

THE EFFECT OF N-3-HYDROXYL-2-NAPHTHOYL
HYDRAZONE DERIVATIVES AS INHIBITORS FOR
CORROSION OF CARBON STEEL
IN H₂SO₄ ACID SOLUTION

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ABSTRACT

The effect of some N-3-Hydroxyl-2-Naphthoyl Hydrazone derivatives, on the corrosion of carbon steel in 0.5 M H₂SO₄ solution was studied using weight loss and polarization techniques. The percentage inhibition efficiency was found to increase with increasing concentration of inhibitor and with decreasing temperature. Results obtained reveal that these N-3-Hydroxyl-2-Naphthoyl Hydrazone derivatives are a good inhibitors. The addition of KI, KBr and KSCN to N-3-Hydroxyl-2-Naphthoyl Hydrazone derivatives enhanced the inhibition efficiency due to synergistic effect. The inhibitors are adsorbed on the steel surface according to Frumkin's isotherm. Some thermodynamic functions were computed and discussed.

Keywords: Hydrazone derivatives; Carbon steel; Adsorption; corrosion inhibition.

1. INTRODUCTION.

Carbon steel is widely used as constructional material in many industries due to its excellent mechanical properties and low cost. The highly corrosive nature of aqueous mineral acids on most metals requires degree of restraint to achieve economic maintenance and operation of equipment, minimum loss of chemical product and maximum safety condition. Organic compounds containing nitrogen atom are commonly

used to reduce the corrosion attack on steel in acidic media [Bentiss et al., (2000); Popova et al., (2003); Abdallah et al., (2001); Damborenea et al., (1996); Al-Neami et al., (1995); Bastidas et al., (1997); Abd Aal et al., (2001); Mohamed et al., (2000); Abd El-Rehim et al., (1999) and Bentiss et al., (2002)]. These compounds can adsorb on the metal surface, block the active sites on the surface and thereby reduce the corrosion attack. The efficiency of these compounds as corrosion inhibitors can be attributed to the number of mobile electron pairs present [Abdallah et al., (2006)], the π orbital character of free electrons [Hacherman et al., (1960)] and the electron density around nitrogen atom [Abdallah et al., (2006)]. The aim of this work is to study the effect of some N-3-Hydroxyl-2-Naphthoyl Hydrazones derivatives as corrosion inhibitors for dissolution of carbon steel in 0.5 M H_2SO_4 solutions using weight loss and galvanostatic polarization measurements. The effect of temperature on the dissolution of C-steel in free and inhibited acid solution was also investigated. It was found that the percentage inhibition efficiency decreases with increasing temperature.

2. EXPERIMENTAL DETAILS

The experiments were performed with carbon steels having the chemical compositions C 0.2%, Mn 0.35%, P 0.024%, Si 0.003% and the remainder iron. Two different techniques have been employed for studying the inhibition of carbon steel corrosion by N-3-Hydroxyl-2-Naphthoyl Hydrazones derivatives. These are:

- a) Chemical technique (Weight loss method).
- b) Electrochemical technique (Galvanostatic polarization method).
- a) Chemical technique (Weight loss method).

The reaction basin used in this method was a graduated glass vessel 6 cm inner diameter and having a total volume of 250 ml. 100 ml of the test solution were employed in each experiment. The test coupons were cut into 2x2x0.2 cm, they were mechanically polished with emery paper (a coarse paper was used initially and then progressively finer grades were employed), ultrasonically degreased in acetone [Fouda et al., (1990)], rinsed in doubly distilled water and finally dried between two filter papers and weighed. The test pieces were suspended by suitable glass hooks at the edge of the basin, and under the surface of the test

solution by about 1cm. After specified periods of time, 3 test pieces were taken out of the test solution, rinsed in doubly distilled water, dried as before and weighed again. The average weight loss at a certain time for each set of three samples was taken. The weight loss per unit area was calculated as:

$$\Delta W = (W_1 - W_2) / A \quad (1)$$

where W_1 and W_2 are the weights of specimen before and after the reaction, respectively, and A is the surface area in cm^2 .

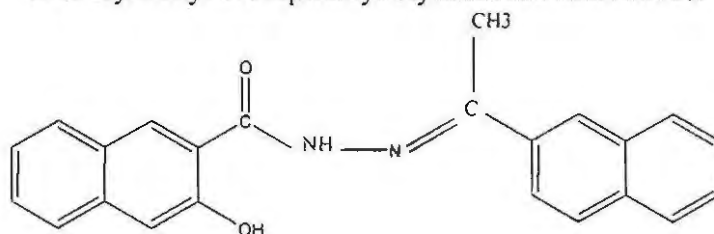
b) Electrochemical Technique (Galvanostatic Polarization Method)

1) Electrochemical Cell:

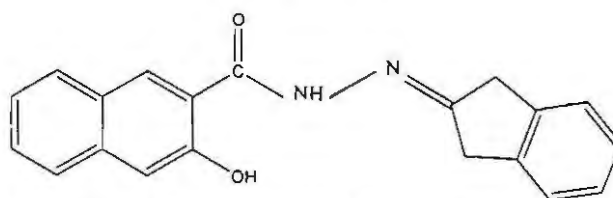
The main requirements in the polarization cell for the polarization measurements are: The cell must be air tight, greased taps must be avoided and the cell must allow the adjustment of the anode in order to touch the tip of the Luggin probe.

2) - Electrodes: Three different types of electrodes were used during polarization measurements: i) Working Electrode. ii) Reference Electrode. iii) Auxiliary Electrode.

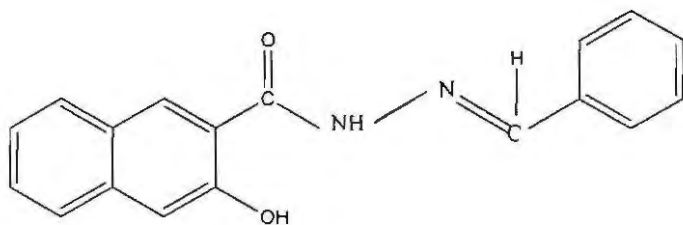
-Organic Additives: The selected organic additives used in this study are N-3-Hydroxyl-2-Naphthoyl Hydrazones derivatives.



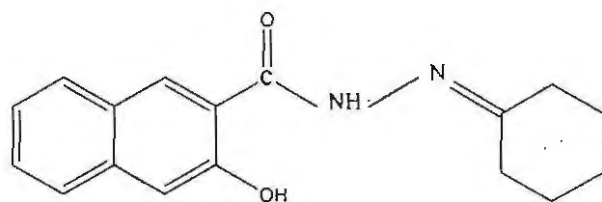
2-Acetophenone [N-3-Hydroxyl-2-Naphthoyl Hydrazone]
Compound (1)



α -Tetralone [N-3-Hydroxyl-2-Naphthoyl Hydrazone]
Compound (2)



Benzaldehyde [N-3-Hydroxyl-2-Naphthoyl Hydrazone]
Compound 3



CycloHexanone [N-3-Hydroxyl-2-Naphthoyl Hydrazone]

Compound (4)

3. RESULTS AND DISCUSSION.

3.1. Weight loss measurements.

Fig.3.1 represents the relation between time and weight losses of C-steel coupons in 0.5 M H_2SO_4 solution devoid of and containing different concentrations of compound (1) as an example. Similar curves were also obtained for other three tested compounds. Inspection of this figure reveals that, the linear variation of weight loss with time in uninhibited and inhibited 0.5 M H_2SO_4 solution indicates the absence of insoluble surface films during corrosion i.e. the inhibitors are first adsorbed on the metal surface and thereafter impede corrosion either by merely blocking the reaction sites (anodic and cathodic) or by altering the mechanism of the anodic and cathodic processes.

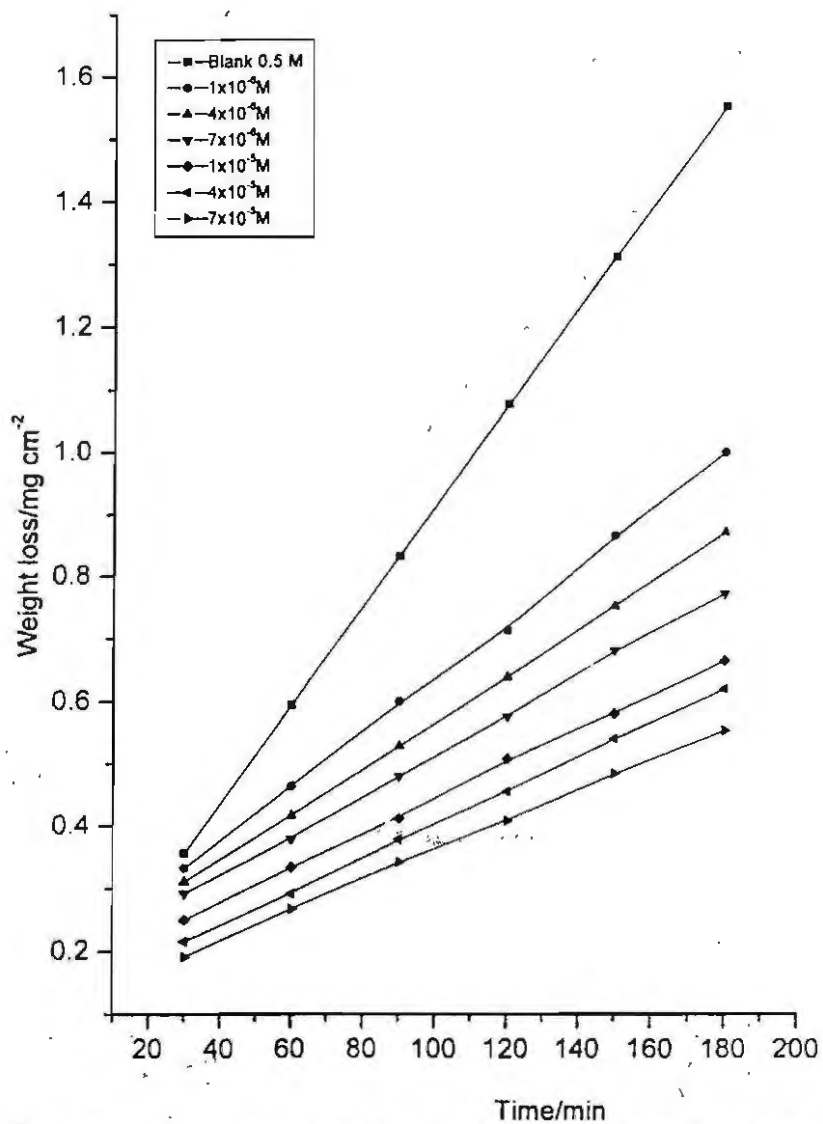


Fig 1 weight loss time curves for carbon steel dissolution in 0.5M H₂SO₄ in absence and presence of different concentration of compound(1) at 303 k

The calculated values of inhibition efficiencies obtained from weight loss are listed in Table (1a). It is obvious that the Inhibition Efficiency increases with increasing the inhibitor concentration, whereas decreases in the following order: compound (1) > compound (2) > compound (3) > compound (4). This behavior will be discussed later.

Table (1): Inhibition efficiency (I%) of some N-3-Hydroxyl-2-Naphthoyl Hydrazones derivatives for carbon steel dissolution in 0.5M H₂SO₄ at different temperatures and at different concentrations of inhibitors (at 120min. immersion).

Inhibitor	Inhibition efficiency (% I)						
	Conc./ M	1x10 ⁻⁶	4x10 ⁻⁶	7x10 ⁻⁶	1x10 ⁻⁵	4x10 ⁻⁵	7x10 ⁻⁵
	Temp./ k						
1	303	33.71	40.67	46.46	52.79	57.73	62.08
	308	27.99	33.58	41.58	48.99	54.77	56.41
	313	28.43	33.69	40.10	45.68	40.4	54.23
	318	26.40	32.33	38.48	43.26	47.52	52.24
	323	22.11	28.2	32.84	36.98	42.92	46.35
2	303	32.06	38.95	44.77	50.94	54.75	59.41
	308	26.15	31.52	39.02	46.51	51.73	55.38
	313	24.92	30.13	37.14	42.75	48.62	51.82
	318	24.36	32.25	36.42	40.56	45.45	50.28
	323	21.03	26.39	31.03	35.35	39.40	43.44
3	303	29.60	35.6	43.64	49.46	53.25	58.18
	308	24.45	29.84	36.98	42.87	47.91	52.12
	313	22.43	28.35	34.77	39.93	45.35	49.72
	318	23.10	28.51	34.41	37.94	42.75	46.74
	323	18.63	23.96	29.75	33.54	37.55	41.18
4	303	23.98	32.06	40.52	46.38	52.60	55.2
	308	21.09	27.99	35.95	42.86	48.14	50.94
	313	20.65	26.58	32.99	38.62	45.06	47.97
	318	21.68	25.23	32.43	35.90	40.73	44.60
	323	16.72	24.04	28.62	31.68	35.81	38.69

3.2. Synergistic effect.

The effect of KI, KSCN and KBr on the inhibitive performance of compounds has been studied using weight loss technique. The values of IE for specific concentration of KI, KSCN and KBr ($1 \times 10^{-2} \text{M}$) in the presence of various concentrations of inhibitors are given in Table (1b). The synergistic inhibition effect was evaluated using a parameter, S_θ , obtained from the surface coverage θ of the anion, cation and both. [Hackerman et al., (1969)] calculated the synergistic parameter, S_θ , using the following equation:

$$S_\theta = 1 - \theta_{1+2} / 1 - \theta'_{1+2} \quad (2)$$

Where:

$$\theta_{1+2} = (\theta_1 + \theta_2) - (\theta_1 \theta_2);$$

θ_1 = surface coverage by anion;

θ_2 = surface coverage by cation;

θ'_{1+2} = measured surface coverage by both the anion and cation

The calculated values of S_θ are given in Table 1c. Inspection of Table (1c), the values of S_θ are nearly equal to unity which suggests that the enhanced inhibition.

3.3. Effect of temperature.

The effect of temperature on the corrosion rate of C-steel in free acid and in presence of different inhibitors concentrations was studied in the temperature range of 303–323 K using weight loss measurements. Similar curves to Fig. 1 were obtained (not shown).

As the temperature increases, the rate of corrosion increases and hence the inhibition efficiency of the additives decreases. This is due to the desorption of inhibitor is aided by increasing the temperature. This behavior proves that the adsorption of inhibitors on C-steel surface occurs through physical adsorption. The apparent activation energy E_a , the enthalpy of activation ΔH^* and entropy of activation ΔS^* for the corrosion of C-steel in 0.5 M H_2SO_4 solutions in absence and presence of different concentrations of N-3-Hydroxyl-2-Naphthoyl Hydrazones derivatives were calculated from Arrhenius-type equation [Putilova et al., (1960)].

$$k = A \exp(-E_a^* / RT) \quad (3)$$

and transition state equation

$$K = (RT/Nh) \exp(\Delta S^*/R) \exp(-\Delta H^*/RT) \quad (4)$$

where k is the rate of metal dissolution, A is the frequency factor, N is Avogadro's number and R is the universal gas constant.

Table (2): Inhibition efficiency at different concentrations of inhibitors + 1×10^{-2} M (KI, KSCN and KBr) as determined from weight loss method at 303 k.

	Conc./M	Compound 1	Compound 2	Compound 3	Compound 4
KI 1×10^{-2} /M	1×10^{-6}	76.2	74.0	73.2	71.7
	4×10^{-6}	77.9	76.4	75.3	73.8
	7×10^{-6}	80.0	78.1	76.6	75.1
	1×10^{-5}	81.8	80.7	78.8	76.9
	4×10^{-5}	84.0	82.5	80.9	78.7
	7×10^{-5}	85.8	84.3	82.8	80.6
	KSCN 1×10^{-2} /M	1×10^{-6}	61.6	59.4	56.7
4×10^{-6}		64.3	62.0	59.7	56.0
7×10^{-6}		66.3	64.4	61.8	58.7
1×10^{-5}		68.0	66.9	64.3	60.9
4×10^{-5}		70.0	68.7	66.4	63.8
7×10^{-5}		72.2	71.5	69.2	66.6
KBr 1×10^{-2} /M		1×10^{-6}	48.8	46.6	44.7
	4×10^{-6}	54.1	51.8	49.2	46.6
	7×10^{-6}	58.7	55.7	53.5	50.3
	1×10^{-5}	63.1	59.0	57.2	54.9
	4×10^{-5}	66.0	62.6	60.0	59.2
	7×10^{-5}	70.0	67.0	63.6	62.5

Fig. 2 represents plot of $\log k$ against $1/T$ for C-steel in 0.5M H_2SO_4 solution in absence and presence of different concentrations of compound (1) as an example. Similar curves were obtained for other compounds (not shown). Straight lines were obtained with slope equal to $-E_a/2.303R$. The values of E_a for the corrosion reaction in the absence and presence of different compounds was calculated and given in Table 2.

Table (3): Synergistic Parameter (S_0 for different concentrations 1×10^{-6} M of KI, KSCN and KBr.

	Conc./ M	S_0			
		Compound 1	Compound 2	Compound 3	Compound 4
KI	1×10^{-6}	1.11	1.04	1.05	1.07
	4×10^{-6}	1.07	1.04	1.04	1.04
	7×10^{-6}	1.07	1.01	0.96	0.96
	1×10^{-5}	1.04	1.02	0.95	0.93
	4×10^{-5}	1.06	1.04	0.98	0.89
	7×10^{-5}	1.07	1.03	0.98	0.92
KSCN	1×10^{-6}	1.12	1.09	1.06	1.05
	4×10^{-6}	1.08	1.05	1.03	1.00
	7×10^{-6}	1.03	1.01	0.96	0.93
	1×10^{-5}	0.95	0.96	0.91	0.89
	4×10^{-5}	0.91	0.94	0.90	0.85
	7×10^{-5}	0.88	0.92	0.89	0.87
KBr	1×10^{-6}	1.04	1.02	1.02	1.05
	4×10^{-6}	1.03	1.01	1.01	1.02
	7×10^{-6}	1.04	0.95	0.97	0.98
	1×10^{-5}	1.03	0.99	0.94	0.95
	4×10^{-5}	0.99	0.97	0.93	0.92
	7×10^{-5}	1.01	0.98	0.92	0.96

Table (4): Activation parameters for the dissolution of C-steel in presence and absence of different concentrations of inhibitors in 0.5M H₂SO₄.

Inhibitor	Conc. /M	Activation parameters		
		E _a / kJ mol ⁻¹	ΔH [‡] / kJ mol ⁻¹	-ΔS [‡] / J mol ⁻¹ K ⁻¹
Free acid (H ₂ SO ₄)	0	60.52	57.84	93.25
1	1x10 ⁻⁶	66.33	63.66	77.40
	4x10 ⁻⁶	66.78	64.10	76.74
	7x10 ⁻⁶	68.92	66.34	70.38
	1x10 ⁻⁵	71.85	69.17	62.16
	4x10 ⁻⁵	72.97	70.29	59.42
	7x10 ⁻⁵	73.68	71.00	57.79
2	1x10 ⁻⁶	66.07	63.39	78.02
	4x10 ⁻⁶	66.71	64.04	77.68
	7x10 ⁻⁶	68.64	65.97	71.26
	1x10 ⁻⁵	71.49	68.81	62.97
	4x10 ⁻⁵	72.21	69.54	61.38
	7x10 ⁻⁵	73.34	70.67	58.46
3	1x10 ⁻⁶	65.73	63.06	78.85
	4x10 ⁻⁶	66.47	63.80	77.12
	7x10 ⁻⁶	68.62	65.95	71.09
	1x10 ⁻⁵	71.15	68.47	63.68
	4x10 ⁻⁵	71.77	69.09	62.39
	7x10 ⁻⁵	73.60	70.97	57.07
4	1x10 ⁻⁶	63.44	60.77	85.86
	4x10 ⁻⁶	64.26	61.59	84.01
	7x10 ⁻⁶	67.56	64.89	74.23
	1x10 ⁻⁵	70.54	67.87	65.38
	4x10 ⁻⁵	72.87	70.19	58.75
	7x10 ⁻⁵	73.00	70.35	58.70

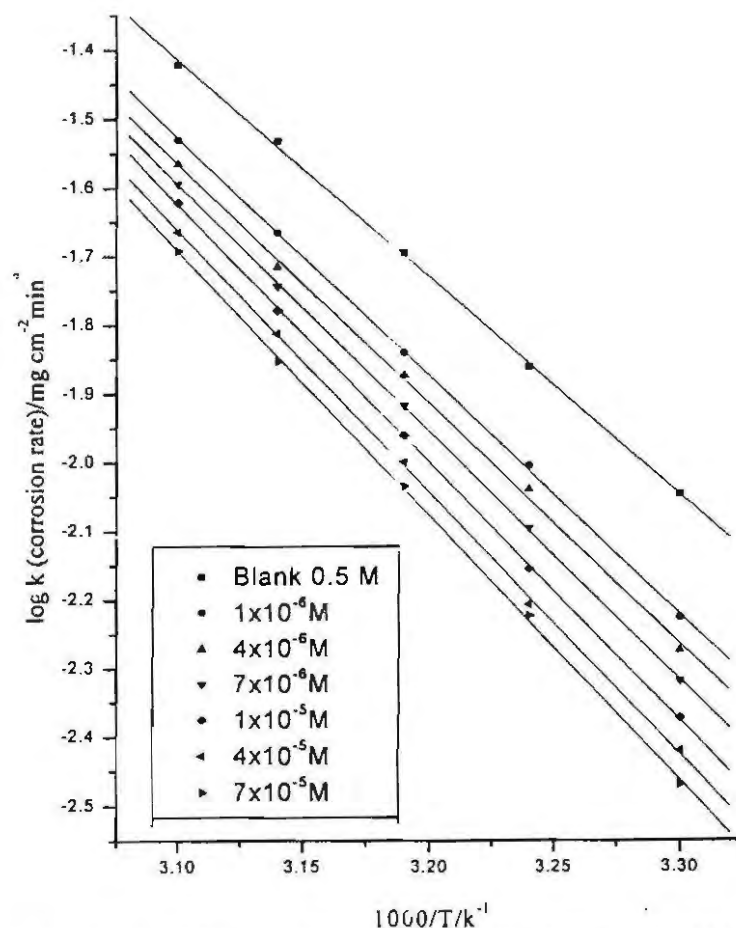


Fig 2 log corrosion rate vs. $1/T$ curves for carbon steel dissolution in $0.5 \text{ M H}_2\text{SO}_4$ in absence and presence of different concentrations of compound(1)

On the other hand, Fig. 3 represents the plots of $\log k/T$ against $1/T$ for C-steel in $0.5 \text{ M H}_2\text{SO}_4$ solution in absence and presence of different concentrations of compound(1). Similar curves obtained for other compounds (not shown). This relation gave straight lines with slope equals to $-\Delta H^*/2.303R$ and the intercept is $\log R/Nh + \Delta S^*/2.303R$. The obtained values of ΔH^* and ΔS^* are given in Table 2. Inspection of Table 2 demonstrates that, the presence of N-3-Hydroxyl-2-Naphthoyl Hydrazones derivatives increases the values of E_a indicating the adsorption of the inhibitor molecule on the metal surface. The values of E_a increases with increasing the concentration of inhibitor. This mean that, the presence of derivatives induce an energy barrier for the

corrosion reaction and this barrier increases with increasing the concentration of these compounds. The positive values of ΔH^\ddagger reflect that the process of adsorption of the inhibitors on the steel surface is endothermic process. The values of ΔS^\ddagger in the presence and absence of the inhibitors is large and negative. This implies that the activation complex is the rate determining step represents association rather than dissociation, indicating that a decrease in disorder takes place on going from reactants to the activated complex [Abd El-Rehim et al., (2001)].

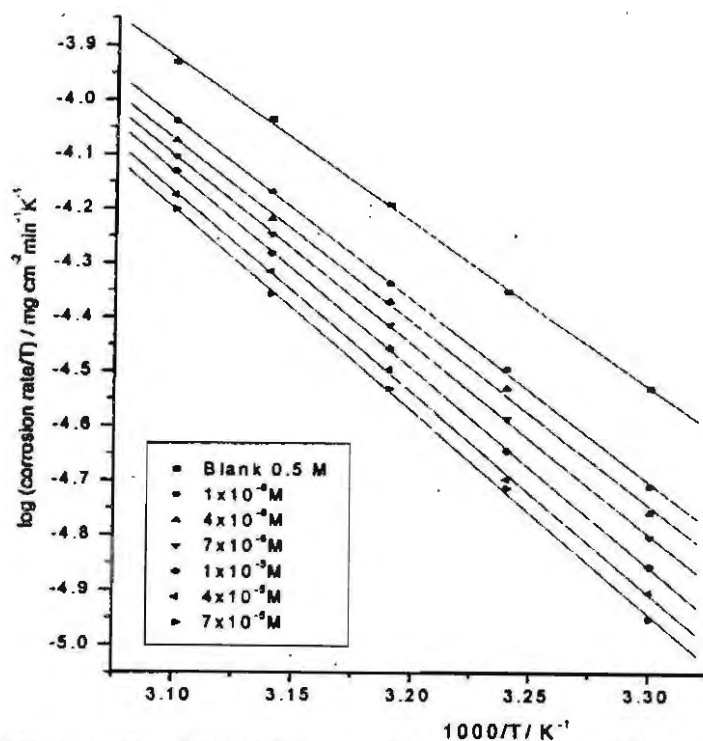


Fig 3 $\log(\text{corrosion rate}/T)-(1/T)$ curves for carbon steel dissolution in 0.5 M H_2SO_4 in absence and presence of different concentrations of compound (1)

3.4. Adsorption isotherm.

The values of the degree of surface coverage, θ were evaluated at different concentrations of the inhibitors in 0.5 M H_2SO_4 solution. Attempts were made to fit θ values to various adsorption isotherms. The Frumkin's adsorption isotherm fits the experimental data. A plot of θ against $\log C$ for all concentrations of inhibitors (Fig. 4) approximately a

S-shape in all cases was obtained. This suggests that the adsorption of N-3-Hydroxyl-2-Naphthoyl Hydrazones derivatives on the steel surface follow Frumkin's isotherm. These results confirm the assumption that, these compounds are adsorbed on the metal surface through the protonated N-atom or via the lone pair of electrons of nitrogen atoms. In addition to, the extent of inhibition is directly related to the performance of adsorption layer which is a sensitive function of the molecular structure.

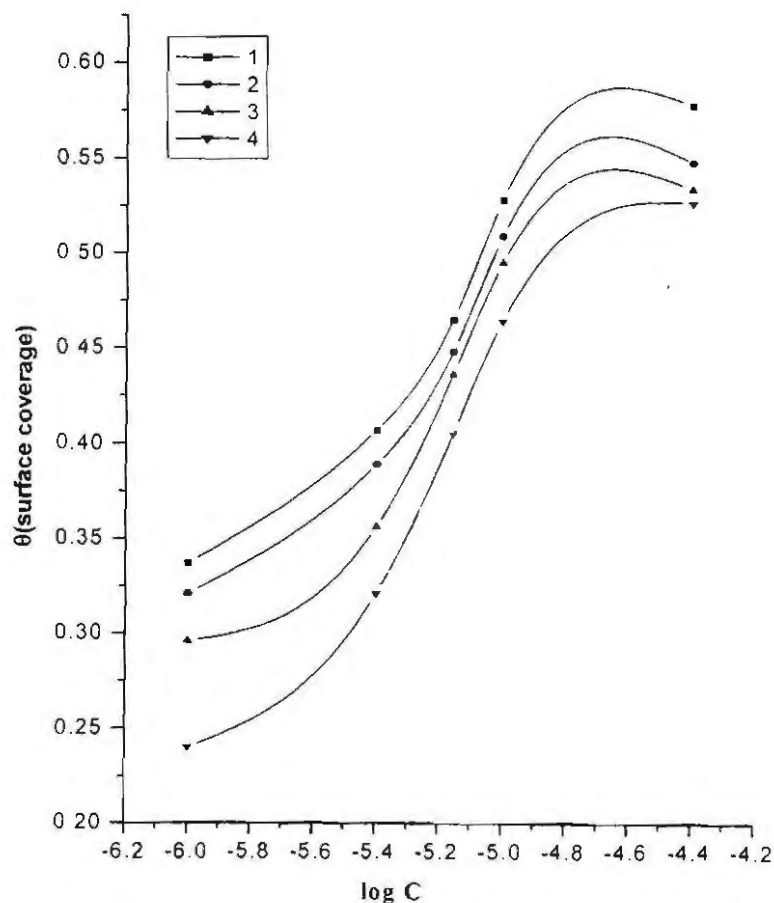


Fig 4 θ - $\log C$ curves for C-steel dissolution in 0.5M H_2SO_4 in presence of all inhibitors from weight loss measurements at 303K .

3.5. Galvanostatic polarization studies.

The effect of addition of N-3-Hydroxyl-2-Naphthoyl Hydrazones derivatives on the anodic and cathodic polarization curves of C-steel in 0.5 M H_2SO_4 solution at 303 K was studied. The effect of increased concentration of compound (1) is represented in Fig.5 as an example.

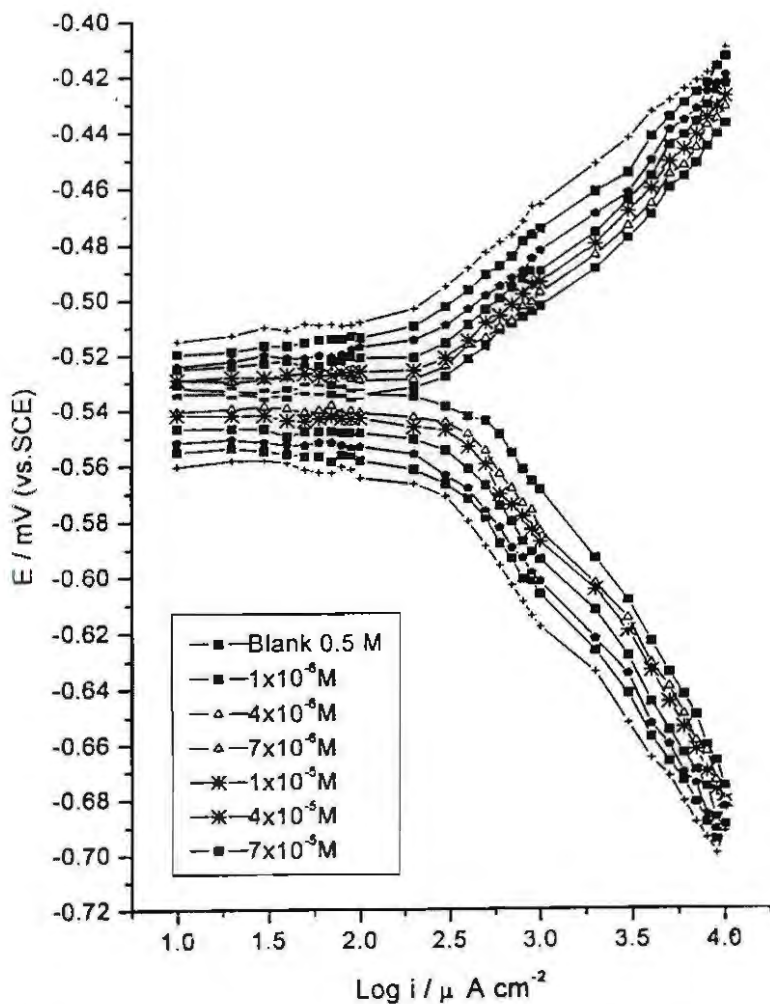


Fig 5 Galvanostatic polarization curves for carbon steel in 0.5M H_2SO_4 in absence and presence of different concentrations of compound (1) at 303K.

However, similar curves were obtained for other compounds. The electrochemical parameters such as, corrosion potential (E_{corr}), corrosion current density (I_{corr}), cathodic Tafel constant (β_c), anodic Tafel slope (β_a) and inhibition efficiency (IE) were calculated and given in Table 3

Table(5): Electrochemical parameters obtained from galvanostatic polarization of C-steel in 0.5M H_2SO_4 containing different concentrations of inhibitors.

Concentration/ M	$-E_{corr}/$ mV	$I_{corr}/$ $\mu A cm^{-2}$	$\beta_a/$ mV dec. ⁻¹	$\beta_c/$ mV dec. ⁻¹	θ	% IE
Compound 1						
0.0	535	469.25	78	112	-	-
$1 \times 10^{-6} M$	528	316.23	65	99	0.320	32
$4 \times 10^{-6} M$	528	281.84	61	96	0.399	40
$7 \times 10^{-6} M$	527	251.19	56	94	0.464	46
$1 \times 10^{-5} M$	526	229.09	52	93	0.511	51
$4 \times 10^{-5} M$	526	208.93	51	90	0.554	55
$7 \times 10^{-5} M$	525	190.55	49	90	0.593	59
Compound 2						
0.0	535	469.25	78	112	-	-
$1 \times 10^{-6} M$	529	436.74	71	103	0.260	26
$4 \times 10^{-6} M$	529	309.03	68	100	0.340	34
$7 \times 10^{-6} M$	527	275.42	63	98	0.412	41
$1 \times 10^{-5} M$	525	263.03	60	100	0.439	44
$4 \times 10^{-5} M$	526	239.88	57	96	0.488	49
$7 \times 10^{-5} M$	523	239.88	51	95	0.564	56
Compound 3						
0.0	535	469.25	78	112	-	-
$1 \times 10^{-6} M$	531	363.08	74	103	0.225	23
$4 \times 10^{-6} M$	528	323.59	71	101	0.309	31
$7 \times 10^{-6} M$	525	259.12	70	98	0.370	37
$1 \times 10^{-5} M$	525	275.42	68	100	0.412	41
$4 \times 10^{-5} M$	525	251.19	63	101	0.464	46
$7 \times 10^{-5} M$	522	223.87	60	103	0.522	52
Compound 4						
0.0	535	469.25	78	112	-	-
$1 \times 10^{-6} M$	532	371.54	77	101	0.200	20
$4 \times 10^{-6} M$	532	338.84	77	101	0.277	28
$7 \times 10^{-6} M$	526	309.03	74	99	0.340	34
$1 \times 10^{-5} M$	525	281.84	71	100	0.398	40
$4 \times 10^{-5} M$	522	254.04	65	100	0.451	45
$7 \times 10^{-5} M$	521	234.42	63	104	0.500	50

The corrosion current density (I_{corr}) and corrosion potential (E_{corr}) were determined by the intersection of the extrapolating anodic and cathodic Tafel lines, % IE was calculated and β_a and β_c are the slopes of the anodic and cathodic Tafel lines. Inspection of Table 3 reveals that, the increasing in the concentration of the additive show the following:

(a) The Tafel lines are shifted to more positive and negative potential for anodic and cathodic processes, respectively, relative to the blank curve. This means that these compounds influence both cathodic and anodic processes.

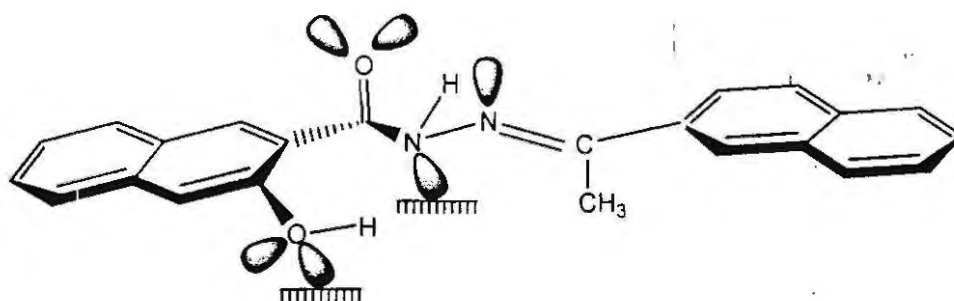
(b) E_{corr} is decreased slightly and the values of I_{corr} decreases indicating the inhibiting effect of these compounds.

(c) The inhibition efficiencies of the four tested compounds by the polarization method in the following order:

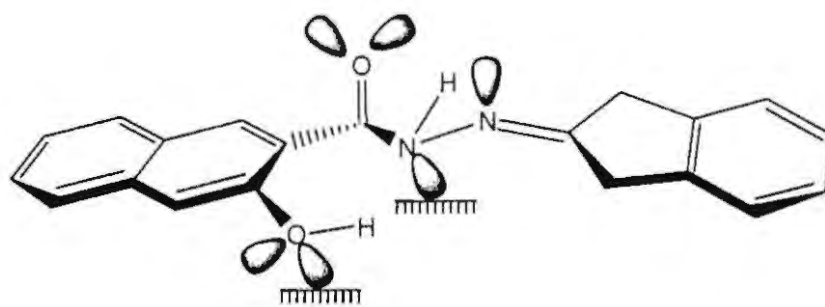
compound (1) > compound (2) > compound (3) > compound (4).

3.6. Chemical structure and corrosion inhibition.

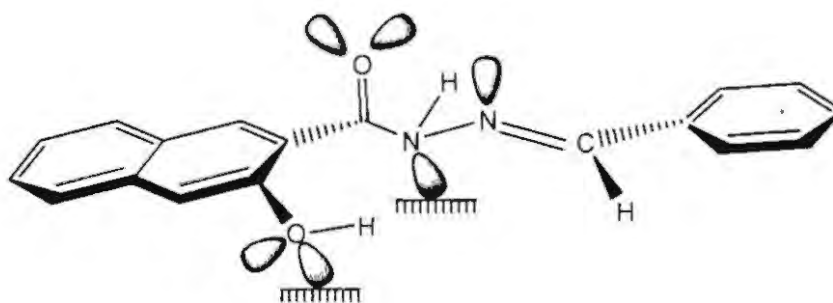
Skeletal representation of the mode of adsorption of N-3-Hydroxyl-2-Naphthoyl Hydrazones derivatives on C-steel surface is shown in Fig (6).



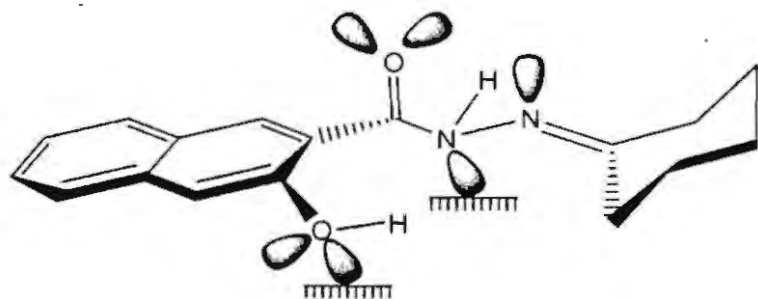
Compound (1)



Compound (2)



Compound (3)



Compound (4)

Fig.(6): Skeletal representation of the mode of adsorption of all N-3-Hydroxyl-2-Naphthoyl Hydrazones derivatives.

As shown from this figure, there are only two adsorption active sites in all investigated compounds (1-4). Nitrogen atom of the hydrazones and oxygen atom of the hydroxyl group. Hence we can not take the adsorption active sites in my comparison in % inhibition for these derivatives. So, the molecular size is the determining factor. Compound (1) is the most efficient one in % inhibition; this is due to its larger molecular size (354) and presence of two benzene rings which provides some of their electronic density to the active sites. Compound (2) comes after Compound (1) in % inhibition. This is due to its lower molecular size (316) than compound (1) and it contains five saturated ring and benzene ring which provide no electrons to the active sites. Compound (3) comes after Compound (2) in % inhibition due to its lower molecular size (290) than Compound (1) & Compound (2) and the larger distance between the benzene ring and the active sites, so the sharing of π -electrons of the benzene ring is lesser. Compound (4) is the least one in % inhibition due to: i) its lower molecular size (282) and ii) the presence of cyclohexyl ring which does not provide charge density for the active sites. The order of decreasing inhibition efficiency is:

Compound (1) [354] > Compound (2) [316] > Compound (3) [290] > Compound (4) [282].

4. CONCLUSIONS

- . N-3-Hydroxyl-2-Naphthoyl Hydrazones derivatives act as inhibitors for corrosion of carbon steel in 0.5M H₂SO₄ solution.
- . The inhibition efficiency increases with increase in the concentration of these inhibitors but decreases with an increase in temperature.
- . The additions of KI, KSCN and KBr to these compounds improve the values of inhibition efficiency due to synergistic effect.
- . The inhibition is due to the adsorption of the inhibitor molecule on the steel surface.
- . The adsorption of these compounds on the steel surface follows Frumkin's adsorption isotherm.

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تأثير مشتقات ان-3-هيدروكسيل-2-نافثويل هيدرازون كمثبطات
لتآكل الصلب الكربوني في محلول حمض الكبريتيك

تم دراسة تأثير بعض مشتقات ان-3-هيدروكسيل-2-نافثويل هيدرازون على تآكل الصلب الكربوني المقاوم في محلول 0.5 مولار من حمض الكبريتيك باستخدام طريقة فقد الوزن وطريقة الاستقطاب الكهربي. أظهرت النتائج أن مشتقات ان-3-هيدروكسيل-2-نافثويل هيدرازون تعمل كمثبطات جيدة. النسبة المئوية لكفاءة التثبيط وجد أنها تزداد مع زيادة تركيز المثبط وتقل برفع درجة الحرارة. وقد وجد أن كفاءة التثبيط تعتمد على الشكل الجزيئي والتركيز للمركبات المقترحة. ووجد أن الامتزاز على سطح الصلب الكربوني يتبع أيزوثيرم فريمكن وبإضافة يوديد وبروميد وثيويثانات البوتاسيوم الى المركبات المقترحة يؤدي الى زيادة التثبيط.