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FULL LENGTH ARTICLE

Studies on the inhibition of mild steel corrosion in hydrochloric acid solution by atenolol drug

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Abstract The inhibition performance of atenolol on mild steel in 1 M hydrochloric acid solution was studied by weight loss and electrochemical methods. The results show the inhibition efficiency was found to increase with increasing the concentration of the inhibitor from 50 to 300 ppm. The maximum inhibition efficiency 93.8% was observed in the presence of 300 ppm inhibitor (in case of potentiodynamic polarization). The inhibition action of atenolol was explained in terms of adsorption on the mild steel surface. The adsorption process follows Langmuir isotherm via physical adsorption. Electrochemical Impedance spectroscopic technique (EIS) exhibits one capacitive loop indicating that, the corrosion reaction is controlled by charge transfer process. Polarization measurements showed that the inhibitor is of a mixed type. The results obtained from the different methods are in good agreement. The surface morphologies of mild steel were examined by Fourier-transform infrared (FT-IR) spectroscopy, scanning electron microscope (SEM). Further, the computational calculations are performed to find a relation between their electronic and structural properties.

1. Introduction

The environmental consequence of corrosion is enormous and its inhibition has been deeply investigated. Hydrochloric acid is widely used in various technological processes in industry, e.g., in pickling baths, in the extraction and processing of oil and gas and in other chemical and petrochemical industries. Also, in the technical cracking of petroleum, acids appear as a result of hydrolysis of salts and may have a destructive effect on the equipment. Corrosion in mild steel is important and expensive problem in the industries and it represents a significant portion of loss as a result of lost production, inefficient operation, and high maintenance. It has been found that one of the best methods of protecting metals against corrosion involves the use of inhibitors which are substances that slow down the rate of corrosion [1,2]. Therefore, the development of corrosion inhibitors based on organic compounds containing nitrogen, oxygen atoms is of growing interest in the field of corrosion and industrial applications [3]. The corrosion inhibition is a surface process, which involves adsorption of the organic compounds on the metal surface. The adsorption

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depends mainly on the electronic structure of the molecule [4]. The inhibition efficiency of organic compounds depends on the mode of interaction with the metal surface and molecular structure. However, there is increasing concern about the toxicity of most corrosion inhibitors. The toxic effects not only affect living organisms but also poison the environment [5]. Due to the toxicity of some corrosion inhibitors, there has been increasing search for green corrosion inhibitors.

Recently, several studies have been carried out on the inhibition of corrosion of metals by drugs [6–12]. Moreover, the pharmaceutically active compound atenolol is big enough (molecular mass 266.336 g/mol, $C_{14}H_{22}N_2O_3$) and likely to effectively cover more surface area (due to adsorption) of the Mild steel. Furthermore, atenolol is very cheap, easily available, environmentally friendly and most importantly is non-toxic. In view of these favorable characteristic properties, atenolol drug was chosen for the corrosion studies.

The main objective here is to investigate the corrosion process of mild steel in 1 M hydrochloric acid solution in the absence and presence of different concentrations of atenolol. It was also the purpose of the present work to test the various electrochemical studies and surface morphologies.

2. Experimental technique

2.1. Material preparation

Mild steel materials used for the study were mechanically cut into specimen of sizes 4 × 1.5 × 0.2 cm. AR grade hydrochloric acid was used for the preparation of aggressive solutions. Various (approximate) concentrations of acid with and without inhibitor were prepared using double distilled water. The IUPAC name of the drug atenolol is (RS)-2-{4-[2-Hydroxy-3-(propan-2-ylamino)propoxy]phenyl}acetamide. The compound atenolol (brand name Betacard-25) was purified by recrystallisation with ethanol. The inhibitor used in this study is non-toxic, with high molecular size, contains a large number of donating atoms (N, O, atoms) and easily available as pharmaceutical drug. Molecular structure of the used inhibitor is presented in Fig. 1.

2.2. Electrochemical studies

The working electrode was polished with different grades of emery papers, washed with water and degreased with acetone. All electrochemical measurements were carried out using a CHI 760D Electrochemical impedance analyzer model. Prior to the electrochemical measurement, a stabilization period of 30 min was allowed, which was proved to be sufficient to attain a stable value of open circuit potential (OCP) [13]. The electrochemical studies were made using a three-electrode cell assembly at room temperature with a platinum counter electrode and a saturated calomel electrode (SCE) as the reference electrode. The working electrode was mild steel with the exposed surface of 1 cm^2 and the rest being covered with commercially available resin. The EIS measurements were carried out from Nyquist plot using AC signal of 0.01 V amplitude for the frequency spectrum from 100 kHz to 0.01 Hz. The potentiodynamic polarization curves were recorded in the potential range of +300 mV from the open circuit potential at a sweep rate of 0.01 mV/s.

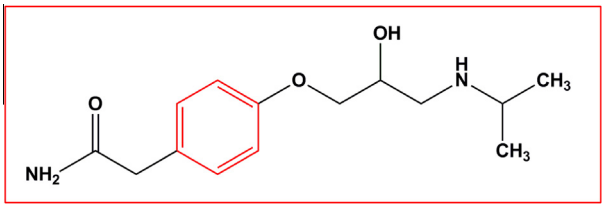

Figure 1 Structure of atenolol (IUPAC name: (RS)-2-{4-[2-Hydroxy-3-(propan-2-ylamino)propoxy]phenyl}acetamide).

2.3. Weight loss measurements

All the tests were conducted in 100 ml aerated 1 M HCl solution at room temperature with different concentrations of atenolol for 3 h immersion period. These samples were polished with emery paper of 1/0, 2/0, 3/0, 4/0, 5/0, and 6/0 grades, washed thoroughly with doubled distilled water, degreased with acetone and finally dried. At the end of the tests, the specimens were carefully washed in distilled water, dried and then weighed. Duplicate experiments were performed in each and the mean value of the weight loss has been reported. From the weight loss measurements, the corrosion rate (W) was calculated using the following equation,

$$\text{C.R.} = W = \frac{m_1 - m_2}{St} \quad (1)$$

where, m_1 is the mass of the specimen before corrosion, m_2 is the mass of the specimen after corrosion, S is the total area of the specimen, t is the corrosion time, and W is the corrosion rate. The (IE%) was determined using the following equation [14],

$$\text{IE}\% = \left[\frac{W_o - W_i}{W_o}\right] \times 100 \quad (2)$$

where, W_o is the corrosion rate in the absence of inhibitor and W_i is the corrosion rate in the presence of inhibitor.

2.4. Surface studies

The scanning electron microscopy (SEM) VEGA3TESCAN model was used to study the morphology of the corroded surface in the presence and absence of atenolol drug for the immersion of 3 h at room temperature. The SEM images were taken from that portion of the specimen where better information was expected.

3. Results and discussion

3.1. Electrochemical impedance spectroscopy

Table 1 shows the experimental results obtained from EIS measurements for the corrosion of mild steel in the presence of atenolol at room temperature. The impedance spectra for mild steel in 1 M HCl solution without and with optimum concentration of atenolol are presented as Nyquist plots in Fig. 2. Clearly, the impedance spectra exhibit a large capacitive loop at high frequencies followed by a small inductive loop at low frequency values. The capacitive loop indicates that the