

The *Hibiscus* extract Potential in Inhibiting Anodic Dissolution of Copper

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Abstract: Copper electro dissolution in H_3PO_4 acid is examined in solution containing different concentration of Hibiscus extract (*Hibiscus abdariffa*). Potential of anode limiting current relation were computed and estimate of gently raising Hibiscus extract concentration (500-2000 ppm), The results reveal that Hibiscus extraction as a natural product has strong retardation behavior ranging from 24.5 – 42.1 % and the thermodynamic factors, adsorption isotherm and dimensionless parameters were given. Copper dissolution behavior in Hibiscus extract containing solution was investigated below ordinary convection and rotating cylinder electrode (RCE) as a compulsory convection. The rotating cylinder electrode RCE speed was investigated. The limiting current increases with increasing rotation, which indicates that the anodic corrosion is a diffusion-controlled process. The limiting current were reduced with raising extract plant concentration and raise with amplifying temperature from 293 -313 K). The activation energy values established which reaction rate was controlled via diffusion. Hibiscus extract adsorption follow Flory Huggins and kinetic thermodynamic models. The result at several circumstance was commanded via dimensionless correlations Sherwood (Sh), Schmidt (Sc) and Reynolds (Re) numbers.

Keywords: copper, Hibiscus extract, Flory Huggins model, kinetic thermodynamic model, dimensionless correlations

1. Introduction

Owing to its perfect thermal connection and excellent perfunctory work capacity, copper is an element usually used in heat and cool systems. Scale and dissolution manufactured goods have an unenthusiastic influence on heat transport and they cause a diminish in the heating effectiveness of the apparatus. Consequently, intervallic descaling and onslaught in acid pickle resolution are necessary.

Several dissolution retardation may be utilized to remove the disagreeable disparaging influence and avoid metal disbanding. Copper regularly did not relocate hydrogen from acid solutions and consequently is almost uncommitted in non-oxidizing situations. Actually, the revolution of hydrogen effervescence in transfer radial momentum transfer that raises the copper dissolution rate [1]. Copper dissolution in acidic medium have been investigate by different researchers [2].

Substantial numbers of organic molecules may be inspected and evaluated to inspect their prospective as dissolution retardation compounds. Allot of these investigations disclose that which organic molecules include heteroatoms such as nitrogen, sulphur, phosphorous and oxygen demonstrate considerable retardation effectiveness [3,4].

Despite these hopeful findings concerning probable dissolution retardation molecules, all these molecules are not only costly but also poisonous non-ecological so originate contamination troubles. Those retardation substances might cause momentary or everlasting injure to appending systems *viz.*, kidneys or liver, or to distress a biochemical procedure or to perturb an enzyme scheme at various strains inside human body. The poisonousness may might obvious moreover throughout the compound combination or throughout its submission. These toxic consequences have led to the employ of plant extracts natural as green dissolution retardation materials that are environmentally -responsive, bio-

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degradable and non-toxic. Therefore, these shortage have punctuated the look for its replacement [5].

Plants have been distinguished as sources of obviously happening composites, some with somewhat multifaceted molecular constructions and having changeable of physical, chemical and biological properties [4,6].

The majority of the complexes removed from agricultural waste are benefit the use in conventional functions like medications and biofuels. Additionally, the use of naturally happening composites are of attention, as a consequence of their charge success, plentiful accessibility and extra prominently their ecological adequacy [7].

The goal of this investigation is to inspect the influence of Hibiscus extraction as copper dissolution inhibitor in phosphoric acid at different circumstances. The copper dissolution rate is controlled via comparing the limiting current of anodic.

2. Materials and methods

2.1. Equipment

The copper composition in weight percent was as a follow: Cd: 0.001, Ag: 0.011, Pb: 0.003, Sn: 0.005, and, Cu 99.98. The solution 8 M H_3PO_4 was planned via analytical grade (85% w/w H_3PO_4) dilution with de-ionized water with a measured resistivity >18 MX/cm. All chemicals were analytical grade reagents and supplied by BDH Chemicals Ltd (laboratory furniture, *chemicals* & consumables to logistics). Copper pieces of 10 cm tallness and 5 cm breadth were used for electrode

2.2. Galvanostatic polarization

2.2.1 Ordinary transportation

The electrolytic compartment is rectangular plexiglass container with a base of 15×5 and of 10 cm height electrodes of copper piece. Separation via electrode was 15 cm. The electrical trial was of (power supply (6V D.C), multi range ammeter, high impedance voltammeter and several confrontation were attached in a series via cell. Temperature parameter (20, 30, 40 and 50°C) $\pm 0.5^\circ\text{C}$ was attained via thermostatic water bath inside compartment (Figure 1).

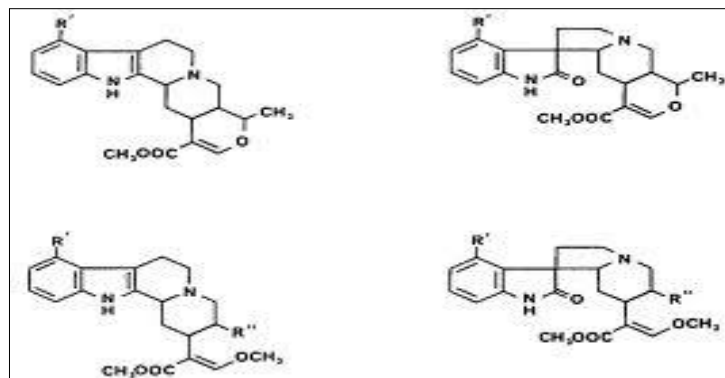
2.2.2 Compulsory transportation

Cylindrical jug of plexiglass (20 cm tallness and 15 cm diameter). Rotating copper bar of 2 cm diameter (working area is 12.56 cm^2) behave as anode that is insulated by epoxy resin. and copper rod of 2 cm diameter and 2 cm working height (copper bar attached to the ray of several speed via a plastic sheathing. copper cylindrical cathode have 5 cm breadth. The cathode backside were covered with epoxy resin. Rotary motion velocity varied from 100 to 900 rpm was adjusted with optical tachometer (Figure 2).

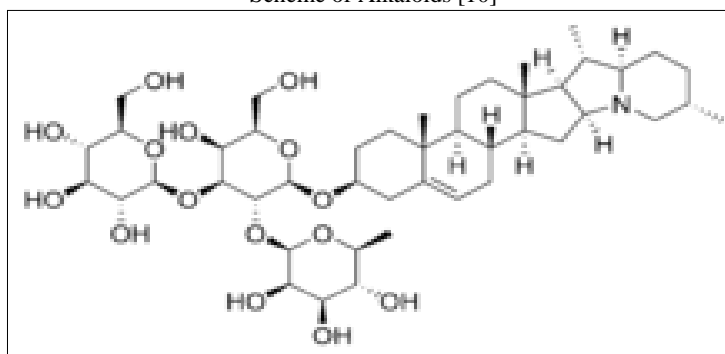
2.3. Plant extracts preparation

The leaves of Hibiscus was collected from Egyptian productions, shade dried and powdered. The extract was prepared by refluxing 10 g of dry leaves face powder in 100 mL of de -mineralized water for 4 days at normal temperature and sieved with Whatman No. 1 filter paper. The active extract constituents in phytochemical screening of aqueous extract of Hibiscus [8 ,9] are:

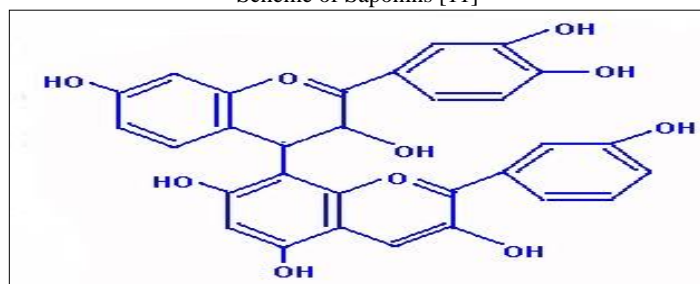
(Alkaloids) - Saponins - Tannins



Scheme of Alkaloids [10]



Scheme of Saponins [11]



Schem of Tannins [12]

Polarization curves were constructed for natural product - phosphoric acid mixtures at different concentrations of natural products

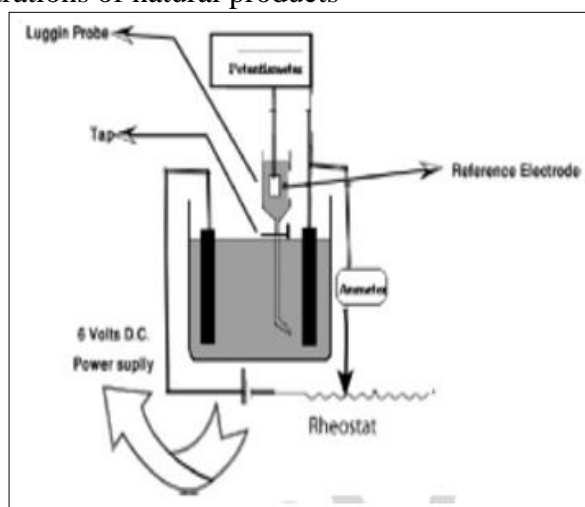


Figure 1. Electrolytic cell and the natural convection electrical circuit

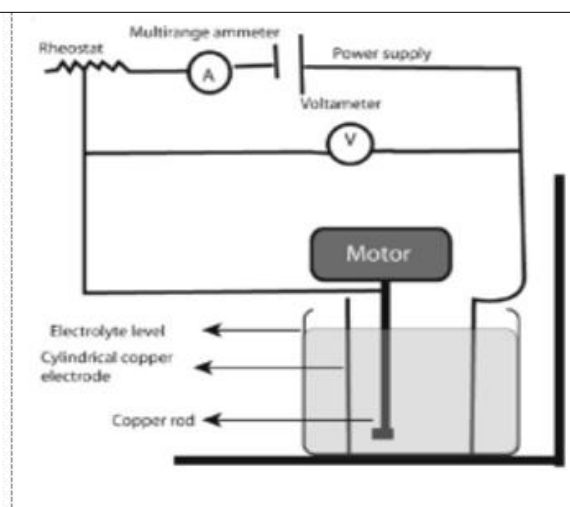


Figure 2. Electrolytic cell and forced convection electrical circuit

3. Results and discussions

Figure 3 and 4 demonstrates current - potential relation using divided and undivided cell for the blank solutions of 8 M H_3PO_4 , and the height of anode 1 cm at different temperatures (20, 30, 40 and 50°C).

The result reflect that on using undivided cell, the anodic limiting current raises. This amplify in the limiting current is characteristic in part to the fact that, the rebellion hydrogen bubbles persuade a radial momentum transfer that improves the polishing rate at the anode. Also it is pointed to that the temperature raising, the limiting current enlarges owing to the anodic corrosion process catalytic effect [13].

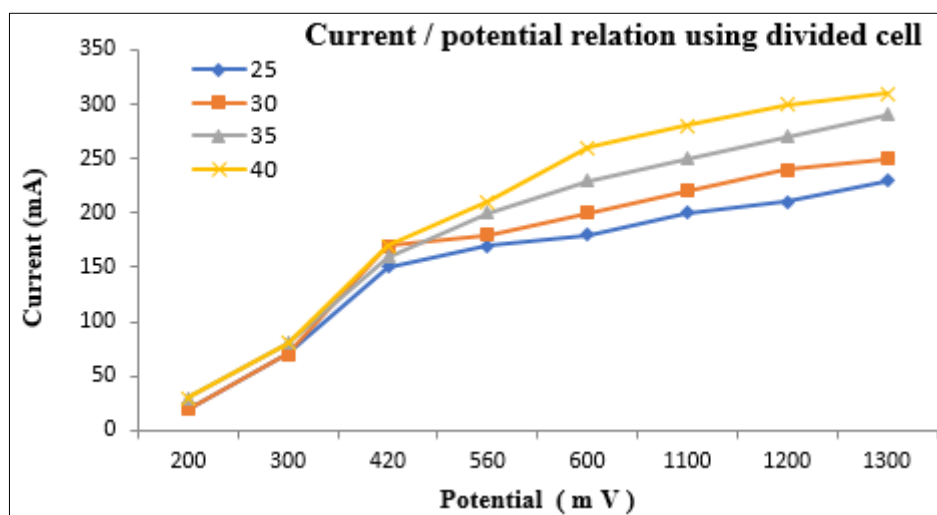


Figure 3. The relation between the current and potential at different temperatures, in 8 M H_3PO_4 , and the height of anode 1 cm and at different temperatures using divided cell

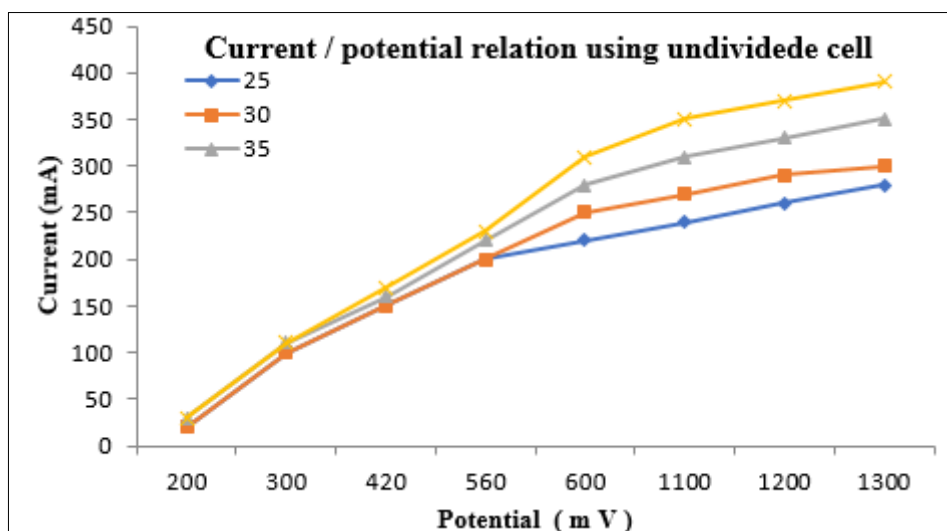


Figure 4. The relation between the current and potential at different temperatures, in 8 M H_3PO_4 , and the height of anode 1 cm and at different temperatures using undivided cell

3.1. Effect of electrode height on limiting current

Figure 5 is demonstrating that I_L diminishes via the raise in height. In anodic corrosion and metal dissolution, the thermodynamic border flow direction coating and the distribution coating enlarge in the descending track, i.e. the mass transfer confrontation enlarges in the downward track. Therefore, the

confined I_L raises in the anode uphill direction. This demonstrates why anodic corrosion is reached at the electrode superior fractions prior to the inferior fractions at the limiting current section. This was approved by chart inspection throughout anodic dissolution. The regular I_L reduces with height enlarge consistent with the subsequent equation [14]:

$$I_L = C / (H)^{0.368} \quad (1)$$

where C is constant, H is the height of electrode.

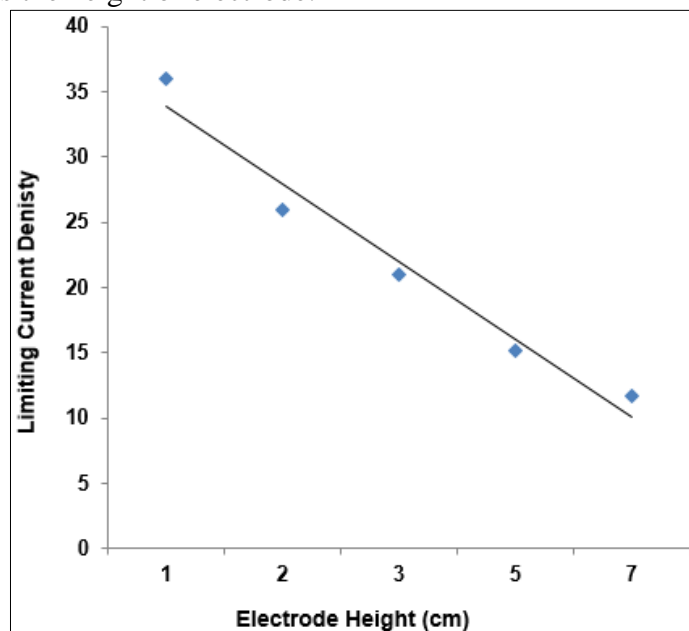


Figure 5. The anodic height effect on the limiting current density

3.2. Effect of Hibiscus extract on the limiting current

The observed limiting current, which represents the rate of copper metal corrosion in phosphoric acid at different temperatures, decreases with increasing the concentration of the Hibiscus extract under test. Table 1 shows the relation between the limiting current for different concentrations of Hibiscus extract at different temperatures. It is found that the limiting current decreases with increasing the concentration of Hibiscus extract.

If the values of limiting current in absence of Hibiscus extract ($I_{L(\text{blank})}$), and in the presence of Hibiscus extract. ($I_{L(\text{organic})}$), the percentage inhibition can be calculated from the following equation:

$$\text{Inhibition \%} = (I_{L(\text{Blank})} - I_{L(\text{extract})} / I_{L(\text{Blank})} \times 100 \quad (2)$$

Figure 6 and Table 2 show the relation between the inhibition percentage for different concentrations of Hibiscus extract and for divided cell at different temperatures, the percentage inhibition ranged between (24.5 - 42.1 %) depending on concentration and temperature.

Table 1. The temperature effect on the limiting current at different concentrations of Hibiscus extract using divided cell

Temperature °C	Concentration (ppm)	0	500	1000	1500	2000
20		433	281	270	262	255
30		467	297	288	280	270
40		500	332	320	310	300
50		533	403	396	380	373

Tables 2. The retardation on several concentration of *Hibiscus* extract at several temperatures in 8 M H₃PO₄ at 3 cm height using divided cell

% IE	C (ppm)	500	1000	1500	2000
	20°C	35.2	37.7	39.6	41.1
	30°C	36.4	38.2	40	42.1
	40°C	33.7	36	38	40
	50°C	24.5	25.8	28.8	30

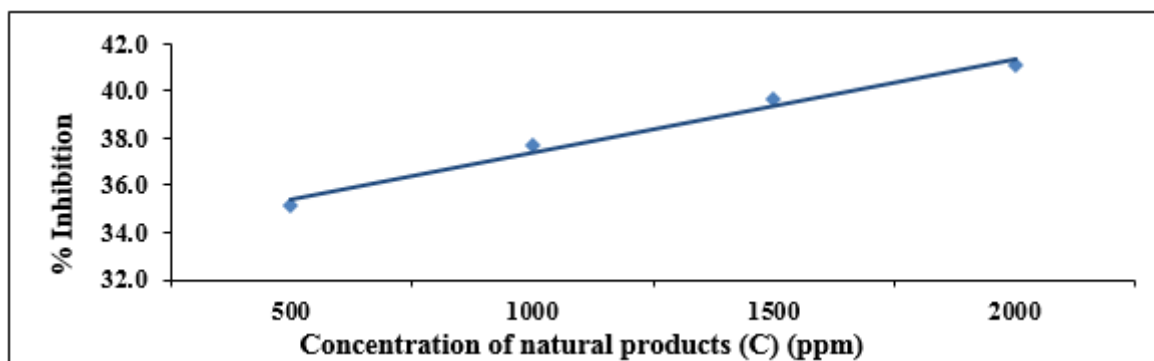


Figure 6. The retardation percentage Hibiscus extract concentration plot for divided cell

3.3. Adsorption isotherms

It is generally agreed that the adsorption isotherm of the inhibitor at the metal interface is the first core role of the inhibitors mechanism action in destructive acid media. Four types of adsorption may happen in the retardation phenomena concerning organic molecules at the metal-solution interface namely:

- Electrostatic attraction between charged molecules and the charged metal.
- Interaction of lone pairs electron in the molecules with the metal.
- Interaction of electrons with the metal.
- A combination of the above [14].

Chemisorptions engages allocation or charge transfer from the inhibitor molecule to the metal surface so as to outline coordinate bond, actually, electron transfer is characteristic in transition metals which have unoccupied low energy electron orbital.

Relating to inhibitors, electron transfer can be estimated with compounds having moderately loosely bound electrons. This condition may occur owing to the presence of multiple bonds or aromatic rings of a Π character (in adsorbed inhibitor) [15].

The retardation efficiency of homologous series of organic substances, diverge only in the hetero atom, is usually in the following sequence:



The electrochemical processes on the metal surface are probable to be closely to the inhibitor adsorption which is known to depend on the inhibitor structure [16].

Adsorption isotherms are very essential in mechanism determining electrochemical reactions. The most frequently used isotherms are those of Langmuir, Frumkin, Parsons, Temkin, Flory-Huggins, and Bockris-Swinkels [17].

Figure 7 and Table 3 demonstrate the Flory-Huggins adsorption isotherm meant for copper electrode in H₃PO₄, planned as $\log \Theta / C$ against $\log (1 - \Theta)$ at several temperature. Instantly stripes are obtained with a slope X and intercept $\log x K$. The investigational result fit the Flory-Huggins adsorption isotherm that is correspond to:

$$\log \Theta / C = \log x k + x \log (1 - \Theta) \quad (3)$$

where x is the number of water molecules replaced by one molecule of the inhibitor. The adsorption of inhibitors at metal-solution interface may be due to the formation of electrostatic or covalent bonding between the adsorbents and the metal surface [18].

The kinetic thermodynamic isotherm may be written in the form [19]:

$$\log (\Theta / 1-\Theta) = \log k' + y \log C \quad (4)$$

where y is the inhibitor molecules number connect one energetic spot. The compulsory adsorption constant $K = k'^{1/y}$, where $1/y$ is the active surface sites number connected to one retardation molecule, and k' is the compulsory constant. Figure 8 and Table 4 point to linear association among $\log \Theta / 1 - \Theta$ and $\log C$ at several temperature, and the computed $1/y$ and K values are shown in Table 4.

The $1/y$ values count on the category of retardation substances. From Table 4 it is understandable that the value of $1/y$ for all natural products is more than one implying that, the compounds are found in more than one energetic spots for every retardation molecules.

The adsorption free energy (ΔG_{ads}) at several natural products concentrations is computed via the subsequent form:

$$\Delta G_{ads} = -RT \ln (55.5K) \quad (5)$$

where the value 55.5 is the molar concentration of water in the solution mol/L.

The negative ΔG_{ads} values are shown in Table 5 that reflect spontaneous adsorption of retardation substances on copper facade and strapping communication among the retardation particles with metal facade. The negative (ΔG_{ads}) estimates are and lie in the range of (22.5 - 39.7) kJ/mol. It's establish that (ΔG_{ads}) significances are > -40 suggesting that the retardation molecules are adsorbed physically on the metal façade [19].

Table 3. The percent retardation and façade exposure (Θ) for the *Hibiscus* extract used at different concentrations at 25°C

C (ppm)	Log C	% inh.	Θ	$\Theta / 1-\Theta$	Log $\Theta / 1-\Theta$	1- Θ	Log 1- Θ	Log Θ / C
500	2.7	35.2	0.352	0.542	-0.27	0.65	-0.188	-3.15
1000	3	37.7	0.377	0.605	-0.22	0.62	-0.205	-3.42
1500	3.18	39.6	0.396	0.656	-0.18	0.6	-0.219	-3.58
2000	3.3	41.1	0.411	0.697	-0.16	0.59	-0.23	-3.69

Table 4. The K , X and $1/Y$ values of *Hibiscus* extract according to Flory - Huggins, and Kinetic Thermodynamic isotherm

t (k)	Flory-Huggins		Kinetic Thermodynamic Isotherm			
	X	K	K'	Y	1/Y	K
298	12.83	0.45	5.7	0.18	5.54	15313.1
303	12.88	0.36	5	0.17	6.01	15602.2
308	12.05	0.96	6.6	0.19	5.2	18115.6
313	13.81	3.61	11.4	0.21	4.84	130099.7

x : The number of water molecules replaced by one molecule of the inhibitor,

y : The number of inhibitor molecules occupy one active site,

$1/y$: The number of the active surface sites occupied by one molecule of the inhibitor,

K : The binding constant of adsorption = $k'^{1/y}$ and k' is the binding constant).

Table 5. The calculated values of free energy of adsorption, ΔG_{ads} , (kJ . mol⁻¹) of the adsorbed extract of *Hibiscus*

T (k)	Flory -Huggins	Kinetic Thermodynamic Isotherm
	$-\Delta G_{ads}$ (kJ . mol ⁻¹)	$-\Delta G_{ads}$ (kJ . mol ⁻¹)
293	8	33.83
303	7.5	34.4

313	10.2	35.4
313	13.8	39.7

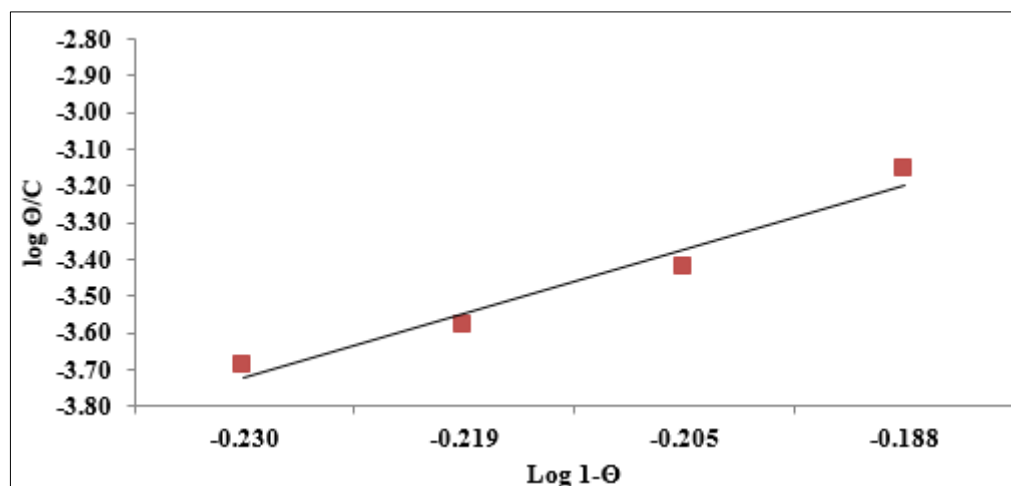


Figure 7. Flory-Huggins adsorption isotherm at 298k, of the adsorbed *Hibiscus* extract

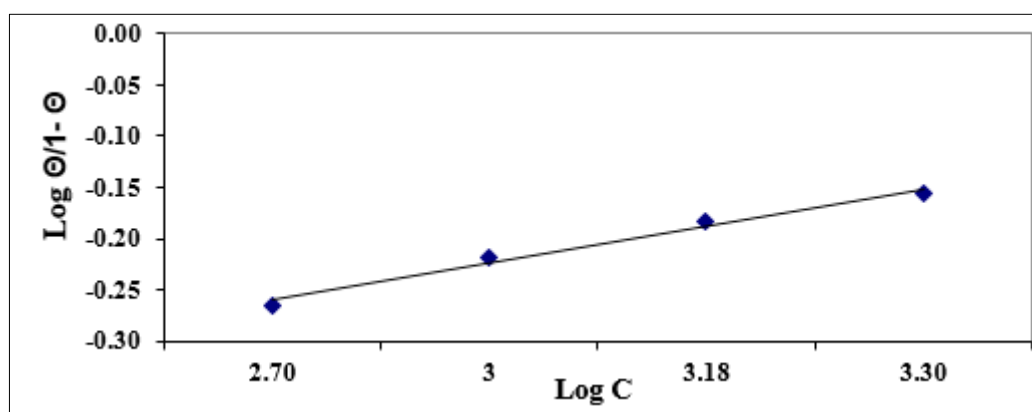


Figure 8. The kinetic thermodynamic isotherm at 298k, of the adsorbed *Hibiscus* extract

3.4. Temperature influence

The temperature influence on the anodic copper dissolution speed in the absence and the presence of natural products was established in the temperature range among (25°C - 40°C). It was showed that the anodic dissolution rate enlarged with elevating in temperature for the several concentrations of Hibiscus extract. The E_a values which have been computed from the Arrhenius plots slopes [20,21].

$$\log I = \text{Log } A - E_a / 2.303 R T \quad (6)$$

A is pre-exponential factor, R is the universal gas constant and T is the absolute temperature.

Figure 9 correspond to log I and 1/T the relation for the Hibiscus extract free solution and for several Hibiscus extract concentration, this Figure illustrates instantly plots and the E_a value have been computed from slopes of Arrhenius plots and are shown in Table 6. It is clearly shown that E_a significances in Hibiscus extract free solution and solution containing Hibiscus extract are $< 40 \text{ k.J. mol}^{-1}$ signifying that the anodic dissolution procedure is under a diffusion control [22].

3.5. Thermodynamic treatment of the results

From the integrated form of Arrhenius equation:

$$\text{Ln } I = - E_a / RT + \text{ln } A \quad (7)$$

It can be shown that $-E_a/R$ is slope and intercept is $\ln A$. Table (6) demonstrate the E_a values for the investigated Hibiscus extract. The values of enthalpy ΔH^* , entropy ΔS^* , and free energy (ΔG^*) values may be computed via the following form:

$$\Delta H^* = E_a - RT \quad (8)$$

$$\Delta S^* / R = \ln (k T_e / h) \quad (9)$$

$$\Delta G^* = \Delta H^* - T \Delta S^* \quad (10)$$

where k is Boltzmann 's constant, $e = 2.7183$, h is Plank 's constant, T is absolute temperature and R is the universal gas constant. Adsorption is frequently followed by liberation of adsorption heat, so that $E_a < 0$. Consequently, the adsorption rate diminishes with temperature elevation and accordingly, the surface coverage, Θ , at given concentration decreases among temperature growing. It is acknowledged that an enlarge in the adsorption heat of leads to an increase in the energy of adsorption. Though, temperature growing behaves in the opposite trend, rising the molecules kinetic energy, assisting disruption (accordingly in the adsorption physically).

Tables 6 demonstrate that the negative values of entropy ΔS are indicative of extremely prearranged plant extract in the investigated solution.

Difference in the speed among the procedure series may be owing to modification in either, or both, the enthalpy or the entropy. The ΔH^* and ΔS^* correlation is a straight correlation may that could be asserted algebraically as

$$\Delta H^* = \beta \Delta S^* + \text{constant} \quad (11)$$

$$\delta \Delta H^* = \beta \Delta S^* \quad (12)$$

The operator, δ , concerns difference between any two reactions in series. Substituting from the equation (11) into the familiar relationship:

$$\delta \Delta H^* = \delta \Delta G^* + T \delta \Delta S^* \quad (13)$$

We obtain

$$\beta \delta \Delta S^* = \delta \Delta G^* + T \delta \Delta S^* \quad (14)$$

It observes that when $\delta \Delta G^* = \text{zero}$, then $\beta = T$. In other meaning, the slope obtained from $\Delta H^* - \Delta S^*$ linear plot is the temperature at which all procedures that support the plot happen at the identical rate. β is consequently identified as the isokinetic temperature. The ΔH^* and ΔS^* isokinetic plot for several concentrations of the Hibiscus extract under investigation. Figure 10 and Table 6 was established to be linear and the isokinetic temperature (β) was calculated from the plot slope as 353 K using divided cell. These standards are more greater than that of the investigational temperature 298 K, implying that the reaction rate is enthalpy monitored [20, 21].

Table 6. The activated parameters values for several concentrations of the plant extract in H_3PO_4 using divided cell

C (ppm)	E_a^* (kJ.mol ⁻¹)	ΔH^* (kJ.mol ⁻¹)	$-\Delta S^*$	ΔG^*
500	18.4	16	144.8	59
1000	19.4	16.9	141.9	59.1
1500	18.8	16.3	144.1	59.2
2000	19.2	16.8	142.9	59.3

(ΔG : Net free energy change (kJ.mol⁻¹)

E_a : activation energy (kJ.mol⁻¹)

ΔH : enthalpy (kJ.mol⁻¹)

ΔS : entropy (J.mol⁻¹. K⁻¹)

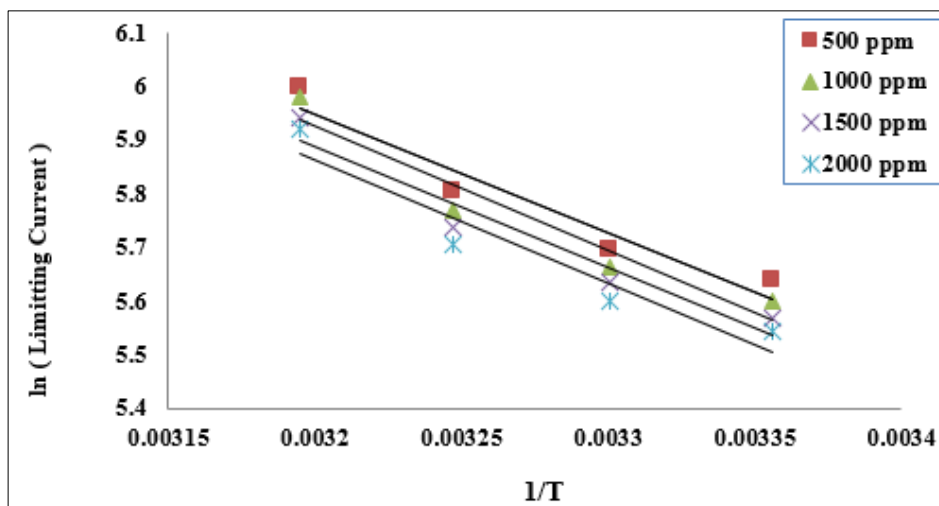


Figure 9. Arrhenius plot for Hibiscus extract at several concentration using divided cell

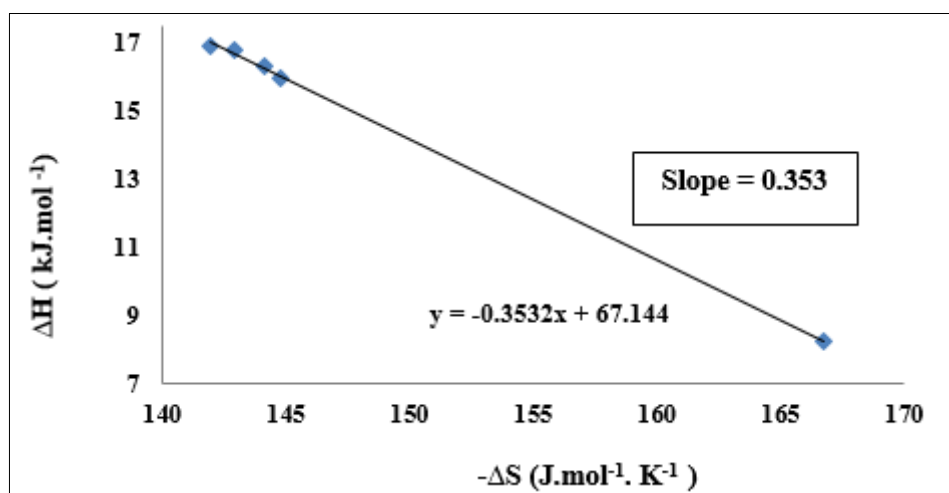


Figure 10. The iso kinetic for several concentration of Hibiscus extract

3.6. Stirring influence and dimensionless application

The speed rotation influence on the copper anodic dissolution rate in presence of Hibiscus extract containing solution may also be utilized to decide whether the anodic dissolution procedure is regulated with diffusion or chemical system. If the rate of anodic dissolution enlarges via raising the rotation velocity, then the process is controlled by diffusion. Conversely, if the anodic dissolution rate is autonomous of the rotary motion, it is probable to be a chemically manipulated procedure.

Table 7 demonstrates the change of the limiting current and rotation speed. The data illustrate that the limiting current is enhanced with mounting the velocity due to the influence of stirring. The bony velocity is specified by:

$$\omega = 2\pi \text{ rpm} \quad (15)$$

where r is the radial detachment in cm and rpm is the rebellion per minute.

Figure 11 demonstrates I_L -angular velocity $\omega^{0.7}$ at several compositions of Hibiscus extract at 25°C. Straight plots were attained and I_L raises with mounting rotary motion, that signifies that the anodic corrosion is proscribed via diffusion procedure.

Table 7 illustrates the velocity rotation influence in I_L in Hibiscus extract containing solution. The result fulfills the Eisenberg equation.

$$I_L = 0.079 n F C_b \nu^{-0.344} d^{-0.3} U^{0.7} D^{0.644}$$

where: n is the exchanged electrons number.

F is the Faraday constant

C_b is the solution bulk concentration (mol. cm^{-3}).

U is the peripheral speed = ωr in $\text{cm rad} \cdot \text{s}^{-1}$ and where, ω is the bony speed in $\text{rad} \cdot \text{s}^{-1}$, r is the radial detachment in cm or

$$U = 2 \pi \omega r \text{ in } \text{cm s}^{-1}$$

d is the distinguishing extent for the revolving cylinder = the cylinder diameter in cm ,

D is the Cu^{+2} ion diffusion coefficient in $\text{cm}^2 \text{s}^{-1}$, and ν is the kinematic thickness in Stoke ($\nu = \eta / \rho$).

Values of (D) and (ν) for all solutions under several circumstances are estimated. The copper ions diffusion coefficient (D) in the several solutions was established from the values of the limiting current densities corresponding to Eisenberg form [22, 23].

The Cu^{+2} ions diffusion coefficient, D in solutions containing Hibiscus extract diminishes owing to the amplify in the viscosity η referring to Stokes-Einstein:

$$\eta D/T = \text{constant} \quad (16)$$

The dimensionless groups were:

$$\text{Sherwood number } Sh = kd/D \quad (17)$$

$$\text{Schmidt number } Sc = \nu/D \quad (18)$$

$$\text{Reynolds number } Re = ud/\nu \quad (19)$$

where k is the mass transport coefficient.

ν , kinematic viscosity and d , space from the access.

To obtain the general mass transfer association beneath the investigated circumstances via by means of dimensional analysis method it is assumed that:

$$Sh = a Re^b (Sc)^{0.33} \quad (20)$$

where (a , b) are constants.

By scheming $\log \{Sh / (Sc)^{0.33}\}$ against $\log (Re)$, a instantly line is attained with b as slope and a as intercept. Figure 12 demonstrates the total mass transfer associations for Hibiscus extract under investigation. Table 8 recapitulates the dimensional groups values (Sh , Sc , and Re) used in attaining the association.

The equations attained are as the subsequent:

$$Sh = 1.01971 Re^{0.71874} (Sc)^{0.33} \quad (21)$$

Table 7. The limiting current variayion with the cylinder rotation speed at several concentration of *Hibiscus* extract

C ppm r.p.m.	0	500	1000	1500	2000
100	11.4	9.37	8.9	7.962	7.49
200	12.7	10.15	9.37	8.742	7.63
300	13.43	10.93	9.991	9.367	8.115
500	14.52	12.33	12.02	11.24	8.742
700	15.93	13.11	12.333	11.71	9.367
900	17.17	14.67	13.43	12.177	10.941

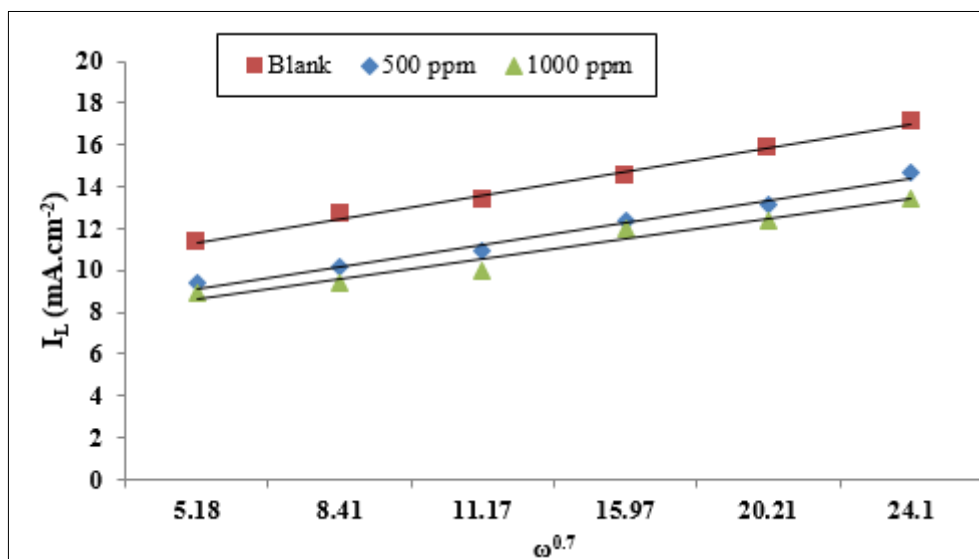


Figure 11. The relation between limiting current density (I_L) ($\text{mA}\cdot\text{cm}^{-2}$) and angular velocity ($\omega^{0.7}$) for *Hibiscus* extract at different concentrations

Table 8. The general mass transfer correlation of copper in 8 M H_3PO_4 in the presence of *Hibiscus* extract at different concentrations at different r.p.m. and 20°C

C(ppm)	I_L (mA/cm^{-1})	r.p.m.	$\eta * 10^2$ (centipoise)	U (cm s^{-1})	D * 10^5 (cm s^{-1})	Sc	Sh	Re.	Log Re	Log Sh/(Sc) ^{0.33}
0	11.4	100	3.43	5.24	18.8	182.2	19.2	152.6	2.18	0.54
	12.7	200		10.47	10.4	329.5	38.4	305	2.48	0.73
	13.43	300		15.71	7.35	466	57	487	2.69	0.83
	14.52	500		26.18	4.77	720	94.5	763	2.88	1.03
500	9.37	100	3.5	5.24	14	249.5	31.36	149.6	2.17	0.54
	10.5	200		10.47	7.48	468	43.9	299	2.48	0.73
	10.93	300		15.71	5.4	648.4	64.1	448	2.65	0.88
	12.33	500		26.18	3.75	936	104.2	748	2.87	1.04
1000	8.9	100	3.504	5.24	13	270	22.23	149.6	2.17	0.54
	9.37	200		10.47	6.61	530	43.91	299	2.48	0.71
	9.991	300		15.71	4.7	745	67.99	448	2.65	0.88
	12.02	500		26.18	3.59	974	105.6	748	2.87	1.04
	12.333	700		36.65	2.6	1330	156.1	1047	3.02	1.19
	13.43	900		47.12	2.25	1550	186	1346	3.13	1.22
1500	7.962	00	3.507	5.24	10.91	321	25.14	149.6	2.17	0.56
	8.742	200		10.47	5.94	590	51	299	2.48	0.71
	9.365	300		15.71	4.25	821	74.19	448	2.65	0.89
	11.24	500		26.18	3.24	1092	123	748	2.87	1.03
	11.71	700		36.65	2.4	1480	173	1047	3.02	1.15
	12.177	900		47.12	1.44	1810	215	1346	3.13	1.23
2000	7.49	100	3.49	5.24	9.8	341	26.36	149.6	2.17	0.59
	7.63	200		10.47	4.2	661	57.6	299	2.48	0.79
	8.115	300		15.71	3.8	961	88.1	448	2.65	0.91
	8.742	500		26.18	3.1	1434	141.6	748	2.87	1.07
	9.367	700		36.65	1.9	1911	190.7	1047	3.02	1.16
	10.941	900		47.12	1.2	2237	238	1346	3.13	1.24

(I_L : limiting current density ($\text{mA}\cdot\text{cm}^{-1}$))

r.p.m.: revolution per minute

η : viscosity of the solution (centipoise).

U: peripheral velocity of copper ion ($\text{cm rad}\cdot\text{s}^{-1}$)

D: diffusion coefficient for the copper ions ($\text{cm}^2\cdot\text{s}^{-1}$)

Sc: Schmidt number

Sh: Sherwood number

Re: Reynolds number)

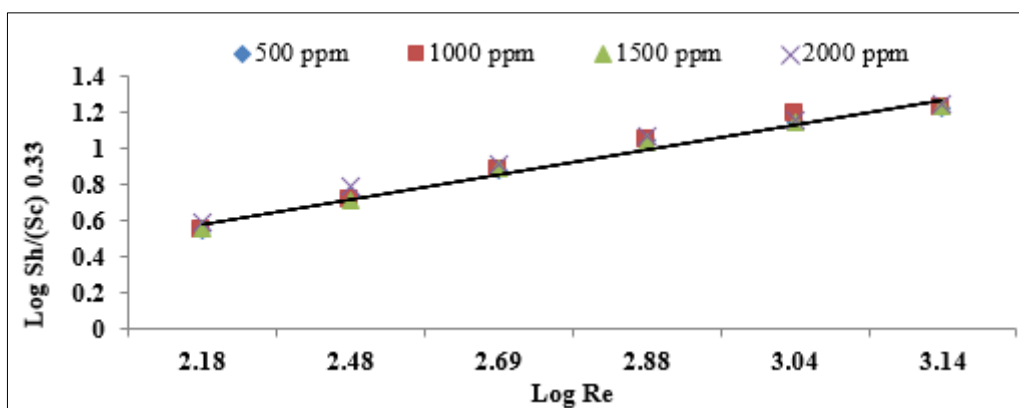


Figure 12. The overall correlation between $\log Sh / (Sc)^{0.33}$ and $\log Re$ for *Hibiscus* extract at different concentrations at 25°C

Structural effect of plant extract

The corrosion retardation recital in almost all the sited plant extracts could be due to the presence of surface active constituents that usually improve the film formation over the metal surface, thus extenuating corrosion. Examination of the chemical structures of some of the constituents of the plants extracts reveal that all molecules are long chain hydrocarbons carrying a polar group(s) at one or either ends. The polar groups normally contain oxygen, nitrogen or sulphur atoms. These are in accordance to Riggs 1973 [3], narration about molecular properties of organic inhibitors which include molecular size and its geometrical structure, bonding type, carbon chain length, type of atoms and characteristic molecular groups which are present in the molecule, molecular ability to form continuous layer on the metal surface or cross link, ability to react and form complex with metal atoms, metal ions or with corrosion products and the bonding strength to the metal surface [3].

The action of inhibitors depends on the function of the substrate, the ion to be reduced the electrolytic conditions.

The extracted plant in this work (*Hibiscus*) show inhibition percentage range from (24.5 - 42.1 %) depends on the concentration. This can be explained in that the investigated *Hibiscus* extract considered as mixed molecules inhibitor due to the presence of some active ingredient: (alkaloids, tannins and saponins)

The active extract constituents in phytochemical screening of aqueous extract of *Hibiscus* [8, 9] are: (Alkaloids) - Saponins - Tannins - (β -sitosterol) - (anthocyanine) - (Citric acid) - (Cyaniding-3-rutinoside) - (Flavonoids (as:hibiscetine, gossypetine & sabdaretine) - (delphinidin) - (pectin)- (quercetin) - (Protocatechuic acid) - (Stearic acid)

4. Conclusions

It's important to find corrosion inhibitors which are environmentally friendly and willingly available, there has been a growing trend by using natural products such as leaves or plants extract as corrosion inhibitors for copper dissolution.

From the data attained, the subsequent suppositions might be strained:

-the investigated plant extract which are cheap inhibitors and available with very low environmental impact, act as a good inhibitors for copper dissolution;

-the limiting current value which is considered to be the dissolution rate was found to reduce by mounting the anode height and by rising H_3PO_4 concentration;

-The dissolution rate and the percentage inhibition are established to depend on the type of the natural products used and concentration;

-adsorption of these natural products is founded to obey Flory - Huggins and Kinetic adsorption Isotherms but not Langmuir Isotherm;



-the activation energy value are $< 40 \text{ K J. mol}^{-1}$ signifying that the procedure is controlled via diffusion;

-the exponent of Reynolds numbers are about 0.7 indicating that electro-polishing is controlled by a turbulent flow of ions.

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