Global Journals LaTeX JournalKaleidoscope™
Artificial Intelligence formulated this projection for compatibility purposes from the original article published at Global Journals. However, this technology is currently in beta. *Therefore, kindly ignore odd layouts, missed formulae, text, tables, or figures.*

Expired Cidamex Drug as Corrosion Inhibitor for Aluminum in Acidic Solution

A. S. Fouda[1]

[1] Delta Higher Institute for Engineering and Technology, Egypt

Received: 13 December 2015 Accepted: 1 January 2016 Published: 15 January 2016

Abstract

The inhibitive effect of expired Cidamex drug on aluminum in 1M HCl solution was studied using weight loss, hydrogen evolution, potentiodynamic polarization, electrochemical impedance spectroscopy (EIS) and electrochemical frequency modulation (EFM) techniques. The results indicate that Cidamex is good inhibitor and inhibition efficiency improved with concentration and reached 99.6

Index terms— expired cidamex drug, corrosion inhibitors, inhibition efficiency, aluminum, HCl.

1 Introduction

luminum and its alloys are widely used materials for their excellent electrical and thermal conductivities in many applications and recently in the manufacture of integrated circuits [1,2]. So, the study of its corrosion inhibition is of great importance. The most widely used pickling acid is the hydrochloric acid, so this medium induced a great deal of research on aluminum [3][4][5]. A number of organic compounds are known to be applicable as corrosion inhibitors for aluminum in acidic environments. Such compounds typically contain nitrogen, oxygen or sulphur in a conjugated system and function via adsorption of the molecules on the metal surface, creating a barrier to corrodent attack [6][7][8][9]. The adsorption bond strength is dependent on the composition of metal, inhibitor structure and concentration as well as temperature [10]. Because of the fact that most of the chemical compounds that prevent the corrosion of metals and alloys are toxic, and thus pose threat both for human health and environment, their usage is limited. For this reason, several authors reported the use of natural products as corrosion inhibitors [11]; also, some various metals and alloys [12][13][14][15][16][17][18][19][20]. The use of environmental friendly pharmaceutical compound (expired Cidamex) as corrosion inhibitor for aluminum has not been reported before. Most of the pharmaceutical active substances are far more expensive than the organic inhibitors currently implemented. Therefore, our study was focused on the usage of expired drugs or unused drugs because of patient's non-compliance that contain in their composition active substances with inhibitory properties. This will solve two problems: a) Limitation of environmental pollution with pharmaceutically active compounds and b) reduction of the disposal costs of expired drugs.

2 II.

3 Experimental a) Materials and Solutions

The investigated compound (expired Cidamex) shown in Figure1, this drug was obtained from CID Giza Co. for Pharmaceuticals, Egypt., Analytical grade HCl (37%) was used as corrosive solution. Double distilled water used throughout experiments for the preparation of solutions. The weight experiments carried out using specimens of aluminum having dimensions (2 x 2 x 0.05 cm) and with composition more than 99.9%. The test pieces of aluminum samples were weight up to fourth decimal place using digital electronic balance. The aluminum specimens were polished by a series of emery paper (grade 320-1200 grit size) and then washed with double distilled water and acetone. After weighing, the specimens were totally suspended in beakers containing test solutions using glass hooks at temperature (25 and 45 0 C) in thermostat water bath. Each piece taken out of the test solution, rinsed with double distilled water, dried between two filter papers and weighed again. The difference in weights for an exposed period was taken as weight loss. The experiments carried out at various concentrations of Cidamex. Triplicate samples were used to check reproducibility of results.

4 ii. Hydrogen evolution and corrosion rates

The gas-volumetric technique provides a rapid and sensitive method of monitoring any perturbation by an inhibitor regarding gas evolution at the metalcorrodent inter phase. The corrosion of aluminum in acid solution is characterized by rapid effervescence resulting from hydrogen gas evolution. The corrosion rates of aluminum in the absence and presence of drug assessed by measuring the volume of H 2 gas evolved during the corrosion reaction. An ideal device for hydrogen evolution collection is easy to set up and operate. Figure **??** schematically illustrates a simple setup that used for the hydrogen evolution rate measurements in this study. This is actually a classic set-up for detection of the negative difference effect. The aluminium specimen put in a beaker containing the test solution. A funnel placed over the specimen, which ensured the collection of all the hydrogen from the specimen surface as well as from any undermined metal particles at the bottom of the beaker. A burette was mounted over the funnel, and was initially full of the test solution. The hydrogen collected by the funnel went into the burette and gradually displaced the test solution in the burette. In this way, the volume of the evolved hydrogen easily measured by reading the position of the test solution level in the burette.

iii. Potentiodynamic polarization measurements scan rate of 1 mVs -1 . The Tafel plots of the anodic and cathodic curves extrapolated to obtain the corrosion potential (E corr) and corrosion current density (i corr .).

5 iv. Electrochemical impedance spectroscopy measurements

Electrochemical impedance spectroscopy (EIS) is a powerful technique for the characterization of electrochemical systems and mechanistic information. For this reason this technique is being applied to an increasing extent to understand corrosion process in solution, to study rate determination, inhibitor performance, coating performance and passive layer characteristics [21][22][23] experiments always repeated at least three times to check reproducibility of the results. Impedance diagrams are given in Nyquist representations. The electrical equivalent circuit Figure 3 was used to fit EIS data which consists from R s is the solution resistance, R ct is the charge transfer resistance and C dl is the double layer capacitance.

For potentiodynamic polarization studies of aluminum, a cylindrical rod embedded in araldite with an exposed surface area (1 cm 2) used and the experiments were carried out at 25 0 C. It was abraded with different grades of emery papers up to 1200 grit size. After that, the electrode washed with acetone, rinsed different times with distilled water and dried. The potentiodynamic measurements performed in a conventional three electrodes glass cell, which consists of aluminum as working electrode, platinum counter electrode and a saturated calomel electrode(SCE) as the reference electrode. All measurements carried out in aerated solution of 1 M HCl in the absence and presence of different concentrations of Cidamex. Potential curves were recorded by changing the electrode potential automatically from -0.8 to 0.5 V at a v. Electrochemical frequency modulation (EFM) measurements

The electrochemical frequency modulation has many features [24][25][26][27][28]. EFM is a non-destructive technique, rapid test, gives directly value of the corrosion current without a prior of knowledge of Tafel constants and has a great strength due to casually factors, which serve an internal check on the validity of the EFM measurement.

All electrochemical measurements were performed using Gamry Instrument (PCI 300/4) Potentiostat / Galvanostat /ZRA. This includes a Gamry framework system based on the ESA 400. Gamry applications include DC105 software for potentiodynamic polarization measurements, EIS300 software for EIS and EFM140 software for EFM measurements along with a computer for collecting data. Echem Analyst 6.03 software was used for plotting, graphing, and fitting data.

6 III.

7 Results

The weight loss recorded to the nearest 0.0001g was given by equation (1):?w=w 1 -w 2**(1)**

Where w 1 and w 2 are the weights of metal before and after exposure to the corrosive solution, respectively.

Corrosion rates calculated using the following expression [29]:Corrosion rate = ?W AT mg cm -2 min -1**(2)**

The percentage inhibition efficiency (% IE) of different concentration of expired Cidamex calculated from the corrosion rate values by using the following equation:

8 Global

% IE = ? x 100 = [(W 1 -W 2)/W 1] x100 (**3**)

Where ?w is the weight loss in mg, A is the area of the specimen in sq-cm and " T " is the exposure time in min.

where w 2 and w 1 are the weight losses (mg) for aluminum sample in the presence and absence of the inhibitor and ? is the degree of surface coverage of the inhibitor. The % inhibition efficiency (% IE) and the degree of surface coverage (?) were tabulated .Figure 4 shows the plots of corrosion rate against different concentrations of drug. while Fig. **??** Table **??** : Data from weight loss of Al in 1 M HCl for various concentration of expired Cidamex after 1.5 h at 298 and 318 K

9 b) Adsorption isotherms

The adsorption of organic molecules provides information about the interaction between the adsorbed molecules themselves as well as their interaction with metal surface. When the fraction of the surface covered is determined as function of the concentration at The results show that the inhibitor influenced on reducing the dissolution of aluminum in 1M HCl solution at all concentrations used. The inhibition efficiency increased with increasing the concentrations while at the same time the corrosion rates significantly decreased.298 K298 K 318 K ?W mg cm -2 ? % IE C.R., mg cm -2 h -1 ?W mg cm -2 ? %IE C.R., mg cm -2 h -1 Blank 1.950 —— —- 1.297 4.553 —- —-**3**

Flory-Huggins and Bockris-Swinkless [30][31][32][33]. The degree of surface coverage (?) for different concentrations of expired Cidamex in 1 M HCl was calculated from weight loss measurements Table **??** and was tested graphically for fitting a suitable adsorption isotherm. Figure **??** confirms that the inhibition processes due to adsorption of the inhibitor on the Al surface. This is because a straight line is obtained when log (C/?) is plotted against log C and the linear correlation coefficient of the fitted data is close to unity. This indicates that the adsorption of expired Cidamex molecules obeys the Langmuir adsorption isotherm [34] which expressed as:C ? = 1 K + C (**4**)

Where C is the expired Cidamex concentration and K ads is the equilibrium constant for the adsorption/ desorption process of the inhibitor molecules on the metal surface.

The relationship between the equilibrium constant, K ads , of adsorption and the free energy of adsorption, ?G 0 ads is given by the following expression [35].K ads = 1/55.5 exp [?Î?"G o ads /RT](**5**)

Values of free energy of adsorption calculated from equation (5) using K ads values obtained from Langmuir adsorption isotherm is presented in Table 2. The values are negative and less than -40 kJ mol -1 . This implies that the adsorption of the inhibitor on aluminum surface is spontaneous and confirms the physical adsorption isotherm mechanism [36]. c) Effect of temperature From our study, the protection efficiency decreases with an increase in temperature. This can be due to the decrease in the strength of adsorption process at higher temperature, suggesting that physical adsorption of the inhibitor on the sample surface. The apparent activation energies (E a) for the corrosion, process in absence and presence of expired Cidamex can be evaluated from Arrhenius equation (6):Log (C.R.) 2 /(C.R.) 1 = E a /2.303R(1 ??1 - 1 ??2)(**6**)

Whereas estimates of the heats of adsorption (Q ads) can be obtained from the trend of surface coverage with temperature as follows [37] Q ads = 2.303R [log (??2 1???2) -log (??1 1???1)] x ??1??2 ??2???1] (**7**)

Table **??** : Calculated values of apparent activation energy (E * a) and heat of adsorption (Q ads) of expired Cidamex on aluminum in 1 M HCl at different temperatures

10 C

Increased activation energy, E a in inhibited solutions compared to the blank suggests that the expired Cidamex is physically adsorbed on the corroding metal surface while either unchanged or lower (E a) in the presence of inhibitor suggest chemisorptions [38]. It seen in Table **??** that E a values increased with inhibitor concentrations, showing that the expired Cidamex retards corrosion at ordinary temperature and its corrosion retarding efficiency considerably diminished at higher temperature [39]. The low and negative Q ads values are indicative of less surface coverage with rise in temperature, supporting the earlier proposed mechanism of physisorption [40].

11 d) Hydrogen evolution method

The method of hydrogen evolution (via gasometric assembly) was determined as previously described elsewhere [41][42][43]. From Figure 7 and Table 4 when the concentration of expired Cidamex increases the hydrogen evolution decreases and inhibition efficiency increases, so expired Cidamex consider having an excellent ability to inhibit the corrosion of aluminum in the acid solution.

12 e) Potentiodynamic polarization measurements

Potentiodynamic polarization curves for aluminum in 1M HCl solution in the absence and presence of different concentration of expired Cidamex at 25 0 C are shown in Figure **??** the polarization parameters such as E corr , i corr; anodic and cathodic Tafel slopes (? a, ? c)are summarized in Table 5. Both anodic and cathodic Tafel slopes were slightly changed on increasing the expired Cidamex concentration. This means that there is no change of the mechanism of the inhibition in presence and absence of expired Cidamex drug and this drug affects both cathodic and anodic reactions, i.e. it is mixed-type inhibitor [44]. The E corr values show that the expired Cidamex behaves as mixed type, with small variations in the E corr values of the blank specimens. The degree of surface coverage (?) and inhibition efficiency (% IE) were calculated using equation (8):% IE = ? x 100 = [1-(i/ i°)] x 100 (**8**)

where i° and i are the current densities in the absence and presence of the extract, respectively. Z CPE = Y 0 -1 (j ?) -n (9) %IE = [(R ct -R 0 ct)/R ct] ×100(**11**)

Where R o ct and R ct are the charge transfer resistance in the absence and presence of inhibitor, respectively, the results listed in Table 6.By increasing the inhibitor concentration, the R ct values increase and the calculated C dl values decrease, as it can be seen from Table 6, the C dl values tend to decrease with the increase of the concentration of inhibitor in 1 M HCl. The decrease in the C dl , which can result from a decrease in local dielectric constant and/or an increase in the thickness of the electrical double layer, suggests that inhibitor molecules function by adsorption at the metal/solution interface. Deviations from the ideal semicircle are generally attributed to the frequency dispersion as well as in homogeneities, roughness of metal surface and mass transport process [51][52][53]. The resistances between the metal and outer Helmholtz plane (OHP) must be equal to the R ct . The adsorption of expired Cidamex molecules on the metal surface decreases its electrical capacity because they displace the water molecules and other ions originally adsorbed on the metal surface. This modification results in an increase of charge-transfer resistance. The R ct values increased with inhibitors concentrations may suggest the formation of a protective layer on the aluminum surface. This layer makes a barrier for mass and charge-

13 C

EIS was employed to investigate the effect of concentration on inhibitive behavior of inhibitor in 1 M HCl at 25 0 C. The EIS results in form of Nyquist and Bode phase plots have been presented in Figure **??**a,b. The impedance spectra consist of a large capacitive loop at high frequency followed by a small inductive one at low frequency. The values of polarization resistance and double layer capacitance were recorded in Table 6. Generally, the small inductive loop at low frequency (LF) observed for aluminum in HCl [45][46][47][48]. The diameter of Nyquist plots (R p) increases on increasing the inhibitor concentration. These results suggest the inhibition behavior of inhibitor. The Nyquist plots analyzed in terms of the equivalent circuit composed with classic parallel capacitor and resistor Figure 2 [49]. The impedance of a CPE is described by the equation 9:

transfer. The Bode plot, Figure **??**b Shows resistive region at high frequencies and capacitive region at intermediate frequencies but do not show a clear resistive region (horizontal line and a phase angle = 0) at low frequencies. These plots show two overlapped phase maxima at intermediate and low frequencies. According to act circuit theory, an impedance plot obtained for a given electrochemical system can be correlated to one or more equivalent circuits.

where Y 0 is the magnitude of the constant phase element (CPE), j is an imaginary number, ? is the angular frequency at which the imaginary component of the impedance reaches its maximum values and n is the deviation parameter of the CPE: -1 ? n ? 1.

The values of the interfacial capacitance C dl can be calculated from CPE parameter values Y 0 and n using equation **??**0 [50]:C dl = (2?f max R ct) ?1 (**10**)

Where f max is the frequency value, at which the imaginary component (Z") of impedance is maximum. The degree of surface coverage (?) and the inhibition efficiency (% IE) were calculated from the charge transfer resistance (R ct) values using the following equation (11

14 g) Electrochemical frequency modulation (EFM) measurements

The EFM like EIS, it is a small signal ac technique. Unlike EIS, however, two sine waves (at different frequencies) are applied to the cell simultaneously. Because current is a non-linear function of potential excitation. The current response contains not only the input frequencies, but also contains frequency components, which are the sum, difference, and multiples of the two input frequencies. The two frequencies may not choose at random. They must both be small, integer multiples of a base frequency that determines the length of the experiment. The calculated electrochemical parameters at different concentrations of drug at 25°C (i corr , ? a , ? c , CF-2, CF-3 and % IE EFM) are given in Table 7. Figure 10 represents the EFM intermodulation spectra (spectra of current response as a function of frequency) of aluminum in 1 M HCl devoid of and containing 300 ppm of Cidamex. The inhibition efficiency, % IE FM and the degree of surface coverage (?) of drug was calculated using equation (12): % IE = ? x 100 = [1-(i corr /i°c orr)] x 100 (12) Where i°c orr and i corr are corrosion current density in the absence and presence of black tea extract. The causality factors calculated from the frequency spectrum of the current response. If the causality factors differ significantly from the theoretical values of 2.0 and approximately the predicted values of 2.0 and 3.0, there is a causal relationship between the perturbation signal and the response signal. Then the data are assumed to be reliable [54] From the results of Table 7, it can be seen that by increasing the concentration of extract to the medium the corrosion current density (i corr) decreases, indicating that the extract inhibits the 1 M HCl corrosion of carbon steel through adsorption. The calculated inhibition efficiency % IE EFM enhances with increasing drug concentration.

15 h) Mechanism of inhibition

The above observations and analysis show that the inhibitor is adsorbed on Al. Four mechanisms have been suggested for the adsorption of the inhibitor at the metal-solution interface [55]. These are: i) electrostatic attraction between charged molecules and charged metal ii) interaction of unshared electron pairs in the molecule with the metal iii) interaction of ? -electrons with the metal and iv) a combination of all the above. The adsorption of investigated drug compound can be attributed to the presence of polar unit having atoms of nitrogen, sulphur and oxygen and aromatic/heterocyclic rings. Therefore, the possible reaction centers are unshared electron pair of hetero-atoms and ?-electrons of aromatic ring [56]. As discussed above the thermodynamic and kinetic parameters, the adsorption is mainly electrostatic. Physical adsorption requires presence of both electrically charged surface of the metal and charged species in the bulk of the solution. In the acid solution, the drug could be protonated due to the interaction between O atom and H + . The value of pH zch , which is defined as the threshold pH at a point of zero charge, is equal to 9.1 for aluminum [57]. So aluminum surface is positively charge due to accumulation of Al????OH 2 + species in acidic solution [58]. The acid anions (Cl -) adsorb electrostatically on the positively charged, giving rise in for a net negative charge on the metal surface; and the organic cations are physically attracted to the anions layer which is formed on the metal surface, forming electrostatic protective layer on aluminum. IV.

16 Conclusions

The results obtained show that expired Cidamex drug is a good corrosion inhibitor for aluminum under acidic conditions. The adsorption of expired Cidamex drug on aluminum surface obeys Langmuir adsorption isotherm. The adsorption process is spontaneous. The adsorption of the expired Cidamex drug onto the aluminum characterized by the decrease in: (a) Weight loss of aluminum (b) hydrogen evolution (c) the cathodic and anodic current densities observed in the potentiodynamic polarization curves carried out in the presence of drug, (d) the double-layer capacitance computed from electrochemical impedance spectroscopy experiments and (e) the current obtained from electrochemical frequency modulation (EFM). The negative values of ?G 0 ads show the spontaneity of the adsorption. Inhibition efficiency increases with increase in expired Cidamex concentration and decreases with rise in temperature. From this study, it was concluded that these unused drugs can be used as save corrosion inhibitors for water cooling systems, oil pipelines, degreasing solutions, deicing solutions for aircrafts, paints and coatings, inhibitors for concrete fuels and lubricants, metal processing solutions [59] [1]

4

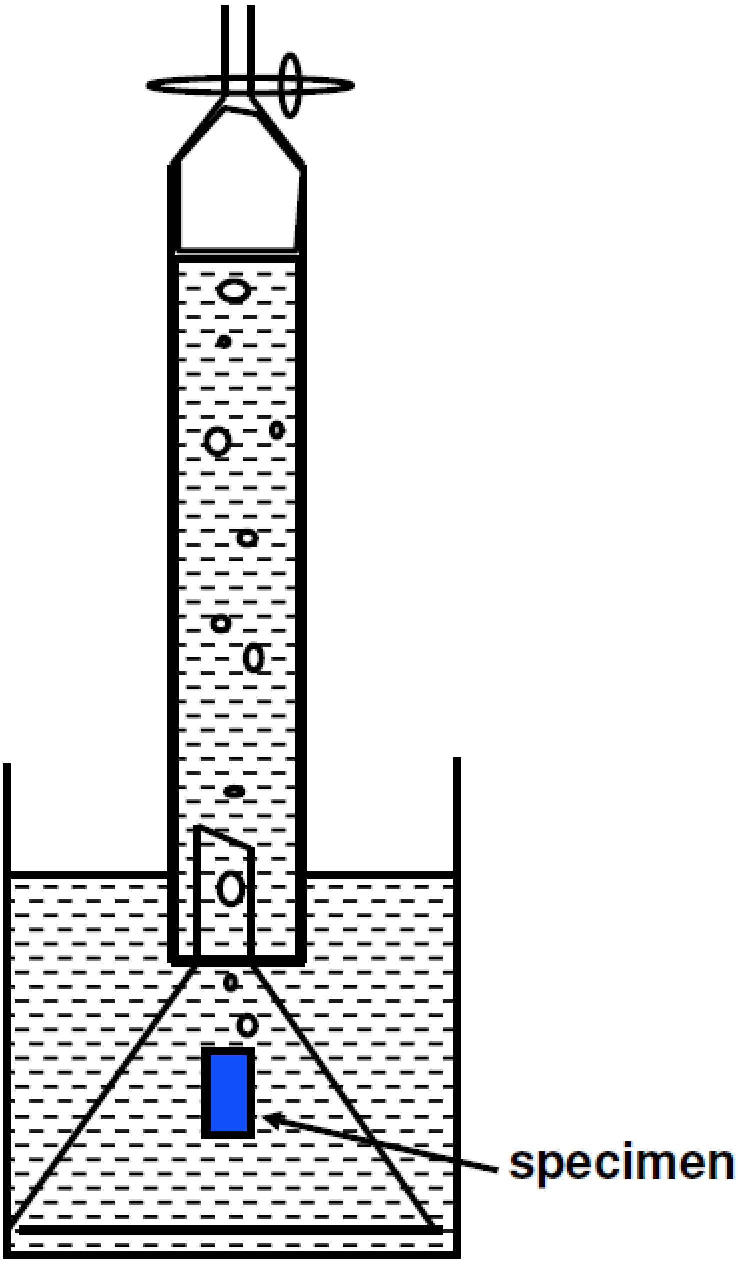
Figure 1: Formula = C 4

---

[1] © 2016 Global Journals Inc. (US)

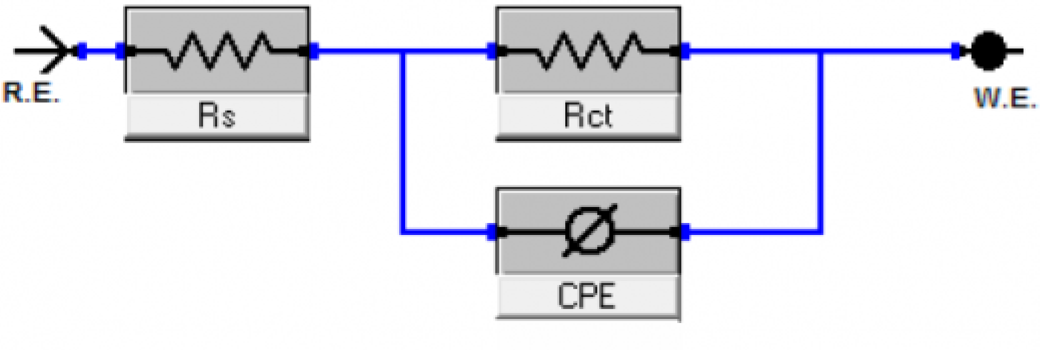
1

Figure 2: Figure 1 :



820162

Figure 3: 8 2016 CFigure 2 :



920162016

Figure 4: 9 2016 C© 2016

2

Figure 6 : Langmuir adsorption isotherm for expired Cidamex adsorption on aluminum in 1 M HCl at two different
temperatures after 1.5h immersion

[Note: C© 2016 Global Journals Inc. (US)]

Figure 5: Table 2 :

4

Conc., ppm	Volume of hydrogen gas evolved (ml)	% IE
blank	1.50	——
50	0.50	66.6
100	0.30	80.0
150	0.20	86.0
200	0.10	93.3
250	0.05	96.7
300	0.02	98.7

Figure 6: Table 4 :

5

Conc., ppm	-E corr , mV vs SCE	i corr , mA cm -2	? a , V dec -1	? c , V dec -1	?	% IE

[Note: C© 2016 Global Journals Inc. (US)Figure 8 : Anodic and cathodic Tafel polarization curves for aluminum in the absence and presence of various concentrations of Cidamex]

Figure 7: Table 5 :

6

Year 2016
14
( ) Volume
XVI Issue I
Version I
Global Journal
of Researches
in Engineering

Conc.,	R ct ,	R s	Y° x 10	n 1.059	C dl, x10	?	% IE
ppm	m? cm	2704	6 ?? -1 s	1.095	4 ?F cm	0.148	14.8
Blank	-2 607.3	2017	n 195.30	1.085	-2 3.20	0.194	19.4
50 100	853.5	3138	118.40	1.010	2.63 4.13	0.274	27.4
150	902.1	4167	210.90	1.123	2.61 1.93	0.290	29.0
200	1002.0	2690	240.60	1.061	1.38 1.21	0.730	73.0
250	1023.0	2436	67.29 85.19	1.014		0.810	81.0
300	2645.0	2783	108.90				
	3827.0						

Figure 8: Table 6 :

7

BLANK

1E-5
1E-6
logi(A/cm 2) 1E-7
1E-8
-0.2 0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6
Fr.(HZ)

Figure 9: Table 7 :

[Int.J.Pure Appl. Sci. Technol ()] , *Int.J.Pure Appl. Sci. Technol* 2011. 6 (2) p. .

[Journal of Electrochemical Science and Technology ()] , *Journal of Electrochemical Science and Technology* 2013. 4 (2) p. .

[C ()] , C . *Global Journals Inc* 2016.

[Amin et al. ()] 'A study of the inhibition of iron corrosion in HCl solutions by some amino acids'. A Amin , K F Khaled , Q Mohsen , A Aridah . *Corros. Sci* 2010. 52 p. .

[Al-Mobarak et al. ()] 'Abdel-Azim, Corrosion inhibition of copper in chloride media by 2-mercapto-4-(p-methoxyphenyl)-6-oxo-1, 6-dihydropyrimidine-5-carbonitrile: Electrochemical and theoretical study'. N A Al-Mobarak , . F Khaled , M N H Hamed , KM . *Arab.J.Chem* 2010. 3 p. .

[Solmaz et al. ()] 'Adsorption and corrosion inhibition effect of 2-((5-mercapto-1,3,4-thiadiazol-2-ylimino)methyl)phenol Schiff base on mild steel'. R Solmaz , E Altunbas , G Kardas . *Mater. Chem. Phys* 2011. 125 p. .

[Ogoko et al.] *Adsorption and Inhibitive Properties of Clarithromycin for the Corrosion of*, E C Ogoko , S A Odoemelam , B I Ita , N O Eddy . (Zn in 0.01 to 0.05)

[Khaled ()] 'Application of electrochemical frequency modulation for monitoring corrosion and corrosion inhibition of iron by some indole derivatives in molar hydrochloric acid'. K F Khaled . *Mater. Chem. Phys* 2008. 112 p. .

[Prabhu et al. ()] 'Carmine and Fast Green as Corrosion Inhibitors for Mild Steel in Hydrochloric Acid Solution'. R A Prabhu , T V Venkatesha , A V Shanbhag . *J.Iran. Chem. Soc* 2009. 6 (2) p. .

[Imran Naqvi et al. ()] 'Cefixime: A drug as Efficient Corrosion Inhibitor for Mild Steel in Acidic Media. Electrochemical and Thermodynamic Studies'. A R Imran Naqvi , S Saleemi , Naveed . *Inter.J.Electrochem.Sci* 2011. 6 p. .

[Anozie et al.] *Corrosion inhibition of aluminium alloy in acidic medium by Euphorbia hirta and Dialumguineenseextracts*, U Anozie , C S Akoma , L A Nnanna .

[Zhang and Hua ()] 'Corrosion inhibition of aluminium in hydrochloric acid solution by alkylimidazolium ionic liquids'. Q B Zhang , Y X Hua . *Mater. Chem.Phys* 2010. 119 p. .

[Chetouani et al. ()] 'Corrosion inhibitors for iron in hydrochloride acid solution by newly synthesized pyridazine derivatives'. A Chetouani , A Aouniti , B Hammouti , N Benchat , T Benhadda , S Kertit . *Corros. Sci* 2003. 45 p. .

[Vaszilcsin et al. ()] 'Corrosion inhibitors from expired drugs'. N Vaszilcsin , V Ordodi , A Borza . *Inter.J.Pharm* 2012. 431 p. 241.

[Singh and Quraishi ()] 'Effect of Cefazolin on the corrosion of mild steel in HCl solution'. A K Singh , M A Quraishi . *Corros. Sci* 2010. 52 p. .

[Umoren et al. ()] 'Effect of halide ions on the corrosion inhibition of aluminium in alkaline medium using polyvinyl alcohol'. S A Umoren , E E Ebenso , P C Okafor , U J Ekpe , O Ogbobe . *J Appl Polym. Sci* 2007. 103 (5) p. .

[Umoren et al. ()] 'Effect of halide ions on the corrosion inhibition of mild steel in acidic medium using polyvinyl alcohol'. S A Umoren , O Ogbobe , E E Ebenso , U J Ekpe . *Pigm Resin Technol* 2006. 35 (5) p. .

[Samide et al. ()] 'Effect of sulfacetamide on the composition of corrosion products formed onto carbon steel surface in hydrochloric acid Dig'. A Samide , B Tutunaru , C Negrila , I Trandafir , A Maxut . *I. Nanomater. Bios* 2011. 6 p. .

[Von Fraunhofer and Stidham ()] 'Effects of fusedring antibiotics on metallic corrosion'. J A Von Fraunhofer , S H Stidham . *I. Biomed. Eng* 1991. 13 p. .

[Yurt et al. ()] 'Electrchemical and theoretical investigation on the corrosion of aluminium in acidic solution containing some Schiff bases'. A Yurt , S Ulutas , H Dal . *Appl.Surf. Sci* 2006. 253 p. .

[Doche et al. ()] 'Electrochemical behaviour of aluminium in concentrated NaOH solutions'. M L Doche , J J Rameau , R Durand , F Novel-Cattin . *Corros. Sci* 2007. 41 p. .

[El-Rehim et al. ()] 'Electrochemical frequency modulation as a new technique for monitoring corrosion inhibition of iron in acid media by new thiourea derivative'. S S El-Rehim , K F Khaled , N S Abd-Elshafi . *Electrochim. Acta* 2006. 51 p. .

[Mansfield ()] 'Electrochemical impedance spectroscopy (EIS) as a new tool for investigating methods of corrosion protection'. F Mansfield . *Electrochim. Acta* 1990. 35 p. .

[Kissi et al. ()] 'Establishment of equivalent circuits from electrochemical impedance spectroscopy study of corrosion inhibition of steel by pyrazine in sulphuric acidic solution'. M Kissi , M Bouklah , B Hammouti , M Benkaddor . *Appl. Surf. Sci* 2006. 252 p. .

[Khaled ()] 'Evaluation of electrochemical frequency modulation as a new technique for monitoring corrosion and corrosion inhibition of carbon steel in perchloric acid using hydrazine carbodithioic acid derivatives'. K F Khaled . *J.Appl. Electrochem* 2009. 39 p. .

[Burleigh and Smith ()] 'Evaluation of Natural Oxides on Aluminum in Neutral Borate Electrolyte technical papers'. T D Burleigh , A T Smith . *J. Electrochem. Soc* 1992. 139 p. .

[Oguzie et al. ()] 'Evaluation of the inhibitory effect of methylene blue dye on the corrosion of aluminium in hydrochloric acid'. E E Oguzie , B N Okolue , E E Ebenso , G N Onuoha , A I Onuchukwu . *Mater.Chem.Phys* 2004. 2016. 87 p. .

[Oguzie et al. ()] 'Evaluation of the inhibitory effect of methylene blue dye on the corrosion of aluminium in hydrochloric acid Mater'. E E Oguzie , B N Okolue , E E Ebenso , G N Onouoha , A I Onuchukwu . *Chem. & Phy* 2004. 87 p. .

[Mansfeld and Kendig ()] 'Evaluvation of Protective Coatings with Impedance Measurements'. F Mansfeld , M Kendig . *International Congress on Metalic corrosion* 1984. 3 p. .

[Fouda et al. ()] 'Extract of Camellia sinensis as Green Inhibitor for the Corrosion of Mild Steel in Aqueous Solution'. A S Fouda , Dina Mekkia , Abeer H Badr . *J. Korean Chem. Soc* 2013. 57 (2) p. .

[Fouda et al.] A S Fouda , A M El-Defrawy , M W El-Sherbeni . *Lornoxicam & Tenoxicam Drugs as Green Corrosion Inhibitors for Carbon Steel in 1 M H*, 2.

[Olesegun Abiola et al. ()] 'Gossipium hirsutum L. extracts as green corrosion inhibitor for aluminum in NaOH solution'. K Olesegun Abiola , J O E Otaigbe , O J Kio . *Corros. Sci* 2009. 51 p. .

[Khaled ()] 'Guanidine derivative as a new corrosion inhibitor for copper in 3% Na Clsolution'. K F Khaled . *Mater. Chem. Phys* 2008. 112 p. .

[Harckerman and Hurd ()] N Harckerman , R M Hurd . *1st International Congress on Metallic Corrosion*, (Butterworths, London) 1962. p. 166.

[Barsoukov and Macdonald ()] *Impedance Spectroscopy, Theory, Experiment and Applications*, E Barsoukov , J R Macdonald . 2005. New York: Wiley Interscience publications. (2nd Ed)

[Deng and Li ()] 'Inhibition by jasminum nudiflorum lindl. Leaves extract of the corrosion of aluminium in HCl solution'. Shuduan Deng , Xianghong Li . *Corros.Sci* 2012. 64 p. .

[Li et al. ()] *Inhibition by tetradecylpyridinium bromide of the corrosion of aluminiumin hydrochloric acid solution*, Xianghong Li , Shuduan Deng , Hui Fu , Corr Sci . 2011. 53 p. .

[Li and Deng ()] 'inhibition effect of dendrocalamus brandisii leaves extract on aluminium in HCl, H 3 PO 4 solutions'. Xianghong Li , Shuduan Deng . *Corros. Sci* 2012. 65 p. . (Corros.Sci.)

[Morad ()] 'Inhibition of iron corrosion in acid solutions by Cefatrexyl: Behaviour near and at the corrosion potential'. M S Morad . *Corros. Sci* 2008. 50 p. .

[Ahamad et al. ()] 'Inhibition of mild steel corrosion in acid solution by Pheniramine drug: Experimental and theoretical study'. I Ahamad , R Prasad , M A Quraishi . *Corros. Sci* 2010. 52 p. .

[Umoren et al. ()] 'Inhibition of mild steel corrosion in acidic medium using synthetic and naturally occurring polymers and synergistic halide additives'. S A Umoren , O Ogbobe , I O Igwe , E E Ebenso . *Corros. Sci* 2008. 50 p. .

[Eddy et al. ()] 'Inhibition of the Corrosion of Zinc in 0.01 -0.04 M H 2 SO 4 by Erythromycin'. N O Eddy , S A Odoemelam , E C Ogoko , B I Ita . *Port. Electrochim. Acta* 2010. 28 p. .

[Abdel-Gaber et al. ()] 'Inhibitive action of some plant extracts on the corrosion of steel in acidic media'. M Abdel-Gaber , B A Abd-El-Nabey , I M Sidahmed , A M El-Zayaday , M Saadawy . *Corros. Sci* 2006. 48 p. .

[Irshedat et al. ()] 'Investigation of the inhibition of aluminum corrosion in 1 M NaOH solution by Lupinus varius l. extract'. K Irshedat , M Eyad Nawafleh , T Tareq Bataineh , Riyadh Muhaidat , A Mahmoud Al-Qudah , A Ahmed Alomary . *Portugaliae Electrochemica Acta* 2013. 31 (1) p. .

[Hassan and Zaafarany ()] 'Kinetics of corrosion inhibition of aluminum in acidic media by watersoluble natural polymeric pectates as anionic polyelectrolyte inhibitors'. R M Hassan , I A Zaafarany . *Materials* 2013. 6 p. .

[Laarej et al. ()] K Laarej , M Bouachrine , S Radi. Kertite , B Hammouti . *Quantum chemical studies on the inhibiting effect of bipyrazoles on steel corrosion in HCl*, 2010. 7 p. .

[M H 2 SO 4 Port. Electrochim. Acta ()] 'M H 2 SO 4'. *Port. Electrochim. Acta* 2009. 27 p. .

[Bosch et al. ()] 'Mobile Hydrogen Monitoring in the Wall of Hydrogenation'. R W Bosch , J Hurecht , W F Bogaerts , B C Syrett . *Corrosion* 2001. 57 p. .

[Bockris et al. ()] *Modern electrochemistry 2A, Fandamental of electrodics, 2 nd edn*, O'm Bockris , K N Amulya , M Reddy . 2000.

[Shyamala and Arulanantham ()] 'Ocimum sanctum (Tulasi) as Corrosion Inhibitor on Mild Steel in Hydrochloric Acid'. M Shyamala , A Arulanantham . *Nature environment and Pollution Tech* 2008. 7 p. .

[Noor Ehteram et al. ()] *Potential of aqueous extract of Hibiscus sabdariffa leaves for inhibiting the corrosion of aluminum in alkaline solutions*, J Noor Ehteram , Apple , Electrochem . 2009. 39 p. .

[Fouda et al. ()] 'Pyrazolone derivatives as corrosion inhibitors for C-steel in hydrochloric acid solution'. A S Fouda , A A Al , E E Sarawy , El , Katori . *Desalination* 2006. 201 p. .

[References Références Referencias] *References Références Referencias*,

[Ramachandran et al. ()] *Self-assembled monolayer mechanism for corrosion inhibition of Iron by imidazolines*, S Ramachandran , M Tsai , H Blanco , W A Chen , Tang . 1996. 12 p. .

[Al-Sarawy and Fouda ()] 'Shehab El-Dein, Some thiazole derivatives as corrosion inhibitors for carbon steel in acidic medium'. A A Al-Sarawy , A S Fouda , WA . *Desalination* 2008. 229 p. .

[Singh et al. ()] 'Stem Extract of Brahmi (Bacopa monnieri) as Green Corrosion Inhibitor for Aluminum in NaOH Solution'. Ambrish Singh , Eno E Ebenso , M A Quraishi . *Int.J. Electrochem.Sci* 2012. 7 p. .

[Umoren et al. ()] 'Synergistic inhibition of aluminium corrosion in acidic medium by gum Arabic and halide ions'. S A Umoren , O Ogbobe , E E Ebenso . *Trans SAEST* 2006. 41 p. .

[Gao et al. ()] 'Synthesis of tertiary amines and their inhibitive performance on carbon steel corrosion'. G Gao , C H Liang , H Wang . *Corros. Sci* 2007. 49 p. .

[Lee and Pyun ()] 'The effect of oxide chemistry on the passivity of aluminium surfaces'. E J Lee , S J Pyun . *Corros.Sci* 1995. 37 p. .

[Mareci et al. ()] 'The electrochemical behaviour of various non-precious Ni and Co based alloys in artificial saliva'. D Mareci , Gh , N Nemtoi , C Aelenei , Bocanu . *Euro. Cells Mater* 2005. 10 p. .

[Abd El Rehim et al. ()] 'The inhibition of 4-(2?-amino-5?-methylphenylazo) antipyrine on corrosion of mild steel in HCl solution Mater'. S S Abd El Rehim , M A M Ibrahim , K F Khalid . *Chem.Phys* 2001. 70 p. .

[Behpour et al. ()] 'The inhibitive effect of some bis-N,Sbidentate Schiff bases on corrosion behavior of 304 stainless steel in hydrochloric acid solution'. M Behpour , S M Ghoreishi , N Soltani , M Salavati-Niasari . *Corros. Sci* 2009. 51 p. .

[Badr ()] 'The role of some thiosemicarbazide derivatives as corrosion inhibitors for C-steel in acidic media'. E G Badr . *Corros. Sci* 2009. 51 p. .

[Hadi and Al-Sawaad ()] 'Thermodynamic and quantum chemistry study for dimethylol-5-methylhydantoin and its derivatives as corrosion inhibitors for carbon steel N-80 in raw water (cooling water system)'. Z M Hadi , J Al-Sawaad . *Mater. Environ. Sci* 2011. 2 (2) p. .