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Sinapis alba as an anti-rusting agent for corrosion of stainless steel in Hydrochloric acid medium

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Abstract: Protection against corrosion using Sinapis *alba* was studied for the corrosion control of stainless steel in 0.5M HCl. The electrochemical techniques such as potentiodynamic polarization (PDP) measurements and electrochemical impedance spectroscopy (EIS) method were used for the stainless steel protection studies. Surface morphology studies were done for the specimen immersed in the inhibitor solution and the aggressive medium. Mechanism for the corrosion inhibition was proposed. Results showed that Sinapis *alba* acted as mixed type of inhibitor, with maximum inhibition efficiency of 88% for the concentration of $0.1gL^{-1}$ at 323K. It got chemically adsorbed on stainless steel by obeying Langmuir adsorption isotherm. Sinapis *alba* emerged as an effective eco-friendly corrosion inhibitor for the corrosion control of stainless steel in HCl acid medium.
Keywords: Stainless steel,Green inhibitor, Sinapis *alba*, Electrochemical measurements, SEM, EDX

1 Introduction

Stainless steel is an alloy of iron, carbon and chromium. It has wide range applications in various fields such as oil and gas industries, building and constructions. These immense applications are due to the formation of chromium oxide film on the metal surface [1-3].But when the metals come in contact with mineral acids like hydrochloric acid and Sulfuric acid etc., especially during prickling process and there will be material loss [4].

In order to prevent the material loss, the corrosive environment can be altered by adding the corrosion inhibitors. Most commonly organic compounds containing heteroatoms like O, N, S and P are used as protective agents, but preparation of organic compounds involves toxic substances which lead to environmental hazardous [5-7]. In order to overcome this, now-a-days research is geared towards the use of green inhibitors. Green inhibitors are biodegradable, environmentally benign, inexpensive and non-toxic [8-9].

Sinapis *alba* is commercially called as white mustard. White mustard seeds are hard round seeds, usually around 1.0 to 1.5 mm in diameter, with pale yellow colour[10].The major active constituent present in Sinapis *alba* is reported to be Benzyl isothiocyanate. In addition to this, Sinapis alba also contain large number of heterocyclic compounds like alkonoids, flavonoids etc., As a part of our research work with green corrosive inhibitors [11]we report herein the use of Sinapis *alba* as an eco-friendly corrosion inhibitor for the corrosion control of stainless steel in HCl acid medium.

2 Experimental

2.1 Material

Stainless steel material composition is given in the table1. From this material we performed the experiment.

Table1: Composition of the stainless steel specimen.

Element	C	Si	Mn	Cr	Ni	Fe
Composition(%)	0.0450	0.332	1.97	18.33	8.43	Balance

2.2 Preparation of test coupon

Test coupon of stainless steel having 1cm^{2}diameter with 5cm height of cylindrical rod was prepared by moulding with cold setting acrylic resin. Polishing was done with different graded emery papers and finally with disc polisher using levigated alumina to obtain mirror like surface. Then it was cleaned by double distilled water followed by acetone and dried for further use.

2.3 Preparation of medium

Acid stock solution was prepared by using 37% HCl and double distilled water. It was standardized by using previously standardized sodium hydroxide solution by volumetric titration method. The standardized stock solution was diluted appropriately to get 0.5M HCl solution.

2.4.1 Preparation of inhibitor solution

White mustard seeds were collected from the commercial store. The seeds were washed with double distilled water and dried up to 1 weak without exposing light directly. Then it was finely powdered using domestic mixer grinder.

Sinapis alba seed extract (SASE) in aqueous medium was prepared by taking 25g of powdered white mustard seeds. It was refluxed in 500mL distilled water up to 5 h and kept for overnight to settle down and filtered, filtrate was collected. It was then evaporated to complete dryness at 40 ºC, in order obtain brown colour solid residue. The solid residue obtained was weighed and preserved in a desiccator for further use. It was then used for corrosion inhibition studies with concentration ranging from 0.005 – 0.01 gL^{-1}.

2.5 Electrochemical Measurements

The electrochemical measurement of stainless steel in 0.5M HCl was performed by using electrochemical work station (CH600D-series, U.S. Model with CH instrument beta software). The electrochemical cell used was a conventional three electrode compartment Pyrex glass cell with platinum as counter electrode and a saturated calomel electrode (SCE) as reference electrode. Stainless steel was used as a working electrode.

2.5.1 Potentiodynamic polarisation (PDP) measurements

Potentiodynamic polarisation studies were carried out for the stainless steel in 0.5M HCl acid at different temperatures in presence and absence of inhibitor. Steady state open circuit potential was obtained at the end of 300 seconds with respect to SCE. The potentiodynamic plots were obtained by polarising the stainless steel from −250mV cathodically to +250mV anodically with respect to OCP with a scan rate of 1mVsec^{-1}. With this corresponding corrosion current density (i_{corr}), corrosion potential (E_{corr}) and Tafel slope value were obtained.

2.5.2 Electrochemical impedance spectroscopy (EIS) studies

Electrochemical impedance spectroscopy studies for stainless steel was carried out in the frequency ranging from 10000 to 0.01Hz by applying a small amplitude ac signal of 10mV at the OCP. The procedure was repeated 3-4 times and best of the three agreeing values were repeated.

2.6 Surface studies: SEM and EDX analysis

Surface morphology studies of stainless steel were carried out by immersing the specimen in 0.5M HCl in the presence and absence of SASE for 2h using analytical scanning electron microscope (JEOL JSM─6380L) and elemental mapping was done by Energy Dispersive X-ray analysis.

3 Results and discussions

3.1 Fourier transforms infrared (FTIR) spectroscopy of SASE

Figure 1is the FTIR spectrum of solid residue of SASE. In which –N=C=S appears in the frequency range of 2360cm^{-1}.The fingerprint region at 2929cm^{-1}is for aromatic ring. The -C=C- Stretching frequency appears at 1668cm^{-1} and 1541cm^{-1} respectively. The phenolic –OH stretching appears at 3618cm^{-1}. The FTIR spectrum confirms the presence of electron rich heteroatoms.

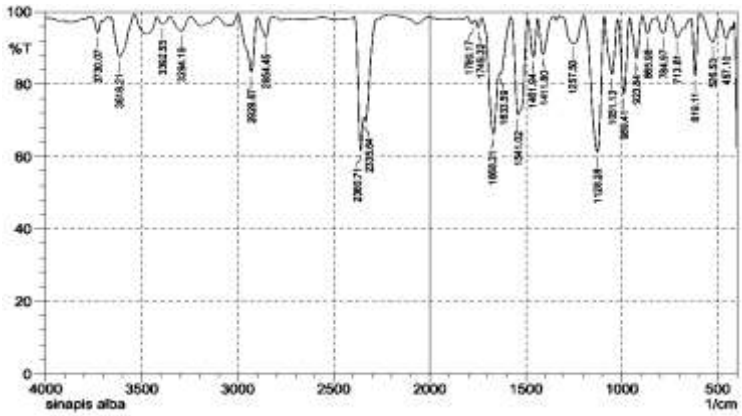

Fig1: IR spectrum of solid residue of SASE

3.2 Electrochemical measurements

3.2.1 Potentiodynamic polarisation (PDP) measurements

Figure 2 shows the Potentiodynamic polarization plots for stainless steel 0.5M HCl with various concentrations of SASE along with blank at Similar plots were obtained at different temperatures. Figure 2 shows that as the SASE inhibitor concentration increased there was a positive shift in the corrosion potential with respect to blank at 30 ^{0}C.This indicates that, introduction of SASE inhibitor controls the corrosion of stainless steel in acid medium. A change in the shape of anodic slope is because of passivation observed in between −0.3V to −0.1V.The cathodic polarization curves have linear behaviour and values of cathodic slope (−βc) are not varying significantly with increase in inhibitor concentration. This indicates that the hydrogen evolution is activation-controlled and the presence of inhibitor did not alter the inhibition mechanism[12-13]. According to the literature, if displacement in corrosion potential is more than ±85 mV with respect to corrosion potential of the uninhibited solution the inhibitor can be considered as a cathodic or anodic type of inhibitor. However, the maximum displacement in this study is not more than 85 mV, which indicates that inhibitor is act as a mixed type inhibitor [14].

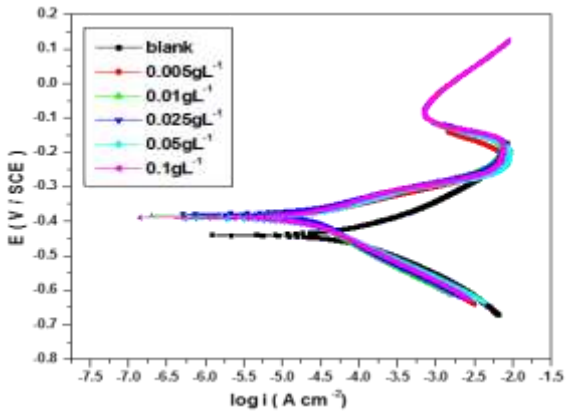

Fig 2: Potentiodynamic polarization plots for corrosion of stainless steel in 0.5M HCl containing different concentrations of SASE at 30 ^{0}C.

The potentiodynamic parameters for stainless steel in acid medium in the presence and absence of SASE are obtained from this study. Corrosion rate and % efficiency of the SASE was calculated using equation 1 and 2 respectively.

$$CR\ (mmy^{-1}) = \frac{3270 \times M \times i_{corr}}{\rho \times z} \qquad (1)$$

where 3270 is a constant that defines the unit of corrosion rate, i_{corr} is the corrosion current density in Acm^{-2}, ρ is the density of the corroding material (gcm^{-3}), M is the atomic mass of the metal and Z is the number of electrons transferred per atom.

$$I.E(\%) = \frac{i_{corr} - i_{corr(inh)}}{i_{corr}} \times 100 \qquad (2)$$

where i_{corr} and $i_{corr\ (inh)}$ are the corrosion current densities in the absence and in the presence of inhibitor, respectively. Table 2 shows potentiodynamic polarization values for stainless steel in presence and absence of SASE at different temperatures.

Table 2: Results of potentiodynamic polarization studies for corrosion of stainless steel in 0.5M HCl containing various concentrations of SASE at different temperatures

Temp (K)	[SASE] gL^{-1}	E_{corr} (mV vsSCE)	i_{corr} x 10^{-5} (A cm^{-2})	β_a (mV dec^{-1})	$-\beta_c$ (mV dec^{-1})	CR (mmy^{-1})	I.E (%)
303	Blank	-440	7.385	1023	1031	16.61	---
	0.005	-390	2.381	1938	827	5.35	67.88
	0.01	-383	2.173	1987	775	4.88	70.57
	0.025	-379	1.937	2238	781	4.35	73.77
	0.05	-393	1.784	2277	987	4.01	75.84
	0.1	-389	1.662	2393	902	3.73	77.49
308	Blank	-441	10.51	1073	1053	23.63	---
	0.005	-365	2.827	1842	783	6.35	73.10
	0.01	-408	2.580	2029	979	5.80	75.45
	0.025	-411	2.402	2230	986	5.40	77.14
	0.05	-380	2.039	2664	903	4.58	80.59
	0.1	-392	1.905	2849	1029	4.28	81.87
313	Blank	-444	14.40	1104	1080	32.39	---
	0.005	-402	3.463	2114	1038	7.78	75.95
	0.01	-373	2.793	2129	806	6.01	80.60
	0.025	-378	2.315	2428	885	4.40	83.92
	0.05	-388	2.064	2734	985	4.28	85.66
	0.1	-392	1.970	2912	1054	4.07	86.31
318	Blank	-442	15.49	1157	1047	34.83	---
	0.005	-406	3.575	1747	1040	8.04	76.92
	0.01	-396	2.676	2511	1018	6.28	82.72
	0.025	-391	1.959	2608	1072	5.20	87.35
	0.05	-392	1.905	2849	1029	4.64	87.70
	0.1	-393	1.784	2277	9879	4.01	88.48

As the inhibitor concentration increased the corrosion current density decreased. It is evident that percentage of efficiency of the inhibitor increased with increase in the concentration of SASE and also with increasing the temperature because of adsorption of inhibitor on the metal surface. The maximum inhibition efficiency 88% was observed at 45 ^{0}C for higher concentration of inhibitor of 0.1g L^{-1}. This indicates SASE gets adsorbed over the metal surface at very high temperature and protects the stainless steel from undergoing the corrosion.

3.2.2 Electrochemical impedance spectroscopy (EIS) studies

Figure 3 shows the Nyquist plot of stainless steel in 0.5M HCl with different concentrations of SASE and same plots are obtained for all temperature. The Semicircle in this plot because of charge transfer controlled process [15] and the diameter of semicircle increases with increase in inhibitor concentration indicates that inhibitor protects the metal by corrosion. The Nyquist plots with a depressed capacitive loop at high-frequency range (HF), this is because of the surface roughness, inhomogeneity of the solid surface and also the adsorption of the inhibitor on the metal surface [16]. The large capacitive loop at high frequency region indicates that charge transfer process occur during corrosion and double layer behaviour. The high frequency capacitive loop could be assigned to the charge transfer of the corrosion process and to the formation of oxide layer [17].

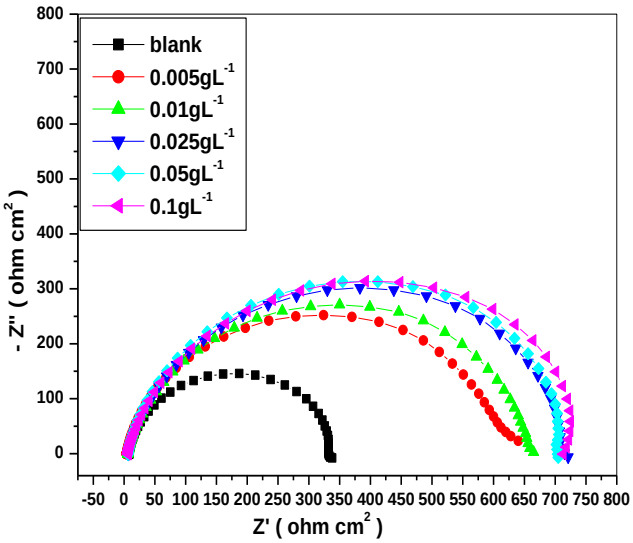

Fig 3: Nyquist plot for corrosion of stainless steel in 0.5M HCl containing different concentrations of SASE at 30 ^{0}C.

Impedance data were simulated to get appropriate equivalent circuit using 3.21 version of Zimpwin software. It is represented in Figures 4(a) and 4(b) respectively.

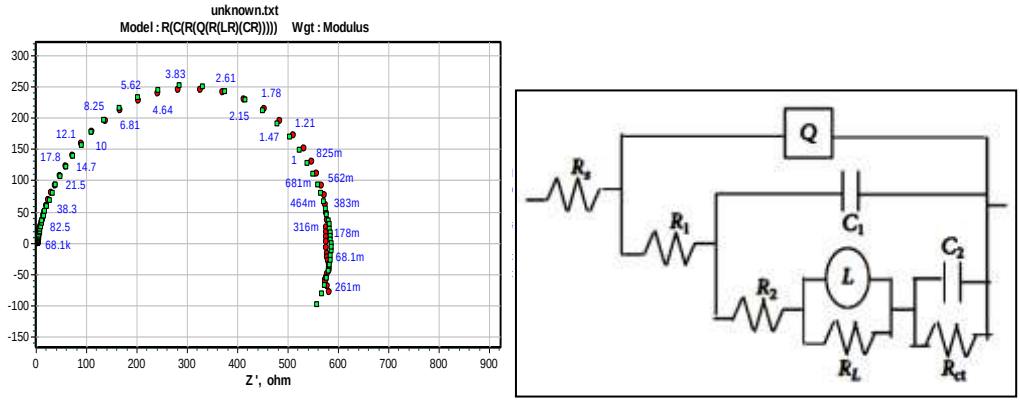

Fig4 (a): Simulated Impedance data for stainless steel corrosion in 0.5M HCl at 35^{0}C (b) Equivalent circuit of nine elements

The equivalent circuit consists of solution resistance (R_S), charge transfer resistance (Rct), Inductive resistance (R_L) and inductive element (L). It also consists of CPE (constant phase element, Q), which is parallel to the series of capacitance C_1 and C_2 and resistor R_1, R_2, R_L and Rct and R_L is parallel to L inductor.

Double layer capacitance (C_{dl}) and polarization resistance (R_P) can be obtained by using the equations (3) and (4) respectively,

$$C_{dl} = C_1 + C_2 \quad (3)$$

$$R_P = R_1 + R_2 + R_L + Rct \quad (4)$$

Rp is inversely proportional to the corrosion current and it can be used to calculate the percentage inhibition efficiency using the relation (5).

$$IE\ (\%) = \frac{R_{p.corr(inh)} - R_{p.corrr}}{R_{p.corr(inh)}} \times 100 \quad (5)$$

where $R_{P.corr(inh)}$ and $R_{P.corr}$ are the polarization resistances in the presence and absence of inhibitor.

Table 3 shows the results obtained from electrochemical impedance spectroscopy technique. Double layer capacity was calculated using equation (6).

$$C_{dl} = Q_{dl} \times (2\pi f_{max})^{(a-1)} \quad (6)$$

Table 3: Impedance values obtained for corrosion of stainless steel in 0.5 M HCl containing various concentrations of SASE at different temperatures.

Temp (K)	[SASE] g L^{-1}	C_{dl} x10^{-5} (F cm^{-2})	R_P (Ω cm^2)	I.E (%)
303	Blank	11.72	287	---
	0.005	10.51	660	56.5
	0.01	9.24	724	60.35
	0.025	8.55	743	61.37
	0.05	8.43	747	61.57
	0.1	6.93	794	63.85
308	Blank	16.90	195	---
	0.005	14.80	586	66.72
	0.01	11.16	560	65.17
	0.025	10.64	563	65.36
	0.05	5.95	589	66.89
	0.1	5.26	598	67.39
313	Blank	18.12	138	---
	0.005	11.70	398	75.32
	0.01	8.29	530	73.93
	0.025	7.67	556	75.17
	0.05	6.82	566	75.61
	0.1	5.42	567	75.66
318	Blank	22.61	127	---
	0.005	12.34	436	70.89
	0.01	9.95	460	72.39
	0.025	8.38	589	78.43
	0.05	6.93	604	78.97
	0.1	6.08	747	82.99

As observed in Table 3 R_p values are increased with the concentration of SASE but C_{dl} value decreased because of increase in the thickness of electrical double layer in between metal and solution interface [18]. The results of potentiodynamic polarization method showed good agreement with results of electrochemical impedance spectroscopy methods.

3.3 Effect of temperature

To understand the adsorption behaviour of SASE on stainless steel the effect of temperature was studied and the activation parameters such as energy of activation (Ea), the enthalpy (ΔHa) and entropy of activation (ΔSa) values was obtained from this study. The energy of activation (Ea) can be calculated from Arrhenius law equation given in the equation 7.

$$\ln (CR) = B - \frac{E_a}{RT} \qquad (7)$$

Where B is Arrhenius constant which depends upon the metal type and R is equal to 8.314 $JK^{-1}mol^{-1}$, T is the absolute temperature.

Figure 5 wasfor Arrhenius plot of stainless steel plotted against ln(CR) verses 1/T .Which gave the straight lines with a slope from which calculate the value of energy of activation (Ea).

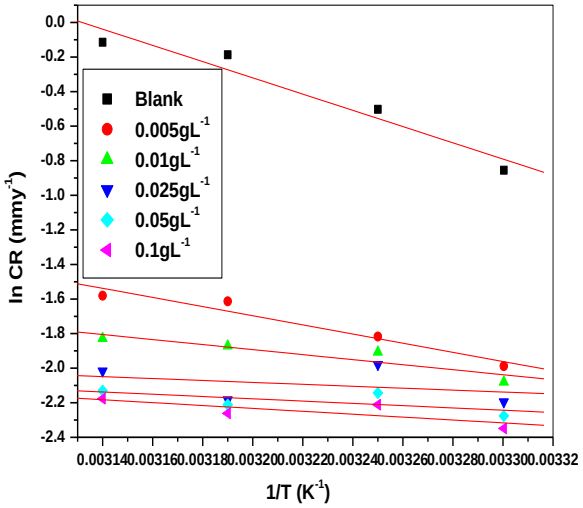

Fig 5: Arrhenius plots for the corrosion of stainless steel in 0.5M HCl at different concentrations of SASE.

The transition state equation 8 was used to calculate the enthalpy (ΔHa) and entropy of activation (ΔSa) for the dissolution of metal.

$$CR = \frac{RT}{Nh} \exp\left(\frac{\Delta S_a}{RT}\right) \exp\left(-\frac{\Delta H_a}{RT}\right) \qquad (8)$$

where h is planks constant (6.626×10^{-34} Js), N is Avogadro's number (6.023×10^{-23} mol^{-1}).

From the plot of ln(CR/T) verses 1/T also gave a straight line from this straight line slope gave the value of enthalpy of activation and the intercept gave the value of entropy of activation. Figure 6 is the plot of ln(CR/T) verses 1/T for stainless steel in various concentration of SASE in 0.5M HCl.

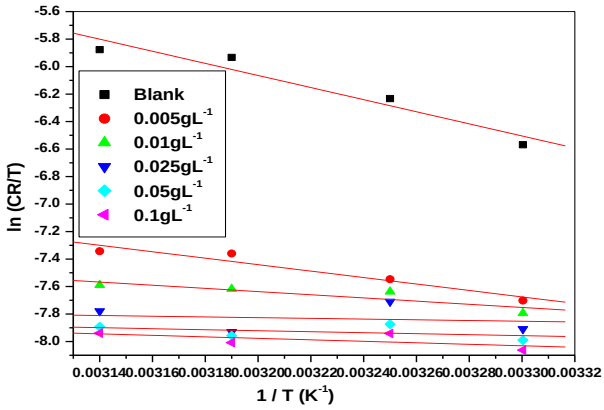

Fig 6: Plots of ln(CR/T) vs 1/T for the corrosion stainless steel in 0.5M HCl containing different concentration of SASE

Table 4: Activation parameter for the corrosion of stainless steel in 0.5M HCl containing different concentrations of SASE

[SASE] g L^{-1}	E_a (kJ mol^{-1})	$\Delta \mathbf{H}_a$ (kJ mol^{-1})	$\Delta \mathbf{S}_a$ (J $mol^{-1} K^{-1}$)
Blank	39.061	36.589	− 189.51
0.005	21.991	19.519	− 197.46
0.01	12.084	9.612	− 201.47
0.025	4.634	2.162	− 204.53
0.05	5.486	3.014	− 204.29
0.1	6.969	4.497	− 203.78

Data for the Activation parameters for corrosion of stainless steel in 0.5M HCl containing different concentrations of SASE are given in Table 4. Energy of activation (Ea) values of the stainless steel in presence of SASE is lesser as compared with absence of inhibitor. This decrease in the Ea value of the inhibited solution is indicates that chemical adsorption of the SASE inhibitor on the surface of the stainless steeland attains equilibrium at higher temperature [19, 20]. The inhibitor molecule gets chemically adsorbed on the metal surface and decreases the electrochemical corrosion process [21, 22, 23]. The positive sign of ΔHa indicates that the endothermic process of stainless steel metal dissolution process [24]. The entropy of activation (ΔSa) data are negative which indicates that, in rate determining step the activated complex is association not dissociation i.e. decrease in the disorderness on going from reactants towards the activated complex [25,26].

3.4 Adsorption isotherm

For understanding the mechanism of adsorption of inhibitor on metal surface and inhibition of stainless steel in acid medium we study the adsorption isotherm. The degree of surface coverage value obtained from the potentiodynamic polarisation studies were applied for various types of various adsorption isotherms such as Langmuir, Freundlich, Temkin and Frumkin and the data was best fitted with Langmuir adsorption isotherm which can be related by the relationship (9)

$$\frac{C}{\theta} = \frac{1}{K} + C \qquad (9)$$

Where, K is adsorption/desorption equilibrium constant ($Lmol^{-1}$), C is the concentration of inhibitor molecule in the electrolyte, then θ is given by the equation (10)

$$\theta = \frac{I.E\ (\%)}{100} \qquad (10)$$

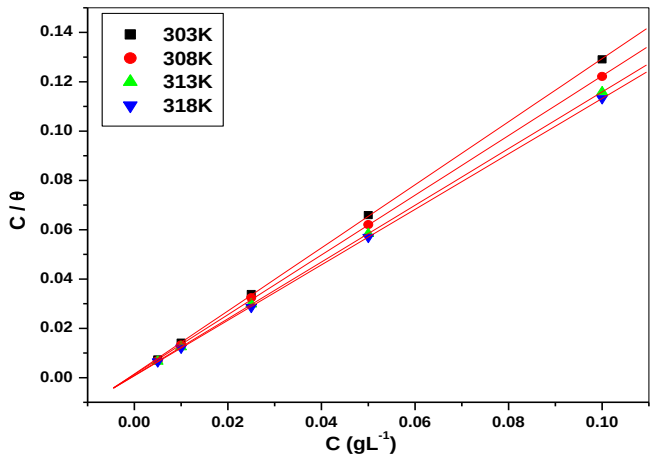

Fig 7: Langmuir adsorption isotherm for the adsorption of SASE on stainless steel in 0.5M HCl at different temperatures.

Figure 7 indicates Langmuir adsorption isotherm plot for stainless steel. The plot of $\frac{c}{\theta}$ versus C gave straight line from the intercept $\frac{1}{K}$ values were obtained. The isotherm slopes showed deviation from the value of unity as would be expected for the ideal Langmuir adsorption isotherm equation. This deviation may be because of the interaction among the adsorbed inhibitor on the metal surface. Standard free energy of adsorption ($\Delta G_{ads}{}^{0}$) can be calculated by using the values of K, which is related by the equation (11).

$$K = \frac{1}{55.55}\exp\left(\frac{-\Delta G^{0}_{(ads)}}{RT}\right) \qquad (11)$$

Where R is universal gas constant, T is the absolute temperature; the value 55.55 in the above equation is the concentration of water in the solution in mol^{-1}.

The values of Standard enthalpy of adsorption (ΔH^{0}_{ads}) and Standard entropy of adsorption (ΔS^{0}_{ads}) were obtained by plotting ΔG^{0}_{ads} verses T in Figure 8. The figure 8 shows linear plot; from the slope of straight line ΔS^{0}_{ads}value and from the intercept of the straight line ΔH^{0}_{ads}values were calculated by using Gibbs Helmholtz equation (12).

$$\Delta G^{0}_{ads} = \Delta H^{0}_{ads} - T\Delta S^{0}_{ads} \qquad (12)$$

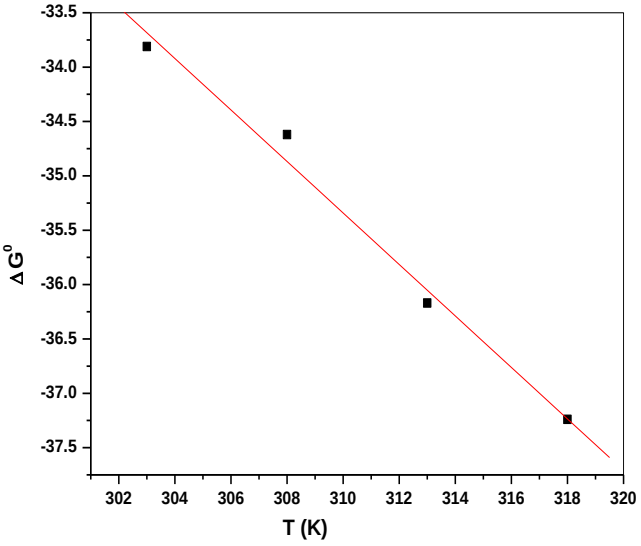

Fig 8: Plot of ΔG^{0}_{ads} vs. T

When theΔG^0_{ads} value up to −20 kJ mol^{-1} then we considered that there is an electrostatic interaction between the negatively charged metal surface and protonated inhibitor moleculei.e. Physisorption. The value is more negative than −40kJmol^{-1} then considered that sharing or transfer electrons from the inhibitor molecule to the surface of the metal through coordinate bond formation i.e. chemisorption [26].

Table 5: Thermodynamic parameters of stainless steel in 0.5M HCl

Temp (K)	ΔG^0_{ads} (kJ mol^{-1})	ΔH^0_{ads} (kJ mol^{-1})	ΔS^0_{ads} (kJ $mol^{-1}K^{-1}$)
303	−33.81		
308	−34.62		
313	−36.17	38.06	0.236
318	−37.24		

Thermodynamic parameters for stainless steel in 0.5M HCl are given in the table 5. The table shows that the negative value ofΔG^0_{ads} imply inhibitor adsorption is spontaneous. The ΔG^0_{ads} value is less than −40 kJ mol^{-1} and increased with increasing the temperature which implies that the adsorption of inhibitor increases with increasing temperatures and also the inhibitor molecules are chemically adsorbed on the surface of the stainless steel [27]. When theΔH^0_{ads} values less than −40 kJmol^{-1} indicates physical adsorption of inhibitor on the metal surface and if it is in between −40 kJmol^{-1} and −100 kJmol^{-1}, then it is considered as chemical adsorption of inhibitor. The table shows the ΔH^0_{ads} value is positive which clearly indicates that chemical adsorption of SAES on the surface of metal.

3.5 Mechanism of corrosion

Based on the adsorption phenomenon the corrosion inhibition of metals in acidic solution can be described. In this present study of work the adsorption of SASE on the stainless steel can be attributed to either sharing of electrons between the hetero atoms and iron or πelectron interaction between the aromatic ring of the SASE and the metal surface [28].

SASE is rich in hetero atoms which have active constituent of SASE is benzyl isothiocyanate shown in Figure 9.

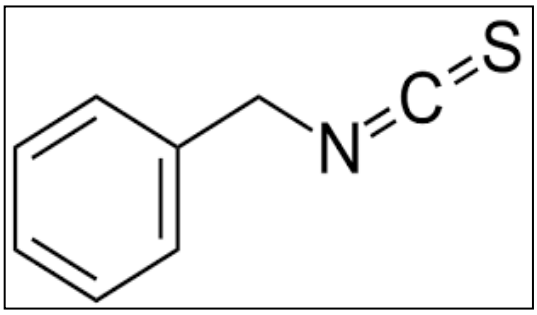

Fig 9: Structure of Benzyl isothiocyanate

The mechanism of inhibition can be predicted from the knowledge of the interaction between the inhibitor molecules and the surface of the metal. In acid solution the mechanism of dissolution of stainless steel takes place as follows.

At the anodic region;

$Fe + Cl^- \rightarrow FeCl^-_{(ads)}$ (13)

$FeCl^-_{(ads)} \leftrightarrow FeCl_{(ads)} + e^-$(14)

$FeCl_{(ads)} \leftrightarrow (FeCl)^+ + e^-$(15)

$(FeCl)^+ \leftrightarrow Fe^{2+} + Cl^-$ (16)

The major cathodic reaction is evolution of hydrogen gas according to the following steps:

$Fe + H^+ \leftrightarrow FeH^+_{(ads)}$ (17)

$FeH^+_{(ads)} + e^- \leftrightarrow FeH_{(ads)}$ (18)

$FeH_{(ads)} + H^+ + e^- \leftrightarrow Fe + H_2$ (19)

The adsorption of the inhibitor molecule is often a displacement reaction [29] involving removal of adsorbed water molecules from the metal surface as shown in the following:

$Inh_{(sln)} + nH_2O_{(ads)} \leftrightarrow Inh_{(ads)} + nH_2O_{(ads)}$ (20)

The vacant 3d orbital of iron can form coordinate type of bond with inhibitor due to the interaction of p-electron clouds of aromatic rings as well as unshared electron pairs on nitrogen or sulphur atoms of the benzyl isothiocyanate leading to predominant chemisorption and prevent the stainless steel from undergoing corrosion in acid medium.

3.6 Surface studies: SEM and EDX

SEM investigation was carried out to differentiate between the surface morphology of the metal surface after its immersion in 0.5M hydrochloric acid for 2 h in the absence and presence of SASE. Figure 10(a) is the SEM image of the freshly polished stainless steel surface. Figure 10(b) shows the cracks due to the corrosive action of 0.5M hydrochloric acid on the stainless steel surface with cracks and rough surface. Smooth sample surface without any visible corrosion attack or pits in the presence of SASE is shown in Figure 10(c). This confirms the adsorption of SASE on the stainless steel surface through the formation of protective film of inhibitor on the metal surface.

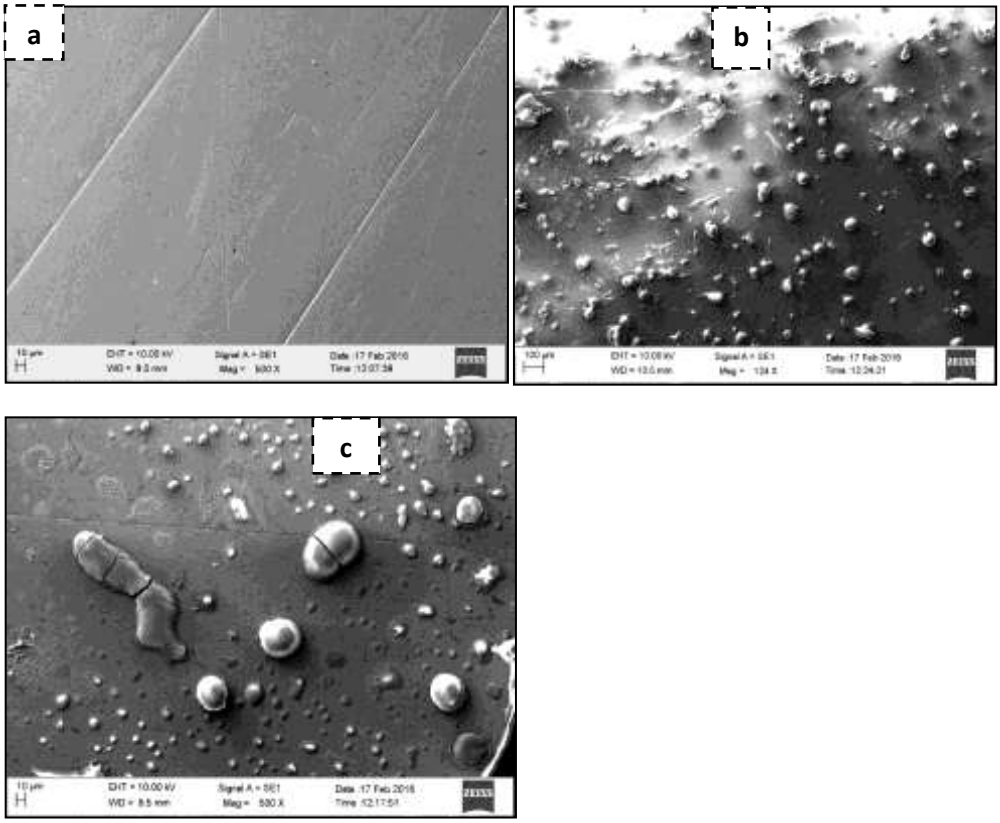

Fig 21: SEM image: (a) Freshly polished surface of SS (b) SS + 0.5 M HCl (c) SS + 0.5 M HCl + 0.1gL^{-1} SASE

Elemental mapping was done with the help of Energy dispersive X ray analysis. Results are tabulated in Table 6.

Table 6: EDX data obtained for stainless steel surface analysis before and after corrosion inhibition with SASE

Elements	% Composition								
	C	Si	Cl	Cr	Mn	Fe	O	Ni	Cu
Freshly polished SS	2.62	0.41	---	18.03	1.89	68.94	---	8.11	0.57
SS in 0.5M HCl	---	0.30	4.60	14.45	1.63	54.45	12.66	6.64	0.55
SS in 0.5M HCl+0.1gL^{-1} SASE	14.1	0.56	2.77	15.65	1.74	59.63	7.34	7.19	---

When the specimen was immersed in the corrosive, there was a peak corresponding to chlorine. (4.60%) This indicates the interaction the medium with the material and hence the corrosion of stainless steel. Corrosion of the material is evident due to decrease in the concentration of the Cr (14.45%) and Ni (6.64%). After the addition of the inhibitor, composition of chlorine is decreased (2.77%). Increase in the composition of carbon content (14.1%) confirms the adsorption of the inhibitor on the metal surface.

4 Conclusion

- Inhibition efficiency of SASE increased with increase in the concentration of inhibitor and with increase in temperature.
- SASE acted as a mixed type of inhibitor for stainless steel in 0.5M HCl medium.
- SASE got chemically adsorbed on the metal surface and obeyed Langmuir adsorption isotherm.
- Surface studies such as SEM, EDX supported to the adsorption of inhibitor on metal surface.
- Results obtained by PDP method and EIS method were in good agreement with one another.
- SASE emerged as a potential green corrosion inhibitor with maximum efficiency of 88.48% at 45 ^{0}C for 0.1g L^{-1} of inhibitor.

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