American Journal of Applied Chemistry
2019; 7(2): 72-79
http://www.sciencepublishinggroup.com/j/ajac
doi: 10.11648/j.ajac.20190702.15
ISSN: 2330-8753 (Print); ISSN: 2330-8745 (Online)

Inhibitory Action of Methanol Leaf Extract of *Irvingia Gabonensis* on the Corrosion of Mild Steel in H_2SO_4

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To cite this article:
Vincent Ishmael Egbulefu Ajiwe, Chinedu Emmanuel Ejike. Inhibitory Action of Methanol Leaf Extract of *Irvingia Gabonensis* on the Corrosion of Mild Steel in H_2SO_4. *American Journal of Applied Chemistry*. Vol. 7, No. 2, 2019, pp. 72-79. doi: 10.11648/j.ajac.20190702.15

Received: March 22, 2019; **Accepted**: April 30, 2019; **Published**: June 12, 2019

Abstract: The corrosion inhibition efficiency of methanol leaf extracts of *Irvingia gabonensis* for mild steel in 0.4, 0.5, 0.6 and 2.5M H_2SO_4 was investigated using weight loss and gasometric techniques in other to determine the phytochemical components of the crude leaf extract, the corrosion inhibition potential of the leaf extract, the thermodynamic parameters that aided the corrosion inhibition, the adsorption isotherm of the corrosion inhibition of the extracts using the Langmuir and Freundlich models and investigate the kinetics of the corrosion inhibition process. Preliminary phytochemical screening revealed the presence of tannins, saponnins, flavonoids, terpenes and alkaloids. From the results, the corrosion rates decreased with increase in inhibitor concentration. The maximum inhibition efficiency of 58.71% was obtained at extract concentration of 0.6g/L in 0.4M H_2SO_4 at 303K, 41.83% at extract concentration of 0.6g/L at 303K in 0.5M H_2SO_4 and 57.33% at extract concentration of 0.6g/L in 0.6M H_2SO_4 at 303K, for the gravimetric technique. In 2.5M H_2SO_4, maximum inhibition efficiency for the gasometric technique was 53.53% in 0.6g/L inhibitor concentration at 303K and for the gravimetric technique, the maximum inhibition efficiency was 29.42% in 0.6g/L inhibitor concentration at 303K. The kinetic and thermodynamic studies showed that activation energy (E_a) in the presence of inhibitor is greater than in the absence of inhibitor. From the E_a and ΔG^o_{ads} values obtained, a physical adsorption mechanism was proposed. The Langmuir isotherm was found to show better correlation (R^2) at lower temperature while the Freundlich isotherm had better correlation at higher temperature.

Keywords: Methanol Leaf Extract, *Irvingia Gabonensis*, Corrosion Inhibition

1. Introduction

Mild steel is a structural material used in many industries as construction materials, production / manufacturing equipment, piping and fluid transportation apparatus, water treatment equipment amongst others. This is as a result of the relatively low cost of manufacture of mild steel. However, operational procedures like pickling, descaling and acid cleaning which involves acidic media corrodes the mild steel surface and reduce the lifespan of the equipment. Several protection methods have been applied to reduce the corrosion of mild steel like reducing the impurities in the metal, alloying, coating etc., with attendant higher costs. The use of inhibitors is a viable option except for the environmentally unsafe inorganic inhibitors (chromates, phosphates, molybdates etc.)[1-4]. Several organic inhibitors have shown good efficiency for corrosion inhibition [5-10]. In the present work, the inhibitive properties of the methanol leaf extract of *Irvingia gabonensis* is studied to ascertain its effectiveness as a corrosion inhibitor for mild steel and to determine its mechanism of adsorption.

2. Experimental Methods

2.1. Materials Preparation

The leaves of *Irvingia gabonensis* were collected from Nru in Nsukka LGA (6°51'24"N 7°23'45"E) and identified in the Plant Science department of the University of Nigeria, Nsukka. The leaves were dried under shade for two weeks and pulverized. Cold maceration was used for the extraction, as described by [11] as follows: Powdered samples (500.0g) of *Irvingia gabonensis* was weighed into 1000mL capacity

conical flask. One litre of methanol was added to the sample. The conical flasks containing the mixtures were placed on a shaker for 24h, and then filtered using muslin cloth. The filtered extracts were concentrated using the rotary evaporator and air-dried for 48h to a semi-solid form. The extracts were stored in well corked sample bottles in a refrigerator. 2.0g of the leaf extract was dissolved in 100mL of distilled water to obtain a stock solution of 2g/100mL i.e. 20g/L. To obtain the value of aliquots to be used, a serial dilution of 1mL of stock solution in 100mL of test solution which gave 0.2g/L was resolved. Therefore each 1ml aliquot of stock solution in 100mL of test solution represented 0.2g/L.

Mild steel coupons of 2cm x 3cm x 0.2cm were cut out of a metal sheet obtained from the Nsukka building materials market. Holes were drilled into the top edge of the coupons to aid suspension of the metal in solution. The coupons comprised by %wt: 0.18% C, 0.55% Mn, 0.08% P, 0.04% S and the remainder Fe. The metal coupons were washed with detergent to remove sand and grease, and then cleaned with sandpaper to a glossy finish. It was then rewashed with detergent, rinsed twice in distilled water, degreased in acetone and dried in the electric oven at 40^{o}C for 2h. The dry metal coupons were then stored in desiccators.

2.2. Phytochemical Screening

Preliminary phytochemical analysis was performed as described by [12-14] for the following active principles: Tannins, Saponins, Glycosides, Flavonoids, Terpenes, Steroids and Alkaloids.

2.3. Gravimetric Technique

1mL, 2mL and 3mL aliquots of the extract solution (representing 0.2g/L, 0.4g/L and 0.6g/L respectively) were drawninto three 200mL beakers and each made up to 100mL with 0.4M H_2SO_4. 100mL of 0.4M H_2SO_4 was introduced into an empty 200mL beaker to serve as a blank solution (without inhibitor). The beakers were then introduced into the water bath for 2mins to acclimatize at 30^{o}C. Four mild steel coupons were weighed and one suspended in each of the test solutions using a hook and glass holder. The experiment was timed with the stopwatch on two-hourly duration, after which each coupon was withdrawn, quenched in a solution containing 20%NaOH and 200g/L Zinc dust, washed in detergent and lightly brushed, rinsed twice in distilled water and degreased in acetone. The coupon was then weighed and reintroduced into the experiment media. The process was thereafter repeated for five consecutive measurements. The same experiment was repeated twice at the same set conditions using new coupons making three independent measurements. The experiments were conducted at varied temperatures (30°C, 40°C and 50°C) and varied acid concentration (0.4M, 0.5M and 0.6M).

The difference in weight of the coupon was taken as the weight loss (WL) defined as

$$WL = W_o - W_t \quad (1)$$

Where W_o = initial weight, W_t = final weight

From the weight loss data, the corrosion rates (CR) were calculated from the equation given by [15]:

$$CR = \frac{WL}{A.t} \quad (2)$$

Where WL = weight loss in mg, A = metal surface area and t = time of immersion in hours.

From the corrosion rate, the inhibition efficiencies of the plant extracts (I%) were determined from the equation:

$$I\% = \left[\frac{CR_{blank} - CR_{Inh}}{CR_{blank}}\right] X\ 100 \quad (3)$$

Where CR_{blank} and CR_{inh} are the corrosion rates in the absence and presence of plant extracts respectively.

2.4. GasometricTechnique

1mL aliquot of extract solution was put into a 200mL conical flask with side nozzle, and made up to 100mL with 2.5M H_2SO_4. The side nozzle was connected through an air hose to an inverted burette standing in a 500mL beaker filled with water. The water level in the beaker was adjusted to the last graduated mark on the burette to represent a zero reading. The 200mL conical flask was then introduced into a water bath at 25^{o}C. This experimental set-up used for the gasometric method is as reported by [16]. One mild steel coupon was removed from the dessicator, weighed and introduced into the test solution and immediately stoppered. Volume of gas collected in the burette was recorded every 5 minutes for six consecutive measurements (i.e. 30 minutes). The coupon was then retrieved, quenched in a solution of 20% NaOH and 200g/L Zinc dust, washed and rinsed twice with distilled water, degreased in acetone and air dried. The dry coupon was then weighed. The experiment was then repeated twice with different coupons at the same temperature.2mL and 3mL aliquots representing 0.4g/L and 0.6g/L respectively were in turn used for the measurements as stated above at 25^{o}C. Further measurements were conducted using various aliquots of extract solution (1mL, 2mL and 3mL) at 30^{o}C and 35^{o}C respectively.

The inhibition efficiency (I%) and the degree of surface coverage (θ) were determined from the equations below:

$$I\% = \left[\frac{V_{H0} - V_{H1}}{V_{H0}}\right] X\ 100 \quad (4)$$

$$\theta = \left[\frac{V_{H0} - V_{H1}}{V_{H0}}\right] \quad (5)$$

Where V_{H0} and V_{H1} are the volume of gas evolved in the absence and presence of plant extract respectively.

3. Results and Discussion

3.1. Phytochemical Consideration

The methanol leaf extracts *Irvingia gabonensis* were observed to contain various organic and resinous materials, some of which have good corrosion inhibition properties.

The presence of alkaloids, flavonoids, terpenes, steroids, tannins and saponins has proven to be good corrosion inhibitors in acidic media [10]. It was reported by [17] that the adsorption of green inhibitors could occur through the formation of a bond with metal, involving the sharing of the lone pair of electrons of alkaloid constituents (-NH, -OH and C=O) present in the neutral alkaloid molecule and the metal. The inhibitive properties of tannins have been attributed to the reaction of the polyphenolic fraction of the tannin moieties, which ensures protection of the metal surface [18]. Flavonoids contribute to the inhibition efficiency of the inhibitors possibly due to being a cyclic compound with O atoms attached to it [19].

Table 1. *Qualitative phytochemical results for methanol leaf extract of Irvingia gabonensis.*

PHYTOCHEMICAL	
TANNINS	+
SAPONNINS	+
FLAVONOIDS	+
TERPENES	+
STEROIDS	-
ALKALOIDS	+

+ = present, - = absent.

3.2. Weight Loss Measurements

Table 2. *Weight loss data for corrosion of mild steel in 0.4M H_2SO_4 solution in presence and absence of different concentrations of methanol leaf extract of Irvingia gabonensis.*

		0HRS	2HRS	4HRS	6HRS	8HRS	10HRS
303K	0.2g/L	0	0.0978	0.1436	0.1717	0.1934	0.2158
	0.4g/L	0	0.0626	0.0879	0.1101	0.1274	0.1433
	0.6g/L	0	0.0558	0.0869	0.1026	0.1157	0.1292
	BLANK	0	0.1313	0.2070	0.2496	0.2825	0.3130
313K	0.2g/L	0	0.0924	0.1374	0.1865	0.2278	0.2677
	0.4g/L	0	0.0656	0.0991	0.1381	0.1728	0.2096
	0.6g/L	0	0.0660	0.0999	0.1365	0.1742	0.2084
	BLANK	0	0.1859	0.2642	0.3084	0.3291	0.3452
323K	0.2g/L	0	0.1261	0.2332	0.3015	0.3494	0.3723
	0.4g/L	0	0.1033	0.1908	0.2606	0.3350	0.3708
	0.6g/L	0	0.0730	0.1328	0.1910	0.2742	0.3351
	BLANK	0	0.1652	0.2922	0.3488	0.3772	0.4004

Table 3. *Weight loss data for corrosion of mild steel in 0.5M H_2SO_4 solution in presence and absence of different concentrations of methanol leaf extract of Irvingia gabonensis.*

		0HRS	2HRS	4HRS	6HRS	8HRS	10HRS
303K	0.2g/L	0	0.1219	0.1897	0.2306	0.2605	0.2896
	0.4g/L	0	0.0836	0.1304	0.1632	0.1867	0.2105
	0.6g/L	0	0.0746	0.1165	0.1454	0.1686	0.1875
	BLANK	0	0.1217	0.2032	0.2515	0.2883	0.3224
313K	0.2g/L	0	0.0808	0.1588	0.2266	0.2794	0.3262
	0.4g/L	0	0.0669	0.1155	0.1648	0.2084	0.2483
	0.6g/L	0	0.0600	0.1060	0.1471	0.1844	0.2229
	BLANK	0	0.2301	0.3357	0.3634	0.3745	0.3803
323K	0.2g/L	0	0.2400	0.3642	0.4104	0.4318	0.4464
	0.4g/L	0	0.2055	0.3088	0.3746	0.4143	0.4374
	0.6g/L	0	0.1415	0.2356	0.3027	0.3526	0.3948
	BLANK	0	0.3561	0.4306	0.4485	0.4582	0.4747

Table 4. *Weight loss data for corrosion of mild steel in 0.6M H_2SO_4 solution in presence and absence of different concentrations of methanol leaf extract of Irvingia gabonensis.*

		0HRS	2HRS	4HRS	6HRS	8HRS	10HRS
303K	0.2g/L	0	0.1099	0.1835	0.2263	0.2585	0.2878
	0.4g/L	0	0.0731	0.1272	0.1638	0.1895	0.2148
	0.6g/L	0	0.0604	0.1111	0.1431	0.1652	0.1829
	BLANK	0	0.1577	0.2655	0.3333	0.3853	0.4286
313K	0.2g/L	0	0.1126	0.1826	0.2371	0.2869	0.3298
	0.4g/L	0	0.0890	0.1488	0.1956	0.2431	0.2821
	0.6g/L	0	0.0826	0.1346	0.1772	0.2225	0.2642
	BLANK	0	0.1279	0.2188	0.2781	0.3442	0.3940
323K	0.2g/L	0	0.1564	0.2681	0.3426	0.3928	0.4329
	0.4g/L	0	0.1402	0.2465	0.3298	0.3867	0.4310
	0.6g/L	0	0.1270	0.2196	0.2989	0.3556	0.4128
	BLANK	0	0.2020	0.3291	0.3863	0.4253	0.4388

3.2.1. Effect of Inhibitor Concentration on Weight Loss

From the weight loss data in Tables 2-4, the weight loss was found to decrease with increase in extract concentration, same as reported by [16], probably due to increase in the number of adsorbed inhibitor molecules on the metal surface, thus forming a film that completely covers the metal surface. The methanol leaf extracts of *Irvingia gabonensis* contain alkaloids, flavonoids, tannins etc (Table 1). The adsorption of these compounds on mild steel surfaces greatly reduces the surface area available for corrosion. Thus a higher degree of protection would ordinarily result from an increase in the concentration of the extract [20-21].

3.2.2. Effect of Temperature on Weight Loss

From the Tables 2-4, weight loss was observed to increase with increase in temperature of the corroding media. This can be attributed to higher agitation in the system, displacing inhibitor molecules from the adsorption sites on metal surface. This could also be as a result of more energized acid particles knocking off the more bulky organic particles from the adsorption sites.

Table 5. *Corrosion rate of mild steel in various concentrations of H_2SO_4 at 303K, 313K and 323K in the presence and absence of methanol leaf extract of Irvingia gabonensis.*

CORROSION RATE (x 10^{-3})(mg cm^{-2} hr^{-1})									
	0.4M			0.5M			0.6M		
CONC	303K	313K	323K	303K	313K	323K	303K	313K	323K
0.2g/L	1.5414	1.9121	2.6593	2.0686	2.3300	3.1886	2.0557	2.3557	3.0921
0.4g/L	1.0236	1.4971	2.6486	1.5036	1.7736	3.1243	1.5343	2.0150	3.0786
0.6g/L	0.9229	1.4886	2.3936	1.3393	1.5921	2.8200	1.3064	1.8871	2.9486
BLANK	2.2357	2.4657	2.8600	2.3026	2.7164	3.3907	3.0614	2.8143	3.1343

Table 6. *Inhibition efficiency of methanol leaf extract of Irvingia gabonensis in various concentrations of H_2SO_4 at 303K, 313K and 323K.*

PERCENTAGE INHIBITION EFFICIENCY									
	0.4M			0.5M			0.6M		
CONC	303K	313K	323K	303K	313K	323K	303K	313K	323K
0.2g/L	31.0552	22.4520	7.0175	10.1624	14.2247	5.9604	32.8510	16.2953	1.3464
0.4g/L	54.2157	39.2830	7.3916	34.6999	34.7077	7.8568	49.8824	28.3765	1.7771
0.6g/L	58.7199	39.6276	16.3076	41.8353	41.3893	16.8313	57.3267	32.9460	5.9248

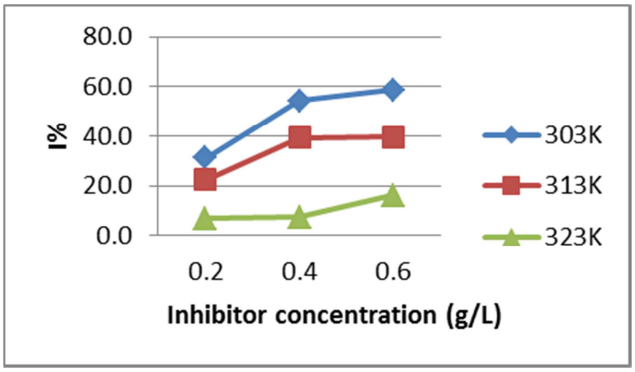

Figure 1. *Variation of inhibition efficiency (I%) with concentrationof inhibitor at 303K, 313K and 323K in 0.4M H_2SO_4.*

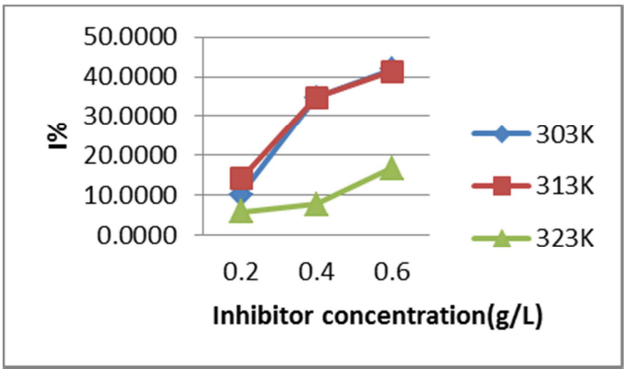

Figure 2. *Variation of inhibition efficiency (I%) with concentration of inhibitor at 303K, 313K and 323K in 0.5M H_2SO_4.*

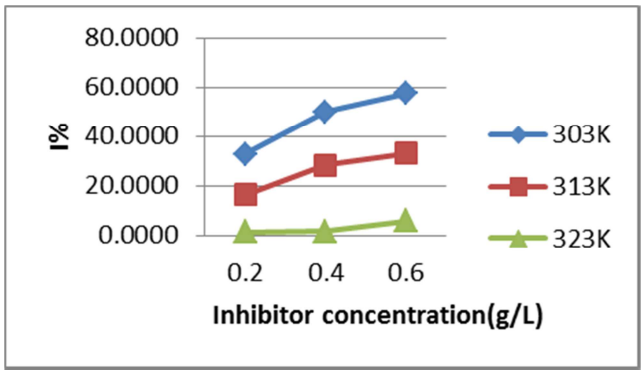

Figure 3. *Variation of inhibition efficiency (I%) with concentrationof inhibitor at 303K, 313K and 323K in 0.6M H_2SO_4.*

It was observed from the Figures 1 to 3 that Inhibition efficiency increased with increase in concentration of methanol leaf extracts of *Irvingia gabonensis* [same as reported by 22] but decreased with increase in temperature and acid concentration with maximum inhibition efficiency obtained as 58.72% for 0.6g/L concentration of extract in 0.4M H_2SO_4 at 303K. Increase in Inhibition efficiency with increasing temperature is suggestive of chemical adsorption while decrease in inhibition efficiency with increase in temperature (as obtained in this study) is suggestive of physical adsorption [23]. The decrease in inhibition efficiency with rise in temperature may be attributed to a possible shift of inhibitor molecules from the sites they

occupy on the metal surface as a result of increased agitation of the media. Also the roughening of the metal surface as a result of increased corrosion can reduce the ability of the inhibitor to adsorb on the metal surface [23]. This therefore suggests that the adsorption of the extract may be physical in nature.

3.3. Kinetic and Thermodynamic Considerations

The dependence of corrosion rate on temperature is given by the Arrhenius' equation:

$$lnk = lnA - \frac{E_a}{RT} \quad (6)$$

Where k is the rate constant, A is the frequency factor, R is the universal gas constant, T is the absolute temperature and E_a is the activation energy. A plot of lnk against 1/T gave a slope ($-E_a/R$) from which the activation energy values in Table 7 were obtained.

$\Delta H^{\ddagger}$ and $\Delta S^{\ddagger}$ values were obtained from the Eyring equation:

$$ln\left(\frac{k}{T}\right) = ln\left(\frac{k_B}{h}\right) + \left(\frac{\Delta S^{\ddagger}}{R}\right) - \left(\frac{\Delta H^{\ddagger}}{RT}\right) \quad (7)$$

Where k is corrosion rate constant, k_B is Boltzmann's constant, T is absolute temperature, h is Plank's constant, $\Delta S^{\ddagger}$ and $\Delta H^{\ddagger}$ are changes in entropy and enthalpy of activation respectively.

Table 7. *Calculated values of activation energy (Ea), change in enthalpy of activation ($\Delta H^{\ddagger}$), change in entropy of activation ($\Delta S^{\ddagger}$) and Average Ea for corrosion of mild steel in H_2SO_4 in the presence and absence of different concentrations of methanol leaf extract of Irvingia gabonensis.*

	0.4M				0.5M				0.6M			
	E_a	Avg E_a	$\Delta H^{\ddagger}$	$\Delta S^{\ddagger}$	E_a	Avg E_a	$\Delta H^{\ddagger}$	$\Delta S^{\ddagger}$	E_a	Avg E_a	$\Delta H^{\ddagger}$	$\Delta S^{\ddagger}$
BLANK	10.01		7.41	-271.41	15.75		13.14	-252.27	0.88		1.70	-299.05
0.2g/L	22.18	33.22	19.57	-234.46	17.55	25.79	14.94	-247.37	16.58	26.01	13.97	-250.57
0.4g/L	38.65		36.05	-183.60	29.64		27.03	-210.44	28.32		25.71	-214.30
0.6g/L	38.83		36.22	-183.63	30.18		27.57	-209.63	33.14		30.53	-199.64

From Table 7, E_a values in the presence of extract are higher than in the blank solution indicating a slower corrosion process in the presence of extract. The higher E_a in the presence of extract is also indicative of physical adsorption. More so, physical adsorption is inferred from the E_a values in Table 7, as they are less than 80KJ/mol [24-25]. Physical adsorption results from electrostatic attraction between charged metal surface and charged species in the solution in contact with the metal surface [26]. The positive $\Delta H^{\#}$ values show the endothermic nature of the dissolution process, whereas the large negative $\Delta S^{\#}$ values implies that the activated complex is the rate determining step, rather than the dissociation step [27].

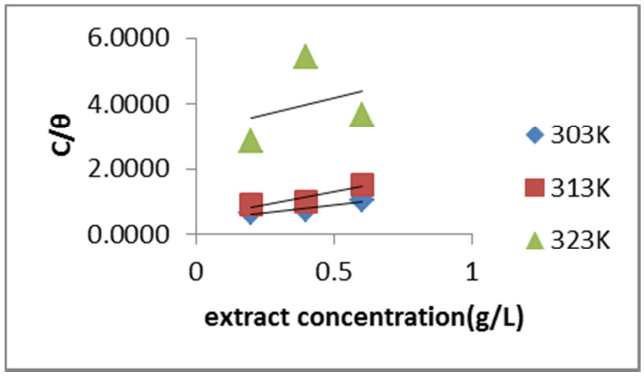

Figure 4. *Langmuir plot for methanol leaf extract ofIrvingia gabonensis in 0.4M H_2SO_4.*

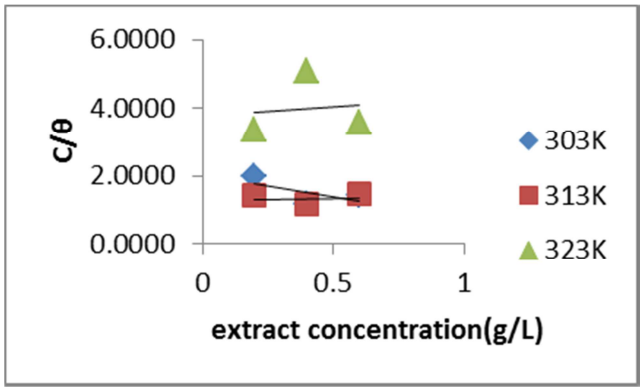

Figure 5. *Langmuir plot for methanol leaf extract of Irvingia gabonensis in 0.5M H_2SO_4.*

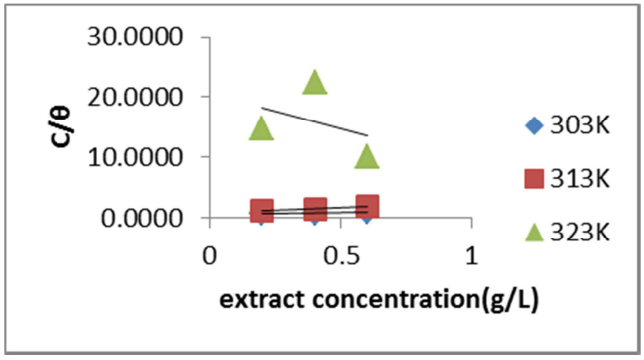

Figure 6. *Langmuir plot for methanol leaf extract ofIrvingia gabonensis in 0.6M H_2SO_4.*

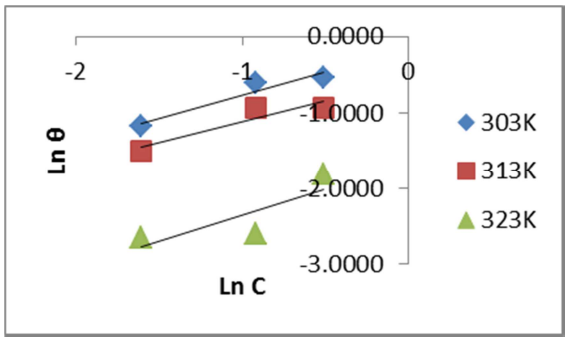

Figure 7. *Freundlich plot for methanol leaf extract of Irvingia gabonensis in 0.4M H_2SO_4.*

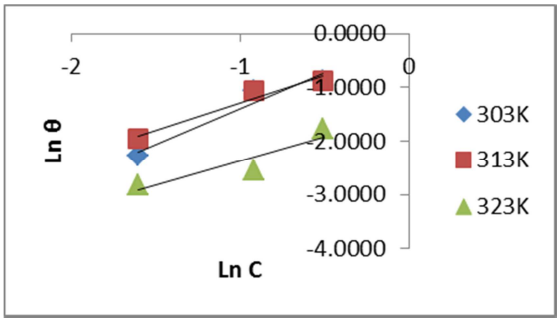

Figure 8. *Freundlich plot for methanol leaf extract ofIrvingia gabonensis in 0.6M H_2SO_4.*

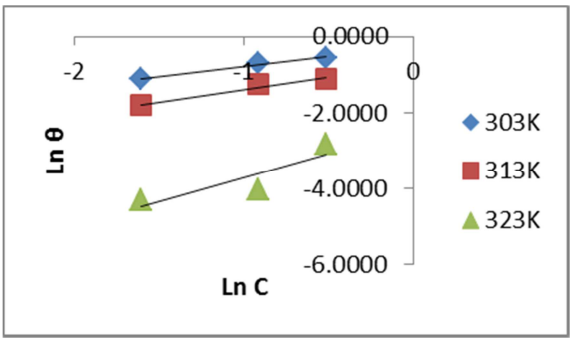

Figure 9. *Freundlich plot for methanol leaf extract ofIrvingia gabonensis in 0.5MH_2SO_4.*

To further ascertain the nature of adsorption, the surface coverage (θ) for the methanol leaf extracts in H_2SO_4 for mild steel corrosion at temperatures of 303K, 313K and 323K were fitted into Langmuir and Freundlich adsorption isotherm models and correlation coefficient (R^2) were used to determine best fit (values of R^2 closest to unity).

Figures 4-6 show Langmuir isotherms which are plots of C/θ against C where C= extract concentration, θ= surface coverage. The ΔG^o_{ads} values were calculated from the equation,

$$\Delta G^o_{ads} = -RT\ln(55.5\ K_{ads}) \quad (8)$$

Where R is the universal gas constant, T is absolute temperature and 55.5 is the molar heat of adsorption of water.

From the derived values of the Langmuir isotherms as found in Table 8, it was observed that the isotherm provides a good representation of the adsorption behavior of methanol leaf extract of *Irvingia gabonensis*in 0.4M and 0.6M H_2SO_4 at 303K and 313K. Thus, suggesting a monolayer adsorption of the extract molecules on the metal surface [28]. From the calculated values as observed in Table 8, ΔG^o_{ads} was found to be negative, and less than 40 KJ/mol indicating that the adsorption of the methanolic leaf extracts of *Irvingia gabonensis* was spontaneous at 303K and 313K suggesting a physical adsorption mechanism [13].

Figures 7-9 show Freundlich isotherms which are plots of Lnθ against LnC. From the derived values of the Freundlich isotherms obtained from Table 9, better correlation coefficient (R^2) were observed for the isotherms of methanol leaf extracts of *Irvingia gabonensis* at higher temperature of 323K as compared to the Langmuir isotherm in all acid concentrations. The values of the slope (1/n) obtained from the isotherms is also indicative of the ease of adsorption. Usually, when $0 < 1/n < 1$, adsorption is believed to be easy, and moderate or difficult when $1/n = 1$ or $1/n > 1$ respectively [29].

Table 8. *Langmuir adsorption parameters for methanol leaf extractsof Irvingia gabonensis on mild steel in 0.4M, 0.5M and 0.6M H_2SO_4 at 303K, 313K and 323K.*

	303K			313K			323K		
	K_{ads}	R^2	ΔG^o_{ads}	K_{ads}	R^2	ΔG^o_{ads}	K_{ads}	R^2	ΔG^o_{ads}
0.4M	2.3641	0.922	-12.28	1.9305	0.895	-12.162	0.3175	0.1	-7.704
0.5M	0.4873	0.415	-8.306	0.7734	0.018	-9.782	0.2636	0.012	-7.204
0.6M	2.6247	0.995	-12.55	1.1223	0.952	-10.751	0.0488	0.141	-2.675

Table 9. *Freundlich adsorption parameters for methanol leaf extractsof Irvingia gabonensis on mild steel in 0.4M, 0.5M and 0.6M H_2SO_4 at 303K, 313K and 323K.*

	303K			313K			323K		
	K	slope (1/n)	R^2	K	slope (1/n)	R^2	K	slope (1/n)	R^2
0.4M	0.8521	0.6030	0.9340	0.5701	0.5480	0.8760	0.1907	0.6920	0.6630
0.5M	0.9531	1.3400	0.9380	0.7573	1.0060	0.9520	0.2267	0.8860	0.8380
0.6M	0.7679	0.5170	0.9830	0.4829	0.6570	0.9710	0.0853	1.2430	0.7720

3.4. Gasometric Measurements

Table 10. *Rate of hydrogen evolution (ml/min) and Corrosion rate of mild steel in 2.5M H_2SO_4 at 298K, 303K and 308K in the presence and absence of methanol leaf extract of Irvingia gabonensis.*

HYDROGEN EVOLUTION RATE/CORROSION RATE IN 2.5M H_2SO_4						
	298K		303K		308K	
CONC	HE (mL/min)	WL ($x10^{-3}$)($mgcm^{-2}hr^{-1}$)	HE (mL/min)	WL ($x10^{-3}$)($mgcm^{-2}hr^{-1}$)	HE (mL/min)	WL ($x10^{-3}$)($mgcm^{-2}hr^{-1}$)
0.2g/L	0.4043	10.9286	1.0421	15.8286	1.4086	16.7143
0.4g/L	0.4100	11.1857	0.9400	13.6857	1.3400	16.5714
0.6g/L	0.4121	11.1143	0.6400	12.5429	1.3214	15.6429
BLANK	0.5679	12.6714	1.3771	17.7714	1.8136	19.4571

Table 11. *Inhibition efficiency of methanol leaf extracts of Milicia excelsa on mild steel corrosion in 2.5M H_2SO_4 at 298K, 303K and 308K.*

PERCENTAGE INHIBITION EFFICIENCY (2.5M H_2SO_4)						
	298K		303K		308K	
CONC	HE	WL	HE	WL	HE	WL
0.2g/L	28.81	13.75	24.33	10.93	22.33	14.1
0.4g/L	27.81	11.72	31.74	22.99	26.11	14.83
0.6g/L	27.43	12.29	53.53	29.42	27.14	19.5

From the plots of volume of hydrogen evolved against time, it was observed that volume of gas evolved decreased with increase in extract concentration. An increase in temperature resulted also in an increase in volume of hydrogen evolved. Measurements obtained from both the weight loss and gasometric methods in 2.5M H_2SO_4 showed similar trends of increase or decrease along the table suggesting that both methods give an accurate representation of the corrosion process. However, the gasometric method gave higher values than the weight loss method. The maximum inhibition efficiency for the gasometric method is 53.53 in 0.6g/L inhibitor concentration at 303K, while the maximum inhibition efficiency for the weight loss method is 29.42 in 0.6g/L inhibitor concentration at 303K.

4. Conclusion

The findings of this study show that the methanol leaf extract of *Irvingia gabonensis* acts as green inhibitor for the corrosion of mild steel in H_2SO_4. The characterization of the plant extracts by qualitative method revealed the presence of alkaloid, tannins, saponins, flavonoids, terpenes and steroids which showed that the plant extracts have the potential of being used as inhibitors for mild steel in acidic medium. It was found that the corrosion rate of the mild steel decreases with increase in inhibitor concentration. The results of the weight loss measurements show maximum inhibition efficiency to be 58.71% for 0.6g/L inhibitor concentration at 303K in 0.4M H_2SO_4, 41.84% for 0.6g/L inhibitor concentration at 303K in 0.5M H_2SO_4 and 57.32% for 0.6g/L inhibitor concentration at 303K in 0.6MH_2SO_4. The effect of immersion time on inhibition efficiency shows that the inhibitor is effective even for longer immersion periods at low concentration. The E_a values obtained were found to be less than 80KJ/mol suggesting a physical adsorption mechanism. The Langmuir isotherm model presented a good fit for the adsorption behaviour of the extract at 303K and 313K suggesting monolayer coverage of the metal surface with negative ΔG^o_{ads} values less than 40 KJ/mol, indicative of a spontaneous reaction and a physical adsorption mechanism. The Freunlich isotherm had better correlation at 323K, indicating varying ease of adsorption obtained from the values of 1/n. Gasometric and weight loss measurements in 2.5M H_2SO_4 show, that both methods give a good representation of the corrosion process and the extract corrosion inhibition potentials.

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