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The Inhibition Action of *Viscum Album* Extract on the Corrosion of Carbon Steel in Hydrochloric Acid Solution

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Abstract: Corrosion rate of carbon steel (CS) in 1M HCl was examined in the absence and presence of *Viscum album* plant extract as a corrosion inhibitor using weight loss, polarization, and impedance techniques. The effect of temperature and extract dose was studied using a weight loss test. The outcome data gained displayed that *Viscum album* extract plays as an inhibitor for CS in HCl and reduces the corrosion rate. The higher inhibition efficacy reached 96.3% for *Viscum album* at greater inhibitor doses (300 ppm) and temperature. Polarization data revealed that this extract acts as a mixed kind inhibitor. The surface analysis of CS was checked by different methods, which showed the formation of extract film on the CS surface. The adsorption of *Viscum album* plant extract was found to obey the Temkin model, and the data of adsorption free energy was more negative than -40 kJ/mol, which means that the adsorption is chemical.

Keywords: corrosion inhibition; *Viscum album* extract; HCl; Temkin isotherm; adsorption.

1. Introduction

Carbon steel is one of the iron alloys that is commonly used in the manufacture of consumer goods because it has best at low-temperature flexibility, hydrogen-induced cracking, and aqueous solutions of acids are commonly used in the pickling, acid washing of descaling, boilers, and well-acidifying oil industries [1,2]. The chief problem with CS functions is its reasonably small resistance to corrosion in an acidic environment, particularly hydrochloric and sulphuric acid solutions. Plant extracts are shown to be excellent corrosion inhibitors because they are green, simple to obtain, environmentally friendly, and low cost-effective [3]. The green corrosion plant extracts mainly contain the requiring elements (such as O, N, and S) that help molecules be adsorbed on the metals or alloys' surface to form a film that protects the surface from getting corroded [4]. Table 1 employs the use of some plant extracts as inhibitors to lower the corrosion of steel in several typical industrial solutions, which was performed by several authors [5-8]:

Table 1. List of plant sources utilized for dissolution inhibition studies.

Extract	Metal/Medium	IE%	Ref.
Gloriosa superba seeds extract	Carbon steel / H_2SO_4	91	5
Mimosa pudica leaves	Mild steel / HCl	77	6
Peach Pomace Extract	Carbon steel / NaCl	18-90	7
Cola acuminata extract	Carbon steel / HCl	74	8

The current paper aims to understand the resistance of corrosion in a solution of 1M HCl using *Viscum album* extract that is derived from a plant origin. Therefore, this extract's choice as corrosion was made in acidic media based on its non-toxicity, cheap and high solubility. Investigation of corrosion inhibition action of *Viscum album* extract on CS in 1M HCl solutions was made by several techniques.

2. Experimental Techniques

2.1. Materials and reagents.

The acid corrosive environment (1 M HCl) was prepared by diluting a reagent of analytical grade HCl 37% with bi-distilled water. The composition of the applied CS as weight % is: C (0.2%), (Mn (0.35%), P (0.024%), Si (0.003%), and balance Fe. The CS sheet of thickness 0.2 cm was mechanically press-cut into 2×2 cm coupons for weight loss tests. The samples were abraded with varying degrees of emery papers from 400 and 2000 grades, cleaned and washed using acetone, rinsed with bi-distilled water, and dried with filter paper. The coupons were then ready to use in the corrosion studies. Proper doses of the acid were prepared to utilize bi-distilled water. *Viscum album* extract doses vary between (50-300 ppm) in 1.0 M HCl.

2.2. Viscum album procedure.

The got dried plant was ground into little pieces of 5 to 20 mm with a grinder processor, and dissolution happened using bi-distilled water. At that point, 0.1 kg of the got dried plant was adding to 250 ml of bi-distilled water at 80ºC for thirty minutes, at that point store for 24 h and filter by a filter paper then diluted to 1 L by bi-distilled water, lastly kept in a cooling framework in a flask closed with a plastic cover. A large quantity of highly polar compounds, such as "amino acids, monosaccharides, sugar acids, sugar alcohols, peptides, organic acids, nucleobases, and nucleosides" were found in the aqueous extract of the *Viscum album* [9,10], as shown in Figure1 with their ratios:

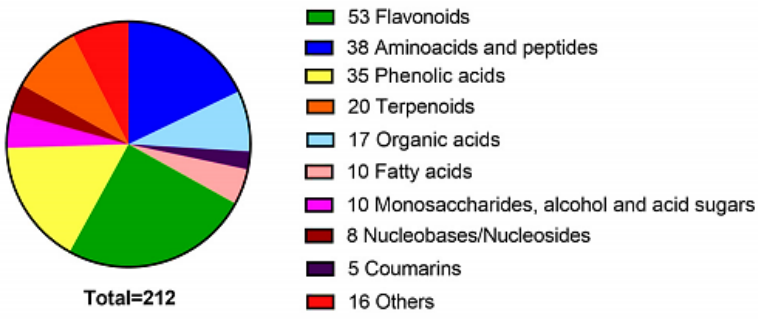

Figure 1. Chemical composition of *Viscum album* extract

2.3. Mass loss (ML) tests.

Carbon steel samples with dimensions 2 x 2 x 0.2 cm were prepared as previous and weighed accurately, then suspended in a solution of 100 ml of the acid corrosive environment without and with (50, 100, 150, 200, 250, and 300 ppm) of *Viscum album* extract for at altered dipping times (3 hours). The average ML at a definite time for these samples were determined after recording the results in each temperature, the surface coverage, θ, and inhibition efficacy, %IE, had been measured utilizing the following equation:

$$\% IE = \theta \times 100 = (W_{inh} - W_{free}) / W_{free} \times 100 \quad (1)$$

where W_{inh} and W_{free} are the MLs of CS specimens in the existence and absence of *Viscum album*, correspondingly [11-13].

2.4. Electrochemical tests.

All electrochemical techniques were utilized through a cell involving three classic electrodes, the working electrode that is utilized CS for study. The second electrode is the reference electrode (saturated calomel electrode, SCE), and the third electrode is the platinum foil. Before each electrochemical procedure, the CS electrode was left 30 min in the solution to give a chance for the open circuit potential (OCP) to attain (a steady-state). Each experiment was achieved on a newly abraded electrode utilizing a freshly prepared electrolyte.

PP acquired by altering the electrode potential from -500 to 500 mV vs. (OCP), with a scan rate of 1 mVs^{-1}.

EIS tests have been performed on the experiment by utilizing AC signals ranging from (100 kHz to 0.1 Hz), with an amplitude of peaks 10 mV at OCP [14, 15]. All the results of impedance were compatible with the appropriate equivalent circuit using the Gamry Echem program,

Electrochemical techniques were achieved by utilizing Potentiostat/ Galvanostat (PCI4-G750) with software DC105, EIS300 for PP and EIS tests, respectively, linked to a computer for data documented and saved.

2.5. Morphology of the surface.

2.5.1 Atomic force microscopy (AFM) analysis.

AFM is an adapted test provide data on the surface examination of CS sample with measured linear purity. Measured knowledge is implemented and valued through persecution From the SPM management computer code [16].

2.5.2. Attenuated total reflection infrared (ATR-IR).

FT-IR spectra were registered in a spectral range 4000 to 500 cm^{-1} with the technique of Attenuated Total Reflectance (ATR) using FTIR-Spectrometer iS 10 (Thermo Fisher Scientific, USA). FT-IR spectrum is an effective way to compare between the inhibitor and corrosion products after inhibitor adsorption. The FT-IR peak values were recorded for *Viscum album* extract and for CS after immersion for 24 hours in the corrosive acid medium with 300 ppm of *Viscum album* extract [17].

2.5.3. X-ray spectroscopy (XPS) examination.

In this study, the morphology of CS metal samples was tested before and after being immersed in a solution of 1 M hydrochloric acid in the presence and absence of *Viscum album* extract (300 ppm) for three hours using electronic X-ray spectroscopy (XPS) and measurements were made using a device ESCALAB 250Xi, Thermo-Scientific, USA. In this technique, CS coupons were handled the same way as previous treatment coupons were treated for an ML experience.

3. Results and Discussion

3.1. ML method.

The corrosion method of CS in an aqueous solution is described by the amount to which it dissolved in the solution [18]. The ML is a conventional test to calculate the rate of corrosion. These tests clearly estimate the *Viscum album* extract's quality and the surface protecting capability of the *Viscum album* at maximum temperatures. This method is proved to be the most accurate test to determine the efficacy of the inhibitor (%IE) and corrosion rate (k_{corr}) (Figure 2 and Table 2).

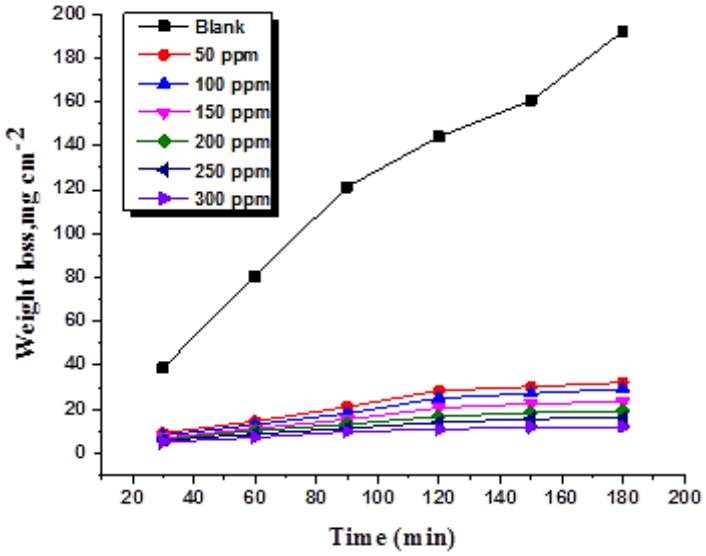

Figure 2. Time-ML curves for the dissolution of CS in 1 M HCl in the attendance and absence of altered doses *of Viscum album* extract at 25℃.

Table 2. Variation of k_{corr}, Θ and %IE for altered doses of *Viscum album* extract at 2 ˚C.

Conc., ppm	k_{corr}, mg cm^{-2} min^{-1}	Θ	%IE
Blank	1.201	----	----
50	0..238	0.802	80.2
100	0.209	0.826	82.6
150	0.172	0.857	85.7
200	0.139	0.884	88.4
250	0.116	0.903	90.3
300	0.09	0.925	92.5

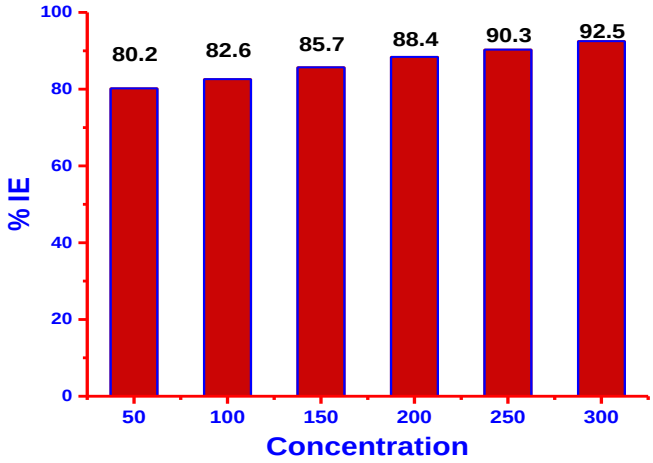

Figure 3. Variation of %IE with CS doses in 1 M HCl for *Viscum album* extract at 25°C.

The ML test is usually preferred because the quantity calculated was directly proportional to the amount of dissolution. The difference of ML with time in uninhibited and inhibited aerated acid indicates the absence of insoluble surface films through corrosion where the *Viscum album* extract is first adsorbed on the CS surface, therefore, decreased the corrosion rate and increased %IE by blocking the active centers on CS surface Figure 3.

3.2. Effect of temperature.

The %IE of CS corrosion in the attendance of altered doses of the *Viscum album* extract at various temperatures (25-45˚C) was achieved by Eq. (1). "It was established that the ML improves with raising the temperature from 25ºC till it reached 45ºC. This can be described as conferring to the rule that higher temperatures might give rise to a protective layer formed on CS surface. They are suggesting that the *Viscum album* extract species are adsorbed on the CS /solution interface chemically and form a coated film on the CS surface, which hindrance the action of the corrosion". A rising in the *Viscum album* extract efficacy with increment temperature was detected, demonstrating that *Viscum album* extract adsorbed on CS surface at these conditions chemically and reveals that the corrosion rate (k_{corr}) of CS in HCl in the presence of *Viscum album extract* decreases as temperatures increased as shown in Table 3.

Table 3. Variation ML (k_{corr}, (mg cm^{-2} min^{-1}) and θ for the dissolution of CS in 1M HCl without and the existence of altered doses of *Viscum album* extract at different temperatures.

Conc, ppm	25ºC		30ºC		35ºC		40ºC		45ºC	
	$k_{corr.}$	Ɵ	$k_{corr.}$	Ɵ	$k_{corr.}$	Ɵ	$k_{corr.}$	Ɵ	$k_{corr.}$	Ɵ
Blank	1.201	----	1.433	----	2.334	----	4.742	----	5.417	----
50	0..238	0.802	0.272	0.81	0.413	0.823	0.792	0.833	0.894	0.835
100	0.209	0.826	0.225	0.843	0.334	0.857	0.653	0.862	0.661	0.878
150	0.172	0.857	0.186	0.870	0.285	0.878	0.473	0.900	0.498	0.908
200	0.139	0.884	0.142	0.901	0.224	0.904	0.389	0.918	0.412	0.924
250	0.116	0.903	0.119	0.916	0.154	0.934	0.294	0.938	0.303	0.9422
300	0.09	0.925	0.095	0.934	0.11	0.953	0.199	0.958	0.200	0.963

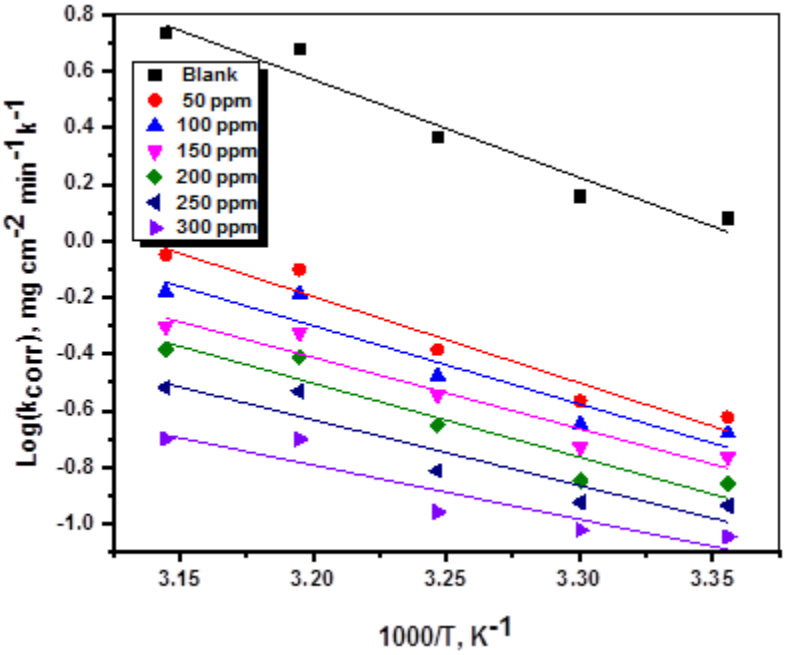

Figure 4. log k_{corr} of CS vs. 1000/T in the absence and attendance of altered doses of *Viscum album* extract in 1M HCl.

3.3. Thermodynamic corrosion parameters.

The activation energy (E_a^*), the enthalpy ($\Delta H^{*)}$ and entropy of activation (ΔS^*) for the dissolution of CS in hydrochloric acid solution in the attendance and absence of altered doses of *Viscum album* extract at 25- 45 °C were measured from Arrhenius Eq. below [19]:

$$(k_{corr}) = A \exp(-E_a^*/RT) \quad (2)$$

where "A is the Arrhenius pre-exponential factor, and h is the Planck's constant". A drawn of 1 / T vs. log k_{corr} displayed in Fig. (4). ΔH^* and ΔS^* for the transitional complex were acquired by relating the transition state [20].

$$(k_{corr}) = RT/Nh \exp(\Delta S^*/R) \exp(-\Delta H^*/RT) \quad (3)$$

A draw of log (k_{corr} / T) against 1 / T would give straight lines from which the data of $\Delta H^*$and ΔS^* were intended, correspondingly as displayed in Figure 5.

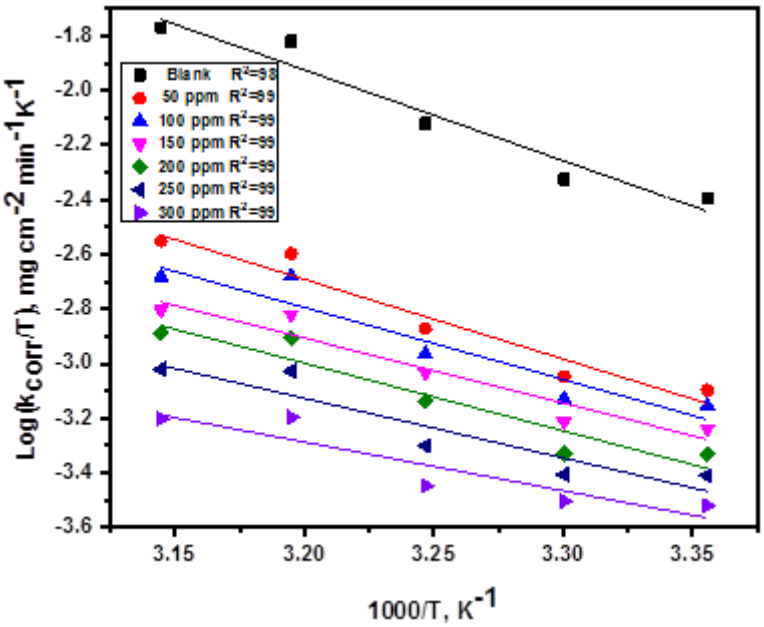

Figure 5. log k_{corr} of CS vs. 1000/T in the absence and attendance of altered doses of *Viscum album* extract in 1M HCl.

Table 4. Kinetic parameters of Arrhenius and transition state equations.

Compound	Conc. ppm	E_a^* kJ mol^{-1}	ΔH^* kJ mol^{-1}	$-\Delta S^*$ J mol^{-1} K^{-1}
Blank	1 M HCl	66.24	63.61	30.48
Viscum album	50	58.47	55.90	70.12
	100	53.01	50.43	89.55
	150	48.19	45.61	107.13
	200	49.97	47.48	102.89
	250	44.40	41.82	123.50
	300	36.70	34.08	151.13

As displayed in Table 4, E_a^* has lesser values in the solution containing the *Viscum album* extract than that of the *Viscum album*'s absence. "The lowered in the E_a^* on the protected solutions lead to the higher IE of *Viscum album* extract. The decrease data of the E_a^* refers to the adsorption of *Viscum album* extract on the CS surface chemically and creating a stable metal-inhibitor complex. ΔH^* have a positive symbol designates endothermic procedure and designates strong adsorption of *Viscum album* extract on the CS" and confirm the chemical adsorption of the extract on CS surface. ΔS^* have negative data that leads to the activated

complex in the rate-determining stage. It demonstrates coagulation not an isolated, that designates the reduction in disorder [21].

3.4. Adsorption isotherm.

The analysis of adsorption isotherm offers some supporting details on the corrosion inhibition process. After examination of all adsorption isotherms, we conclude that the best isotherm that fits the results is Temkin isotherm, so:

$$\Theta = 2.303/a \log K_{ads} + 2.303/a \log C \quad (4)$$

where "C is the dose (M), K_{ads} is the adsorption equilibrium constant, (a) is a molecular interaction parameter". A graph of θ against log C gives straight lines as appeared in Fig.6. Thermodynamic parameters of adsorption were calculated and tabulated in Table 5. The essential parameters were calculated as ($\Delta G°_{ads}$), ($\Delta H°_{ads}$) and ($\Delta S°_{ads}$) after assessment of K_{ads}. at various temperatures Fig.7. The change in free energy can be calculated from Eq. (5):

$$\log K_{ads} = 1/55.5 \exp(\Delta G°_{ads}/2.303RT) \quad (5)$$

where 55.5 is to the water dose in (mol/L) at the interface of solution/metal. The counted values of K_{ads} and $\Delta G°_{ads}$ were tabulated in Table 5. The negative values of $\Delta G°_{ads}$ point out that the adsorption process of the extract on the CS surface is spontaneous. The higher values for $\Delta G°_{ads}$ lie between 45.7 to 49.9 kJ/mol for *Viscum album* extract exhibiting chemisorption [22]. The enthalpy of adsorption ($\Delta H°_{ads}$) was computed utilizing the following Vant Hoff Eq.:

$$\log K_{ads} = -\Delta H°_{ads}/2.303RT + \text{constant} \quad (6)$$

Plotting $\log K_{ads}$ versus 1/T gives a straight line, as shown in Fig. 7. The entropy of adsorption ($\Delta S°_{ads}$) can be calculated from the following Eq.:

$$\Delta S°_{ads} = (\Delta H°_{ads} - \Delta G°_{ads})/T \quad (7)$$

The calculated $\Delta H°_{ads}$ and $\Delta S°_{ads}$ values are listed in Table 5. $\Delta H°_{ads}$ was 18.3 kJ mol^{-1} for *Viscum album* extract with a positive signal signifying endothermic reaction, which expected to be more chemisorption than physisorption. The calculated values of $\Delta S°_{ads}$ point out that an entropy decrease accompanied the process of adsorption.

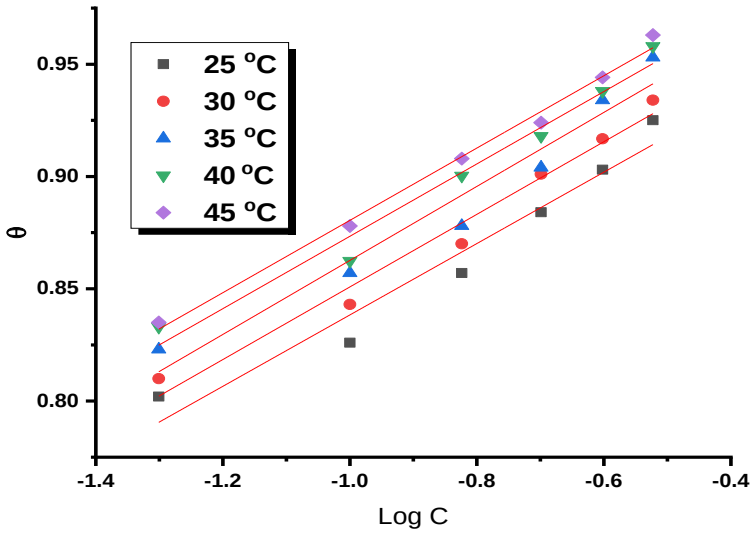

Figure 6. log C of *Viscum album* extract with Θ Applied at altered temperatures in 1M HCl.

Table 5. Adsorption parameters for CS in the corrosive acid medium in the existence of *Viscum album* extract at altered temperatures.

Temp., °C	R^2	Intercept	Log K_{ads}	$-\Delta G_{ads}$ kJ mol^{-1}	ΔH_{ads} kJ mol^{-1}	ΔS_{ads} J $mol^{-1}K^{-1}$
25	0.958	0.997	6.27	45.7	18.3	61.5

Temp., °C	R^2	Intercept	Log K_{ads}	$-\Delta G_{ads}$ kJ mol^{-1}	ΔH_{ads} kJ mol^{-1}	ΔS_{ads} J mol^{-1}K^{-1}
30	0.978	1.012	6.30	46.6		60.5
35	0.952	1.027	6.34	47.7		59.5
40	0.974	1.034	6.41	48.9		58.6
45	0.996	1.041	6.46	49.9		57.6

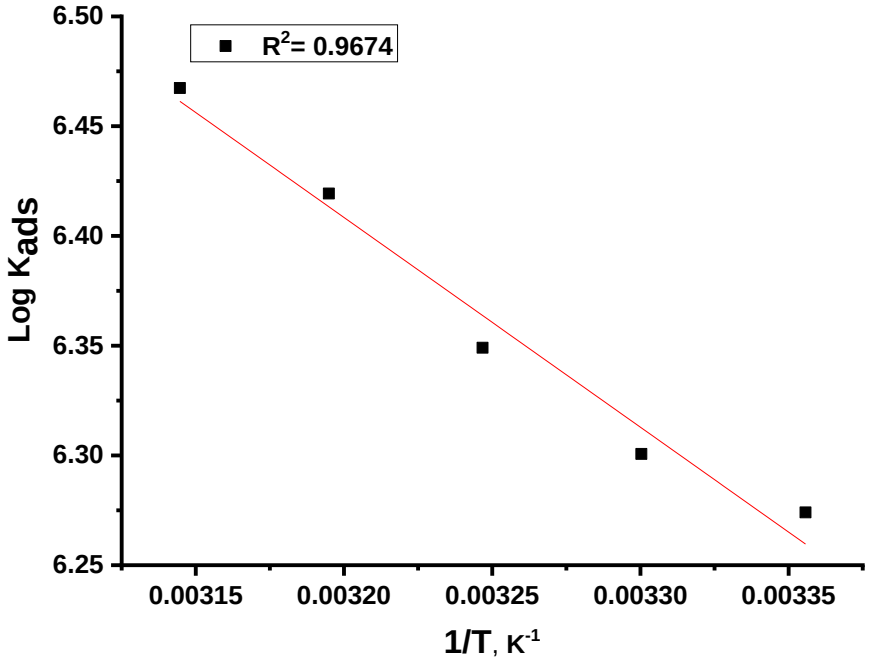

Figure 7. log K_{ads} vs. temperature 1/T (Van Hoff equation).

3.5. Potentiodynamic polarization (PP)measurements.

Anodic and cathodic diagrams from PP tests at 25℃ for CS in the acid corrosive medium with and without altered doses of *Viscum album* extract were documented in Figure 8. "kinetic parameters as corrosion current (i_{corr}), corrosion potential (E_{corr}), and Tafel slopes β_a and β_c were gotten from the obtained figure and are shown in Table 6 for CS in 1M HCl corrosive environment. %IE rises with increasing the doses of the *Viscum album* extract. Figure 8 demonstrates that the $i_{corr.}$ data reduced by adding the extract, which lowered the CS oxidation indicating that *Viscum album* extract is a good inhibitor for CS corrosion in the acidic environment [23]. The increase of the *Viscum album* extract dose affects the anodic and cathodic directions of the PP diagrams. The parallel lines of the Tafel lines after the addition of the *Viscum album* extract indicate no change in the mechanism". As seen from Table 6, the corrosion potential (Ecorr) value change after adding the Viscum album extract is less than 85 mV, which proves a mixed-kind inhibitor [24-27]. %IE and θ can be calculated from PP measurements as illustrated in Eq. (8):

$$\%IE = \theta \times 100 = [1 - (i_{corr} / i^{o}_{corr})] \times 100 \quad (8)$$

where i_{corr} and i^{o}_{corr} are the corrosion current with *Viscum album* extract and without it, correspondingly.

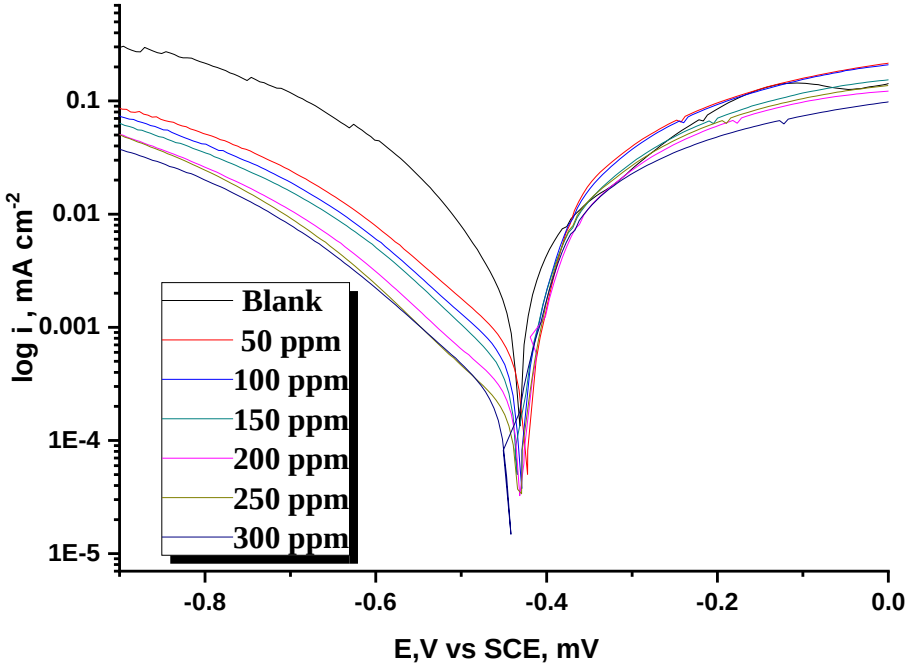

Figure 8. PP diagrams for CS in the HCl medium without and with altered doses of *Viscum album* extract at 25°C.

Table 6. Electrochemical parameters were calculated by PP procedures for CS in HCl medium without and with altered doses of *Viscum album* extract at 25°C.

Con. ppm	i_{corr}, μA cm^{-2}	- E_{corr}, mV vs SCE	β_a mV dec^{-1}	β_c mV dec^{-1}	C.R mpy	Θ	% IE
Blank	995	433	120.0	151	390	--	--
50	240	420	118	144	261	0.759	75.9
100	210	419	119	141	255	0.789	78.9
150	181	422	113	141	241	0.818	81.8
200	144	412	111	147	231	0.855	85.5
250	129	409	103	149	228	0.870	87.0
300	99	400	100	148	122	0.900	90.0

3.6. EIS test.

Nyquist and Bode diagrams obtained for CS dipping in 1.0 M HCl in the attendance and nonattendance of altered doses of *Viscum album* extract are displayed in Figs.10 &11. EIS parameters are given in Table 7. The equivalent circuit utilized to appropriate the EIS values was given in Figure 9. This circuit consists of stationary phase elements (CPE) rather than capacitors to give many heterogeneity types ideal for corrosion electrodes. Nyquist diagrams (Figure 10) showed that the semicircle diameter increases with the *Viscum album* extract dose rise. Subsequently, the charge transfer impedance is improved by the corrosion reaction. Nyquist plots' semi-circular shape proves that the process of charge transfer essentially controls the corrosion of CS [28]. The formed *Viscum album* film on CS surface minimizes the double-layer capacitance (C_{dl}) and increases the charge transfer resistance (R_{ct}). The interfacial capacitance C_{dl} data can be estimated from CPE parameter (Y_0 and n) is defined in next Eq.:

$$C_{dl} = Y_0 (\omega_{max})^{n-1} \quad (9)$$

where "Y_0 is the CPE magnitude, and n is the variance CPE data of the: -1 < n < 1". From Table 7, we observed a lower in the data of C_{dl} with an addition in the dose of *Viscum album* extract, due to a lower in the local dielectric constant and/or rises in the thickness of the electrical double-layer [29]. %IE and θ from EIS measurements were calculated as shown below:

$$\%IE = \theta \times 100 = [1 - (R^{o}_{ct}/ R_{ct})] \times 100 \quad (10)$$

where R_{ct} and R^{o}_{ct} represent with *Viscum album* and without it, respectively

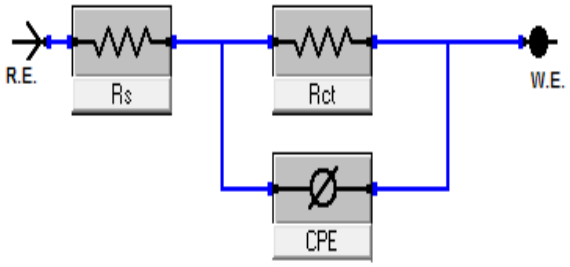

Figure 9. The equivalent circuit for fitting the EIS values.

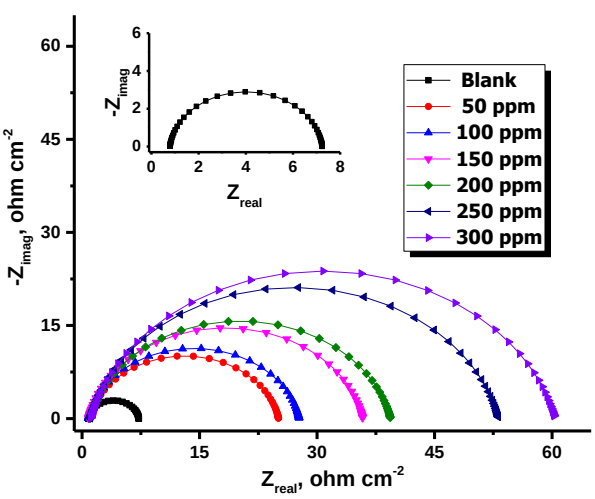

Figure 10. The Nyquist plots for CS dissolution in 1M HCl existence and nonexistence of altered doses of *Viscum album* extract at 25°C

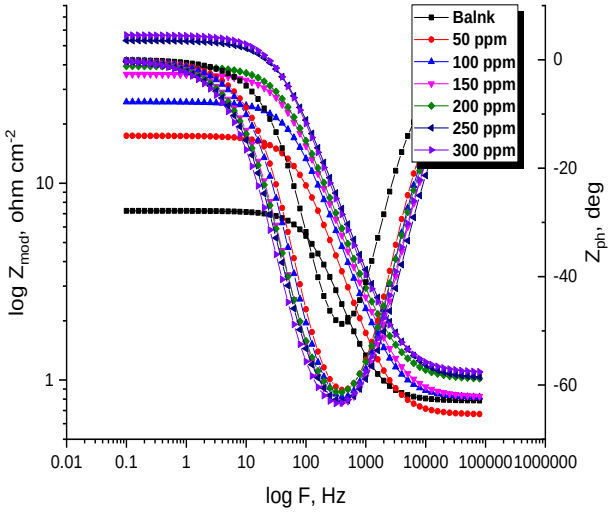

Figure 11. The Bode plots for CS dissolution in 1M HCl attendance and absence altered dose of *Viscum album* at 25°C

Table 7. EIS results for the dissolution of CS in 1.0 M HCl acid at altered doses of *Viscum album* extract at 25°C.

Conc., ppm	Y_ox 10^6 ($\mu\ \Omega^{-1}\ s^n\ cm^{-2}$)	n	R_{ct}, $\Omega\ cm^2$	C_{dl}, $\mu F\ cm^{-2}$	Θ	% IE
1 M HCl	313	0.931	6	200	----	----
50	183	0.910	24	107	0.750	75.0
100	179	0.906	28	103	0.786	78.6
150	163	0.885	39	85	0.846	84.6
200	161	0.873	42	78	0.857	85.7
250	155	0.866	58	74	0.897	89.7
300	151	0.858	61	69	0.902	90.2

3.7. Atomic force microscope (AFM) analysis.

The CS morphology surface was analyzed using AFM experiments after dipping in 1 M HCl in attendance and absence of 300 ppm of *Viscum album* extract for 24 h immersion, it can be gained regarding the roughness on the surface. "The mean roughness profile (Sa) values play an important role in identifying and reporting the efficacy of the extract under study [30]. Among the roughness, take a role in explaining the nature of the adsorbed film on the surface. Figure 12a gives the surface of the metal that was damaged by HCl (blank), which display high roughness (Sa=668)" and Figure 12b shows the surface of the CS in the

existence of 300 ppm of *Viscum album*, which is not affected by corrosion and becomes lower roughness (Sa=179).

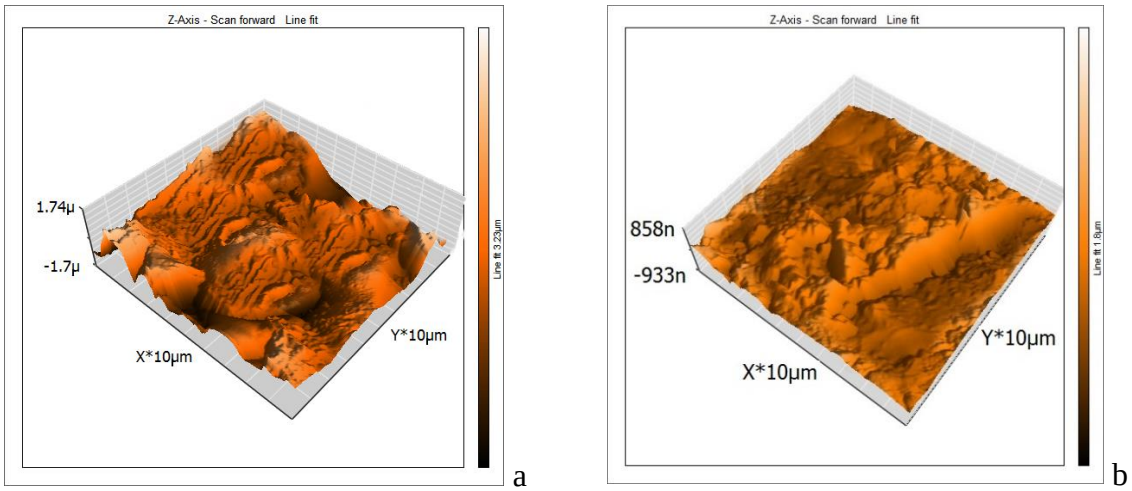

Figure 12. (**a**) An image was obtained for the immersion CS specimen in 1 M HCl without *Viscum album* extract; (**b**) referred to CS specimen after immersion of 1M HCl + 300 ppm *Viscum album* extract for 24 hours.

3.8. Fourier Transform Infrared Spectroscopy (FTIR) Characterization.

FTIR analysis of the extract was utilized to characterize the functional groups in it, while that of the corrosion product was utilized to check that the inhibition comes from the interaction between the metal and the extract [31]. "The FTIR spectra for crude *Viscum album*, *Viscum album* extract in 1M HCl solution, and the corrosion products are presented in Fig. 13. The results obtained indicate that the interaction between the extract and the CS resulted in the inhibition process. FTIR of *Viscum album* in 1M HCl displayed functional groups O-H, carboxylic acid O–H stretching vibration, C=O, C-H, C-O, aromatic C–H bending vibration and NH contain oxygen and nitrogen atoms and unsaturated (C=C). The oxygen and nitrogen atoms in the extract give the general features of model corrosion inhibitors". The moves in the spectra in the existence of the CS to *Viscum album* extract in 1M HCl due to interaction among Viscum album extract and the CS through the functional groups' attendance in the Viscum album extract resulted in protection.

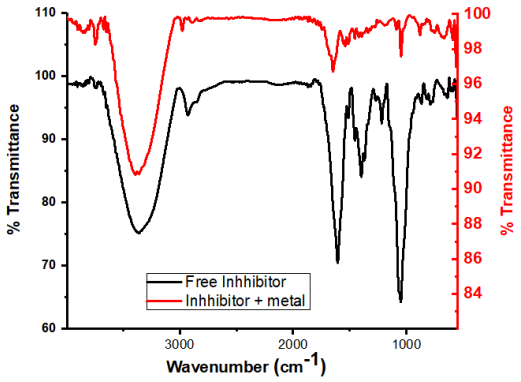

Figure 13. FTIR of *Viscum album* extract alone and HCl + *Viscum album* after 24h immersion.

3.9. XPS analysis.

The formed layer of the extract on the surface of the CS metal in 1M HCl, proving the adsorption nature of the *Viscum album* extract. Figure 14 shows the XPS decomposition spectra for each element separately, which are found in the surface layer formed in a solution that controls the existence of the *Viscum album* extracted. The CS metal spectra recorded when

dipped in a 1.0M HCl inclosing the highest concentration of *Viscum album* extract (300 ppm) were for Cl 2p, Fe 2p, O 1s, N1s, and C1s. Table 8 shows the binding energies date (BE, eV) and the same assignment for every peak constituent [31]. Different peaks were observed at binding energy data of the Cl 2p, Fe 2p, O 1s, N1s, and C1s, which were found in 1 M hydrochloric acid and 300 ppm of *Viscum album* extract. Previous results obtained from XPS analysis established the adsorption of *Viscum album* molecules on the CS surface.

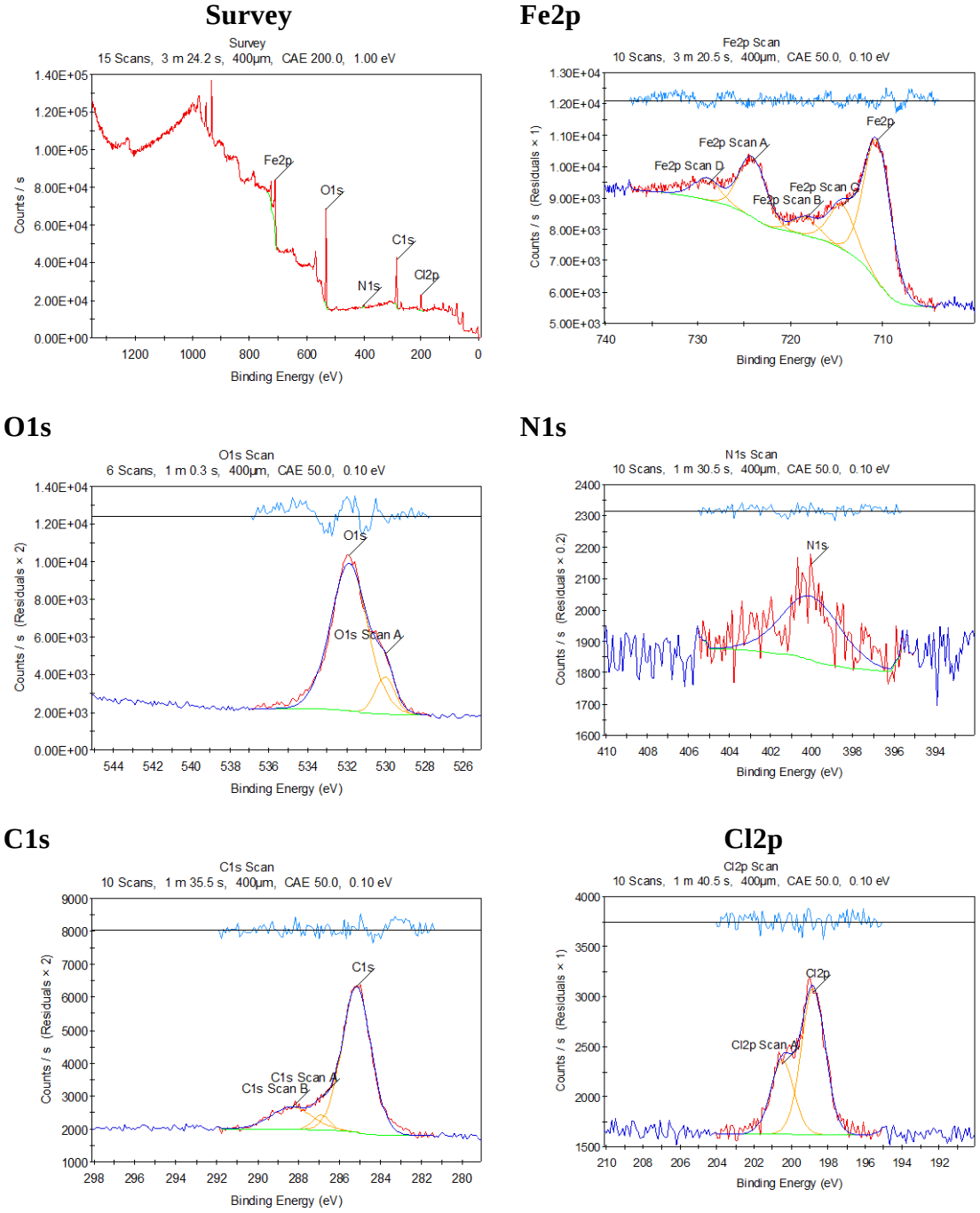

Figure 14. Photoelectric X-rays results from Survey, Fe2p, O 1s, N1s, C1s, and Cl2p for CS at 1M hydrochloric acid solutions with 300ppm from *Viscum album* extract.

3.10. Mechanism of inhibition.

The mechanism of adsorption and protection of *Viscum album* extract in HCl solution can be clarified as the chemisorption process.

Table 8. Binding energies (eV) for the large core lines observed for the surface of CS, which is handled by *Viscum album* extract.

Core element	BE, eV	Assignments
C1s	285.17	C-C, -C=O, C-H
	286.91	
	288.34	
O1s	531.87	Fe_2O_3 , $Fe(OH)_3$
	530.03	
N1s	400.03	N-Fe
Fe2p	710.59	Fe_2O_3/ Fe_3O_4/ FeOOH $FeCl_3$
	724.07	
	718.34	
	714.41	
	728.99	
Cl2p	198.8	Cl 2p3/2

The coordinate bond is formed among the *Viscum album* molecules and the metal surface by sharing or transferring the electrons. The corrosion inhibition of the *Viscum album* molecules is, in fact, due to the existence of electron donor groups (O and N) and π-electrons on an aromatic ring in its *Viscum album* molecules. The existence of transition metal with unoccupied d-orbital and *Viscum album* with chemical constituents containing π-electrons and hetero atoms with a free lone pair of electrons (N, O, S) is necessary and widely aid in the adsorption process. The interactions among the vacant d-orbitals of iron atoms (an electron acceptor) and the π-electrons on the ring (an electron donor) facilitate *Viscum album* molecules' adsorption by chemical adsorption. The *Viscum album* molecules can form an insoluble complex by reacting with the Fe2+ present on the CS surface and making a barrier on the metal surface [32, 33].

4. Conclusions

The impact of *Viscum album* extract as a green corrosion inhibitor for the CS in aqueous environment was performed utilizing ML, PP and EIS techniques. The ML, PP, and EIS measurements support the assumption that corrosion inhibition primarily occurs through adsorption of the *Viscum album* molecules on the CS surface following Temkin adsorption isotherm. PP data revealed that this extract acted as a mixed kind inhibitor. The %IE depends upon the temperature and doses of the extract. Agreement among these different independent techniques indicates the validity of the obtained results. *Viscum album* extract adsorbed on the CS surface and via the free electrons of oxygen or nitrogen atoms in addition to the electrons in benzene rings. The adsorbed protective film was confirmed using AFM, FTIR, and XPS techniques. This study shows that *Viscum album* extract has proven to be an important, environmentally friendly, and low-cost inhibitor for CS in acid medium.

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Conflicts of Interest

The authors declare that there is no conflict of interest between them and anybody else.

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