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Inhibitory effect of amlodipine drug on corrosion of mild steel in HCl solution

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The corrosion inhibition of mild steel in HCl solution with amlodipine drug at room temperature (~30°C) has been studied using the weight loss technique. The result show that the inhibition efficiency increased with increase in concentration of amlodipine. It is found that the inhibition process with amlodipine obey the Langmuir adsorption isotherm. From the weight loss trends of the metal over time, the concentration of corroded mild steel is estimated; from which the inhibition process is predicted to follow a first order kinetics.

Keywords: Corrosion inhibition, Amlodipine, Mild steel, HCl, Weight loss technique

Industrial leakages due to corrosion of metallic structures can result in economic waste in a far greater extent than if considerable precautionary measures were put in place to checkmate their adverse effects. In addition, failures of bridges in Nigeria as well as many other countries in recent times are a consequence for the sustained study of corrosion process and their inhibition.

It is well known that corrosion processes tend to be more deleterious in solutions containing aggressive ions[1]. The use of inhibitors is one of the most practicable ways for providing protection for metals against corrosion, especially in acidic solutions[2]. It has been found that nitrogen, phosphorus, sulphur, and oxygen containing compounds are more effective as corrosion inhibitor in hydrochloric acid media[2-8].

The advent of environmentally safe inhibitors may have been caused by the toxicity of certain organic inhibitors[9]. Currently, researchers pursue environmentally friendly, cost effective and commercially available materials as corrosion inhibitors. The possession of most inhibitive parameters like heteroatoms, π-electrons and large molecular weights of drugs are indicators that have made drugs to find new application in the fight against corrosion[10-18].

In this research, the authors present the study of the corrosion inhibition of mild steel in 0.1M HCl by amlodopine drug by weight loss technique.

Experimental Section

Hitherto, various techniques have been employed to monitor corrosion of metals, ***viz***: weight loss method, gasometric methods, thermometric methods, electrochemical methods, etc[19-21]. The experimental model developed for this study was implemented using the weight loss technique. The weight loss method of monitoring corrosion rate is useful because of its simple application and reliability[22].

Mild steel specimens

Commercially available grade of mild steel sheets (purity 98%) of 0.10 cm in thickness used in this study were identified and obtained locally. The sheets were mechanically pressed cut into 3 cm × 3 cm coupons with small hole of about 5 mm diameter near the upper edge to help hold them with glass hooks. The coupons were not polished. However, they were degreased with acetone, washed in double distilled water and dried in a desiccator before use[23]. The concentrations of the hydrochloric acid were prepared by dilution method[24].

Inhibitor

The drug employed in this study was amlodipine. It is an antihypertensive drug. However it has other medicinal uses. The systematic (IUPAC) nomenclature of the drug is (RS)-3-ethyl-5methyl-2-[(2-aminoethoxy)methyl]-4-(2-chlorophenyl)-6-methyl-1, 4-dihydropyridine-3,5-dicarboxylate and has a molecular formula $C_{20}H_{25}ClN_2O_5$ with molecular weight 408.876 g/mol. It has the chemical structure as shown in Fig. 1.

The tablets of amlodipine were obtained from a local drug shop sold under the trade name “Amlovar.” The drug was used without further purification. Different concentrations of the drug were prepared by dissolving appropriate quantities of the tablets.

Weight loss measurements

In the weight loss experiment, five plastic containers were labelled A to E, each containing 500 mL of HCl solution. The first beaker was reserved as blank while each of the four remaining

beakers contain the drugs at different concentrations all placed at room temperature (about 30°C). The metal coupons were immersed in the experimental solutions with the help of glass hooks and monitored daily (after 24 h). The weights of the specimens were noted before immersion. After every immersion time of 24 h, the specimens were removed, polish with emery papers, washed in double distilled water, degreased with acetone, dried in warm air and re-weighed. From the initial and final weights of the specimens, the loss of weights was calculated and the corrosion rate (in mpy^{-1} –millimetre penetration per year) was computed from the equation below[25]:

$$Corrosion\ rate, CR = \frac{534W}{DAt} \quad \ldots (1)$$

where W is the weight loss (g), D is the density of the specimen (7.85g/cm^3), A is the surface area of specimen (cm^3) and t is the immersion time (days).

The efficiency of the inhibitor was computed using the equation below[26]:

$$Inhibition\ efficiency, \%IE = \frac{W_o - W_1}{W_o} \times 100 \quad \ldots (2)$$

where W_o is the weight loss without inhibitor and W_1 is the weight loss with inhibitor,

$$\frac{C}{\theta} = {}^1/_k + C \quad \ldots (3)$$

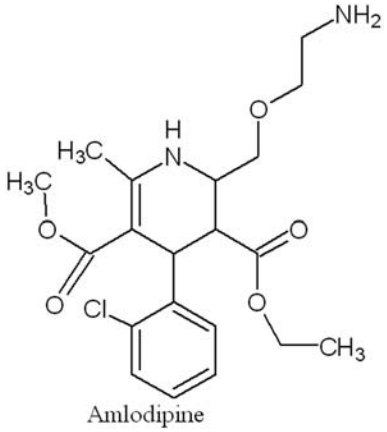

Fig. 1 — Chemical structure of amlodipine

where C is the concentration of the corrosion inhibitor, Θ is the degree of surface coverage and k is the adsorption equilibrium constant[27].

Results and Discussion

Weight loss measurements

The acid corrosion of mild steel in the absence and presence of different concentrations of amlodipine drug as inhibitor was studied at room temperature using the weight loss technique. The results obtained from the weight loss measurements are summarized in Table 1. The results reveal that amlodipine acted as a corrosion inhibitor for mild steel in the medium and conditions under investigation. It is observed from Table 1 that the inhibition efficiency increased with increase in the inhibitor concentration while the corrosion rate decreases with increase in the inhibitor concentration. These may have occurred as a result of sufficient adsorption owing to wider surface coverage by more inhibitor molecules.

Furthermore, the variation of weight loss with exposure time shown in Fig. 2 reveals that the weight

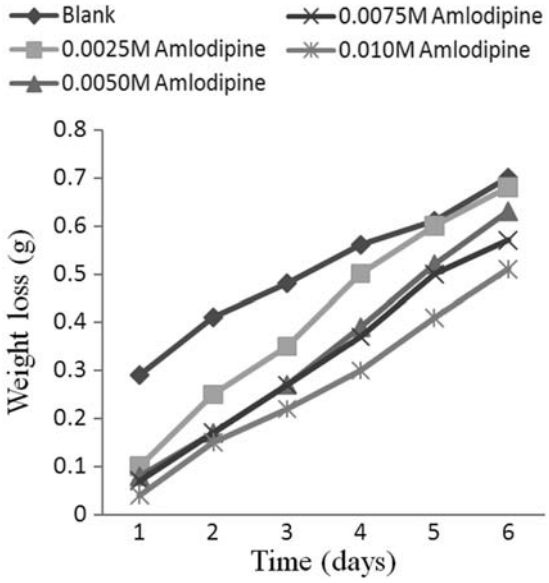

Fig. 2 — Variation of weight loss with exposure time for mild steel in 0.1M HCl in the presence and absence of different concentrations of amlodipine at room temperature.

Table 1 — Values of Inhibition efficiency, corrosion rate, and surface coverage for corrosion of mild steel in 0.1M HCl containing different concentrations of amlodipine as inhibitor.

Medium/Concentration	Weight loss (g)	Inhibition efficiency (%IE)	Corrosion rate (mp/y)	Surface coverage (Θ)
Blank (0.1M HCl)	0.29	-	0.0437	-
2.5×10^{-3}M Amlopidine	0.10	66	0.0151	0.6552
5.0×10^{-3}M Amlopidine	0.08	72	0.0121	0.7241
7.5×10^{-3}M Amlopidine	0.07	76	0.0106	0.7586
10.0×10^{-3}M Amlopidine	0.04	86	0.0060	0.8621

loss values increase with increase in the exposure time and are higher in the corrosive medium without the inhibitor. The result obtained is comparable with previously published data obtained by electrochemical polarisation method[28].

Chemical kinetics

Chemical kinetic treatment of the data was necessary in order to obtain information about the order of the reaction. If the concentration of the corroding metallic material is estimated in terms weight loss per volume (g/L) of the corrodent, and later converted to molar concentrations via mass of metal-molar mass of iron relation, then, the kinetics of the system may be proposed. Following the work of Sharma and Sharma[27] and as reported in one of our recent works[30], we assume that if a mol/L is the initial concentration of the mild steel (Fe) and after time, t, x mol/L of Fe had decomposed into corrosion products. Therefore, the remaining concentration of Fe at time, $t = (a–x)$ mol/L. If a plot of $\log(a-x)$, i.e. log [Fe] against t gives a straight line graph, then the reaction can be said to be a first order reaction. It was based on this that we calculated for the reacted concentration of Fe from weight loss measurements and obtained a graph shown in Fig. 3. The shape of the graph in Figure 3 shows that the system under consideration followed a first order kinetics.

Adsorption isotherms

The inhibitory property of corrosion inhibitors is widely believed to be by adsorption on metal substrates. In finding out the possible adsorption mode, the experimental data are tested with several adsorption isotherms. On consideration of the Langmuir adsorption isotherm, which is well described by Eqn (3)[30,31], it has been found that the experimental data gave a straight line graph on a plot of C/Θ versus C and fitted the adsorption isotherm as shown in Fig. 4. The Langmuir's adsorption isotherm assumes that there is no strong interaction between the adsorbed molecules and the metal surface[32].

Proposed mechanism of inhibition

The inhibitor may have succeeded in protecting the metal surface against corrosion by physical displacement of the water molecules carrying aggressive ions from the metal surface according to the scheme shown below[33]:

$$Org_{(sol)} + nH_2O_{(ads)} \longrightarrow Org_{(ads)} + nH_2O_{(sol)}$$

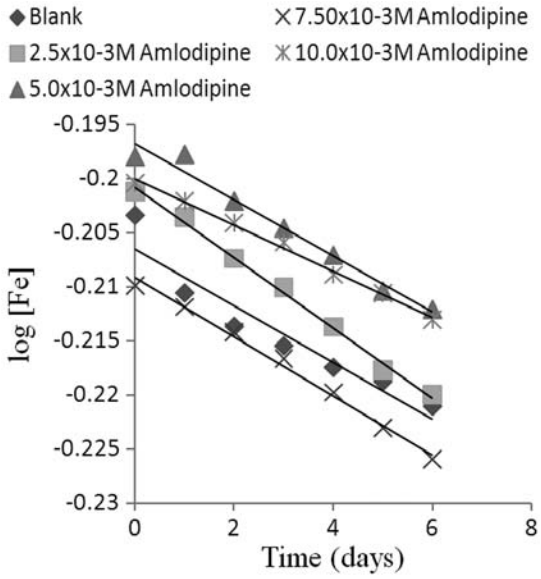

Fig. 3 — Linear plots of logarithm of mild steel concentrations against time of exposure

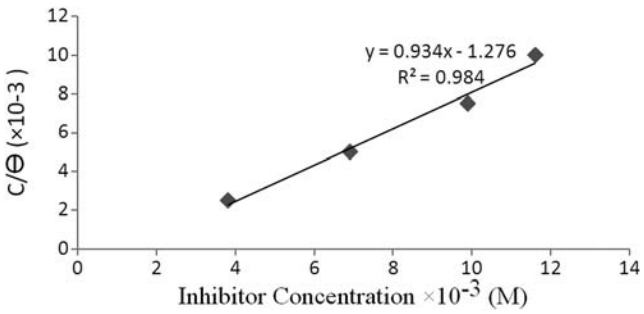

Fig. 4 — Langmuir adsorption isotherm for mild steel corrosion in 0.1M HCl containing various concentrations of amlodipine.

Another possible mode is adsorption due to weak electrostatic interaction between the partially charged polar groups formed by nitrogen, oxygen and possibly chlorine atoms. Also, donor-acceptor interaction between the π-electrons from the aromatic rings and the vacant d-orbital of the iron atoms at the interface may also be a possible occurrence. There is however, a possibility of the nitrogen atoms being protonated and at the same time synergistic interactions may occur with negatively charged chloride ions which would aid in increase inhibitive action[34].

Conclusion

In the study of the inhibitory effect of an environmentally friendly and easily accessible drug, amlodipine, on the corrosion of mild steel in 0.1M HCl by weight loss method at room temperature the following conclusions may be drawn:

1. The corrosion rate of mild steel reduced on introduction of the drug into the corrodent medium.
2. Inhibition efficiency increased with increase in the concentration of the inhibitor.
3. The corrosion inhibition process followed a first order kinetics.
4. The adsorption of amlodipine obeyed Langmuir adsorption isotherm.
5. The inhibitory behaviour of the drug depicts the action of its molecular structure.

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