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Research Article

# Comparative Studies of Corrosion Inhibition on Mild Steel by Using N-Methylaniline in 1n Sulphuric Acid Medium at Various Hours and Temperatures

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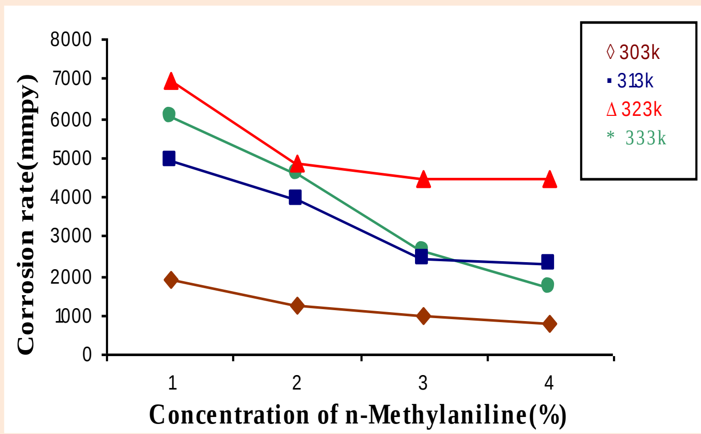
**Abstract**

The corrosion inhibition of mild steel has been studied by using an inhibitor as N-Methylaniline in 1N $H_2SO_4$ acid solution. Corrosion inhibition of mild steel has been investigated by using weight loss method, Potentiostatic polarization and electrochemical impedance spectroscopy techniques. The corrosion rate and inhibition efficiency were evaluated. The obtained result shows that the inhibition efficiency increased with increase in inhibitor concentration. The polarization studies show that these compounds act as mixed type inhibitors. The results of electrochemical impedance for mild steel on n-Methylaniline have shown that the change in the impedance parameters, charge transfer resistance and double layer capacitance.

**Keywords:** N-Methylaniline, weight loss method, polarization, impedence studies

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## Introduction

Corrosion is a major problem with materials. It cannot be fully controlled but its effect can be minimized with the help of suitable corrosion control techniques [1]. Mild steel finds wide application in a broad field of industry and machinery [2]. It undergoes considerable dissolution when they are exposed to acid solutions or aggressive environment [3]. It is very prone to corrosion particularly in acidic medium [4]. Acid solutions are used for the removal of undesirable scale &rust in many industrial processes [5]. The most important areas of application are acid pickling, oil well acidizing, acid cleaning and acid descaling, etc [6]. One of the most useful and practical methods that is used to control and protect metals against corrosion is the use of inhibitors, especially in acidic media [7]. An inhibitor is a chemical substance which when added in small concentration to an environment effectively checks, decrease or prevent the reaction of the metal with the environment [8-9]. The use of inhibitors is one of the most practical methods to prevent the corrosion or to reduce the corrosion rate [10]. Most of well-known acid corrosion inhibitors are organic compounds containing nitrogen, sulphur or oxygen atoms and heterocyclic compounds containing functional groups and conjugated double bonds, and multiple bonds in the molecule [11-21].

In this study N-Methylaniline has been used as an inhibitor in mild steel corrosion. By using this above inhibitor the present study analyse the corrosion rate and inhibition efficiency are calculated. The polarization and impedence spectroscopy method were also studied.

## Experimental work
### *Mild steel*

All the test specimens of mild steel were cut to an over all apparent size of 5×1cm. The specimens were mechanically polished by using different grades of Sic (grades 120-400-600) emery papers, degreased with acetone, dried and then stored in desicator before use.

### *Inhibitor*

The inhibitor used in this study is aniline derivative of N-Methylaniline. It is a one of the organic compound with the chemical formula $C_6H_5NH(CH_3)$.The substance is exists as a colourless or slightly yellow viscous liquid and turns brown when exposed to air. The molecular weight of N-Methylaniline is 107.15.The structure of the inhibitor is shown below.

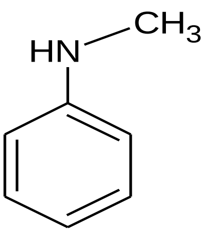


**Figure 1** N-Methylaniline

### *Weight loss method*

Pure mild steel specimens cut to get length of 5 cm and widths of 1 cm were used for this study. The Mild Steel was weighed and tied with threads and suspended in 100 ml HCl solution, with and without inhibitor. The concentration of inhibitor used in this study is 1ml, 2ml, 3mland 4ml.The weight loss measurement is carried out with different temperatures (303k, 313k, 323k and 333k) and different hours (3hours, 4hours and 5hours). By using this method corrosion rate and inhibition efficiency can be calculated.

### *Polarization method*

The polarization studies were carried out for mild steel strips having an exposed area of 1 $cm^2$. The specimens were mechanically polished using different grades of emery paper and washed thoroughly with distilled water and degreased with acetone. Polarization experiments were performed using different concentration of inhibitor in different corrosive medium. A conventional three-electrode compartment consisting of steel specimen, saturated calomel and platinum as the working, reference and counter electrodes respectively were selected. The anodic and cathodic polarization curves were recorded at a constant scan rate. Inhibition efficiencies were determined from corrosion currents calculated by the Tafel extrapolation method.

### *Electrochemical Impedance Spectroscopy*

The EIS measurements were made at corrosion potentials over a frequency range of 10 KHz to 0.01 Hz with signal amplitude of 10 mV. The impedence of the corroding system for various frequencies can be measured using lock-in-amplifies or by using more sophisticated modern digital techniques like frequency response analysis From the Nyquist plot ($Z_{real}$ vs $Z_{imaginary}$), electrochemical resistance $R_{ct}$ and double layer capacitance $C_{dl}$ were obtained.

## Result and discussion
### *Weight loss measurement*

From the weight loss measurement the corrosion rate decreases with increase in concentration. The inhibition efficiency increases with increase in concentration. The inhibitor can adsorb on the mild steel surface and block the active sites on the surface, thereby reducing the corrosion rate in the medium. The highest inhibition efficiency (83.09%) was attained at 323k for 4% N-Methylaniline for three hours, (82.43%) at 313k for 4% N-Methylaniline for four hours, (91.98%) at 323k for 4% n-Methylaniline for five hours. It is evident from the graph obtained by plotting percentage of n-Methylaniline against the rate of corrosion and inhibition efficiency.

**Table 1** Performance of N-Methylaniline on mild steel in 1N $H_2SO_4$ at various temperatures for three hours

| Concentration of inhibitor (%) | Temperature (k) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 303k | | 313k | | 323k | | 333k | |
| | CR (mmpy) | IE (%) | CR (mmpy) | IE (%) | CR (mmpy) | IE (%) | CR (mmpy) | IE (%) |
| Bank | 3341.3 | — | 6248.8 | — | 6379 | — | 9799.5 | — |
| 1ml | 1465 | 56.15 | 3971.2 | 36.44 | 4016.2 | 37.04 | 8939.3 | 8.77 |
| 2ml | 1032.8 | 69.08 | 2285.9 | 63.41 | 2403.5 | 62.32 | **7904.8** | 19.33 |
| 3ml | 744.18 | 77.72 | 1818.7 | 70.89 | 1651.8 | 74.1 | 6031.1 | 38.45 |
| 4ml | 624.8 | 81.39 | 1318.1 | 78.89 | 1078.7 | 83.09 | 4017.1 | 59 |

Where CR=corrosion rate, IE=inhibition efficiency

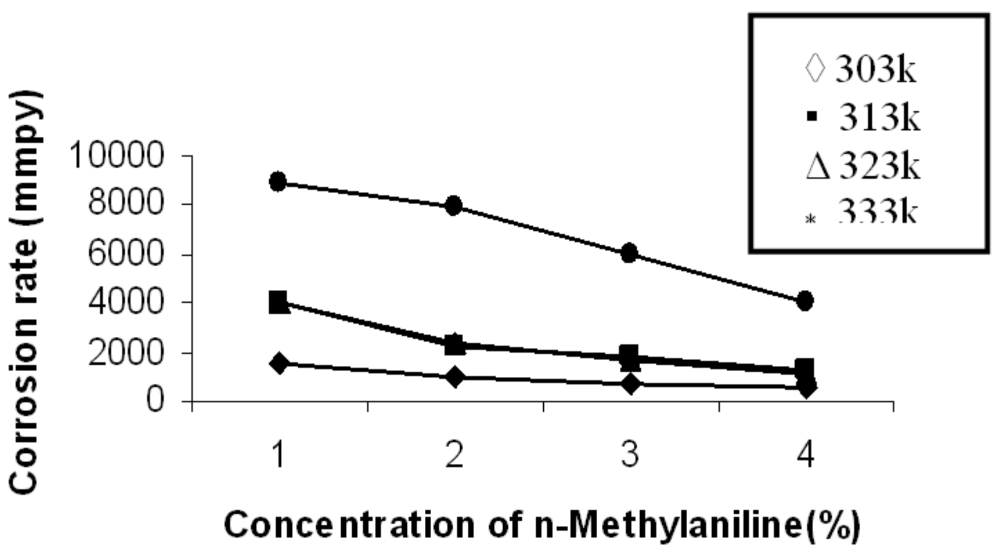


**Figure 2** The rate of corrosion for N-Methylaniline (1, 2, 3 & 4 ml) on mild steel in 1N $H_2SO_4$

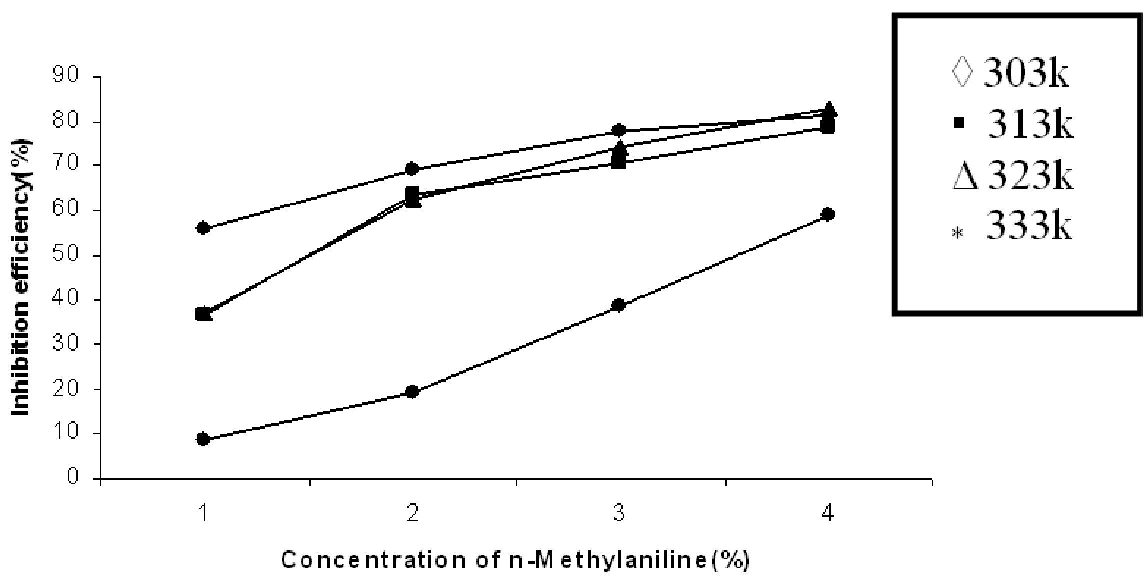


**Figure 3** The inhibition efficiency for N-Methylaniline (1, 2, 3 & 4ml) on mild steel in 1N $H_2SO_4$

**Table 2** Performance of N-Methylaniline on mild steel in 1N $H_2SO_4$ at various temperatures for four hours

| Concentration of inhibitor (%) | Temperature (k) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 303k | | 313k | | 323k | | 333k | |
| | CR (mmpy) | IE (%) | CR (mmpy) | IE (%) | CR (mmpy) | IE (%) | CR (mmpy) | IE (%) |
| Bank | 3463.3 | — | 9617.2 | — | 9472.1 | — | 5891.7 | — |
| 1ml | 1874.6 | 45.87 | 6000.6 | 37.54 | 6967.3 | 26.44 | 4946.8 | 16.03 |
| 2ml | 1248.3 | 63.94 | 4592.7 | 52.24 | 4834.8 | 48.95 | 3966.7 | 32.77 |
| 3ml | 964.2 | 72.15 | 2609.2 | 72.86 | 4437.5 | 53.15 | 2290.1 | 61.13 |
| 4ml | 787.7 | 77.25 | 1689.4 | 82.43 | 4436.9 | 53.16 | 2235.1 | 62.06 |

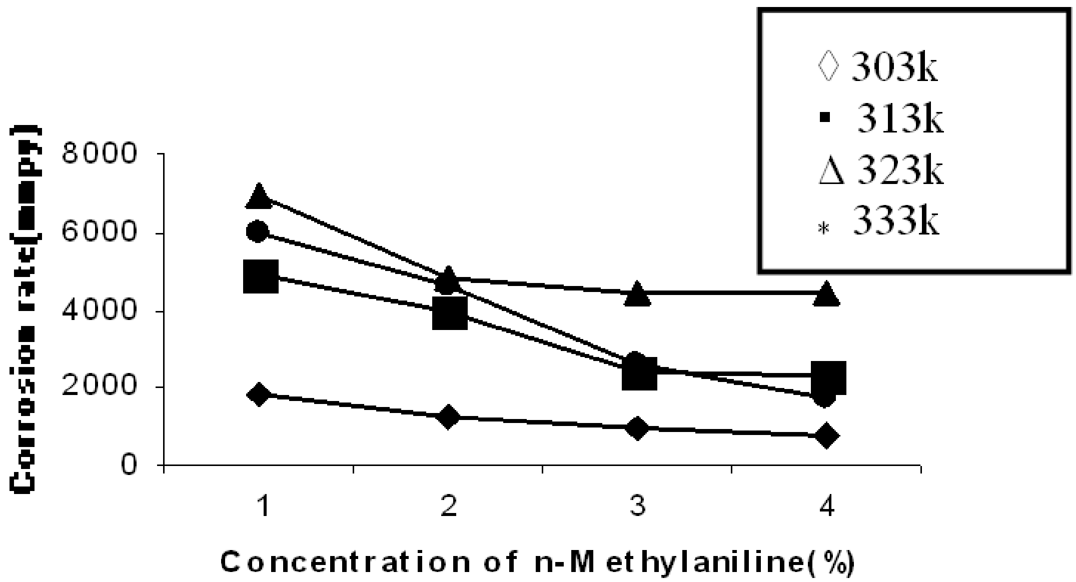


**Figure 4** The rate of corrosion for N-Methylaniline (1, 2, 3 & 4 ml) on mild steel in 1N $H_2SO_4$

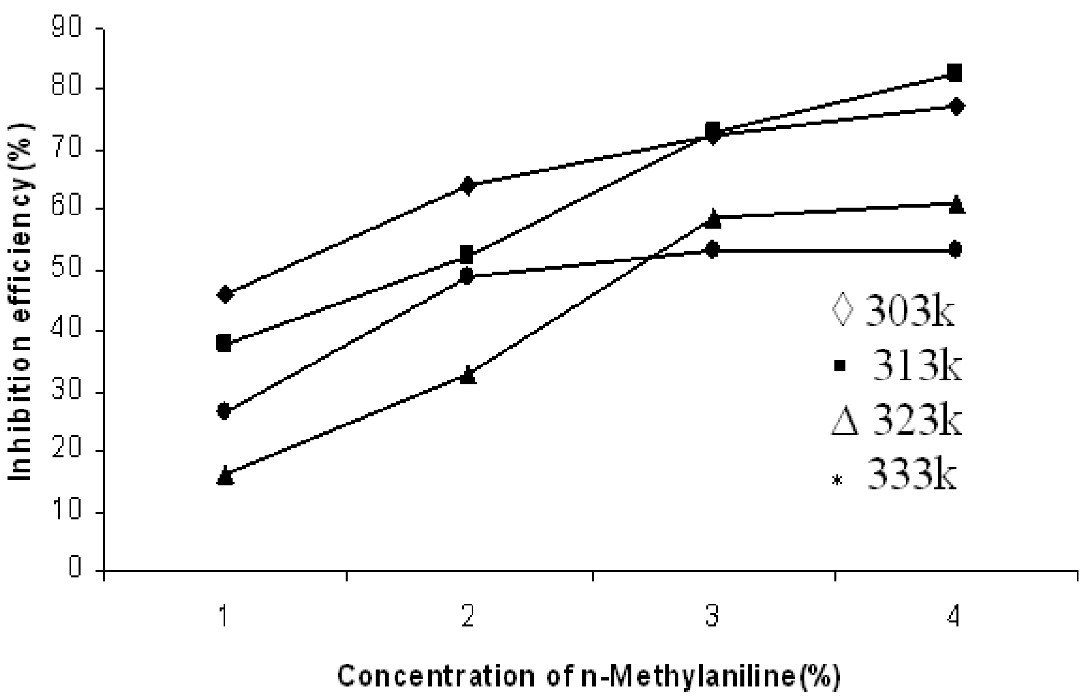


**Figure 5** The inhibition efficiency for N-Methylaniline (1, 2, 3 & 4 ml) on mild steel in 1N $H_2SO_4$

**Table 3** Performance of N-Methylaniline on mild steel in 1N $H_2SO_4$at various temperatures for five hours

| Concentration of inhibitor (%) | Temperature (k) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 303k | | 313k | | 323k | | 333k | |
| | CR (mmpy) | IE (%) | CR (mmpy) | IE (%) | CR (mmpy) | IE (%) | CR (mmpy) | IE (%) |
| Bank | 2994.4 | — | 5781.6 | — | 5148.3 | — | 12568.8 | — |
| 1ml | 1644.8 | 45.07 | 3549.1 | 38.61 | 3241.7 | 37.03 | 8281.9 | 34.1 |
| 2ml | 1197.8 | 59.99 | 2287.6 | 60.43 | 1615.8 | 68.61 | 7183.7 | 42.84 |
| 3ml | 707.3 | 76.37 | 1656.8 | 71.34 | 872.4 | 83.05 | 5569.8 | 55.68 |
| 4ml | 705.3 | 76.44 | 1496.7 | 74.11 | 412.4 | 91.98 | 4456.5 | 64.54 |

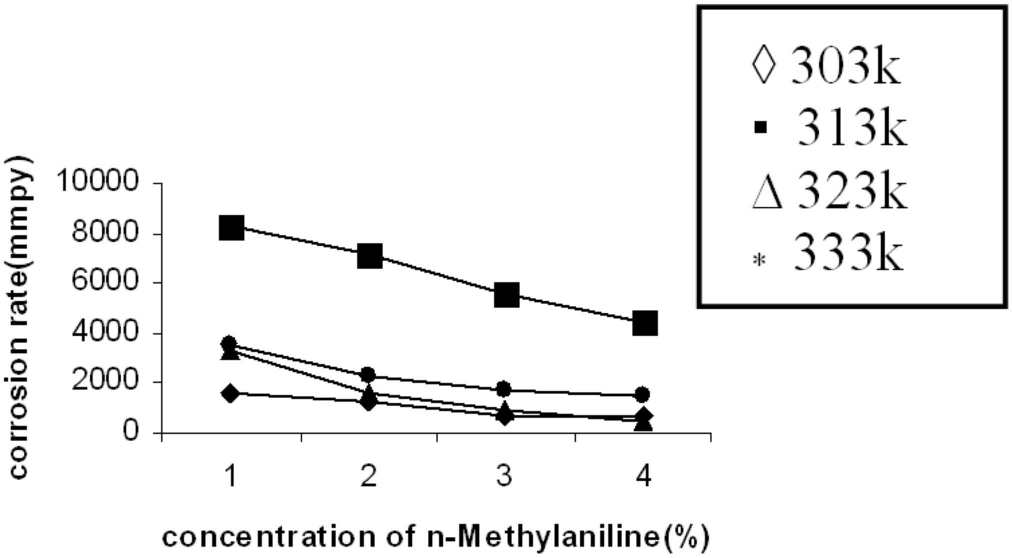


**Figure 6** The rate of corrosion for N-Methylaniline (1, 2, 3 & 4 ml) on mild steel in 1N $H_2SO_4$

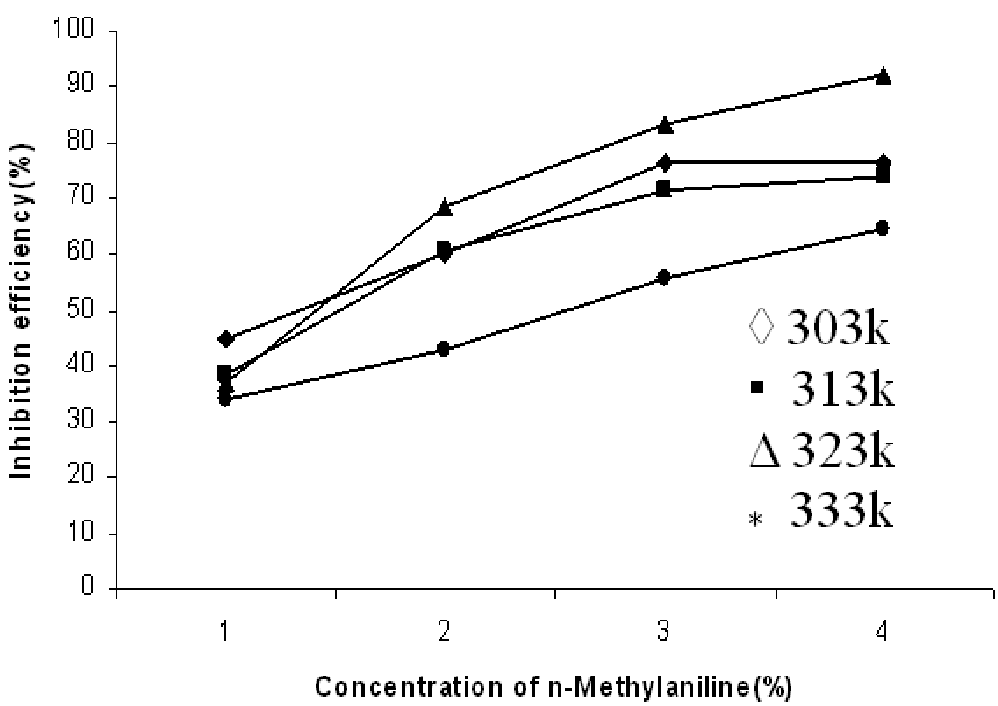


**Figure 7** The inhibition efficiency for N-Methylaniline (1, 2, 3 & 4 ml) on mild steel in 1N $H_2SO_4$

***Polarization Measurement***

Polarization behaviour of mild steel functioning as cathode as well as anode in the test solution of 1N sulphuric acid with n- Methylaniline and the electrochemical data obtained from the studies were shown in table. n- Methylaniline serves as a protective layer on mild steel surface and reduces the corrosion rate. Both cathodic and anodic reactions are take place and it acts as mixed type inhibitor, when the surface is protected with n- Methylaniline in 1N sulphuric acid solution [22]. Both cathodic and anodic inhibition through the presence of blocking active sites on the mild steel surface [23]. The decrease in $I_{corr}$ and increase in inhibition efficiency confirm the uniform and better protective film formation over mild steel surface. Increase in the concentration of n- Methylaniline increases $I_{corr}$ however the corrosion rate is decreases. The inhibition efficiencies were determined from the values of corrosion current density and the values were found to be same trend with those obtained from weight loss method

**Table 4** Potentiostatic polarization data for 1N sulphuric acid with n- Methyl aniline

| S. No | Conc. Of inhibitor (ml) | OCP (mv) | $E_{corr}$ vs SCE(mv) | $i_{corr}$ A/ cm$^2$ | $R_P$ (Ω) | Corrosion rate (mm/y) | Inhibition efficiency (%) |
|---|---|---|---|---|---|---|---|
| 1 | Blank | -0.505 | -0.5009 | 0.000429 | 54.43 | 1.405 | 0 |
| 2 | 1 | -0.507 | -0.5072 | 0.000277 | 80.51 | 0.9061 | 35.43 |
| 3 | 2 | -0.504 | -0.496 | 0.000236 | 80.57 | 0.7734 | 44.98 |
| 4 | 3 | -0.495 | -0.491 | 0.000224 | 90.2 | 0.7322 | 47.78 |

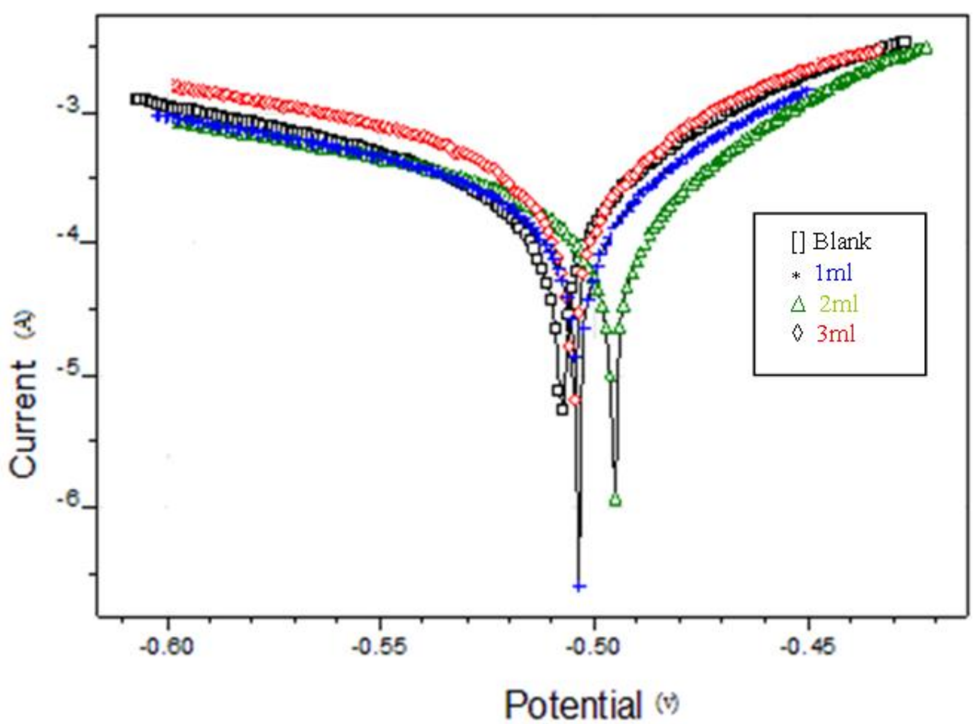


**Figure 8** Tafel polarization curve for mild steel in the presence of N-Methylaniline (1, 2, 3 & 4 ml)

***EIS Measurement***

In order to obtain information on the electrochemical processes at the substrate interface in the absence and presence of n- Methylaniline, electrochemical impedance spectroscopy (EIS) has been carried out. EIS has been used to study the formation and characteristics of barrier coatings. The metal surface active centres are blocked by coating which decreases $C_{dl}$ value and increases the $R_{ct}$ value. The increase of $R_{ct}$ could be related to the formation of a more compact film and also the more dense the film packs, the larger the diameter of the semicircle. . Therefore there is higher resistance to corrosion which results in higher $R_{ct}$ value and lower $C_{dl}$ value. Results obtained from the impedance spectroscopy showed that $R_{ct}$ value increases and $C_{dl}$ value decreases. This decreases the extent of dissolution reaction. The decrease in $C_{dl}$ value is due to increase in the thickness of double layer on the substrate surface. The increase in $R_{ct}$ is due to the formation of protective film on the substrate/solution interface [24].

**Table 5** Impedence studies on mild steel in sulphuric acid

| Concentration Of inhibitor(ml) | $R_{ct}$ (Ohm) | $C_{dl}$ (F) | IE% |
|---|---|---|---|
| Blank | 42.8 | $1.691 \times 10^{-4}$ | 0 |
| 1ml | 75.6 | $5.542 \times 10^{-5}$ | 43.38 |
| 2ml | 79.7 | $6.659 \times 10^{-5}$ | 46.29 |
| 3ml | 81.4 | $7.824 \times 10^{-5}$ | 47.42 |

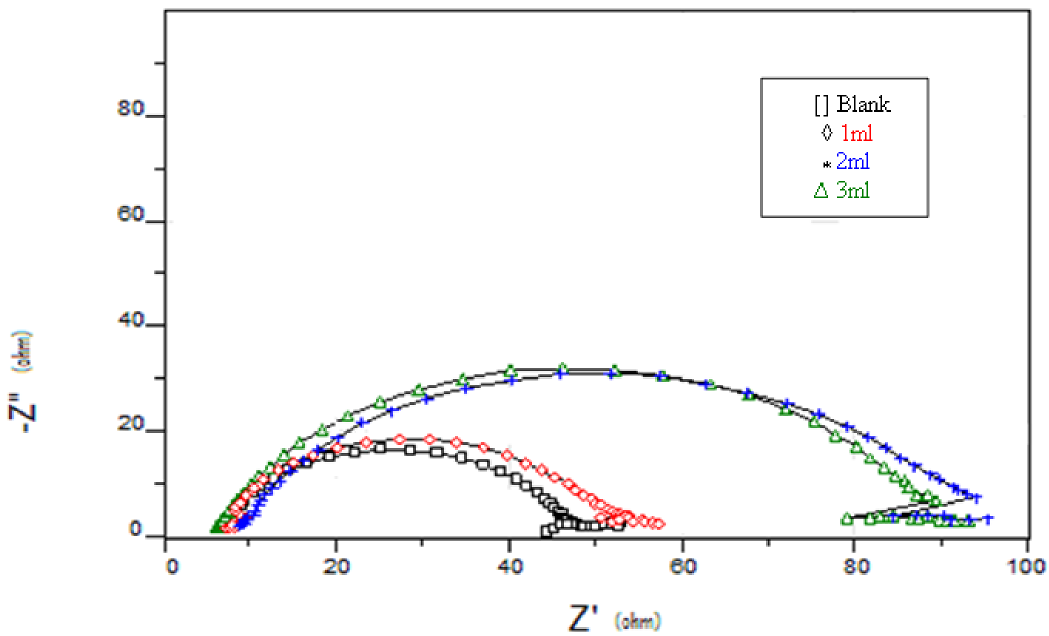


**Figure 9** Nyquist plot for N-Methylaniline on mild steel in 1N $H_2SO_4$

## Conclusion

Corrosion rates of mild steel in sulphuric acid decreased with increase in concentration of n-Methylaniline. From the comparative studies, the corrosion rate (412.47) of mild steel in 1N sulphuric acid for five hours shows better results at 323k for 4% of N-Methylaniline than that of three hours and four hours. The inhibition efficiency increased with respect to the concentration of n-Methylaniline at all temperature compared to blank. From the comparative studies, five hours shows better inhibition efficiency (91.98%) at 323k than three hours and four hours inhibition efficiency. From the polarisation studies, it could be concluded that the inhibitor is a mixed type inhibitor. The impedence spectroscopy was conducted; the results should be confirmed that the double layer is formed on metal surface.

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