Int. j. adv. multidisc. res. stud. 2022; 2(4):22-26

Received: 13-05-2022
Accepted: 23-06-2022

International Journal of Advanced Multidisciplinary Research and Studies

ISSN: 2583-049X

An Inhibitor (3-Methylisoquinoline) Prevents Mild Steel Corrosion in 1 M HCl Media

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Abstract

The inhibitor 3-methylisoquinoline at various concentrations ranging from 100 to 600 ppm was used in this work, and its effect on the corrosion of mild steel in 1M HCl was examined. The results showed that this type of inhibitor is effective and of excellent quality, as the efficiency of the inhibitor increases when the concentration of the inhibitor is increased at 303 K and 600 ppm, and as the temperature increases from 313 to 323 K, the efficiency decreases. Adsorption is of a physical type when it is in low concentrations and mixed with high concentrations, the thermodynamic parameters of the system such as activation energy, enthalpy energy, and free energy of adsorption, all of which increase with increasing concentration of inhibitor.

Keywords: Weight Loss, Mild Steel, Hydrogen Gas Evolution, 3-methylisoquinoline, HCl Media, Corrosion

Introduction

Corrosion is the deterioration of metal properties as a result of harsh conditions such as pickling with acid solutions, chemical and electrochemical etching of metal, cleaning of oil refinery equipment, acidizing, industrial acid clean-up, oil wells, and acid removing sediments [1-6]. Corrosion of big industrial metal equipment has received a great interest in recent years it is still a subject of worry for engineers and academics since it impacts the metallurgy, oil, and chemical sectors [7-10]. Inhibitors usually work by adsorption on metallic surface, with the structure of the adsorbed metal and unfriendly conditions for the metallic portion, in addition to synthesized inhibitor chemicals and their interaction with metal surfaces [11]. For mild steel, organic inhibitors in HCl acid medium have previously been studied [12-15].

Researchers [16] claimed that the weight loss method was used to study quinoline (QL), quinaldine (QLD), and quinaldic acid (QLDA) as steel corrosion inhibitors at varying temperatures in hydrochloric acid. The inhibitory effectiveness of the investigated chemicals increased as concentration increased, but decreased as temperature increased. According to the statistics, the sequence of inhibitory effectiveness is QLDA > QLD > QL. In kinetic thermodynamics, inhibitor adsorption on the steel surface follows the Langmuir models.

The effects of 3-formyl 8-hydroxy quinoline (FQ) and 8-hydroxy quinoline (HQ) on mild steel corrosion in hydrochloric acid were tested by researchers [17]. According to the findings, increasing inhibitor concentration improved corrosion surface covering and inhibiting efficacy while decreasing with increasing temperature and acid content. The methods of electrochemical impedance spectroscopy, polarization, and weight loss were investigated. As a result, corrosion inhibition thermodynamic factors were computed. The inhibitors have a Langmuir adsorption isotherm. Corrosion inhibition efficiency was higher in the complex FQ than in the HQ.

Weight loss, potentiodynamic polarization, and impedance spectroscopy were all employed by the researchers [18], to investigate the corrosion inhibition effects of two quinoline derivatives, (2-chloroquinoline-3ylmethyl)-p-tolyl-amine (CQA) and 2-chloroquinoline 3-carbaldehyde (CQC), on mild steel (MS) in 1N HCl solution. MS taster weight loss has demonstrated that CQC and CQA are both good corrosion inhibitors. The mixed form of inhibition is used in electrochemical polarizations. Variations in impedance characteristics like as double-layer capacitance and charge transfer resistance were discovered using electrochemical impedance spectroscopy, showing that inhibitors adsorb substantially on the MS surface.

In this paper, the effect of 3- Methyl isoquinoline (fig 1) as an inhibitor for mild steel in HCl acid solution at different temperatures 303-323 K and inhibitor concentrations of 100-600 ppm are demonstrated using weight loss and hydrogen gas evolution techniques.

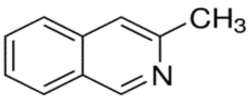

Fig 1: Chemical construction of 3- Methylisoquinoline

As can be seen from fig 1 above that the inhibitor molecule contains nitrogen atom with free electrons that could be considered as an active inhibitor.

Experimental work

Composition of mild steel specimen: 0.10 % C, 0.31 % Mn, 0.15 % Si, 0.03 % S, 0.40 % P, 0.025 % Cu, and balance Fe (in weight %). The study used seven coupons with dimensions of (4 cm x 2 cm x 0.2 cm) and six different concentrations of (3-Methylisoquinoline) as inhibitor. Every experiment was carried out in a 50 ml volume utilizing the hydrogen gas evolution method, both with and without inhibitor [5-13].

Results and discussion

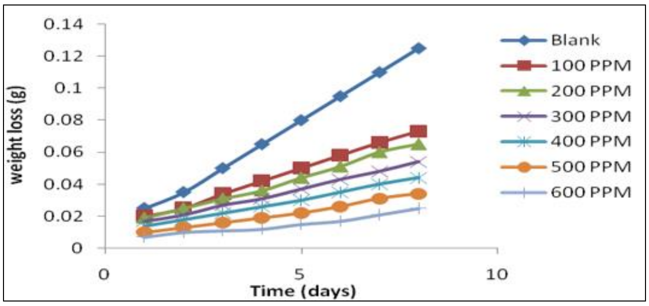

Fig 2: Relationship between weight loss and time at 30 °C

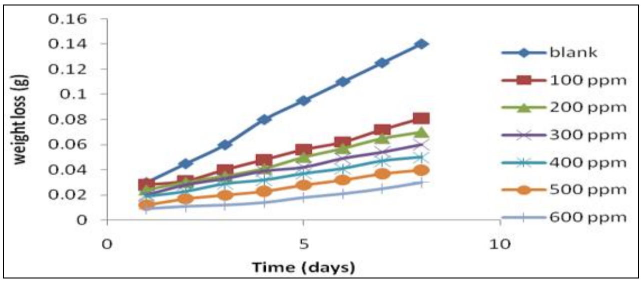

Fig 3: Relationship between weight loss and time at 40 °C

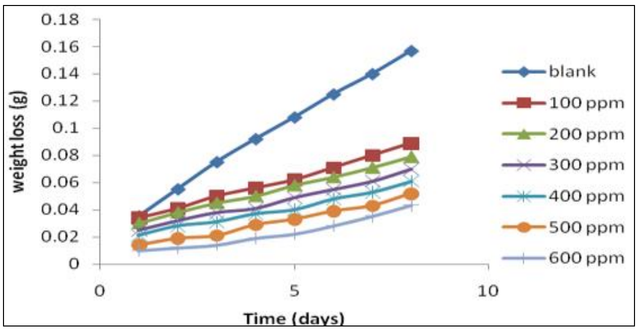

Fig 4: Relationship between weight loss and time at 50 °C

Fig 2 shows the relationship between weight loss over time. In the absence of the inhibitor, an increase in weight loss is observed. When we gradually add the concentration, the decrease in weight loss is observed due to the effectiveness of the corrosion inhibitor at 30ºC, the best concentration is at 600 ppm. As the temperature increases, 40 and 50ºC. Weight loss and thus the inhibition efficiency decreases as in Fig 3 and 4, respectively according to studies [10-17].

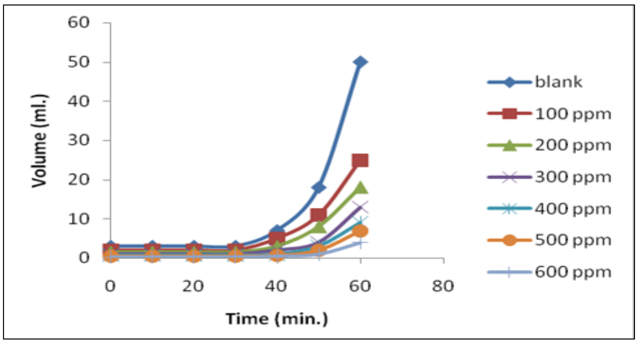

Fig 5: The relationship between hydrogen gas volume and time at 30ºC

Fig 5 displays the connection between hydrogen gas evolution volume and time, indicating that without and with concentration inhibitors, hydrogen gas evolution declines with time [18-25].

At a temperature of 30ºC, Table 1 shows that increasing the inhibitor enhanced corrosion inhibition effectiveness, whereas increasing the temperature decreased inhibition efficiency. From the equation below, the inhibition efficiencies (% E) were calculated [20-25]:

$$\%E = \frac{w_u - w_i}{w_u} \quad (1)$$

Where Wu and Wi are the weight loss values for metallic coupons without and with inhibitor, respectively.

Table 1: At varying temperatures, the percentage inhibition efficiency is affected by inhibitor concentration

Inhibitor conc. ppm	Percentage of inhibition efficiency %		
	30 ºC	40 ºC	50 ºC
Blank	0	0	0
100	43.2	33.3	27.3
200	49.5	43.2	38.5
300	57.3	49.4	44.3
400	66.7	57.3	51.2
500	75.2	67.2	58.3
600	82.4	75.2	67.6

Fig 6 shows that raising the temperature reduces the efficacy of inhibition, but raising the inhibitor concentration enhances the efficiency of inhibition [26-30].

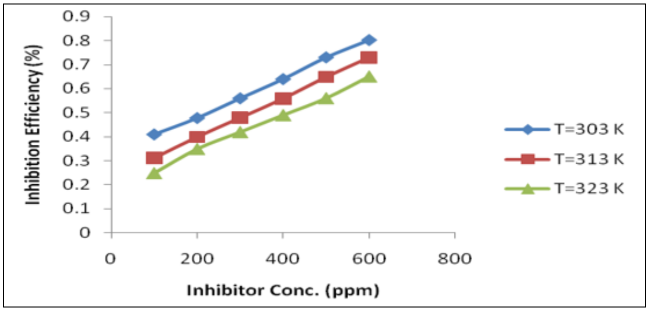

Fig 6: Relationship between inhibition efficiency and inhibitor concentration

Fig 7 shows a Kinetic model diagram of Log C.R versus 1/T with or without inhibitor, where corrosion rate (C.R) is determined using the formula:

$$C.R = \frac{87.6 * w}{D * a * t} \qquad (2)$$

Where; (C.R) stands for corrosion ratse, (w) for weight loss, (D) for alloy density, (a) for exposed area, and (t) for time [27-32].

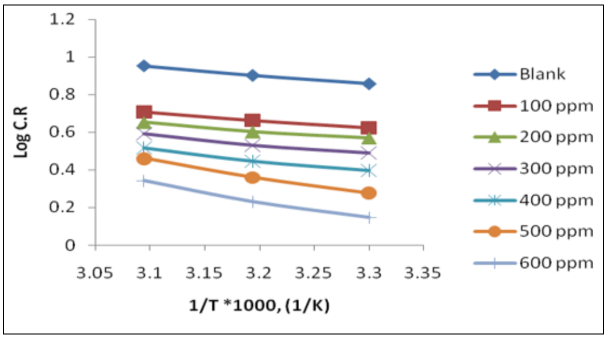

Fig 7: Relationship between log (C.R) and inverse temperature 1/T

As demonstrated in Table 2, relationship between Log (C.R/T) and (1/T) is depicted in Fig 8, with factors H and S calculated from the slope and intercept, respectively [28-33].

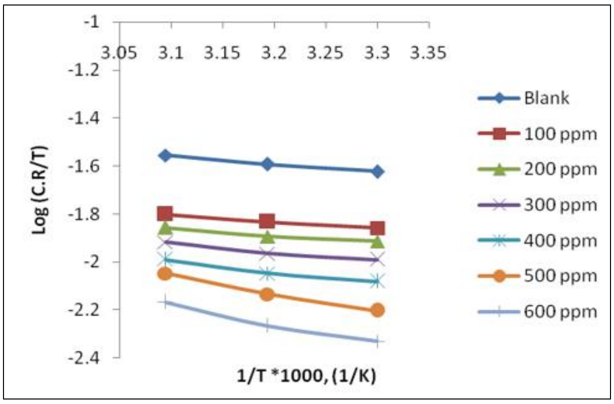

Fig 8: Relationship between log (C.R/T) and inverse temperature (1/T)

Table 2: Parameters of thermodynamic adsorption of mild steel in 1M HCl acid without and with inhibitor

Inhibitor conc. ppm	E_a kJ/mol	ΔH kJ/mol	ΔS kJ/mol.k	ΔGads kJ/mol at 298 K
Blank	37.42	29.82	-0.0963	57.53
100	33.52	23.93	-0.0980	53.16
200	34.64	24.31	-0.0983	54.70
300	43.21	31.50	-0.0988	598.95
400	50.53	38.93	-0.0994	67.45
500	77.32	64.92	-0.0998	94.63
600	82.42	68.85	-0.1007	97.73

The activation energy (Ea), enthalpy energy (ΔH), entropy energy (ΔS), and free energy (ΔG) of mild steel in 1M HCl acid with and without inhibitor were calculated using Equations 3,4, and 5 [30-35].

$$R_{corr} = Ae(-\frac{Ea}{RT}) \qquad (3)$$

$$R_{corr} = \frac{RT}{Nhe}\left(\frac{\Delta S}{R}\right).e(-\frac{\Delta H}{RT}) \qquad (4)$$

$$\Delta G = \Delta H - T\Delta S \qquad (5)$$

Where (R corr) is the rate of corrosion as a function of weight loss, (A) is the frequency factor, (N) is Avogadro's number, (h) is Planck's constant, and (R) is the universal gas constant.

Chemisorption and physisorption are two types of adsorption processes. Chemisorption has an activation energy larger than 80 KJ/mol, whereas physisorption has an activation energy less than 40 KJ/mol [30-33]. The activation energy Ea grows with rising inhibitor concentration given the presence of cationic surfactants. These findings point to a physical process that results in the formation of an adsorption layer for presence methyl and nitrogen groups that for them active role for corrosion reduce. Adsorption of inhibitors on the steel surface is an endothermic process that results in positive ΔH values. The activated complex is the rate-determining step, which signals association rather than dissociation, resulting in negative values of ΔS without and with inhibitor [30-35]. Interactions between empty iron d-orbitals and -electrons of heterocyclic donor-acceptor provide the basis of this adsorption. In acid solution, the steel surface carries positive charges as a consequence [30-33]. The physisorption technique may be used to adsorbed 3-methyl isoquinoline molecules on metal surfaces, as demonstrated in Fig 1.

Conclusions

3- Methyl isoquinoline is a highly effective and high-quality corrosion inhibitor. At a temperature of 303 K, the inhibition effectiveness improves with the concentration of the inhibitor, but at temperatures of 313 and 323 K, the inhibition efficiency decreases, as the inhibitor concentration grows, the activation energy, enthalpy energy, and free energy for adsorption all are raised. Physical adsorption occurs at low concentrations while physicochemical adsorption occurs at high quantities.

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