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Research Paper

Corrosion Inhibition of Mild Steel in HCl using Methylene Blue as Inhibitor

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Abstract: *The corrosion inhibition of mid-steel in 5M HCl solution in the absence and presence of methylene blue (MB) was studied at 30^0c using the hydrogen evolution technique (gasometric). The results indicate that the methylene blue functioned as a good inhibitor in acidic medium. The inhibition efficiency increased with increase in the concentration of methylene blue. Inhibition therefore, is attributed to the adsorption of the inhibitor on the surface of the mild steel thereby eliminating site for corrosion. The experimental data fit into the Langmuir, Freundlich and Temkin adsorption Isotherms.*

Keywords: Adsorption, Adsorption isotherm, Corrosion inhibitor, Organic inhibitor, Inhibition efficiency.

Introduction

The fact that all metals, with the exception of gold are thermodynamically unstable with respect to oxygen in acid solution means that the writing is on the wall for all metallic artifacts to corrode. Corrosion is a scourge to civilization and is chewing deep into our metal world. Corrosion process obeys well known laws of electrochemistry, thermodynamics and many variables that influence the behavior of metals [(1),] thus putting this into consideration mild steel corrosion has been investigated to be inhibited by means of chemical inhibitor as the most practical and cost effective means of preventing corrosion [(2).] However corrosion process is inevitable as it still remains an impossible task to obtain an inhibitor that is 100% efficient in inhibiting corrosion.

This research work will elucidate and explore the world of corrosion and show how knowledge of the process involved gives us chance to delay these reactions (corrosion). The concept we are about introducing is the inhibitory action of methylene blue on mildsteel coupons in an acid medium. Therefore this study investigates the corrosion inhibition of mild steel in HCl using methylene blue (MB) as inhibitor.

Material and Methods

Materials preparation: The mild steel sheets were obtained from fabman steels Abuja (Nigeria) Ltd, with composition given in table 1. Each sheet was 0.4mm in thickness and was mechanically press cut into 2cm X 5cm coupons. The coupon samples were polished using emery papers of 600 grit, then degreased with absolute ethanol and dried in acetone. All chemicals used were of analar grade.

Inhibitor preparation: The inhibitor test solutions were prepared by dissolving appropriate weight of methylene blue in 5M HCl solution. The concentrations of the test solutions prepared and used for the study were 0.1g/l, 0.2g/l, 0.5g/l, 1.0g/l,and 2.0g/l of methylene blue in 5M HCl. Fig l below is the structure of methylene blue (MB). MB has a molecular weight of 319.85glmol and chemical formula $C_{16}\ H_{18}\ N_3\ ClS$.

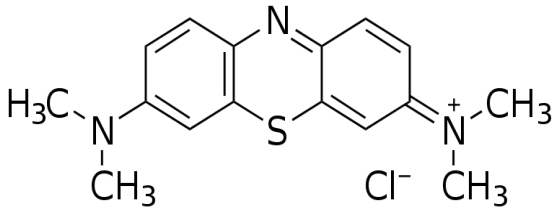

Figure 1: Structure of methylene blue (MB)

Table 1: Mild steel composition

Element	C	Si	Mn	S	Ni	Cr	Mo	Cu	Fe
Composition (%)	0.19	0.26	0.64	0.05	0.06	0.09	0.02	0.27	98.42

Gasometric Experiments

Gasometric analysis was carried out at 30°C as previously described in [5,6,12,14,15]. From the values of hydrogen gas evolved per minute, the degree of surface coverage (θ) and inhibition efficiency were calculated using equation 1 and 2 respectively.

$$\theta = 1 - \frac{V_{Ht}^{i}}{V_{Ht}^{o}} \quad \ldots\ldots(1)$$

$$IE = \left(1 - \frac{V_{Ht}^{i}}{V_{Ht}^{o}}\right) X\ 100 \quad \ldots\ldots(2)$$

Where V_{Ht}^{i} is the volume of hydrogen evolved at time t for inhibited solution and V_{Ht}^{o} is the volume of hydrogen evolved in uninhibited solution.

Results and Discussion

The acidic corrosion of mild steel is characterized by evolution of hydrogen and the rate of corrosion which is proportional to the amount of hydrogen evolved during the corrosion of mild steel in 5M HCl solution in the absence and presence of methylene blue at 30⁰C was measured as a function of time. The results obtained as depicted by figure 2 and 3 respectively, which show graphical representations of volume of hydrogen evolved against concentration of methylene blue (MB) and corrosion rates of the mild steel coupons versus concentration of the inhibitor (methylene blue). Observations from figure 2 shows that the volume of hydrogen evolved reduced in the presence of methylene blue and decreases the more as the concentration of the inhibitor increases. In figure 3, the corrosion rate as well, reduced in the test solutions containing methylene blue from what is observed from the 5M HCl that doesn't contain methylene blue.

This effect became more pronounced as the concentration of methylene blue increased from 0.1g/l to 2.0 g/l. The reduction in corrosion rate indicates that methylene blue inhibited corrosion of mild steel in 5M HCl solution. A plot of inhibition efficiency against concentration of the inhibitor is depicted in figure 3. The result shows increase in inhibition efficiency when the concentration of methylene blue is increased. The inhibitory effect is suggested to come about as a result of methylene blue molecules being able to get absorbed to the metal surface creating a barrier between the metal and the corrodent[3,4,9,12].

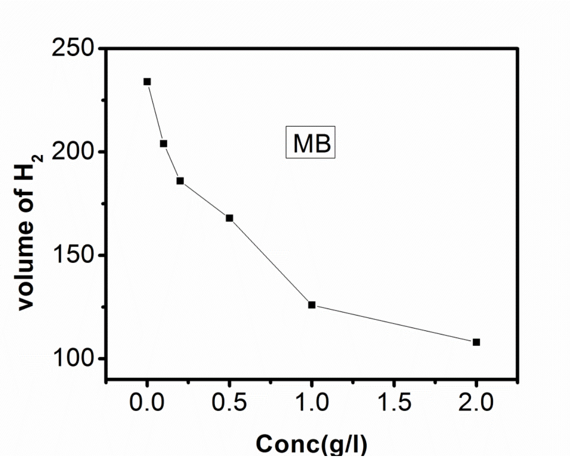

Figure 2: A plot of volume of hydrogen against time

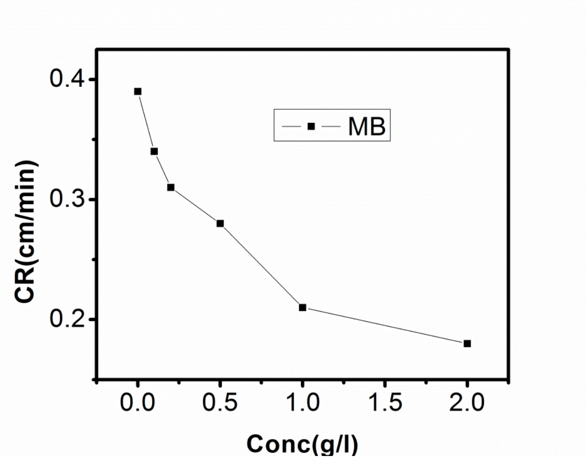

Figure 3: A plot of corrosion rate against concentration of methylene blue

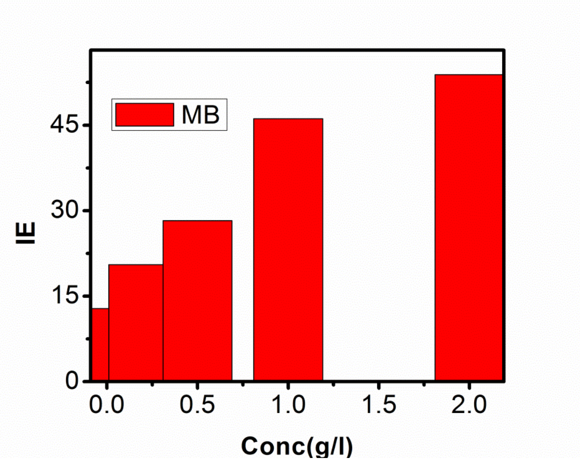

Figure 4: A plot of inhibition efficiency against concentration of methylene blue

Adsorption Behavior

As the methylene blue molecules tend to get adsorbed to the metal surface, the metal surface is being covered by the inhibitor molecules, which prevents direct contacts between the corrodent and the metal surface. The relationship between the degree of surface (θ) and methylene blue molecules can be represented by Langmuir adsorption isotherm according to equation 3.

$$\frac{C}{\theta} = C + \frac{1}{K_{ad}} \quad \ldots\ldots(3)$$

Where C is concentration of inhibitor, θ is the degree of surface coverage and K_{ad} is the constant for adsorption which is related to the free energy of adsorption by the relation in equation 4

$$K = \frac{1}{55.5}\exp\left(\frac{\Delta G^{o}_{ad}}{RT}\right) \quad \ldots\ldots (4)$$

Where R and T are gas constant and temperature at which the adsorption occurred respectively. Other parameters retain their previous meanings. [(7).] Figure 5 shows a plot of C/θ versus concentration of methylene blue to be linear, with intercept $1/K_{ad}$ which suggest that the experiment fits into Langmuir adsorption isotherm.

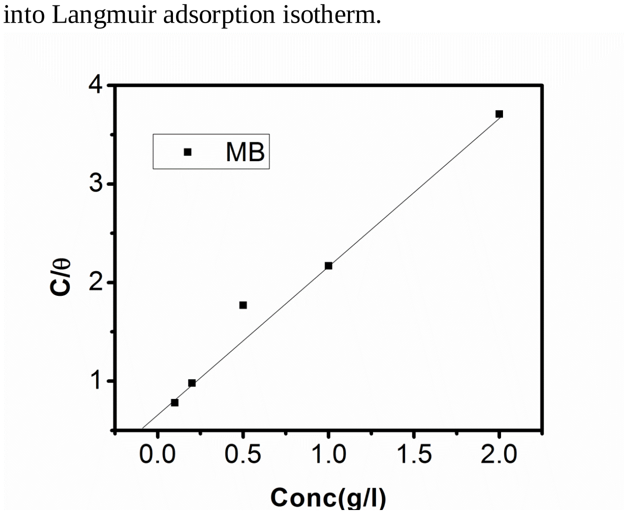

Figure 5: Langmuir adsorption isotherm

Table 2: presentation of free energy of adsorption

System (g/l)	ΔG^{o}_{ad} (KJ)
0.1	-6.31
0.2	-6.64
0.5	-7.89
1.0	-7.67
2.0	-8.64

The calculated values of free energy of adsorption are shown in table 2. The negative sign indicates that methylene blue molecules were spontaneously adsorbed to the metal surface in the acidic medium[8 10,13].

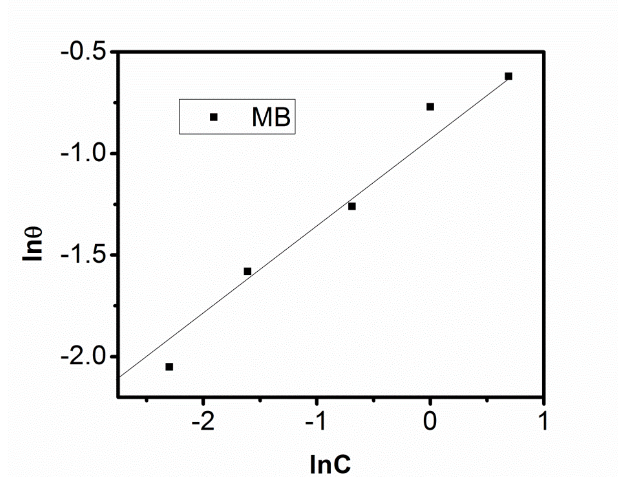

Figure 6: Freundlich adsorption isotherm

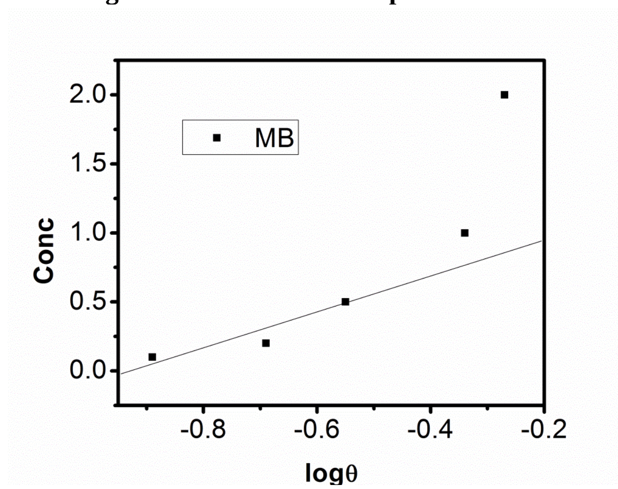

Figure 7: Temkin adsorption isotherm

Other linear plots in figures 6 and 7 which are plots of ln θ against ln C and C versus log θ, were fitted into Freundlich and Temkin adsorption isotherms.

Conclusion

Based on the result obtained, the following was concluded.

- Methylene blue (MB) inhibits the corrosion rate of mild steel in 5M HCl solutions
- The inhibition efficiencies of Methylene blue (MB) increased with increase in Methylene blue (MB) concentrations
- Corrosion inhibition is attributed to adsorption of methylene blue molecules on the surface of the metal
- The adsorption of the inhibitor molecules fitted into Langmuir, Temkin and Freundlich adsorption isotherms.

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