



## ICNSCET20- International Conference on New Scientific Creations in Engineering and Technology

### “Corrosion inhibition performance of mild steel in 0.1 M HCl solution”

Dr.S.Devimeenakshi, Ms. M.Priyadharshini

*Department of Chemistry, Nadar Saraswathi College of Arts and Science, Theni*

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#### Abstract:

Corrosion inhibition of mild steel in 0.1 M HCl solution was investigated in the absence and presence of different concentrations of inhibitors. Weight loss measurements and electrochemical studies were used analysed. The results obtained shows that the inhibition was found to increase with increasing concentration of the inhibitor. Weight loss method shows the inhibition efficiency of 87.2% for 0.1MHCl+AA system and 85% for 0.1MHCl+AA+SPT system. Polarization curves revealed that inhibitor acts as cathodic type inhibitor.

Key words: Mild steel, HCl, amino acid, Tryptophan Sodium Potassium tartrate

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#### 1. Introduction:

Corrosion is a natural and costly process of destruction like earthquakes, tornados, floods and volcanic eruptions, with one major difference. Whereas we can be only a silent spectator to the above processes of destruction, corrosion can be prevented or at least controlled. Corrosion is the surface wastage that occurs when metals are exposed to reactive environments. Corrosion is the result of interaction between a metal and environments which results in its gradual destruction [1]. Mild steel is the commonly used alloy in the industries due to its remarkable features such as low cost, easy availability, high strength, durability etc. It is largely used in designing of various reaction vessels, tanks, for handling of various corrosive liquids, various aggressive solutions like acidic solutions, basic solutions, salt solutions etc [2]. Acid solutions are generally used for descaling, acid cleaning, acid pickling,

and in various petrochemical processes. Hydrochloric acid, acetic acid and sulphuric acids are widely used in the pickling process [3]. These acids are also largely used for drilling fracturing and acid simulations at various stages in oil exploration, production and descaling operations and with many industrial applications [4]. Acidic environment corrode mild steel easily. Corrosion is a natural and electrochemical phenomenon caused by potential difference between metal and acid [5]. H<sup>+</sup> ions and dissolved oxygen are named natural motors of corrosion [6] Corrosion results large economic loss of any country across a year. Corrosion is a continuous process and cannot be stopped completely [7]. Therefore application of corrosion inhibitors in industries and in different other fields, is the most effective method to protect the metal from corrosion [8]. Corrosion inhibitors are compounds those cause lowering in the corrosion rates of a metal, when added in suitable amounts without significantly changing the concentration of other agents [9]. Tryptophan (symbol Trp or W) is a  $\alpha$ -amino acid that is used in the biosynthesis of proteins. Tryptophan contains a  $\alpha$ -amino group, a  $\alpha$ -carboxylic acid group, and a side chain indole, making it a non-polar aromatic amino acid [10]. Sodium Potassium tartrate is also known as “Rochelle salt” is a double salt of tartaric acid. Sodium Potassium tartrate and Mono Potassium phosphate were the first materials discovered to exhibit “piezoelectricity” [11].

## 2. Materials and methods:

The Mild steel specimens were chosen from the same sheet of the following composition: Carbon - 0.1 %, Sulphur – 0.026 %, Phosphorus - 0.06 %, Manganese - 0.4 % and the balance iron. Mild steel specimen of the dimension 3x2x0.2cm were polished to mirror finish, degreased with acetone and used for mass – loss and surface examination studies.

### 2.1 Weight loss method:

The weight loss method is the simplest and most widely used method for evaluating corrosion rates and corrosion damage of the component materials. The percentage inhibition and corrosion rate can be calculated as follows

$$IE(\%) = \frac{W_0 - W_1}{W_0} \times 100$$

Where,

W<sub>0</sub> = weight loss without the inhibition.

W<sub>1</sub> = weight loss in the presence of inhibitor.

$$\text{Corrosion rate (MPY)} = 534W/DAT$$

Where,

W is the loss in grams.

A is the area of the specimen in square.

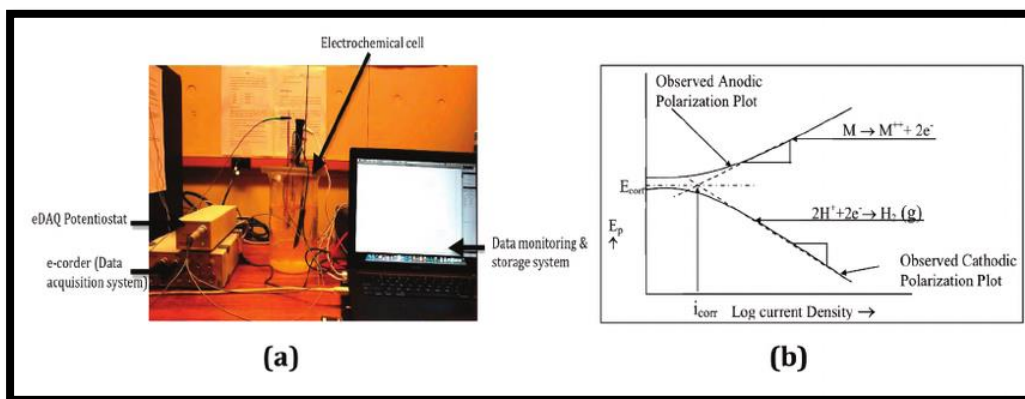
D is the density of the specimens in gram/cm<sup>3</sup> in hours.

The corrosion rate can be expressed either in mills per year(MPY) (or) milligram per square decimeter per day .[8]

## 2.2 Electrochemical studies:

### 2.2.1 Potentiodynamic polarization study:

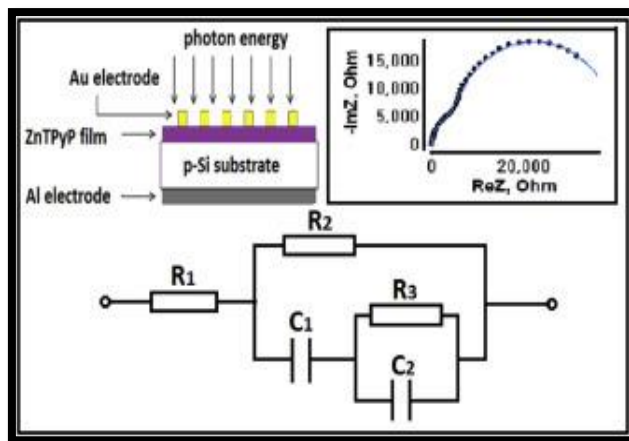
Polarization study was carried out in Electrochemical Impedance analyzer model CHI 660A three electrode cell assembly was used. The working electrode was used as a rectangular specimen of mild steel with one face of the electrode of constant 1 cm<sup>2</sup> area exposed. A saturated calomel electrode (SCE) was used as the reference electrode and a rectangular platinum foil was used as the counter electrode. Polarization curves were recorded after doing ire compensation. The corrosion parameters such as corrosion potential ( $E_{corr}$ ), corrosion current ( $i_{corr}$ ) and Tafel slopes (anodic =  $b_a$  and cathodic =  $b_c$ ) and Linear polarization resistance (LPR) were calculated. During the polarization study, the scan rate (V/s) was 0.005; Hold time at Eve (s) was zero and quite time (s) was 2.



**Fig1. Three electrode cell assembly**

### 2.2.2 AC impedance measurements:

AC impedance studies were carried out in electrochemical impedance work station analyzer model CHI 660A three electrode cell assembly was used.



**Fig2. AC impedance method**

The working electrode was used as a rectangular specimen of mild steel with one face of the electrode of constant 1 cm<sup>2</sup> area exposed. A saturated calomel electrode (SCE) was used as the reference electrode and a rectangular platinum foil was used as the counter electrode. AC impedance spectra were recorded after doing ire compensation. The real part ( $Z'$ ) and imaginary part ( $Z''$ ) of the cell impedance were measured in ohms at various frequencies. The corrosion parameters such as charge transfer resistance ( $R_t$ ) and the double layer capacitance ( $C_{dl}$ ) were calculated. During AC impedance spectra were recorded the scan rate (V/s) was 0.005; Hold time at Eve(s) was zero and quite time (s) was 2.  $C_{dl}$  values were calculated using the following relationship.

$$C_{dl} = \frac{1}{2 \times 3.14 \times R_t \times \omega_{max}}$$

### 3. Result and discussion:

#### 3.1 Weight loss study:

The corrosion rates and the inhibition efficiencies (IE) of L-tryptophan and Sodium Potassium tartrate in controlling corrosion of mild steel immersed in 0.1M HCl for a period of one day in the absence of and presence of them is given in Table 1. The corrosion rates of the L-tryptophan and Sodium Potassium tartrate systems at various concentrations are shown in Fig1.

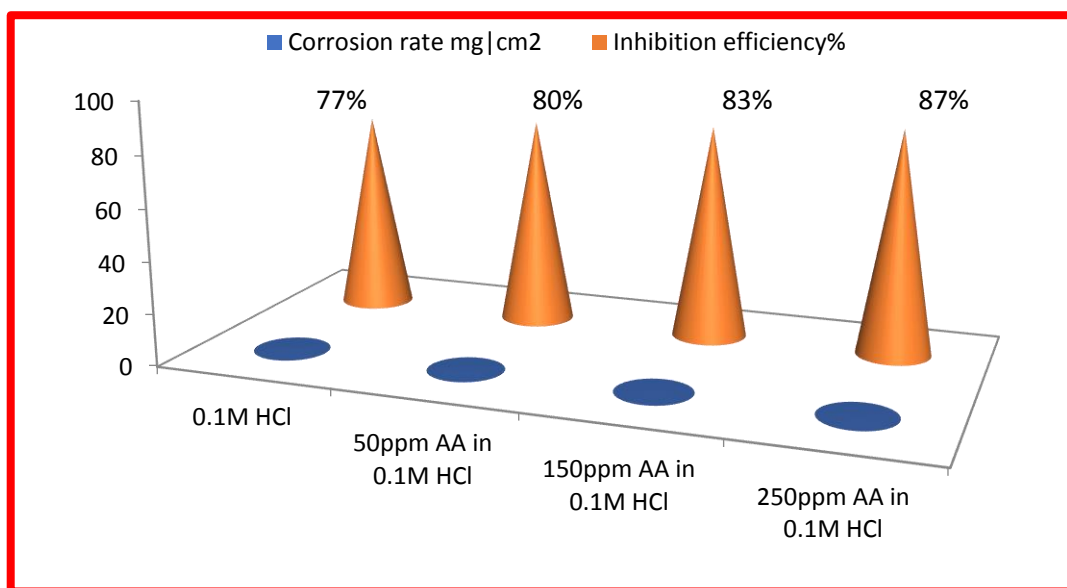
It is observed from Table1 that L-tryptophan shows some inhibition efficiency. 50ppm AA has 80.56%IE. As the concentration of AA increases, the IE increases, and corrosion rate decreases. 50ppm of AA has 80.56% IE, 150ppm of AA has 83.21% IE and 250ppm of AA has 87.23%. That is addition of AA and 0.1M HCl increases the corrosion protection of mild steel immersed in the solution. That is, the system passes from active to

passive region. The co-inhibitor SPT is added in different concentrations. 50ppm of SPT has 80.99%, 150ppm of SPT has 83.21% and 250ppm of SPT has 85.43%. That is addition of SPT and 0.1M HCl increases the corrosion protection of mild steel immersed in the solution. That is, the system passes from active to passive region.

**Table1. Inhibition efficiencies (IE%) and corrosion rates (CR) obtained from AA- in controlling corrosion of mild steel immersed in 0.1M HCl**

Inhibitor system: AA-Immersion period: 1 day

Electrolytic solution	Corrosion rate mg cm <sup>2</sup>	Inhibition efficiency %
0.1M HCl	0.2250	77.58
50ppm AA in 0.1M HCl	0.2115	80.56
150ppm AA in 0.1M HCl	0.1341	83.21
250ppm AA in 0.1M HCl	0.1211	87.23



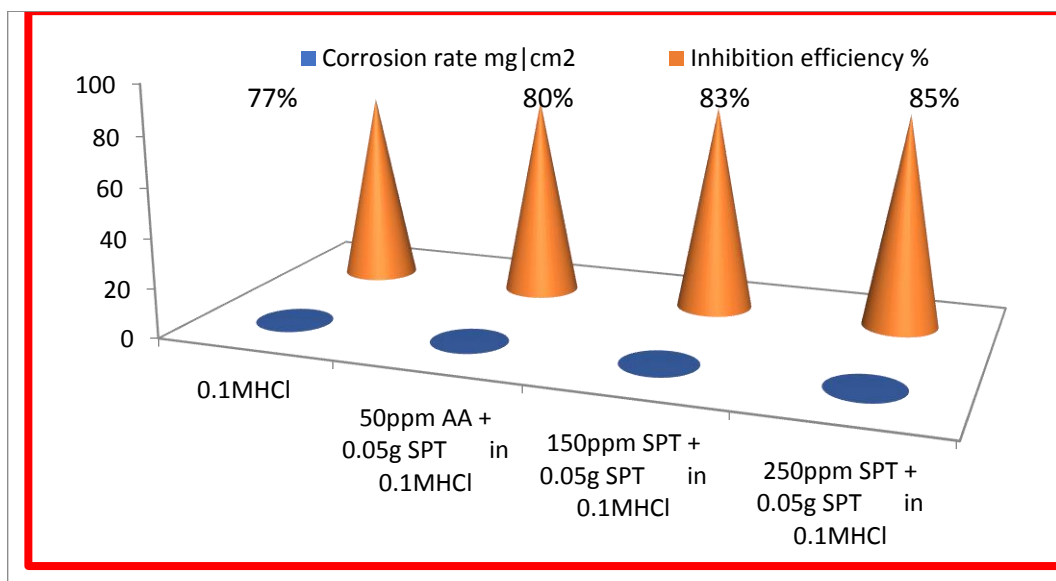
**Fig 3. Corrosion rate (CR) (IE) of AA system in controlling corrosion of mild steel immersed in 0.1M HCl.**

**Table2. Inhibition efficiencies (IE%) and corrosion rates (CR) obtained from AA with 0.05g of SPT in controlling corrosion of mild steel immersed in 0.1M HCl**

Inhibitor system: AA-Immersion period: 1 day

Electrolytic solution	Corrosion rate mg cm <sup>2</sup>	Inhibition efficiency %
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0.1MHCl	0.2250	77.58
50ppm AA + 0.05g SPT in 0.1MHCl	0.1901	80.99
150ppm SPT+ 0.05g SPT in 0.1MHCl	0.1797	83.21
250ppm SPT+ 0.05g SPT in 0.1MHCl	0.1559	85.43



**Fig 4. Corrosion rate (CR) (IE) of SPT system in controlling corrosion of mild steel immersed in 0.1M HCl.**

### 3.2. Electrochemical study:

#### 3.2.1. Analysis of potentiodynamic polarization study:

Electrochemical study such as Polarization study has been used to confirm the formation of protective film on the metal surface during corrosion inhibition process. If a protective film is formed on the metal surface, the linear polarization resistance values (LPR) increases and the corrosion current value ( $I_{corr}$ ) decreases.

The potentiodynamic polarization curves of mild steel immersed in 0.1M HCl in the absence and presence of inhibitor are shown in Fig2.1. The corrosion parameters namely, corrosion potential ( $E_{corr}$ ), Tafel slopes (anodic slope  $b_a$  and cathodic slope  $b_c$ ) Linear polarization resistances (LPR) and corrosion current ( $I_{corr}$ ) values are given in the Table2.1. When mild steel is immersed in 0.1M HCl the corrosion potential was -0.5190 mVvs SCE

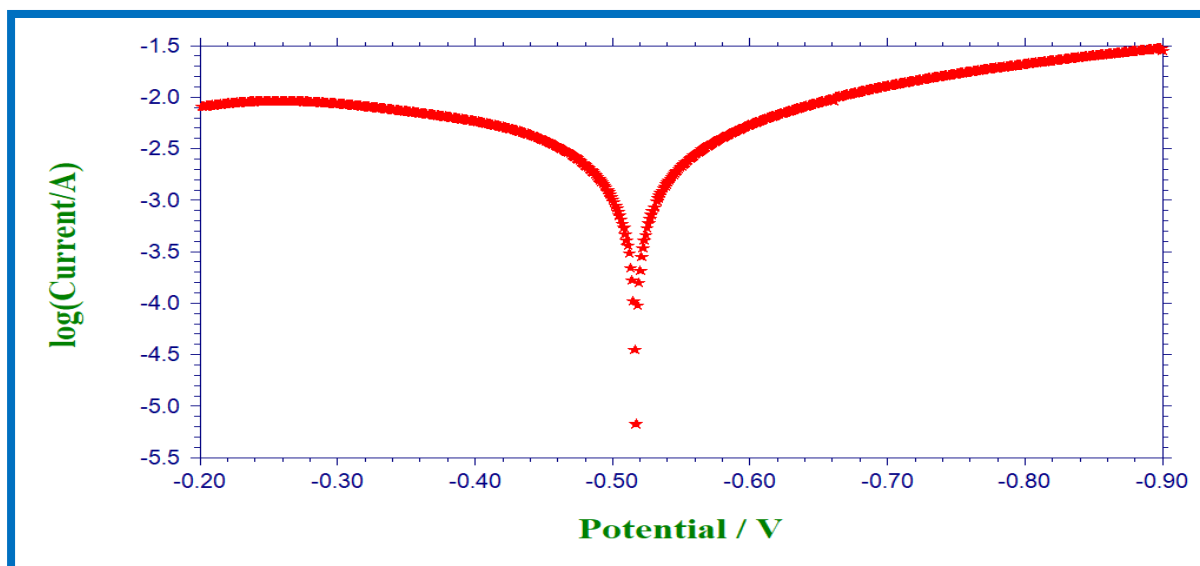
(saturated calomel electrode). When AA (50ppm) was added to the above system the corrosion potential shifted to the anodic side -0.5190mVvs SCE; When AA (150ppm) was added to the above system the corrosion potential shifted to the anodic side -0.2276 mVvs SCE; When AA (250ppm) was added to the above system the corrosion potential shifted to the anodic side -0.2344 mVvs SCE that is noble side. This indicates that the AA system controls anodic reaction predominantly. This indicates that the passive film is formed on the metal surface in presence of inhibitor. Further, the LPR value increases from 15.9 ohmcm<sup>2</sup> to 10829.4, 9925.6, 8839.6 ohmcm<sup>2</sup> the corrosion current decreases from 0.03232x10<sup>-6</sup> A/cm<sup>2</sup> to 0.03976x10<sup>-6</sup>, 0.04342x10<sup>-6</sup>, 0.04970x10<sup>-6</sup> A/cm<sup>2</sup>. When a passive film is formed on mild steel surface, in presence of inhibitor system, the electron transfer from the metal surface towards the bulk of the solution is difficult and prevented. So rate of corrosion decreases and hence corrosion current decreases in presence of inhibitor system.

**Table 3: Corrosion parameters of mild steel immersed in 0.1M HCl the absence and presence of inhibitor system obtained from Potentiodynamic Polarization Study**

System	E <sub>corr</sub> mV vs SCE	b <sub>c</sub> mV/ decade	b <sub>a</sub> mV/ decade	LPR ohmcm <sup>2</sup>	I <sub>corr</sub> Acm <sup>-2</sup>
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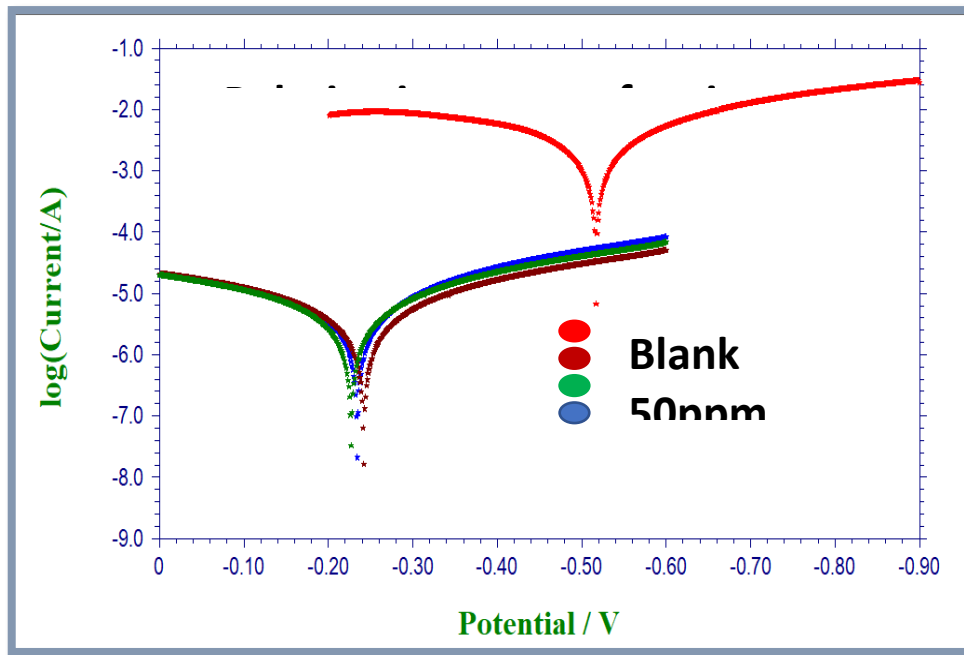
System	$E_{corr}$ mV vs SCE	$b_c$ mV/ decade	$b_a$ mV/ decade	LPR ohmcm <sup>2</sup>	$I_{corr}$ Acm <sup>-2</sup>
in 0.1M HCl	-0.5271	6.204	4.155	5550.1	0.01255x10 <sup>-6</sup>
0.1M HCl 150ppm AA+SPT	-0.5190	4.733	3.730	15.9	0.03232x10 <sup>-6</sup>
50ppm AA in 0.1M HCl	-0.3373	6.288	3.385	2593.9	0.01733x10 <sup>-6</sup>
in 0.1M HCl 250ppm AA+SPT	-0.2433	5.332	4.764	10829.4	0.03976x10 <sup>-6</sup>
150ppm AA in 0.1M HCl in 0.1M HCl	-0.3684 -0.2276	5.561 5.596	3.670 4.492	2420.8 9925.6	0.01946x10 <sup>-6</sup> 0.04342x10 <sup>-6</sup>
250ppm AA in 0.1M HCl	-0.2344	5.882	4.015	8839.6	0.04970x10 <sup>-6</sup>

**Table 4: Corrosion parameters of mild steel immersed in 0.1M HCl the absence and presence of inhibitor system with 0.05g SPT obtained from Potentiodynamic Polarization Study**

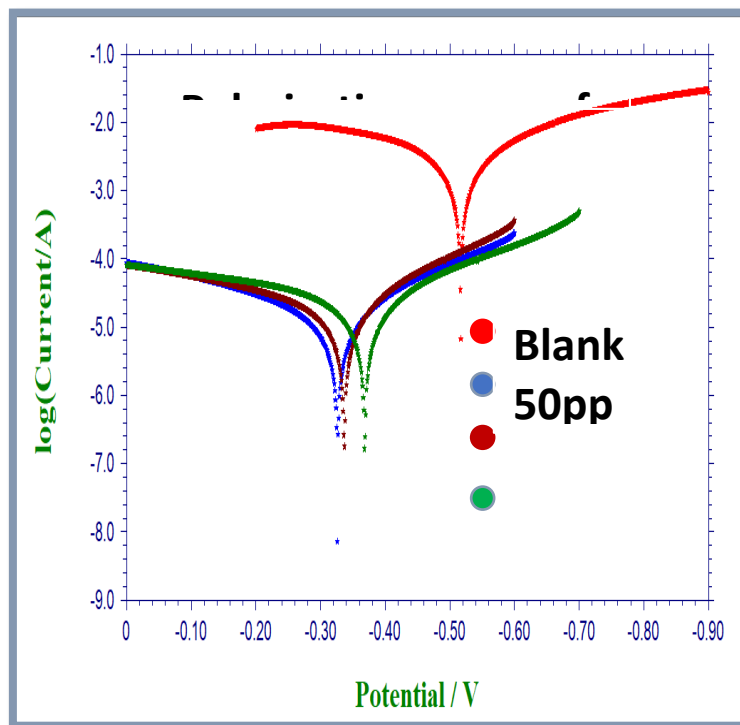


**Fig.5 Polarization curves of mild steel immersed in 0.1M HCl solution**





**Fig.6 Polarization curves of mild steel immersed in 0.1M HCl solution with various concentrations of AA**



**Fig.7 Polarization curves of mild steel immersed in 0.1M HCl solution with various concentrations of AA + 0.05g SPT**

### 3.2.2. Analysis of AC impedance spectra:

AC impedance spectra (electro chemical impedance spectra) have been used to confirm the formation of protective film formed on the metal surface. If a protective film on the metal surface, the charge transfer resistance ( $R_t$ ) increases, double layer capacitance value ( $C_{dl}$ ) decreases and the impedance log ( $z/\text{ohm}$ ) value increases. The AC impedance spectra of mild steel immersed in 0.1M HCl in the absence and presence of inhibitor are shown in Fig 2.2.(Nyquist plot) and Fig 2.2.(Bode plot).The AC impedance parameters such as charge transfer resistance( $R_t$ ),double layer capacitance( $C_{dl}$ ) and impedance value log( $z/\text{ohm}$ ) are given in table 2.2.

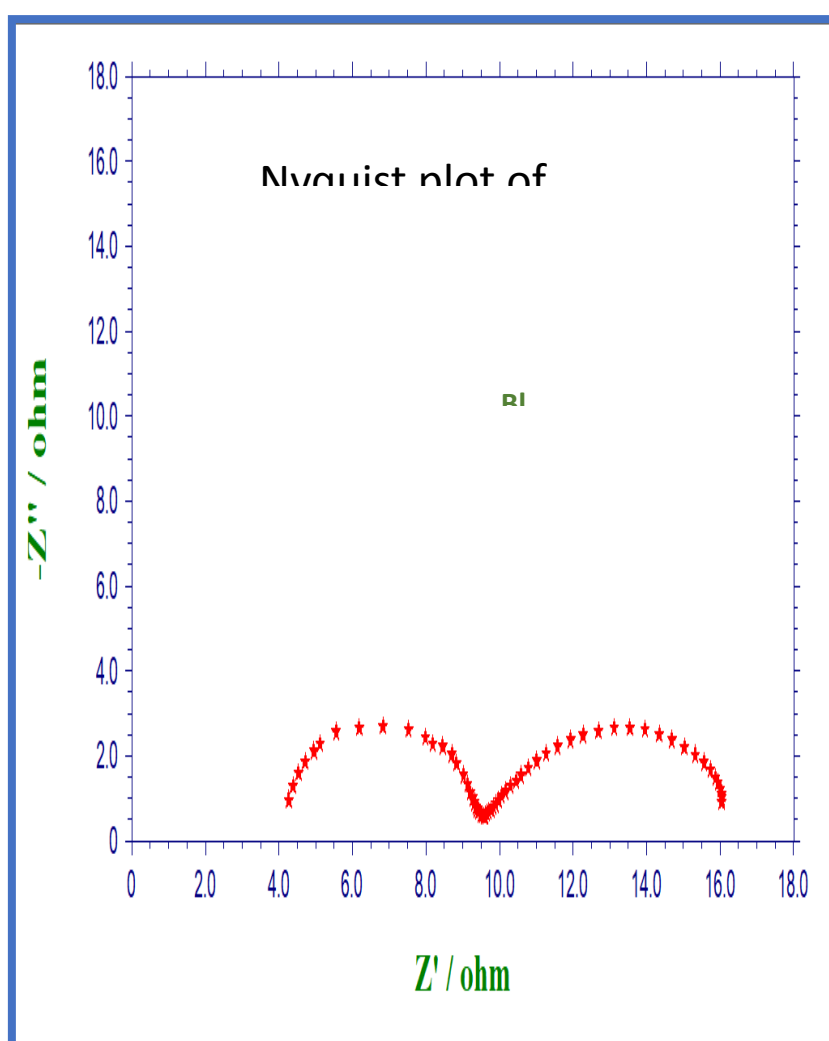
It is observed that when mild steel is immersed in 0.1M HCl  $R_t$  value is 11.792ohm  $\text{cm}^2$  and  $C_{dl}$  value is  $4.2401 \times 10^{-9} \text{F}/\text{cm}^2$ . When the inhibitor (AA50, 150, 250ppm with 0.1M HCl) is added to the above system  $R_t$  values increases from 11.792 ohm  $\text{cm}^2$  to 662.19, 401.62, 410.48ohm  $\text{cm}^2$  and the  $C_{dl}$  value decreases from  $4.2401 \times 10^{-9} \text{F}/\text{cm}^2$  to  $1.1752 \times 10^{-9}$ ,  $1.2449 \times 10^{-9}$  and  $1.2180 \times 10^{-9} \text{F}/\text{cm}^2$ . The impedance log ( $z/\text{ohm}$ ) value increase from 1.2 to 3.2, 3.5, 3.6.This suggests that a protective film is formed on the metal surface.

**Table 5: Impedance parameters of mild steel immersed in 0.1M HCl in the absence and presence of inhibitor system obtained from AC impedance spectra**

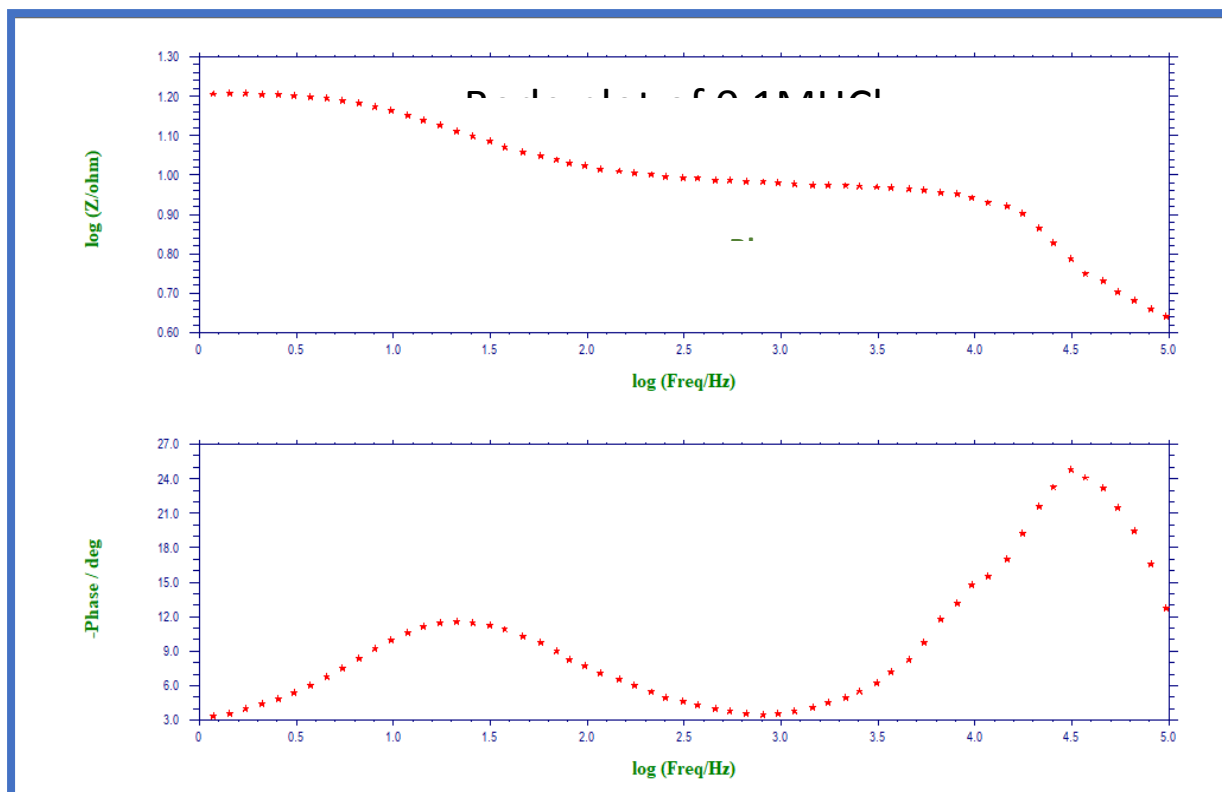
System	Nyquist plot		Bode plot
	$R_t$ ohm $\text{cm}^2$	$C_{dl}$ F/ $\text{cm}^2$	Impedance value log ( $z/\text{ohm}$ )
0.1M HCl	11.792	$4.2401 \times 10^{-9}$	1.2
0.1M HCl + 50ppmAA	4254.3	$1.1752 \times 10^{-9}$	3.2
0.1MHCl + 150ppmAA	3884.8	$1.28706 \times 10^{-9}$	3.5
0.1MHCl + 250ppmAA	3004.7	$1.66405 \times 10^{-9}$	3.6

**Table 6: Impedance parameters of mild steel immersed in 0.1M HCl in the absence and presence of AA + 0.05g SPT obtained from AC impedance spectra**

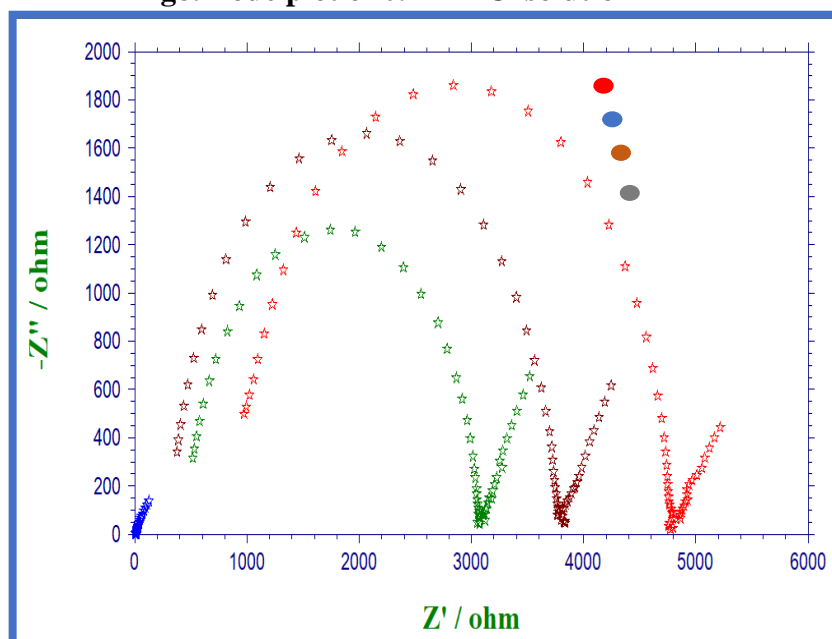
System	Nyquist plot		Bode plot
	$R_t$ ohm $cm^2$	$C_{dl}$ F/ $cm^2$	Impedance value log (z/ohm)
0.1M HCl	11.792	$4.2401 \times 10^{-9}$	1.2
0.1MHCl+50ppmAA+SPT	662.19	$7.5507 \times 10^{-9}$	2.7
0.1MHCl+150ppmAA+SPT	401.62	$1.2449 \times 10^{-9}$	2.8
0.1MHCl+250ppmAA+SPT	410.48	$1.2180 \times 10^{-9}$	2.9



**Fig7. Nyquist plot of 0.1M HCl solution.**

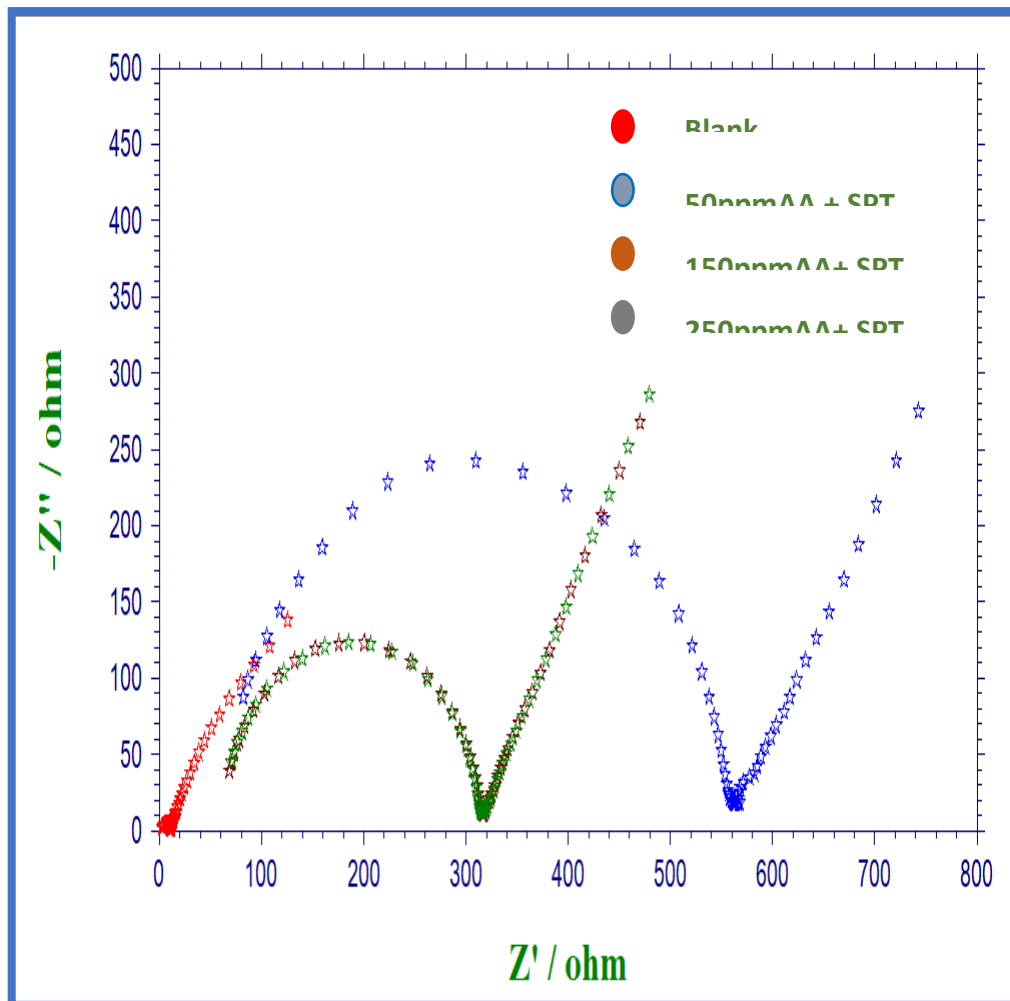


**Fig8. Bode plot of 0.1M HCl solution**



**Fig.9 AC impedance spectra of mild steel immersed in various test solutions**

**(Nyquist plot) 0.1M HCl+50ppm AA+150ppm AA+250ppm AA**



**Fig.10 AC impedance spectra of mild steel immersed in various test solutions**

**(Nyquist plot) 0.1M HCl+50ppm AA+150ppm AA+250ppm AA+SPT.**

#### **4.Conclusion:**

The corrosion study of amino acid(Tryptophan) in the presence of Sodium Potassium tartrate has revealed that the inhibition efficiency tended to increase with increasing inhibitor concentration. Polarization measurements show that they are cathodic-type inhibitors. From the above studies we are reported that 250ppm of amino acid in the presence of Sodium Potassium tartrate as a best corrosion inhibitor for Mild Steel corrosion in 0.1MHCl solution.

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