Journal of Applied Science and Education, 2022,
Vol. 02, Iss. 02, S. No. 006, pp. 1-9
ISSN (Online): 2583-1372

Studies of Some Aromatic Compounds for Corrosion Inhibition of Aluminum in Acidic Medium

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How to cite this paper: S. L. Meena and L. C. Yadav, "Studies of Some Aromatic Compounds for Corrosion Inhibition of Aluminum in Acidic Medium," *Journal of Applied Science and Education (JASE)*, Vol. 02, Iss. 02, S. No. 006, pp 1-9, 2022.

https://doi.org/10.54060/jase.v2i2.37

Received: 30/09/2022
Accepted: 19/11/2022
Published: 25/11/2022

Abstract

The aim of this work is to investigate corrosion inhibition characteristics of Aluminum in Hydrochloric acid (0.1N) in presence of different concentration(0.2, 0.4% and 0.6%) of two inhibitors namely p-Nitrophenol and Nitrobenzene using Tafel polarization studies and weight loss methods. Open circuit potential, inhibition efficiency, corrosion current and corrosion rate have been determined in the absence and presence of inhibitors at different concentrations such as 0.2, 0.4% and 0.6%.It is observed that the inhibition increases with the increase in concentration of the inhibitors in acidic media. The experimental data showed that the maximum inhibition performance could reach about 72-78% at the concentration of 0.6%. The inhibition efficiency of the p-Nitrophenol is found to be higher than that of Nitrobenzene.

Keywords

Aluminium, inhibitors, inhibition efficiency, Tafel plot, weight loss

1. Introduction

Aluminum is the third most common element and the most abundant metal in the Earth's crust, accounting for about 8 % of the total mineral components [1]. The most important feature of aluminum is its high strength-to-weight ratio. Aluminum is highly electrically and thermally conductive, which, in addition to its relatively low price, makes aluminum very attractive in various applications [2]. In terms of corrosion, aluminum itself is not resistant, but when an oxide layer is formed on the surface, it becomes very resistant to corrosion attacks in different media. However, when exposed to a medium containing acid, alkaline, and chloride, the oxide layer is damaged, and aluminum materials are exposed to the impact of corrosive environments [3,4]. Acid solutions are usually used in the metal industry for removal, acid pickling; the presence of cleaning processes and these corrosive materials is the main reason for increasing the rate of metal decomposition. Corrosion is the result of metal interactions with the environment and gradually leads to its destruction. Corrosion is the deterioration of metals that form chemical attacks and interact with the environment. It is a persistent and permanent problem that cannot be completely eliminated. Prevention is more realistic and feasible than complete elimination, and it is necessary to use corrosion inhibitors to prevent metal corrosion [5,6].

Corrosion inhibitors are substances that, when added in small concentrations to corrosive media decrease or prevent the interaction of the metal with the media. Compounds withπbonds generally exhibit marked inhibitory properties due to the interaction ofπ-orbital with the metal surface [7-8]. Most of the well-known acid inhibitors in acid are organic compounds holding sulphur, oxygen and nitrogen atoms. The effectiveness of these molecules mainly depends on their ability to get adsorbed on the surface of metal particularly through polar groups. Most effective inhibitors are used to contain a homogenous such as O, N, S and multiple bonds in their molecules by which they stepped on the metal surface Significant amount of effort is devoted to develop efficient and novel corrosion inhibitors, in recent years [9-10]. Various compounds containing nitrogen, sulphur, and/or oxygen, especially certain amino derivatives have attracted more and more attention in this area. The present investigation was undertaken to examine the corrosion inhibition efficiencies of two inhibitors such as p-Nitrophenol and Nitrobenzene, on Aluminum in 0.1N HCl solution using gravimetric weight loss measurements, polarization studies. It has been found that these inhibitors are effective in acidic medium and that this effectiveness increases with increase in the concentration (in the studied range of concentration.

2. Materials and Methods

2.1. Inhibitors and Solutions

All chemicals used are analytical quality. The aggressive solution of 0.1N HCl was prepared by standard HCl (Merck) and de-ionized water. The solution of different concentrations of inhibitors (P-nitrophenol and nitrobenzene) (0.2%, 0.4%, 0.6%) was prepared by distilled water and ethanol.

2.2. Gravimetric method

Weight loss experiments were conducted using rectangular aluminum samples (99.9% purity) with dimensions of 3x2x0.16 cm3 and a small hole about 3 mm in diameter near the upper edge for hanging. They were polished with pearl paper, washed with benzene, distilled water, and finally acetone, and then dried for half an hour in an oven at 60 °C. They are kept in a desiccator, cooled to room temperature, and accurately weighed using digital balances. They were further heated, cooled and weighed until they reached a constant weight. Mass loss experiments were carried out in 0.1 N HCl acid with 0.2, 0.4, and 0.6 percent inhibitor concentrations. The metal samples were immersed for 24 hours in a hostile medium at room temperature, periodically assessing the rate of corrosion. Each sample is suspended with glass hooks and sunk in a jar of 100 ml of ambient-temperature test solution. Subsequently, the test sample was cleaned with distilled water, dried for 20 minutes in the oven, and finally weighed. Similar experiments have been conducted in acidic solution with inhibitors. A stock solution of 10% p-Nitrophenol and Nitrobenzene was prepared, diluted, and different concentrations (0.2–.6%) were obtained. These experiments were carried out in duplicate and the average values were reported. The rate of corrosion was determined by the following equation [11,12].

$$Corrosion\ rate\ (mpy) = \frac{(K\Delta\ W)}{DAT} \qquad (1)$$

Where R = corrosion rate (mpy), D = density of specimen (g/cm3), W = weight loss (g), A = surface area of metal specimen (cm2), t = time of treatment (h), and K = constant. The inhibition efficiency (η %) was obtained by the following equation:

$$Inhibition\ Efficiency(\eta)\% = \frac{100\ (\Delta M_u - \Delta M_i)}{\Delta M_u} \qquad (2)$$

Where ΔMi and ΔMu are weight loss with and without inhibitors.

2.3. Electrochemical studies

Electrochemical studies were carried out using three electrode cell assemblies composed of aluminum as the working electrode (1cm2), platinum as the counter electrode (1cm2) and saturated calomel (SCE) as the reference electrode at ambient temperature. For acid corrosion, metal samples were placed in contact with electrolyte for 60 minutes before the experiment [13].

2.4. Polarization method

For polarization research, a test aluminum plate used for corrosion inhibitory research was covered with teflon tape with a total surface area of 1 cm^2. It is then exposed to corrosion solutions (0.1N HCl) and used as a working electrode. It is cleaned with a polisher, polished with emery paper, and degreased with acetone before use. A standard active potentiostat was used for polarization studies in 0.1 N HCl with or without inhibitors. The test solution is prepared with double-distilled water. Various concentrations of inhibitor solutions (0.2, 0.6, and 0.4%) were prepared in distilled water or ethanol. Platinum foils are used as counter electrodes and saturated calomel electrodes (SCEs) as reference electrodes. The electrochemical experiments were performed by applying different currents in the directions of the cathode and the anode. Finally, the working electrode is released into the experimental cell until the stationary open circuit is reached. By changing the potential, the corresponding current change is obtained. The first cathodic and anodic polarization data were recorded. Then, according to the standard procedure [14–16], the corresponding polarization curves were drawn from the recorded observations. The values of the corrosion current (I_{corr}) and potential are obtained from the intersections of the Cathodic and Anodic Tafel lines. The slope analysis of the Tafel curve gives the corrosion current, the inhibition efficiency (ɳ%), and the corrosion rate (mpy millilitres per year) calculated by the following equations:

$$Inhibition\ Efficiency\ (\eta) = \frac{[I_{corr(blank)} - I_{corr(inhib.)}]\times 100}{I_{corr(blank)}} \qquad (3)$$

$$corrosion\ rate = \frac{0.1288\times I_{corr}\times Eq.Wt(Al)}{Area\times Density\ (Al)} \qquad (4)$$

Where I_{corr}(inhib) and I_{corr}(blank) are corrosion current of the working electrode in the presence and absence of inhibitors.

3. Results and Discussions

In general, high-purity aluminum metals are more resistant to corrosion than commercially pure aluminum metals. Aluminum corrodes more rapidly than distilled water in acidic and alkaline media. When aluminum is dissolved in the anode, Al^{3+} and Al^{+} are form first. The single ion then reduces H2O and forms the triple ion according to the following equation:

$$Al \rightarrow Al^{3+} + 3e^{-} (E^{0} = -1.7\ volt)$$

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

$$Al^{+} + 2H_2O \rightarrow Al^{3+} + H_2 + 2HO$$

When aluminum is anoded, H_2 develops in the anodes and cathodes. The evolution of hydrogen in anodes can be explained by a higher corrosion rate during local action during anode dissolution. In acidic solutions, the general reaction during Al corrosion is shown as follows:

$$2Al + 6H^{+} \rightarrow 2Al^{3+} + 3H_2$$

In order to protect metals from corrosion, inhibitors have been added, and their effects have been studied. The present study uses nitrogen benzene and p-Nitrophenol as corrosion inhibitors, and their effects on acidic environments are studied by using the Tafel interstripping polarization method and weight loss method to study the inhibitory effects of these aromatic inhibitors on the corrosion of aluminum metals. Corrosion parameters such as the corrosion current (I_{corr}), the corrosion rate, and the inhibitor effectiveness of these inhibitors are determined at different concentrations, and the results are presented in Tables 1 and 2.

3.1. Gravimetric corrosion inhibition studies

The corrosion inhibition efficiency and corrosion rate of the two aromatic compounds p-Nitrophenol and Nitrobenzene over 24 hours at room temperature are shown in Table 1. The two molecules show excellent inhibition efficiency on the surface of aluminum, which may be due to the presence of highly polarized nitrogen atoms in the aromatic ring. The presence of the p-Nitrophenol link and the aromatic rings of Nitrobenzene increase its inhibition efficiency even at very low concentrations. For a 24-hour period, p-Nitrophenol showed a higher inhibition rate than nitrobenzene. Furthermore, this highly delocalized π electron cloud in the aromatic ring increases the efficiency of inhibition. Although there is structural similarity between Nitrobenzene and p-Nitrophenol, the corrosion inhibition efficiency of Nitrobenzene and p-Nitrophenol is relatively low, possibly due to the deviation of the coplanarity of molecules [17–18].

Table 1. Gravimetric corrosion inhibition efficiencies (η) and corrosion rate of p-Nitrophenol and Nitrobenzene on Al in 0.1N HCl for 24 hr at room temperature

Inhibition Concentration (%)	p- Nitrophenol		Nitrobenzene	
	Corrosion Rate	Inhibition Efficiency (η),%	Corrosion Rate (mpy)	Inhibition Efficiency (η),%
0.2	46.03	51.78	61.37	35.71
0.4	35.23	63.09	48.87	48.80
0.6	27.27	71.42	29.55	69.04

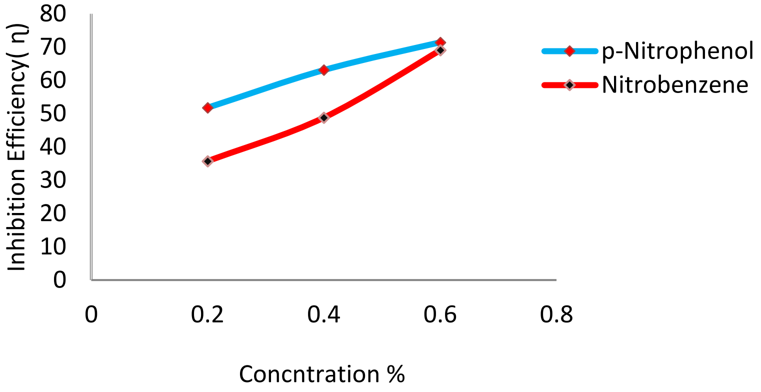

Figure 1. Variation of corrosion inhibition efficiencies of p-Nitrophenol and Nitrobenzene with concentration on Al in. 1N HCl

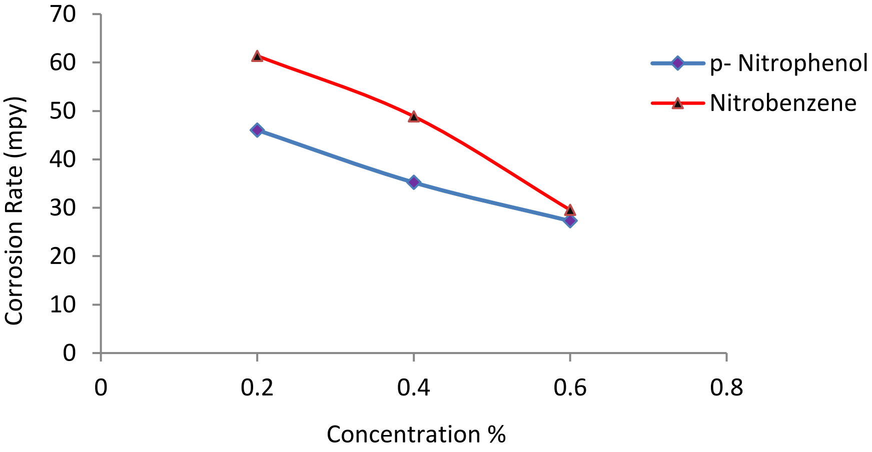

Figure 2. Variation of corrosion rate of Al with concentration of P-Nitro- phenol and Nitrobenzene in 0.1NHCl

Figures 1 and 2 show the variation in corrosion inhibition efficiency and corrosion rate at concentrations of inhibitor molecules between 0.2% and 0.6%. The plot shows that corrosion rates decrease with an increase in the concentration of the inhibitor and that inhibition efficiency (η) increases with the concentration of the inhibitor. This may be due to the high concentration of these molecules on the surface of metals and the slow hydrolysis of these molecules in the acid environment. Based on gravimetric corrosion studies, it can be concluded that p-nitrophenol and nitrobenzene molecules are good corrosion inhibitors.

3.2. Polarization measurements

Potentiostatic methods are used to measure polarization. When DC current is applied an experimental source to a corrosion metal in contact with a solution, a net current passes through the metal. This current is due to the difference in partial current due to cathodic reactions (Ic) and anodized reactions (Ia) of metal dissolution. These currents are caused by cathodic and anodic reactions, respectively. The graph is divided between the current potential and logarithm (Tafel plots). The total Tafel polarization curves are shown in Figure 3 (a, b, and c). The cathodic and anodic polarization curves give corresponding cathodic and anodic Tafel lines. The intersecting points of the cathodic and anodic Tafel lines give corrosion current (Icorr) and potential [19–22]. Using polarization measurements, the kinetics of anodic and cathodic reactions produced on aluminum electrodes with 0.1N HCl solutions at different inhibitor concentrations (0.2% to 0.6%) were studied.

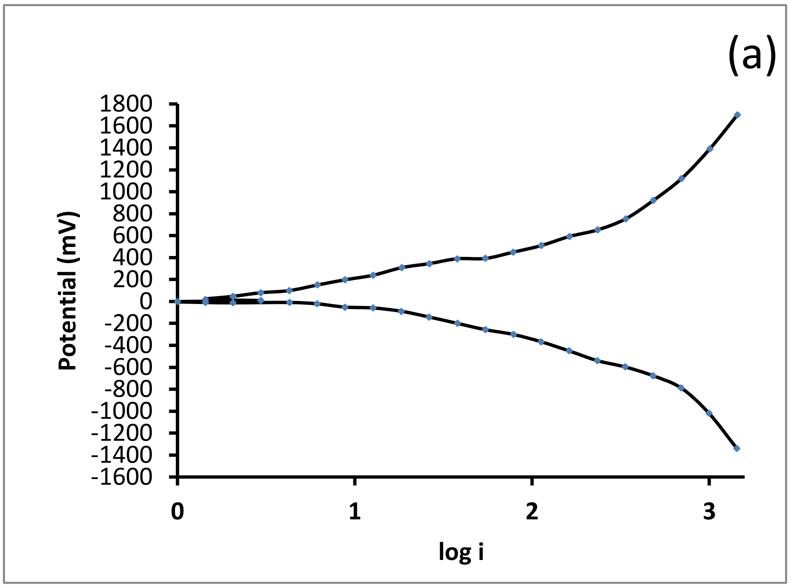

Figure 3(a). Tafel plot for Al in 0.1 N HCl without inhibitor

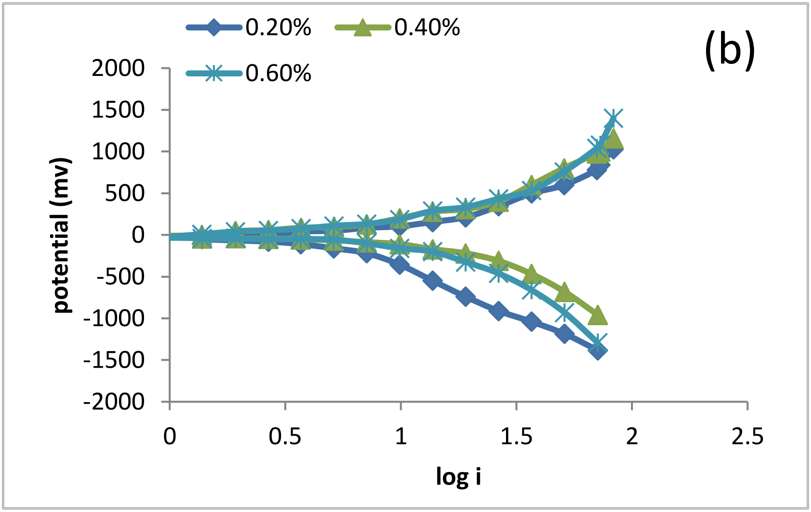

Figure 3(b). Tafel plots in presence of Nitro benzene and

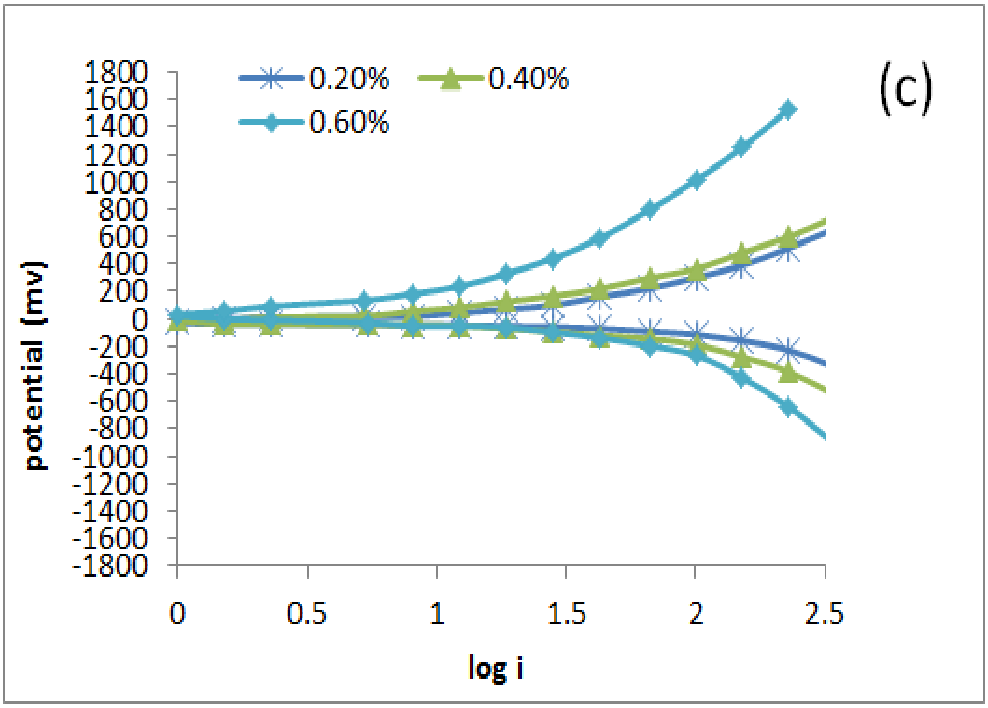

Figure 3(c). Tafel plots in presence of p-Nitro phenol

The results of the electrochemical corrosion parameters (i.e., the corrosion current (i_{corr}), the inhibition efficiency (η), and the corrosion rate shown in Table 2) were collected from a Tafel diagram and polarization experiment obtained under unhampered and inhibited conditions. The corrosion rate is calculated by applying the polarization method of the Tafel.

Table 2. Polarization corrosion inhibition efficiencies (η) and corrosion rate of p-Nitrophenol and Nitrobenzene on Al in 0.1N HCl for 24 hr at room temperature

Inhibition Concentration (%)	p- Nitrophenol			Nitrobenzene		
	I_{corr} mA	Corrosion Rate (mpy)	Inhibition Efficiency (η),%	I_{corr} mA	Corrosion Rate (mpy)	Inhibition Efficiency (η),%
Blank	243.78	260		243.78	260	
0.2	104.23	111.09	57.14	138.99	148.14	42.14
0.4	99.78	106.35	59.06	108.39	115.52	55.53
0.6	52.48	55.93	78.47	65.52	70.90	72.71

Figure 2 shows that the presence of p-Nitrophenol and nitrobenzene reduces the rate of aluminum corrosion. In the case of p-Nitrophenol, the value of is found to be the highest (78.47%) at the highest concentration (0.6%), and the minimum value of is observed when the inhibitory concentration of p-Nitrophenol increases (from 57.14 percent to 78.47 percent). Both inhibitors inhibit aluminum corrosion to the maximum extent at a weight of 0.6%. The inhibitory effect of p-Nitrophenol on aluminum corrosion is also found to be the highest at higher concentrations (η= 78.47%; 0.06%); it is higher than that of Nitrobenzene (η=72.71%; 0.6%). As the Tafel-interceptor polarization method is more sensitive, the results obtained by the method show that the corrosion rate of aluminum in p-Nitrophenol presence decreases from 111.09 mpy to 55.93 mpy. In the case of nitrobenzene, the corrosion rate was 148.14 mpy to 70.90 mpy, with an increase in concentration from 0.2% to 0.6%. Thus, p-Nitrophenol can be considered a more corrosion-resistant substance. It was also observed that the inhibition of p-nitrophenol is higher than that of nitrobenzene. The percentage efficiency of aluminum inhibition is determined by different concentrations (weights) of inhibitors (0.2, 0.4, and 0.6 percent). The protective actions of the two inhibitors (in both methods) are best observed at their highest concentrations. The I_{corr} and mass loss values decrease with increasing inhibitor concentrations. The inhibition efficiency increased with increasing concentrations of inhibitors in acidic mediums (0.1N HCl). The inhibition efficiency obtained by weight loss measurement is consistent with the values obtained by the Tafel method. The results of both methods are consistent with each other.

4. Conclusion

The aromatic compounds under study are good inhibitors in acidic medium for aluminium. The inhibition efficiency of both aromatic compounds was exceeded from 72% to 78% which may be due to the presence of lone pair of electrons on aromatic rings and Nitrogen atom etc; All corrosion monitoring studies have shown that the inhibition efficiency of nitrobenzene is lower at all concentrations than that of p-Nitrophenol. The maximum inhibition efficiency was observed in case of p-Nitrophenol. It can be concluded that p-Aminophenol is more protective than Nitrobenzene for corrosion of Aluminum in acidic media.

Acknowledgements

The author is thankful to HOD Department of Chemistry, Jai Narian Vyas University, Jodhpur for providing research facilities.

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