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Investigation of (4-Chlorobenzylamine) As A Corrosion Inhibitor for mild Steel in Hydrochloric Acid Media

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Abstract

4-Chlorobenzylamine inhibitor was investigated as a mild steel corrosion inhibitor in HCl solution by weight loss and thermometric techniques. In hydrochloric acid media, inhibitor above has been demonstrated to be an excellent corrosion inhibitor for mild steel. The inhibition process is connected to the formation of an inhibitor-adsorbed layer on the metal surface that protects it against corrosion. Surface coverage and inhibitory efficiency (% IE) increased as inhibitor concentration increased, but declined as temperature increased. The adsorption of inhibitors compounds on the mild steel surface was discussed using Langmuir's adsorption isotherm. The free energy value (Gads) suggested that the inhibitor molecule adsorption was physisorption, indicating the creation of a protective layer on the mild steel surface. The results demonstrate that 4-Chlorobenzylamine inhibitor is an efficient corrosion inhibitor with good anticorrosion capabilities in HCl acid for mild steel.

Keywords: 4-Chlorobenzylamine, thermometric, weight loss, corrosion, adsorption, HCl, inhibitor

1. Introduction

Metal corrosion is a significant issue for many businesses. As a result, scientists and engineers are investing a large amount of time and money to corrosion research, focusing not only on metal corrosion behavior in diverse conditions, but also on corrosion-prevention strategies. Because of its low cost, outstanding mechanical qualities, high strength, environmental stability, weight ratio, and high thermal and electrical conductivities, mild steel is the most widely used metal alloy in the industrial sector for structural and scientific research applications [1-15]. Because it is more effective and inexpensive, sulfuric acid is used for acid cleaning, acid descaling, petrochemical etching, and industrial cleaning [16-25]. Metal corrosion prevention is a major problem in the business, and utilizing inhibitors to protect metals from corrosion in acidic environments is a viable solution [26-33].

Corrosion inhibitors can be found in both organic and inorganic chemicals. These compounds have anti-corrosive capabilities due to the heteroatoms in their long chain structure [34-40]. The high expense of using these inhibitors, as well as the fact that they are poisonous and pose health and environmental risks, are two of the most major disadvantages [41-47]. Corrosion is a pollution process in which steel is chemically stabilized or reverted to its ores, such as oxide or hydroxide. Chemical contact with the metal's environment, on the other hand, causes its sluggish deterioration. Corrosion is the breakdown of metal structures due to environmental exposure. Metals are employed in pipelines, constructions, and other metal-based items, to name a few [48-53].

Corrosion is a crucial component in the chemical industry since it produces a slew of issues in production lines and is frequently the cause of production halts and delays [54-56].

Corrosion inhibition of Al-Mg alloy in 2.0 M HCl was studied by scientists [57] without and with various concentrations of Benzylamine-N-(p-methoxybenzylidene). The researchers used weight loss, galvanostatic polarization, scanning electron microscopy (SEM), and electrochemical impedance spectroscopy (EIS). The inhibition effectiveness decreased as the temperature rose and increased as the inhibitor concentration increased. Schiff base adsorption was shown to follow the Langmuir adsorption isotherm. Thermodynamic variables Gads, Qads, and energy of activation (Ea) were computed to

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further explain the process of corrosion inhibition. As revealed by the polarization test, the inhibitor is of mixed type. The mechanism of corrosion inhibition and the surface features of inhibited and uninhibited metal were studied using electrochemical impedance and scanning electron microscopy, respectively.

Researchers [58] investigated corrosion prevention of steel in hydrochloric acid using 2-methoxy methyl-benzyl amine concentrations ranging from 0.0001 to 0.1 ppm, temperatures ranging from 313 to 333 K, and polarization and weight loss procedures. The results showed that the corrosion potential between the anode and cathode tends to be mixed, and that this type of corrosion inhibitor is active and efficient when concentrations of inhibitor corrosion and efficiency increase with temperature, as well as the calculation of thermodynamic parameters such as activation, enthalpy, entropy, and free of adsorption and exhibited good results, and that type of adsorption is also active and efficient.

The present work investigate of (4-Chlorobenzylamine) as a Corrosion inhibitor for mild steel in hydrochloric acid media.

2. Experimental work

Both weight loss and thermometric methods were used in this paper, as well as an acidic medium diluted with hydrochloric acid where diluted with double-distilled water to make the test solution (1M HCl). Corrosion tests were performed on polished mild steel samples that were mechanically crushed into 3.3 x 2.4 x 0.3 cm coupons. The polished surface was cleaned with acetone and rinsed with double distilled water before being stored in a desiccator [15-22].

3. Results and Discussion

Gravimetric Measurement (Weight loss method)

The Weight Loss technique was used to determine the fundamental corrosion rate. The mild steel coupons were submerged completely in 100 ml of the acidic environment test solution (1M HCl) in triplicate at varied temperatures in the presence and absence of the inhibitor. After 6 hours of temperatures of 313K, 323K, and 333K, Metal specimens were removed from the test solutions. The specimens were cleaned in double distilled water, degreased with acetone, and dried after being removed. A Citizen CY 220 digital balance with a sensitivity of 0.001g was used to quantify the difference in weight between the specimens before and after immersion [23-35].

$$C.R = (87.6\times W) / DAT \qquad \ldots\ldots (1)$$

C.R is for corrosion rate (millimeters /year), **W** stands for weight loss (mg), **D** stands for specimen density (gm/cm3), **A** stands for specimen area (cm^2), and **T** stands for time in hours. Equations (2) and (3) were used to compute the inhibitory efficiency (% IE) and degree of surface covering (θ).

$$\% IE = (W_1-W_2) \times 100 \qquad \ldots\ldots (2)$$

$$\theta = (W_1-W_2) / W_1 \qquad \ldots\ldots (3)$$

W1 and **W2** are the corrosion rates without and with the inhibitor, respectively.

Thermometric Method

The effectiveness of the inhibition was also measured using thermometric techniques. Mylius' reaction vessel was virtually identical to the one used in thermometry research. On the basis of the temperature rise per minute, equations 4 and 5 were used to calculate the reaction number (RN) and inhibitory efficiency (% IE) [12-22].

$$R.N = (T_m - T_i) / t \qquad \ldots\ldots (4)$$

Tm denotes the highest temperature, **Ti** is the lowest temperature, and **t** denotes the time.

The inhibition efficiency (% IE) of the chosen inhibitor will be calculated using the equation below.

$$\%IE = (RN_{aq} - RN_{wi}) / RN_{aq} \times 100 \qquad \ldots\ldots (5)$$

R.N aq is the aqueous acid reaction number in the absence of inhibitors, while **R.N wi** is the aqueous acid reaction number in the presence of inhibitors.

Weight loss measurement:

The effect of different concentrations of (4-Chlorobenzylamine) on mild steel corrosion in 1M HCl solution was evaluated using weight loss measurements at 313K, 323K, and 333K after 6 hours of immersion. Table 1-3 shows the inhibitory effectiveness (% IE) and corrosion rate (C.R) acquired using the weight loss method. The data revealed that the rate of corrosion is proportional to the inhibitor concentration, and that the plant extract is more effective in preventing corrosion at lower concentrations [8-16].

Table 1: Corrosion properties of mild steel in 1M HCl solution at 313K in without and with of various concentrations of (4-Chlorobenzylamine).

Conc. of inhibitor, ppm	Weight loss, (mg)	Corrosion rate, (mm/y)	Inhibition efficiency, (E%)	Surface coverage, (θ)
blank	1006	241.31	0	0
100	641	119.31	50.62	0.50
200	572	98.67	59.33	0.59
300	502	70.54	70.74	0.70
400	426	57.46	76.18	0.76
500	272	40.73	83.11	0.83

Table 2: Corrosion properties of mild steel in 1M HCl solution at 323K in without and with of various concentrations of (4-Chlorobenzylamine).

Conc. of inhibitor, ppm	Weight loss, (mg)	Corrosion rate, (mmpy)	Inhibition efficiency, (E%)	Surface coverage, (θ)
blank	1544	293.47	0	0
100	985	168.66	42.66	0.42
200	778	134.71	54.26	0.54
300	663	120.82	59.04	0.59
400	551	87.65	70.10	0.70
500	435	60.46	79.52	0.79

Table 3: Corrosion properties of mild steel in 1M HCl solution at 333K in without and with of various concentrations of (4-Chlorobenzylamine).

Conc. of inhibitor, ppm	Weight loss, (mg)	Corrosion rate, (mmpy)	Inhibition efficiency, (E%)	Surface coverage, (θ)
blank	2029	385.42	0	0
100	1153	251.11	34.80	0.34
200	923	187.51	51.42	0.51
300	834	174.23	54.80	0.54
400	669	128.82	66.75	0.66
500	597	94.73	75.58	0.75

The inhibitor molecules are adsorbed on the mild steel surface as the inhibitor concentration rises, generating a larger surface area and a barrier to mass and charge transfer. Starting at 500 ppm, the inhibitor's inhibitory efficiency (% IE) increases with increasing concentration are 83.11 % at 313K, 79.52 % at 323K, and 75.58 % at 333K. The stronger the reaction site protection, the larger the surface area covered (θ) by the amount of molecules adsorbed on the metal surface. At 313K, 323K, and 333K, respectively, Figures 1 and 2 indicates to the effect of inhibitor concentration on inhibition efficiency and corrosion rate [15-29].

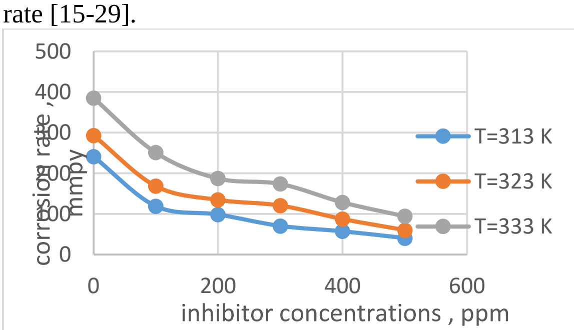

Figure 1: Relationship between inhibitor concentration and mild steel corrosion rate at various temperatures in 1M HCl solution by weight loss method.

Effect of temperature

The dissolving behavior of mild steel in 1M HCl with varying concentrations of (4-Chlorobenzylamine) was studied for 6 hours at various temperatures, including 313K, 323K, and 333K, as shown in Figure 2. According to Table 1, inhibitor molecules adsorb on the metal surface in a 1M HCl solution at all temperatures tested, and inhibition efficiency decreases as temperature increases. A rise in the temperature of metal corrosion under acidic circumstances is commonly followed by the creation of H2 gas, which speeds up the corrosion processes and leads to a faster rate of metal dissolution. Inhibition efficacy reduces as the temperature of the test solution rises [28-39].

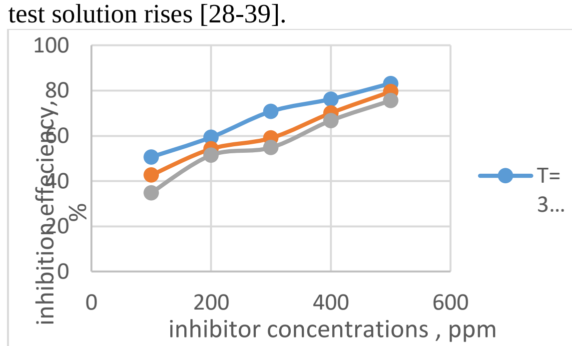

Figure 2: Relationship between inhibitor concentration and mild steel inhibition efficiency at various temperatures in 1M HCl solution by weight loss method.

Adsorption Isotherm

The adsorption isotherm's development aids in the comprehension of the corrosion prevention process on metal surfaces. The adsorption approach and adsorption isotherm were used to investigate the interaction of inhibitor compounds on metal surfaces. At 313K, 323K, and 333K, the Langmuir adsorption isotherm defines the adsorption process for inhibitors and fits experimental data. Eq. 6 below may be used to study the Langmuir adsorption isotherm [40-48].

$$C / \theta = (1/ K_{ads}) + C \qquad …..(6)$$

C denotes to inhibitor concentration, **Kads** denotes to adsorption coefficient, and **θ** is denotes surface coverage.

C/ θ and **C** plots reveal a straight line with a slope close to one, indicating Langmuir adsorption (Figure 3).

Each inhibitor molecule replaces the H_2O molecules that cover the mild steel surface in acidic solution, indicating that each adsorption site contains one adsorbate (molecule). The adsorption behavior is thought to have obeyed Langmuir adsorption isotherms since the linear regression coefficient (R2) values are almost unity at all temperatures [35-46].

Using the following equation, the free energies of adsorption, **Gads**, were determined from the equilibrium constant of adsorption:

$$\Delta G_{ads} = -2.303RT.Log\,[55.5Kads] \quad ……(7)$$

Where; **R** is an abbreviation for constant of universal gas, **T** is an abbreviation for temperature (absolute). **Gads** values up to -20 kJ/mol often imply physisorption, which is an electrostatic connection between charged inhibitor molecules and charged metal, but Gads values around -40 kJ/mol show a coordinate kind of binding between metal and inhibitor molecules. The low adsorption capacity is reflected in the value of Gads. Inhibitor molecules adsorb spontaneously on the metal surface, as evidenced by the negative values of Gads [16-27].

The reciprocal of the intercept of the Langmuir plot line in Table 4 , the average value of **Kads is** 0.008 l/g, and the slop of the line is 0.7 , implying that each inhibitor molecule occupies one active site on the metal surface. **Gads** values at 313K, 323K, and 333K were -1.284 kJ/ mol, -1.581 kJ/ mol, and - 3.549 kJ/ mol, respectively, indicating that molecules adsorb on the metal surface by physisorption, whereas a negative value of **Gads** indicates that adsorption occurs spontaneously.

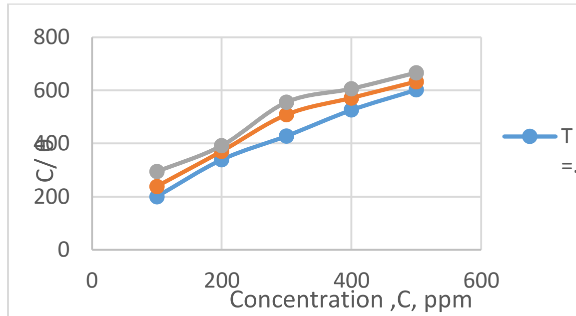

Figure 3: Relationship Adsorption of varying concentrations of (4-Chlorobenzylamine) on mild steel in 1M HCl solution for 6 hours at various temperatures using the Langmuir adsorption isotherm

Table 4: At different temperatures, the change in free energy and the Langmuir adsorption constant

Temp. K	slope	K_{ads}	$-\Delta G_{ads}$ (kJ /mol)
313	0.98	0.011	1.284
323	0.63	0.010	1.581
333	0.51	0.005	3.549
average	0.70	0.008	2.138

Thermometric Measurement

According to this concept, the corrosion process on metal behaves differently in inhibited and uncontrolled conditions. Table 5 depicts the corrosion rates of mild steel and reaction numbers in the presence and absence of various amounts of (4-Chlorobenzylamine). Table 5 shows that when the inhibitor concentration increases, the reaction number reduces, implying that the inhibition efficiency increases as well. Figure 4 depicts a thermometric plot of temperature vs. time for mild steel corrosion in a 1M HCl solution with and without different inhibitor doses. Figure 5 shows the relationship between the efficiency of inhibition and the concentration of the inhibitor, as the higher the concentration of the inhibitor, the higher the inhibitory efficiency in this method. [10-23].

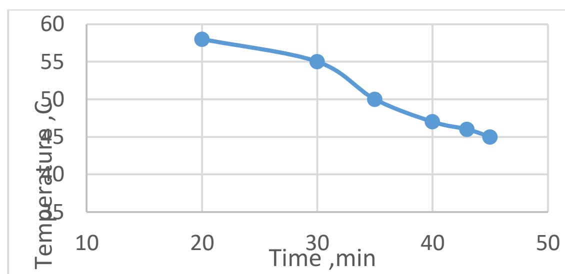

Figure 4: A temperature-time curve for mild steel in different inhibitor concentrations of HCl solution at 40 ºC by thermometric method.

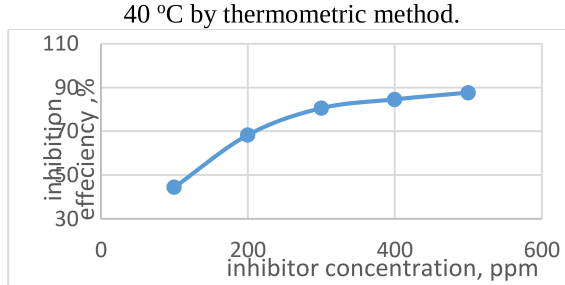

Figure 5: Inhibitor concentration curve for mild steel in HCl solution at 40 ºC in terms of inhibition efficiency by thermometric method

Table 5: In a 1M HCl solution at 40 C, the reaction number and inhibition efficiency of mild steel at several concentrations

Concentration of Inhibitor , ppm	Initial temp. Ti ,C	Final temp. Tm ,C	Time min.	Reaction no. $R.N_{wi}$	Reaction no. $R.N_{aq}$	IE %
blank	40	58	20	--	0.90	0
100	40	55	30	0.50	0.90	44.43
200	40	50	35	0.285	0.90	68.32
300	40	47	40	0.175	0.90	80.55
400	40	46	43	0.139	0.90	84.56
500	40	45	45	0.111	0.90	87.67

It is clear from the above that the inhibitor in the figure below No. 6 has the chemical structure, which contains the amine and chlorine groups that are responsible for forming a protective layer of the film to protect the metal from corrosion in acid conditions and different temperatures and this matches many researchers.[50-58]

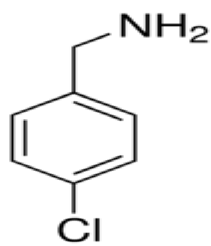

Figure 6: inhibitor structure (4-Chlorobenzylamine)

4. Conclusions

Based on the above, we conclude the following:

1- The results showed that (4-Chlorobenzylamine) is an effective corrosion inhibitor and has anti-corrosion properties in HCl for mild steel.

2- The inhibition process is related to the creation of an adsorbed inhibitor film on the surface of the metal that protects it from corrosion.

3- With the growth of the inhibitor concentration, the surface coverage (θ) and the inhibition efficiency (IE %) increased.

4- But as the temperature increased, the surface coverage (θ) and the inhibition efficiency (IE %) decreased.

5- Investigate the adsorption of inhibitor components on the surface of mild steel, Langmuir adsorption isotherms were used. According to the value of free energy (Gads), the adsorption of the inhibitor molecule was *physisorption*, which means the creation of a defensive film on the surface of mild steel.

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