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Adsorption characteristics of *Croton sparsiflorus* Leaves extract on corrosion of Mild steel in acidic media

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ABSTRACT

The inhibition efficiency of leaves extract of *Croton sparsiflorus*(CSL) on corrosion of mild steel in1 M HCl was carried out by mass loss and electrochemical techniques. To understand the nature of the adsorption process, thermodynamic and kinetic parameters were evaluated using temperature studies results. A maximum of 98 % inhibition efficiency was obtained for 0.7% concentration of CSL. Influence of temperature on the corrosion inhibitive nature of CSL was also studied. Thermodynamic parameters demonstrated that the inhibition was due to spontaneous adsorption of inhibitor on the metal surface. The inhibitor was found to follow Langmuir and Temkin adsorption isotherms. Electrochemical studies confirmed that CSL acted as mixed type inhibitor. Surface analytical studies further ascertained the inhibitive nature of the inhibitor.

Key words: Corrosion, inhibitor, *Croton sparsiflorus* leaves, Mass loss, Electrochemical techniques, Surface analytical techniques.

INTRODUCTION

In acidic solutions, the prime feature of the corrosion of mild steel are, that it is rapidly corroded without the formation of a passive layer of corrosion products and that the cathodic reaction consists mainly of hydrogen evolution. Acid solutions are widely used for the removal of oxide from the metallic parts before coating (acid pickling), removal of undesirable scales and rust (acid cleaning) and in several other industrial processes . Hydrochloric acid and Sulphuric acids are the most important pickling acids used for steel and ferrous alloys in industry. Inhibitors are commonly used in these processes to control the metal dissolution and acid consumption. The use of corrosion inhibitors is one of the most effective methods to protect metal surfaces against corrosion, especially in acid media. The most suitable inhibitors are the adsorptive type which adsorb immediately and have high efficiency. In recent years, plants have been emerging as an excellent source for the development of novel and effective green corrosion inhibitors for metals. Consequently, research into the use of plant extracts and several pure organic molecules (phytomolecules)from the plant origin as effective green corrosion inhibitors for metals have been intensified[1-11] as they are well thought-out to be environmentally acceptable, non-toxic, renewable, easily accessible and biodegradable[12-15].

Our research team investigated several plant extracts for corrosion inhibition studies which include sprouted seeds of *Phaseolus aureus*, *Cocos nucifera* Shell, seed extract of

Cyamopsis tetragonoloba, petiole extract of *Cocos nucifera, staminate flower extract of Cocos nucifera* and,leaf extract of *Ervatamia coronaria,Cocos nucifera L. Peduncle, leaf extract of Mundulea sericea, leaves extract of Dodonaea viscosa(L)* [16-25]

Croton sparsiflorus Morong belongs to the plant family Euphorbiaceae and is a small annual herb, growing up to 1-2ft tall. This plant contains main chemical constituents like glycosides saponins, tannins, flavanoids, terpenoids, alkaloids[26,27]. Most of the phytoconstitutes were isolated from leaves of *C.Sparsiflorus Morong*. Hence, the leaves of this plant have been used for all pharmacological activities. In this direction the *Croton Sparsiflorus* leaves extract (CSL) has been tried for its potency in the retardation of corrosion of mild steel.

MATERIALS AND METHODS

Mild steel(MS) specimens of dimension 1×5 cm^2 strips with 2 mm thickness was mechanically polished, washed in double distilled water, dried, stored in a dessicator and used for the entire immersion studies. 1 M HCl solution was prepared from analytical grade reagent HCl and de-ionized water.

Preparation of plant extract

CS Leaves were collected from the nearby locality and shade dried. Identification of the plant species was carried out by a plant taxonomist of dept. of botany of our university. 25 g of the dried flowers were refluxed with 500 ml of 1M HCl for 3 hours and kept overnight. The cooled extract was filtered and made up to 500 ml (5% extract).

Mass loss method

Pre weighed test pieces were immersed in triplicate in 100 ml of the solution containing various concentration of the inhibitor and in the absence of inhibitor for a predetermined time period. The test specimens were removed and then washed with de-ionised water, dried and reweighed. From the initial and final masses of the specimen, the mass loss was calculated as per ASTM[28] G1-2[29]. From the mass loss, corrosion rate, inhibition efficiency and surface coverage were determined using the following relationship.

$$\text{Corrosion Rate (mpy)} = \frac{K \times W}{DAT} \quad (1)$$

K = Constant-$3.45*10^6$ (mpy), W = Mass loss in grams; D = Density of mild steel in mg / cm^3; A = Area of the specimen in cm^2; T = Exposure time in hours

$$\text{Inhibitor Efficiency (\%)} = \frac{CR_{blank} - CR_{inh}}{CR_{blank}} \times 100 \quad (2)$$

CR_{blank} = Corrosion rate of mild steel in acidic medium, CR_{inh} = Corrosion rate of mild steel in the presence of inhibitor.

$$\text{Surface Coverage } (\theta) = \frac{W_o - W}{W_o} \quad (3)$$

W_o = Mass loss of mild steel without inhibitor (blank); W = Mass loss of mild steel in the presence of the inhibitor.

Electrochemical measurements

Potentiodynamic measurement

A conventional three-electrode system, consisting of mild steel as working electrode, platinum foil as counter electrode, and saturated calomel as reference electrode, was used for the polarization measurement. Electrochemical measurements were carried out using Biologic model v10.23 operated with EC lab software.

Tafel polarization curves were recorded using Biologic model v10.23 operated with EC lab software. In this setup a platinum electrode, calomel electrode and MS specimens were used as auxiliary, reference and working electrodes respectively which were immersed in acidic medium in the presence and absence of different concentration of the inhibitor. Potentiodynamic polarization studies were carried out from a cathodic potential of-0.1V to an anodic potential of -1V with respect to corrosion potential at sweep rate of 2m/sec.

The inhibitor efficiency was calculated using the following equation

$$\text{Inhibition efficiency (\%)} = \frac{I_{corr(blank)} - I_{corr(inh)}}{I_{corr(blank)}} \times 100 \qquad (4)$$

$I_{corr\ (blank)}$ and $I_{corr\ (inh)}$ are linear corrosion current in the absence and presence of the inhibitor respectively.

I.E from LPR technique

$$\text{Inhibition efficiency (\%)} = \frac{R_{p(inh)} - R_{p(blank)}}{R_{p(inh)}} \times 100 \qquad (5)$$

$R_{p(inhi)}$ and $R_{p(blank)}$ are linear polarization resistance in the presence and absence of the inhibitor respectively.

Impedance Spectroscopy:

The impedance spectral response of mild steel in the presence of CSL was recorded by means of Biologic model v10.23 operated with EC lab software In this method an AC signal of 5 – 10 mV of frequency 10 KHz to 10MHz is applied to the system. Impedance data can be presented in the form of Nyquist or Bode plot. From the data, the R_{ct} and C_{dl} are obtained.

The I.E can be calculated using the equation,

$$\text{Inhibition efficiency (\%)} = \frac{R_{ct(inh)} - R_{ct(blank)}}{R_{ct(inh)}} \times 100 \qquad (6)$$

$R_{ct(inh)}$ and $R_{ct(blank)}$ are charge transfer resistance in the presence and absence of the inhibitor respectively.

With the help of the double layer capacitance C_{dl}, θ can be calculated using the equation,

$$\text{Surface Coverage } (\theta) = \frac{C_{dl(blank)} - C_{dl(inh)}}{C_{dl(blank)}} \qquad (7)$$

$C_{dl\ (blank)}$ and $C_{dl\ (inh)}$ are the double layer capacitance in the absence and presence of the inhibitor respectively.

SEM-EDAX Analysis

The surface morphologies of mild steel specimens after exposure to 1 M HCl solution in the absence and presence of extract for 3h were examined by SEM using a JEOL MODEL JSM 6390 SEM instrument.

FT-IR

FTIR was recorded using Nexus 670/ Thermo Electron Corporation Spectrometer which extended from 4000 and 400 cm^{-1}. The interaction between the organic molecules and the metal surface has been studied by FTIR spectra.

RESULTS AND DISCUSSION

Effect of concentration of the inhibitor

The mass loss of Mild Steel specimes in 1M HCl solution, without and with different concentrations of the inhibitor, was investigated at different times of immersion at

room temperature. The results are illustrated in table (1) and fig (1).It is imperative from the figure that as the dosage of the inhibitor is increased, the inhibition efficiency also increased.

The increase in inhibition efficiency with increase in concentration of the extract may be attributed to the increase in the number of molecular adsorbed over the mild steel surface. This blocks the active sites in which direct acid attack proceed there by effectively protecting the metal from corrosion[30].

In the presence of 0.7% of CSL solution, the maximum efficiency was found to be 98.3% for HCl acid.

Effect of Immersion Time

Efforts have been taken to find out the optimum time of immersion for the extract under investigation. The extract has been analysed for different periods of time in 1M HCl. The result obtained for the variation of IE with exposure time for the mild steel specimen immersed in 1M HCl with and without the addition of varied concentration of CSL extract are presented in table-1 and depicted in fig -1

Analysis of the table reveals that as the concentration of inhibitor increased the IE was also found to increase with all periods of immersion. A maximum IE of 98% was obtained for 6 hours at 0.7 % concentration. In the present investigation it is observed that the extract behaved as an excellent one at all periods of immersion. This proves the inhibitive nature of the adsorbed molecule on the surface of mild steel.

TABLE -1
EFFECT OF CONCENTRATION AND TIME ON INHIBITION EFFICIENCY OF CSL EXTRACT IN 1M HCl

S. No	Conc (%)	Corrosion rate and Inhibition efficiency											
		½ h		1h		3h		6h		12h		24h	
		CR (mpy)	IE (%)	CR (mpy)	IE (%)	CR (mpy)	IE (%)	CR (mpy)	IE (%)	CR (mpy)	IE (%)	CR (mpy)	IE (%)
1.	0.1	277.20	5.1	102.35	81.8	109.47	49	69.30	93.6	94.89	87.4	142.16	88.6
2.	0.2	183.38	37.2	93.83	83.3	81.08	62.2	46.20	95.7	79.25	89.5	97.73	92.1
3.	0.3	162.06	44.4	76.76	86.3	66.81	68.8	42.64	96	74.27	90.1	97.55	92.2
4.	0.4	153.30	47.3	68.23	87.8	62.55	70.8	28.43	98.1	68.94	90.8	61.83	95.0
5.	0.5	136.47	53.2	63.97	88.6	59.71	72.1	26.29	97.3	67.17	91.1	38.56	96.9
6.	0.6	127.94	56.1	55.44	90.1	54.02	74.8	20.61	97.5	62.19	91.7	36.33	97
7.	0.7	102.35	64.9	55.44	90.1	42.65	80.1	18.48	98.3	60.06	92	35.27	97.1

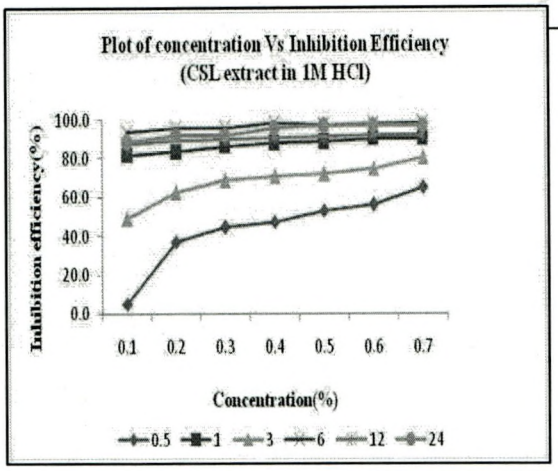


Fig-1

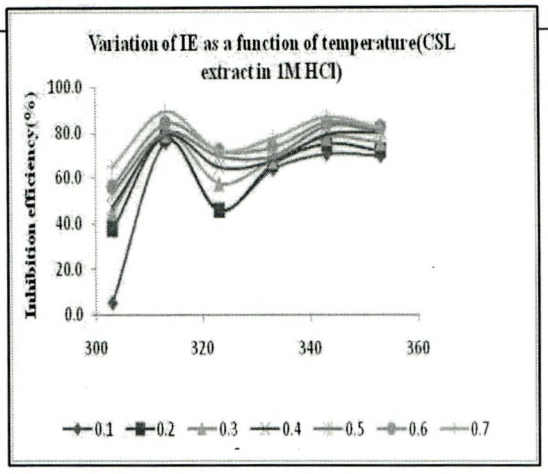


Fig-2

EFFECT OF TEMPERATURE

Temperature has a great effect on the rate of metal electrochemical corrosion. The influence of temperature on the corrosion rate of mild steel in increasing concentrations of inhibitor in 1 M HCl was studied.

To investigate the inhibition mechanism and to determine activation energy and free energy of adsorption of the corrosion process, mass loss measurements were taken in the temperature range of 303K to 353K by varying concentrations of CSL .The results are summarized in table -2 and fig -2. The data indicated that CSL extract was effective up to 313 K and decreased slightly thereafter. The maximum efficiency of 89 % at 313 K indicates that the inhibitor can be effectively used up to 313 K.

The above observation can be explained on the following basis adsorption and desorption of inhibitor molecules continuously occur at the metal surface and an equilibrium exists between these two processes at a particular temperature. With the increase of temperature the equilibrium between adsorption and desorption processes is shifted leading to a high desorption rate until equilibrium is again established at a different value of equilibrium constant. It explains the lower inhibition efficiency at higher temperatures.

TABLE - 2
EFFECT OF TEMPERATURE ON THE INHIBITION EFFICIENCY OF CSL EXTRACT IN 1MHCl

S.No	Conc (%)	Corrosion rate and inhibition efficiency											
		303K		313K		323K		333K		343K		353K	
		CR (mpy)	IE (%)	CR (mpy)	IE (%)	CR (mpy)	IE (%)	CR (mpy)	IE (%)	CR (mpy)	IE (%)	CR (mpy)	IE (%)
1	0.1	277.2	5.1	477.7	75.5	759.1	45.7	1518.2	63.6	3983.2	70.3	4392.6	69.5
2	0.2	183.4	37.2	426.5	78.1	631.2	54.8	1424.4	65.9	3386.2	74.8	4068.5	71.8
3	0.3	162.1	44.4	400.9	79.4	597.1	57.3	1356.1	67.5	3010.9	77.6	3539.7	75.4

4	0.4	153.3	47.3	409.4	79	494.7	64.6	1356.1	67.5	2806.2	79.1	2874.4	80
5	0.5	136.5	53.2	383.9	80.3	426.5	69.5	1270.8	69.5	2311.4	82.8	2755.0	80.9
6	0.6	127.9	56.1	307.1	84.2	392.4	71.9	1108.8	73.4	2089.7	84.4	2567.3	82.2
7	0.7	102.4	64.9	204.7	89.5	392.4	71.9	938.2	77.5	1774.1	86.8	2601.4	81.9

ADSORPTION ISOTHERMS

One of the most convenient ways of expressing adsorption quantitatively is by deriving the adsorption isotherm that characterizes the metal/inhibitor/environment system[31]. Basic information on the interaction between the investigated inhibitor CSL and mild steel surface can be provided by the adsorption isotherms. Various adsorption isotherm were applied to fit θ values but the best fit was found obey Langmuir adsorption isotherm[32], and Temkin adsorption isotherms may be expressed by:

Langmuir [log (θ/1-θ] vs log C (8)

Temkin θ vs log C (9)

LANGMUIR ADSORPTION ISOTHERM

A plot of log (θ/1- θ) Vs log C gave a straight line showing that the adsorption of CSL can be fitted to Langmuir adsorption isotherm. (Figure 3) For a reliable and linear plot, surface coverage should fall within the linear window (monolayer) for inhibitor adsorption. The strong correlation for the Langmuir adsorption isotherm plot for CSL extract confirms the validity of this approach. These results demonstrated that the inhibition of mild steel by CSL extract was attributed to adsorption of the phytochemical compounds present in the inhibitor onto the mild steel surface.

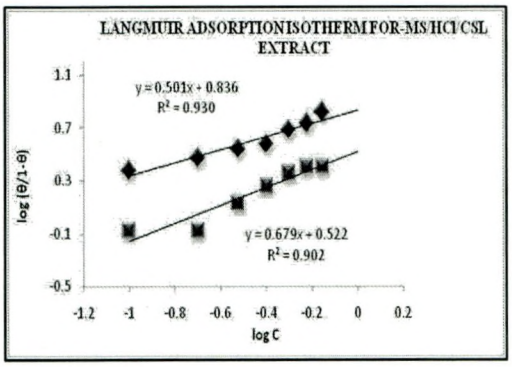


Fig-3

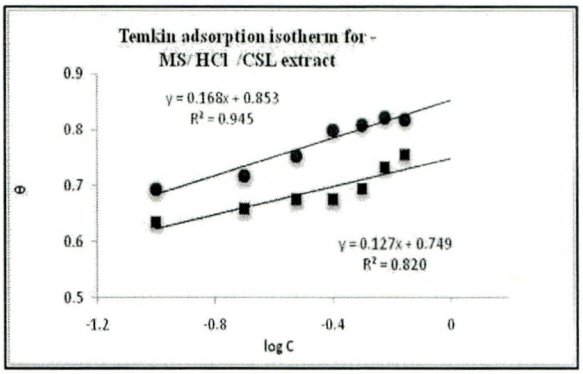


Fig-4

TEMKIN ADSORPTION ISOTHERM

Temkin adsorption isotherm was tested by plotting θ Vs log C. A straight line obtained proves that the adsorption of the inhibitor on the surface of mild steel obeys Temkin adsorption isotherm which is pictorially represented in Figure 4.

KINETIC PARAMETERS

The effect of temperature on the inhibited acid-metal reaction is highly complex, because many changes occur on the metal surface, such as rapid etching desorption of the inhibitor. Generally the corrosion rate increases with the rise of temperature. It was found that the inhibition efficiency decreases with increasing temperature and increases with increasing the concentration of the inhibitor. The activation energy (E^*_a) of the corrosion process was calculated using Arrhenius equation[33]:

$$\text{Log CR} = A \exp(-E^*_a/RT) \qquad (10)$$

Where CR is corrosion rate and A is Arrhenius constant. The values of activation energies E^*_a can be obtained from the slope of the straight lines of plotting log CR Vs 1/T in the presence an absence of investigated compounds at various temperatures [Fig.5] and are given in Table 3. It was found that the E_a value of the blank was higher than that of the systems studied in the presence of the inhibitor. This is due to the formation of a film of inhibitors on mild steel. The activation energy for the corrosion of mild steel in 1M HCl was found to be around 50-60KJ/mol-1 which is in good agreement with the work carried out by others[34,35].

THERMODYNAMIC PARAMETERS:

FREE ENERGY OF ADSORPTION, CHANGE IN ENTROPY AND ENTHALPY:

The values of free energy of adsorption can be calculated by using the standard equation,

$$\log C = \log (\theta/1-\theta) - \log B \qquad (11)$$

where,

C = Inhibitor concentration

$$\log B = -1.74 - (-\Delta G/2.303\ RT) \qquad (12)$$

The results obtained were tabulated in the table (3). From the table, it is noted that the values of ΔG are found to be negative in the presence and absence of the inhibitor. This indicates that adsorption behaviour of inhibitor is a spontaneous process under the experimental conditions. This negative value also indicates the strong interaction between the metal surface and the inhibitor molecules.

The heat of adsorption ΔH and entropy of adsorption ΔS are related to free energy of adsorption by Gibbs Helmholtz equation,

$$\Delta G = \Delta H - T\Delta S \qquad (13)$$

A plot of -ΔG Vs T is a straight line, which is depicted in figure (6). The values of ΔH are taken from intercept and that of ΔS from slopes. The values of ΔH and ΔS indicate that the system is enthalpy and entropy controlled.

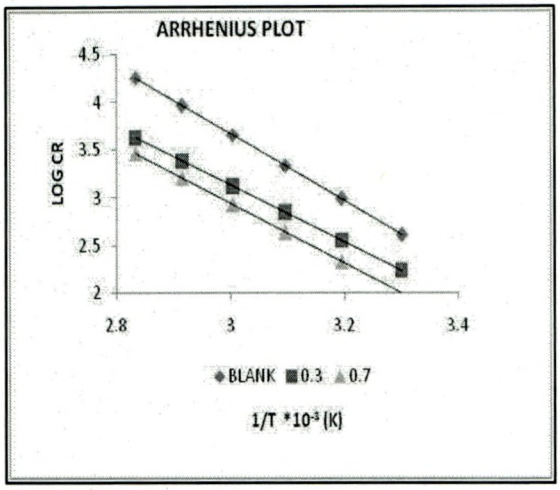


Fig-5

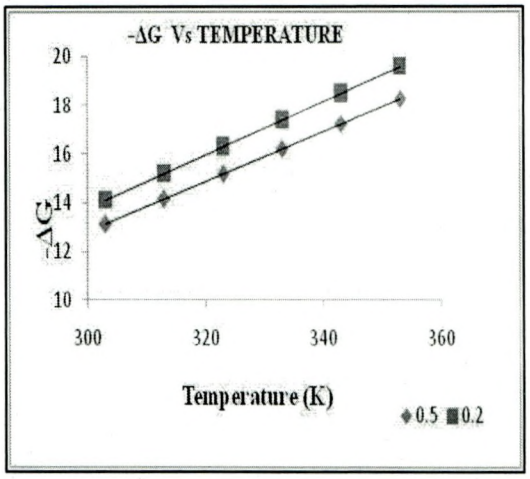


Fig-6

TABLE- 3
VARIATION OF THERMODYNAMIC AND KINETIC PARAMETERS WITH CONCENTRATION AND TEMPERATURE (CSL IN 1M HCl)

S.No	-Ea (KJ/mol)	- ΔG at various temperature (KJ/mol)						ΔS KJ/mole	ΔH KJ/mole
		303K	313K	323K	333K	343K	353K		
1.	62.67	8.53	19.35	16.48	19.02	15.06	20.94	-3.27	14.38
2.	49.59	12.83	17.93	14.62	17.38	19.12	19.23	-2.59	10.97
3.	53.08	12.56	17.07	14.78	16.45	18.41	18.58	-2.77	11.47
4.	52.95	12.13	16.26	14.84	15.66	17.84	18.52	-2.77	11.39
5.	50.9	12.16	15.89	14.83	15.29	17.89	18.03	-2.66	11.03
6.	51.09	11.99	16.11	14.66	15.32	17.7	17.75	-2.67	11.01
7.	51.76	12.54	16.93	14.24	15.51	17.82	17.24	-2.71	11.07

ELECTROCHEMICAL MEASUREMENTS:

POLARISATION MEASUREMENT

Figure7 illustrates the polarization curves of Mild Steel in 1M HCl solution without and with various concentrations of CSL at 30° C. The presence of the inhibitor shift both anodic and cathodic branches to the lower values of corrosion current densities and thus causes a remarkable decrease in the corrosion rate. The parameters derived from the polarization curves in Figure 7 are given in Table 4. In 1M HCl solution, the presence of CSL causes a remarkable decrease in the corrosion rate i.e., shifts both anodic and cathodic curves to lower current densities. In other words, both cathodic and anodic reactions of mild steel electrode are retarded by CSL in hydrochloric acid solution. The Tafel slopes of β_a and β_c do not change remarkably upon addition of CSL, which indicates that the presence of CSL does not change the mechanism of hydrogen evolution and the metal dissolution process. Generally, an inhibitor can be classified as cathodic or anodic type if the shift of corrosion potential in the presence of the inhibitor is more than 85mV with respect to that in the absence of the inhibitor[36,37]. In the presence of CSL, E_{corr} shifts to less negative but this shift is very small (about 20-30mV), which indicates that CSL can be arranged as a mixed-type inhibitor.

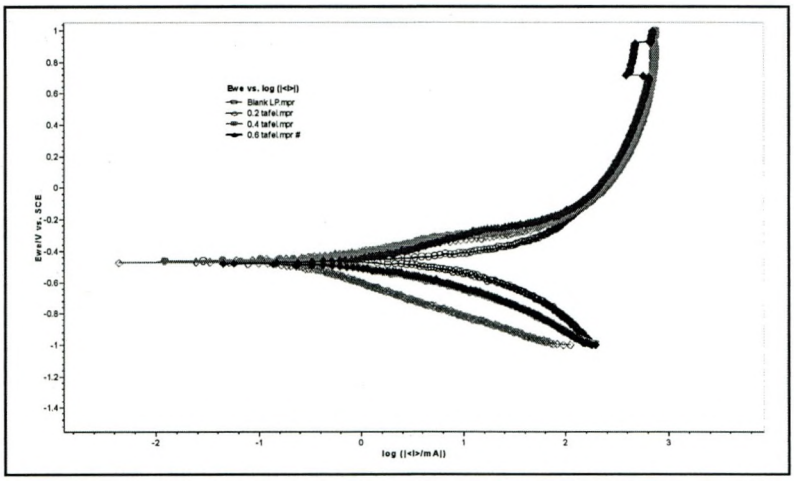


Fig -7

TABLE 4

POTENTIODYNAMIC POLARIZATION PARAMETERS FOR THE CORROSION OF MILD STEEL IN 1M HCL WITHOUT AND WITH EXTRACT OF CSL

S.NO	Conc v/v(%)	$-E_{corr}$ mV/SCE	I_{corr} $\mu A/cm^2$	b_a mV/dec	b_c mV/dec	IE (%)	R_pOhm/cm^2	IE (%)
1.	Blank	479	109.4	93.8	150.5	-	30.7	-
2.	0.2	450	53.0	73.6	218.0	51.9	55.4	44.5
3.	0.4	431	45.06	96.2	160.5	58.8	56.9	46.0
4.	0.6	461	19.42	176.7	175.3	82.2	122	74.8

Increase in R_p value with increase in concentration of the inhibitor under study indicates the effective inhibitive action of the CSL extract. The maximum inhibition efficiency using R_p values was found to be 84.27 % .The values of R_p increases with increase in concentration of the extract.

ELECTROCHEMICAL IMPEDANCE SPECTROSCOPY:

Electrochemical impedance spectroscopy is sophisticated technique and it is an important tool to study the mechanism of inhibition process. Nyquist representation of the impedance with and without the addition of CSL is given in Figures 9. The Nyquist plots exhibit one single depressed semi circles with centers below the real axis.

The diameter of semicircle increases with the increase of CSL concentration. The impedance spectra exhibit one single capacitive loop, which indicates that the corrosion of steel is mainly controlled by a charge transfer process[38] and presence of CSL does not change the mechanism of mild steel dissolution[39]. In addition, these Nyquist diagrams are not prefer semicircles in 1M HCl that can be attributed to the frequency dispersion effect as a result of the roughness and inhomogeneous of electrode surface[40]. Furthermore, the diameter of the capacitive loop in the presence of inhibitor is larger than that in the absence of inhibitor (blank solution), and increased with the inhibitor concentration. This indicates that the impedance of inhibited substrate increased with the inhibitor concentration[39,40].

Generally, when a non-ideal frequency response is presented, it is commonly accepted to employ the distributed circuit elements in the equivalent circuits. What is most widely used is the constant phase element(CPE), which has a non-integer power dependence on the frequency. Thus, the equivalent circuit depicted in Fig-4 is employed to analyze the impedance spectra, where Rs represents the solution resistance, R_{ct} denotes the charge-transfer resistance, and a CPE instead of a pure capacitor represents the interfacial capacitance. The impedance of a CPE is described by the equation 3.

$$Z_{CPE} = Y_0^{-1}(j\omega)^{-n} \qquad (15)$$

Where Y_0 is the magnitude of CPE, j is an imaginary number, ω is the angular frequency at which the imaginary component of the impedance reaches its maximum values, and n is the deviation parameter of the CPE: $-1 \leq n \leq 1$. The values of the interfacial capacitance C_{dl} can be calculated from CPE parameter values Y_0 and n using equation4.

$$C_{dl} = Y_0(\omega_{max})^{n-1} \qquad (16)$$

Maximum inhibition efficiency using R_{ct} values was found to be 93% at 0.6%. Concentration values of C_{dl} decreases with increase in concentration of the extract indicate that the inhibition is taking place through adsorption process.

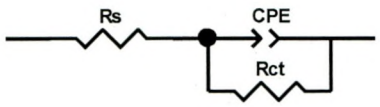


Figure- 8 Proposed equivalent circuit model

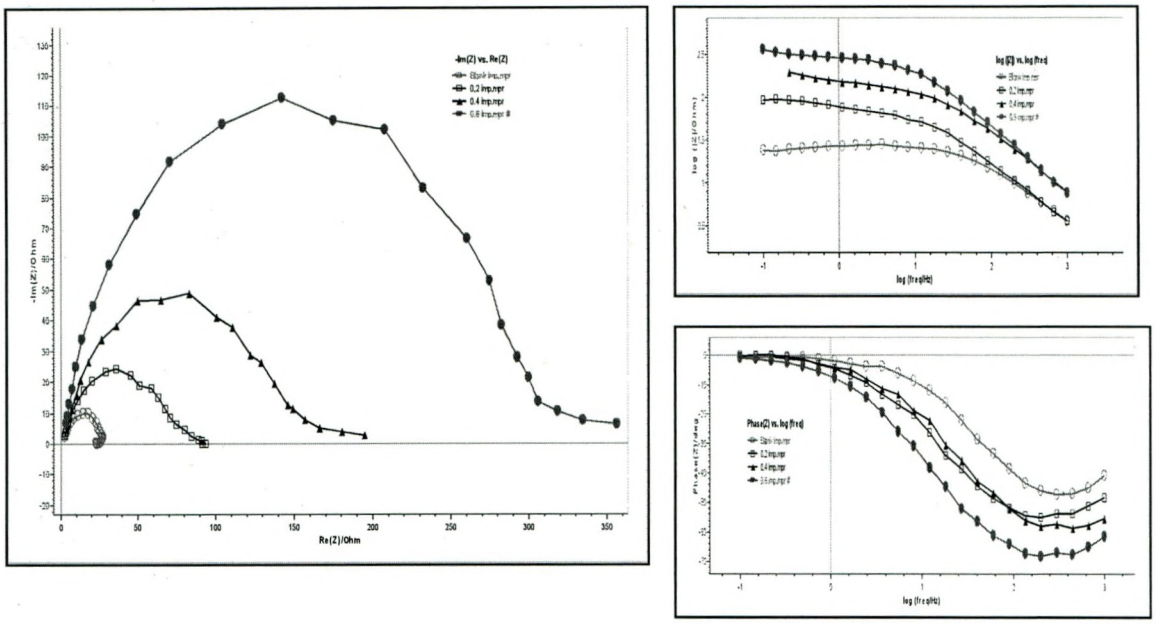


FIGURE 9 : NYQUIST AND BODE PLOT FOR MS/IS/1M HCl

TABLE.6
IMPEDANCE PARAMETERS FOR MS/CSL/1M HCl

Conc v/v (%)	R_S	Y0	n	R_{ct} Ohmcm^2	IE (%)	f_{max}	C_{dl} (μ Fcm^{-2})	θ	τ
Blank HCl	1.59	7049	0.61	22.59	-	40.7	173	-	0.0039
0.2	0.25	1788	0.62	89.08	74.6	18.4	97	0.44	0.0086
0.4	0.99	911	0.62	174.8	87	18.3	49.8	0.71	0.0087
0.6	0.50	487	0.65	327.1	93	12.2	39.8	0.77	0.0130

MECHANISM OF INHIBITION

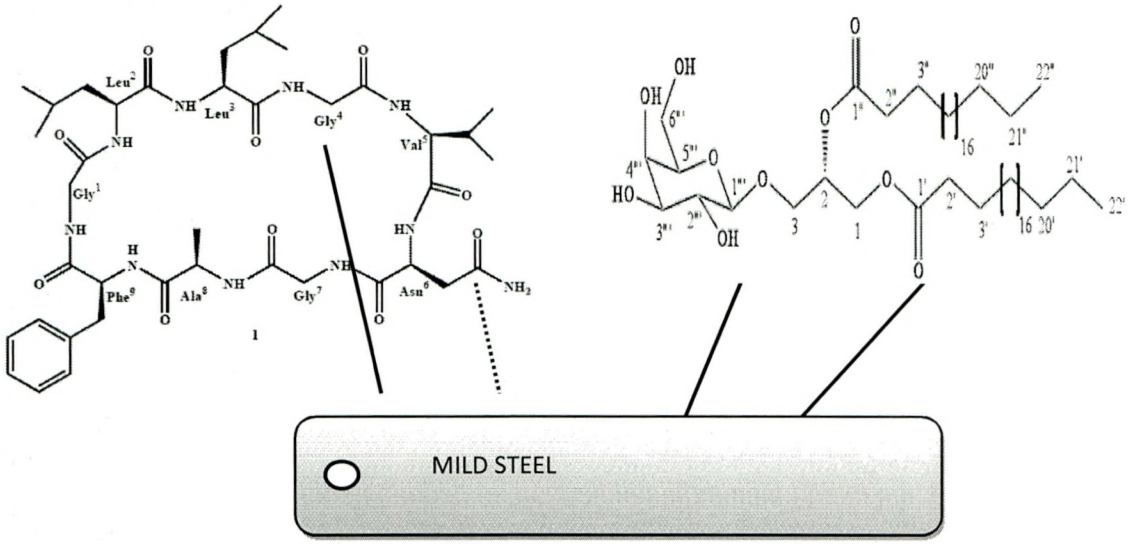
Generally the first stage in the corrosion inhibition mechanism is the adsorption of inhibitor molecules on the mild steel surface. The process of adsorption is influenced by the type of the aggressive electrolyte, the chemical structure of the inhibitor molecules, and the nature and charge of the metal.

As far as the inhibition process is concerned, it is generally assumed that the adsorption of the inhibitor at the metal-solution interface is the first step in the mechanism of action of inhibitor in aggressive media. Four types of adsorption may take place involving organic molecules at the metal- solution interface.

* Electrostatic interaction between charged molecule and charged metal.
* Interaction of unshared electron pairs in the molecule with the metal.
* Interaction of the p electrons with the metal.

Phytochemical analysis from literature revealed that the main constituents are Sparsioamide , a new sphingolipid, sparsioside , a new diglyceride galactoside[41], Crotosparsamide , a new cyclic nonapeptide, p-hydroxy methyl cinnamate , kaempferol , carbohydrate (reducing sugars), alkaloids, steroids, flavonoids, saponin & tannins

In the present study, the phytochemical constituents typically contain nitrogen, sulphur or oxygen in the system and corrosion inhibition occurs via adsorption on the constituents on the metal surface. Skeletal representation of adsorption of the inhibitor on MS is pictorially represented in the fig . The inhibitor act as the interface created by corrosion product between the corroded and the metal surface. Thus the formation of adsorbed layer between the metal surface and the phytochemical constituents of the plant extract for the inhibitive effect.



SUMMARY AND CONCLUSION

Efforts have been taken to find out the inhibition efficiency of leaves extract of CS on corrosion of mild steel in1 M HCl by weight loss and electrochemical techniques. The experiments were conducted to optimize the concentration of the inhibitors and time of exposure at room temperature and at high temperatures. To understand the nature of the adsorption process, thermodynamic and kinetic parameters were evaluated using temperature studies results. Experimental results were fitted into various adsorption isotherms. Electrochemical techniques-Linear polarization techniques, Tafel intercept method and electrochemical impedance spectroscopy was performed. The results obtained by Tafel, Linear polarization resistance and impedance spectroscopy have been correlated with the classical weight loss measurements. A possible mechanism of inhibition process was also suggested.

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