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Examination and study of (thiazole-5-carboxylic acid) as an inhibitor in sodium chloride medium for a mild steel corrosion

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Abstract

The corrosion inhibitor (thiazole-5-carboxylic acid) was tested in this study using a weight loss technique and at temperatures range from 30 to 50 °C, and concentrations range from 100 to 400 ppm. Since the corrosion inhibitor contains atoms of oxygen, nitrogen, and sulfur, as well as thiazole that can be inhibit the corrosion process, the corrosion inhibitor's efficiency decreases as temperatures rise to 40 and 50°C, due to the formation of a layer of film on the metal's surface, and because the corrosion inhibitor contains atoms of oxygen, nitrogen, and sulfur, as well as thiazole that can be inhibit the corrosion process. The reaction's thermodynamic characteristics, such as activation energy, enthalpy, entropy, and free energy of adsorption, were determined and were satisfactory in the inhibitory processes.

Keywords: NaCl , carboxylic acid, inhibitor, polarization, weight loss, entropy, efficiency.

1. Introduction

Corrosion is the loss of metal characteristics as a result of hostile conditions, such as when using of acid solutions for pickling, chemical and electrochemical engraving of metal, industrial acid clean-up, cleaning of oil refinery equipment, acid removing sediments, and acidizing oil wells [1-8] . Corrosion of significant industrial metal equipment, which has drawn a lot of attention in recent years, continues to be a source of concern for scientists, engineers, and researchers, as it impacts the metalworking, chemical, and oil sectors [9-15] . Inhibitors usually work by adsorption on metal surfaces, with the nature of the surface adsorbed metal and hostile media for the metal portion, as well as synthetic inhibitor molecules and their interaction with the metal surface [16-23] . Organic inhibitors for mild steel in hydrochloric acid medium have previously been investigated. Carbon steel is prone to pitting corrosion in an oxidizing environment [20-25]. Furthermore, in an oxidizing environment, carbon steel is expected to corrode faster than in a reducing environment. On the other hand, the effect of pitting corrosion can be mitigated by raising the total corrosion rate [26-29]. Mild steel pipes and vessels are commonly used to transport water or are submerged in some way while in operation. Temperature, flow velocity, pH, and other factors can all influence corrosion rates [28-31]. The relative acidity of the solution is the most important factor to consider. Adsorption is one of the necessary and very useful processes in industrial, chemical and petrochemical processes, which is the adhesion of atoms, molecules, or ions from a liquid, gas, or dissolved solid to a surface. This process creates a film or layer of the inhibitor on the surface of the metal in the process of inhibiting corrosion intended to reduce the oxidation and reaction processes.[32-40]

2. Experimental Work

Mild Steel specimen with the following composition by weight: 0.18 % carbon, 0.39 % manganese, 0.17 % silicon, 0.09 % sulphur, 0.47 % phosphorus, 0.028 % copper, and balance Fe. The metal sample had been prepared, grease had been removed, and it had been cleaned thoroughly. Seven mild steel coupons with dimensions of 4cm x 3cm x 0.2cm were employed in the tests, each containing NaCl and concentrations of (thiazole-5-carboxylic

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acid) as an inhibitor. However all experiment was conducted by using the hydrogen gas evolution technique with a 50 ml volume, both without and with inhibitors.[5-15]

3. Results and Discussion

Figure 1 shows a large difference of weight loss over time without and with inhibitors; when adding inhibitors, a reduction in weight loss or corrosion rate of mild steel in NaCl, observed as shown in equation 1 below; when a gradual increase the inhibitor concentration takes place, a decrease in weight loss of mild steel in NaCl media at 30 oC observed, as shown in Figures 2 and 3. These results agree very well with reported data of many workers.[8-16]

Figure 4 depicts the relationship between hydrogen gas evolution volume and time, demonstrating that hydrogen gas evolution decreases with time without and with concentration inhibitors.[5-9]

Table 1 shows that increasing the inhibitor content enhanced corrosion inhibition effectiveness at 30 oC, whereas increasing the temperature decreased inhibition efficiency took place.[4-12]

The inhibition efficiencies (% E) were calculated by using the following equation:[6-15]

$$E = (Wu-Wi) / Wu * 100 \% \qquad (1)$$

Where wu is denotes to the weight loss for uninhibited solution and wi is denotes to the weight loss for inhibited solution.

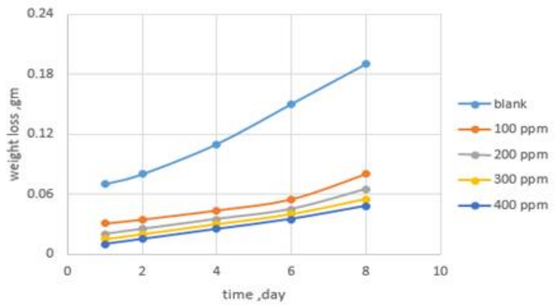


Fig. 1: Scheme weight loss vs. time at 30 ºC without and with inhibitors

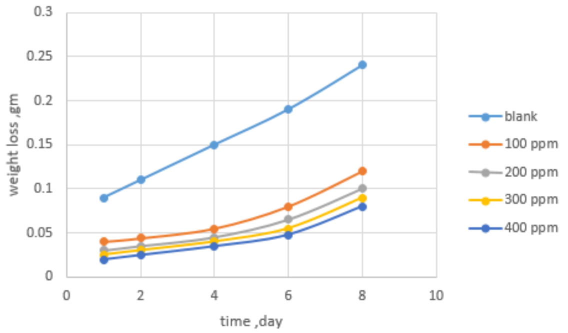


Fig. 2: Scheme weight loss vs. time at 40 ºC without and with inhibitors

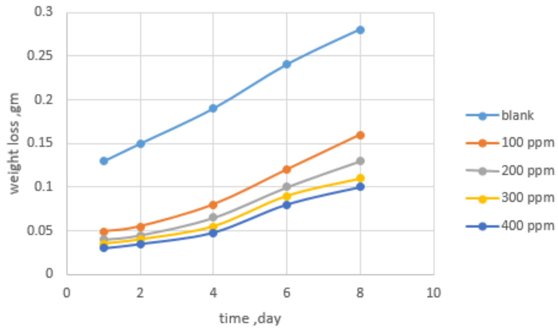


Fig. 3: Scheme weight loss vs. time at 50 ºC without and with inhibitors

Table 1: Influence inhibitor concentrations on inhibition efficiency by weight loss method

Inhibitor conc. ppm	**Corrosion rate C.R**			**Inhibition efficiency %**		
	30 ºC	40 ºC	50 ºC	30 ºC	40 ºC	50 ºC
Blank	0.446	0.576	0.712	0	0	0
100	0.112	0.151	0.216	74.8	73.7	69.6
200	0.088	0.139	0.184	80.2	75.8	74.1
300	0.075	0.121	0.171	83.1	78.9	75.9
400	0.057	0.097	0.148	87.2	83.1	79.2

Table 1 illustrates corrosion rates and efficiency without and with inhibitors for different concentrations of nanoparticles at temperatures of 30, 40, and 50 °C. Results showed shows that the rate of corrosion reduces as the inhibitor concentration increases and the efficiency of the inhibition increases [12-19]. The explanation of these phenomena is an electric double layer is formed by the adsorption of an inhibitor in the metal surface. Carbon steel offers the most effective protection of corrosion at 400ppm and 30 °C, as shown in Figure 5.[15-22]

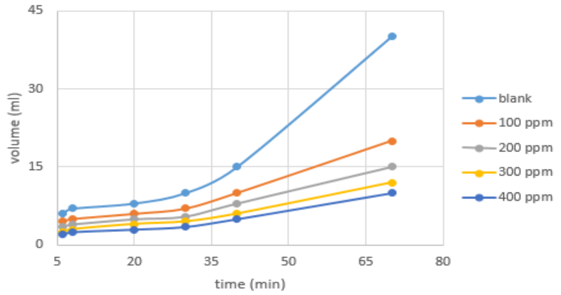


Fig. 4: Scheme of volumes of hydrogen gas evolved with time

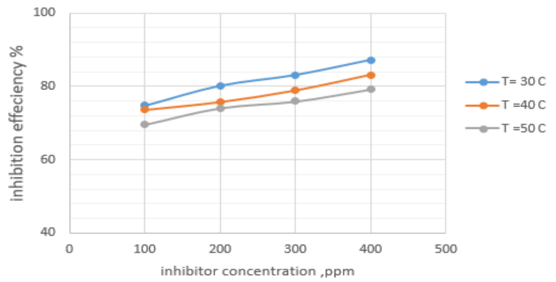


Fig. 5: Scheme inhibition efficiency vs. inhibitor concentrations

The effects of temperature in NaCl on carbon steel metal were examined during this experiment. By utilizing Equation 2, results have shown that raising temperatures from 30 to 50 °C decreases the effectiveness of prevention of corrosion due to higher rates of corrosion.[11-19, 32-40]

Corrosion rate is expressed using the equation below.

C.R = 87.6 w /D.a.t **(2)**

Where **C.R** represents corrosion rate (mmpy), **w** represents weight loss (mg), **D** represents density (g/cm3), **a** represents area (cm2), and **t** represents time (hr).

Using the Arrhenius equation, the activation energy may be calculated using the following corrosion rate equation:[7-16]

C.R = A $e^{-Ea/RT}$ **(3)**

The activation energy is **Ea**, the universal gas constant is **R**, and the absolute temperature is **T**. The frequency factor is **A**.

C.R = [R.T/N.h].e $^{[\Delta S/R]}$ **. e** $^{-[\Delta H/RT]}$ **(4)**

Where **h** refer to the Planck constant, **N** for Avogadro's number, **ΔS** for entropy energy, and **ΔH** for enthalpy energy.

The reactions free energy can be estimated by using the following equation:

ΔG = ΔH-TΔS **(5)**

ΔG represents to the adsorption free energy.[13-20]

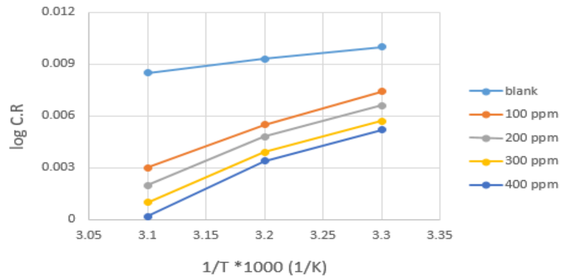


Fig.6: Plot of log C.R vs. 1/T for several concentrations

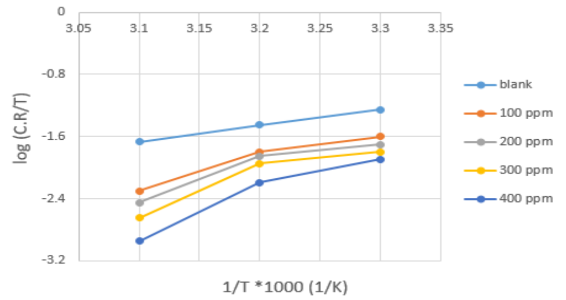
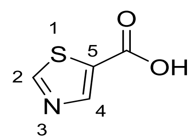


Fig.7: Plot of log C.R/T vs. 1/T for several concentrations

Figures 6 and 7 were used to determine kinetic activation parameters, enthalpy, entropy, and free energies from the Arrhenius equation, as shown in Table 2.[16-25]

Table 2 shows activation, enthalpy, entropy, and free energy of adsorption, which were determined by using Figures 6 and 7. Because the inhibitor's adsorbent layer is a film on the metal's surface, increasing the inhibitor causes a rise in activation values and enthalpy energy, as well as a decrease in entropy energy [22-29]. Chemical and physical adsorption are the two types of adsorption that have been seen in present work, with activation values exceeding 80 kJ / mol , The presence of nitrogen, sulfur, and oxygen atoms, in addition to thiazole , can cause excellent inhibition by forming a film on the surface of the metal as shown in Figure 8 the represents structure of the inhibitor.[32-40]



thiazole-5-carboxylic acid

Table 2: Parameters of thermodynamic adsorption

Inhibitor conc. ppm	Ea (kJ/mole)	ΔH (kJ/mole)	ΔS (kJ/mole.K)	ΔG (kJ/mole)
blank	62.35	17460	$7.2*10^{-10}$	17460
100	182.90	29100	$9.4*10^{-10}$	29100
200	191.22	31177	$10.2*10^{-10}$	31177
300	195.37	35334	$12.1*10^{-10}$	35334
400	207.85	44064	$13.6*10^{-10}$	44064

4. Conclusions

In this research, the inhibitor (thiazole-5-carboxylic acid) was evaluated by weight loss method and at temperature ranging from 30 to 50 °C, different concentrations of corrosion inhibitor were used from 100 to 400 ppm. Found that corrosion inhibitor was able to reduce corrosion at 30°C, and when temperature increased to 40 and 50°C, the efficiency of the inhibition decreases, due to the formation of a layer of film on the surface of the metal, and also because of the corrosion inhibitor contains atoms of oxygen, nitrogen and sulfur, as well as thiazole that can inhibit the corrosion process. The thermodynamic parameters of the reaction such as activation energy, enthalpy, entropy, and free energy of adsorption were also determined and it was very satisfactory in the inhibition processes.

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