1}\right) \quad (7)$$

Where R is the gas constant, $\theta_1$and θ_2 are the degree of surface coverage at temperatures T_1 and T_2 respectively.

Table-1
Activation parameters of the corrosion of Al in 1 M NaOH in the absence and presence of *S. Judica* extract

Extract conc. (ml)	Ea (KJ/mole)	ΔH^* (kJ/mol)	ΔS^* (J/mol.K)
0	41.773	7.377	-64.226
2	58.818	10.572	-54.52
4	67.281	12.183	-49.89
6	70.980	12.885	-48.10
8	73.849	13.425	-46.76
10	78.951	14.376	-43.85

The calculated Q_{ads} values are ranged from -4.86 to-11.82 kJ/mol. This negative value indicates that the adsorption of *S. Judica* extract on the surface of aluminum metal is exothermic.

Figure - 5 also confirms that the inhibition process is due to adsorption of the active organic molecules on the metal surface. since a straight line is obtained when Log(C/θ) is plotted against logC and the linear correlation coefficient of the fitted data is very close to 1. This indicates that the adsorption of *S. Judica* extract molecules obeys the Langmuir adsorption model[22,23], equation 8.

$$Log\left(\frac{C}{\theta}\right) = \log C - \log K \quad (8)$$

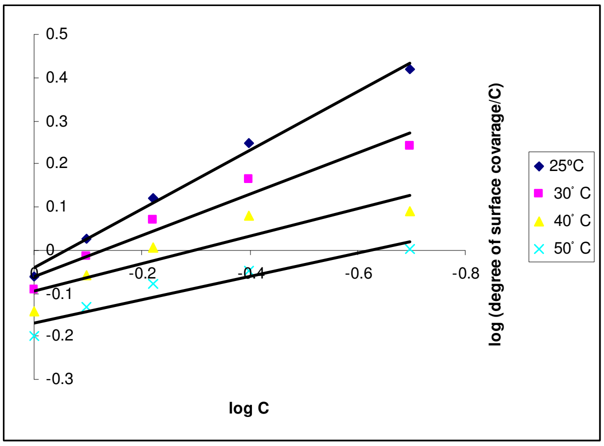

Figure-5
Langmuir adsorption model on Al surface of S. *Judica* extract in 1 M NaOH solution for 2 hour at different temperatures

Where K is the adsorption/desorption equilibrium constant, C is the corrosion inhibitor concentration in the solution.

The inhibitor also obeys Temkin adsorption isotherm which is represented in figure-6, equation 9. Values of adsorption parameters deduced from the plots are tabulated on table-2.

$$Exp^{(-2a\,\theta)} = KC \quad (9)$$

The relationship between the equilibrium constant, K, of adsorption and the free energy of adsorption, ΔG_{ads}, is given by the following expression[17,16].

$$\Delta G_{ads} = -2.303RT \log (55.5 K) \quad (10)$$

The values of free energy of adsorption calculated from equation (10) using K values obtained from the Langmuir adsorption and Temkin adsorption isotherm are presented in table-2.

Table-2
Langmuir and Temkin adsorption parameters for the adsorption of *S. Judica* extract on Al in 1M NaOH for 2hr immersion period at different temperatures

Isotherm	Temperature (K)	Log K	R^2	ΔGads, kJmol^{-1}
Langmuir	298	0.0423	0.9931	-10.19
	303	0.0603	0.9474	-10.46
	313	0.0951	0.8254	-11.02
	323	0.1674	0.9002	-11.82
Temkin	298	-0.8916	0.9869	-4.86
	303	-0.8329	0.9878	-5.29
	313	-0.7509	0.9907	-5.95
	323	-0.6369	0.9908	-6.85

The values are negative and less than -11.82 kJmol^{-1}. This implies that the adsorption of the inhibitor on aluminum surface is spontaneous and confirms physical adsorption mechanism[16].

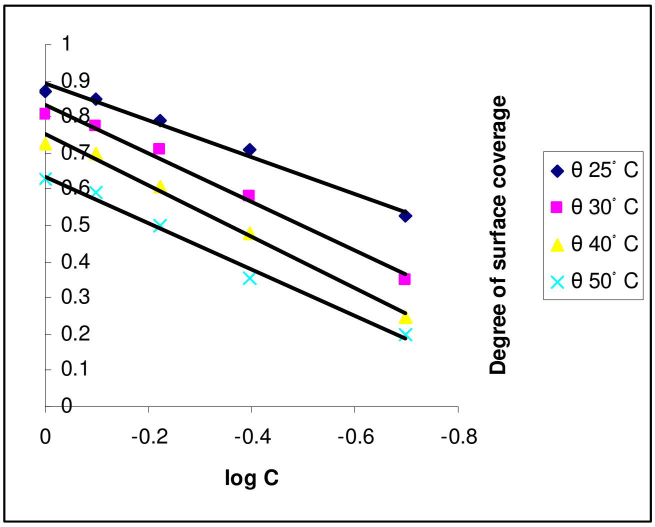

Figure-6
Temkin adsorption isotherm plot as θ against log C for *S. Judica* extract at different temperatures for Al corrosion

Conclusion

From the experimental results obtained in the present study, the following conclusions could be drawn: i. *S. Judica* extract acts as inhibitor for Al corrosion in NaOH solution. ii. The efficiency of inhibition increased with increase in amount of the *S. Judica* extract but decreased with increase in temperature. Phytochemical constituents in the extract play a very vital role in the inhibiting action. iii. Activation energies were higher in the presence of the exudates gum suggesting physisorption mechanism. iv. This present study provides new information on the inhibiting characteristic of a *S. Judica* extract under the specified conditions. The adsorption of *S. Judica* extract fits into Langmuir isotherm and Temkin isotherm models.

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