Adenine as Environmentally- Friendly Corrosion Inhibitor for Stainless Steel in Sodium Chloride Acid Solution

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Abstract

The corrosion behavior and the influence of the concentration of adenine (AD) on the corrosion of 316L stainless steel in 0.6 mol.dm^{-3} sodium chloride acid solutions were studied. The research was performed in two pH values (pH=2 and pH=4) over the temperature range (293- 308)K. The investigation involved electrochemical polarization method using potentiostatic technique. Tafel polarization study revealed that (AD) acted as a mixed inhibitor. The inhibition efficiency increased with an increase in the concentration of adenine, but decreased with increase in temperature. (efficiency= 87% at 0.01 M AD & at T= 293K). The adsorption of (AD) has been found to occur on the surface of 316L stainless steel according to the Langmuir isotherm. The kinetic and thermodynamic parameters for stainless corrosion and adenine adsorption respectively were determined and discussed.

Key Words: Stainless steel; Adenine, Tafel polarization, kinetic parameters, Thermodynamic parameters.

1. Introduction

Stainless steel has found very wide applications both in modern chemical industries and other places such as desalination plants, construction materials, pharmaceutical industry thermal power plants, chemical cleaning and pickling process due to high strength, workability and weldability. The corrosion of stainless steel in acidic solutions has become a fundamental academic and industrial concern that have received a considerable amount of attention, since aggressive acid solutions are widely used for industrial purposes[1].

The anticorrosive properties of the stainless steel materials which a chromium contained higher than 12% are assigned to the spontaneous formation on the surface of a passive thin film layer, mainly composed of chromium and iron oxide/ hydroxides[2]. The rate of corrosion of stainless steel can be reduced by a thin oxide layer formed naturally on the metal surface[3]. Passive films an surface of stainless steel form in an aqueous acid environment are usually very thin, compact and highly enriched in chromium[4,5]. Despite the established corrosion resistance of stainless steel can be chemically attacked by acids, and some organic compounds. The passive layer of the steel is eroded by these acids resulting in corrosion of the stainless steel.

Corrosion control is important in extending the life of equipment. Organic compounds with functional groups containing nitrogen, sulfur and oxygen are widely used as corrosion inhibitors to prevent or minimize material loss during contact with acid. The inhibitors can be adsorbed on the metal surface through donation of electrons such as π electrons in aromatic rings or unpaired electrons and multiple bonds[6,7].

Physisorption and chemisorption are two types of interactions between organic inhibitors and metal surface. The adsorption of inhibitors depends on several factors such as type of acid, distribution of charge in molecule, nature and surface charge of metal and type of interactions between inhibitors and metallic surface[8,9].

Most of the inhibitors are toxic in nature, therefore, their replacement by environmentally benign inhibitors is necessary. These compounds include such amino acids and its derivatives which have tested in acid solutions of various metals[10,11].

An important N-hetero cyclic compound, purine (Pu) and purine derivatives are non toxic and biodegradable, which makes the investigation of their inhibiting properties significant in the context of the current priority to produce eco-friendly inhibitors. Recently, purine and adenine (AD) have been studied as[12] corrosion inhibitors of copper in aggressive solutions. However, it appeared that purine considerably slows down corrosion of stainless steel[13,14].

The industrial consumption and development of new corrosion inhibitors have been continuously increasing of the years.

The present work reported the inhibitive effect concentration of adenine (AD) and temperature on the corrosion of 316L stainless steel in sodium chloride acid solution.

2. Experimental Part

2.1 Materials

The experiments were performed with stainless steel type 316 L specimens in the form of disks with the following composition in Table(1).

All chemicals and reagents used are with analytical grade and used without further purification, they include:

a. Sodium chloride (analar grade) was used for preparation of the electrolyte solution of concentrations (0.1, 0.3 and 0.6) mol. dm^{-3}.

b. Hydrochloric acid (analar grade).

c. Adenine $C_5H_5N_5$ (> 99.4%) was purchased from merck (Darmstadt, Germany)

2.2 Solutions

The aggressive solutions used were made of AR sodium chloride to prepare three different concentrations (0.1, 0.3 and 0.6) mol. dm^{-3} in two pH values (pH=2 and pH=4). Double distilled water was used for preparation, and for each experiment a freshly made solution was used.

2.3 Potentiostatic polarization measurements:

The potentiostatic polarization measurements were carried out with specimens of 316L stainless steel which were cut in circular form [2cm diameter and 0.2 cm thickness] having an exposed surface area of 1 cm^2 to corrosive medium. The working electrode (316 L SS) was abraded mechanically and successively with different grades of emery paper [100,200, 400, 800, 1200 and 2000] and washed with double distilled water. Further the samples were degreased with acetone and thoroughly washed with distilled water then dried in air and kept in a desicator until use.

Polarization experiments were carried out in a conventional three- electrodes cell with 316L SS specimens of 1cm^2 exposed area, a platinum electrode and silver- silver chloride in saturated KCl were used as working, auxiliary (counter) and reference electrodes respectively. The measurements were performed using M lab potentiostat/ Galvanostat 200 Germany obtained from Bank Electronic Intelligent controls Gnb H. it was connected to personal by computer desktop. The M lab software cares for controlling the potentiostat, recording and processing data. It provides with electrochemical calculations like tafel line evaluation, re-scaling of the potential and integration.

The experiments were performed in the electrolyte solutions of (0.1, 0.3 and 0.6)mol.dm^{-3} NaCl in two values of pH (2 and 4) in absence and presence of three different concentrations of the inhibitor (adenine) over the temperature range (293- 308) K. The experiments were carried out at a scan rate of 10 mV/s. corrosion current density (i_{corr}) and corrosion potential (E_{corr}) were determined from the polarization curve, in addition other information were obtained such tafel slopes (b_c and b_a), weight loss and penetration. In order to test the reproducibility of the results, the experiments were done in triplicate.

3. Results and Discussions

Figures 1 and 2 show the anodic and cathodic polarization curves of 316L stainless steel in 0.6mol.dm^{-3} NaCl solution at four temperatures in the range of (293-308)K and two pH values (pH= 2 and pH= 4).

Tafel extrapolation method was used to calculate the corrosion parameters from the polarization curves.

The resulting data were displayed in Table (2) and these data show that corrosion current density (i_{corr}) increases with increasing temperature and concentration of NaCl solution. Also it was noticed that all values of (i_{corr}) at pH= 2 are more than those at pH= 4 at all temperatures of study which indicate that 316L SS has more tendency to corrode in more acidic medium, and this result is enhanced by the values of penetration and weight loss. (Table2) Corrosion potential (E_{corr}) values, mostly show less negative values at pH=2 than pH=4 at all temperatures.

The shift of the corrosion potential to the noble direction (Less negative) implies generally the tendency of 316L SS specimen for corrosion under certain conditions, also the variation of E_{corr} reflects the heterogeneous reaction on 316L SS surface.

Anodic and cathodic tafel slopes show variation in their values which can be attributed to the variation of the rate determining step (r.d.s) of the metal dissolution reaction (Anodic) and the charge transfer process (desorption or electrochemical desorption) cathodic.[16]

3.1 Temperature dependence of the corrosion current density

The rate of 316L SS corrosion (r) (Which is expressed by i_{corr}) at a given concentration increased considerably with the rise of temperature. The dependence of the corrosion current density (i_{corr}) on temperature followed Arrhenius equation [17]:

$$\text{rate (r)} = i_{\text{corr}} = \text{A exp} (- E_a/RT) \ldots\ldots\ldots\ldots (1)$$

Which can be expressed in logarithmic form :

$$\text{Log } i_{corr} = \text{LogA} - \frac{E_a}{2.3RT} \ldots\ldots\ldots (2)$$

Where **A** and **E_a** are respectively the pre-exponential factor and the activation energy of corrosion reaction. A typical linear plot relating values of log i_{corr} to the reciprocal of temperature $\left(\frac{1}{T}\right)$ is shown in Figures 3 and 4.

The values of E_a could be derived from the slope of the line, and when the linear plot of Figures 3 and 4 was extrapolated to log i_{corr} value at $\frac{1}{T} = 0$, the value of A could be obtained.

Table 3 presents the values of **E_a** and the pre-exponential factor **A** for 316L SS corrosion in two pH values 2 and 4. It was found that there is a direct relation between the values of **E_a** and **A**, i.e. simultaneous increase or decrease in **E_a** and **log A** for particular system which can be ascribed to the compensation effect which describe the kinetics of catalytic and tarnishing reaction on the metal [18].

Entropy of activation (ΔS*) was calculated from the value of **A** using the relationship:

$$\mathbf{A} = \frac{\mathbf{K.T}}{\mathbf{h}} \mathbf{exp} \left(\frac{\Delta S^*}{R}\right) \ldots\ldots\ldots\ldots\ldots (3)$$

Where K is Boltzmann constant, h is Plank constant, R is the universal gas constant and T the temperature of the solution.

The negative values of the entropy of activation (ΔS*) for 316L SS corrosion implies a loss in the over-all degrees of freedom throughout the formation of the activated complex for the reaction of 316L SS constituent with negative species (Cl^- & OH^-) leading to the formation of corrosion product, when the activated complex results.

Only after considerable arrangements of the structure of reaction molecules, making the complex a less probable structure, ΔS* is negative and the reaction will be slower [19].

3.2 Corrosion inhibition of 316 L stainless steel (SS) by adenine

Figures 5 and 6 show the typical polarization curves of 316L SS in 0.6 mol.dm^{-3} NaCl solutions containing three different concentrations of adenine as inhibitor over the temperature range (298-303) K. Table 4 presents the polarization data (E_{corr} and I_{corr}) and from these data it can be noticed that the addition of adenine caused a decrease in corrosion current densities of 316L SS, and the inhibition effect of adenine increases as the concentration of the inhibitor increased in the range ($10^{-2} – 10^{-3}$) mol.dm^{-3} at all temperatures of study.

Table (5) shows the values of inhibition efficiencies (IE%) which are calculated from equation (4):

$$\text{IE\%} = \frac{i^{\circ}_{\text{corr}} - i_{\text{corr}}}{i^{\circ}_{\text{corr}}} \ldots\ldots\ldots\ldots (4)$$

Where: i°_{corr} and i_{corr} are corrosion current densities in absence and presence of the inhibitor respectively.

The activation parameters such as: the activation energy E_a^* and the entropy of activation (ΔS_a^*) in the range of studied temperatures (293-308)K for corrosion inhibition of 316L stainless steel in 0.6 mol.dm^{-3} NaCl solution in the presence of various concentrations of adenine were calculated from Arrhenius -type plot:

$$i_{\text{corr}} = \text{A exp} \left(\frac{-E_a}{RT}\right) \ldots\ldots\ldots\ldots (5)$$

The calculated values E_a and ΔS_a are summarized in Table (6). In the presence of adenine, an increase in E_a values was observed, the variation of activation energy E_a in the presence of different concentrations of adenine can be illustrated as follows [20]: higher values of (E_a) were found in presence of inhibitor than those without inhibitor, i.e., the addition of adenine raises the energy barrier for the corrosion process of 316L SS in sodium chloride acid solution[21].

The entropy values of activation, ΔS^*_a in the presence of adenine are negative implying the rate determining step for the activated complex is the association rather than the dissociation step.

In the presence of the inhibitor ΔS_a^* moves in the direction of negative values Table (6) which impels the adsorption process is accompanied by an decrease in entropy, which is the driving force for the adsorption of adenine onto the 316L stainless steel surface [22].

3.4 Thermodynamic parameters of the adsorption isotherm

The efficiency of organic molecules as good corrosion inhibitors depends mainly on their adsorption ability on the metal surface. Basic information about the interaction between inhibitor and metal can be provided by the adsorption isotherm. The investigation of the relation between corrosion inhibition and adsorption of inhibitor is of great importance.

The surface coverage Table (7) and the concentration of adenine solution (C_{AD}) were tested by fitting to various isotherms like: Langmuir, Temkin and Freundlich. However, the fit was obtained with Langmuir isotherm as shown in Figure (7) which is given by the following equation [20]:

$$\frac{C_{AD}}{\theta} = \frac{1}{k_{ad}} + C_{AD} \ldots\ldots\ldots\ldots\ (6)$$

Where $k_{ads.}$ is the equilibrium constant of the adsorption/desorption processes, and it reflects the affinity of the inhibitor molecules towards surface adsorption sites .

From the intercepts of the straight lines on the C_{AD}/θ axis Fig (7) leads to the equilibrium constant for the adsorption/desorption of adenine process Table (7). The high value of k_{ads} reveals that the AD molecule possesses strong adsorption ability onto the 316L SS.

However, k_{ads} decreased with an increase of temperature indicating that adsorption of adenine onto the metal surface was favorable at lower temperatures.

The equilibrium constant of the adsorption/desorption (K_{ads}) was related to the standard free energy of adsorption according to equation,[23] :

$$\Delta S°_{ads} = -RT\ ln\ (55.5\ k_{ads}) \ldots\ldots\ldots\ldots\ (7).$$

Where R is the universal gas constant, T is the absolute temperature, and value 55.5 is concentration of water in solution.

The standard free energy of adsorption was calculated and is given in Table (8) .Generally the standard free energy of adsorption values of $-24\ kJ.mol^{-1}$ or less negative is associated with an electrostatic interaction between charged metal surface or more negative involves charge sharing or transfer from the inhibitor molecules to the metal surface to form a co-ordinate covalent bond .So it can be concluded that adsorption of adenine onto steel surface takes place through both physical and chemical adsorption[24] .

It is generally accepted that the first step in the adsorption of adenine on the metal surface usually involves the replacement of one or more water molecules adsorbed at the metal surface.

$$AD_{(sol)} + H_2O_{(ads)} \leftrightarrows AD_{(ads)} + H_2O_{(sol)} \ldots\ldots\ (8)$$

The inhibitor adenine may then combine with freshly generated Fe^{+2} ions on the stainless steel surface , forming metal inhibitor complex[25]

$$Fe \rightarrow Fe^{+2} + 2e^{-} \ldots\ldots\ (9)$$

$$Fe^{+2} + AD_{ads.} \rightarrow [\ Fe - AD]_{ads.} \ \ldots\ldots (10)$$

Valuable information about the mechanism of corrosion inhibition can be provided by the values of thermodynamic parameters for the adsorption of inhibitor .Thermodynamically , $\Delta G°_{ads}$ were related to the standard enthalpy, $\Delta H°_{ads}$ and standard entropy, $\Delta S°_{ads}$ according to[17] :

$$\Delta G°_{ads} = \Delta H°_{ads} - T\ \Delta S°_{ads} \ldots\ldots\ldots\ldots (11)$$

and the standard enthalpy of adsorption can be calculated on basis of the Van't Hoff formula:

$$ln\,\mathrm{k_{ads}} = -\frac{\Delta H°_{ads}}{RT} + \text{constant} \;\ldots\ldots\ldots.\ (12\ )$$

A plot of *l*n k$_{ads}$ vs.1/T gives a straight line as shown in Fig (8). The slope of straight line is $\frac{-\Delta H°_{ads}}{R}$

The negative sign of ΔH°$_{ads}$ reveals that the adsorption of inhibitor molecules is an exothermic process. Generally, an exothermic adsorption process suggests either physisorption or chemisorption while endothermic process is attributed to chemisorption. The unshared electron pairs in investigated molecules may interact with d-orbitals of SS type 316L to provide a protective chemisorbed film[26].

The values of ΔS°$_{ads}$ in the presence of inhibitor are negative that is accompanied with exothermic adsorption process. ΔS°$_{ads}$ of inhibitor can be calculated from equation (13) according to: [17]

$$\Delta S°_{ads} = \frac{\Delta H°_{ads} - \Delta G°_{ads}}{T} \ldots\ldots\ldots.(13)$$

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Table No.(1): The chemical composition of 316L stainless steel[15]

Stainless steel 316L	Wt%						
	C%	Si%	Mn%	P%	S%	Cr%	Mo%
	0.044	0.374	1.28	0.026	0.000	19.14	0.261
	Ni%	Al%	Co%	Cu%	V%	Fe%	
	8.19	0.001	0.109	0.343	0.051	Bal	

Table No.(2): Data of polarization curve for corrosion of 316L SS in 0.6 mol-dm^{-3} NaCl solution at pH values (2 and 4) over the temperature range (293-308)K.

pH	T/K	I_{corr}/ µA.cm^{-2}	$-E_{corr}$/ mv	ba/mv. decade^{-1}	-bc/mv decade^{-1}	Weight loss/ g.m^{-2}. day^{-1}	Penetration loss/mm.year^{-1}
2	293	16.21	156	472.1	-149.6	3.40	0.158
	298	16.59	146	2467.1	-116.2	3.98	0.169
	303	17.37	144	567.6	-310.4	4.41	0.205
	308	18.62	124	1692.9	-237.5	4.82	0.224
4	293	14.12	126	269.0	-1430.6	2.94	0.137
	298	14.79	159	235.2	-466.7	3.50	0.162
	303	15.48	183	718.6	-1483.8	4.24	0.197
	306	16.59	198	276.7	-503.4	4.74	0.202

Table No.(3): Activation energy (E_a); pre-exponential (A) and entropy of activation (ΔS^*) for 316L SS corrosion in 0.6 mol.dm^{-3}NaCl solution.

pH	Ea/kJ.mol^{-1}	$-\Delta S^*$/J.k^{-1}.mol^{-1}	A/molecule.cm^{-2}.S^{-1}
2	5.90	204.11	10882x10^{22}
4	6.67	202.59	13083x10^{22}

Table No.(4): Values of ($-E_{corr}$, I_{corr} and inhibitor efficiency percent) with different concentrations of Adenine at temperature range (293-308) K in pH= 2 and 4.

pH	T/K	Inhibitor conc.mol.dm^{-3}	$-E_{corr}$/mv	I_{corr}.µA.cm^{-2}	IE%
2	**293**	0	146	16.59	-
		1×10^{-3}	264	4.36	74
		5×10^{-3}	255	2.82	86
		1×10^{-2}	295	2.14	87
	303	0	144	17.37	-
		1×10^{-3}	284	4.67	73
		5×10^{-3}	275	3.38	85
		1×10^{-2}	323	2.39	86
	308	0	124	18.62	-
		1×10^{-3}	310	5.62	70
		5×10^{-3}	305	4.07	79
		1×10^{-2}	345	3.09	84
4	**293**	0	159	14.79	-
		1×10^{-3}	195	5.24	65
		5×10^{-3}	165	3.55	76
		1×10^{-2}	162	2.81	81
	303	0	183	15.48	-
		1×10^{-3}	225	5.75	63
		5×10^{-3}	186	4.17	73
		1×10^{-2}	188	3.31	79
	308	0	198	16.59	-
		1×10^{-3}	236	6.60	61
		5×10^{-3}	203	4.79	71
		1×10^{-2}	195	3.98	77

Table No.(5): Values of inhibition efficiencies (IE%) calculated from I_{corr}.

pH	Conc.of AD	T/K	IE% from i_{corr}
2	1×10^{-3}	298	74
		303	73
		308	70
	5×10^{-3}	298	86
		303	85
		308	79
	1×10^{-2}	298	87
		303	86
		308	84
4	1×10^{-3}	298	65
		303	63
		308	61
	5×10^{-3}	298	76
		303	73
		308	71
	1×10^{-2}	298	81
		303	79
		308	77

Table No.(6): Activation energy (E_a), pre-expopential factor (A) and entropy of activation (ΔS^*) for the corrosion of 316L SS in the pH values 2 and 4 in 0.6 mol.dm^{-3} NaCl solution and different concentrations of Adenine.

Ph	Conc. Of Adenine mol.dm^{-3}	Ea/ kJ.mol^{-1}	$-\Delta S^*$/ J.K^{-1}. mol^{-1}	A/ molecule cm^{-2}. S^{-1}
2	1×10^{-3}	14.20	172.52	80407×10^{22}
	5×10^{-3}	19.68	172.76	48595×10^{23}
	1×10^{-2}	20.5	187.62	49830×10^{23}
4	1×10^{-3}	12.57	176.47	50571×10^{22}
	5×10^{-3}	15.86	183.59	21727×10^{24}
	1×10^{-2}	18.59	191.44	31081×10^{23}

Table No.(7): Chosen corrosion parameter, degree of surface coverage and corrosion inhibition efficiency for 316L stainless steel in 0.6 mol.dm^{-3}NaCl solution with different concentrations of adenine at various temperatures.

pH	Temp/ K	Conc. AD/ mol. dm^{-3}	-E_{corr} /mv	I_{corr}/µA. cm^{-2}	θ	IE%
2	298	0	146	16.59	-	-
		1×10^{-3}	264	4.36	0.74	74
		5×10^{-3}	255	2.82	0.86	86
		1×10^{-2}	295	2.14	0.87	87
	303	0	144	17.37	-	-
		1×10^{-3}	284	4.67	0.73	73
		5×10^{-3}	275	3.38	0.85	85
		1×10^{-2}	323	2.39	0.86	86
	308	0	124	18.62	-	-
		1×10^{-3}	310	5.62	0.70	70
		5×10^{-3}	305	4.07	0.79	79
		1×10^{-2}	345	3.09	0.84	84
4	298	0	154	14.79	-	-
		1×10^{-3}	195	5.24	0.65	65
		5×10^{-3}	165	3.55	0.76	76
		1×10^{-2}	162	2.81	0.81	81
	303	0	183	15.48	-	-
		1×10^{-3}	225	5.75	0.63	63
		5×10^{-3}	186	4.17	0.73	73
		1×10^{-2}	188	3.31	0.79	79
	308	0	198	16.59	-	-
		1×10^{-3}	236	6.60	0.61	61
		5×10^{-3}	203	4.79	0.71	71
		1x10^{-2}	195	3.98	0.77	77

Table No.(8): Equilibrium constant adsorption/desorption and standard free energy, enthalpy and entropy of adsorption onto 316L SS in 0.6 mol.dm^{-3}NaCl solution in the presence of Adenine at various concentrations.

pH	T/K	K_{ads} mol^{-1}	$-\Delta G^\circ_{ads}$ kJ.mol^{-1}	$-\Delta H^\circ_{ads}$ kJ.mol^{-1}	$-\Delta S^\circ_{ads}$ J.mol^{-1}.K^{-1}
2	298	1000	27.06	57.125	100.87
	303	500	25.77		103.47
	308	333	25.15		103.79
4	298	500	25.34	34.436	30.49
	303	333	24.74		31.97
	308	250	24.42		32.51

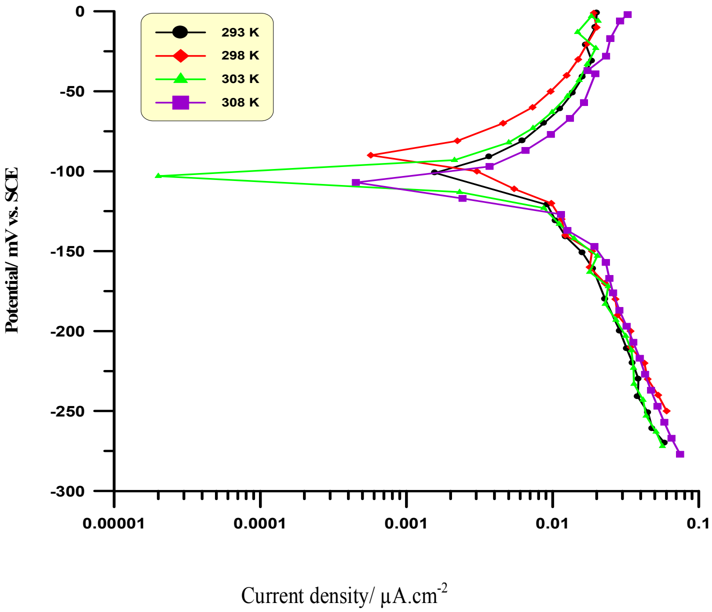
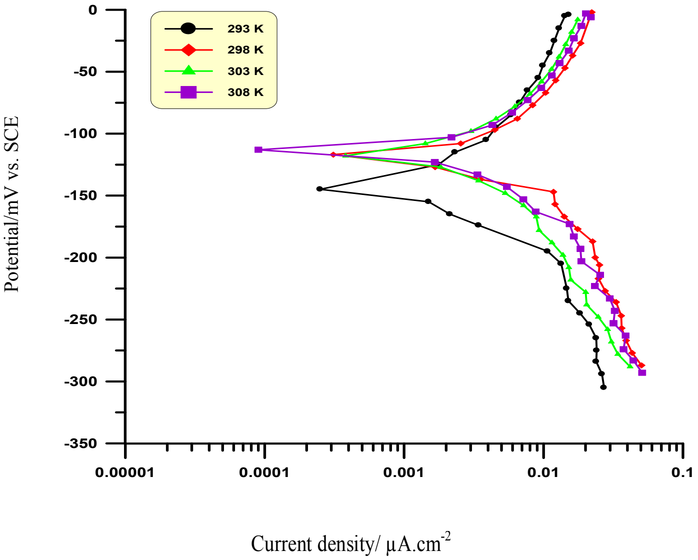
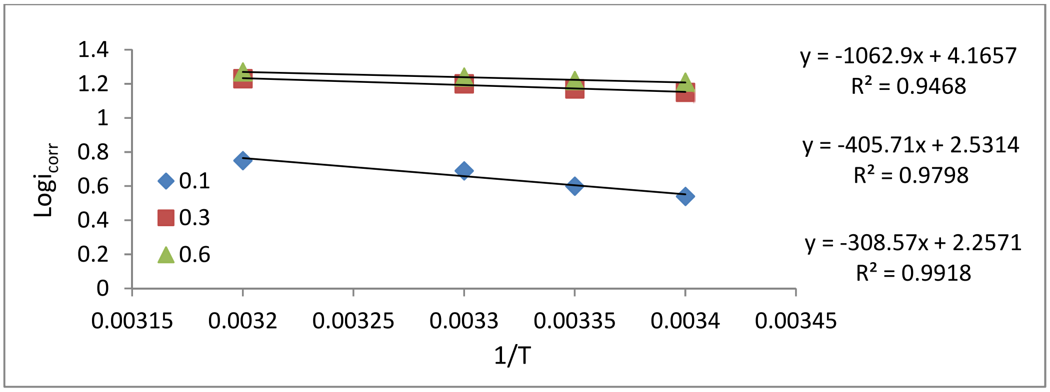


Figure No.(1): Polarization curves of (SS) corrosion in pH = 2 with 0.6 mol.dm^{-3} NaCl solution at four temperatures in the range of (293-308)K.



Figuer No.(2): Polarization curves of (SS) corrosion in pH = 4 with 0.6 mol.dm^{-3} NaCl solution at four temperatures in the range of (293-308)K.



Figuer No. (3): Arrhenius plots relating log i_{corr} to $\frac{1}{T}$ for the corrosion of 316L SS in the pH=2 in the different NaCl concentration over the temperature range (293-308)K.

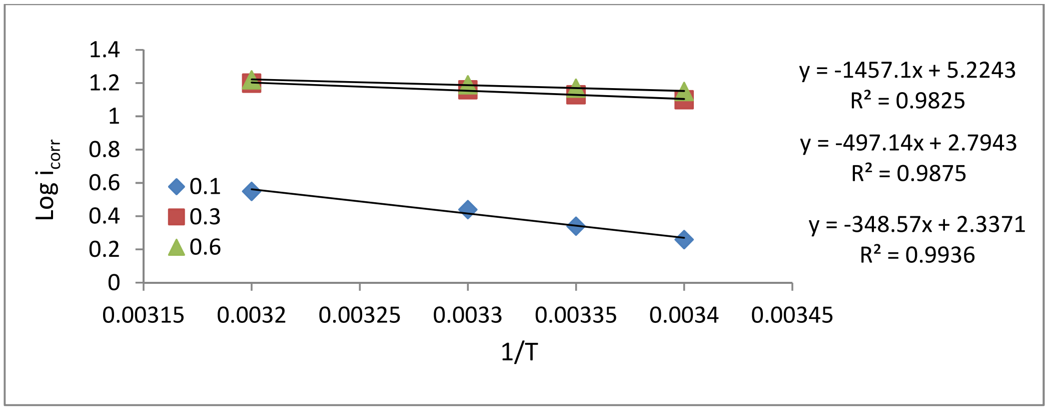


Figure No.(4): Arrhenius plots relating log i_{corr} to $\frac{1}{T}$ for the corrosion of 316L SS in the pH=4 in the different NaCl concentration over the temperature range (293-308)K

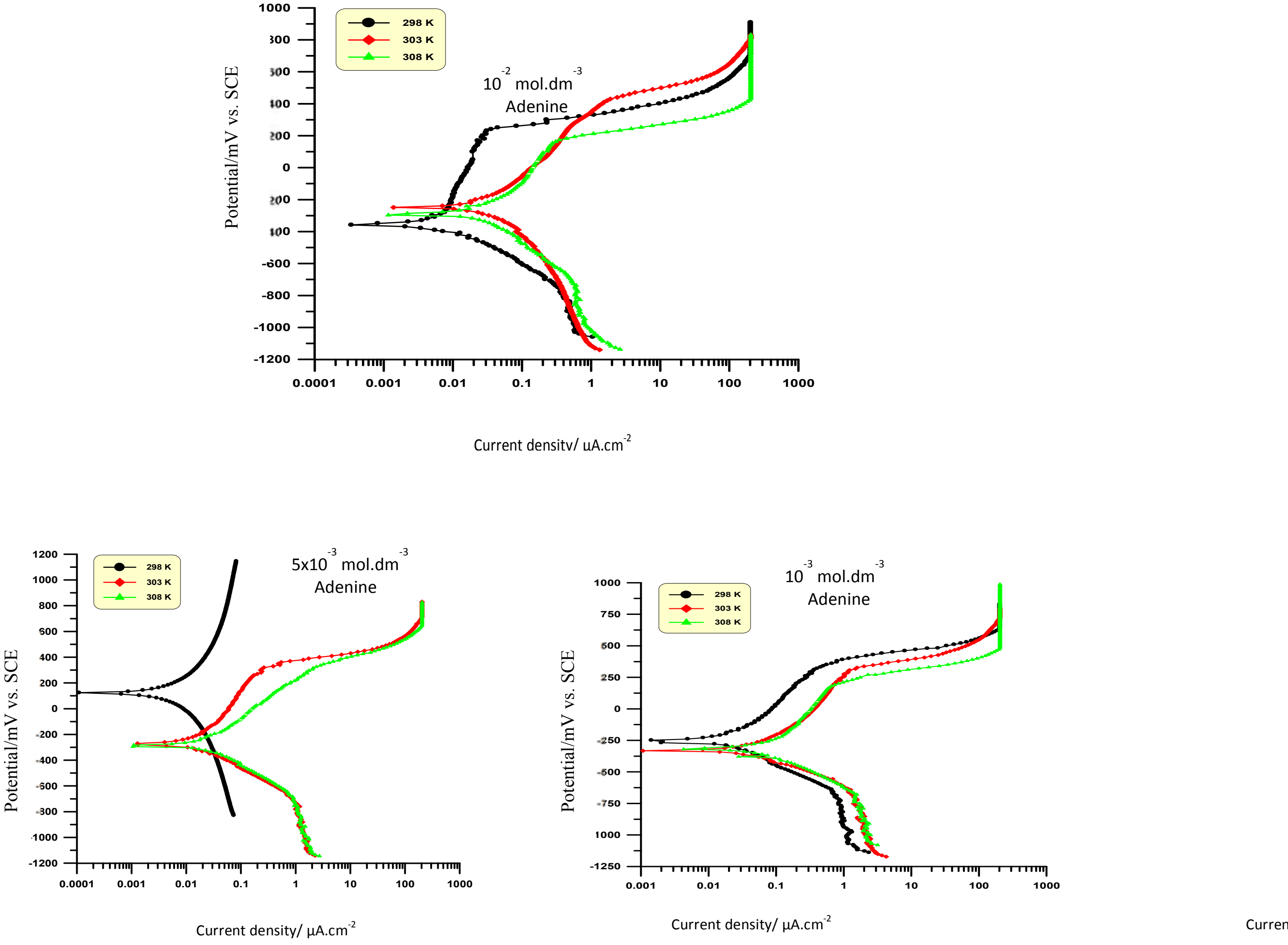


Figure No.(5): The typical polarization curves of 316L SS in 0.6 mol.dm^{-3} NaCl solutions containing three different concentrations of adenine as inhibitor over the temperature range (298-303)K.

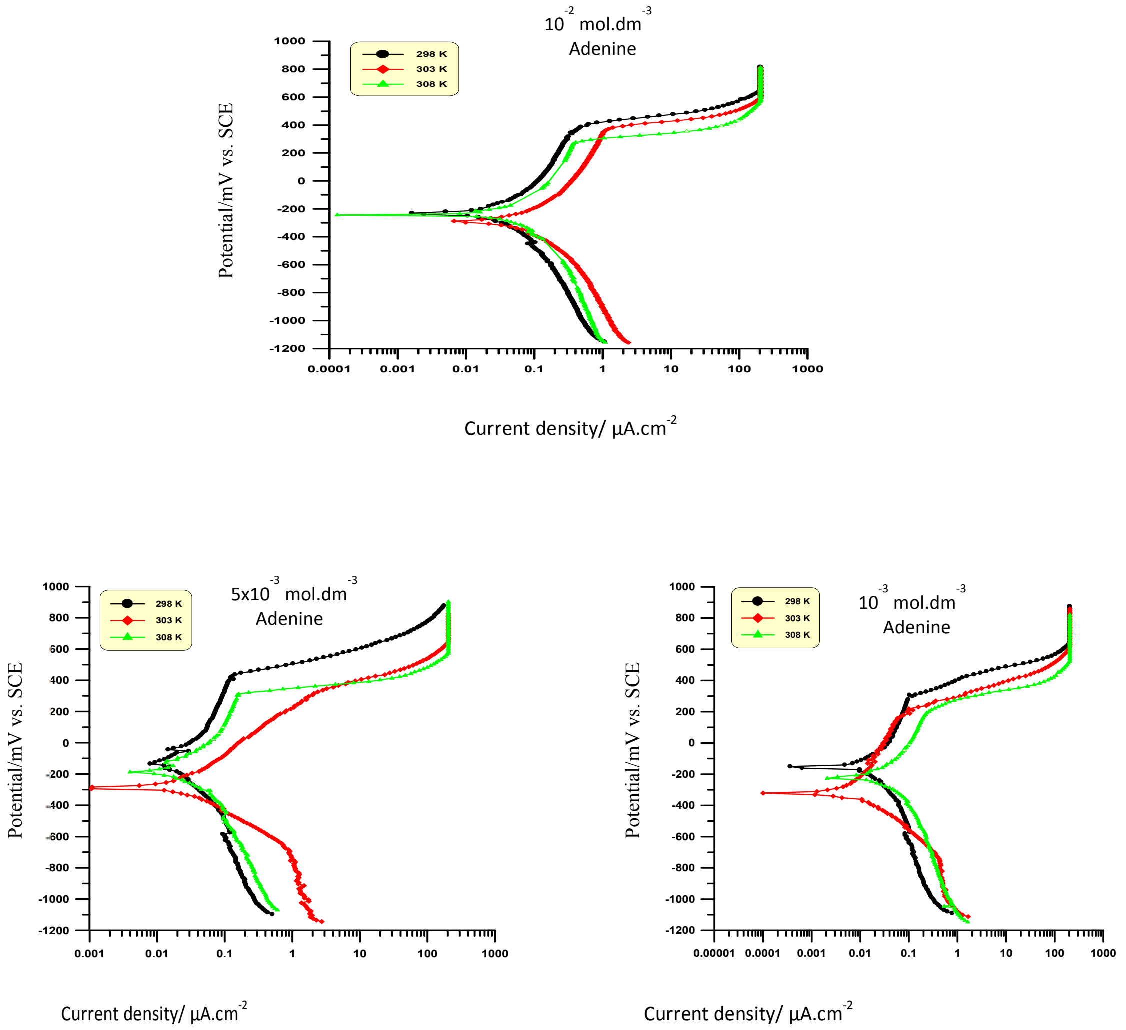


Figure No.(6):The typical polarization curves of 316L SS in 0.6 mol.dm^{-3} NaCl solutions containing three different concentrations of adenine as inhibitor over the temperature range (298-303)K.

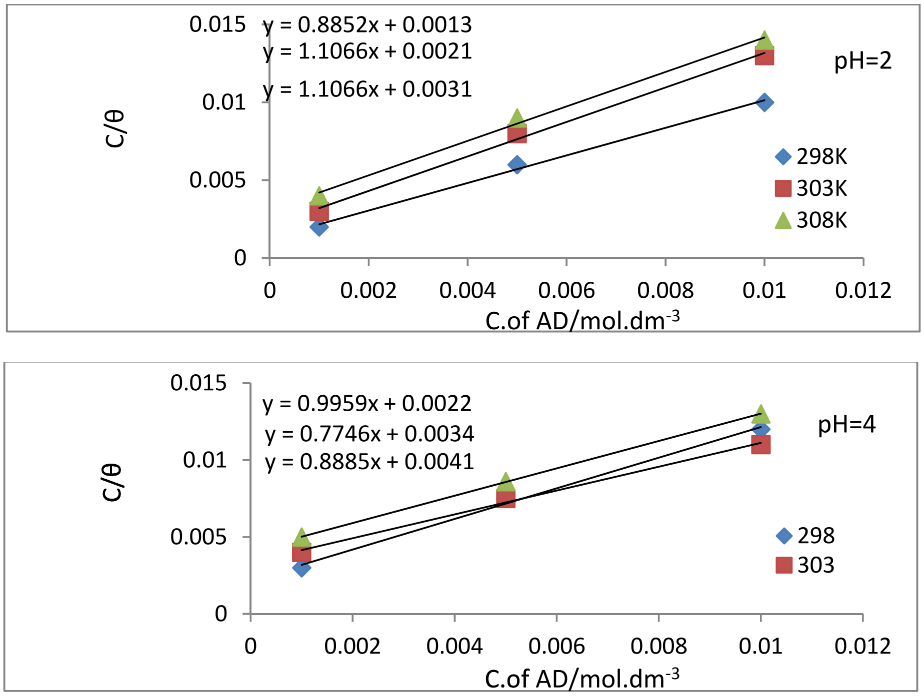


Figure No.(7): Langmuir adsorption plots of adenine on to the 316L SS in 0.6 mol. dm^{-3} NaCl solution at various temperatures.

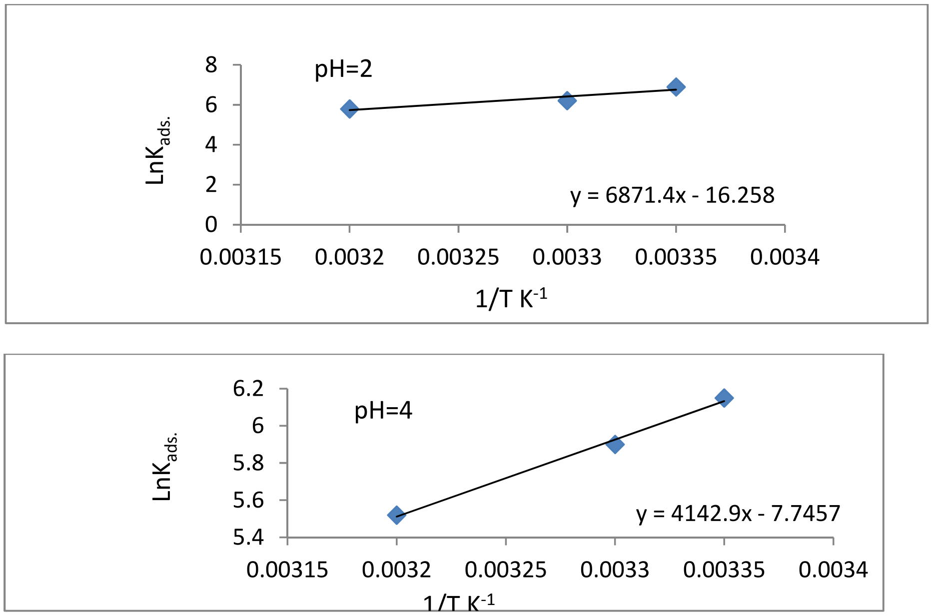


Figure No. (8): Van't Hoff plot 316 L SS in 0.6 mol.dm^{-3} NaCl solution containing adenine.

الإدينين كمثبط صديق بيئياً لتآكل الفولاذ المقاوم للصدأ في محلول حامضي لكلوريد الصوديوم

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قسم الكيمياء/ كلية التربية للعلوم الصرفة(ابن الهيثم)/ جامعة بغداد.

استلم البحث في:28تشرين الاول 2014،قبل البحث في :21كانون الاول 2014

الخلاصة

يتناول موضوع في دراسة كهروكيميائية لسلوك تآكل الفولاذ المقاوم للصدأ نوع (316L) وتأثير تركيز مثبط الإدينين [Adenine (AD)] على اعاقة التآكل في محلول حامضي لكلوريد الصوديوم بتركيز ($0.6\ mol.dm^{-3}$). تم اجراء البحث عند قيمتين للأس الهيدروجيني ($pH = 2$ و $pH = 4$) على مدى من درجات الحرارة (293-308 K) كما اشتملت الدراسة على طريقة الاستقطاب الكهروكيميائي (استقطاب تافل) باستعمال جهاز المجهاد الساكن ، إذ تم التوصل عن طريقه الى معرفة سلوك مثبط (AD) بانه يعمل على تقليل كل من التفاعلين الانودي والكاثودي (mixed inhibitor)، أي إنه يقوم بعملية تثبيط تآكل سبيكة الفولاذ المقاوم للصدأ بكفاءة مقدارها 87%. كما وجد بان الكفاءة تزداد بزيادة تركيز المثبط وتقل بزيادة درجة الحرارة؛ اذ ان قيمة الكفاءة 87% تقع عند تركيز المثبط (AD) المساوي (0.01 M) عند درجة حرارة 293K. كما اوضحت الدراسة ان عملية امتزاز مثبط الإدينين (AD) على سطح الفولاذ المقاوم للصدأ تتبع متساوي درجة الحرارة للامتزاز للانكمير (Langmuir Isotherm for Adsorption).

تم حساب ومناقشة المعلمات الحركية والثرموديناميكية لعمليتي تآكل الفولاذ المقاوم للصدأ وامتزاز مثبط AD على التوالي.

الكلمات المفتاحية: الفولاذ المقاوم للصدأ, الإدينين , استقطاب تافل, المعلمات الحركية والثرموديناميكية.