The Corrosion Inhibition of Mild Steel in 0.5m Phosphoric Acid and Crown Cork in Water By Folic Acid

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Abstract: ***The corrosion inhibition of mild steel in 0.5M H_3PO_4 solutionand crown cork in water by folic acid was investigated using weight loss experimentat different temperature (30^0C, 40^0C, 50^0C). The finding indicates that, folic acid acts as an effective corrosion inhibitor for mild steel in phosphoric acid solutionand crown cork in water at 10^0C. The inhibition process was attributed to the formation of an adsorbed film of inhibitor on the surface of mild steel which protect the metal from corrosion. The inhibition efficiency and surface coverage of mild steel increased with increasing concentration of folic acid, but reduced as temperatureincreases. The kinetic treatment of the results confirms a first order reaction kinetics with respect to corrosion of mild steel in 0.5M H_3PO4 andthe crown cork in waterin the present of folic acid. The adsorption isotherm model which was determined from the results obtained from weight loss experiment performed on mild steel coupon in phosphoric acid solution fits the Langmuir model. The inhibitive ability of folic acid was attributed to the presence of oxygen, nitrogen and aromatic pyrimidine in its structure.***

Keywords: Corrosion, Folic acid, Inhibition, Mild steel, Phosphoric acid.

1. Introduction

Mild steel is an alloy of iron that contains the following elements and percentages: Carbon (0.05 – 0.15%), Silicon (0.18%), Phosphorous (0.04%), Sulphur (0.02%), Manganese (0.70 – 0.48%), and Iron, the rest of the composition (about 98.9%) [1]. Mild steel remains one of the alloy that is heavily sort for in the industry because of its essential nature. One of the most challenging and difficult task for industries are the protection of mild steel from corrosion [2, 3]. Corrosion is a serious problem that continues to be a great threat to the relevance of metals in a wide range of industrial applications and products. This is because it results in the deterioration and eventual failure of component and system both in processing and manufacturing industries [4].

Acid media are always used in the study of corrosion of mild steel owing to the fact that acids (HCl, H_2SO_4, H_3PO_4, etc.) are commonly used for pickling, industrial cleaning, descaling etc. [4]. Corrosion damages resulted from exposure of metals to these media lead to decrease in functional Properties of materials. In the effort to mitigate mild steel from corrosion, various methods have been employed, such as upgrading materials, blending of production fluid, process control and chemical inhibition [5]. A number of chemical inhibitors [6-8] are known to be applicable as good corrosion inhibitors of metals, but the use of chemical inhibitors is depleting, due to strict environmental regulation and toxic effect of the chemical compound on human and animal life. Hence, there is need to develop a new class of corrosion inhibitors with low toxicity, eco-friendliness, good efficiency, acceptability and low cost etc [9]. A lot of natural products were previously used as corrosion inhibitor for different metals in various environments [10-15] and there optimum concentrations were reported [16]. Theirsuccess indicates that the plant extract could serve as effective corrosion inhibitors. It has also been established that corrosion inhibition occurs via adsorption of the organic molecule in these natural products on the corroding metal surface. And that the efficacy of the corrosion inhibition depends on the mechanical, structural and chemical nature of the adsorption layer formed under particular condition. Extracts of plant material contain a wide variety of organic compounds; most of them contain heteroatoms such as P, N, S& O [17]. These atom coordinate with the corroding metal atom (their ion), through their electron and prevent corrosion by formation of protective layer on the metal surface [18, 19].

The purpose of the study is to reveal the use of folic acid to combat the corrosion of mild steel in phosphoric acid at different temperature and crown cork immersed in 10^0C cold water at a given period.

Folic acid is an organic compound with the molecular formula $C_{19}H_{19}N_7O_6$, relative molecular mass of 441.0, solubility in water is 1.6mg/l at 25^0C and melting point 250^0C. Folic acid is a synthetic form of folate which is a generic form of a naturally occurring family of B group vitamins which contain an aromatic pteridine ring linked to P-amino-benzoic acid and one or more glutamate residue[20]. Folic acid is found naturally in variety of food including green leaf, vegetable, fruit, liver, and yeast.It is also used for food supplement [20].

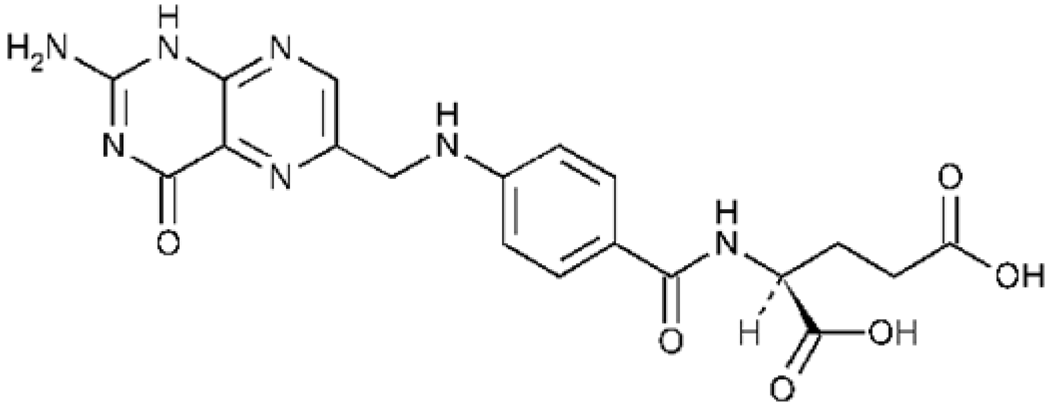

Figure 1: Structure of Folic acid

Some of the functional group in the structure of folic acid are:
1) Carboxylic acid (- COOH)
2) Amide (- $CONH_2$)
3) Amine (- NH_2)
4) Hydroxyl – (OH)
5) Hetrocyclic containing nitrogen

Due to of the presence of nitrogen, oxygen and heterocyclic aromatic pyrimidine in the structure of folic acid, it is imperative that folic acid can be used as an organic inhibitor of mild steel in phosphoric acid. Folic acid has been vastly use in medicine for curative purposes, the essence of the paper is to diversify the use of folic acid in the industry. Folic acid is environmentally safe, and so the advantage of using folic acid as corrosion inhibitor is for both economic and environmental benefits. Mild steel was chosen in the study because of its vast application in the industries while crown cork is used in breweries industries.

Figure 2: Crown cork bottle cap.

Crowncorks get corroded when refrigerated (i.e in cold andhigh humidity environment) and its corrosion inhibition becomes very necessary. Hence, this study aims at inhibiting the corrosion of mild steel and crown cork using folic acid.

2. Methods

2.1 Preparation of Mild Steel Coupon and the Crown Cork

The commercial mild steel of thickness 1.0mm with a dimension of 3 by 3mm used for this study was obtained at the World Bank engineering workshop, university of Port-Harcourt, Choba, Port-Harcourt. The crown corks used for this study were obtained from Coca-Cola bottling company, Trans-Amadi Industrial layout, Port-Harcourt. Cleaning and degreasing was done with high grade acetone followed by rinsing with distilled water.

2.2 Corrosive Medium

0.5M concentration of phosphoric acid was used as corrodent to explore inhibition potential of different concentration of folic acid. Thereafter water was used as a corrodent in order to test the inhibitive efficiency of folic acid on crown cap.

2.3 Preparation of test Solution

The inhibitor, folic acid was purchased from the pharmaceutical store. The following masses (0.005g, 0.010g, 0.015g, 0.020g and 0.025g) were each dissolved in 100ml of distilled water.

2.4 Weight Loss Measurement

Different weighted mild steel specimens were immersed in 50ml of 0.5M of phosphoric acid and 50ml of different concentration of folic acid (1.13×10^{-4}m, 2.27×10^{4}M, 3.4×10^{-4}M. 4.54×10^{-4}, and 5.67×10^{-4}M). All the different concentration of folic acid are mixed respectively with 50ml of 0.5M of phosphoric acid in beaker and mild steel coupon allowed to stay for the intervals of 30minutes for a duration of 4hours (240minutes) before the mild steel coupons was reweighed.

The experiment was carried out at different temperature of 30°C, 40°C and 50°C. The weights of the mild steel coupons were recorded in order to determine the weight loss of the metal. Inhibition efficiency was calculated using the equation:

$$\text{The percentage inhibition efficiency} = \frac{\Delta W\ \text{Blank} - \Delta W\ \text{Inhibitor}}{\Delta W\ \text{Blank}} \ x\ 100 \qquad (1)$$

Surface coverage is an important parameter to known the interaction of inhibitor with mild steel surface, it was determined using the formula:

$$\theta = \frac{Wo - W1}{Wo} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where W_o and W_i are weight loss of mild steel in blank and inhibitor solution respectively. Corrosion rate of mild steel is a measure of the effectiveness of inhibitor and directly related with weight loss in corrosive medium for estimated period. It was computed from the following formula:

$$Cr = \frac{87.6W}{td} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Where Cr is corrosion rate in mm/yr, w – weight loss per unit area of specimen, t – exposure time, and d – density of mild steel (density of mild steel 7.85gcm^{-3}).

2.5 Method of Determining Corrosion Inhibition in Crown Cork

The folic acid concentration that gave highest percentage inhibition in mild steel - phosphoric acid experiment was used to test corrosion inhibition of folic acid on crown cork at 10^{0}C. Weighted crown cork was immersed in 5.67 x 10^{-4}M of folic acid solution and blank solution of water and allowed for 14days. The crown cap was weighted at interval of one day and the weighted loss was recorded.

3. Results and Discussion

Table1: Corrosion Parameter for mild steel in 0.5M H_3PO_4 with different concentration of folic acid at different temperature

	30^{o}C			40^{o}C			50^{o}C		
Inhibition concentration	Surface Coverage	Corrosion rate	%I	Surface Coverage	Corrosion rate	%I	Surface Coverage	Corrosion rate	%I
1.1 3x10^{-4-}	0.4368	1.76	43.68	0.3864	1.87	38.64	0.3549	1.94	35.49
2.27x10^{-4}	0.6607	1.04	66.67	0.6275	1.14	62.76	0.5932	1.12	59.32
3.40x10^{-4-}	0.8544	0.46	87.44	0.8240	0.54	82.40	0.7921	0.63	73.21
4.45 x 10^{-4-}	0.9079	0.29	90.79	0.8795	0.37	87.95	0.8561	0.43	85.61
5.67 x10^{-4-}	0.9600	0.12	96.00	0.9313	0.27	93.13	0.9220	0.23	92.20

Table 2: Crown cork in cold water without folic acid at 10^{o}C

Time (days)	Initial weight W1	Final weight WF	Weight lossΔW	Change in weight W1-ΔW	Log W1-ΔW	% Inhibition
0	0.072	0.072	0	0.070	-1.1427	-
4	0.072	0.068	0.007	0.065	-1.1675	-
7	0.072	0.065	0.007	0.065	-1.1871	-
11	0.072	0.063	0.009	0.063	-1.2007	-
14	0.072	0.062	0.010	0.062	-1.2076	-

Table 3: Crown Cap in cold water with 5.67x10^{-4}M folic acid at 10^{o}C

Time (days)	Initial weight W1	Final weight WF	Weight lossΔW	Change in weight W1-ΔW	Log W1-ΔW	% Inhibition
0	0.068	0.068	0	0.068	-1.1675	100
4	0.068	0.067	0.001	0.067	-1.1739	85.71
7	0.068	0.066	0.002	0.066	-1.1805	71.42
11	0.068	0.065	0.003	0.065	-1.1871	66.67
14	0.068	0.064	0.004	0.064	-1.1938	60.00

Table 1 shows the variation of surface coverage, corrosion rate and efficiency of inhibition at 30^{o}C, 40^{o}C and 50^{o}C respectively. Increase in concentration of inhibitor lead to increase in surface coverage, decrease in corrosion rate and increase in percentage inhibition. It is also evident from table 1 that increase in temperature decreases the surface coverage and does not favour the inhibition by the folic acid.

Table 2 displays the variation of the weight loss of crown corkin cold water without folic acid at 10^{o}Cwithin the duration of 14days. Prolong exposure increases the weight loss. The variation of weight loss in crown cap in water with 5.67x10^{-4}M of folic acid at 10^{0}c is portrayed in table 3. The weight loss in table 2 is greater than the one in table 3. This drastic reduction in the weight loss indicates the inhibitory action of folic acid.

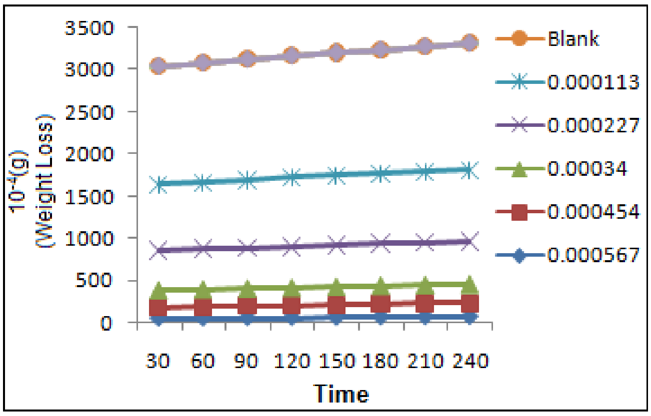

Figure 3: Variation of weight loss with time for mild steel coupon in 0.5M solution containing different concentration of folic acid at 30^{o}C

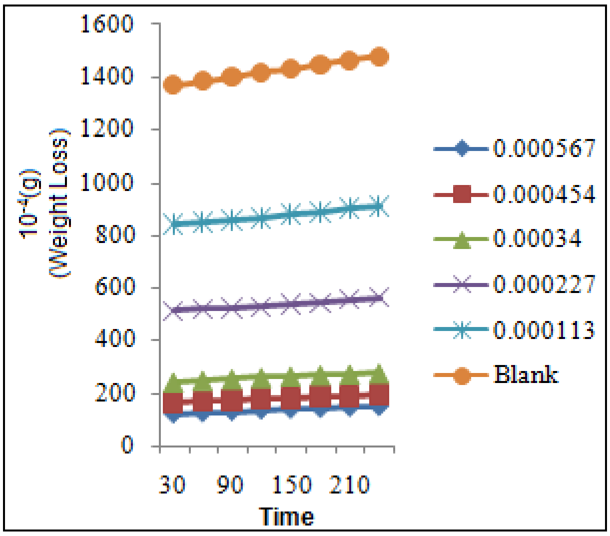

Figure 4: Variation of weight loss with time for mild steel coupon in 0.5M solution containing different concentration of folic acid at 40°C

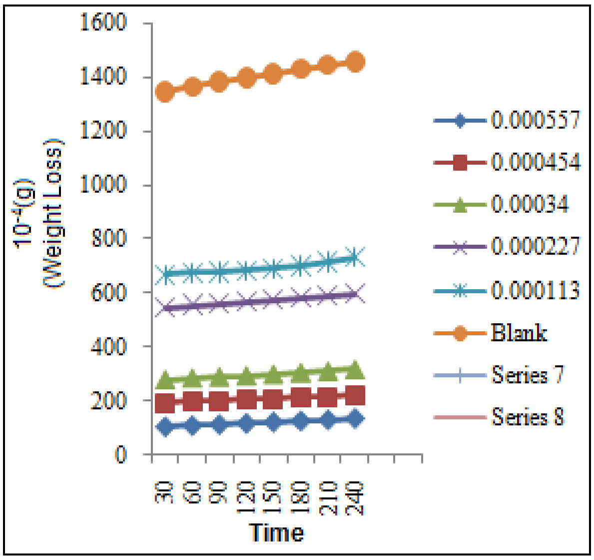

Figure 5: Variation of weight loss with time for mild steel coupon in 0.5M solution containing different concentration of folic acid at 50°C

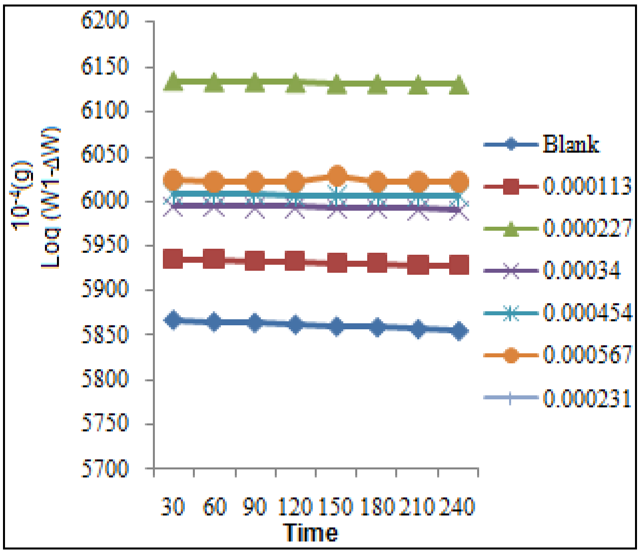

Figure 6: Variation of Log (W1-ΔW) with time for mild steel coupon in 0.5M of H_3PO_4 solution with different concentration of folic acid at 30°C

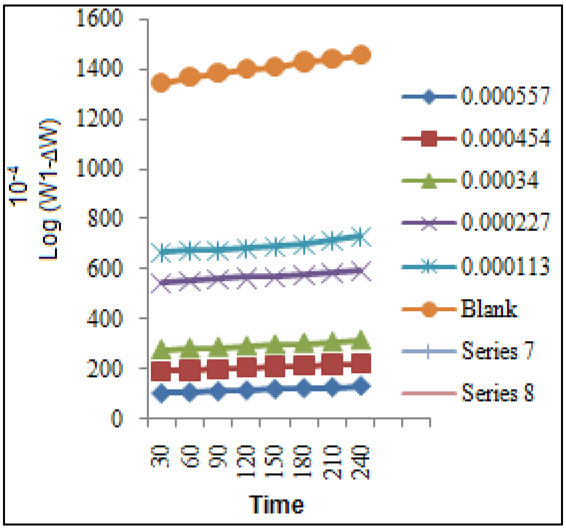

Figure 7: Variation of Log (W1-ΔW) with time for mild steel coupon in 0.5M of H_3PO_4 solution with different concentration of folic acid at 40°C.

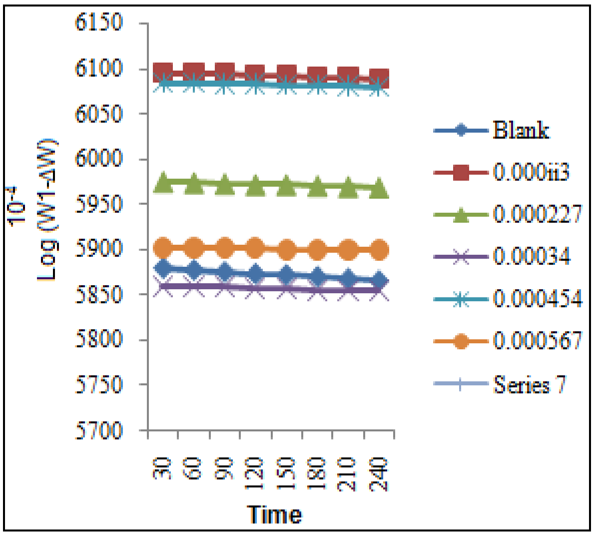

Figure 8: Variation of Log (W1-ΔW) with time for mild steel coupon in 0.5M of H_3PO_4solution containing different concentration of folic acid at 50°C.

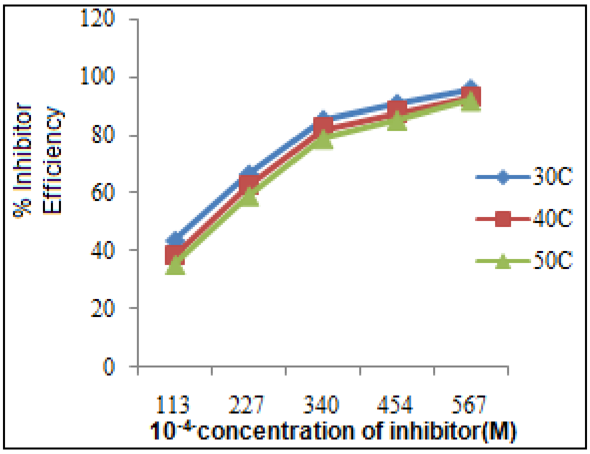

Figure 9: Variation of inhibitor efficiency with inhibitor concentration for mild steel coupon in 0.5M solution containing folic acid at three different temperatures

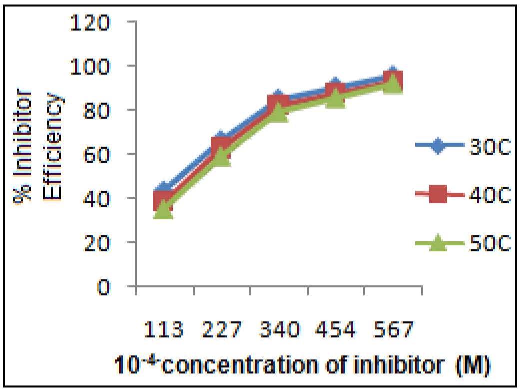

Figure 10: Variation of inhibitor efficiency with inhibitor concentration for crown cork in 0.5M solution containing folic acid at three different

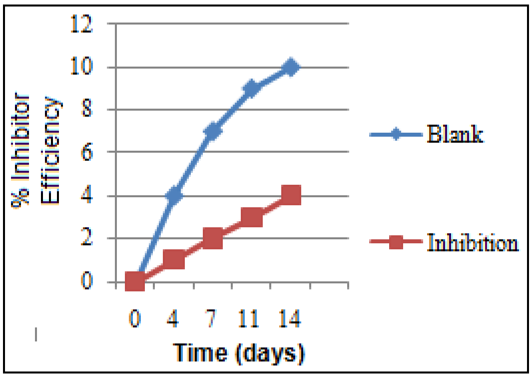

Figure 11: Variation of weight loss with time for crown cork in water solution containing $5.67x10^{-4}$M of folic acid inhibitor at 10^0c.

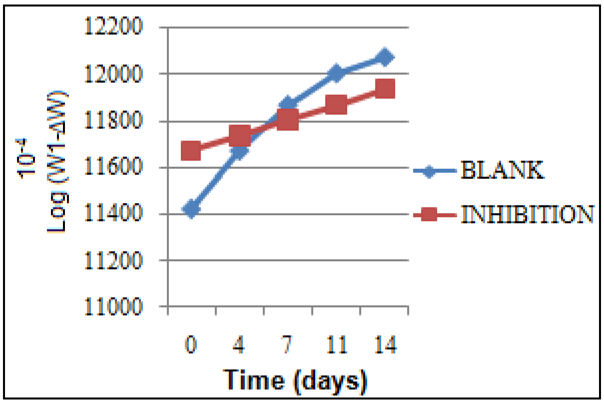

Figure 12: Variation of Log (W1-ΔW) with time forcrown cork in water with different concentration of folic acid inhibitor at 10^0c.

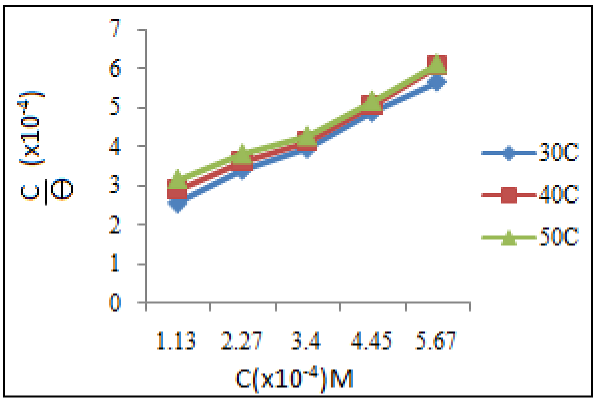

Figure 13: Langmuir Isotherm adsorption of folic acid on mild steel in 0.5M H_3PO_4.

3.1.1 Inhibitory Action of Folic acidon the corrosion of mild steel in 0.5M H_3PO4

Figs. 3-5 shows that folic acid is a corrosion inhibitor for mild steel in 0.5M phosphoric acid solution, since there was a general decrease in weight loss at the end of the corrosion monitoring process at the temperature studied.

From the variation of weight loss with time of exposure of mild steel in 0.5M H_3PO4 (blank) at 30°C (fig. 3) compared with those containing inhibitors, there is a remarkable decrease in weight loss which indicates that corrosion inhibitor is effective. At 40°C, fig 4, shows reduction in weight losses of mild steel coupon when the concentration of folic acid is increased within the range of $1.13x10^{-4}$M to $5.67x10^{-4}$M. Fig. 5also shows a reduction in weight losses of mild steel coupon at 50°C. This depicts that at high temperature of 50^0C, folic acid can still offer some inhibitive properties.

3.1.2 Effect of temperature on the inhibition efficiency of folic acid

Fig. 9 shows the effect of increase in temperature on the inhibition efficiency of folic acid. From the graph, it is obvious that as the temperature increases from 30 – 50°C, the inhibitory efficiency decreases.

3.1.3 Kinetic treatment of weight losses of mild steel coupon in 0.5M H_3PO4

Figs. 6-8show the variation of log (wi-Δw) with time for mild steel coupon in 0.5M H_3PO4 solution containing different concentration of folic acid at different temperature (30– 50°C). The initial weight loss of mild steel coupon at time (t) is represented with W_1, weight losses are Δw, and the weight change at t_1 is (wi --Δw). The plot of log (wi--Δw) against time at the temperatures studied showed a linear variation which confirms a first order reaction kinetics with respect to corrosion of mild steel in 0.5M H_3PO_4 in the present of folic acid.

3.1.4 Inhibitory action of folic acid on the corrosion of crown cap in water at 10^0c

Fig 10 shows that folic acid is a corrosion inhibitor of crown cap in water at 10°C. From the graph (fig 10) there was a general weight losses in crown corkimmersed in water at 10°C without and with the presence of folic acid. The weight loss difference between blank and solution containing $5.67x10^{-4}$M of folic acid reveals the inhibitive ability of folic acid (fig. 11). Fig. 12 shows a linear variation of first order reaction kinetics when log (w_1 - Δw) was plotted against time for exposure in days.

3.1.5 Adsorption Studies

The Langmuir adsorption isotherm can be expressed by $^C/_Θ$ = $^1/_K$ – C. Where inhibition concentration is C, the fraction of the surface covered Θ, adsorption coefficient k_{ads}. The linear graph between $^C/_Θ$ versus C in fig. 13 show that folic acid obeys the Langmuir isotherm at the concentration and temperature of the metal. It supports the assertion that the mechanism of corrosion inhibition is due to the formation and maintenance of a protective film on the metal surface and the additive covers both the anode and cathode sites through uniform adsorption following Langmuir isotherm. The inhibitory action of folic acid should be attributed to the adsorption of its component on the mild steel surface. The presence of N, O, C = O, N-H, C-O, -OH and N-hetero cyclic ring in folic acid are responsible for the inhibitive effect of folic acid.

4. Conclusion

Folic acid is an effective inhibitor of corrosion of mild steel in phosphoric acid.The oxygen, nitrogen atom and aromatic pyrimidinein it are electron rich and served as good adsorption site on the mild steel surface. These are responsible for inhibitory action of folic acid.Its inhibition efficiency decreased, as the temperature increases, which indicates that physical adsorption predominate mechanism of inhibition.The adsorption fits the Langmuir adsorption model. Folic acid also inhibits the corrosion of crown cork in waterin cold environment (about 10^oC). Since folic acid is a relatively cheap, non-toxic effective corrosion inhibitor, it can be applied in bottling company to reduce the extent of corrosion in crown cork during their storage in refrigerator. This will likely eliminate the corrosion product depositat the tip of the bottle when consumers open the bottle. Some of the limitation that this inhibitor might face is the operating condition (i.e high temperature and pressure). Therefore, it should not be exposed to condition that will denature the molecule of folic acid and reduce its effectiveness as corrosion inhibitor.

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