Corrosion Inhibition of Zinc Metal in Hydrochloric acid Solution by Using Ciprofloxacin Drug as an Inhibitor

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Abstract

The corrosion of zinc in 4 M HCl by has been investigated at room temperature, and at different temperatures using weight loss measurements, and inhibited by using ciprofloxacin drug. Results obtained showed that ciprofloxacin is a convenient inhibitor and its inhibition efficiency (IE %) increased with the increase of inhibitor concentration. The best temperature which showed the lowest corrosion rate values was at 318K.The mechanism of adsorption had been explained on the basis of chemical structure of the investigated inhibitor. It was found that the protection of zinc metal using this corrosion inhibitor is not complicated at room temperature, and the optimum concentration of inhibitor has been calculated which had showed the maximum surface coverage.

Keywords: inhibition efficiency; Zinc metal; ciprofloxacin.

Introduction

Corrosioncan be defined as the degradation of a material when it comes in contact with the environment. The dissolving of a material by a corrosive liquid is called chemical corrosion [1]. The material continues to dissolve until either it is consumed or the liquid is saturated. A simple example is salt dissolving in water. The removing of metal atoms from a solid material as the result of an electric circuit is called electrochemical corrosion [2]. In this form of corrosion, metal atoms lose electrons and become ions thus forming a byproduct. Electrochemical corrosion occurs most frequently in aqueous mediums, in which ions are present in water or moist air. In this process, an electric circuit is created and the system is called an electrochemical cell. Corrosion of a steel pipe or a steel automobile panel, creating holes in the steel and rust as the byproduct, are examples of this reaction [3]. An inhibitor is a substance which when added in small quantities to a corrosive fluid decreases the corrosion rate by several orders of magnitude [6]. An inhibitor can be regarded as a retarding catalyst. They can be classified into several groups according to the mechanisms by which they function.

a. The Absorption Type get absorbed on the surface of the metal that corrodes and suppress the metal dislocation and reduction reactions. (ex. organic amines).
b. Scavengers are a special type of inhibitors which remove the corrosion causing reagents from the environment. (ex. sodium sulfite, hydrazine).
c. Vapor Phase Inhibitors are similar to the adsorption type and possess a high vapor pressure. They can be placed in the environment without any contact with the metal. They form a thin adsorbed layer on the metal by sublimation followed by condensation on the surface.
d. Oxidizers are the substances which are effectively used to inhibit the corrosion of metals that demonstrate active-passive transitions like iron, titanium etc. (ex. chromate, nitrate).
e. Hydrogen Evolution Inhibitors, such as antimony, retard the hydrogen reduction reaction [7,8].

Experimental Part

Zinc strips of BDH grade were used in dimension (8cm*2cm *0.5mm) (length, width, and thickness), and a solution of 4M HCl was prepared. Ciprofloxacin inhibitor was prepared in 500 ppm concentration, thereafter subsequent dilution was employed to prepare solutions 400,300,200, and 100ppm.Zinc strip was immersed in HCl solution in absence of inhibitor for specific periods of time and weighed in electronic balance after each period. Weight loss measurements [9]:For weight loss measurements, the following formulae were employed [10, 11]:

$$\Delta m = (m_1 - m_2) \quad \text{.................................} (1)$$

Where m_1 and m_2 are the weights of metal before and after exposure to the corrosive solution, respectively. The percentage of inhibition efficiency (IE %) and the degree of surface coverage (θ) of the investigated compounds was calculated from the following equations:

$$IE\ \% = [1 - (\Delta m_{inh} / \Delta m_{free})] \times 100 \quad (2)$$
$$\theta = [1 - (\Delta m_{inh} / \Delta m_{free})] \quad (3)$$

Where Δm_{free} and Δm_{inh} are the weight losses in the absence and presence of inhibitor, respectively.

Results and Discussion

The Table (1) shows the values of corrosion rate of zinc strips in 4 M HCl solution during specific periods, and the weight loss measurements were achieved, the weight of strips was decreasing, and the evolution of hydrogen gas was so obvious during the corrosion experiments, and the formation of zinc chloride as well.

Table (1)
The corrosion rate of zinc strip during specific periods at 298K.

Time/minutes	*Δm/Δt (Corrosion rate)*
20	0.316
40	0.294
60	0.214
80	0.121
100	0.04
120	0.05
140	0.055
160	0.083
180	0.054

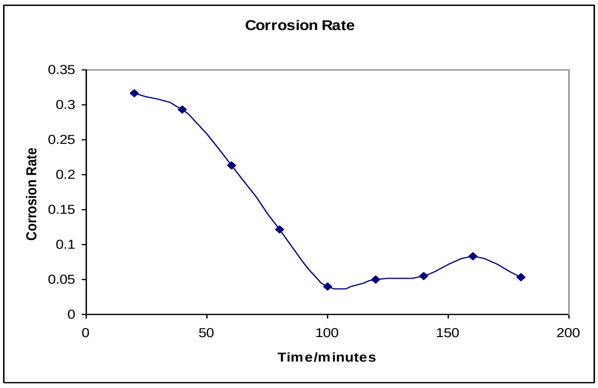

Fig.(1) The corrosion rate of zinc strip at 298K.

Fig.(1) showed that the corrosion is decreasing during the time, since the corrosion graph is descending to the lowest value of the corrosion rate. The introduction of ciprofloxacin as an inhibitor was via experiencing its own capability to be dispersed on the surface of the zinc strips, the chemical structure of ciprofloxacin is as follows:

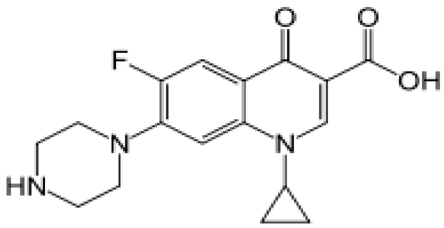

Fig. (2) The chemical structure of ciprofloxacin.

According to its structure, the ciprofloxacin drug might be considered as an adsorption inhibitor according to the classification of inhibitors that formerly mentioned, so the adsorption was occurred on the surface of zinc strip, but it is necessary to know what is the optimum concentration.

Table (2)
The corrosion rates at different concentration of ciprofloxacin at 298 K.

Time/ minutes	*500 ppm*	*400 ppm*	*300 ppm*	*200 ppm*
20	0.017	0.018	0.01	0.717
40	0.015	0.014	0.105	0.674
60	0.02	0.022	0.023	0.015
80	0.016	0.021	0.014	0.017
100	0.021	0.021	0.025	0.02

It could be inferred from Table (2) that the corrosion rates are descending during time, in comparison with table-1, the corrosion rate at 20 minutes was 0.316, but in table-2 the values are less than that number except in the concentration of 200 ppm, but it is optimum at 300 ppm.

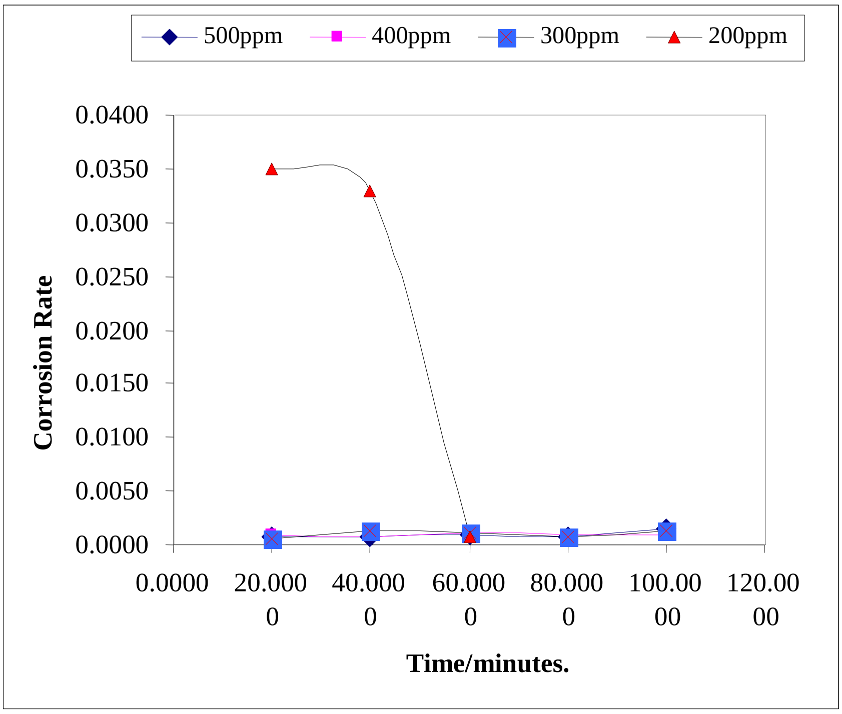

Fig. (3) The corrosion rate values in presence of ciprofloxacin drug at 298 K.

Table (3)
The values of surface coverage (θ) of ciprofloxacin at different concentrations at 298 K.

Concentration	*20 min.*	*40 min.*	*60 min.*	*80 min.*	*100 min.*
500 ppm	0.964	0.949	0.906	0.867	0.475
400 ppm	0.943	0.952	0.897	0.826	0.475
300 ppm	0.969	0.909	0.893	0.885	0.375

Table (3) shows that the maximum surface coverage is at 300 ppm, and after 20 minutes of exposure to the ciprofloxacin drug, almost most of ciprofloxacin molecules have oriented themselves to be in a maximum attraction to the surface of zinc, so the adsorption would occur on the surface of zinc strip. The inhibition efficiency was calculated for all concentrations of ciprofloxacin drug and it was 96.9 for 300 ppm concentration.

Table (4)
The values of inhibition efficiency of ciprofloxacin drug at 298 K.

Concentration	*20 min.*	*40 min.*	*60 min.*	*80 min.*	*100 min.*
500 ppm	96.4	94.9	90.6	86.7	47.5
400 ppm	94.3	95.2	89.7	82.6	47.5
300 ppm	96.9	90.9	89.3	88.5	37.5

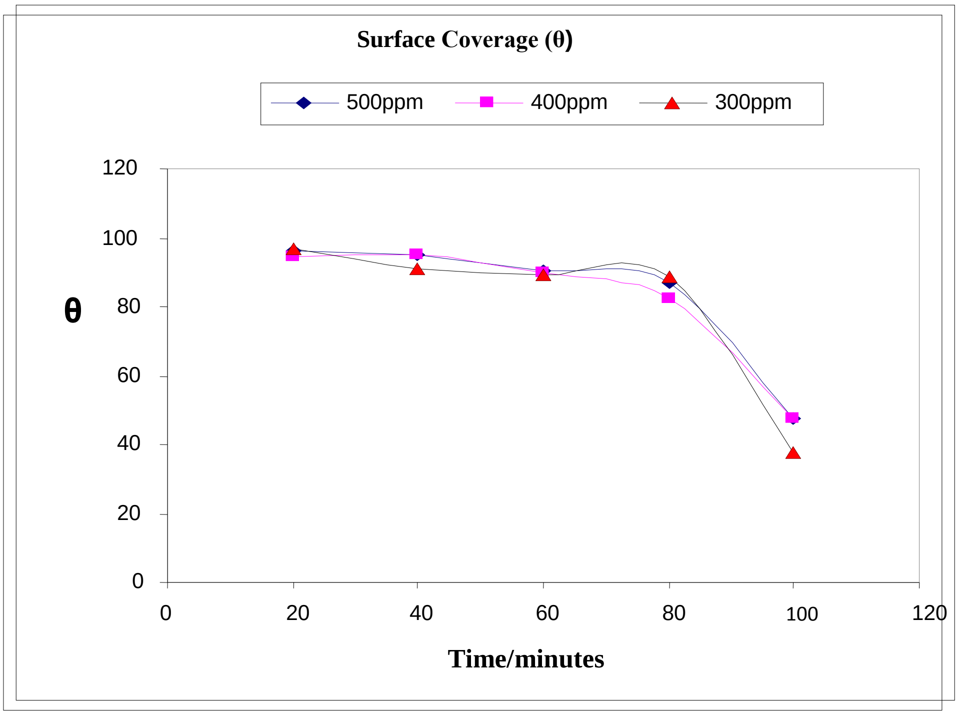

Fig. (4) The surface coverage at different concentrations of ciprofloxacin drug at 298 K.

Table (5)
The corrosion rates at different temperatures.

Time/minutes	*308K*	*318K*	*328K*
	CR	*CR*	*CR*
20	0.211	0.162	0.0177
40	0.314	0.084	0.096
60	0.367	0.099	0.123
80	0.425	0.121	0.201
100	0.229	0.0789	0.179

Table (5) shows the corrosion rates of zinc at different temperatures, at 308K the corrosion rate has been increased, and also it has been increased at 328K, but the values of corrosion rate at 318K has been decreased. As shown in the Fig.(5), the rate of corrosion has been increased only at 308K, and 328K, but at 318K there was a slight decrement in the corrosion rate, referring to the Fig.(1), there was also a decrement in the corrosion rate of zinc. As shown in the Fig.(5), the rate of corrosion has been increased only at 308K, and 328K, but at 318K there was a slight decrement in the corrosion rate, referring to the Fig.(1), there was also a decrement in the corrosion rate of zinc.

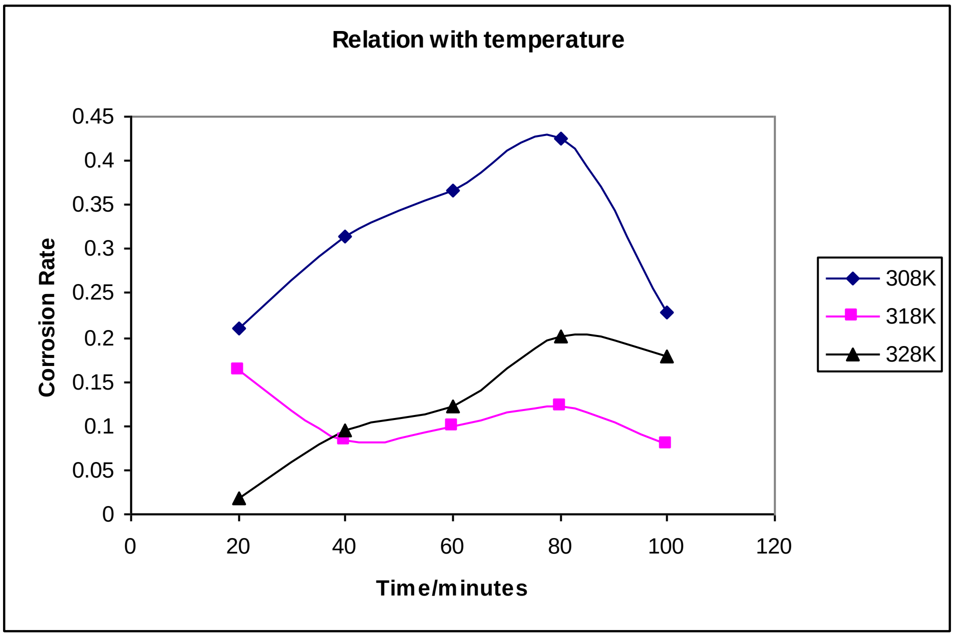

Fig.(5) The corrosion rate of zinc at different temperatures.

Conclusion (s)

In the light of the present study the following points have been concluded:

First, the zinc was stronger towards corrosion in presence of inhibitor (ciprofloxacin), and at 300 ppm. Second, the corrosion rate was decreased at 298K, and 318K, but it was increased at 308K, and 328K. Third, the surface coverage was high at 300 ppm inhihibitor concentration which proves that the adsorption on the surface of zinc was optimum at this concentration, and the dispersal of ciprofloxacin molecules, penetration and coating was optimum as well.

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الخلاصة

لقد تم دراسة تآكل معدن الخارصين في محلول ٤ مولاري حامض الهيدروكلوريك وفي درجات حرارية مختلفة باستخدام طريقة النقص في الوزن، وقد تم تثبيط تآكل الخارصين باستخدام دواء السبروفلوكساسين، وقد بينت الدراسة ان دواء السبروفلوكساسين كان مثبطاً جيداً، وان نسبة كفاءة التثبيط قد ازدادت بازدياد تركيز المثبط. لقد كانت درجة الحرارة المثلى والتي كانت فيها اقل قيمة لمعدل التآكل هي ٣١٨ كلفن. تم دراسة ميكانيكية الامتزاز على اساس التركيب الكيميائي للمثبط، ولقد كانت حماية معدن الخارصين وامتزازه على سطح المعدن عملية غير معقدة ولقد كان تركيز الدواء الامثل هو ٣٠٠ جزء من المليون والذي اظهر اكبر تغطية لسطح المعدن.