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INVESTIGATION OF CORROSION BEHAVIOUR OF IRON IN FOUR DIFFERENT ORGANIC ACIDS

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ABSTRACT
The corrosion behaviour of iron in four different organic acid have been investigated using weight loss method. The acids used includes succinic, formic, maleic and citric acid. The results of the corrosion rates of iron in $C_4H_4O_4$, $C_4H_6O_4$, HCOOH and $C_6H_8O_7$ are 1.125, 1.100, 0.800 and 0.500 mg $cm^{-2}h^{-1}$ respectively. The rate of corrosion increases with increasing concentration of acid and with increase in temperature. The study shows that the rate of corrosion follows the order of reactivity $C_4H_4O_4 > C_4H_6O_4 >$ HCOOH $> C_6H_8O_7$.
Keyword: Iron, weight loss, corrosion rate.

INTRODUCTION

Corrosion is defined as the destruction or deterioration of material because of reaction with its environment which is often restricted to metals but the corrosion engineers consider both metals and non-metals (Venkatachalam *et al.,* 2011). Corrosion attack infrastructures such as bridges, pipelines, vehicles, utilities (electrical, water, telecommunications, and nuclear power plant), engineering and manufacturing, chemical industry, and the oil and gas industry (Ugi *et al.,* 2017). However, the acids responsible for metal surface corrosion through acid attack mechanisms, resulting in millions of dollars being spent annually on maintenance. It is reported that, with proper corrosion prevention techniques, 25–30% of maintenance costs can be avoided (Isam *et al.,* 2018). Corrosion of metal is an electro-chemical reaction between the metal and its environment in which the metal revert to iron oxide (Usman *et al.,* 2015). The electro-chemical process causes a gradual alteration or wearing away of the metal surface and since the process returns the metal to its stable thermodynamic state, the action is considered as a degradation of the material (Wang and Zhang 2011). Corrosion of metal components has been recognized as a major problem in many engineering applications, due to failure of engineering systems such as brittle fracture and fatigue (Hurlen *et al.,* 2013). Iron is known to be the best preferred materials for industry as it has many industrial applications ,Because It is easy availability, excellent physical properties, stronger and more workability, low cost, uncomplicated fabrication made it to use in different applications like pipeline materials in oil and gas industry water pipe lines (Noor *et al.,* 2008).The corrosive nature of acids also has its applications include chemical cleaning and processing, acid treatment of oil wells and other applications (Soltani *et al.,*2016). To control the corrosion, good understanding of the effect of operating conditions such as different types of acids, concentrations and different heat treatment procedures on the corrosion behavior is required (Umuran *et al.,* 2015). In addition different environment and other tend to effect the corrosion of iron. Many studies have been reported in the corrosion rate of various organic acids in different environment (Musa and Ghoneium 2012).But yet here is not full investigation on the corrosion behaviour of iron in organic acid containing carbonyls, carboxylic acid functional groups. Therefore, in this study corrosion rate of iron in succinic acid, maleic acid, citric acid and formic acid was studied at different concentration and temperature using weight loss method.

MATERIAL AND METHODS

Materials and Methods

Iron sheets (Fe 99% purity) was obtained from Metal Focus Fabrication Technology incubation Canter Complex, Kano State Nigeria .Each sheet was press cut in 2cm x 2 cm × 0.1cm dimensions. The iron coupons were polished with 240, 620, 800 and 1000 grade of different emery paper. The coupons were degreased in ethanol and dried in acetone, kept in desiccator prior to use.

Corrosive Media Preparation

A stock solution of Succinic acid (97%, 1.56g/cm^3), maleic acid (99% 1.59 g/cm^3), citric acid (99%, 1.67 g/cm^3), and formic acid (96%, 1.22 g/cm^3) where prepared by using double distilled water.

The acid solutions of required concentrations of 0.1, 0.2, 0.3, 0.4, 0.5 and 0.6M were prepared by appropriate dilutions.

Weight loss Measurement

During the weight loss experiments, the weight of iron coupon was weight (W_1) and suspended completely in 0.1 -0.6M solutions of different acid in 100ml beaker containing 50ml of acids solution. The coupons were retrieved after 30, 60, 90, 120, 150 and 180 min, washed with distilled water dried in acetone and reweighed (W_2). Similarly the effect of temperature was studied by immersion the prepared weighted iron coupon in 0.6M corrodent concentration at 308, 313, 318, 323 and 328K for 3hrs. The difference in weight and corrosion rate was calculated using equation 1 and 2 respectively.

$$\Delta w = W_1 - W_2 \quad (1)$$

Where Δw is the difference in weight

W_1 and W_2 are the weight loss of the coupon before and after immersion.

Corrosion rate (mg cm^{-2} h^{-1} = weight loss / (Area x Time)

$$C_R = \frac{\Delta W}{At} \quad (2)$$

Corrosion rate (mg cm^{-2} h^{-1} = weight loss / (Area x Time).

Where C_R = Corrosion rate, Δw = weight loss in gram, A = Exposed Surface area of coupons, t = time.

RESULTS AND DISCUSSION

The Effect of Immersion Time

The result presented in Table 1 shows that the weight loss of iron in $C_4H_6O_4$, $C_4H_4O_4$, $C_6H_8O_7$ and HCOOH increased with increase in immersion time. the weight loss of $C_4H_6O_4$, $C_4H_4O_4$, $C_6H_8O_7$ and HCOOH at least immersion time of 30min are 0.0005, 0.0005, 0.0004 and 0.0023g, but at highest of 3hrs the weight loss increased to 0.0083, 0.0088, 0.0053 and 0.0080g.

Table 1: Weight loss of iron Corrosion at Different Immersion Time

Time (min)	Weight Loss(g)			
	$C_4H_6O_4$	$C_4H_4O_4$	$C_6H_8O_7$	HCOOH
30	0.0005	0.0005	0.0004	0.0023
60	0.0011	0.0010	0.0011	0.0035
90	0.0015	0.0018	0.0015	0.0047
120	0.0020	0.0022	0.0016	0.0060
150	0.0022	0.0024	0.0020	0.0069
180	0.0083	0.0088	0.0053	0.0080

The Effect of Concentration

The result presented in table 2 shows that the weight loss and the corrosion increases with increase in acids concentration. At the lowest concentration of 0.1M the weight loss and corrosion rate of iron in $C_4H_6O_4$, $C_4H_4O_4$, $C_6H_8O_7$ and HCOOH are (0.0008, 0.0016, 0.0018 and 0.0050g) and (0.0666, 0.1333, 0.1500 and 0.4166 mg cm^{-2} h^{-1}). While at highest acid concentration of 0.6M the weight loss and corrosion rate increased to (0.0132, 0.0135, 0.0060 and 0.0096g) and (1.1000, 1.1250, 0.5000 and 0.8000 mg cm^{-2} h^{-1})

Table 2: Corrosion rate of Iron at Different Acids Concentration

Concentration (mold m^{-3})	**Weight Loss (g)**				**Corrosion Rate** (mg cm^{-2} h^{-1})			
	$C_4H_6O_4$	$C_4H_4O_4$	$C_6H_8O_7$	HCOOH	$C_4H_6O_4$	$C_4H_4O_4$	$C_6H_8O_7$	HCOOH
0.1	0.0008	0.0016	0.0018	0.0050	0.0666	0.1333	0.1500	0.4166
0.2	0.0016	0.0058	0.0026	0.0058	0.1333	0.4833	0.2166	0.4833
0.3	0.0023	0.0102	0.0029	0.0076	0.1916	0.8500	0.2416	0.6333
0.4	0.0027	0.0127	0.0038	0.0079	0.2250	1.0166	0.3166	0.6583
0.5	0.0041	0.0132	0.0041	0.0083	0.3416	1.0583	0.3416	0.6916
0.6	0.0132	0.0135	0.0060	0.0096	1.1000	1.1250	0.5000	0.8000

The Effect of Temperature

The results for the temperature effect were shown in Table 3, it can be seen from the result the weight loss and corrosion rate increases with increase in temperature. At the lower temperature value (303K), the weight loss and corrosion rate of iron in $C_4H_6O_4$, $C_4H_4O_4$, $C_6H_8O_7$ and HCOOH are (0.0031, 0.0048, 0.0041 and 0.0041g) and (0.2583, 0.4000, 0.3416 and 0.3416 mg cm^{-2} h^{-1}). At higher temperature value of 328K the weight loss and corrosion rate increased to (0.0102, 0.0400, 0.0210 and 0.0227g) and (0.8500, 3.3333, 1.7500 and 1.8917 mg cm^{-2} h^{-1}).

Table 3: Corrosion rate of iron in Acid at Different Temperature

Temperature (K)	**Weight Loss (g)**				**Corrosion Rate** (mg cm^{-2} h^{-1})			
	$C_4H_6O_4$	$C_4H_4O_4$	$C_6H_8O_7$	HCOOH	$C_4H_6O_4$	$C_4H_4O_4$	$C_6H_8O_7$	HCOOH
303	0.0031	0.0048	0.0041	0.0041	0.2583	0.4000	0.3416	0.3416
308	0.0034	0.0151	0.0116	0.0090	0.2833	1.2583	0.9666	0.7500
313	0.0040	0.0232	0.0122	0.0126	0.3333	1.9333	1.0166	1.0500
318	0.0051	0.0251	0.0156	0.0132	0.4250	2.0916	1.3000	1.1000
323	0.0093	0.0308	0.0181	0.0195	0.7750	2.5666	1.5080	1.6250
328	0.0102	0.0400	0.0210	0.0227	0.8500	3.3333	1.7500	1.8917

Conclusions

Based on the results obtained from weight loss measurements conclusions are made in this study; weight loss increases with increase of the time of dissolution of iron in all given acid medium. The corrosion rate increases as the concentration and temperature increases. The result was found to follow the order of reactivity $C_4H_4O_4$> $C_4H_6O_4$ >HCOOH >$C_6H_8O_7$.

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