



CHEMISTRY JOURNAL OF MOLDOVA.
General, Industrial and Ecological Chemistry

Publication details, including instructions for authors information:
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**STUDY OF 3-ANILINOMETHYLPROPIONATE ON
 MILD STEEL SURFACE CORROSION IN
 SULPHURIC ACID SOLUTION**

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Accepted version posted online: 12 October 2026

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To cite this article: S. Sharma, A. Dwivedi, R. Singh, N. Mishra, S.K. Shukla, A. Bardhan, P.K. Singh, G. Ji, A. Srivastava, A. Porwal. Study of 3-Anilinomethylpropionate on Mild Steel Surface Corrosion in Sulphuric Acid Solution. *Chemistry Journal of Moldova*, 2026, DOI: doi.org/10.19261/cjm.2026.1489

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STUDY OF 3-ANILINOMETHYLPROPIONATE ON MILD STEEL SURFACE CORROSION IN SULPHURIC ACID SOLUTION

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Abstract. Organic compounds with biological properties such as 3-anilinomethylpropionate have been utilized in this study for assessing corrosion inhibition performance on mild steel within 0.5M sulphuric acid solution. In this experiment, weight loss, polarization resistance, Tafel polarization, and electrochemical impedance spectroscopy methods were used to assess the performance of the corrosion inhibitors and the mechanisms involved. In this regard, 3-anilinomethylpropionate is classified as mixed type corrosion inhibitor with a performance level of 96.5% at a concentration of 70 ppm. According to the impedance study, the higher the concentration of inhibitors the greater the charge transfer resistance whereas the lower the double layer capacitance. In summary, this paper presents the use of 3-anilinomethylpropionate for corrosion inhibition on mild steel surface within 0.5M sulphuric acid solution. In order to analyse the performance of the corrosion inhibitors as well as the mechanism involved, weight loss, polarization resistance, Tafel polarization, and impedance spectroscopy methods were used. As indicated by potentiodynamic polarization, 3-anilinomethylpropionate acts as mixed type corrosion inhibitor with a performance level of 96.5% at a concentration of 70 ppm.

Keywords: aniline, ester, potentiodynamic polarization, EIS, mixed type inhibitor.

Received: 8 June 2026/ Revised final: 7 September 2026/ Accepted: 11 September 2026

Introduction

Mild steel is one of the most widely utilized engineering materials because of its low cost, excellent mechanical strength, ease of fabrication, and extensive industrial applicability. It is commonly employed in chemical processing plants, petroleum refineries, pipelines, heat exchangers, storage tanks, acid pickling units, and desalination systems [1]. The financial implications of corrosion do not end at the cost of material loss and replacement but include other costs such as production delay, environmental destruction, and reduced safety measures.

The problem of corrosion is significant and long-standing within different industries, having significant economic and safety implications [2-4]. Because of its flexibility, it is regarded as an important component in many industries like manufacturing, transport, construction, and infrastructure construction. Mild steel is renowned because of its high strength as well as being easily weldable [5-6]. Furthermore, its cheapness and durability have made it important in various fields of engineering [7-9]. However, despite its many benefits, mild steel remains susceptible to corrosion, particularly in environments containing

high levels of acids or moisture. To address this vulnerability, effective corrosion control strategies are essential. This emphasizes the importance of ongoing research and innovation in the development of new corrosion inhibitors and protective coatings [10,11]. By shielding metallic structures and equipment from corrosion-related deterioration, these strategies not only safeguard valuable assets but also enhance operational efficiency, safety standards, and overall sustainability across industries [12-15]. In environments laden with hydrochloric acid, and sulphuric acid such as those encountered in cleaning processes, pickling, metal etching, and chemical synthesis, mild steel is particularly susceptible to corrosion [16-18]. In the perpetual pursuit of corrosion mitigation strategies, corrosion inhibitors have emerged as a focal point of research and development efforts. These inhibitors are classified based on their chemical compositions, mechanisms of action, and other pertinent factors [19,20]. Inorganic inhibitors, leveraging compounds like chromates and phosphates, have historically played a pivotal role in corrosion inhibition. However, their environmental and health-related concerns have spurred the exploration of organic alternatives [21-23]. Organic inhibitors have gained prominence owing to their effectiveness, versatility, and relatively benign environmental impact. Compounds containing heteroatoms such as nitrogen, oxygen, sulphur, and phosphorus exhibit notable corrosion inhibition capabilities, with varying degrees of efficacy. Among these heteroatoms, oxygen (O) ranks lowest in terms of corrosion inhibition potential, followed by nitrogen (N), sulphur (S), and phosphorus (P). The presence of these heteroatoms facilitates the formation of coordination bonds, wherein electrons from the heteroatoms are transferred to the free d-orbitals of iron atoms on the mild steel surface [24-28]. The strength of the chemisorption bond between the inhibitor molecules and the metal surface is contingent upon several factors, including the electron density of the donor atom within the inhibitor's functional group and the polarizability of the group itself. Additionally, electrostatic interactions between inhibitor molecules and the metal surface play a crucial role in corrosion inhibition mechanisms [29,30]. Mannich bases having the functionalities of amine, aromatic and ester have received much attention as good corrosion inhibitors for mild steel in acid environments. Inhibition efficiency of such compounds can be explained on the basis of adsorption of the electron rich nitrogen and oxygen

atoms and also π -electrons of the aromatic system on the metal surface resulting in the formation of a stable protective film. It has been established through research work that substituted anilinomethyl propionates and the Mannich bases have high inhibition efficiencies, the efficiencies of which depend greatly upon the electronic nature of the substituent [31,32].

The present study aims to evaluate the corrosion inhibition performance of 3-anilinomethylpropionate on mild steel in aqueous sulphuric acid solution using gravimetric, electrochemical, and surface characterization techniques. The adsorption behaviour and inhibition mechanism of the inhibitor on the mild steel surface are also investigated. The study is expected to provide valuable insights into the application of aniline-based ester compounds as efficient corrosion inhibitors for industrial acidizing and pickling operations.

Experimental Materials

Mild steel specimens employed in the present investigation were mechanically cut into appropriate dimensions for electrochemical and gravimetric measurements. The composition (wt%) of the mild steel was as follows: Fe, 99.21; C, 0.21; Si, 0.38; P, 0.09; S, 0.05; Al, 0.01. Prior to each experiment, the steel samples were polished successively using silicon carbide abrasive papers of different grades (400–2000 grit) to obtain a smooth and homogeneous surface. The polished specimens were rinsed thoroughly with distilled water, degreased with acetone, washed again with deionized water, and dried under ambient conditions before use. The corrosive medium used throughout the study was 0.5 M aqueous sulphuric acid (H_2SO_4), prepared using analytical grade sulphuric acid and double-distilled water. Different concentrations of 3-anilinomethylpropionate were prepared in the acidic medium to evaluate its corrosion inhibition performance. All reagents used were of analytical reagent (AR) grade and utilized without further purification. The experiments were carried out in unstirred and naturally aerated conditions [33-35].

Synthesis of Inhibitor

Inhibitor molecule was synthesized by the procedure reported in the literature [36] using equimolar amount of aniline and methyl acrylate refluxed on a heating mantle for 15hrs in presence of glacial acetic acid. The content was poured onto crushed ice. The resulting compound was extracted by diethyl ether. Compound was characterized and found similar to the reported in the literature [36].

Chemical structure of the inhibitor molecule reported in Figure 1.

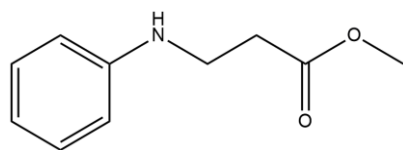


Figure1. Chemical structure of the 3-anilinomethylpropionate.

Weight-loss analysis

Weight-loss analysis involved immersing predetermined Mild Steel samples in 100 mL of sulphuric acid solution for 3 hours at an ambient temperature of 303 K and samples were rinsed thoroughly with distilled water and acetone, dried, and weighed. Corrosion rate (C_R mm/y) and percentage inhibition efficiency (IE%) were computed based on the weight loss data collected during the exposure period [33-35]. The corrosion rate (CR) was calculated using Eq.(1).

$$C_R = \frac{87.6W}{dat} \quad (1)$$

where, W represents the weight loss in milligrams, d is the density in gram cm^{-3} , a denotes the total area in square centimeters, t signifies the exposure time in hours, the constant 87.6 is included in the formula.

Percentage inhibition efficiency (IE) was determined using the Eq.(2):

$$IE = \frac{w_1 - w_2}{w_1} \times 100 \quad (2)$$

where, w_1 and w_2 represent the weight loss of specimens in the presence and absence of specific concentrations of inhibitor, respectively.

The inhibition efficiency was calculated for each inhibitor concentration throughout the exposure duration. The surface coverage (θ) was calculated from the weight-loss measurements according to Eq.(3), where θ represents the fraction of the mild steel surface occupied by adsorbed inhibitor molecules.

$$\theta = \frac{w_1 - w_2}{w_1} \quad (3)$$

Electrochemical measurement

Electrochemical measurements were performed using a Gamry Instrument Potentiostat / Galvanostat / ZRA model Ref 600 in three

electrode assembly where mild steel acts as working electrode, a platinum counter electrode and calomel reference electrode, along with DC105 and EIS300 software by Gamry, was utilized for potentiodynamic scans.

Linear polarization resistance measurements were carried out using the same three-electrode setup connected to the Gamry Reference 600 potentiostat. The measurements were performed within a narrow potential range of ± 10 mV around the open circuit potential at a scan rate recommended for corrosion analysis. The polarization resistance (R_p) values were obtained from the slope of the potential-current curves near the corrosion potential.

The polarization curves were recorded by sweeping the electrode potential from -250 mV to $+250$ mV with respect to the open circuit potential at a scan rate of 1 mVs^{-1} . The anodic and cathodic polarization branches were extrapolated to determine the corrosion current density (I_{corr}), corrosion potential (E_{corr}), anodic Tafel slope (β_a), and cathodic Tafel slope (β_c). Measurements were initiated approximately 30 minutes after immersing the working electrode in the solution to stabilize the steady-state potential. All measurements were conducted in triplicate, and average values were reported [37,38].

Electrochemical impedance spectroscopy measurements were performed using EIS300 software coupled with the Gamry Reference 600 instrument. The impedance spectra were recorded at open circuit potential over a frequency range from 100 kHz to 0.01 Hz with an AC perturbation amplitude of 10 mV. Nyquist plot was obtained to evaluate the corrosion behaviour of mild steel in the absence and presence of the inhibitor. The impedance data were fitted using equivalent electrical circuit models to determine charge transfer resistance (R_{ct}) and double-layer capacitance (C_{dl}). The increase in charge transfer resistance and decrease in double-layer capacitance in the presence of inhibitor were attributed to adsorption of inhibitor molecules on the mild steel surface and formation of a protective barrier film.

Results and discussion

Weight loss study

All the weight loss experiments were done in triplicate and the average of this has been considered. The average weight loss of mild steel without inhibitor and with various concentrations at room temperature in 0.5M sulphuric acid was reported in Table 1. On the basis of the data reported in Table 1, graph between Inhibitor's

concentrations with inhibitor's efficiency has been shown in Figure 2. It is evident from the Figure 2 that the by increase in the concentration of inhibitor up to 70 ppm inhibition efficiency increases to 96.33% and after that saturated to show the stable inhibition efficiency by increasing the concentration of the inhibitor.

It is found that the inhibition efficiency in maximum 96.33% and the corrosion rate is 1.15 mm/y at 70 ppm concentration of the inhibitor. It is evident from the Figure 2 and Table 1 that after achieving the maximum inhibition efficiency at 70 ppm, inhibition efficiency not increases with the addition of inhibitor molecules.

By adding the more inhibitor, the corrosion rate is not decreasing substantially. This is due to the optimization of the surface coverage by the inhibitor molecule. The rate of increment in inhibition efficiency is due to the adsorption of the inhibitor molecules on the surface of mild steel. The surface coverage by increasing the inhibitor concentration is reported in Table 1 which is responsible for the inhibitor efficiency. The molecule probably adsorbed on to the mild steel surface by the use of the electron cloud present in the benzene ring as well as the lone pair of electrons present on to the hetero atoms present in the inhibitor molecule [39,40].

Table 1

Impact of variable inhibitor concentration in aqueous condition on mild steel surface.

Inhibitor's Concentration (ppm)	Weight loss (mg)	Inhibitor's Efficiency (%)	Corrosion Rate (mm/y)
Blank	84.5	-	31.43
40	28.8	65.91	10.71
50	14.4	82.95	5.36
60	7.0	91.71	2.60
70	3.1	96.33	1.15
80	3.1	96.33	1.15

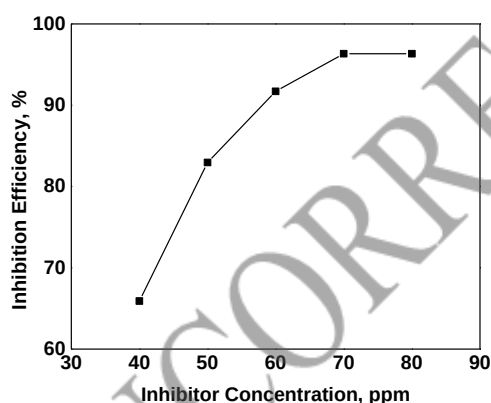


Figure 2. Inhibitor concentration vs. inhibition efficiency.

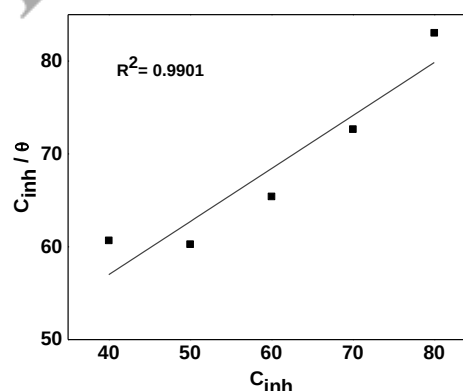


Figure 3. Langmuir adsorption isotherm.

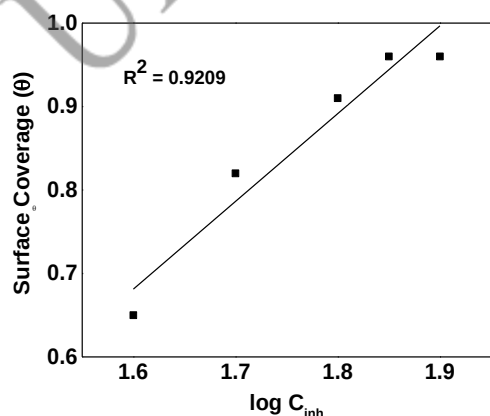


Figure 4. Temkin adsorption isotherm.

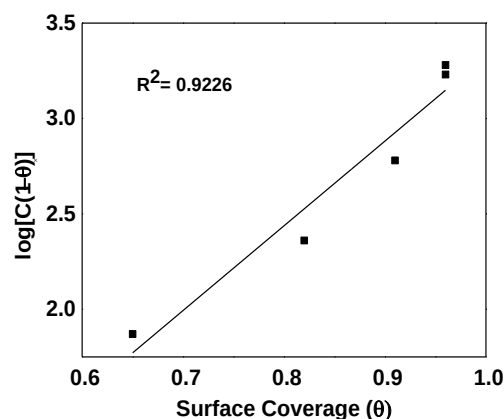


Figure 5. Temkin adsorption isotherm.

Adsorption isotherm

Corrosion inhibition may be studied using adsorption isotherm [29]. The weight loss was employed to determine the degree of surface coverage (θ) for each inhibitor concentration. In order to graphically test the experimental data, different isotherms like Langmuir, Temkin and Frumkin isotherm were plotted. Adsorption isotherms were plotted by the data generated by the weight loss study. Langmuir adsorption isotherm plotted by using the Eq.(4) [41].

$$\frac{C}{\theta} = \frac{1}{K_{ads}} + C \quad (4)$$

where, K_{ads} is the adsorption equilibrium constant,
 θ is surface coverage and

C is the inhibitor concentration.

For the Temkin adsorption isotherm Eq.(5) is used to relate the degree surface coverage and the inhibitor concentration [42].

$$\exp(-2a\theta) = KC \quad (5)$$

where, a is attractive parameter,

K is adsorption equilibrium constant.

In addition, the Frumkin isotherm can be plotted by using the Eq.(6) [41].

$$\log\left(C \times \frac{\theta}{1-\theta}\right) = 2.303 \log K + 2\alpha\theta \quad (6)$$

where, θ is surface coverage,

C is concentration of inhibitor,

K is adsorption equilibrium constant,

α is the lateral interaction term describing the interaction in adsorbed layer.

All the three adsorption isotherms were plotted and Langmuir, Temkin and Frumkin adsorption isotherm plots were reported in Figure 3, 4 and 5 respectively.

Among all the plotted data it is observed that the Langmuir adsorption isotherm is the best fitted and having regression coefficient (R^2) is near to unity and provide best fit linear graph where as other isotherms not follows the best fit lines near unity. Plotting the graph of C_{inh} versus C_{inh}/θ gave a straight line with regression coefficient (R^2) near unity, i.e: 0.9901 with 3-anilinomethylpropionate adsorption (Figure 3). Plotting surface coverage for adsorption of inhibitor molecules on mild steel surface indicates that the adsorption takes place according to Langmuir adsorption isotherm. The reason behind the enhanced inhibition capacity of 3-anilinomethylpropionate is due to the presence of π electrons, quaternary nitrogen atom, amino group, and large molecular size which leads to

greater coverage of mild steel surface. The adsorption of inhibitor molecules onto the mild steel surface is well described by the Langmuir adsorption isotherm, implying monolayer adsorption on a homogeneous surface with negligible interaction between adsorbed species. The good fit to the Langmuir model indicates that adsorption occurs through the replacement of water molecules by inhibitor molecules at active corrosion sites [30].

Polarization Resistance

The values of R_p in the case of mild steel when immersed in 0.5M sulphuric acid solution show an increase from 13.99 ohms for the blank sample to 94.54 ohms when the concentration of inhibitor increases up to 70 ppm (Table 2). The increase in polarization resistance suggests that the inhibitor formed a compact and adherent protective film, which effectively restricted both anodic metal dissolution and cathodic hydrogen evolution reactions. The adsorption of 3-anilinomethylpropionate on the mild steel surface reduced the active corrosion sites and enhanced the charge transfer resistance. The highest R_p value obtained at 70 ppm indicates optimum inhibition performance. These findings clearly demonstrate that the corrosion resistance of mild steel in sulphuric acid improves substantially with increasing concentration of 3-anilinomethylpropionate.

Tafel polarization

Tafel polarization studies were conducted in the absence and presence of inhibitors at various concentrations, and the results are reported in the Figure 6. The graphs in Figure 6 illustrate the influence of inhibitor concentrations on the anodic and cathodic polarization effects of mild steel in a 0.5M sulphuric acid solution.

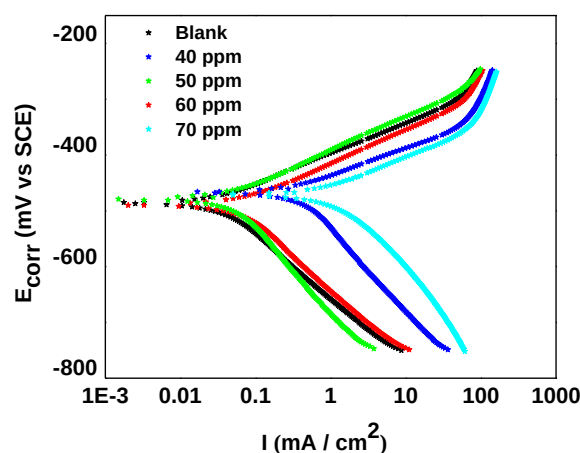


Figure 6. Tafel polarization curves of mild steel in the absence and presence of the inhibitor at various concentrations.

The electrochemical characteristics of the plots, including the density of corrosion current (I_{corr}), potential for corrosion (E_{corr}), resistance to polarization (R_p), inhibitor efficiency (IE%) and anodic slopes (b_a and b_c), are presented in Table 2. The addition of inhibitor in the corrosive medium inhibits both anodic mild steel dissolution and cathode hydrogen development, as shown in Table 2. It is evident from the Table 2 that by increasing the inhibitor concentration inhibition efficiency increases. The inhibitor resulted in a reduced I_{corr} corrosion current density with the increase in corrosion inhibition with depression in cathodic and anodic current reported in the Table 2 clearly reveals that the inhibition process is mixed type inhibition retarding both anodic and cathodic reactions. Therefore, this inhibitor is categorizing as mixed type inhibitor for the preventing mild steel corrosion. (43)

As evident from Figure 4, the disintegration of the air-molded oxide layer resulted in the polarization potential of mild steel being 455 mV (SCE), a higher negative value, in the absence of an inhibitor. The polarization potential moves to the positive side with the addition of an inhibitor to the corrosive solution. The established I_{corr} density drop was found as the inhibitor concentration, exhibits that the protective layer of inhibitor growing as barrier for both anodic and cathodic reactions and decreases the corrosion significantly [44].

Electrochemical impedance spectroscopy

The Nyquist plot of mild steel in 0.5 M sulphuric acid in the absence and presence of inhibitor is shown in Figure 7.

In electrochemical impedance spectroscopy (EIS), the Nyquist plot is obtained by plotting the imaginary impedance component ($-Z_{imag}$) against the real impedance component (Z_{real}). The semicircular capacitive loops observed in the figure are characteristic of a charge-transfer controlled corrosion process occurring at the mild steel/electrolyte interface. The increase in the semicircle of the Nyquist plots by increase in inhibitor concentration reflects the increase in the adsorption of the inhibitor molecules. This increase in capacitance semicircles suggests that the inhibitor's superior adhesion to the mild steel surface during the corrosion process is the cause of its moderating impact.

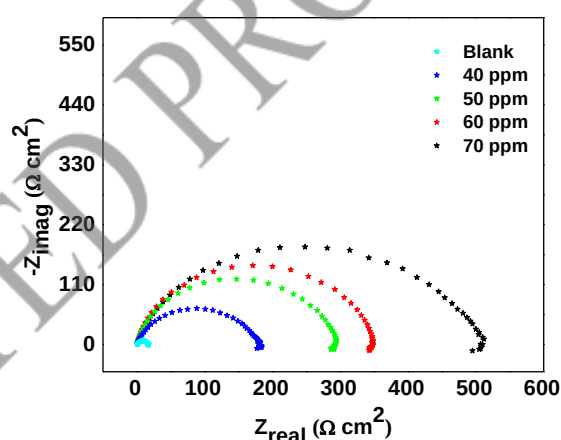


Figure 7. Electrochemical impedance spectroscopy curves of mild steel in the absence and presence of the inhibitor at various concentrations.

Table 2

Potentiodynamic polarization parameters values of the inhibitor at different concentrations on the mild steel surface in 0.5 M sulphuric acid medium.

S.No	Conc. of Inhibitor PPM	Polarization Resistance		Tafel polarization				
		R_p (Ohm)	Inhibitor's Efficiency (%)	$-E_{corr}$ mV vs SCE	I_{corr} $\mu A cm^{-2}$	b_a mVdec ⁻¹	b_c mVdec ⁻¹	Inhibitor's Efficiency (%)
1	Blank	27.98	-	451	1380	83	126	-
2	40	71.34	60.8	471	467	56	130	66.15
3	50	98.82	71.7	472	320	58	138	76.81
4	60	150.72	81.4	483	178	59	134	87.10
5	70	189.08	85.2	485	90	60	135	93.48

Table 3

Electrochemical impedance parameters values of the inhibitor at different concentrations on the mild steel surface in 0.5M sulphuric acid medium.

S.No	Conc. of Inhibitor (PPM)	Solution Resistance (R_s)	Charge transfer resistance (R_t)	Y_0 ($10^{-6} \Omega^{-1} cm^{-2}$)	N	C_{dl} ($\mu F cm^{-2}$)	Inhibitor's efficiency (%)
1	Blank	1.98	20.2	162.0	0.8191	58.3	-
2	40	1.99	189.4	105.1	0.8113	41.5	89.3
3	50	1.18	289.1	80.0	0.8023	30.6	93.0
4	60	1.31	350.5	41.1	0.7982	14.9	94.2
5	70	1.30	525.5	36.4	0.7912	11.5	96.1

The higher and lower frequency regions, which have the same capacitance but differing widths, are likewise depicted in Figure 7. A comparable circuit at a constant phase angle was utilized to demonstrate the impedance data pertinent to the mild steel and acid contact concept [45]. Table 3 lists the pertinent circuit parameters (R_s , R_t , Y_o , and n) for electrochemical impedance. Double layer capacitance value listed in Table 3 were calculated by using Eq.(7).

$$C_{dl} = (Y_o R_t^{1-n})^{1/n} \quad (7)$$

The blank sample exhibits the smallest semicircle diameter, indicating the lowest charge transfer resistance (R_{ct}). A low R_{ct} value corresponds to rapid electron transfer between the mild steel surface and the corrosive medium, which signifies a high corrosion rate. In the absence of inhibitor molecules, the mild steel surface remains directly exposed to the electrolyte, allowing aggressive ions to attack the surface more effectively. Upon addition of the inhibitor, the diameter of the Nyquist semicircle increases progressively with inhibitor concentration from 40 ppm to 70 ppm. This enlargement of the capacitive loop demonstrates a significant increase in charge transfer resistance, confirming that the inhibitor effectively suppresses the corrosion reaction. The increase in R_{ct} occurs because inhibitor molecules adsorb onto the mild steel surface and form a protective barrier layer that restricts the transfer of electrons and limits the diffusion of corrosive species toward the mild steel interface. Among all concentrations, the 70 ppm inhibited system exhibits the largest semicircle diameter, indicating the maximum impedance and highest corrosion resistance. This behaviour suggests that the inhibitor coverage on the mild steel surface becomes more complete at higher concentrations, resulting in enhanced surface protection and improved inhibition efficiency. The systematic increase in impedance with concentration confirms that the inhibition performance is concentration dependent. The depressed nature of the semicircles rather than perfect semicircular shapes indicates non-ideal capacitive behaviour of the electrochemical system. This deviation is commonly attributed to surface heterogeneity, roughness, porosity, and non-uniform distribution of adsorbed inhibitor molecules on the mild steel surface. In practical systems, in such behaviour is usually studied by using a constant phase element (CPE) reported in Figure 8 instead of an ideal capacitor [5,6].

The CPE circuit follows instead of the ideal capacitor because of the heterogeneous surface present on to the mild steel surface and it increases by increase in the corrosiveness of the environment, whereas by use of inhibitor the surface roughness reduced due to homogeneous film formation by the inhibitor molecules [29]. This circuit is generally used to describe the iron/acid interface model [43]. In this circuit R_s is solution resistance, R_t is charge transfer resistance and CPE is a constant phase element. The impedance function of the CPE is as Eq.(8).

$$Z_{CPE} = Y^{-1}(j\omega)^{-n} \quad (8)$$

where, Y is the magnitude of the CPE, ω is the angular frequency and the deviation parameter n is a valuable criterion of the nature of the metal surface and reflects microscopic fluctuations of the surface.

For $n=0$ Z_{CPE} represents a resistance with $R=Y^{-1}$; $n=1$ an inductance with $L=Y^{-1}$ and $n=1$ an ideal capacitor with $C=Y$ [43].

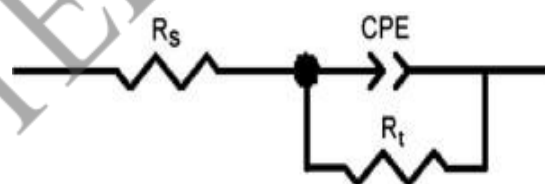


Figure 8. The electrochemical equivalent circuit used to fit the impedance spectra.

In iron/acid interface systems, ideal capacitor behaviour is not observed due to the roughness or uneven current distributions on the electrode surface which results in frequency dispersion. Furthermore, the shift of the curves toward higher Z_{real} values with increasing inhibitor concentration demonstrates enhanced polarization resistance and reduced corrosion kinetics. The absence of inductive loops at lower frequencies suggests that the corrosion process is predominantly governed by charge transfer mechanisms without significant adsorption-desorption relaxation effects. Overall, the Nyquist plot clearly demonstrates that the inhibitor provides effective corrosion protection, with inhibition efficiency increasing significantly as the inhibitor concentration rises from 40 ppm to 70 ppm. The impedance pattern on the mild steel surface is comparable to the adsorption effect of the inhibitor. The adsorption of inhibitor molecules leads to the polarization resistance R_p , which depends on the number of adsorbed molecules.

Consequently, the inhibitor layer formed decreases the capacitance at the mild steel/solution interface by either increasing the mild steel thickness or lowering the dielectric constant between the mild steel and electrolyte [45]. A low-frequency inductive loop in the Nyquist plot of EIS generally indicates the relaxation of adsorbed intermediate species (*e.g.*, corrosion products or inhibitor–metal complexes) on the electrode surface. It reflects adsorption–desorption kinetics, surface film instability, or intermediate reaction pathways, providing evidence of complex interfacial electrochemical processes rather than simple charge transfer [36].

Surface study: scanning electron microscopy

Scanning electron microscopy was performed to analyse the surface roughness and the micrograph reported in Figure 9(a-b). It is evident from the Figure 9(a) that when surface is exposed without inhibitor the surface is strongly damaged and severe pits were formed throughout the surface. Figure 9(a) illustrates a rough, darkly

shaded surface that could be due to corrosion products and/or sulphate ion deposition. Since the organic species had adsorbed at most of the active sites, the presence of the inhibitor reduced the rate of erosion and formed a smooth surface (Figure 9(b)). The brightness of the image indicates that the inhibitor and mild steel are having a good interaction. From the data provided in the Figure 9, it can be deduced that the inhibitor protected the mild steel from the acid by forming an insulating layer on its surface.

Mechanism of inhibition

Sulphuric acid molecule interacted with the mild steel surface to release the Fe^{2+} ion to cause corrosion represented in Figure 10. It was discovered that the presence of an inhibitor prevented mild steel from corroding in sulphuric acid. After analysing the data from several methods, it was determined that the slowed rate of corrosion was caused by the inhibitor molecule's adsorption on the mild steel surface, which changed the steel's surface characteristics.

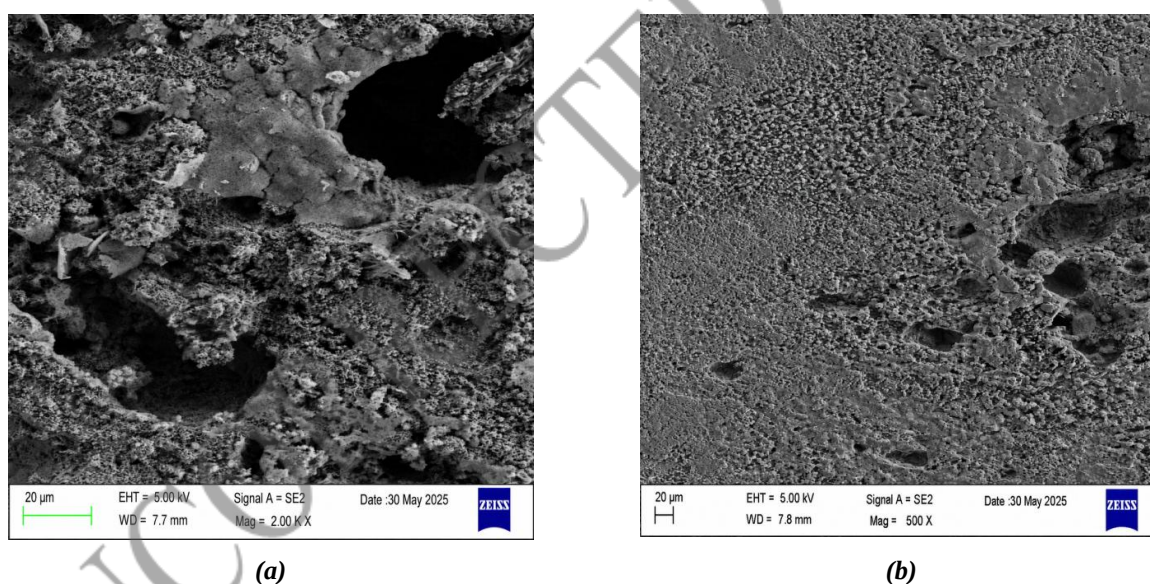


Figure 9. Surface scanning electron micrographs of mild steel in 0.5 M Sulphuric acid(a), and inhibited mild steel in 0.5M sulphuric acid with 70 ppm inhibitor(b)

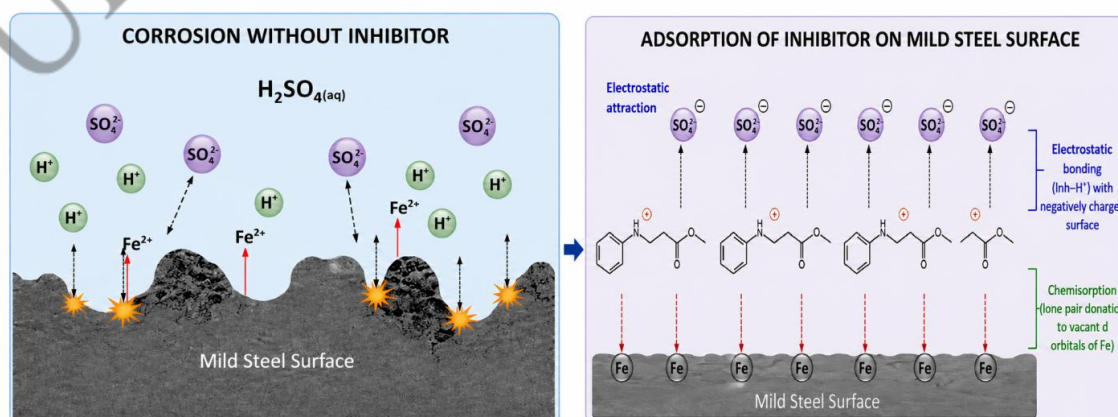


Figure 10. Schematic representation of adsorption mechanism of the inhibitor on mild steel surface.

It is commonly recognized that the majority of inhibitors are classified as adsorption type inhibitors, which prevent corrosion by being absorbed on the surface. This inhibitor most likely underwent protonation in an acidic solution, which promoted their adsorption over the negatively charged mild steel surface (electrostatic bonding) as shown in Figure 10. The imbalanced negative charge created by the adsorption of sulphate ions on mild steel surfaces encouraged the adsorption of inhibitor molecules at the majority of active sites, increasing inhibition efficacy. Additionally, the chemical structures of inhibitor include hetero atoms, fused benzene rings *etc.* that provided electrons for sharing with iron's unoccupied d orbit electrons (chemisorption). Based on the information presented above, it can be concluded that the adsorption of inhibitor molecules on the surface of mild steel plays a major role in corrosion inhibition. In this instance, mild steel was surrounded by a layer of adsorbed inhibitor molecules that gathered at the mild steel/acid interface. Langmuir model indicates that adsorption occurs through the replacement of water molecules by inhibitor molecules at active corrosion sites. The adsorption process may involve both physical and chemical interactions, depending on the functional groups present in the inhibitor and the metal surface charge [46-48]. Surface images of mild steel in sulphuric acid with inhibitor show this layer, which stopped further corrosion. The potentiodynamic polarization results indicate that the inhibitor effectively suppresses both anodic metal dissolution and cathodic hydrogen evolution reactions, demonstrating mixed-type inhibition behaviour. As the inhibitor concentration increases, the polarization resistance (R_p) increases significantly, indicating the formation of a more protective adsorbed layer on the mild steel surface. This protective film acts as a barrier that reduces the active surface area available for electrochemical reactions, thereby lowering the corrosion rate. The improved inhibition efficiency with increasing inhibitor concentration suggests enhanced surface coverage by inhibitor molecules. It is confirmed that corrosion inhibition is primarily achieved through the formation of a stable and compact adsorbed film that effectively isolates the mild steel surface from the aggressive sulphuric acid environment [49-51].

Conclusion

Mild steel corrosion in acid was found to be considerably retarded in the presence of the inhibitor molecule. Results obtained using various techniques were in good connection and showed a maximum inhibition efficiency of up to 96.5%. 3-anilinomethylpropionate was found to act as a mixed type inhibitor based on the polarization curves. Further impedance spectroscopy studies showed that as the inhibitor concentration increased, the

capacitance decreased while the charge transfer resistance increased. The molecular adsorption of the organic material on the mild steel surface was found to be responsible for the inhibitive action of 3-anilinomethylpropionate, which was further supported by surface images of mild steel in acid solution containing the inhibitor.

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