

## Corrosion Inhibition of Mild-Steel in 0.5 M HCl using some prepared 1,2,3-Triazoles Derivatives

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**Abstract:** The Weight loss was employed to investigate the impact of triazole on mild-steel dissolution in 0.5 M HCl solution. The inhibitor's inhibition efficiency was seen to increase with concentration yielding (81.61%, 82.61%, 88.29%, 91.64%, 94.32%) of (T9, T8, T6, T4, T1) at concentration  $1 \times 10^{-4}$  M HCl, at a temperature of 25°C for 240 min. At a temperature range from 25–45°C, we studied the temperature impact on the corrosion behavior, wherein the results demonstrated decrease in inhibition efficiency with rising in temperature to achieve (61.7%, 52.26%, 63.1%, 72.11%, 75.77 %) of (T9, T8, T6, T4 and T1) at a concentration of  $1 \times 10^{-4}$  M, at a temperature 45°C for 240 min. A study was also performed regarding the impact of temperature on the corrosion rate in the presence and absence of triazole. The activation energy and Kinetic parameters were calculated and discussed. Polarization curves revealed that the studied inhibitors represent a mixed – type inhibitors. Adsorption of inhibitors was found to obey Langmuir isotherm and was isotherm physisorption type.

**Keywords:** Corrosion, adsorption, weight loss, acid inhibition, triazole, Langmuir adsorption, kinetic parameters.

### 1. Introduction

The corrosion can be defined as a phenomenon that leads to materials deterioration via electrochemical or chemical interaction with the environment. This process could also compromise the equipment's physical and mechanical characteristics, which cast severe environmental and economic effects on all infrastructure sectors, like oil gas pipelines, roads, water and sewage systems and construction, which results in severe damage as well as threats to public safety and health <sup>1</sup>.

Numerous industrial applications employ acid solutions, such as in cleaning, elimination of located deposits, pickling and many other processes of industrial synthesis. Because of their aggressiveness characteristics, corrosion inhibitors are widely employed to limit the attack by metallic materials. The use of corrosion inhibitors needs to be estimated as per the particular parameters about the system, the kind of the acid employed, temperature solution, its concentration, presence of inorganic or dissolved organic substances and particularly the type of metallic materials employed <sup>2</sup>.

Carbon steel is known for its mechanical properties and cost-effectiveness and thus is widely employed

in the industry. However, low corrosion resistance is associated with this material, which results in a decrease in performance as well as useful life about the engineering products. Thus, it is crucial to apply methodologies to protect against the corrosion process, for example, corrosion inhibitor application and pre-treatments.

The corrosive process can be delayed or minimized with organic corrosion inhibitors. Their effectiveness can be chiefly associated with the adsorption on the metal surface <sup>3</sup>, which behaves as a barrier layer and decreases access to aggressive species <sup>4</sup>. As per the literature, on the metal surface, they usually get adsorbed by the action of water molecules displacement <sup>5</sup>, while improved bonding efficiency is achieved due to the presence of polar functions in the molecule's S, O or N atoms,  $\pi$  electrons and heterocyclic compounds <sup>6</sup>.

As 1,2,3-triazole can form a protective film on various metallic materials, it is broadly employed as a corrosion inhibitor. Also, the literature has shown that it can effectively impede steel corrosion in different types of media <sup>7</sup>. However, currently, there exist disagreements pertaining to inhibitor's toxicity for humans and the environment <sup>8</sup>. Thus, industries

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and researchers are now focusing their efforts towards mitigating this issue. Recent research studies in the corrosion field are directed towards the use of natural corrosion inhibitors that have been derived from plants<sup>9</sup>, natural herbs<sup>10</sup>, seeds<sup>11</sup> and medicinal plants<sup>12</sup>. These are regarded as sustainable, biodegradable, cost-effective and easily available substances. Also, these do not include toxic compounds<sup>13</sup>. Numerous reports showing successful

use of these substances against corrosion in various metals and acidic media<sup>14</sup>.

The current work aims at evaluating the inhibitive action of triazole, Table 1 (T9, T8, T6, T4, T1)<sup>15,16</sup> in corrosion of mild steel in 0.5 M hydrochloric acid by employing weight loss and galvanostatic polarization techniques. Furthermore, the investigation was carried out to determine the impact of temperature on the dissolution carbon mild steel and on the studied compound's inhibition efficiency.

**Table 1.** The structures of Triazoles (T9, T8, T6, T4, and T1).

Symbol	Structure	Name
T1		1,1'-(4,4'-sulfonyl bis (4,1-phenylene)) bis (1H-1,2,3-triazole-4,5-di carboxylic acid)
T4		1,1'-(4,4'-sulfonyl bis (4,1-phenylene)) bis (5-(4- acetyl phenyl)-1 , 6a -di hydropyrrolo[3,4-d] [1,2,3] triazole -4,6(3aH,5H)- dione ).
T6		dimethyl-1-(4-sulfamoylphenyl) -1H -1,2,3-triazole -4,5-dicarboxylate.
T8 Mix.		1-(4-sulfamoylphenyl)-4,5-dihydro-1H-1,2,3-triazole-4- carboxamide
		1-(4-sulfamoylphenyl)-4,5-dihydro-1H-1,2,3-triazole-5- carboxamide
T9		4-(4,6-dioxo-5-phenyl-4,5,6,6a-tetrahydropyrrolo [ 3,4-d] [1,2,3 ] triazole -1(3aH) -yl) benzene sulfonamide.

## 2. Experimental method

The mild-steel sample employed with a dimension of 3×1.9×0.4 cm for measurements of weight loss. The study employed a cylinder rod that was embedded in

Araldite with 1 cm<sup>2</sup> expose e surface area. The corrosive solution was prepared by employing AR grade hydrochloric acid. For weight loss experiments, weighing of the cleaned Mild-steel coupons was done beforehand and post immersion in

the 25 ml test solution for 4 hrs. For the experiments, the expression of weight loss was done in grams.

## 2.1. Synthesis of 1-sulfonyl 1, 2, 3-triazoles derivatives (M1-4) <sup>15,16</sup>

A general description of the process N-substituted maleimide (1 mmol) was combined with N-((4-azidophenyl) sulfonyl) acetamide (1 mmol) before the mixture was subjected to heating for a period stretching between 6 and 15 hours. The resulting precipitate was then filtered and cleansed through re-crystallization in chloroform and hexane.

## 2.2. Potentiodynamic polarisation

To study the corrosion inhibitors in HCl solution, measurement of potentiodynamic polarisation (Tafel) is considered crucial and is achieved via the conventional three-electrode system, while all potential were referred to SCE in this study. Tafel polarization obtained by changing the electrode potential automatically from (+250 mV to -250 mV) at open circuit potential with a scan rate of 0.5 mV

S-1 to study the effect of the inhibitor on mild steel corrosion <sup>17-19</sup>. The calculation of corresponding inhibition efficiency ( $I_E$  %) was done based on Eq. (1) <sup>20</sup>. In this equation,  $I_{corr}$  and  $I_{corr}(inh)$  represent the corrosion current density pertaining to QS corrosion in HCl solution in the presence and absence of various concentrations of Inhi-ST. The linear Tafel segment of cathodic and anodic curves was extrapolated to corrosion potential to obtain the corrosion current densities ( $I_{corr}$ ).

$$IE(100\%) = \frac{I_{corr} - I_{corr}(inh)}{I_{corr}} \times 100 \quad (1)$$

## 3. Results and Discussion

### 3.1. Polarisation method

Table 2 shows the parameters of the polarisation results ( $E_{corr}$ ,  $I_{corr}$  and  $\beta_c$ ) for both inhibited and uninhibited solutions, after which inhibition efficiency was calculated for the MS corrosion process in the collected hydrochloric solutions.

**Table 2.** Electrochemical parameters for corrosion of mild steel in 0.5M HCl in the presence of ( $10^{-4}$  M) concentrations of (T1, T4, T6, T8, T9) Compounds inhibitors.

Optimum Concentration $1 \times 10^{-4}$ M	$I_{corr}$ . $\mu A/cm^2$	$E_{corr}$ . mVolt	$\beta_c$ mV/dm	$\beta_a$ mV/dm	$I_E$ %
Blank	570.65	-342.2	-113.1	95.2	
T1	139.4	-421.3	-114.2	106.9	75.57
T4	125.7	-409.5	-91.8	82.8	77.97
T6	119.8	-411.7	-101.9	115.2	79.00
T8	112.2	-416.9	-116.2	88.7	80.33
T9	109.1	-402.7	-89.6	94.7	80.88

Table 3 shows comparison between  $E\%$  for some triazoles (ATM, 3) <sup>21,22</sup> with compound T9 by using electrochemical method.

**Table 3.**  $E\%$  for some triazoles using electrochemical method at inhibitor con. of  $10^{-4}$ M in 0.5M HCl.

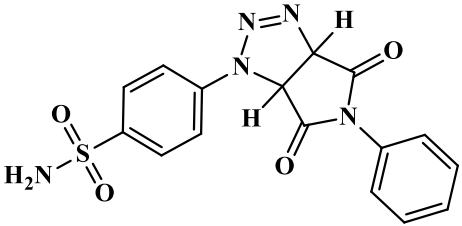
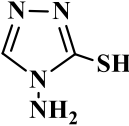
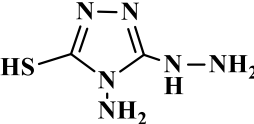
Compd.	Chemical structure	$E\%$
T9		80.88
ATM		84.39
3		76.27

Figure 1 shows a graphical representation of the polarisation curves of MS in an acidic medium, which included  $10^{-4}$  M concentrations of (T9, T8, T6, T4, T1) compound at  $30^{\circ}\text{C}$ . Both reactions, *i.e.* anodic and cathodic, were seen to get inhibited along

with the tested compounds, which resulted in retardation of the hydrogen evolution reaction as well as metal dissolution when tested compounds inhibitors were added.

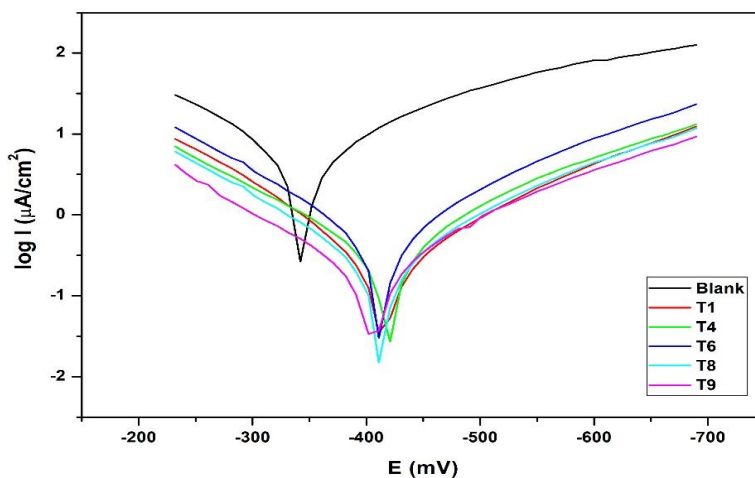


Figure 1. Tafel curves of mild steel in 0.5M HCl solution in the absence and presence of the triazole inhibitors at  $10^{-4}$  M and  $25^{\circ}\text{C}$

### 3.1. Weight Loss Measurement

Tables 6, 7, 8, 9 and 10 (pp; 299-303) demonstrate the measurements results of the corrosion of mild steel in 0.5 M HCl in the presence and absence of various concentrations with regards to the Triazole (T9, T8, T6, T4, T1) at a temperature of  $25^{\circ}\text{C}$ . For the percentage with regards to the inhibition efficiency %IE as well as surface parameter coverage  $\theta$ , which signifies the part of the surface that was covered by inhibitor molecules, the following equation was employed for the calculation<sup>17</sup>:

$$\%IE = \left[ 1 - \frac{W_{add}}{W_{free}} \right] \times 100 \quad (2)$$

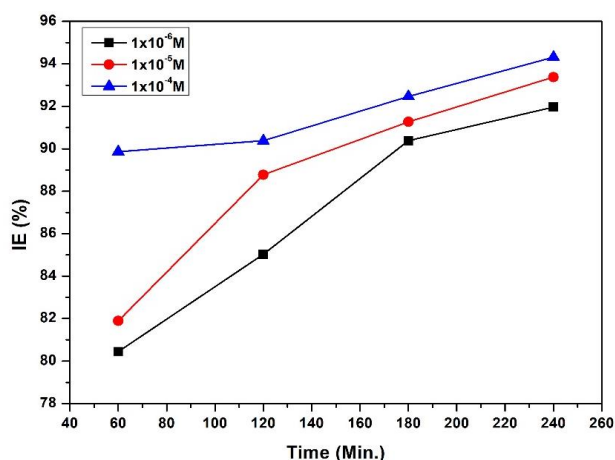


Figure 2. Variation of the Inhibition Efficiency %IE as a Function of the Time in the Presence of Different Concentrations of T1 at  $25^{\circ}\text{C}$  in 0.5M HCl

$$\theta = \left[ 1 - \frac{W_{add}}{W_{free}} \right] \times W_{free} \quad (3)$$

Here,  $W_{add}$  and  $W_{free}$  represented the weight losses of M-Steel in the presence and absence of inhibitors. Figures 2, 3, 4, 5 and 6 demonstrate the variation of the inhibition efficiency %IE that has been considered as a function of time. An increase in inhibition efficiency was observed with a rise in inhibitor concentration. Calculation of the corrosion rate  $R_{corr}$  was done by employing the following equation<sup>23</sup>:

$$R_{corr} = \frac{\Delta W}{S \times T} \quad (4)$$

Where  $\Delta W$ = is the weight losses of metal,  $S$ = is the surface area ( $\text{cm}^2$ ),  $T$ = is the exposed time (min).

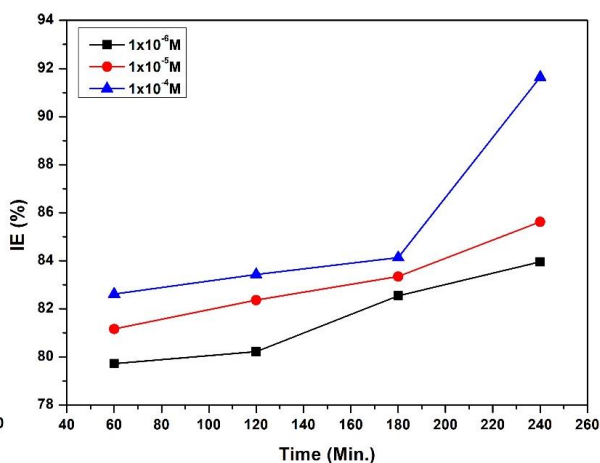
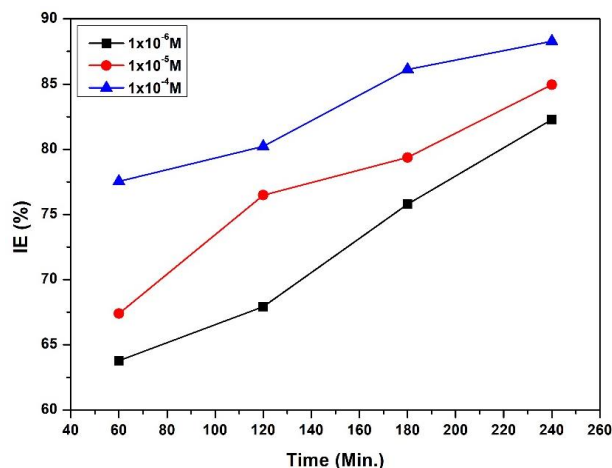
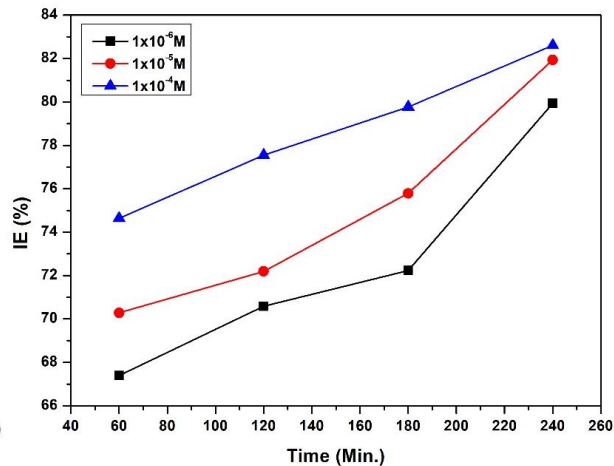


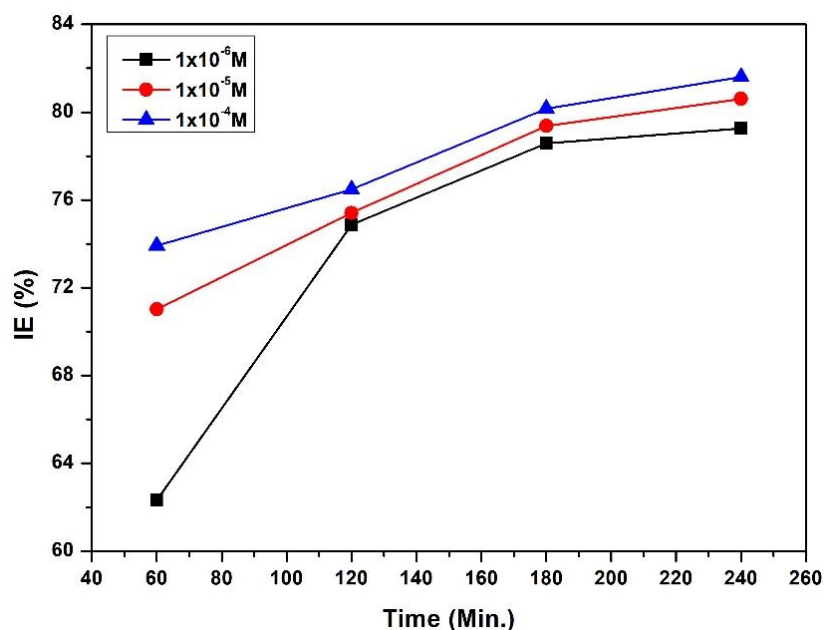
Figure 3. Variation of the Inhibition Efficiency %IE as a Function of the Time in the Presence of Different Concentrations of T4 at  $25^{\circ}\text{C}$  in 0.5M HCl



**Figure 4.** Variation of the Inhibition Efficiency %IE as a Function of the Time in the Presence of Different Concentrations of T6 at 25°C in 0.5M HCl



**Figure 5.** Variation of the Inhibition Efficiency %IE as a Function of the Time in the Presence of Different Concentrations of T8 at 25°C in 0.5M HCl

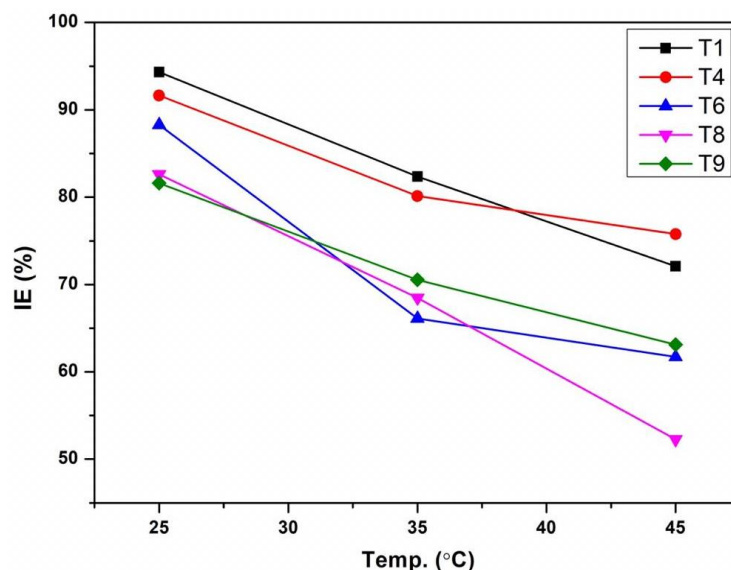


**Figure 6.** Variation of the Inhibition Efficiency %IE as a Function of the Time in the Presence of Different Concentrations of (T9) at 25°C in 0.5M HCl

### 3. 1. 2. Effect of Temperature

The temperature effect on the performance of mild-steel / acid in the presence of Triazole (T1, T4, T6, T8 and T9) at different concentrations was evaluated via weight-loss at a temperature range of 25-45C when immersed for 4 hrs. The variation of inhibition efficiency of Triazole (T1, T4, T6, T8 and T9) along with temperature was seen to reduce with the rise in temperature, which suggests a physical adsorption

mechanism that is improved with rising in temperature <sup>24</sup>. Fig 7 shows the variation in inhibition efficiency %IE with regards to the function of the temperature at a concentration of ( $1 \times 10^{-4}$ M). The results of these measurements are depicted in Table 11 (p. 304). The temperature had an impact on the corrosion parameters of mild-steel at a concentration of 0.5 M HCl.



**Figure 7.** Variation of the Inhibition Efficiency %IE as a Function of the Temperature in the Presence of inhibitor (T1, T4, T6, T8 and T9) in 0.5M HCl

The activation energy  $E_a$  of the corrosion process was calculated using the following equation<sup>25</sup>:

$$\ln(r_2/r_1) = E_a(T_2 - T_1) / R(T_2 \times T_1) \quad (5)$$

Where:

$r_1$ = corrosion rate at 298 K

$r_2$ = corrosion rate at 308 K

$E_a$ = activation energy

$R$ = gas constant ( $8.3143\text{J.K}^{-1}.\text{mol}^{-1}$ )

$T_1$  and  $T_2$ = Absolute temperature (K)

The values of activation energy  $E_a$  has given in Table 4.

**Table 4.** Activation Energy for Dissolution of Mild - Steel in 0.5 M HCl in the Different of (T1, T4, T6, T8 and T9) Concentration.

Comp.	Conc. [M]	Activation Energy $\text{KJ mol}^{-1}$
HCl	0.00	5.10
T1	$1 \times 10^{-4}$	13.74
T4	$1 \times 10^{-4}$	6.72
T6	$1 \times 10^{-4}$	13.22
T8	$1 \times 10^{-4}$	9.55
T9	$1 \times 10^{-4}$	8.70

Radovici<sup>26</sup> categorises the inhibitors into 3 groups as per temperature effects:

1- Inhibitors exhibiting a decrease in IE along with a rise in temperature and having the value of  $E_a$  greater versus the uninhibited solution are indicative of physisorption.

2- Inhibitors that do not exhibit a change in IE in the absence or presence of inhibitors.

3- Inhibitors that exhibit an increase in IE along with temperature, and the value of  $E_a$  is smaller versus the inhibited solution are characteristics of chemisorption.

Furthermore, the interpreted decreases in IE value with a rise in temperature serve as an indication for a physisorption type of adsorption<sup>27,28</sup>. Thus, it can be said that via physisorption, Triazole (T6, T8, T9) gets adsorbed on the surface of mild steel.

Free energy of adsorption  $\Delta G$  was calculated using the following equation<sup>29</sup>.

$$\Delta G = RT \ln[55.5\theta C(1 - \theta)] \quad (6)$$

Where

$\theta$ = degree of coverage on the metal surface

$C$ = concentration of inhibitor (T1, T4, T6, T8 and T9)( $1 \times 10^{-4}$  M)

$R$ = gas constant ( $8.3143\text{J.K}^{-1}.\text{mol}^{-1}$ )

$T$ = Absolute temperature (K)

And for calculating the entropy  $\Delta S$  and enthalpy  $\Delta H$  apply the alternative formulation of the Arrhenius equation is the transition state equation<sup>30</sup>.

$$\text{Rcorr} = \frac{RT}{Nh} \exp\left[\frac{\Delta S}{R}\right] \exp\left[-\frac{\Delta H}{RT}\right] \quad (7)$$

Where

$\text{Rcorr}$ = corrosion rate

$R$ = gas constant ( $8.3143\text{J.K}^{-1}.\text{mol}^{-1}$ )

$T$ = temperature (K)

$N$ = Avogadro's number ( $6.2 \times 10^{23}$ )

$h$ = plank's constant ( $6.62 \times 10^{-34}$  J.S)

The results of these measurements are shown in Tables 5.

**Table 5.** kinetic parameters of (T1, T4, , T6, T8, T9) ( $1 \times 10^{-4}$  M) on the dissolution Mild steel in 0.5 M HCl.

Compounds	Tem.(K)	Activation parameters (KJmol-1)		
		$\Delta H$	$-\Delta S$	$-\Delta G$
Blank		0.007275	0.0818	–
T1	298	0.0952	0.0454	39.732
	308			37.822
	318			37.482
T4	298	0.0482	0.1952	38.703
	308			37.441
	318			37.982
T6	298	0.0794	0.0921	37.77
	308			35.588
	318			36.23
T8	298	0.0719	0.1147	36.632
	308			35.85
	318			35.209
T9	298	0.0596	0.1554	36.463
	308			36.108
	318			36.389

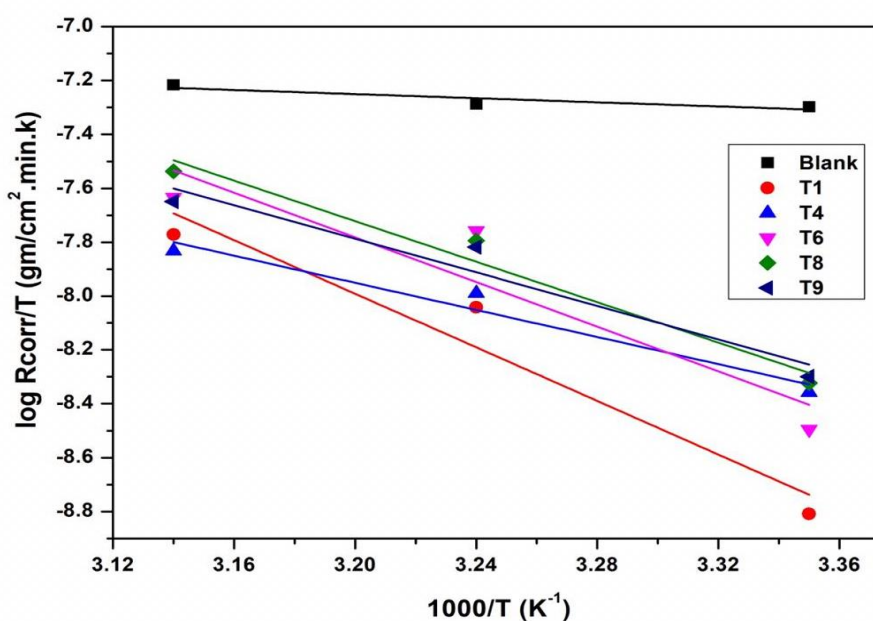
**Figure 8.** Arrhenius Plots  $\text{Log } R_{\text{corr}}/T$  vs.  $1/T$  for Mild-steel in Different Additives of Inhibitor (T1, T4, T6, T8, T9)

Fig. 8 shows Arrhenius Plots  $\text{Log } R_{\text{corr}}/T$  vs.  $1/T$ . Straight lines are obtained with a slope of  $H$  and  $\Delta S$  are  $\Delta$  of  $(\log R/Nh + \Delta S/2.303R)$  from which the values of  $\Delta$  (-calculated and listed in Table 5.

From inspection of Table 5 it is clear that the positive values of  $\Delta H$  reflect that the process of adsorption of the inhibitors on the Mild-steel surface

is an endothermic process. The value of  $\Delta S$  in the presence and absence of the inhibitors are negative.

This implies that the activation complex is the rate-determining step representing association rather than dissociation, indicating that a decrease in disorder takes place on going from reactant to the activated complex<sup>27</sup>.

The negative values of  $\Delta G$  mean that the adsorption of Triazole (T1, T4, T6, T8, T9) on Mild-steel surface is a spontaneous process, and the negative values of  $\Delta G$  also show the strong interaction of the inhibitor molecules on to the Mild-steel surface<sup>31</sup>.

It was found that  $\Delta G$  increases negatively with increasing the temperature. This phenomenon once

again indicates that the adsorption is favourable with increasing experimental temperature and dominates on the desorption of the inhibitor from the Mild-steel surface <sup>32</sup>.

### 3. 2. Adsorption Isotherm

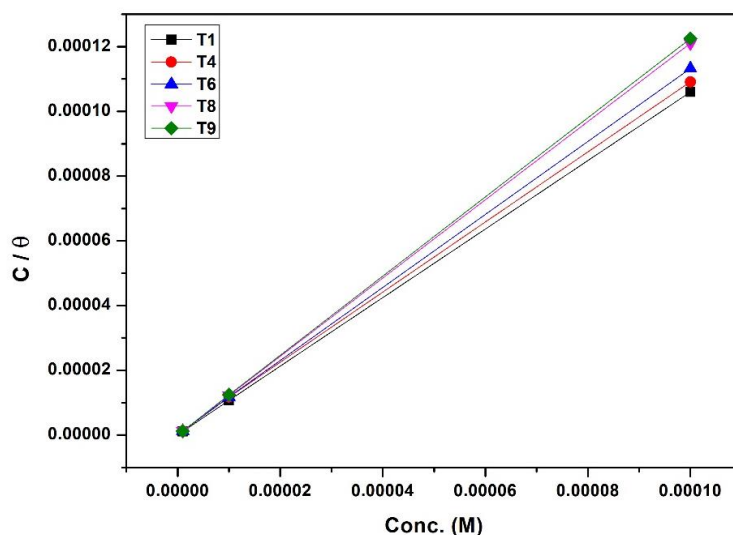
Adsorption isotherms are crucial to understanding the inhibition mechanism of corrosion reaction. Some of the most frequently employed adsorption isotherms include Freundlich, Frumkin, Langmuir and Temkin isotherms. The one that is best fitted follows the Langmuir isotherm. Plotting  $(C/\theta)$

against concentration (C) yields straight lines as presented in Fig.9 On the mild-steel surface, the inhibitor Triazole (T9, T8, T6, T4, T1) gets adsorbs as per the Langmuir kind isotherm model via the relation <sup>33-35</sup>.

$$C/\theta = 1/K + C \quad (8)$$

Where

K= is the equilibrium constant of the adsorption process.



**Figure 9.** Langmuir Adsorption Isotherm Model for Triazole (T9, T8, T6, T4, T1) in 0.5 M HCl on the Surface of Mild- Steel

### Conclusions

Can be used of Triazole compounds as inhibitors corrosion of mild steel in 0.5 M HCl. There is an increase in inhibition efficiency with the rise in the concentration of Triazole compounds. The inhibition efficiency of triazole compounds decreases with temperature while there is increased activation of corrosion energy when the inhibitor is present. The inhibition corrosion of Triazole compounds (T1, T4, T6, T8 and T9) was Physisorption on the metal surface. 1,2,3-triazole derivatives obey Langmuir adsorption isotherm, and the inhibition efficiency of these compounds was in order (T1> T4 >T6 > T8> T8> T9).

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**Table 6. Effect of (T1) on the Dissolution Mild-steel in 0.5M HCl.**

Time (Min.)	60				120				180				240			
Conc (M)	Wt-loss gm	Rcorr., gm.cm <sup>-2</sup> .min <sup>-1</sup>	IE%	Θ	Wt-loss gm	Rcorr gm.cm <sup>-2</sup> .min <sup>-1</sup>	IE%	Θ	Wt-loss gm	Rcorr gm.cm <sup>-2</sup> .min <sup>-1</sup>	IE%	Θ	Wt-loss Gm	Rcorr gm.cm <sup>-2</sup> .min <sup>-1</sup>	IE%	Θ
0.00	0.0138	81.32× 10 <sup>-7</sup>	–	–	0.0187	91.38× 10 <sup>-7</sup>	–	–	0.0252	10.17× 10 <sup>-6</sup>	–	–	0.0299	15.01× 10 <sup>-6</sup>	–	–
1× 10 <sup>-6</sup>	0.0027	29.37× 10 <sup>-7</sup>	80.44	0.4160	0.8044	15.23× 10 <sup>-7</sup>	85.03	0.8503	0.0018	65.27× 10 <sup>-8</sup>	90.38	0.9038	0.0026	.70.71× 10 <sup>-8</sup>	91.97	0.9197
1× 10 <sup>-5</sup>	0.0025	27.19× 10 <sup>-7</sup>	81.89	0.4722	0.8189	11.42× 10 <sup>-7</sup>	88.78	0.8878	0.0022	79.77× 10 <sup>-8</sup>	91.27	0.9127	0.0019	10 <sup>-8</sup> ×51.67	93.38	0.9338
1× 10 <sup>-4</sup>	0.014	15.23× 10 <sup>-7</sup>	89.86	0.7777	0.8986	97.91× 10 <sup>-8</sup>	90.38	0.9038	0.0019	68.90× 10 <sup>-8</sup>	92.47	0.9247	0.0017	46.23× 10 <sup>-8</sup>	94.32	0.9432

**Table 7. Effect of (T4) on the Dissolution Mild - steel in 0.5M HCl.**

Time (Min.)	60				120				180				240			
Conc (M)	Wt-loss gm	Rcorr gm.cm <sup>-2</sup> .min <sup>-1</sup>	IE%	Θ	Wt-loss gm	Rcorr gm.cm <sup>-2</sup> .min <sup>-1</sup>	IE%	Θ	Wt-loss gm	Rcorr gm.cm <sup>-2</sup> .min <sup>-1</sup>	IE%	Θ	Wt-loss Gm	Rcorr gm.cm <sup>-2</sup> .min <sup>-1</sup>	IE%	Θ
0.00	0.0138	81.32× 10 <sup>-7</sup>	–	–	0.0187	91.38× 10 <sup>-7</sup>	–	–	0.0252	10.17× 10 <sup>-6</sup>	–	–	0.0299	15.01× 10 <sup>-6</sup>	–	–
1× 10 <sup>-6</sup>	0.0028	30.46× 10 <sup>-7</sup>	79.72	0.7972	0.0037	20.12× 10 <sup>-7</sup>	80.22	0.8022	0.0044	15.95× 10 <sup>-7</sup>	82.54	0.8224	0.0048	13.05× 10 <sup>-7</sup>	83.95	0.8395
1× 10 <sup>-5</sup>	0.0026	28.28× 10 <sup>-7</sup>	81.16	0.8116	0.0033	17.95× 10 <sup>-7</sup>	82.36	0.8236	0.0042	15.23 × 10 <sup>-7</sup>	83.34	0.8334	0.0043	10 <sup>-7</sup> ×11.69	85.62	0.8562
1× 10 <sup>-4</sup>	0.0024	30.46× 10 <sup>-7</sup>	82.61	0.8261	0.0031	20.12× 10 <sup>-7</sup>	83.43	0.8343	0.0040	15.95× 10 <sup>-7</sup>	84.13	0.8413	0.0025	13.05× 10 <sup>-7</sup>	91.64	0.9164

**Table 8. Effect of (T6) on the Dissolution Mild - steel in 0.5M HCl.**

Time (Min.)	60				120				180				240			
Conc (M)	Wt-loss gm	Rcorr gm.cm <sup>-2</sup> .min <sup>-1</sup>	IE%	Θ	Wt-loss gm	Rcorr gm.cm <sup>-2</sup> .min <sup>-1</sup>	IE%	Θ	Wt-loss gm	Rcorr gm.cm <sup>-2</sup> .min <sup>-1</sup>	IE%	Conc (M)	Wt-loss gm	Rcorr gm.cm <sup>-2</sup> .min <sup>-1</sup>	IE%	Θ
0.00	0.0138	81.32× 10 <sup>-7</sup>	-	-	0.0187	91.38× 10 <sup>-7</sup>	-	-	0.0252	10.17× 10 <sup>-6</sup>	-	-	0.0299	15.01× 10 <sup>-6</sup>	-	-
1× 10 <sup>-6</sup>	0.0050	54.39× 10 <sup>-7</sup>	63.77	0.6377	0.0060	32.63× 10 <sup>-7</sup>	67.92	0.6792	0.0061	24.82 × 10 <sup>-7</sup>	75.79	0.7579	0.0053	14.41× 10 <sup>-7</sup>	82.28	0.8228
1× 10 <sup>-5</sup>	0.0045	48.95× 10 <sup>-7</sup>	67.39	0.6739	0.0044	23.39× 10 <sup>-7</sup>	76.48	0.7648	0.0052	18.85× 10 <sup>-7</sup>	79.37	0.7937	0.0045	10 <sup>-7</sup> 12.23 ×	84.95	0.8495
1× 10 <sup>-4</sup>	0.0031	33.72× 10 <sup>-7</sup>	77.54	0.7754	0.0037	20.12× 10 <sup>-7</sup>	80.22	0.8022	0.0035	12.69× 10 <sup>-7</sup>	86.12	0.8612	0.0035	95.19× 10 <sup>-8</sup>	88.29	0.8829

**Table 9. Effect of (T8) on the Dissolution Mild - steel in 0.5M HCl.**

Time (Min.)	60				120				180				240			
Conc (M)	Wt-loss gm	Rcorr gm.cm <sup>-2</sup> .min <sup>-1</sup>	IE%	Θ	Wt-loss gm	Rcorr gm.cm <sup>-2</sup> .min <sup>-1</sup>	IE%	Θ	Wt-loss gm	Rcorr gm.cm <sup>-2</sup> .min <sup>-1</sup>	IE%	Θ	Wt-loss gm	Rcorr gm.cm <sup>-2</sup> .min <sup>-1</sup>	IE%	Θ
0.00	0.0138	81.32× 10 <sup>-7</sup>	–	–	0.0187	91.38× 10 <sup>-7</sup>	–	–	0.0252	10.17× 10 <sup>-6</sup>	–	–	0.0299	15.01× 10 <sup>-6</sup>	–	–
1× 10 <sup>-6</sup>	0.0045	48.95× 10 <sup>-7</sup>	67.39	0.6739	0.0055	29.91× 10 <sup>-7</sup>	70.59	0.7059	0.0070	25.38× 10 <sup>-7</sup>	72.23	0.7223	0.0060	16.31× 10 <sup>-7</sup>	79.94	0.7994
1× 10 <sup>-5</sup>	0.0041	44.60× 10 <sup>-7</sup>	70.28	0.7028	0.0052	28.28× 10 <sup>-7</sup>	72.19	0.7219	0.0061	22.12× 10 <sup>-7</sup>	75.79	0.7579	0.0054	10 <sup>-7</sup> ×14.68	81.94	0.8194
1× 10 <sup>-4</sup>	0.0035	38.07× 10 <sup>-7</sup>	74.64	0.7464	0.0042	22.84× 10 <sup>-7</sup>	77.55	0.7755	0.0051	18.49× 10 <sup>-7</sup>	79.77	0.7977	0.0052	14.14× 10 <sup>-7</sup>	82.61	0.8261

**Table 10. Effect of (T9) on the Dissolution Mild - steel in 0.5M HCl.**

Time (Min.)	60				120				180				240			
Conc (M)	Wt-loss gm	Rcorr gm.cm <sup>-2</sup> .min <sup>-1</sup>	IE%	Θ	Wt-loss gm	Rcorr gm.cm <sup>-2</sup> .min <sup>-1</sup>	IE%	Θ	Wt-loss gm	Rcorr gm.cm <sup>-2</sup> .min <sup>-1</sup>	IE%	Θ	Wt-loss gm	Rcorr gm.cm <sup>-2</sup> .min <sup>-1</sup>	IE%	Θ
0.00	0.0138	81.32×10 <sup>-7</sup>	–	–	0.0187	91.38×10 <sup>-7</sup>	–	–	0.0252	10.17×10 <sup>-6</sup>	–	–	0.0299	15.01×10 <sup>-6</sup>	–	–
1×10 <sup>-6</sup>	0.0052	56.57×10 <sup>-7</sup>	62.31	0.6231	0.0047	25.56×10 <sup>-7</sup>	74.87	0.7487	0.0054	19.58×10 <sup>-7</sup>	78.58	0.7858	0.0062	16.86×10 <sup>-7</sup>	79.26	0.7926
1×10 <sup>-5</sup>	0.0040	43.51×10 <sup>-7</sup>	71.02	0.7102	0.0046	25.02×10 <sup>-7</sup>	75.41	0.7541	0.0052	18.85×10 <sup>-7</sup>	79.37	0.7937	0.0058	10 <sup>-7</sup> ×15.77	80.61	0.8061
1×10 <sup>-4</sup>	0.0036	39.16×10 <sup>-7</sup>	73.92	0.7392	0.0044	23.93×10 <sup>-7</sup>	76.48	0.7648	0.0050	18.13×10 <sup>-7</sup>	80.16	0.8016	0.0055	14.95×10 <sup>-7</sup>	81.61	0.8161

**Table 11. Effect of (T1, T4, T6, T8 and T9) on the Dissolution Mild - steel in 0.5M HCl in the Different Temperature.**

Comp.,	Temp. °C	25				35				45			
	Conc. (M)	Wt.-loss gm	R corr. gm.cm <sup>-2</sup> .min <sup>-1</sup>	IE%	Θ	Wt.-loss Gm	Rcorr gm.cm <sup>-2</sup> .min <sup>-1</sup>	IE%	Θ	Wt.-loss gm	Rcorr gm.cm <sup>-2</sup> .min <sup>-1</sup>	IE%	Θ
HCl	0.00	0.0299	15.01 × 10 <sup>-6</sup>	-	-	0.0584	15.88 × 10 <sup>-6</sup>	-	-	0.0710	19.31 × 10 <sup>-6</sup>	-	-
T1	1 × 10 <sup>-4</sup>	0.0017	46.23 × 10 <sup>-8</sup>	94.32	0.9432	0.0103	28.01 × 10 <sup>-7</sup>	83.36	0.8236	0.0198	53.85 × 10 <sup>-7</sup>	72.11	0.7211
T4	1 × 10 <sup>-4</sup>	0.0025	13.05 × 10 <sup>-7</sup>	91.64	0.9164	0.0116	31.54 × 10 <sup>-7</sup>	80.13	0.8013	0.0172	46.77 × 10 <sup>-7</sup>	75.77	0.7577
T6	1 × 10 <sup>-4</sup>	0.0035	95.19 × 10 <sup>-8</sup>	88.29	0.8829	0.0198	53.85 × 10 <sup>-7</sup>	66.1	0.661	0.0272	73.97 × 10 <sup>-7</sup>	61.7	0.617
T8	1 × 10 <sup>-4</sup>	0.0052	14.14 × 10 <sup>-7</sup>	82.61	0.8261	0.0182	49.49 × 10 <sup>-7</sup>	68.48	0.6848	0.0339	92.19 × 10 <sup>-7</sup>	52.26	0.5226
T9	1 × 10 <sup>-4</sup>	0.0055	14.95 × 10 <sup>-7</sup>	81.61	0.8161	0.0172	46.77 × 10 <sup>-7</sup>	70.55	0.7055	0.0262	71.25 × 10 <sup>-7</sup>	63.1	0.631