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Corrosion protection of mild steel in Hydrochloric acid solutions using expired Hydrocortisone sodium succinate drug

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Abstract

The erosion hindrance of carbon steel in 1M HCl in nearness and nonappearance of terminated Hydrocortisone Sodium Succinate has been examined utilizing mass-loss. Comes about gotten appeared that the restraint productivity expanded with the increment of the concentration of the utilized medicate and diminished with the increment of temperature. The adsorption of this sedate on carbon steel surface takes after Langmuir's adsorption isotherm. A few thermodynamic parameters were calculated. The motor parameters of erosion of carbon steel in HCl arrangement have been examined.

Keywords: Corrosion inhibition; Carbon steel; Hydrocortisone

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Introduction

Gentle steel has been broadly utilized beneath distinctive conditions in petroleum businesses [1]. Watery arrangements of acids are among the foremost destructive media and are broadly utilized in businesses for pickling, corrosive cleaning of boilers, descaling and oil well [2-5]. The most issue concerning mellow steel applications is its generally moo erosion resistance in acidic arrangement. A few strategies utilized right now to decrease erosion of gentle steel. One of such strategies is the utilize of natural inhibitors [6]. The foremost of the natural inhibitors are poisonous, exceedingly costly and environment hostile. Inquire about exercises in later times are equipped towards creating the cheap, non-toxic and environment inviting erosion inhibitors. Be that as it may, the utilize of these natural compounds has been addressed of late, due to the a few negative effects they have caused within the environment [7]. In this way, the advancement of the novel erosion inhibitors of normal source and non-toxic sort has been considered to be more imperative and alluring [8]. Because of their natural origin [8-11], as well as their non-toxic characteristics [12] and negligible negative impacts on the aquatic environment [13], drugs (chemical medicines) seem to be ideal candidates to replace traditional toxic corrosion. These inhibitors diminish the erosion rate by adsorbing on the

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metal surface and blocking the dynamic destinations by uprooting water atoms and shape a compact obstruction film on the metal surface. The aim of the paper is to investigate the effect of addition of expired Hydrocortisone. Sodium Succinate as a pharmaceutical compound on the corrosion resistance of mild steel in 1 M HCl. The electrochemical behavior of mild steel in 1 M HCl acid solutions with and without the presence of this pharmaceutical compounds is characterized by weight loss method. This compound is nontoxic and inexpensive.

Experimental Methods

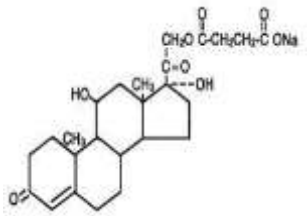
Materials

Materials used for the study were mild steel sheet of composition (wt%) 0.20 C, 0.029 Si, 0.018 S, 0.0067 P, 0.397 Mn, 0.025 Ni, 0.0076 Cr, 0.0020 Mo, 0.0010 V, 0.036 Cu, 0.0010 Sn, 0.0057 Co, 0.126 Al, 0.023 Zn, 0.0020 Mg, 0.0046 Nb, and 0.0025 Bi, the rest Fe.

Chemicals and solutions

Hydrochloric acid HCl (BDH grade) and expired Hydrocortisone Sodium Succinate, the stock solution (1x 10^{-2}M) of expired Hydrocortisone Sodium Succinate was used to prepare the desired concentrations by dilution with bidi stilled water. The concentration range of Hydrocortisone Sodium Succinate used was (2x 10^{-6}-1x10^{-5}) M. Its chemical structure is shown in Table1.

Table1: Chemical structure of Hydrocortisone Sodium Succinate.

Structure	Mol. Formula	Mol.wt.
	$C_{25}H_{34}NaO_8$	485.529 g·mol^{-1}

Weight loss measurements

The weight misfortune estimations were carried out in a 100 ml glass measuring utencil set in an indoor regulator water shower. The arrangement volume was 100 ml. The utilized gentle steel coupons had a square shape (length = 20 mm, width = 20 mm, thickness = 2 mm). The coupons were weighed and suspended in 100 ml of an aerated 1 M HCl solution with and without different concentrations of Hydrocortisone Sodium Succinate for 3 h exposure period of time at (25 -45) ± 1 ºC. At the end of the tests, the coupons were taken out, washed with bi-distilled water, degreased with acetone, washed again with bi-distilled water, dried, and then weighed using an analytical balance. The inhibition efficiency (% IE) over the exposure time period were

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calculated according to the following equation [14]:

$$\%\, IE = \theta \times 100 = \left(1 - \frac{W_{(inh)}}{W_{(free)}}\right) \times 100 \quad (1)$$

where, θ surface coverage, $W_{(free)}$ and $W_{(inh)}$ are the weight loss in the absence and presence of inhibitor, respectively.

Result and Dissection

The curves obtained in the presence of different concentrations of inhibitor fall significantly below that of free acid (Figure 1). Values of % IE are tabulated in Table 1. The increment within the inhibitor concentration was accompanied by a diminish within the weight misfortune and an increment in % IE. These comes about lead to the conclusion that, this compound beneath examination was decently proficient inhibitors for C-steel disintegration in HCl arrangement.

Table 2: Variation of corrosion rate (C.R.) in (mg cm^{-2} min^{-1}) and inhibition efficiency (% IE) of Hydrocortisone Sodium Succinate with its molar concentrations from weight loss measurements at 120 min immersion in 1 M HC l at 25 ºC.

Conc.,M	C.R., mg cm^{-2} min^{-1}	Inhibition efficiency (% IE)
1 M HCl	0.753	52.56
$2x10^{-6}$ M	0.456	58.32
$4x10^{-6}$ M	0.277	64.23
$6x10^{-6}$ M	0.112	72.4
$8x10^{-6}$ M	0.076	77.36
$1x10^{-5}$ M	0.024	81.65

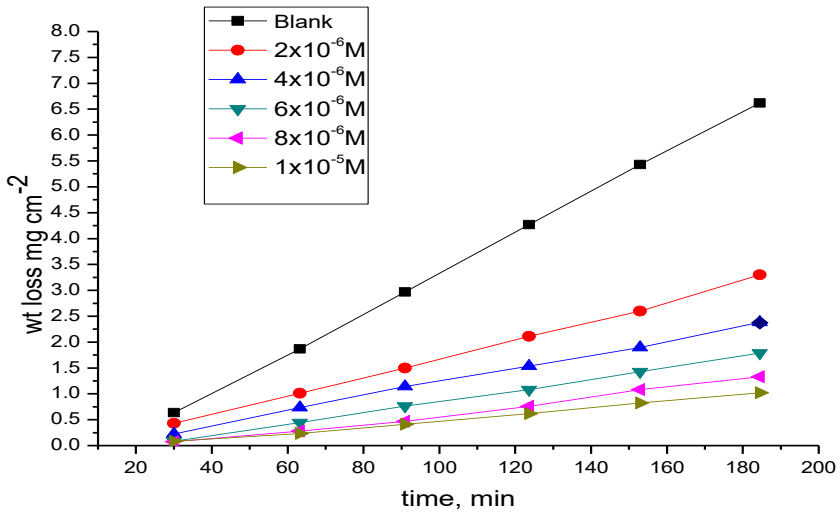

Figure 1: Weight loss-time curves for the corrosion of mild steel in 1 M HCl in the absence and presence of different concentrations of Hydrocortisone Sodium Succinate at 25 ±1°C.

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Effect of temperature and activation parameters of corrosion process

The dissolution of mild steel in 1 M HCl acid increases by increasing temperatures, the dissolution of mild steel in 1 M HCl in the presence of Hydrocortisone Sodium Succinate at $2x10^{-6}$ - $1x10^{-5}$M was studied by weight loss method over a temperature range 25-45°C. The corrosion rate of mild steel dissolution increases as the temperature increases, but at lower rate than in uninhibited solutions as shown in Table 3. The inhibition efficiency of the additives decreases with rising the temperature which proves that the adsorption of these compounds on the surface of mild steel occurs through physical adsorption of the additives on the metal surface. Desorption is aided by increasing the reaction temperature.

The apparent activation energy (Ea*), the enthalpy of activation (ΔH*) and the entropy of activation (ΔS*) for the corrosion of mild steel in 1 M HCl solution in the absence and presence of different concentrations of Hydrocortisone Sodium Succinate were calculated from Arrhenius-type equation:

$$Rate(k) = A\, e^{\frac{-E_a^*}{RT}} \quad (2)$$

and transition-state equation [15]:

$$Rate(k) = \frac{RT}{Nh}\, e^{\frac{\Delta S^*}{R}} e^{\frac{-\Delta H^*}{RT}} \quad (3)$$

where (A) is the frequency factor, (h) is the Planck's constant, (N) is Avogadro's number and (R) is the universal gas constant.

Table 3: Data of weight loss measurements for mild steel in 1 M HCl solution in the absence and presence of different concentrations of Hydrocortisone Sodium Succinate at 25–45 ±1°C.

Conc.	Temp., °C	C.R., mg cm^2min^{-1}	θ	% IE
$2x10^{-6}$M	25 35 45 55	0.465 0.415 0.652 0.722	0.525 0.511 0.492 0.453	52.56 51.12 49.24 45.33
$4x10^{-6}$M	25 35 45 55	0.277 0.392 0.599 0.842	0.642 0.513 0.422 0.394	64.20 51.30 42.20 39.41
$6x10^{-6}$M	25 35 45 55	0.112 0.199 0.447 0.599	0.727 0.696 0.535 0.442	72.40 69.60 53.50 64.24
$8x10^{-6}$M	25 35 45 55	0.076 0.107 0.319 0.464	0.773 0.756 0.624 0.542	77.36 71.60 62.40 54.20
$1x10^{-5}$M	25 35 45 55	0.024 0.059 00.12 0.210	0.816 0.768 0.650 0.693	81.65 79.80 65.00 69.30

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Kinetic parameters obtained from plots of log Rate vs. (1/T) [Figure 2] and log (Rate/T) vs. (1/T) [Figure 3)] are given in Table 4. Inspection of Table 4 shows that higher values were obtained for (Ea*) and (ΔH*) in the presence of inhibitor indicating the higher protection efficiency observed for this inhibitor. here's moreover a papalism between increments in hindrance proficiency and increments in (Ea*) and (ΔH*) values. These comes about demonstrate that this tried compound acted as inhibitors through expanding enactment vitality of gentle steel disintegration by making a boundary to mass and charge exchange by their adsorption on copper surface. The increase in the activation enthalpy (ΔH*) in the presence of the inhibitors implies that the addition of the inhibitors to the acid solution increases the height of the energy barrier of the corrosion reaction to an extent depends on the type and concentration of the present inhibitor. Also, the entropy ΔS* widely decreases with the content of the inhibitor. This means the formation of an ordered stable layer of inhibitor on copper surface [16].

Table 4: Effect of concentration of cefotaxime on the activation energy of mild steel dissolution in 1 M HCl.

Conc. M	Activation parameters		
	Ea * kJ mol $^{-1}$	ΔH* kJ mol $^{-1}$	ΔS* J mol^{-1} K^{-1}
1 M HCl	5.52	2.97	-275.12
2x10^{-6}M	7.15	4.59	-278.13
4x10^{-6}M	7.38	5.33	-280.44
6x10^{-6}M	7.62	6.19	-287.33
8x10^{-6}M	7.14	7.98	-298.22
1x10^{-5}M	7.98	8.55	-295.55

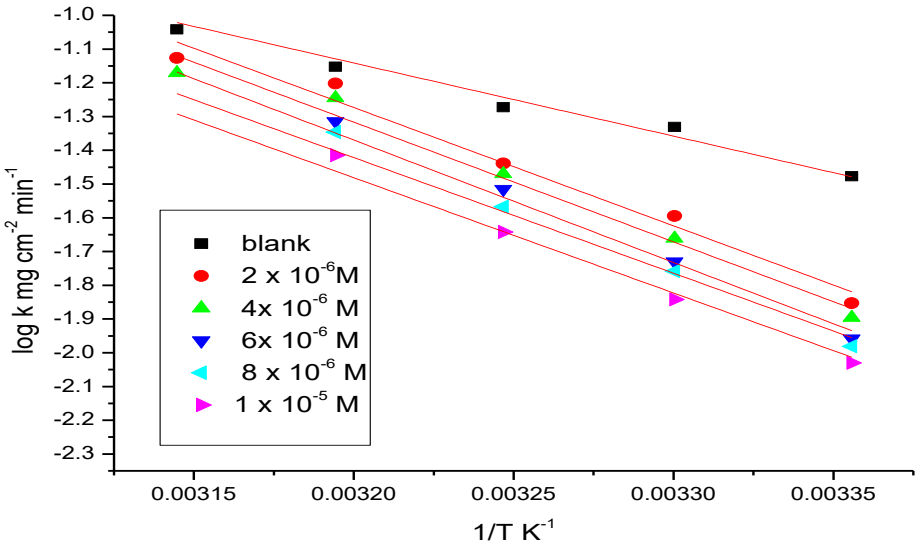

Figure 2: Log corrosion rate vs 1/T curves for mild steel dissolution in 1M HCl in absence and presence of different concentrations of Hydrocortisone Sodium Succinate.

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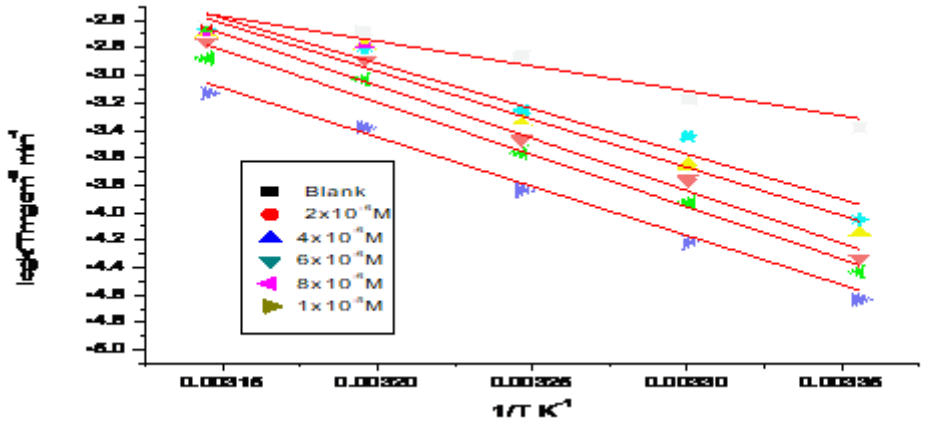

Figure 3: Log corrosion rate vs 1/T curves for mild steel dissolution in 1 M HCl in absence and presence of different concentrations of Hydrocortisone Sodium Succinate.

Adsorption isotherm

A number of numerical connections for the adsorption isotherms have been recommended to fit the explore information of the display work. The degree of surface scope (θ), i.e, the division of the surface secured by the inhibitor atoms at any given concentration of the inhibitor, was calculated from the condition said %IE = (100x θ). The values of θ have been appeared in Tables (2,3). The degree of surface scope was found to extend with expanding concentration of added substances. Endeavors were made to fit θ values to different isotherms counting Langmuir, Freundlich, Temkin and Frumkin. By distant, the finest fit was gotten with Langmuir isotherm. The harmony consistent of the adsorption prepare, K, which is related to the standard free vitality of adsorption (Δ G°ads) by [17]: $\frac{\theta}{1-\theta} = KC$ (4)

$$K = \frac{1}{55.5} e^{\frac{-\Delta G^{\circ}_{ads}}{RT}} \quad (5)$$

Where 55.5 is the concentration of water particle in (mol L-1) at metal/solution interface, R is the all-inclusive gas steady and T is the outright temperature. Figure 4 appears the plot of θ /1- θ vs. C for distinctive concentrations of examined compound. This plot gives straight line with slant exceptionally near to solidarity. The relapse (R2) is more than 0.9. This implies that there's no interaction between the adsorbed species on the anode surface [18]. All the calculated thermodynamic parameters are recorded in Table 5. The negative esteem of ΔG°ads in Table 5 recommended that the adsorption of inhibitor atoms on to mellow steel surface is unconstrained prepare. By and large, values of ΔG°ads up to -20kJ mol-1 are reliable with electrostatic interaction between the charged atoms and the charged metal (physical adsorption) whereas those more negative than -40 kJ mol -1 include charge sharing or exchange of electrons from the inhibitor particles to the metal surface to create a facilitate sort of bond (chemisorption) [19].

Moreover, the adsorption heat can be calculated according to the Van't Hoff equation 6 [20]:

$$\ln K = -\frac{\Delta H^{o}_{ads}}{RT} + const \quad (6)$$

The ΔH°_{ads} values (Table 5) are negative, which show that the adsorption is an exothermic process. Finally, the standard adsorption entropy ΔS°_{ads} can be calculated by the equation 7:

$$\Delta S^{o}_{ads} = \frac{\Delta H^{o}_{ads} - \Delta G^{o}_{ads}}{T} \quad (7)$$

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The ΔS°_{ads} values (Table 5) are negative, which show that the adsorption is an exothermic process and always accompanied by a decrease of entropy. The reason can be explained as follows: the adsorption of organic inhibitor molecules from the aqueous solution. Table 5 lists all the above calculated thermodynamic parameters [21].

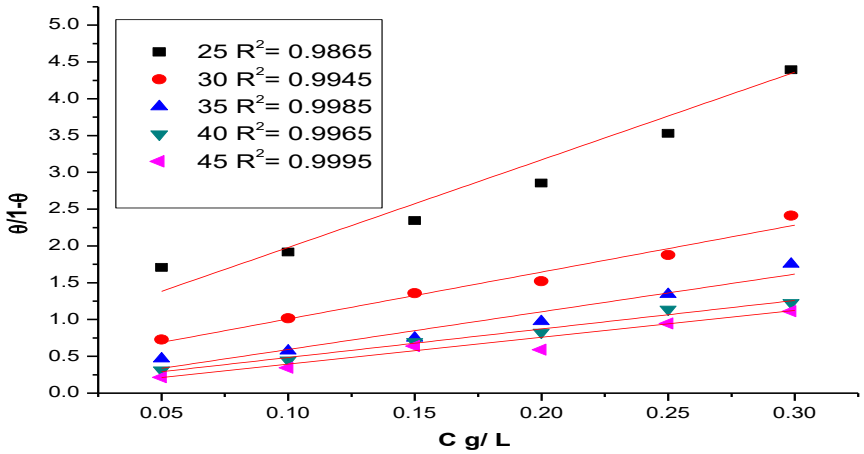

Figure 4: Adsorption isotherm curves for the adsorption of Hydrocortisone Sodium Succinate on mild steel in 1 M HCl at different temperatures.

Table 5: Thermodynamic parameters for mild steel in 1 M HNO_3 for Hydrocortisone Sodium Succinate at 25-45 ± 1°C.

Temp., K	K_{ads}, $g^{-1}l$	ΔG°_{ads}, kJ mol^{-1}	ΔH°_{ads}, kJ mol^{-1}	ΔS°_{ads}, J mol^{-1} K^{-1}
298	40.62	-16.68		-285.83
308	11.45	-15.27		-270.25
318	8.15	-13.66	-65.3	-246.77
328	5.79	-12.17		-232.71

Conclusions

The main assumptions are as follows:
1- Hydrocortisone Sodium Succinate has a significant inhibitory impact on mild steel corrosion in 1 M HCl.
2- As the inhibitor concentration rises, the value of inhibition efficiency falls, and as the temperature rises, the value of inhibition efficiency falls.
3- The Langmuir isotherm governs the adsorption of Hydrocortisone Sodium Succinate on mild steel.
4- The fact that the adsorption free energy was negative suggests that the reaction was exothermic and spontaneous

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