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2-Benzoyl pyridine: An inhibitor for mild steel corrosion in hydrochloric acid solution

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ABSTRACT

Weight loss measurements have shown that 2-Benzoyl Pyridine (2BP) is an efficient corrosion inhibitor for mild steel corrosion in hydrochloric acid solutions. The compound inhibits the corrosion of mild steel in hydrochloric acid to a remarkable extent. Generally, inhibition was found to increase with increasing inhibitor concentration and half-life but with decreasing temperature and first order rate constants at 303K-323K. Physical adsorption mechanism has been proposed for its adsorption behaviour.

Keywords: Corrosion; Mild steel; 2-Benzoyl Pyridine; Kinetic treatment.

INTRODUCTION

The development of science and technology is first manifested in the metallurgical industry, of which iron and steel are the most predominant materials. Recent industrial history shows many failures due to the use of metallic structure in contact with aqueous and non-aqueous media (Abiola et al, 2004). This is a consequence of corrosion which causes a great hazard to the metallurgical as well as oil and chemical industries (Ita and Offiong, 1997). The continued manifestation of corrosion and corrosion products on steel structures is still causing a lot of concern to corrosion scientist and engineers (Ekpe et al, 1997). In recent years, scientists have been concerned with the use of certain organic compounds as corrosion inhibitors in metal-corrodent systems. Several N- and S- containing organic compounds have been reported as corrosion inhibitors for mild steel in acid medium (Ekpe et al, 1995; James et al, 2007).

In continuation of the search for efficient ecofriendly corrosion inhibitors for mild steel in hydrochloric acid, this paper reports the inhibition effects of 2-Benzoyl Pyridine on mild steel corrosion in hydrochloric acid. The inhibition efficiencies, (%E) were calculated from the equation 1 below:

$$\%\,\mathrm{E} = \frac{\Delta W_B - \Delta W_i}{\Delta W_B} \quad x \; \frac{100}{1} \tag{1}$$

Where ΔW_B and ΔW_i are the weight loss (or hydrogen gas evolution) data of metal coupons in the absence and presence of the inhibitors respectively.

MATERIALS AND METHODS

Weight loss and hydrogen gas evolution corrosion test methods were used for this study.

2.1 Material preparation

The sheets of mild steel obtained locally and of thickness 0.01cm, purity 98.76% were mechanically press-cut into 5cm X 2cm coupons. The coupons were prepared as reported in our earlier paper (James et al, 2007).

The 2-Benzoyl Pyridine (Purity, 99.0%), used as inhibitor was supplied by Aldrich-Chemie.

2.2 Weight loss corrosion test method with inhibitor

The inhibitor investigated was 2-Benzoyl Pyridine (2BP). Experimental procedure is as described in our earlier paper (James et al, 2007).

2.3 Hydrogen evolution corrosion test method

The hydrogen gas evolution method was also performed without and in the presence of 2-Benzoyl Pyridine via the gasometric assembly described below.

Six mild steel coupons of dimension 5cm x 2cm x 0.1cm were used in the experiments for test solutions containing 8M HCl with the five different concentrations of 2BP and its blank. A 50ml of each test solution was introduced into the reaction vessel connected to a burette through a delivery tube. The initial volume of air in the burette was recorded. One mild steel coupon was dropped into the test solution and the reaction vessel quickly closed.

Variation in the volume of hydrogen gas evolved with time was recorded every 1minute for 2hours. Each experiment was conducted on a fresh specimen of metal coupon. The hydrogen gas evolved displaced the fluid in the gasometric set-up, which is read directly.

The experiment was repeated in the presence of the five different concentrations of 2BP, 1.0 x10^{-2}M to 1.0x 10^{-6}M as used in the weight loss experiments.

RESULTS AND DISCUSSION

3.1 Corrosion by HCl solutions

The corrosion of mild steel in different concentrations of HCl at 313K without inhibitor was investigated. The results (Fig. 1) obtained show that the weight loss of mild steel in HCl solutions increases with increasing acid concentration and time at a given temperature. The corrosion is attributed to the presence of water, air and H^+, which accelerate the corrosion process.

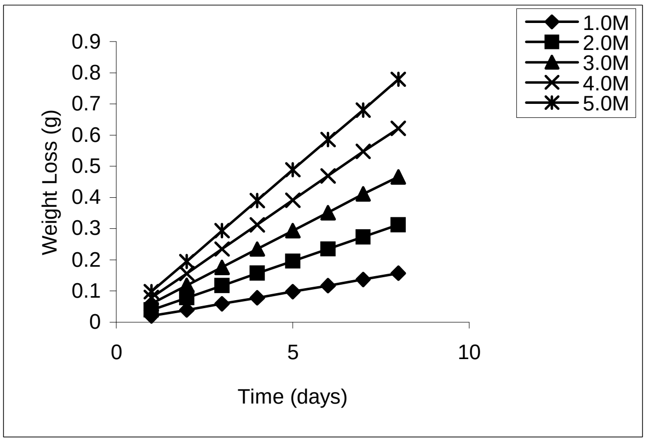

Figure 1: Variation of weight loss (grams) of mild steel with time (days) for different concentrations of HCl solution at 303K

Similar results were obtained at 313K and 323K. This observation is attributed to the fact that the rate of chemical reaction increases with increasing concentration. This observation has been reported by several authors (Ebenso and Ekpe, 1996; Ita and Edem, 2000; James et al, 2007).

3.2 Effect of temperature on the corrosion of mild steel

There is a progressive increase in weight loss as the temperature is increased from 303K to 323K (fig. 2).

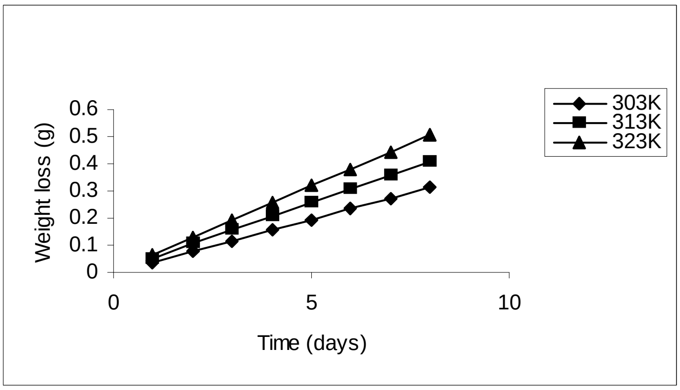

Figure 2: Variation of weight loss (g) with time (days) for mild steel coupons in 2M HCl solutions at different temperatures without inhibitor

This signifies that the dissolution of the metals increased at higher temperatures. This observation is attributed to the general rule guiding the rate of chemical reaction, which says that chemical reaction increases with increasing temperatures. Also an increased temperature favors the formation of activated molecules, which may be doubled in number, with 10°C rise in temperature, thereby increasing the reaction rate. This is because the reactant molecules gain more energy and are able to overcome the energy barrier more rapidly (Ita and Offiong, 1997). An increase in temperature may also increase the solubility of the protective films on the metals, thus increasing the susceptibility of the metal to corrosion (Okafor et al, 2004).

3.3 Inhibitory effect of 2-Benzoyl Pyridine on the corrosion of mild steel in HCl solution

Fig. 3 shows that 2BP is indeed a corrosion inhibitor, since there was a general decrease in weight loss at the end of the corrosion monitoring process. Similar trend was observed at 313K and 323K. The general decrease in hydrogen gas evolution with time as concentration of additives increased from 0.00001M to 0.01M (fig. 4) confirms that the presence of the additives in 8MHCl solution also reduced the corrosion of mild steel. It must be mentioned that the hydrogen evolution technique enables us to assess the inhibitory effect of the inhibitor at very high corrodent concentrations up to 8M HCl which could not be done with the weight loss technique.

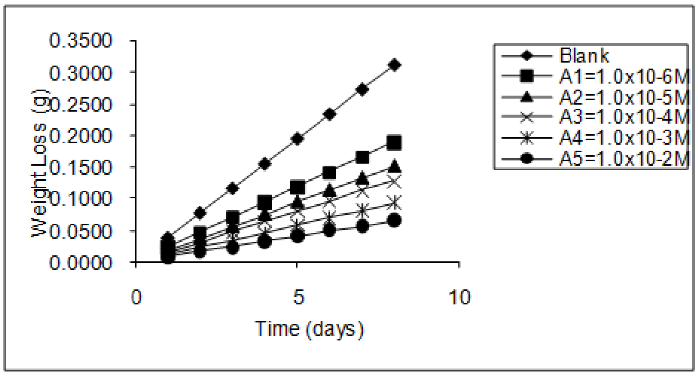

Figure 3: Variation of weight loss (g) with time (days) for mild steel coupons in 2M HCl solutions containing 2-Benzoyl Pyridine at 303K

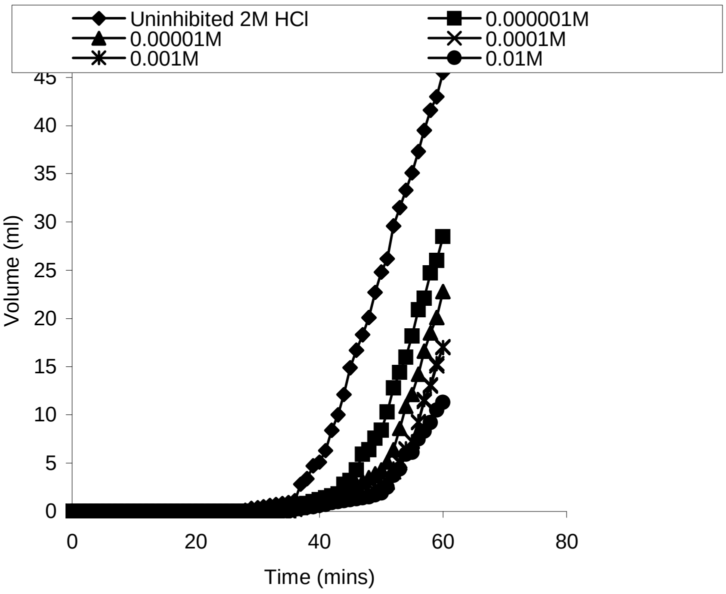

Figure 4: Variation of Volume of Hydrogen gas evolved with time (minutes) for the inhibition of mild steel in 2M HCl solutions by 2-Benzoyl Pyridine at 303K

3.4 Effect of temperature increase on the inhibition efficiency of 2-Benzoyl Pyridine on the corrosion of mild steel in HCl solution

The effect of increase in temperature on the inhibition efficiency of 2-Benzoyl Pyridine is displayed graphically in Fig. 5 below.

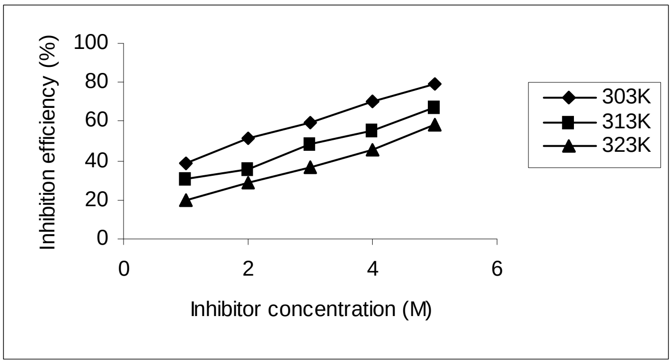

Figure 5: Variation of Inhibition efficiency (%) with inhibitor concentration (M) for mild steel coupons in 2M HCl solutions containing 2-Benzoyl Pyridine at different temperatures

We can observe from the graph that, as the reaction temperature is increased from 303K to 313K and to 323K, the inhibition efficiency decreases. Thus it is appropriate to say that decreased temperature favours the inhibition efficiency of 2-Benzoyl Pyridine on mild steel in hydrochloric acid.

Fig. 5 also portrays an increase in inhibition efficiency of 2-Benzoyl Pyridine as its concentration increases in the acid solution. This can be observed from the upward progression of all three temperatures.

3.5 Kinetics and mechanism of the corrosion inhibition of mild steel in HCl by 2-Benzoyl Pyridine

The corrosion of mild steel in HCl solution is a heterogeneous one, composed of anodic and cathodic reactions. Based on this, kinetic analysis of the data is considered necessary.

The plots of log (Wi - ΔW) against time (days) at 303K and other temperatures studied, (Figs. 6) showed a linear plot, suggesting a first order reaction kinetics with respect to mild steel corrosion in 2M HCl solutions in the presence of the additives.

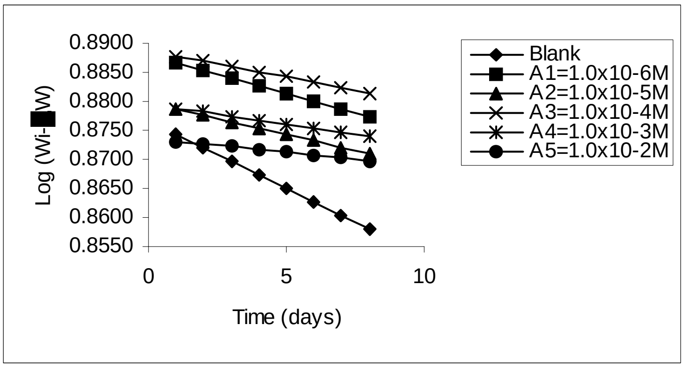

Figure 6: Variation of Log (Wi - ΔW) with time (days) for mild steel coupons in 2M HCl solution containing 2-Benzoyl Pyridine at 303K

Tab. 1: Kinetic data for mild steel in 2M HCl containing 2-Benzoyl Pyridine from weight loss measurement

Inhibitor Concentration (M)	Rate Constant, K (day^{-1}) X 10^{-3}			Half-Life, $t_{1/2}$ (days) X 10^{2}			Activation Energy KJmo1^{-1}		Average Activation Energy KJmo1^{-1}	
	303K	313K	323K	303K	313K	323K	303K – 313K	313K-323K	303K-313K	313K-323K
1.0 X 10^{-6}	3.11	4.37	6.96	2.23	1.59	1.00	26.82	39.13		
1.0 X 10^{-5}	2.54	4.31	6.30	2.73	1.61	1.10	41.70	31.91		
1.0 X 10^{-4}	2.09	3.54	5.75	3.32	1.96	1.21	41.56	40.78	44.08	36.85
1.0 X 10^{-3}	1.55	3.03	4.62	4.47	2.29	1.50	52.86	35.46		
1.0 X 10^{-2}	1.10	2.28	3.54	6.30	3.04	1.96	57.48	36.99		

3.6 Corrosion inhibition and Adsorption behaviour of 2-Benzoyl Pyridine on mild steel surface in HCl acid solution

The inhibitive property of 2BP may be explained by considering the adsorption of the 2BP molecule through the heterocyclic nitrogen of the pyridine (fig.7), available electron-rich oxygen and complex formation (surface chelation) on the corroding metal surface. These may be responsible for the formation of an oriented film layer, which essentially blocks discharge of H^+ and consequent dissolution of the metal ions.

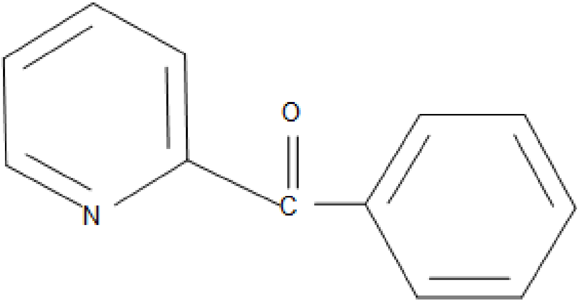

Figure 7: Structure of 2-Benzoyl Pyridine

Two types of adsorption processes had been distinguished, physisorption in which the activation energy is less than about 40 KJmol^{-1} and chemisorption where the activation energy is greater than 80KJmol^{-1} (James et al, 2007). On the basis of the experimentally determined activation energy values (Tab. 1), the additive is physically adsorbed on the mild steel coupons. Therefore, it is probable that a multilayer protective coverage on the entire mild steel surface was obtained.

CONCLUSION

The present study shows that 2BP inhibit the corrosion of mild steel in 2M hydrochloric solution to a remarkable extent, particularly at decreased temperature and increased inhibitor concentration. On the basis of activation energy and the experimentally observed increase in inhibition at low temperatures, a physiosorption process is proposed for the inhibition action of the additive.

The corrosion of mild steel in HCl in both inhibited and uninhibited reactions confirms a first order type of mechanism. This observation could go a along way in assisting corrosion scientists and engineers in solving corrosion problems.

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