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FULL LENGTH ARTICLE

A comprehensive study of ondansetron hydrochloride drug as a green corrosion inhibitor for mild steel in 1 M HCl medium

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Abstract The inhibiting action against the corrosion of mild steel by ondansetron hydrochloride (ODSH) drug was studied, using various studies such as weight loss, electrochemical impedance spectroscopy, potentiodynamic polarization measurement, scanning electron microscopy (SEM), energy dispersive X-ray spectroscopy (EDX), atomic force microscopy (AFM), FT-IR spectroscopy and reactivity of molecule is studied using quantum chemical calculation. The result shows that ondansetron hydrochloride (ODSH) gives better inhibition on mild steel. The value of activation energy (E_a) and various thermodynamic parameters such as adsorption equilibrium constant (K_{ads}), free energy of adsorption (ΔG^0_{ads}), adsorption enthalpy (ΔH_{ads}) and adsorption entropy (ΔS_{ads}) was calculated and discussed. The adsorption of ODSH on mild steel surface obeys the Langmuir adsorption isotherm. Potentiodynamic polarization measurement reveals that ODSH acts as a mixed-type inhibitor. Electrochemical impedance spectroscopy (EIS) spectra exhibit one capacitive loop indicating that, the corrosion reaction is controlled by charge transfer process. SEM, EDX, AFM, FT-IR conforms to the protective film formation. Quantum chemical calculation was calculated and discussed, and it supports the results.

1. Introduction

Corrosion protection studies of iron and its alloys play a vital role due to their wide range of industrial applications especially in the petroleum industry and power plants [1]. An acid solution was generally used for the removal of undesirable scale and rust in several industrial processes, hydrochloric and sulfuric acids are widely used in these processes [2]. A number of methods have been used to reduce the corrosion of metal such as cathodic protection, metal plating, coatings, inhibitors, etc.; the use of inhibitors is one of the most useful methods for the protection of material against corrosion. Most well-known acid inhibitors are organic compounds because they contain polar functional groups (nitrogen, sulfur, oxygen and phosphorus) and aromatic π electrons, they easily contact to the metal surface and form a protecting layer [3–12]. The applicability of organic compound as corrosion inhibitors for

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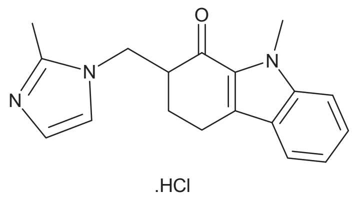

Figure 1 Structure of ondansetron hydrochloride.

metals in the acid medium have been recognized for a long time [13–17]. They exert inhibition action through adsorption of the inhibitor on the metal surface, they block the corrosion active sites by removal of the water molecule and forming a protective layer on the metal surface; this is due to a decrease in the corrosion rate of metal. The adsorption behavior of organic molecules on the metal surface depend on the nature of the metal surface, electrochemical potential of the metal and solution interface, the number of adsorption active centers in the molecule, the size of the molecule, the mode of adsorption and their charge density [18,19].

Up to now, many pharmaceutically active compounds are used as the corrosion inhibitors, for metallic corrosion studies. Some of the compounds are given; Cefatrexyl [20], Antifungal drugs (clotrimazole, fluconazole) [21], Cefotaxime sodium [22], Cefalexin [23], Ketosulfone [24], Rodamine azosulfa drug [25], Esomeprazole [26], Sulfa drugs (e.g. sulfaguanidine, sulfamethazine, sulfamethoxazole and sulfadiazine) [27], Streptomycin [28], Cefazolin [29], Mebendazole [30], Pheniramine [1], Cloxacillin [31] and Cefixime [32].

The main objective here is to investigate the corrosion inhibition process of mild steel in one molar hydrochloric acid using ODSH. The IUPAC name of ondansetron hydrochloride is 9-methyl-3-(2-methyl-imidazol-1-ylmethyl)-1,2,3,9-tetrahydro-carbazol-4-one (Fig. 1). The Mebendazole molecular formula of ODSH is $C_{18}H_{20}N_3OCl$ and the molecular weight is 329.81 g/mol. Furthermore, ODSH is easily available, environmentally friendly and the most important it is non-toxic in nature. It is pharmaceutically used to prevent nausea and vomiting treatment. In view of these favorable characteristics, we are choosing ODSH for the corrosion inhibitor study.

2. Materials and methods

2.1. Materials

The mild steel sample used for the study contains the following composition (in wt.%) 0.104% C, 0.58% Mn, 0.035% P, 0.026% S and the remainder Fe.

2.2. Inhibitor

The inhibitor was purchased from Mankind Pharmacy Pvt. Ltd. (brand name vomikind) New Delhi. It contains three N atom, one O atom, and a heterocyclic ring. These atoms can easily protonate in acid medium and protect the metal surface by forming a protective film in metal/solution interface.

2.3. Solutions

The aggressive solution of 1 M HCl was prepared by dilution of AR grade, 35% HCl with double distilled water. The concentration range of inhibitor was taken in 50–300 ppm. The stock solution is prepared using this relation 1000 ppm = 1000 mg made in 1 l. Stock solution is used to making the different concentrations of inhibitor (50–300 ppm) are prepared based on volumetric law ($V_1N_1 = V_2N_2$).

2.4. Weight loss measurements

A rectangular steel plate had been used in the weight loss study. The size of the steel that is 3.5 × 1.5 × 0.2 cm was cut with a small hole on the upper edge of the specimen. It is mechanically polished with different grades of emery papers 1/0–1/7 and then washed with acetone. After the washing, the specimens were weighed accurately using digital balance and the specimens were immersed in 100 ml 1 M HCl without and with various concentrations of ODSH using glass hooks. The inhibitor concentrations used in the weight loss study are in the ranges of 50–300 ppm. All the aggressive acid solutions were kept open to air. After immersion for 3 h, the specimens were taken out, washed with a bristle brush under running water in order to remove the corrosion product, dried with the hot air stream, and re-weighed accurately to calculate weight loss. In this, experiments were carried out in triplicate method to get good reproducibility results in the measurement. The standard deviation value among parallel triplicate experiments was found to be lower than 5%, indicating good reproducibility. Then the tests were repeated at different temperatures. The temperature study was carried out at 303–333 K. The corrosion rate (CR) is calculated by the following equation [33].

$$\mathrm{CR} = \frac{W}{St} \tag{1}$$

where W is the average weight loss of three rectangular steels, S is the total area of rectangular steel, and t is immersion time (3 h). With the calculated corrosion rate, the inhibition efficiency (IE%) and surface coverage (θ) were calculated as follows [34].

$$\mathrm{IE}\ \% = \left[\frac{W_o - W_i}{W_o}\right] \times 100 \tag{2}$$

$$\theta = \left[\frac{W_o - W_i}{W_o}\right] \tag{3}$$

where W_0 is the corrosion rate in the absence of inhibitor and W_i is the corrosion rate in the presence of inhibitor.

2.5. Adsorption isotherm and thermodynamic parameters

In order to learn about the mode of adsorption of ODSH on the metal surface in 1 M HCl at different temperatures, attempts were made to fit experimental data with various adsorption isotherms. Using these data, thermodynamic parameters were calculated using standard equations.