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Synthesis , Identification and study of some new azo dyes as corrosion Inhibitors for Carbon-Steel in acidic media

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Abstract

The effect of some mono azo dyes compound on the dissolution of C-steel in 0.5M HCl solution was studied using weight loss and galvanostatic polarization techniques .The inhibition efficiency of inhibitor increases with concentration to attain (63.35%,73.28%) of A1and A2 at concentration 5×10^{-3} M ,time 240 min and temperature 30°C. Temperature effect on the corrosion behavior was studied at temperature range from 30-60°C , the results showed that inhibition efficiency increased with increasing temperature to attain (75.50%,83.54%) of A1and A2 at concentration 5×10^{-3} M , time 240 min and temperature 60°C.The effect of temperature on the rate of corrosion in the absence and presence of these compound was also studied. The activation energy and thermodynamic parameters governing the adsorption process were calculated and discussed . Polarization curves revealed that the studied inhibitors represent a mixed – type inhibitors .Adsorption of inhibitors was found to obey Langmuir isotherm and was isotherm chemisorption type.

Introduction

The C-steel is used as essential part in the manufacturing of installations used in the petroleum and other industries . The use of inhibitors is one of the most practical methods for protection against metallic corrosion , especially in acidic media[1,2]. Most of the acid inhibitors are organic compounds that contain nitrogen, sulphur and /or oxygen atoms. It has been reported that many heterocyclic compound containing heteroatoms like N,O,S were proved to be effective inhibitors for the corrosion of C-steel in acid media . The influence of such organic compounds ,on the corrosion of c-steel in acidic solution has been investigated by several authors[3,4] .The inhibition property of these compound is attributed to their molecular structure.

The planarity and lone electron pairs in the heteroatoms are important features that determine the adsorption of these molecules on the metallic surface . They can adsorb on the metal surface , block the active sites on the surface and thereby reduce the corrosion rate[5] . The aim of the present work is to study the inhibitive action of some newly prepared mono azo dye compounds toward the corrosion of c-steel in 0.5M hydrochloric acid solution using weight loss and galvanostatic polarization techniques . Moreover , the effect of temperature on the dissolution carbon steel , as well as , on the inhibition efficiency of the studied compounds was also investigated and some thermodynamic parameters were computed .

Experimental method

The c-steel sample used (N-80) had the composition (wt %) 0.3C, 1.2Mn, 0.05P, 0.06S and the remainder Fe .coupons of c-steel with dimension of 2.2 *4.2 *0.4 cm were used for weight loss measurements . For galvanostatic studies a cylinder rod embedded in araldite with an expose surface area of ($1cm^2$) was used . The electrode surface was polished with different grades of emery paper , degreased with acetone , and rinsed with distilled water . A.R grade hydrochloric acid was used for preparing the corrosive solution . For weight loss experiments , the cleaned c-steel coupons were weighed before and after immersion in 50ml of the test solution for a period of time 4h . The weight loss for experiments was expressed in (gm) . Galvanostatic polarization studies were carried out using Bank EIEIKTRONKIK INTELLGENT CONTROLS Model MLab 200-Chemistry Department- Education College - Basrah University ,for calculation of electrochemical parameters Three compartment cell with a saturated calomel electrode (Reference electrode), platinum for auxiliary electrode and working electrode. The mono azo dyes compounds A1: (4-amino-N,2 pyrmidinyl - benzene sulfonamide azo) resorcinol and A2: [4-amino-N-(3,4dimethyl -5 isoxazolyl) benzene sulfonamide azo] resorcinol prepare used Fox method[6]

(1.2513 gm ,0.005 mole) of sulfadiazine was dissolved in 1.7 ml of Cone. HCl and then add (10 ml) of dionized water . The solution was then cooled to 0 - 5°C in an ice - bath and maintained at this temperature . Sodium nitrite (0.39gm) solution in water (5 ml) was then added dropwise . Stirring was continued to produce diazonium salt at the same temperature .

The diazonium solution was added portion wise to the coupling component solution prepared by mixing of resorcinol (0.05505 gm , 0.005 mole) in water with sodium hydroxide (1.5 gm) dissolve in (100 ml) of water . During the procedure the pH value was maintained with 9 – 10 , and the temperature at 0 - 5°C . The mixture was stirred for 30 min , and then the pH value was decreased to ∼ 6. The mixture was left overnight . The precipitated crude dyes were collected by filtration , and washed with water , ethanol and acetone .

The ether dyes A2 was Synthesis similarly . The structure and some physical properties of azo dyes compounds were given in Table 1.

Table 1: Some Physical Properties of Azo Dyes Compounds

Compound	Chemical structure	physical stat	Color	Melting Point
A1		Powder	Blood Red	Over 300°C
A2		Powder	Dark Orange	Over 300°C

Results and Discussion

Identification of Prepared Azo Dyes
The chemical structure of the prepared azo dyes were confirmed by the FTIR , mass spectra and H^1NMR.

Ftir Spectra

FTIR Spectra of the synthesized compounds were carried out using (FT- IR- 8400S. Fourier Transform Infrared Spectrophotometer) Shimadzu (Japan)- Chemistry Department- College Science- Basrah University . The Spectra were shown in Figs 1 and 2 and the characterized bands were given in Table 2

Table 2: Characterized Bands in FTIR Spectra for Prepared Azo Dyes

Compound	ν OH, NH (cm^{-1})	ν CH Arom (cm^{-1})	ν -C=C- (cm^{-1})	ν -N=N- (cm^{-1})	ν -C=N-	ν C-N (cm^{-1})
A1	3450.41 b	3095.54 w	1481.23 w	1434.94 w	1587.31 s	1220.86 w
A2	3452.34 b	3097.47 w	1479.30 w	1421.44 w	1631.67 s	1251.72 w

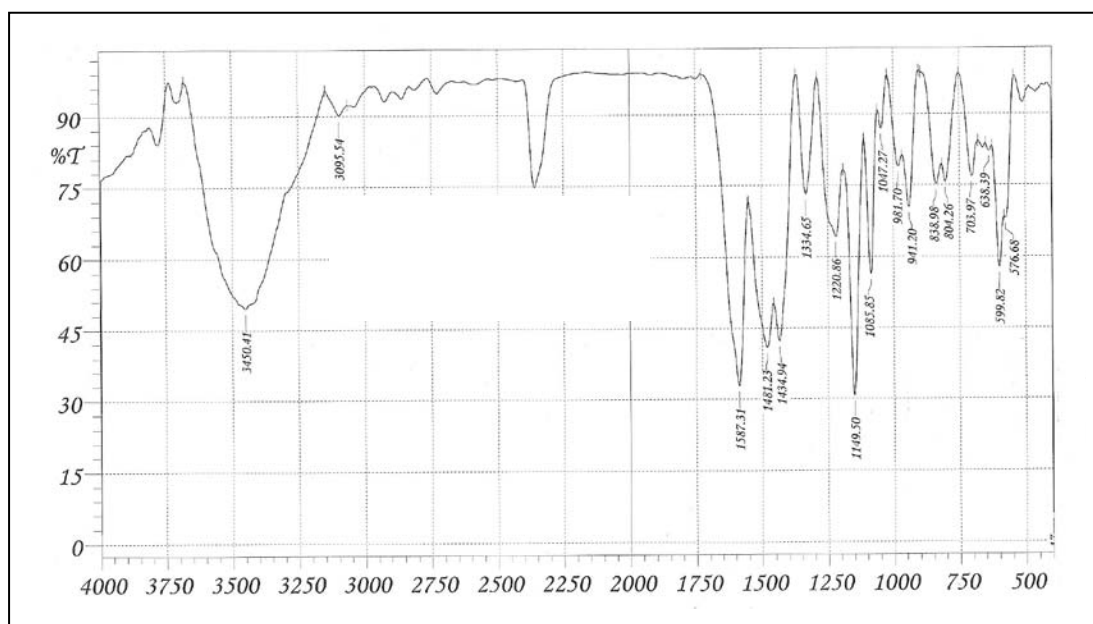b= broad   w= weak   s= strong

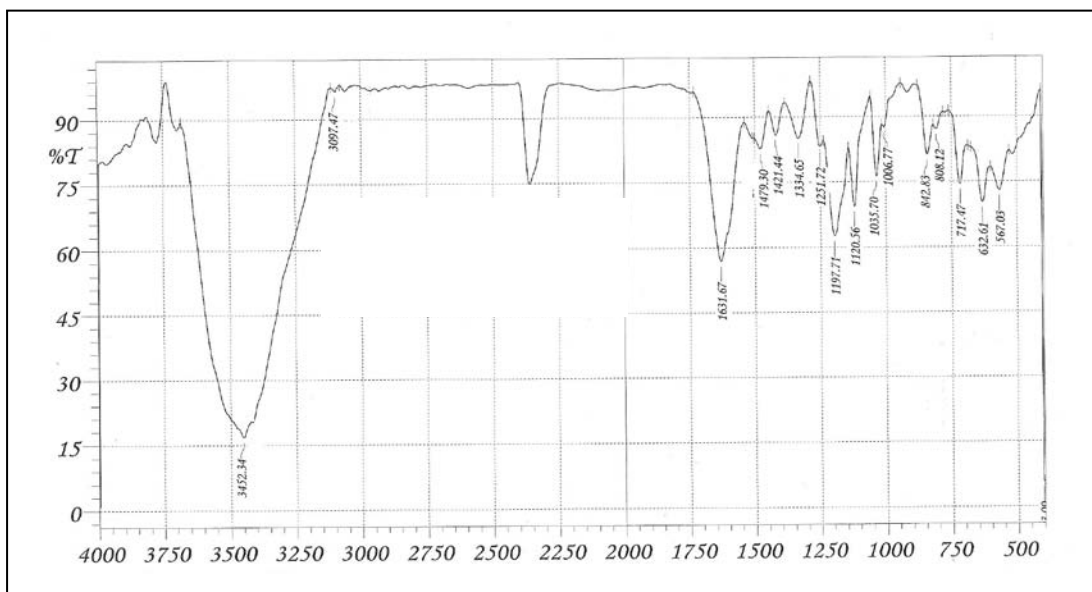**Fig1: FTIR Spectrum of A1**

Fig2: FTIR Spectrum of A2

Mass Spectra

Mass spectra of the synthesized compounds were carried out using Agilent Technologies- 5975C –Tehran-Iran-Trabiat Modares University. Mass spectra of the prepared inhibitors showed molecular ion peak (M^+) at 371.3,which corresponds to the molecular formula of inhibitor (A1)and at 388.3 which corresponds to the molecular formula of inhibitor (A2). Mass spectra of A1and A2 are shown in Figs 3 and 4
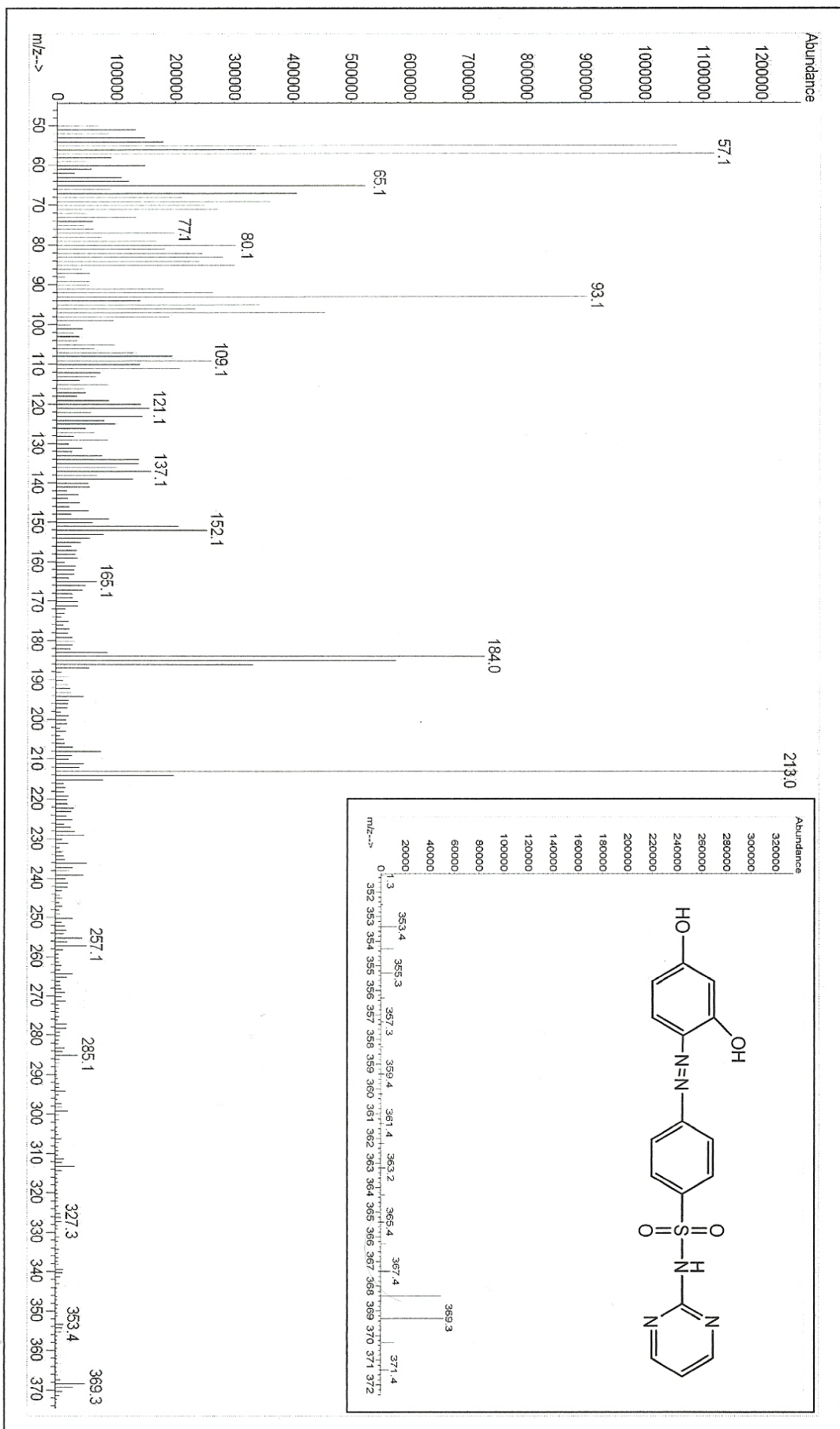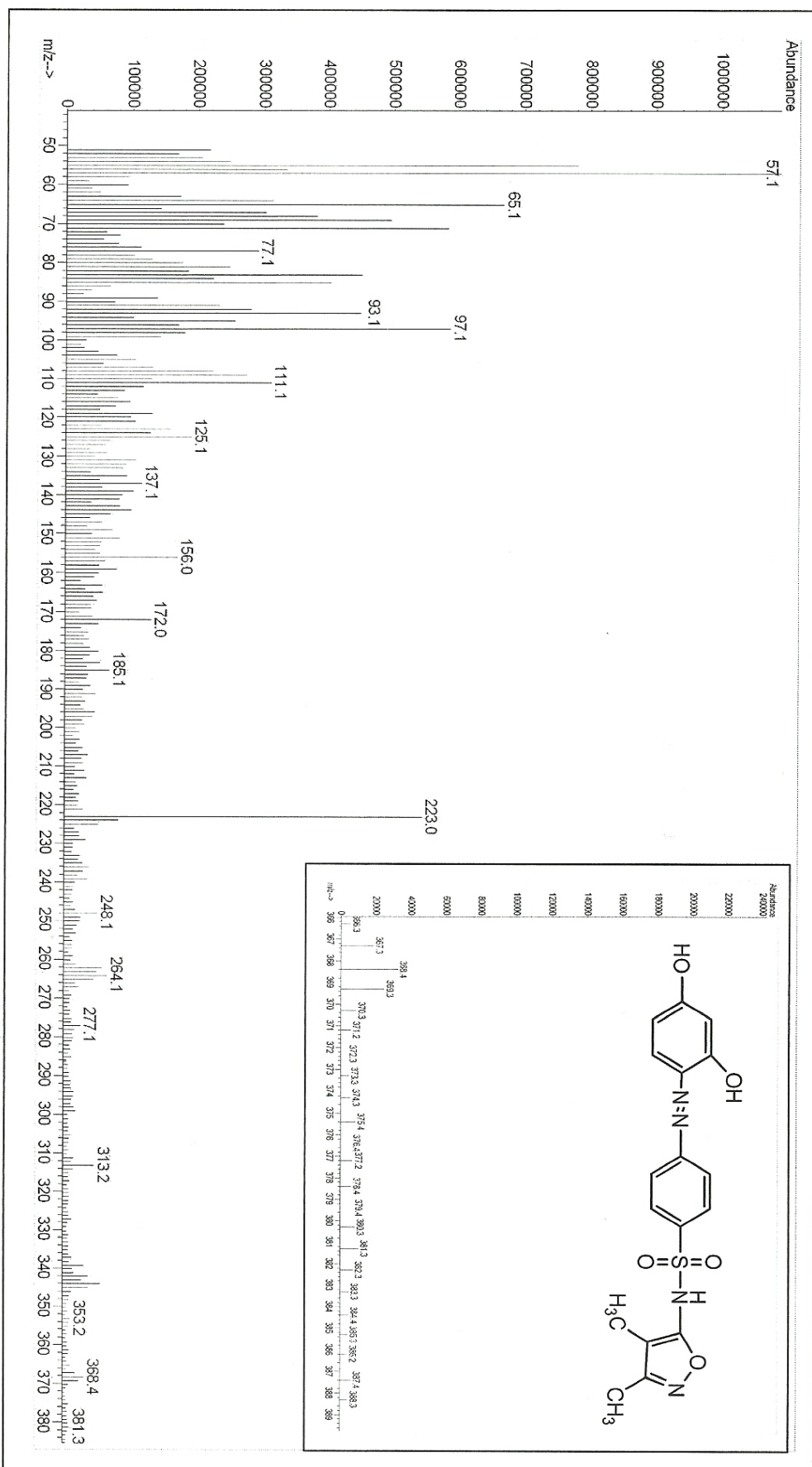
Fig3: Mass Spectrum of A1

Fig4: Mass Spectrum of A2

H^{1}NMR Spectra

H^{1}NMR Spectra of the synthesized compounds were carried out using BRUKER-500 MHZ–Tehran-Iran-Trabiat Modares University. Chemical shifts of H^{1}NMR for the prepared azo dyes in d DMSO are given in Table 3 and in Figs 5 and 6

Table 3: Chemical Shifts of H^{1}NMR for Prepared Azo Dyes in d DMSO

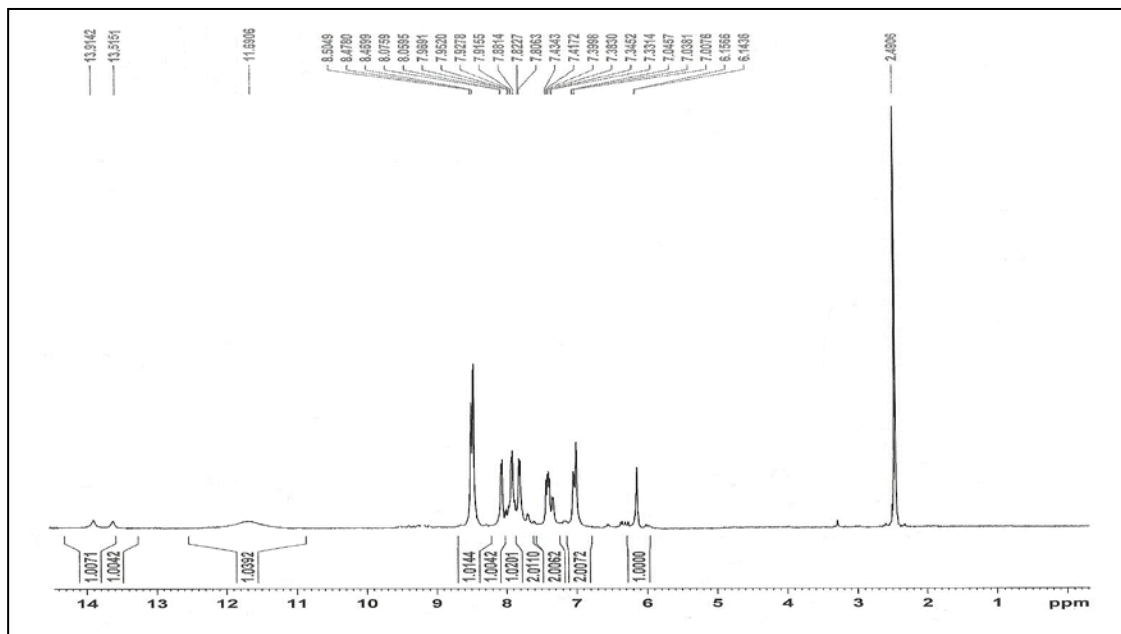| Compound	Chemical structure	Chemical shift (δ ppm)
A1		6.14-8.50 (m,10H,Ar-H) 11.69 (S,1H,NH) 13.51,13.91 (S,2H, OH)
A2		2.1,2.22 (S,6H,CH3) 6.38-8.01 (m,7H,Ar-H) 10.68 (S,1H,NH) 12.41,12.88 (S,2H,OH)

S=singlet   ,m=multiple
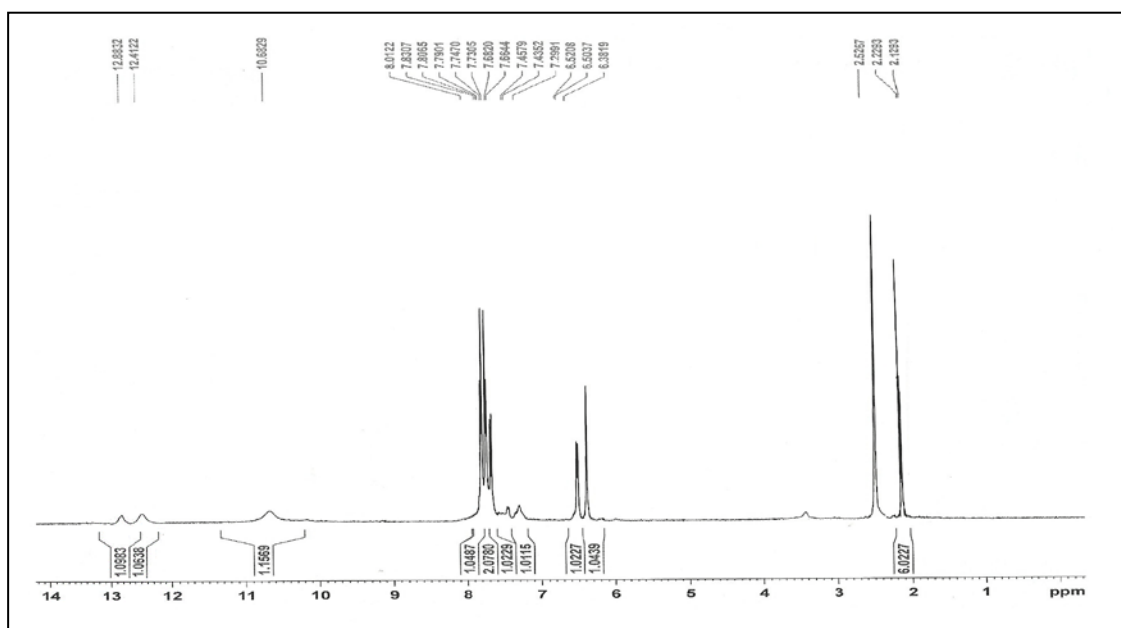
Fig5: H^{1}NMR spectrum of A1

Fig6: H^{1}NMR spectrum of A2

Weight Loss Measurements

The results of the measurements are shown in Tables 4 and 5 for the corrosion of c-steel in 0.5M HCl in the absence and in the presence of different concentrations of the azo dyes compounds (A1&A2) at the temperature of 30°C.The percentage of inhibition efficiency %IE and surface parameter coverage θ which represents the part of the surface covered by the inhibitor molecules were calculated using the following equation[7] :-

$$\%IE = \left[\ 1 - \frac{W_{add}}{W_{free}}\ \right]\ \times 100 \quad \text{-----------} \quad (1)$$

$$\theta = [\ 1 - \frac{W_{add}}{W_{free}}\ ] \qquad \text{------------} \quad (2)$$

Where W_{free} and W_{add} are the weight losses of c-steel in absence and presence of inhibitors

Fig 7 and 8 represent the variation of the inhibition efficiency %IE as function of the time. The inhibition efficiency increased with increasing the inhibitor concentration .

The corrosion rate R_{corr} where calculated using the following equation[8] :-

$$R_{corr} = \frac{\Delta W}{St} \qquad \text{------------} \quad (3)$$

Where $\Delta W=$ is the weight losses of matel , $S=$ is the surface area (cm^2), $T=$ is the exposed time (min)
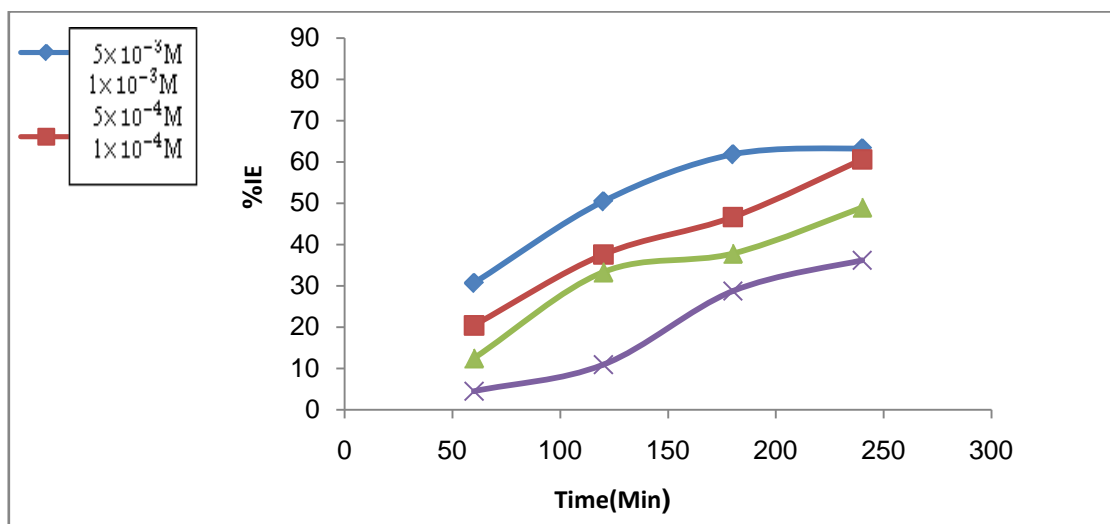

Fig 7: Variation of the Inhibition Efficiency %IE as a Function of the Time in the Presence of Different Concentrations of A1 at 30°C
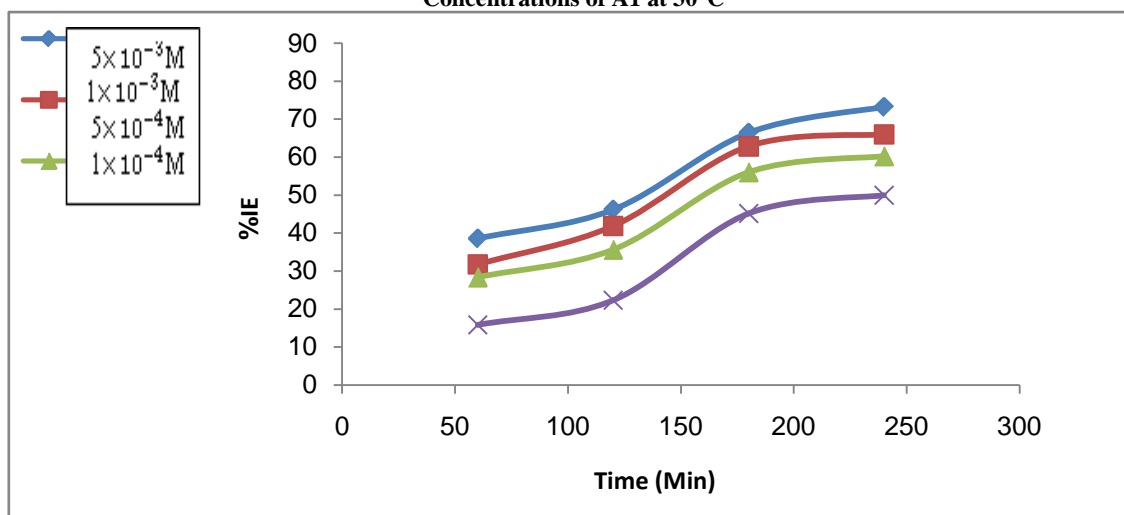

Fig 8: Variation of the Inhibition Efficiency %IE as a Function of the Time in the Presence of Different Concentrations of A2 at 30°C

Table 4 : Effect of Mono Azo Dyes Compound (A1) on the Dissolution C- steel in 0.5M HCl

Time (Min)		60				120				180				240			
Conc (M)	Wt-loss gm	Rcorr gm.cm⁻².min⁻¹	% IE	Θ	Wt-loss gm	Rcorr gm.cm⁻².min⁻¹	% IE	Θ	Wt-loss gm	Rcorr gm.cm⁻².min⁻¹	% IE	Θ	Wt-loss gm	Rcorr gm.cm⁻².min⁻¹	% IE	Θ	
0.00	0.0088	61.52×10^{-7}	—	—	0.0210	73.40×10^{-7}	—	—	0.0396	87.44×10^{-7}	—	—	0.0524	91.58×10^{-7}	—	—	
1×10^{-4}	0.0084	58.72×10^{-7}	4.54	0.0454	0.0187	65.36×10^{-7}	10.95	0.1095	0.0282	62.26×10^{-7}	28.78	0.2878	0.0334	58.37×10^{-7}	36.25	0.3625	
5×10^{-4}	0.0077	53.83×10^{-7}	12.50	0.1250	0.0140	48.93×10^{-7}	33.33	0.3333	0.0246	54.31×10^{-7}	37.87	0.3787	0.0267	46.66×10^{-7}	49.04	0.4904	
1×10^{-3}	0.0070	48.93×10^{-7}	20.45	0.2045	0.0131	45.79×10^{-7}	37.61	0.3761	0.0211	45.59×10^{-7}	46.71	0.4671	0.0206	36.00×10^{-7}	60.68	0.6068	
5×10^{-3}	0.0061	42.64×10^{-7}	30.68	0.3068	0.0104	36.35×10^{-7}	50.47	0.5047	0.0151	35.18×10^{-7}	61.86	0.6186	0.0191	33.38×10^{-7}	63.35	0.6335	

Table 5 : Effect of Mono Azo Dyes Compound (A2) on the Dissolution C- steel in 0.5M HCl

Time (Min)		60				120				180				240			
Conc (M)		Wt-loss gm	Rcorr gm.cm^{-2}.min^{-1}	% IE	Θ	Wt-loss gm	Rcorr gm.cm^{-2}.min^{-1}	% IE	Θ	Wt-loss gm	Rcorr gm.cm^{-2}.min^{-1}	% IE	Θ	Wt-loss gm	Rcorr gm.cm^{-2}.min^{-1}	% IE	Θ
0.00		0.0088	61.52×10^{-7}	–	–	0.0210	73.40×10^{-7}	–	–	0.0396	87.44×10^{-7}	–	–	0.0524	91.58×10^{-7}	–	–
1×10^{-4}		0.0074	63.83×10^{-7}	15.90	0.1590	0.0163	63.71×10^{-7}	22.38	0.2238	0.0217	56.54×10^{-7}	45.20	0.4520	0.0262	51.20×10^{-7}	50.00	0.5000
5×10^{-4}		0.0063	54.34×10^{-7}	28.40	0.2840	0.0135	52.76×10^{-7}	35.71	0.3571	0.0174	45.34×10^{-7}	56.06	0.5606	0.0208	40.65×10^{-7}	60.30	0.6030
1×10^{-3}		0.0060	51.75×10^{-7}	31.81	0.3181	0.0122	47.68×10^{-7}	41.90	0.4190	0.0147	38.30×10^{-7}	62.87	0.6287	0.0178	34.78×10^{-7}	66.03	0.6603
5×10^{-3}		0.0054	46.58×10^{-7}	38.63	0.3863	0.0113	44.16×10^{-7}	46.19	0.4619	0.0133	34.65×10^{-7}	66.41	0.6641	0.0140	27.36×10^{-7}	73.28	0.7328

Effect of Temperature

The influence of temperature on the behavior of C- steel∕acid added of azo dyes at various concentrations is investigated by weight loss trends in the temperature range 30-60°C during 4hrs of immersion . The variation of the inhibition efficiency of azo dyes with temperature is increased with increasing temperature is suggestive chemical adsorption mechanism which is effectively enhanced with increasing temperature[9] . Figs 9 and 10 represent the variation of the inhibition efficiency %IE as a function of the temperature . The results of these measurements are shown in Tables 6 and 7 . The effect of temperature on the corrosion parameters of C-steel in 0.5 M HCl containing different concentrations of inhibitors are shown in the above tables .
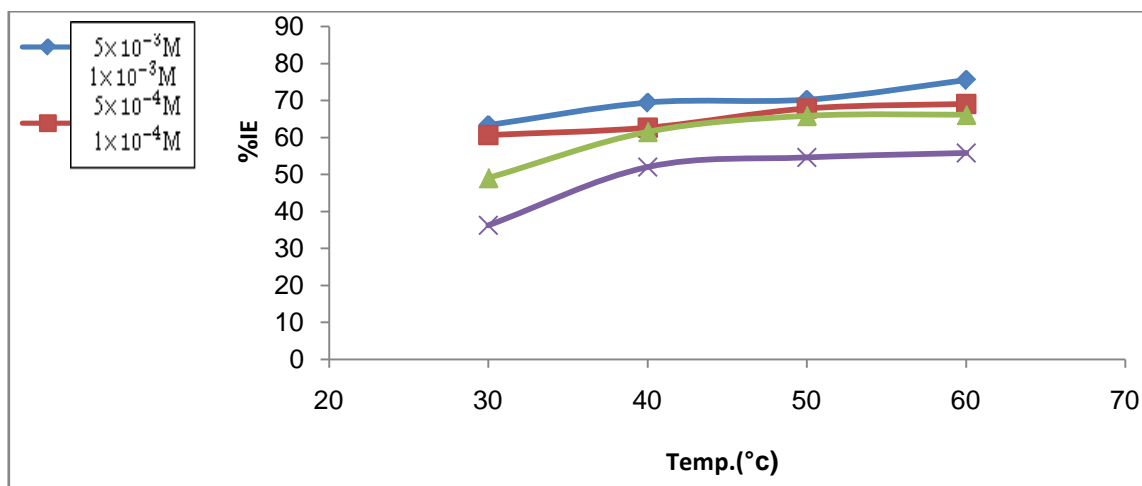

Fig 9:Variation of the Inhibition Efficiency %IE as a Function of the Temperature in the Presence of Different Concentrations of A1
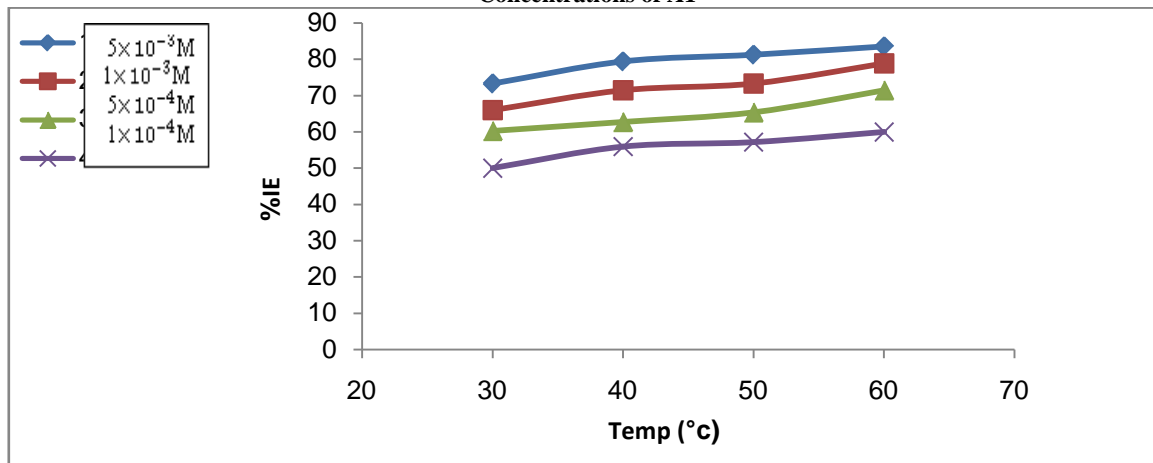

Fig 10: Variation of the Inhibition Efficiency %IE as a Function of the Temperature in the Presence of Different Concentrations of A2

Table 6 : Effect of Mono Azo Dyes Compound (A1) on the Dissolution C- steel in 0.5M HCl in the Different Temperature

Temp°C		30				40				50				60			
Conc (M)	Wt-loss gm	Rcorr gm.cm⁻².min⁻¹	% IE	θ	Wt-loss gm	Rcorr gm.cm⁻².min⁻¹	% IE	θ	Wt-loss gm	Rcorr gm.cm⁻².min⁻¹	% IE	θ	Wt-loss gm	Rcorr gm.cm⁻².min⁻¹	% IE	θ
0.00	0.0524	91.58×10^{-7}	-	-	0.1587	27.73×10^{-6}	-	-	0.3199	55.91×10^{-6}	-	-	0.7025	12.27×10^{-5}	-	-
1×10^{-4}	0.0334	58.37×10^{-7}	36.25	0.3625	0.0761	13.30×10^{-6}	52.04	0.5204	0.1452	25.37×10^{-6}	54.61	0.5461	0.3102	54.21×10^{-6}	55.84	0.5584
5×10^{-4}	0.0267	46.66×10^{-7}	49.04	0.4904	0.0611	10.67×10^{-6}	61.49	0.6149	0.1093	19.10×10^{-6}	65.83	0.6583	0.2380	39.41×10^{-6}	66.12	0.6612
1×10^{-3}	0.0206	36.00×10^{-7}	60.68	0.6068	0.0592	98.03×10^{-7}	62.69	0.6269	0.1029	17.04×10^{-6}	67.83	0.6783	0.2173	37.97×10^{-6}	69.06	0.6906
5×10^{-3}	0.0191	33.38×10^{-7}	63.35	0.6335	0.0485	85.20×10^{-7}	69.43	0.6943	0.0953	16.65×10^{-6}	70.20	0.7020	0.1721	30.07×10^{-6}	75.50	0.7550

Table 7: Effect of Mono Azo Dyes Compound (A2) on the Dissolution C- steel in 0.5M HCl in the Different Temperature

Temp°C		30				40				50				60		
Conc (M)	Wt-loss gm	Rcorr gm.cm^{-2}.min^{-1}	% IE	θ	Wt-loss gm	Rcorr gm.cm^{-2}.min^{-1}	% IE	θ	Wt-loss gm	Rcorr gm.cm^{-2}.min^{-1}	% IE	θ	Wt-loss gm	Rcorr gm.cm^{-2}.min^{-1}	% IE	θ
0.00	0.0524	91.58×10^{-7}	–	–	0.1587	27.73×10^{-6}	–	–	0.3199	55.91×10^{-6}	–	–	0.7025	12.27×10^{-5}	–	–
1×10^{-4}	0.0262	51.20×10^{-7}	50.00	0.5000	0.0699	13.66×10^{-6}	55.95	0.5595	0.1369	26.75×10^{-6}	57.20	0.5720	0.2811	54.93×10^{-6}	59.98	0.5998
5×10^{-4}	0.0208	40.65×10^{-7}	60.30	0.6030	0.0591	11.55×10^{-6}	62.75	0.6275	0.1106	21.61×10^{-6}	65.42	0.6542	0.2003	39.14×10^{-6}	71.48	0.7148
1×10^{-3}	0.0178	34.78×10^{-7}	66.03	0.6603	0.0452	88.33×10^{-7}	71.51	0.7151	0.0852	16.65×10^{-6}	73.36	0.7336	0.1481	28.94×10^{-6}	78.91	0.7891
5×10^{-3}	0.0140	27.36×10^{-7}	73.28	0.7328	0.0326	70.30×10^{-7}	79.45	0.7945	0.0599	12.91×10^{-6}	81.27	0.8127	0.1156	24.93×10^{-6}	83.54	0.8354

The activation energy Ea of corrosion process was calculated using the following equation[10] :-

$$\ln(r_2/r_1) = (Ea\ (T_2-T_1)/R\ (T_2 * T_1) \qquad ------------ \quad (4)$$

Where

r_1 = corrosion rate at 303 K

r_2 = corrosion rate at 313 K

Ea= activation energy

R= gas constant (8.3143J.K^{-1}.mol^{-1})

T_1 and T_2 = Absolute temperature (K)

The values of activation energy Ea given in Table 8

Table 8: Activation Energy for Dissolution of C- steel in 0.5M HCl in the Different Concentration of A1and A2

Conc. [M]	activation energy KJ mol^{-1}	
	A1	A2
0.00	87.37	
1×10^{-4}	64.93	77.37
5×10^{-4}	65.27	75.11
1×10^{-3}	78.99	73.49
5×10^{-3}	73.47	74.41

Radovici[11] classifies the inhibitors into 3 groups according to temperature effects :-

1- Inhibitors whose IE decreases with temperature increase and Ea greater than that in the uninhibited solution . This is can indication of physisorption .

2- Inhibitors whose IE does not change with the presence or absence of inhibitors.

3- Inhibitors whose IE increases with temperature and Ea is smaller for the inhibited solution, which is characteristic of chemisorption.

Also the interpreted the increases of IE value with temperature increase as an indication for a chemisorption type of adsorption . Therefore it can be concluded that azo dyes (A1and A2) are adsorbed on the c-steel surface by chemisorption .

Free energy of adsorption ΔG was calculated using the following equation[12] :-

$$\Delta G = -RT\ln[55.5\ \theta/C\ (1-\theta)] \qquad ---------- \quad (5)$$

Where

θ = degree of coverage on the metal surface

C= concentration of inhibitor

R= gas constant (8.3143J.K^{-1}.mol^{-1})

T= Absolute temperature (K)

The values of free energy ΔG given in Tables 9 and 10

Table 9:- Free Energy of Dissolution of C-steel in 0.5M HCl in the Presence of Different Concentrations of A1

Free energy (KJ.mol^{-1})				
Conc. [M]	temperature (K)			
	303	313	323	333
1×10^{-4}	-31.89	-34.63	-36.01	-37.27
5×10^{-4}	-29.16	-31.45	-32.96	-34.01
1×10^{-3}	-28.63	-29.77	-31.34	-32.46
5×10^{-3}	-24.84	-26.37	-25.01	-28.90

Table 10:- Free Energy of Dissolution of C-steel in 0.5M HCl in the Presence of Different Concentrations of A2

Free energy (KJ.mol^{-1})				
Conc. [M]	temperature (K)			
	303	313	323	333
1×10^{-4}	-33.32	-35.04	-36.29	-37.74
5×10^{-4}	-30.31	-31.58	-32.91	-34.70
1×10^{-3}	-29.19	-30.82	-32.05	-33.89
5×10^{-3}	-26.00	-27.75	-28.95	-30.28

The negative values of ΔG means that the adsorption of azo dyes on C-steel surface is a spontaneous process ,and furthermore the negative values of ΔG also show the strong interaction of the inhibitor molecules on to the c-steel surface[13] .

It was found that ΔG increases negatively with increasing the temperature . This phenomenon once again indicates that the adsorption is favourable with increasing experimental temperature and dominates on the desorption of the inhibitor from the C-steel surface[14] .

For calculating the entropy ΔS and enthalpy ΔH apply the alternative formulation of the Arrhenius equation is the transition state equation[15]:-

$$\text{Rcorr} = \frac{RT}{Nh}\exp\left[\frac{\Delta S}{R}\right]\exp\left[-\frac{\Delta H}{RT}\right] \quad \text{------------} \quad (6)$$

Where

Rcorr= corrosion rate

R= gas constant (8.3143J.K^{-1}.mol^{-1})

T= temperature (K)

N= Avogadro 's number (6.2× 10^{23})

h= plank 's constant (6.62×10^{-34}J.S)

Figs 11and 12 show straight lines of plots of log R∕T vs. 1∕T with a slope of (ΔH∕2.303R) and intercept of (log Rcorr∕ Nh+ΔS∕2.303R)from which the values of ΔH and ΔS are calculated respectively and the result listed in Table 11 .
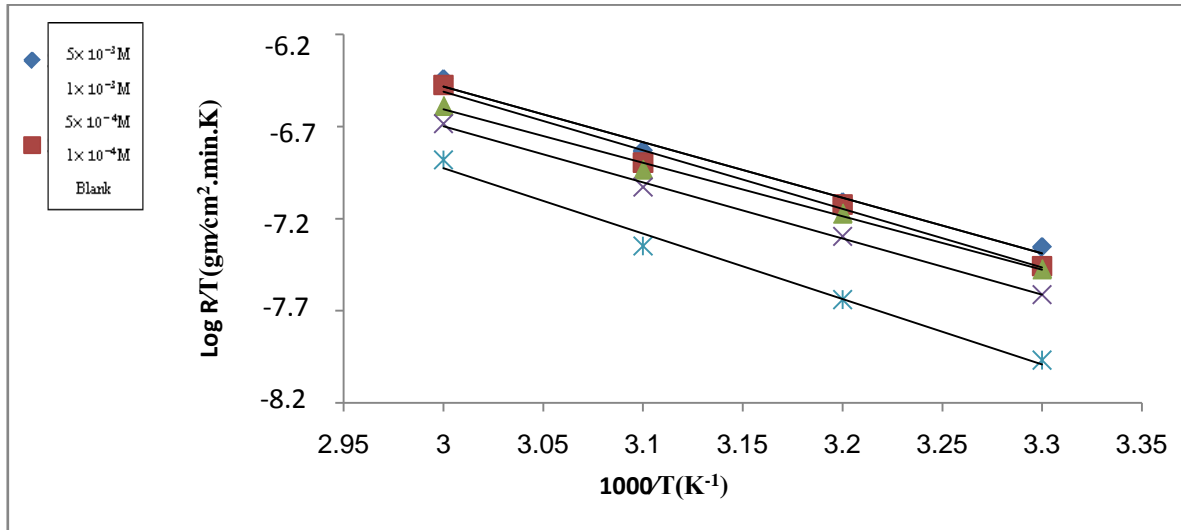

Fig 11: Plots of Log R$_{corr}$ ∕T) vs. 1∕T for C-steel in Different Additives of Inhibitor (A1)
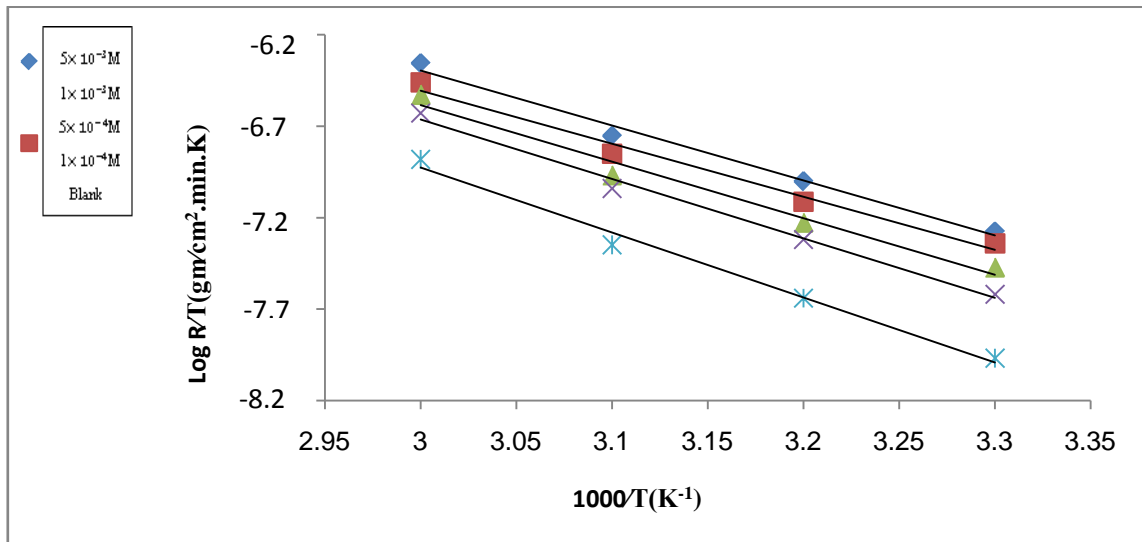
Fig12: Plots of Log R$_{corr}$ ∕T) vs. 1∕T for C-steel in Different Additives of Inhibitor (A2)

Table 11:- Activation Parameters of Dissolution C-steel in o.5M HCl in the Absence and Presence of Different Concentrations of (A1and A2)

Inhibitor	A1		A2	
Conc. [M]	ΔH (KJ.mol^{-1})	ΔS (KJ.mol^{-1})	ΔH (KJ.mol^{-1})	ΔS (KJ.mol^{-1})
Blank	0.0679	-0.1161	0.0679	-0.1161
1×10^{-4}	0.0583	-0.1522	0.0622	-0.1401
5×10^{-4}	0.0554	-0.1635	0.0591	-0.1519
1×10^{-3}	0.0608	-0.1477	0.0555	-0.1651
5×10^{-3}	0.0578	-0.1581	0.0575	-0.1606

The values of thermodynamic parameter for the adsorption of inhibitors can provide valuable information about the mechanism of corrosion inhibition . The endothermic adsorption process ($\Delta H \gt 0$) is attributed unequivocally to chemisorption while generally , an exothermic adsorption process .($\Delta H \lt 0$) may involve either physisorption or chemisorption or mixture of both the process in the present case , the positive sign of ΔH indicates that the adsorption of inhibitors molecules is an endothermic process[16-18].

The negative values of ΔS this order may more probably be explained by the possibility of the formation of iron complex on the metal surface[19,20] .

Fig 13 shows the liner dependence of C / θ as function of C.
The inhibitor adsorbs on the c-steel surface according to the Langmuir kind isotherm model by the relation[21] :-

$$C/\theta = 1/K + C \qquad ------------- \qquad (7)$$

Where
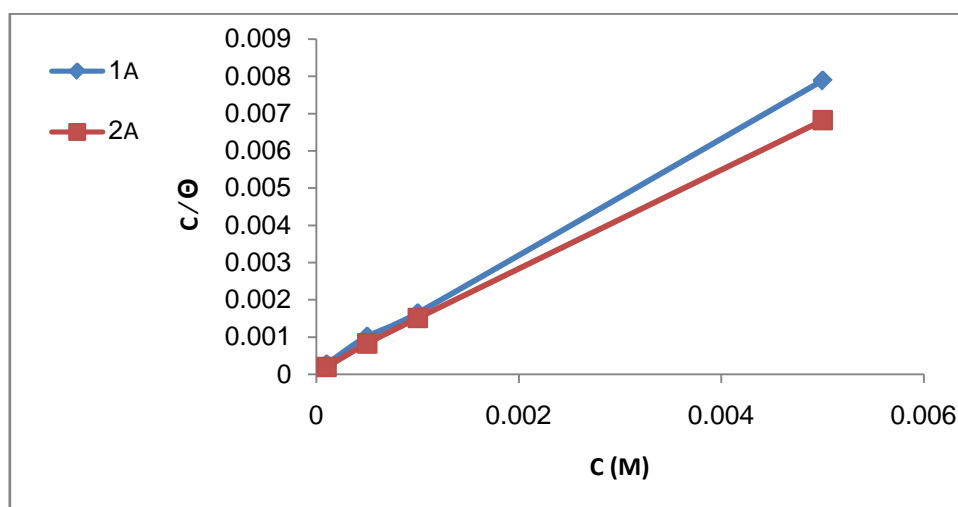K= is the equilibrium constant of the adsorption process.

Fig13: Langmuir Adsorption Isotherm Model for Azo Dyes in 0.5M HCl at Different Temperature

Polarization Measurements

Polarization behavior of C-steel in 0.5M HCl in the presence and absence of azo dyes compounds at 30°C is shown in Figs (10-18) .It was found that , both anodic and Cathodic reaction of c-steel electrode corrosion were inhibited with increasing concentration of synthesized inhibitors . These results suggest that not only the addition of synthesized inhibitors reduce anodic dissolution but also retard the hydrogen evolution reaction .

Electrochemical parameters such as corrosion potential (E_{corr}) , corrosion current density (I_{corr}), Cathodic Tafel constant (βc) and anodic Tafel constant (βa) were calculated from Tafel plots. Data

$$\%IE = [\ 1 - \frac{I_{add}}{I_{free}}\ ] \times 100 \qquad ----------- \quad (8)$$

Where
I_{add} , I_{free} are the corrosion current in absence and presence of inhibitors .

in Tables 12 and 13 represents the results of electrochemical parameters . The addition of inhibitors causes a decrease of the current density, the maximum decrease in I_{corr} was observed for (A2). The E_{corr} values of A1and A2 inhibitors were shifted slightly toward both Cathodic and anodic directions and did not show any definite trend in 0.5M HCl . This may be contributed to the mixed –type behavior of the studied inhibitors . Moreover , these inhibitors caused change in the anodic and Cathodic Tafel slope indicating that , the inhibitors are affecting the anodic and Cathodic reaction mechanism without blocking the reaction sites of c-steel surface . Inhibition efficiency (%IE) was calculated by the relation[22]:-

Data in Table 12 and 13 shows that the inhibition efficiency increased with increasing the
inhibitor concentration , indicating the inhibiting effect of these compounds .
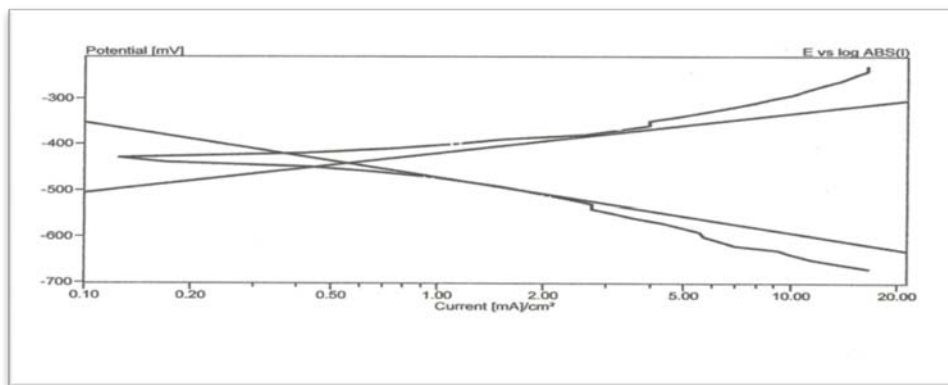

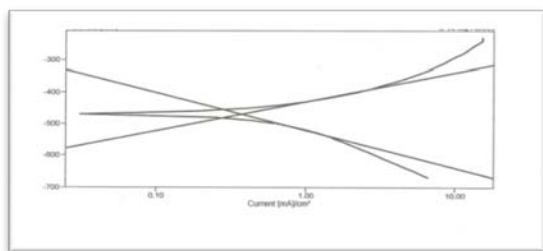**Fig 14: Galvano Static Polarization Curve of C-steel in 0.5M HCl in Absence Inhibitor at 30°C**
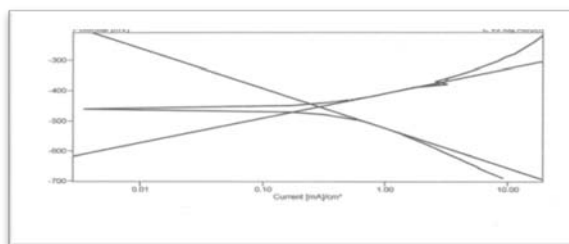
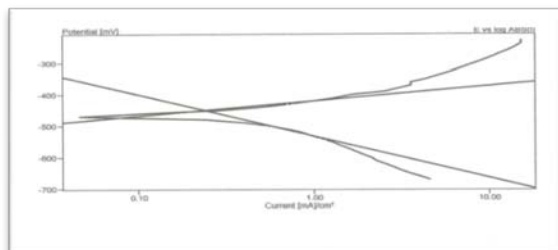**Fig15: (1×10^{-4} M) A1**

Fig16: (5×10^{-4} M) A1

Fig17: (1×10^{-3} M) A1
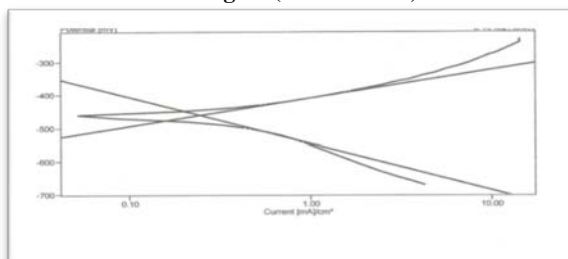
Fig18: (5×10^{-3} M) A1
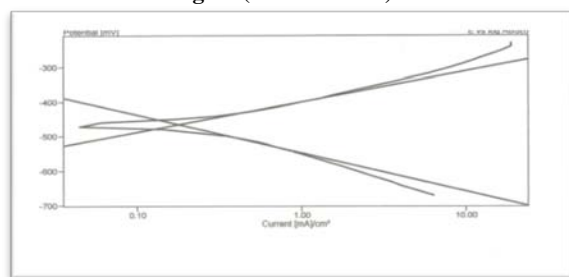
Fig 19: (1×10^{-4} M) A2
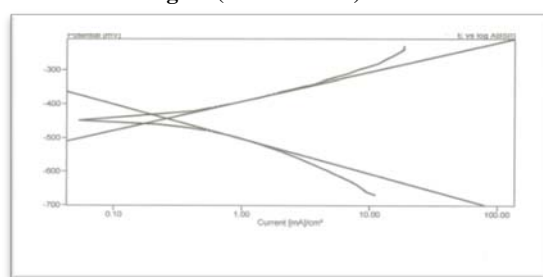
Fig 20: (5×10^{-4} M) A2
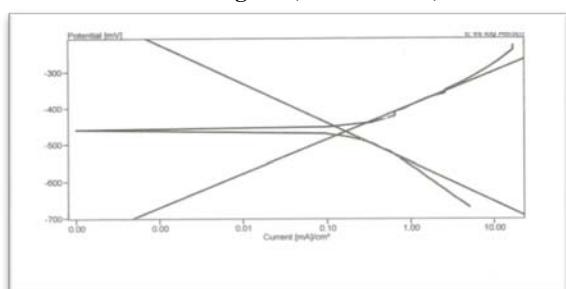

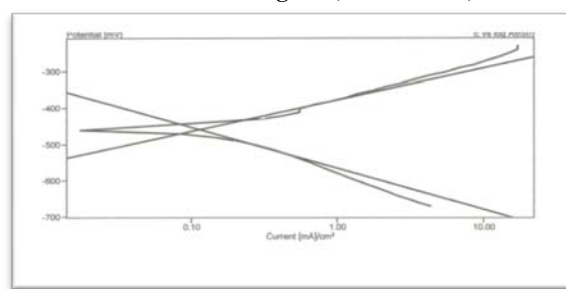**Fig 21: (1×10^{-3} M) A2**

Fig 22: (5×10^{-3} M) A2

Galvano Static Polarization Curves of C-steel in 0.5M HCl in Presence
Inhibitor (A1and A2) at 30°C

Table 12:- The Values of Corrosion Parameters for the Corrosion of C-steel in 0.5M HCl by Galvanostatic Polarization in Presence A1

Conc (M)	Icorr $\mu A/Cm^2$	Ecorr mV	βc mV.dec^{-1}	βa mV.dec^{-1}	% IE
0.00	555.38	-441.6	-119.7	86.9	_
1×10^{-4}	374.83	-470.0	-118.7	91.9	32.50
5×10^{-4}	288.57	-453.5	-132.3	81.8	48.04
1×10^{-3}	244.91	-461.0	-139.5	85.8	55.90
5×10^{-3}	238.59	-449.4	-132.0	48.0	57.04

Table 13:- The Values of Corrosion Parameters for the Corrosion of C-steel in 0.5M HCl by Galvanostatic Polarization in Presence A2

Conc (M)	Icorr $\mu A/Cm^2$	Ecorr mV	βc $mV.dec^{-1}$	βa $mV.dec^{-1}$	% IE
0.00	555.38	-441.6	-119.7	86.9	_
1×10^{-4}	259.14	-443.6	-103.2	86.4	53.34
5×10^{-4}	179.40	-465.4	-110.1	88.0	67.69
1×10^{-3}	166.84	-464.6	-106.8	92.5	69.95
5×10^{-3}	114.73	-459.0	-113.0	86.8	79.34

Mechanism of Inhibition

From the results obtained from electrochemical and weight loss measurements ,it was concluded that the (A1&A2) inhibit the corrosion of c-steel in 0.5M HCl by adsorption at c-steel solution interface. It is general assumption that the adsorption of organic molecules may adsorb on the metal surface in four types, namely[23,24].
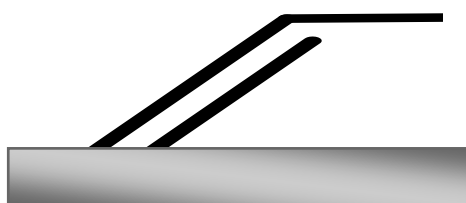
1-Electrostatic interaction between the charged molecules and the charged metal .

2- Interaction of unshared electron pairs in the molecule with metal .

3- Interaction of pi-electrons with the metal .

4-A combination of types (1,3).

Conclusions

The following conclusions could be predict from this study:-

1- The corrosion of c-steel in o.5M HCl is inhibited by the addition of some mono azo dyes compounds .

2- The inhibition efficiency increases with increases in the concentration of these compounds .

3- The inhibition efficiency of azo dyes compounds increases with the temperature and the activation corrosion energy decreases in presence of the inhibitor .

4- The inhibition of corrosion by azo dyes compound is due to chemical adsorption on the metal surface .

5- These compounds act as mixed type of inhibitors , and obey Langmuir adsorption isotherm

References

1-B.G.Clubby: ″ **Chemical Inhibitors for Corrosion Control** □**.** Royal Sco. Chem ., Cambridge, p.141,(1990) .

2-E. Sputnik, Z.Ademovic and Lisac,in: Proceeding of the 8th European Symposium on Corrosion Inhibitors (8SEIC)Ann. Univ. Ferrara, N.S.,SezV,Suppl., P.257,(1995).

3-M.Lagrenee, B.Mernari, M.Bouanis, M.Traisnel and F.Bentiss, Corros.Sci,J.44.574,(2002).

4-S.S.Al.Juaid, J.Electrochem.Soc.India,50.99,(2001).

5-SS.Abd EL- Rehim,MAM.Ibrahim and KF.Khaled,J.J.Appl.Electrochem,29.593,(1999).

6-J.J.Fox, J. of Chem. Soc, P.1339,(1910).

7-M.Abdallah, A.SFouda,S.A.Shama and E.A.Afifi,African.J.of pure and Appl.Chem.,P.083, (2008).

8-F.Bensajjay,S.Alehyen,M.El-AChouri and S.Kertit,Anti-Corros.Meth.&Mater.,50(6).402,(2003).

9-B.I.Ita and O.E.Offiong, Mater.Chem.Phys.70.330,(2001).

10-N.O.Eddyand S.A.Odoemelam, Afr .J. Pure appl Chem.2,132,(2008).

11-O.Radovici, Proceedings of the 2nd European Symposium on Corrosion inhibitors, Ferrara,178, (1965).

12-M Z A Rfiquee, Nidhisxena, Sadaf Khan and M A Quraishi ,Indian J. Chem Technol.,14.576, (2000).

13- M.Elachouir, M.S. Hajji, M.Salem, S. Kertit, J.Aride, R. Coudert and E.Essassi, Corrosion,52,103, (1996).

14-B.V.Savitri and S. Mayanna,Ind.Chem.Technol.3,256, (1996).

15-S.T.Arab and E.M.Noor,Corrosion,49,122, (1993).

16-A.S.Fouda,A.Abd-El-Aal and A.B.Kandil, Desalination, 201,216, (2006).

17-M.Bouklah,N.Benchat,B.Hammouti,A.Aouniti and S.Kertit,Mater.Letts.60,1901, (2006).

18-S.A.Ali,A.M.El-Shareef,R.F.Al-Ghamdi and M.T.Saeed,Corros.Sci,47,2659, (2005).

19-A.Bousseksou,G.Molnar,J.A.Real and K.Tanaka,Coord.Chem.Rev,251,1822, (2007).

20-L.Herrag,A.Chetouani,S.Elkadiri,B.Hammouti and A.Aouniti,Port.Electrochimica Acta,26,211, (2008).

21-I.Langmuir and J.Amer,Chem.Soc.39,1848, (1947).

22-Q.Qu,L.Li,W.Bai,S.Jing and Z.Ding,Corros.Sci.51,2423, (2009).

23-X.H.Li,S.D.Deng,H.Fu and G.N.Mu, J. Appl Electrochem,39.1125,(2009).

24-P.Lowmunkhong,D.Vngthararak and P.Sutthivaiyakit,Corros Sci,52.30,(2010).