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# Effect of Temperature on the Corrosion Inhibition of 4-ethyl-1-(4-oxo-4-phenylbutanoyl)thiosemicarbazide on Mild Steel in HCl Solution

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**Abstract:** The temperature effect of 4-ethyl-1-(4-oxo-4-phenylbutanoyl)thiosemicarbazide (EOPT) on the mild steel corrosion in 1 M HCl solution was studied by gravimetric techniques at temperatures varying from 303 to 333 K. The investigated inhibitor concentrations were started from 100 ppm and ended with 500 ppm. The inhibition efficiency increased with the increase of the concentration of the inhibitor and reached 96.1% with the concentration of 500 ppm at 303 K and decreased to 66.3% at 333 K. Moreover, the inhibition efficiencies decreased with the temperature increase for both acids. Using the Langmuir adsorption isotherm for the adsorption of this inhibitor on the mild steel surface was determined. EOPT was found to be an efficient corrosion inhibitor due to its structural molecules, which contain sulfur, nitrogen, and oxygen, hetero atoms an addition to the aromatic ring.

**Keywords:** thiosemicarbazide; corrosion inhibitor; mild steel; inhibitive efficacy; temperature effect; inhibitive efficacy.



## 1. Introduction

Mild steel is frequently employed in a variety of manufacturing industries. Pickling, industrial acid cleaning, acid descaling, oil well acidifying, and other industrial procedures typically involve acidic solutions [1–9]. Corrosion prevention systems emphasize using natural and/or synthetic organic compounds that have little or no negative impact on the environment. Metal corrosion rates are reduced, saving resources and money in industrial applications while improving equipment life and reducing the dissolution of hazardous metals from components into the environment [10-16]. One of the most practical approaches for preserving metals from corrosion is using organic compounds as corrosion inhibitors, which is becoming frequently common. Existing evidence indicates that organic inhibitors act through adsorption and protect iron by forming a coating [17-23]. Organic molecules with highly electronegative heterogeneous atoms, such as phosphorous, sulfur, nitrogen, and oxygen, or those with many bonds acting as adsorption centers, work well as corrosion inhibitors [24–31]. Herein, we used weight loss measurements and the effect of temperature on the corrosion inhibition of mild steel to evaluate their behavior as a tested inhibitor for mild steel corrosion in 1.0 M HCl solution.

## 2. Materials and Methods

### *2.1. Material preparation.*

The mild steel sample utilized for the research was regularly split into coupons of 4.5 cm × 2.5 cm × 0.2 cm. Hydrochloric acid of analytical grade was diluted by double distilled water to the concentration of 1 M to be utilized as a corrosive solution. The chemical structure of the tested inhibitor is shown in Figure 1.

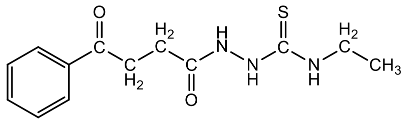

**Figure 1.** Structure of 4-ethyl-1-(4-oxo-4-phenylbutanoyl)thiosemicarbazide (EOPT).

### *2.2. Gravimetric analysis.*

All the experiments were carried out in 250 ml of 1 M HCl medium and open to the air, at 303 K with various concentrations of EOPT for 5 h exposure time. The coupon was polished with sandpaper, cleaned completely with doubled distilled water, acetone and finally dried in the oven. Finally, the coupons were thoroughly rinsed in distilled water, dried in the oven, and weighed accurately. The analyses were conducted three times individually, and the mean weight loss value was recorded [32-35]. From the gravimetric techniques, the rate of corrosion ($C_R$), inhibition efficiency (IE%) and Surface coverage ($\theta$) were determined according to Equations (1), (2), and (3), respectively [36-38].

$$C_R = \frac{m_1 - m_2}{at} \quad (1)$$

$$IE(\%) = \frac{C_{Ro} - C_{Ri}}{C_{Ro}} \times 100 \quad (2)$$

$$\theta = \frac{C_{Ro} - C_{Ri}}{C_{Ro}} \times 100 \quad (3)$$

where $m_1$ and $m_2$ are the coupons masses before and after corrosion, a is the coupon area, t is the exposure time, $C_{Ro}$ and $C_{Ri}$ are represent the corrosion rate in the absence and presence of the corrosion inhibitor, respectively.

## 3. Results and Discussion

### *3.1. Effect of temperature.*

Weight loss measurement data in the absence and presence of varying doses (100-500 ppm) of the examined inhibitor at varied temperatures (303-333 K) were used to evaluate mild steel corrosion characteristics in 1M HCl solution. Investigation of the experimental findings in Figure 2 reveals that inhibitive efficacy increases with inhibitor concentration increasing up to 500 ppm concentration. After 500 ppm, the inhibitor concentration still relatively steady hence 500 ppm was considered as optimum concentration [39-44]. The assessed inhibitory activity decreases with increasing temperature. This behavior can be explained by the fact that the inhibitor acts by adsorbing its molecules on the metal surface, and the increase in temperature caused most of the adsorbed inhibitor molecules to be adsorbed, thus reducing the inhibitory efficacy. It is obvious from Figure 2 that the tested inhibitor is an excellent inhibitor even at a concentration as minimum as 100 ppm. The inhibitive efficacy of the tested inhibitor at 500 ppm concentration was found to be 96.1%, while it was 66.3% at 333 K [45-48].

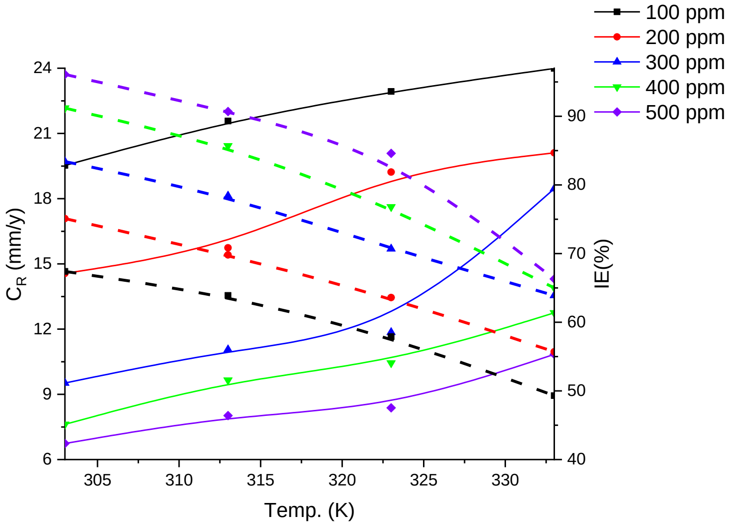


**Figure 2.** Various corrosion rates and inhibitive efficacy in 1 M HCl on the surface of mild steel with different temperatures.

*3.2. Activation energy.*

Because various changes occur on the metal surface, such as rapid etching and inhibitor, adsorption and decomposition, and/or rearrangement, the effect of temperature on the inhibitor-metal acid reaction is very complex. Weight loss coefficients in the absence and presence of the inhibitor at temperatures from 303 to 333 K were explored to determine the inhibitor adsorption and activation properties of mild steel surface corrosion processes in an acidic medium. The Arrhenius equation (Equation 4) is often used to describe the correlation between the rate of corrosion and metallic coupon in acidic [49-55] environments and temperature:

$$C_R = A\ EXP(\frac{-E_a^*}{RT}) \qquad (4)$$

where $E_a^*$ is the activation energy, A is the constant, $R$ is referred to the universal gas constant, and $T$ is the solution temperature.

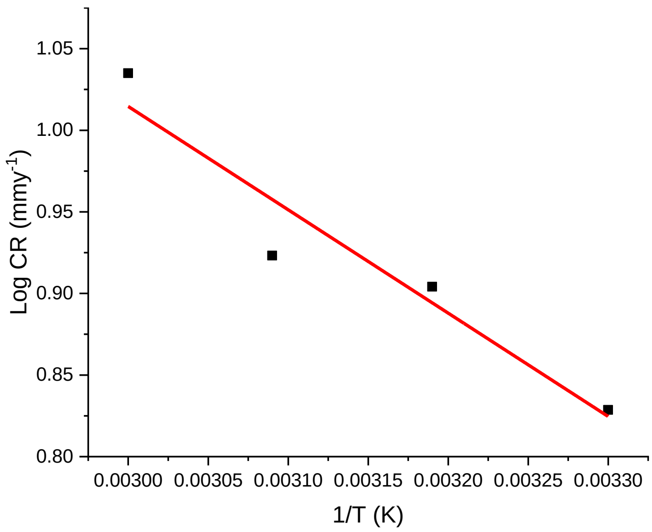


**Figure 3.** Log corrosion rate (mm year$^{-1}$) versus 1/T curves for mild steel dissolution in 1.0 M HCl in the absence and presence of 500 ppm of tested inhibitor.

The activation energy value can be evaluated from the Arrhenius plot slop (log *v* corr versus 1/*T*) as presented in Figure 3. Determined values of rate of corrosion rate and inhibition efficiency have been shown in Figure 2. As demonstrated from Figures 2 and 3, activation energy in the presence of the tested inhibitor is lower than that achieved in the absence of the tested inhibitor, meaning that the mild steel corrosion reaction is inhibited by the inhibitor and therefore confirms the chemisorption phenomenon [56-58]. Activation energy with a high value in the presence of tested inhibitors may increase the protected film thickness, enhancing the corrosion process's activation energy [59, 60].

## 4. Conclusions

The tested inhibitor, namely 4-ethyl-1-(4-oxo-4-phenylbutanoyl)thiosemicarbazide (EOPT), exhibits excellent inhibitive efficacy for the corrosion of mild steel in 1.0 M HCl solution. The inhibitive efficacy was observed to increase with increasing EOPT concentration. The inhibition efficiency decreases with the increase the temperature.

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## Conflicts of Interest

The authors declare no conflict of interest.

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