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Examining the effects of tert-butylamine under different circumstances an inhibitor of mild steel corrosion in HCl acid

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Abstract
The study explored how well mild steel resists corrosion. For this, tert-butylamine was used in an HCl solution at temperatures between 30, 50 °C and concentrations ranging from 50,200ppm. The research utilized polarization measurements and weight loss techniques to gather data. The findings show that the corrosion inhibitor, tert-butylamine, works best at higher concentrations. However, its effectiveness decreases with increasing temperatures. This inhibitor prevents corrosion by attaching to the surface of the metal and forms shielding layer, and the study assessed various thermodynamic factors, such as entropy, activation energy, free energy of adsorption, and enthalpy, to understand how this protective layer works. Amine and methyl groups within the inhibitor's chemical structure play a crucial role in forming this protective layer. This layer would act as barrier that resists corrosion and helps preserving the metal surface. The efficacy of the inhibitor was confirmed via both the measurement of weight loss as well polarization techniques, aligning well with previous research findings. These results indicate that increasing the concentration of the inhibitor leads to better protection against corrosion.

Keywords: Tert-butylamine, polarization, weight loss, inhibition, HCl, entropy, enthalpy

Introduction
One of the biggest issues the globe has in the oil sector, industrial sector as well as other sectors in various gaseous as well as aqueous conditions is corrosion. The mild steel being on top of corrosive metals; corrosion is the process by which a metal is returning to the natural state transforming it to an oxide or a hydroxides. Pipeline production lines have a number of issues and challenges due to corrosion, which also results in interruption, subpar output, and delays. Pollution and health dangers are also posed to the public by corrosion [1-6].

To prevent corrosion and maintain the integrity of minerals, materials such as organic, inorganic, or natural must be added. The compounds that are added to liquids or gases in extremely small concentration in the range of ppm scale are referred to as inhibitors. Their purpose is to form a film that covers the surface of substance, prevents any chemical reactions from occurring, and shields it from outside influences. A variety of amine-containing inhibitory chemicals have been used in previous studies to reduce corrosion.

The present investigation employed an inhibitor type tert-butylamine $(CH_3)_3CNH_2$ with varying concentrations and temperatures to evaluate the process and inhibitor type behavior [7-12].

Expermental Work
This study employed two methodologies: firstly, the rate of weight loss was calculated, and secondly, a computerized potentiostat was utilized to assess the corrosion's density of the polarization as well the potential of the corrosion by analyzing the polarization profiles of the anode. The sample of mild steel has 0.15% C, 0.39% Mg, 0.15% Si, 0.13% S, 0.42% p, and 0.021% copper wt %. The coupons with dimensions of 3 cm width, 5 cm length, and 0.3 cm thickness. In this study, the corrosion inhibitor tert-butylamine (CH3)3CNH2 was chosen to examine its effectiveness in preventing corrosion. The examination was carried out in a solution of HCl at temperatures ranging from 30 to 50 °C [13-18].

Conclusion and Discussion

Figure 1 presents the patterns of anodic as well the cathodic polarization, showing the relation of potential density and the current at 30 °C for various inhibitor concentrations. It's evident that both corrosion current and potential are high without an inhibitor. When the concentration of the inhibitor increases, both the current as well as the potential decrease, indicating improved inhibition efficiency. Figures 2, 3, and Table 1 highlight that in the absence of an inhibitor, both current and potential density each levels higher than those observed at 30 °C. This trend continues with the rise in the temperature up to 50 °C, while the inhibitor's effectiveness decreases. At 30 °C, however, the inhibition effect is significantly stronger [19-23].

The following factors influence the inhibition efficiency:

$$\eta\,\% = \frac{(Icorr)w - (Icorr)i}{(Icorr)w} * 100$$

It is illustrated as (Icorr) w being corrosion current lacking inhibitor and (Icorr) i being corrosion current in the presence of the inhibitor.

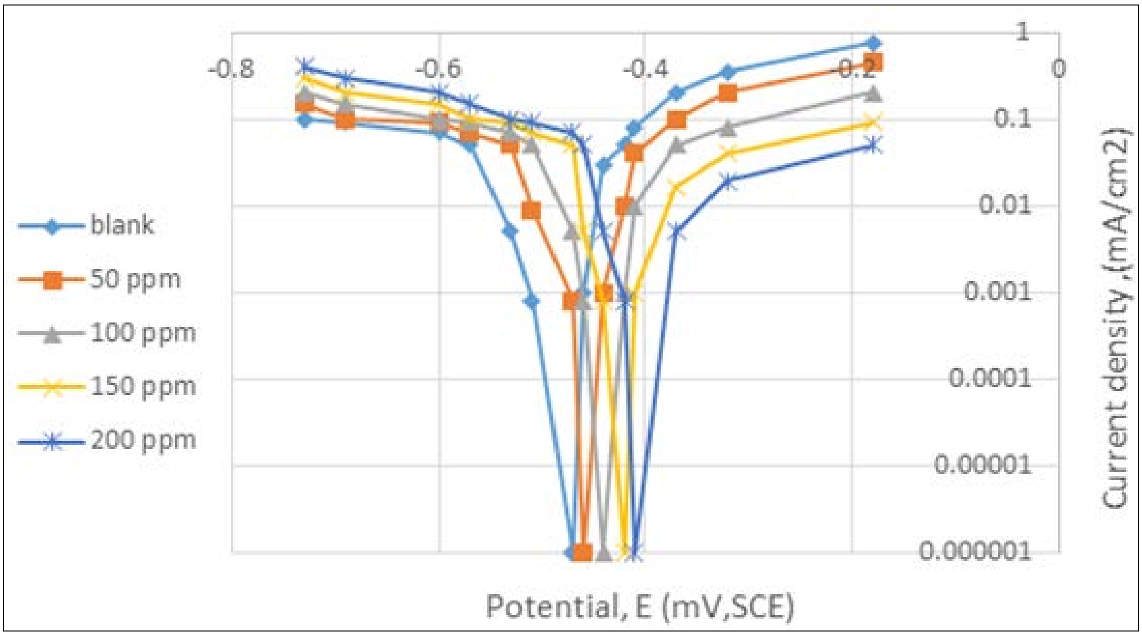

Fig 1: Potential-current profiles at 30 °C with various inhibitor concentrations

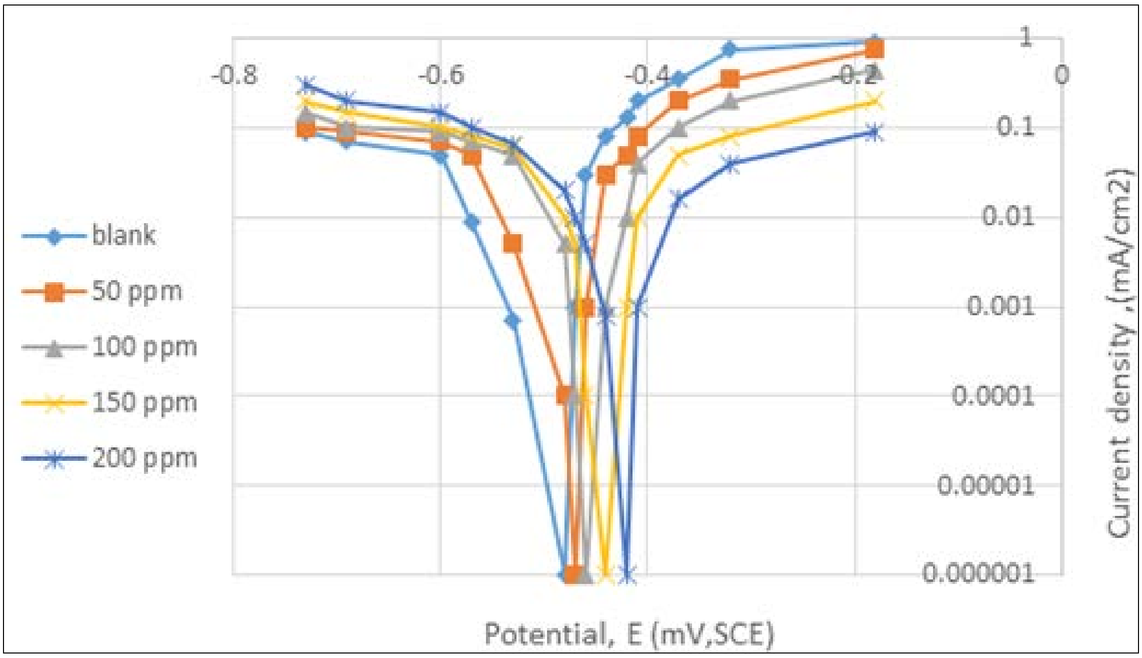

Fig 2: Potential-current profiles at 40 °C with various inhibitor concentrations

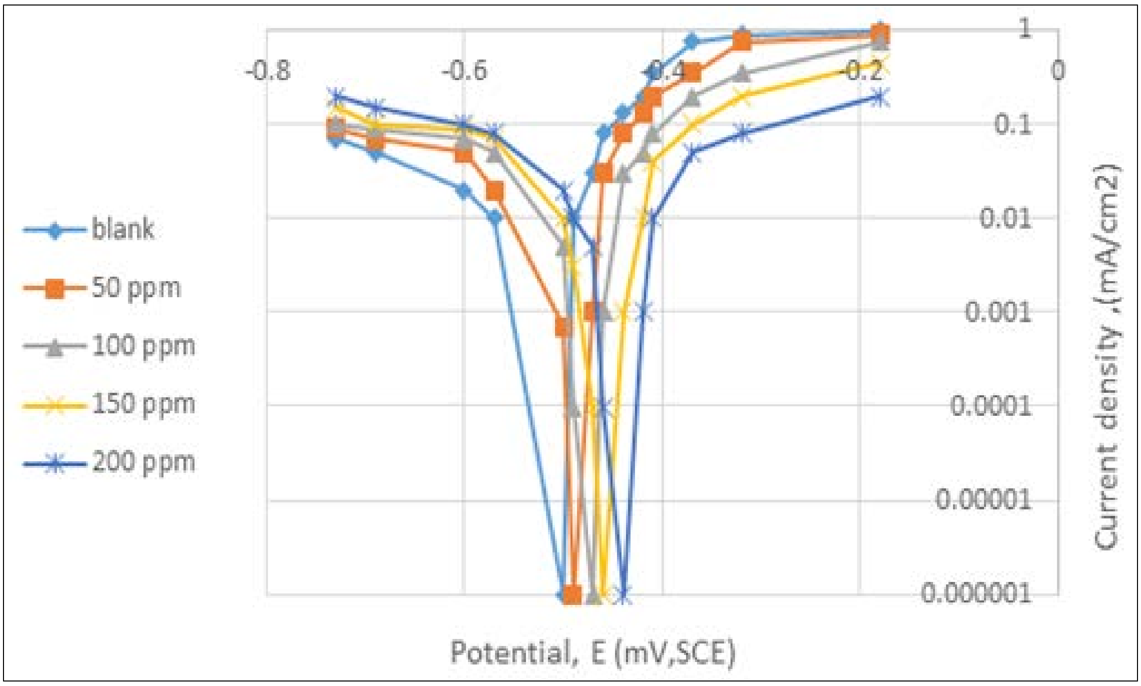

Fig 3: Potential-current profiles at temperature of 50 °C with various inhibitor concentrations

Table 1: Impact the inhibitor's concentration on Icorr, Ecorr, and the effectiveness of inhibition

Conc. of inhibitor (ppm)	E_{corr} (mV)		Corrosion current Density, (µA/cm^2)				Inhibition efficiency (%)		
	30 °C	40 °C	50 °C	30 °C	40 °C	50 °C	30 °C	40 °C	50 °C
Blank	-476	-486	-507	139	169	208	--	--	-
50	-464	-475	-498	82	108	137	41.00	36.09	34.13
100	-444	-466	-474	60	87	105	56.83	48.52	48.07
I50	-420	-445	-469	51	69	92	63.30	59.17	55.76
200	-415	-424	-448	22	36	51	54.17	78.69	75.48

Figure (4) demonstrate the relation among weight loss over time as a function to inhibitor concentration. The weight losses approach a minimum value when inhibitor concentration increased (Weight loss decreased). The decreases in corrosion rates at the temperatures (30 °C, 40 °C, as well as 50 °C) are demonstrated in Figures 5 and 6 [24-30].

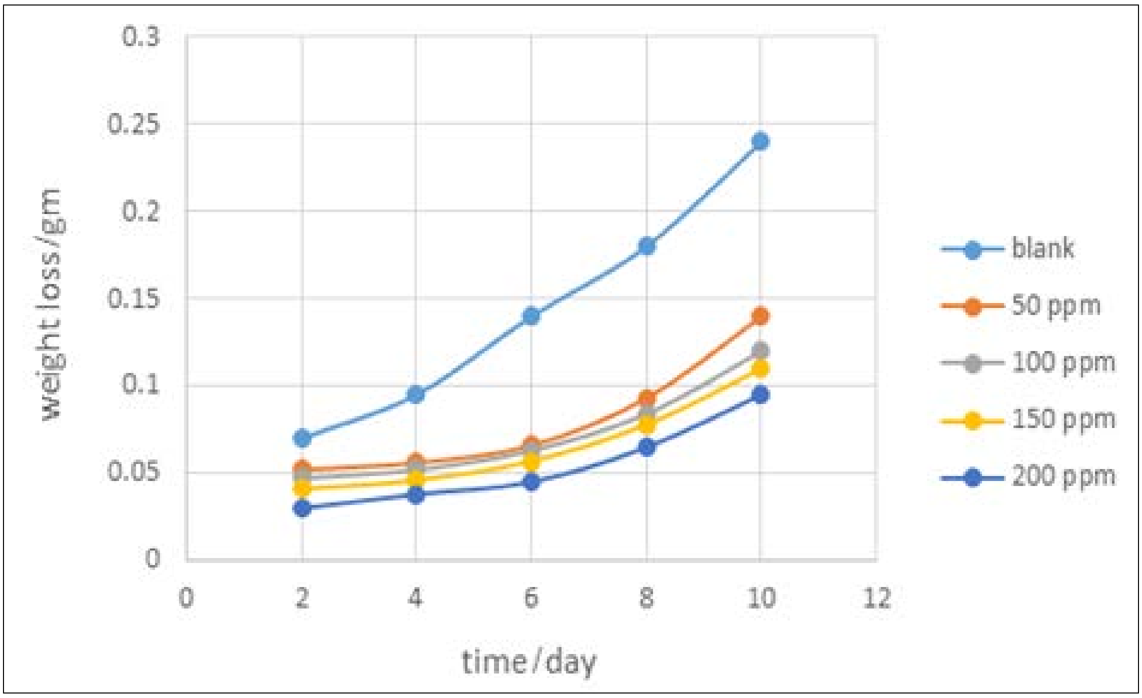

Fig 4: Calculating the weight loss over a period of time with 30 °C temperature with the inhibitor as well as without it

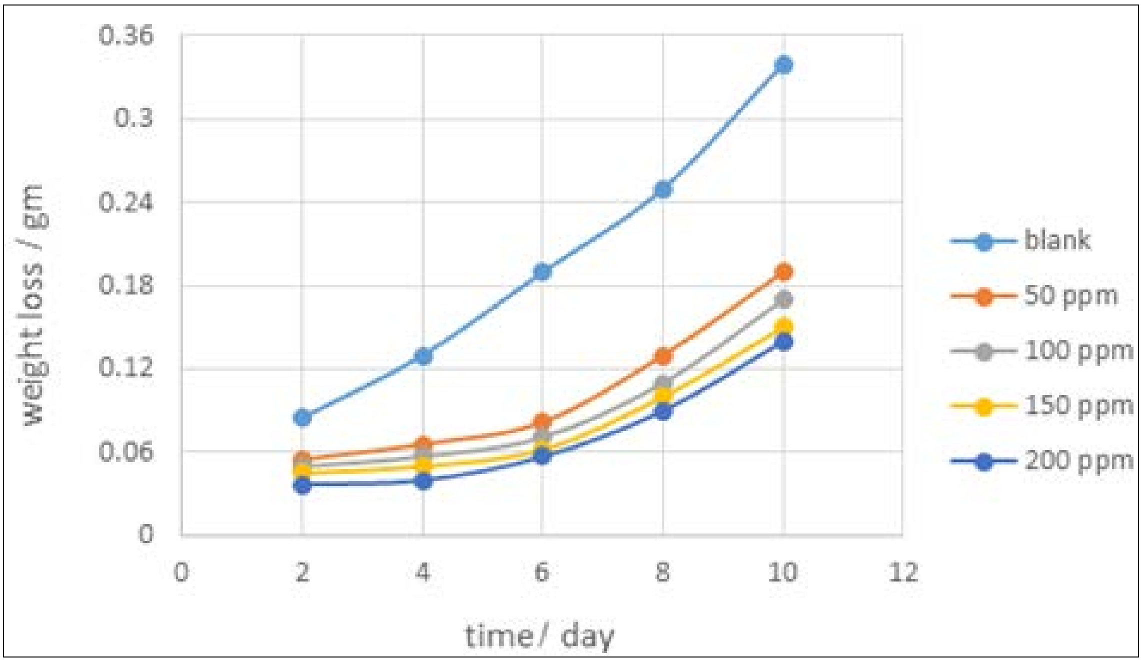

Fig 5: Quantifying the rate of weight loss over time at a temperature of 40 °C using inhibitor as well as without it

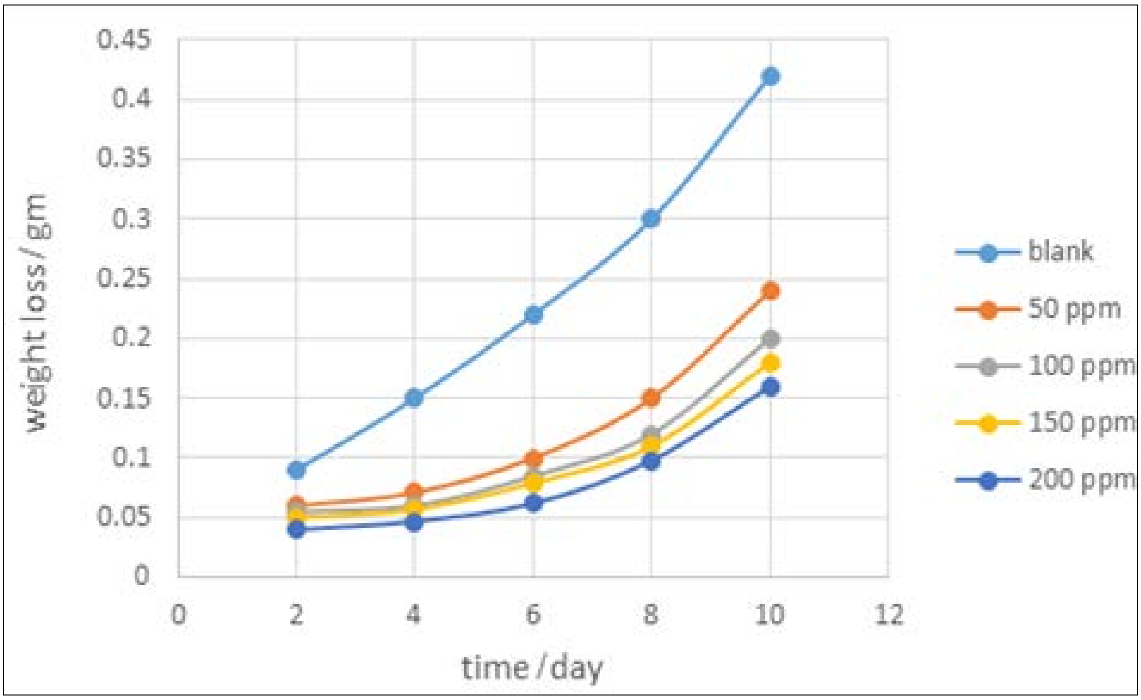

Fig 6: The relation of weight loss with time at 50 °C using inhibitor as well as without it.

Table 2: Inhibitor effectiveness in weight reduction as a function of dosage

Inhibitor conc. ppm	Rate of corrosion			Efficiency of inhibition %		
	30 °C	40 °C	50 °C	30 °C	40 °C	50°C
Blank	0.0225	0.0320	0.0377	0	0	0
50	0.0110	0.0177	0.0210	51.11	44.68	44.29
100	0.0091	0.0151	0.0197	59.55	52.81	47.74
150	0.0068	0.0132	0.0176	69.77	58.75	53.31
200	0.0049	0.0125	0.0166	78.22	60.93	55.96

Table 2 outlines how corrosion rates and inhibition efficiency vary with different inhibitor levels and temperatures, ranging from 30 °C to 50 °C. Figure 7 clearly illustrates that higher concentrations of inhibitors boost their ability to prevent corrosion. This enhancement in protection occurs as the inhibitor would form a protecting layer over the surface of metal, effectively slowing down corrosion. Significantly, the combination of 200 ppm (Parts per million) of inhibitor at a temperature of 30°C is identified as the most effective scenario for minimizing corrosion. This specific condition optimizes the inhibitor's capability to attach into the surface of metal and providing the best protection [32-37].

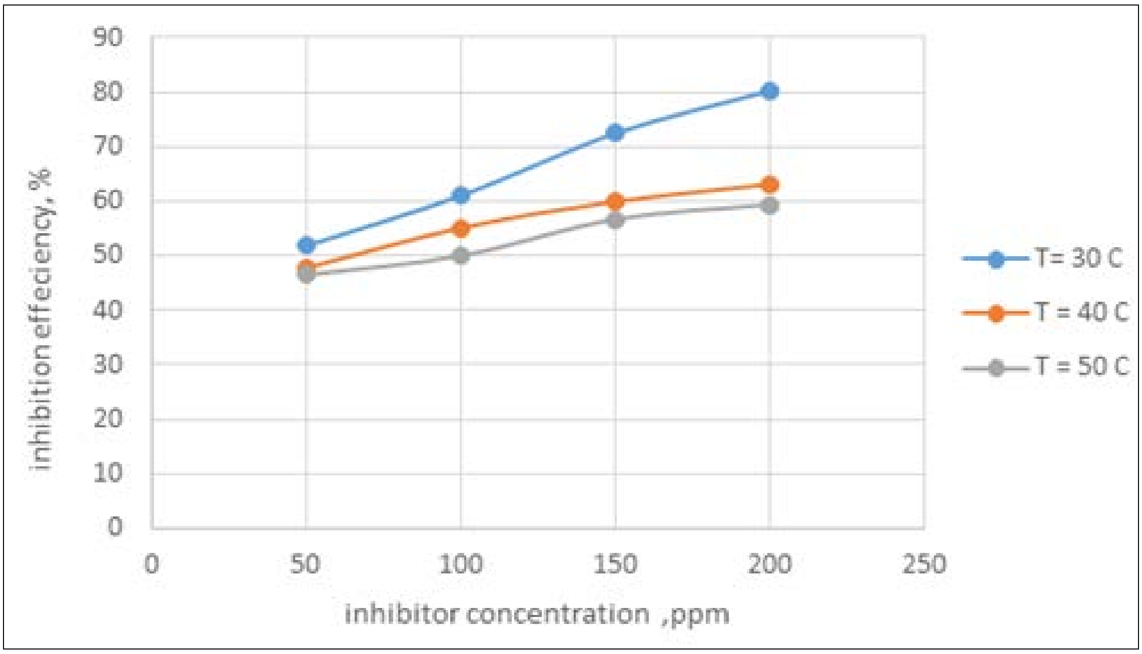

Fig 7: Plot the inhibitor concentrations vs the inhibition effectiveness at various temperatures.

Temperature influence

A study was performed in order to examine the impact of temperature fluctuations on the mild steel in hydrochloric acid, the Arrhenus equation use. The findings demonstrated that raising the temperature range 30-50 °C, caused a rise within the rate of corrosion, leading to a reduction to the effectiveness of the inhibition [37-39].

$$C.R = A \exp\left(\frac{-Ea}{R.T}\right)$$

Where Ea is denoting to activation energy, while R is symbolizing the universal constant of gas, and a constant is represented by A

The activation energy may be determined by using Fig. 8.

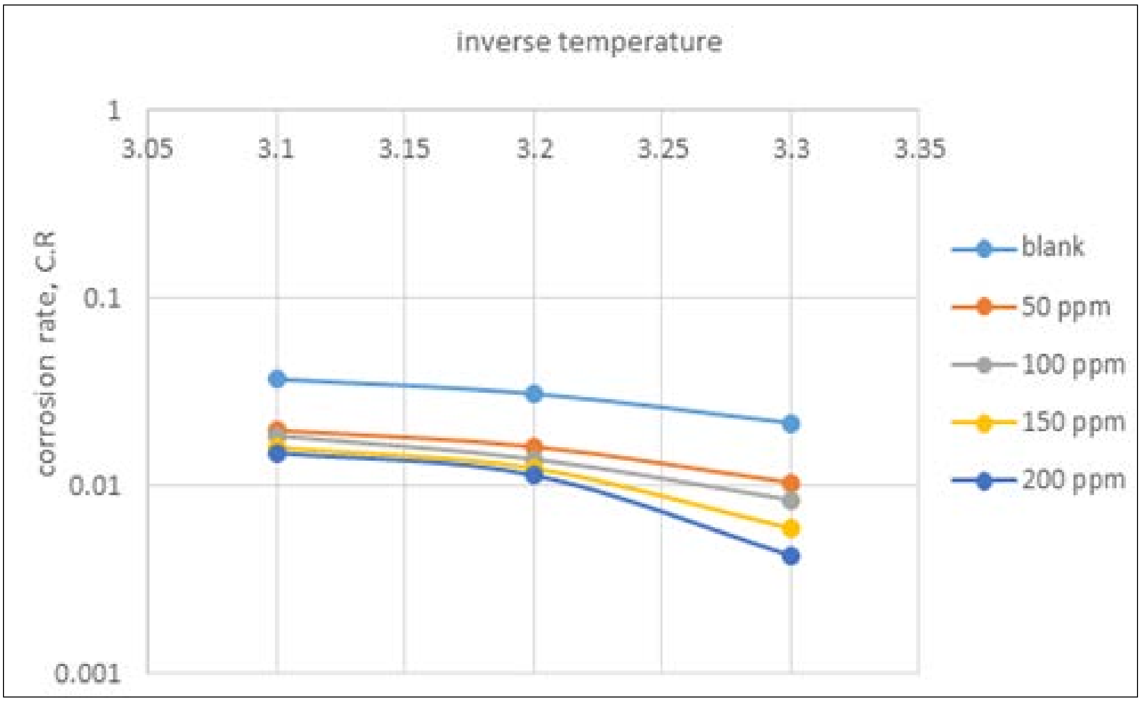

Fig 8: Log (C.R) vs. 1/T plotted at various inhibitors

Table 3 presents the activation energy of corrosion for carbon steel, both in the presence and absence of an inhibitor. Figure8, An observation was made that when the concentration of inhibitors grew, the efficacy of activation energy reduced.Higher magnitude of activation energy found at higher inhibitor concentrations suggests that corrosion may not have occurred.Equation 2 states that activation energy decreases with temperature, accelerating corrosion. ΔH, ΔS, and ΔG the kinetic parameters were calculated [35-39].

$$(C.R) = \left(\frac{RT}{Nh}\right) \exp\frac{\Delta S}{R} \exp\frac{-\Delta H}{RT}$$

where the Plank constant (h), temperature T, Avogadro number N, and universal gas constant (R) To calculate the entropy and enthalpy energies, using the following formulas.

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

$\Delta H = Ea - RT$

Where Ea is the activation energy, ΔH is the enthalpy, ΔS is the entropy, and ΔG is the free energy for adsorption.

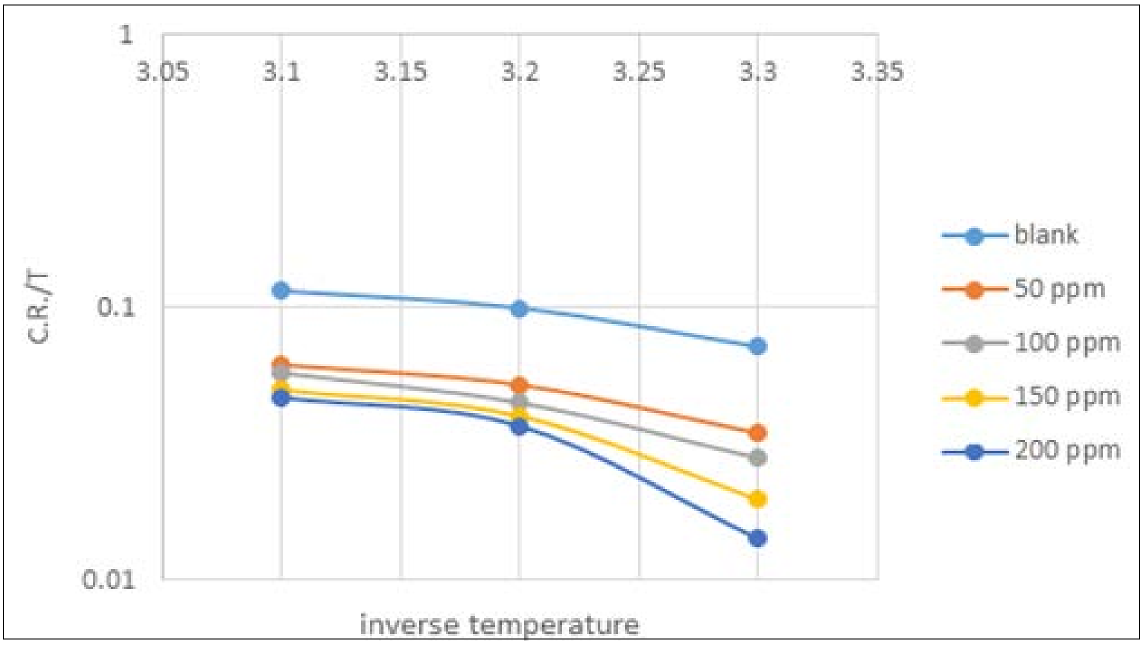

Fig 9: The relationship between log (C.R/T) and 1/T for various inhibitor concentrations

Table 3: Thermodynamic parameter attained at 30 °C as a function of inhibitor concentration

Conc. Or Inhibitor (ppm)	Ea kJ/mole	ΔH kJ/mole	ΔS kJ/mole. K	ΔG kJ/mole
Blank	0.669	1.809	$8.8*143^{11}$	1.809
50	.0410	1.133	$4.5*10^{11}$	1.133
100	.0428	1.245	$4.0*H0^{11}$	1.245
150	.0433	1.259	$3.5*10^{11}$	1.259
200	.0454	1.370	3.0*10"	1.370

A protective film layer develops on metal surfaces to guard against the harsh effects of acidic environments. Where this layer is enhanced by increasing the concentration of inhibitors, which also leads to a rise in enthalpy, free energy, and the energy needed to start a reaction. When the enthalpy value exceeds zero, it points to an endothermic system, meaning the reaction absorbs energy. The protective coating, containing methyl and amine molecules, forms on the metal surface, effectively shielding it from corrosion. Figure 10 illustrates the inhibitor structure used to create this protective layer [35-39].

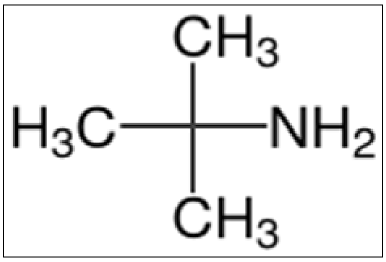

Fig 10: Chemical structure of tert-butylamine

Conclusion

The current study's findings demonstrated that there is a mixed corrosion potential between the anode and cathode. When tert-butylamine concentrations increase, the efficacy of the corrosion inhibitors improved, becoming extremely effective; conversely, increasing temperature resulted in adecrease in efficacy, weight loss, and polarization. All parameters activation, enthalpy, entropy, and free energy of adsorption turned out to be adequate when compared to earlier research. The amine and methyl molecules cause chemical adsorption on the metal surface, which leads to the development of a thin film layer. This thin-film layer has strong inhibitory and anti-corrosion properties.

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