January 2008 Volume 4 Issue 1

Materials Science
An Indian Journal

Trade Science Inc.

Full Paper

MSAIJ, 4(1), 2008 [55-59]

Inhibition of aluminium (3sr) corrosion in hydrochloric acid solution by 2-benzoyl pyridine

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Received: 22nd December, 2007 ; Accepted: 27th December, 2007

ABSTRACT

The inhibition of the corrosion of aluminium in HCl solution by 2-Benzoyl pyridine has been studied using weight loss and gasometric techniques. The inhibition efficiency was found to increase with increasing inhibitor concentration and decreasing temperature. A first order reaction kinetics me has been deduced from the kinetic treatment of the weight loss results.

KEYWORDS

Corrosion inhibition;
2-Benzoyl pyridine;
Aluminium;
First order kinetics
Hydrochloric acid.

INTRODUCTION

Aluminium and its alloys are very attractive materials for engineering applications because of their lightweight and mechanical strength[1]. Aluminium, being an industrially important metal, is subject to corrosion in service by various corrosive agents, of which the aqueous acids are the most dangerous. The corrosion of aluminium and its alloys in HCl solutions has been extensively studied[2]. Compounds containing nitrogen and sulphur have been proved to be very effective in inhibiting the corrosion of metal by adsorption on the metal surface through these atoms' lone pair electrons[3]. A number of organic compounds have been introduced as aluminium corrosion inhibitors in acidic and alkaline media[4]. Amines, amides, quinolines, thiourea, semicarbazide and thiosemicarbazone and its derivatives have been reported as effective inhibitors for aluminium alloys in acid solutions[5].

This work is aimed to investigate the inhibitory effect of 2-Benzoyl pyridine(2BP) on corrosion of aluminium in 2M HCl solution using weight loss and gasometric techniques.

EXPERIMENTAL

Material preparation

Aluminium (3SR) sheets used in the present work were supplied by First Aluminium Plc, Port Harcourt, Nigeria. The Chemical composition and preparation of the aluminium coupons are described in detail in our previous report[6].

The inhibitors used and all other reagents were of Analar grade and doubly distilled water was used for the preparation of all solutions.

Inhibitor concentrations of 1.0×10^{-6}, 1.0×10^{-5}, 1.0×10^{-4}, 1.0×10^{-3} and 1.0×10^{-2}M were prepared in 2M HCl solutions. The prepared inhibitor solutions were used for all measurements.

Weight loss determination

Aluminium coupons of 5.0cm by 2.0cm and 0.053cm thickness were used for weight loss measurements. The total geometric surface area of coupon exposed is $20cm^2$. The coupons were suspended through a hole of 1mm diameter. Five different concentrations of 2-Benzoyl pyridine 1.0×10^{-6}M, 1.0×10^{-5}M, 1.0×10^{-4}M, 1.0×10^{-3}M, 1.0×10^{-2}M and 2M HCl solution without inhibitor were maintained at 303, 313, and 323K. The weight loss of the aluminium coupons was determined as previously described in our report[6]. The percentage inhibitor efficiency was calculated as;

$$\text{Percentage efficiency I} = \frac{W_B - W_{in}}{W_B} \times 100 \quad (1)$$

where W_B and W_{in} are the weight loss of aluminium specimens without and with inhibitor, respectively.

Hydrogen evolution measurements

The procedure for the measurement of hydrogen gas evolution via gasometric assembly are as previously described elsewhere[6,7].

The percentage efficiency was calculated as:

$$\%\ \text{Efficiency} = \frac{V_B - V_{in}}{V_B} \times 100\% \quad (2)$$

where V_B and V_{in} are the volumes of hydrogen evolved without and with inhibitor respectively.

RESULTS AND DISCUSSION

It can be seen from figure 1 that aluminium corrodes in different concentration of HCl solutions because there is a decrease in original weight of aluminium coupon. The anode dissolution reaction in HCl solutions is a follows

$Al \rightarrow Al^{3+} + 3e^-$

The plot of weight loss versus time as depicted in the figure 1 shows an increase in the weight loss of aluminium as corrodent concentration increases at 303K. The presence of water, air and hydrogen ions(H^+) accelerate the rate of metal dissolution in an acidic medium.

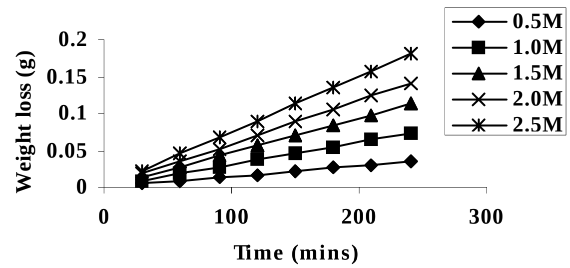

Figure 1: Variation of weight loss (grams) of aluminum with time (mins) for different concentrations of HCl solution at 303K

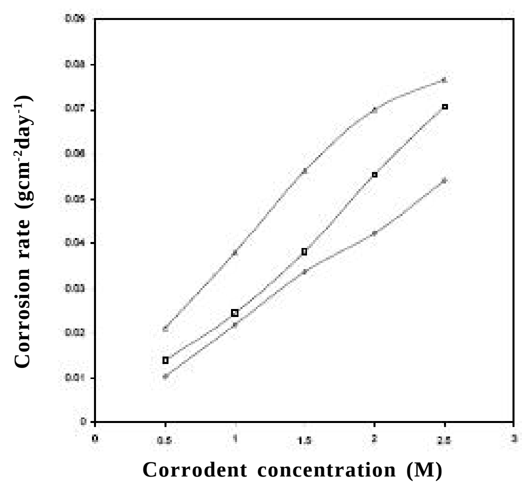

Figure 2: Variation of corrosion rate ($gcm^{-2}day^{-1}$) with corrodent concentration for aluminium coupons in 2M HCl solutions at different temperatures without inhibitor

TABLE 1: Inhibition efficiency (%) for the inhibition of aluminium corrosion in 2M HCl solutions by 2-Benzoyl pyridine at different temperatures from weight loss measurements

Inhibitor concentration (M)	Inhibitor efficiency (%)		
	303K	313K	323K
1.0×10^{-6}	62.51	40.94	31.60
1.0×10^{-5}	67.14	52.34	48.22
1.0×10^{-4}	69.32	55.92	50.01
1.0×10^{-3}	76.81	65.73	58.66
1.0×10^{-2}	83.32	70.24	62.72

It was observed that the corrosion rate($gcm^{-2}day^{-1}$) of aluminium increases with increasing temperature as seen in figure 2. The increase in the corrosion rate of aluminium with increase in temperature may be attributed to increase in diffusion velocity and ionization of reacting species in the corrosion process as temperature increases.

TABLE 1 depicts the effect of increasing concentration of 2BP on the % inhibition efficiency. At 303K, the highest % inhibition efficiency is 83.32% at concen-

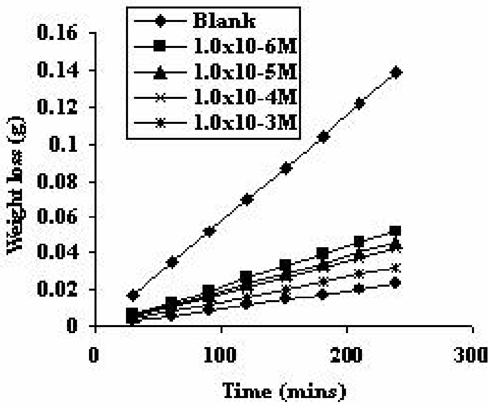

Figure 3: Variation of weight loss (g) with time (mins) for aluminium coupons in 2.0M HCl solution containing different concentrations of 2-Benzoyl pyridine at 303K

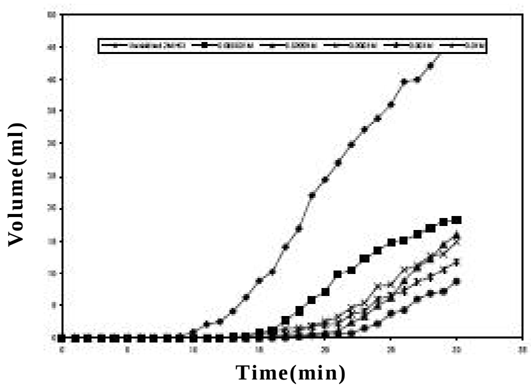

Figure 4: Variation of volume of hydrogen gas evolved with time (minutes) for the inhibition of aluminium in 2M HCl solution by 2-Benzoyl Pyridine at 303K

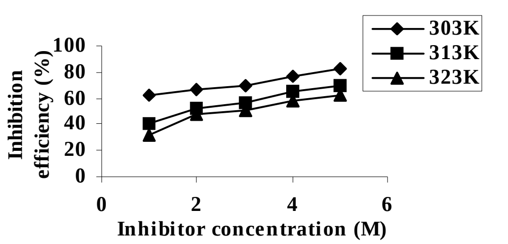

Figure 5: Variation of inhibition efficiency with inhibitor concentration(M) for aluminium coupons in 2.0M HCl solutions containing 2-Benzoyl Pyridine at different temperatures

TABLE 2: Percentage inhibitor efficiency for aluminium in 2M HCl containing 2-Benzoyl Pyridine at 303K from hydrogen evolution measurements

Inhibitor concentration (M)	Inhibitor efficiency (%)
1.0×10-6	60.57
1.0×10-5	65.14
1.0×10-4	67.54
1.0×10-3	74.29
1.0×10-2	81.05

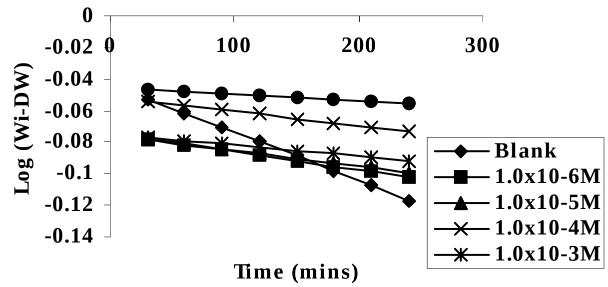

Figure 6: Variation of log(wi-ΔW) with time(mins) for dissolution of aluminium coupons in 2.0M HCl solution containing different concentration of 2-Benzoyl Pyridine at 303K

tration of 1.0 X 10^{-2}M and the least, 62.51% at concentration of 1.0×10^{-6}M. Thus increase in 2BP concentrations increase the percentage inhibition efficiency at all temperatures studied.

The 2-Benzoyl Pyridine used as inhibitor actually inhibits the acid corrosion of aluminium to a remarkable extent in 2M HCl solutions since the weight loss reduces in the presence of the inhibitor as presented in figure 3.

There is a general decrease in the volume of hydrogen gas evolved with time as 2BP concentration increased from 1.0×10^{-6}M to 1.0×10^{-2}M(figure 4). The maximum volume of hydrogen gas evolution was observed with the uninhibited 2M HCl solution showing that 2BP actually inhibits the corrosion of aluminium in 2M HCl acid solution.

The percentage inhibitor efficiency(%) of the aluminium coupons in 2M HCl solution obtained from hydrogen gas evolution were determined in the presence of different concentrations of 2BP at 303K. The inhibitor efficiency increased with increasing concentration of 2BP(TABLE 2). This result agrees well with what was obtained in weight loss measurements for 2M HCl with 2BP as inhibitor.

Increase in temperature was observed to lower the inhibition efficiency of 2BP as shown in figure 5. This makes us suspect a physical adsorption mechanism for the adsorption of 2BP on the metal surface.

Kinetic analysis of the weight loss results

When log(wi-ΔW) was plotted against time(mins.) as shown in figure 6 at temperature of 303K, a linear variation is observed which confirms a first order reaction kinetics with respect to aluminium corrosion with

TABLE 3: Kinetic data for aluminium in 2M HCl containing 2-Benzoyl Pyridine from weight loss measurement

Inhibitor concentration (M)	Rate constant, K $(day^{-1})\times10^{-4}$			Half-Life, $t_{1/2}$ $(days)\times10^{3}$			Activation energy kJ $mo1^{-1}$	
	303K	313K	323K	303K	313K	323K	303K–313K	313K-323K
1.0×10^{-6}	2.62	5.08	8.42	2.65	1.36	0.82	52.26	42.61
1.0×10^{-5}	2.30	4.04	6.53	3.01	1.72	1.06	44.13	40.56
1.0×10^{-4}	2.03	3.58	5.87	3.41	1.94	1.18	44.58	41.59
1.0×10^{-3}	1.62	2.78	4.47	4.28	2.13	1.15	55.06	39.93
1.0×10^{-2}	1.08	2.60	4.19	6.42	2.67	1.65	69.37	40.04

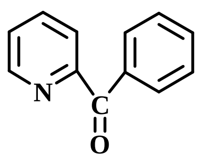

Figure 7: The structure of 2-Benzoyl pyridine[2BP]

and without inhibitor. This observation was in agreement with earlier report[6,8,9] on the kinetics of acid corrosion of aluminium. The rate constants were calculated from first order rate equation as:

$$K = \frac{1}{t}\ In\ \frac{w_i}{w_f} \qquad (3)$$

w_i = Initial weight of the coupon, w_f = Final Weight and t = time in minutes.

The half-life time, $t^1/_2$ from the first order half-life equation is given as:

$$t^1/_2 = \frac{0.693}{K} \qquad (4)$$

The rate constants and the half-life time, $t^1/_2$ of the corrosion of aluminium in 2.0M HCl without inhibitor at different temperature, are listed in TABLE 3.

The apparent activation energy between 313 and 323K of the metal-corrodent system with and without inhibitor was obtained from the integrated form of the Arrhenuous equation as:

$$Log\ \frac{k_2}{k_1} = \frac{Ea}{2.303R}\left[\frac{T_2 - T_1}{T_1T_2}\right] \qquad (5)$$

The kinetic data obtained in the presence of 2BP from weight loss measurements is presented in TABLE 3.

The rate constants generally decrease with increased inhibitor concentration at a particular temperature but increased as the temperature increases. Also as the inhibitor concentration increases, the percentage inhibitor efficiencies and the half-life time, $t_{1/2}$ increases for 2BP at a particular temperature but decreases as the temperature increases.

The increase in the half-life, $t_{1/2}$ when the inhibitor is present as seen in TABLE 3 shows that 2-Benzoyl Pyridine inhibits the corrosion of aluminium in 2M HCl solutions but as the temperature increases, the half-life, $t_{1/2}$ decreases confirming that 2-Benzoyl Pyridine inhibits best at lower temperatures. Similar trend in kinetic data has been reported by several investigators[5,7] and indicates that a good inhibitor is one that is able to increase the time of conversion of metals to corrosion products.

The values of apparent activation energy obtained in the presence of the inhibitor are between 39.93 and 69.37KJ/mol^{-1}. These values are significantly greater than that obtained in the uninhibited HCl solution; 27.17KJmol^{-1}. The high value of apparent activation energy suggests that the corrosion of aluminium occurs at the uncovered part of the metal surface[10].

2-Benzoyl Pyridine is a good inhibitor because it contains nitrogen and oxygen, which are electron rich and can donate electrons into the empty orbitals of the metal ion forming a complex.

CONCLUSION

The following concluding statements can be made concerning the inhibition of aluminium corrosion in HCl solution with 2BP.

- Kinetic treatment of the results of the corrosion of aluminium in HCl in both inhibited and uninhibited reactions confirm a first order kinetics reaction.
- 2-Benzoyl Pyridine inhibited the corrosion of aluminium probably through physical adsorption mechanism onto aluminium surface.
- The percentage efficiency increases with increasing inhibitor concentration and decreasing temperature.

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