

## Effect of Deaeration on the Corrosion of Pure Aluminum and Its Three alloys in NaOH solution at pH=11

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### Abstract

In this work, the corrosion behaviour of pure Al and its three alloys (Al-Cu-Mg, Al-Mg, and Al-Zn-Mg) was studied in aerated and deaerated  $1 \times 10^{-3}$  mol.dm<sup>-3</sup> NaOH solutions to show the role of dissolved oxygen gas and its reduction at cathode. Also the aim of this study was to obtain the corrosion parameters such as the corrosion potential ( $E_{\text{corr}}$ ), corrosion current density ( $i_{\text{corr}}$ ), cathodic and anodic Tafel slopes (b), and polarization resistance ( $R_p$ ) besides the thermodynamic and kinetic functions were also calculated ( $\Delta G$ ,  $\Delta S$ , and  $\Delta H$ ) and ( $E_a$  and  $\log A$ ) to comparison these values in the presence and absence of the oxygen.

From the general results for this study can be seen that the polarization resistances for pure Al and its alloys were higher in deaerated solutions and the values of ( $\Delta G$ ) were less spontaneous in deaerated solution, also the activation energy (energy barrier) was higher in deaerated solution.

**Keywords:** Corrosion of Aluminium and its alloy, Effect of deaeration on corrosion, Thermodynamic and Kinetic function of corrosion.

### تأثير عدم التهوية على تآكل اللامنيوم النقي وثلاث من سبائكه في محلول هيدروكسيد الصوديوم عند أس هيدروجيني (11)

#### الخلاصة

في هذا العمل تم دراسة السلوك التآكلي للامنيوم النقي وثلاث من سبائكه (المنيوم-نحاس-مغنيسيوم و المنيوم-مغنيسيوم و المنيوم-زنك-مغنيسيوم) في محلول هيدروكسيد الصوديوم في حالة التهوية وعدمها وذلك لمعرفة دور الاوكسجين المذاب والممتلة بجهد التآكل وكثافة تيار التآكل وميول تافل ومقاومة الاستقطاب. كما تم حساب الدوال الترموديناميكية والمتضمنة التغير في الطاقة الحرة لكيبس والتغير في الانتروبي والانتالبي بالإضافة الى الدوال الحركية والتي تشمل حساب طاقة التنشيط ولوغاريتم ثابت ارينيوس ومقارنة النتائج في حالة غياب ووجود الاوكسجين.

وقد اظهرت النتائج عموماً، بان مقاومة الاستقطاب كانت اكبر في حالة المحاليل عديمة التهوية، كما وان قيم الطاقة الحرة لكيبس كانت اقل تلقائية بغياب الاوكسجين هذا بلاضافة الى ان قيم طاقة التنشيط والتي تمثل حاجز الطاقة كانت اعلى في المحاليل عديمة التهوية.

### Introduction

Most aqueous solution are in contact with the atmosphere and it contain dissolved oxygen, which act as a cathode reactant. The saturated solubility of oxygen in pure water at 25°C is only about  $1 \times 10^{-3}$  mol.dm<sup>-3</sup>, and the solubility

decreases significantly with increase in temperature and slightly with concentration of dissolved salts. On the other hand, the concentration of  $H_3O^+$  in acid solutions is high, and since this ion has high rate of diffusion, its rate of

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reduction is normally controlled by the activation energy for electrode transfer.

Furthermore, the vigorous evolution of hydrogen that occurs during corrosion facilitates transport, so that diffusion is not a significant factor in controlling the rate of the reaction except at very high current densities. As the pH in acid solution increases the hydrogen evolution reaction becomes kinetically more difficult, and requires a higher overpotential.

The situation is different, however, in near-neutral or alkaline solutions in which the concentration of  $H_3O^+$  will be small ( $< 1 \times 10^{-7} \text{ mol.dm}^{-3}$ ), and in these solutions the water molecule will act as the electron acceptor, and although diffusion occurs rapidly, its reduction is kinetically more difficult than that of  $H_3O^+$ , and will therefore require a higher activation overpotential [1].

Aluminium-base alloys are relatively insensitive to the concentrations of oxygen present in most aqueous solutions. In general, high concentrations of dissolved oxygen tend to stimulate attack some what, especially in acid solution, although this effect is less pronounced than for most of the other common metals [see Table (1)].

Carbon dioxide or hydrogen sulfide, even in high concentrations, appears to have a slight inhibiting action on the effect of aqueous solutions on aluminium alloys. Water solutions of sulfur dioxide have some etching action on aluminium, but even so aluminium resists the action of such solutions better than copper or steel [see Table (2)]. Water solutions of hydrogen, nitrogen and chloride are strongly corrosive to aluminium. Hydrogen and nitrogen are without effect, except as they influence the oxygen content [2].

### Experimental Part

Aluminium and its alloys were cut into square shape with ( $1 \text{ cm}^2$ ) area, and made

into electrode by pressing a copper wire into a hole on one side and then insulating all but one side with an epoxy resin.

The exposed area was grinding on emery papers 220, 500, and 800 – mesh grit. A braiding was done by powder-driven wheels. The alloys used Al-Cu-Mg (2024), Al-Mg (5083), and Al-Zn-Mg (7075).

The electrochemical cell was of the usual type with provision for working electrode (pure metal and its alloys), auxiliary electrode (Pt electrode), and a Luggin capillary for connection with an SCE reference electrode.

The basic solution was NaOH solution with concentrations of ( $1 \times 10^{-3} \text{ mol.dm}^{-3}$ ) which corresponding to pH value of (11), NaOH obtained by Ferak with M.wt 40  $\text{g.mol}^{-1}$  and purity  $>99.5\%$ , which prepared in distilled water (specific conductivity  $1 \times 10^{-6} \text{ S.m}^{-1}$ ).

To study the effect of deaerated condition, the solution was purged for a minimum of 2 hour with nitrogen gas (purity 99.99%) at rate of  $150 \text{ cm}^3/\text{min}$  to remove oxygen from solution.

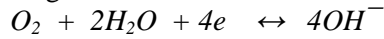
Electrochemical measurements were performed with a potentiostat (Corroscript) which was obtained from Tacussel (France) at a scan rate of 0.3 mVolt per minute. The main results obtained were expressed in terms of the corrosion potentials ( $E_{\text{corr}}$ ) and corrosion current density ( $i_{\text{corr}}$ ) in addition to calculate the cathodic and anodic Tafel slopes by using extrapolation method.

### Results and Discussion

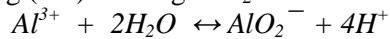
#### - Corrosion Behaviour

Figure (1) shows a typical curve of the polarization for pure Al metal and its three alloy in aerated  $1 \times 10^{-3} \text{ mol.dm}^{-3}$  NaOH solution (pH = 11) at 313 K, which was showed the regions that observed in the behaviour of metal or alloy under experimental solution.

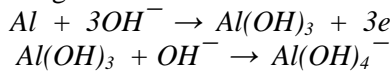
The section (abc) represents the cathodic region where the reduction reaction can be occur as shown in the following reaction:



Anodic dissolution of pure Al and its alloys begin at point (c) and continue along (cde) forming  $AlO_2^-$  ion.

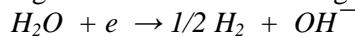


Along this section the metal hydroxide is expected to be formed according to the following reactions :



The difference between the polarization behaviour in aerated and deaerated solution for pure Al and its alloy was in the corrosion parameters  $E_{corr}$ ,  $i_{corr}$ ,  $b$  ..etc. only and there are no effect on the general behaviour of polarization curve as shown in Fig. (2).

Generally, the deaeration leads to shift the corrosion potentials to the noble direction and the corrosion current densities to the lower values. This is may be due to the decreasing in the cathodic reaction which contains the reduction of oxygen to hydroxide ions and the following reaction can be occurring:



In addition to this, the presence of oxygen in solution reacts with hydrogen to produce water molecules, then the absence of oxygen lead to accumulate the hydrogen on the electrode and impedance the hydrogen ions ( $H^+$ ) to neutralize at cathode and then reduce the rate of reaction.

By using Tafel extrapolation method can be calculate cathodic and anodic Tafel slopes ( $b_c$  and  $b_a$ ) [3].

The polarization resistance ( $R_p$ ) may be defined as the slope of a potential ( $\Delta E$ )-current density ( $\Delta i$ ) as [4,5]:

$$R_p = \left( \frac{\partial h}{\partial i} \right)_{T,C} \text{ at } h \rightarrow 0 \dots(1)$$

where  $\eta$ , overpotential ( $\eta = E - E_{corr}$ ).

From the polarization resistance  $R_p$ , the corrosion current density  $i_{corr}$  can be calculated as :

$$i_{corr} = \frac{b}{R_p} \dots\dots\dots(2)$$

Where  $\beta$  is a combination of the anodic and cathodic Tafel slopes ( $b_a, b_c$ ) as :

$$b = \frac{b_a b_c}{2.303(b_a + b_c)} \dots(3)$$

For the general case, by inserting equation (2) into equation (3) one obtains the so – called the Stern – Geary equation[6]:

$$R_p = \frac{b_a b_c}{2.303(b_a + b_c) i_{corr}} \dots\dots(4)$$

The values of  $R_p$  have been calculated from equation (4), which is presented in tables (3) to (6). The term ( $R_p$ ) corresponds to the resistance ( $R$ ) of the metal/solution interface to charge – transfer reaction. It is also a measure of the resistance of the metal to corrosion in the solution in which the metal is immersed. In general, the difference in polarization resistance takes the following sequence:

$$R_p (\Omega.cm^{-2}) \quad Al-Zn-Mg \text{ alloy} > Al-Cu-Mg \text{ alloy} > Al-Mg \text{ alloy} > \text{pure Al}$$

Generally, Tables (3) to (6) show that the polarization resistance in the absence of oxygen higher than the polarization resistance in the presence of oxygen, this is enhancing the results of corrosion potentials and current densities. The absence of oxygen in solution leads to reduce the main cathodic reaction

(reduction of oxygen to hydroxide ions) and because of alkali solution the reduction of hydrogen ions was slightly occurrence and then reduces the cathodic reaction. The decreasing of any reaction (anodic or cathodic) leads to decreases the rate of reaction or the corrosion current density, this means increasing the resistance of electrode according to ohm law ( $R=E/I$ ).

**- Thermodynamic Function**

Thermodynamic laws tell us that there is a strong tendency for high energy state in a system to transform into low energy state. It is this tendency of metals to recombine with components of the environment that leads to the phenomenon known as corrosion[7]. The change in free energy ( $\Delta G$ ) is a direct measure of the work capacity or maximum electric energy available from a system. The free-energy change accompanying an electrochemical reaction can be calculated by the following equation[1]:

$$\Delta G = -nFE \quad \dots\dots(5)$$

where  $\Delta G$  is the free – energy change,  $n$  is the number of electrons involved in the reaction (in this study = 3),  $F$  is the Faraday constant (96484 C.mol<sup>-1</sup>), and  $E$  is the corrosion potential and its sign is reversed prior to its use in equation (5) to represent the potential of the reversibly operating cell and not the applied potential from the potentiostat.

Table (7), show that the values of  $\Delta G$  were negative suggesting the existence of thermodynamic feasibility for the corrosion of the electrodes materials in  $1 \times 10^{-3}$  mol.dm<sup>-3</sup> NaOH solution. The values of free energy change show, in general, that the reactions of corrosion in the presence of oxygen more spontaneous than in the absence of oxygen in environment, since the oxygen

increase of the cathodic reaction and then increases the corrosion.

From the value of  $\Delta G$  at several temperatures, as shown in Fig. (3a, b), the change in the entropy ( $\Delta S$ ) of corrosion process could be derived according to the well – known thermodynamic relation:

$$\Delta S = -\frac{d(\Delta G)}{dT} \quad \dots\dots(6)$$

Values of  $\Delta S$  were generally positive due to negativity of  $\Delta G$ , this suggests a lower order in the solvated states of the metal ions as compared with the state of metal atoms in the crystal lattice of the corroding electrodes.

The change in free energy,  $\Delta G$ , is related to  $\Delta H$ , the change in the enthalpy, and  $\Delta S$ , the change in entropy of the corrosion reaction at a constant temperature,  $T$ , by the equation[8,9]:

$$\Delta G = \Delta H - T\Delta S \quad \dots\dots(7)$$

Values of the enthalpy of corrosion ( $\Delta H$ ) reflect the enthalpy changes associated with the corrosion reaction and ranged from negative to positive values indicating exothermic or endothermic nature of corrosion reaction.

**- Kinetic Functions**

The rate ( $r$ ) of corrosion in a given environment is directly proportional with its corrosion current density ( $i_{corr}$ ) in accordance with the relation[10,11]:

$$r = 0.13(e/r)i_{corr} \quad \dots\dots(8)$$

here ( $e$ ) is the equivalent weight of the metal and ( $\rho$ ) is its density. For the increasing values of ( $i_{corr}$ ) with a temperature follow Arrhenius equation, it is reasonable as:

$$i_{corr} = A \exp(-E_a / RT) \quad \dots\dots(9)$$

where  $A$  and  $E_a$  are the pre- exponential factor and energy of activation of the corrosion process respectively.

Values of  $E_a$  were derived from the slopes of the  $(\log i_{\text{corr}})$  versus  $(1/T)$  linear plots, while those of  $(A)$  were obtained from the intercepts of the plots at  $(1/T=\text{zero})$  as shown in Fig. (4a, b). The results were shown in Table (8), from these results it can be seen that the activation energy values ( $E_a$ ) in deaerated solution were higher than of the aerated solution except for Al-Cu-Mg alloy. The activation energy represents the energy barrier which required to forming the production of corrosion. The results ( $E_a$ ), in general, enhance the decreasing rate of reaction in the absence of oxygen in solution. Also the results of  $(\log A)$  values in deaerated solution were higher than of the aerated solution except for Al-Cu-Mg alloy.

The relationship existed between values of the activation energy ( $E_a$ ) and logarithm of pre – exponential factor ( $\log A$ ) in different media suggesting the operation of a compensation effect in kinetics of corrosion. This suggests that, the corrosion reaction proceeds on surface sites, which were associated with different energies of activation.

The corrosion reaction is assumed to start on sites with lower ( $E_a$ ) and  $(\log A)$  values first, spending thereafter to those sites on which ( $E_a$ ) and  $(\log A)$  were higher. The results of Fig.(5) indicate the existence of a linear relationship between the values of  $(\log A)$  and the corresponding values of ( $E_a$ ) which may be expressed as[12]:

$$\log A = mE_a + I \quad \dots\dots(10)$$

where  $m$  and  $I$  are respectively the slope and intercept of the plots, such a behaviour is referred to as "compensation effect" which describes the kinetics of a great number of catalytic and tarnishing reactions on metals[13,14].

Above equation indicates that simultaneous increases or decreases in ( $E_a$ ) and  $(\log A)$  for a system tend to compensate from the standpoint of the reaction rate.

A number of interpretations[15] have been offered for the phenomenon of the compensation effect in surface reaction, among which the effect could be ascribed to the presence of energetically heterogeneous reaction solution. A decrease in ( $E_a$ ) at constant  $(\log A)$  implies a higher rate, while an increase in ( $E_a$ ) at constant  $(\log A)$  implies a lower rate.

Simultaneous increase in ( $E_a$ ) and  $(\log A)$  therefore tend to compensate from the standpoint of the corrosion rate. When such compensation operates, it is possible for striking variations in ( $E_a$ ) and  $(\log A)$  through a series of surface sites on a metal or an alloy to yield only a small variation in reactivity, as shown in Fig. (5).

### Conclusions

From the results of the polarization behaviour of pure Al and its alloys, it can be seen that removed the oxygen from the environment of corrosion decrease the rate of reaction. This phenomenon can be note during the data of polarization resistance ( $R_p$ ) in addition to the data of the change in free energy ( $\Delta G$ ) and the activation energy ( $E_a$ ) and compensation effect. The reason of this phenomenon indicates that the cathodic reactions decrease because of the absence oxygen in the medium, where the main cathodic reaction is reduction of oxygen to the hydroxide ions.

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**Table (1) : Effect of gas atmosphere on the corrosion rate of Aluminium.**  
 Test run on three specimens. Immersed area of specimen – 37.8 sq cm., Volume of solution -150 ml., Temperature – room., Rate of aeration -15 ml per min.

Solution	Gas	Duration of test	Corrosion rate	
			ipy	mdd
1.0% Na <sub>2</sub> CO <sub>3</sub>	Oxygen bubbled through solution	18 hr	0.17	320
1.0% Na <sub>2</sub> CO <sub>3</sub>	Air bubbled through solution	18 hr	0.17	320
1.0% Na <sub>2</sub> CO <sub>3</sub>	Nitrogen bubbled through solution	18 hr	0.18	338
0.1% NaOH	Oxygen bubbled through solution	6 hr	0.65	1220
0.1% NaOH	Air bubbled through solution	6 hr	0.64	1200
0.1% NaOH	Nitrogen bubbled through solution	6 hr	0.63	1190
0.1% HCl	Oxygen bubbled through solution	48 hr	0.066	124
0.1% HCl	Air bubbled through solution	48 hr	0.036	68
0.1% HCl	Nitrogen bubbled through solution	48 hr	0.006	11
0.1% HCl	Air over quiescent solution	48 hr	0.007	13

**Table (2) : Resistance of aluminium to water solution of several gases.**

Metal	Carbon dioxide and water		Sulfur dioxide, Air, and water		Hydrogen sulfide and water	
	Av. Wt. loss (gm)	Av. (ipy)	Av. Wt. loss (gm)	Av. (ipy)	Av. Wt. loss (gm)	Av. (ipy)
Al	0.0003	0.00004	0.150	0.0498	0.002	0.00028
Cu	---	---	0.681	0.0701	0.237	0.01030
Steel	0.2153	0.00977	8.583	1.02	1.366	0.06800

**Table (3) : Values of E<sub>corr</sub> corrosion potentials, corrosion current densities i<sub>corr</sub>, cathodic and anodic Tafel slopes b<sub>c</sub> and b<sub>a</sub>, and polarization resistances R<sub>p</sub>, for the polarization of pure aluminium in 1x10<sup>-3</sup> mol.dm<sup>-3</sup> NaOH solution at four temperatures.**

Environment	T (K)	Corrosion		b (V.decade <sup>-1</sup> )		R <sub>p</sub> /10 <sup>+2</sup> Ωcm <sup>-2</sup>
		-E <sub>corr</sub> (V)	i <sub>corr</sub> A.cm <sup>-2</sup>	-b <sub>c</sub>	+b <sub>a</sub>	
Aerated	298	1.66	5.86x10 <sup>-4</sup>	0.028	0.031	0.1092
	303	1.64	7.81 x10 <sup>-4</sup>	0.030	0.032	0.0862
	308	1.63	9.77 x10 <sup>-4</sup>	0.034	0.035	0.0767
	313	1.62	11.72 x10 <sup>-4</sup>	0.036	0.040	0.0703
De-aerated	298	1.66	0.147x10 <sup>-6</sup>	0.036	0.031	492.66
	303	1.62	0.220 x10 <sup>-6</sup>	0.037	0.033	344.721
	308	1.58	0.275 x10 <sup>-6</sup>	0.038	0.040	308.098
	313	1.56	0.550 x10 <sup>-6</sup>	0.042	0.047	175.334

Table (4) : Values of corrosion potentials  $E_{corr}$ , corrosion current densities  $i_{corr}$ , cathodic and anodic Tafel slopes  $b_c$  and  $b_a$ , and polarization resistances  $R_p$  for the polarization of Al-Cu-Mg alloy in  $1 \times 10^{-3}$  mol.dm<sup>-3</sup> NaOH solution at four temperatures.

Envir- onment	T (K)	Corrosion		b (V.decade <sup>-1</sup> )		$R_p/10^{+2}$ $\Omega cm^{-2}$
		$-E_{corr}$ (V)	$i_{corr}/10^{-6}$ A.cm <sup>-2</sup>	$-b_c$	$+b_a$	
Aerated	298	1.50	8.87	0.026	0.043	7.942
	303	1.46	17.24	0.029	0.048	4.559
	308	1.44	18.23	0.060	0.052	6.644
	313	1.42	19.70	0.063	0.054	6.417
De-aerated	298	1.48	0.19	0.033	0.032	371.766
	303	1.46	0.25	0.035	0.034	299.937
	308	1.45	0.29	0.043	0.047	336.665
	313	1.43	0.34	0.051	0.107	441.662

Table (5) : Values of corrosion potentials  $E_{corr}$ , corrosion current densities  $i_{corr}$ , cathodic and anodic Tafel slopes  $b_c$  and  $b_a$ , and polarization resistances  $R_p$  for the polarization of Al-Mg alloy in  $1 \times 10^{-3}$  mol.dm<sup>-3</sup> NaOH solution at four temperatures.

Envir- onment	T (K)	Corrosion		b (V.decade <sup>-1</sup> )		$R_p/10^{+2}$ $\Omega cm^{-2}$
		$-E_{corr}$ (V)	$i_{corr}/10^{-6}$ A.cm <sup>-2</sup>	$-b_c$	$+b_a$	
Aerated	298	1.66	8.74	0.034	0.031	8.0665
	303	1.65	9.66	0.035	0.032	7.5238
	308	1.64	11.49	0.036	0.034	6.6166
	313	1.63	13.79	0.037	0.036	5.7529
De-aerated	298	1.55	0.11	0.028	0.028	553.35
	303	1.53	0.34	0.030	0.034	203.80
	308	1.48	0.59	0.036	0.045	147.38
	313	1.44	0.91	0.068	0.047	132.78



Table (6) : Values of corrosion potentials  $E_{corr}$ , corrosion current densities  $i_{corr}$ , cathodic and anodic Tafel slopes  $b_c$  and  $b_a$ , and polarization resistances  $R_p$  for the polarization of Al-Zn-Mg alloy in  $1 \times 10^{-3}$  mol.dm<sup>-3</sup> NaOH solution at four temperatures.

Envir- onment	T (K)	Corrosion		b (V.decade <sup>-1</sup> )		$R_p/10^{+2}$ $\Omega cm^{-2}$
		$-E_{corr}$ (V)	$i_{corr}/10^{-6}$ A.cm <sup>-2</sup>	$-b_c$	$+b_a$	
Aerated	298	1.75	6.23	0.031	0.041	12.319
	303	1.60	7.27	0.032	0.042	10.861
	308	1.56	8.65	0.035	0.043	9.6983
	313	1.50	10.38	0.039	0.045	8.7513
De-aerated	298	1.60	0.09	0.028	0.047	847.66
	303	1.48	0.17	0.030	0.054	493.24
	308	1.46	0.69	0.052	0.064	180.77
	313	1.41	1.21	0.062	0.086	129.45

Tables (7) : The thermodynamic quantities for pure Al and its alloy in  $1 \times 10^{-3}$  mol.dm<sup>-3</sup> NaOH solution at pH=11 at four temperatures.

Elect.	T (K)	$-AG$ (kJ.mole <sup>-1</sup> )		$\Delta S$ (J.mol <sup>-1</sup> .K <sup>-1</sup> )		$\Delta H$ (kJ.mole <sup>-1</sup> )	
		Aerated	Deaerated	Aerated	Deaerated	Aerated	Deaerated
Pure Al	298	480.54	480.54	752.6	74450.2	-256.27	21905.56
	303	474.75	468.91			-	-
	308	471.85	457.33			-	-
	313	468.96	451.55			-	-
Al-Cu-Mg	298	434.18	428.39	1505.3	926.0	14.40	-152.442
	303	422.60	422.60			-	-
	308	419.71	419.71			-	-
	313	411.02	413.92			-	-
Al-Mg	298	480.54	448.65	578.9	2199.8	-308.03	206.890
	303	477.64	442.86			-	-
	308	474.75	428.39			-	-
	313	471.85	416.81			-	-
Al-Zn-Mg	298	506.59	463.17	4573.8	3418.2	856.40	555.454
	303	463.17	428.39			-	-
	308	451.59	422.60			-	-
	313	434.22	408.13			-	-

Table (8) : Values of activation energy ( $E_a$ ), log pre- exponential factors log(A) for pure Al and its alloys in  $1 \times 10^{-3}$  mol.dm<sup>-3</sup> NaOH solution at pH=11.

Electrode	$E_a$ (kJ.mol <sup>-1</sup> )	Log A	$E_a$ (kJ.mol <sup>-1</sup> )	Log A
	Aerated	Aerated	Deaerated	Deaerated
Pure Al	35.78	3.048	64.71	4.489
Al-Cu-Mg	38.29	1.733	29.44	-1.548
Al-Mg	23.86	-0.887	107.22	11.911
Al-Zn-Mg	26.43	-0.577	142.67	17.925

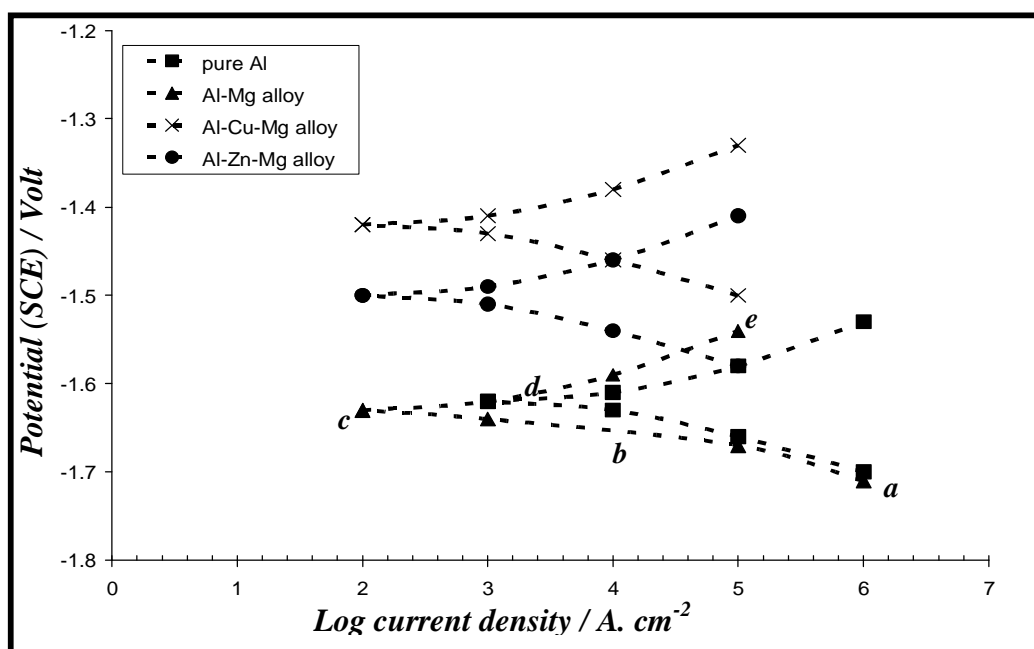


Fig. (1) : The Typical polarization curve of pure Al and its alloys in aerated NaOH solution at pH = 11 and 313K.

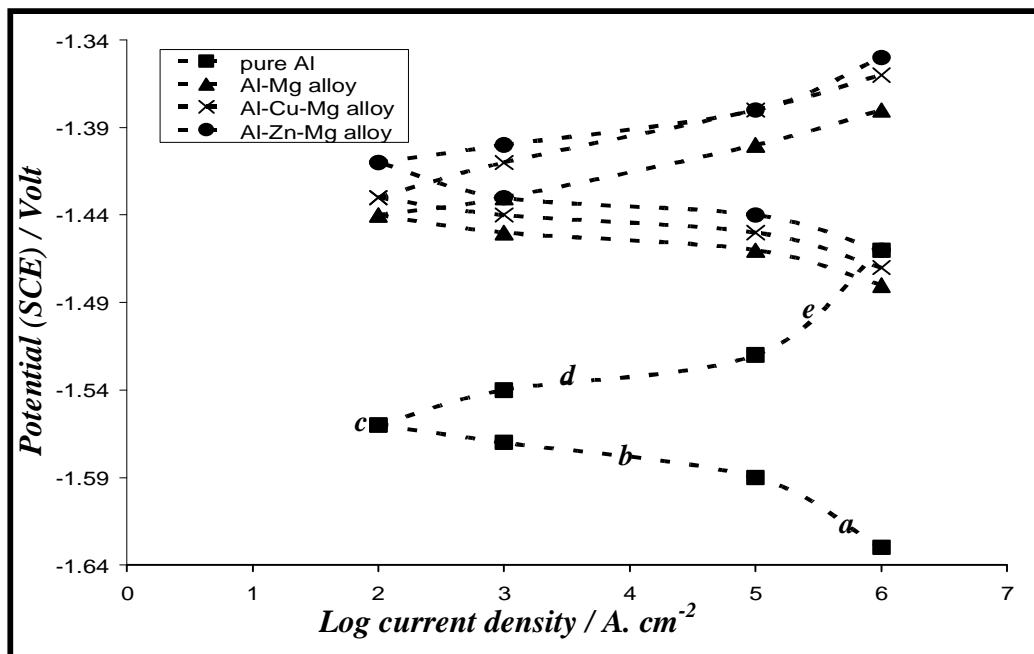


Fig. (2) : The Typical polarization curve of pure Al and its alloys in deaerated NaOH solution at pH = 11 and 313K.

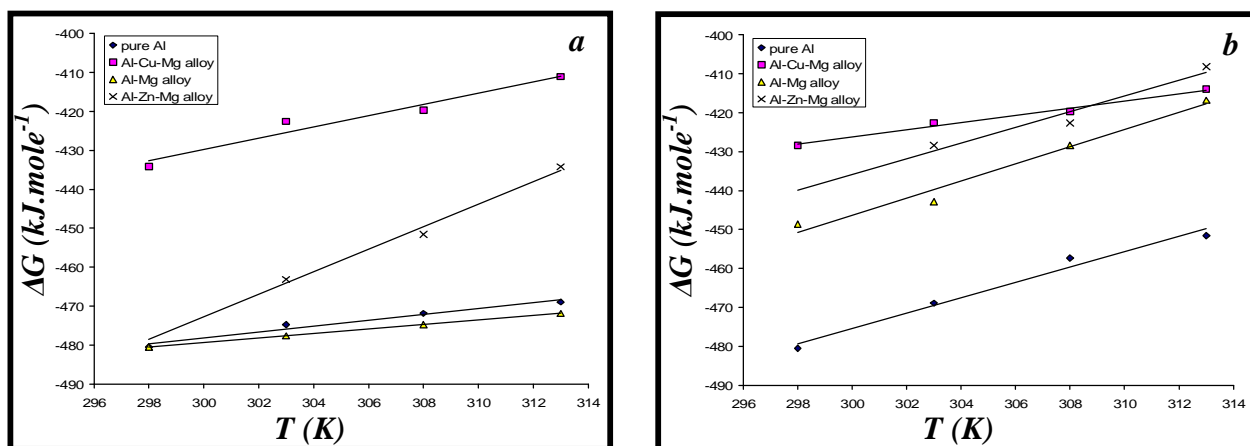


Fig. (3) : The variation of the (-ΔG)with temperature (T) for corrosion of pure Al and its alloys in  $1 \times 10^{-3}$  mol.dm<sup>-3</sup> NaOH solution (a) Aerated solution, (b) Deaerated solution.

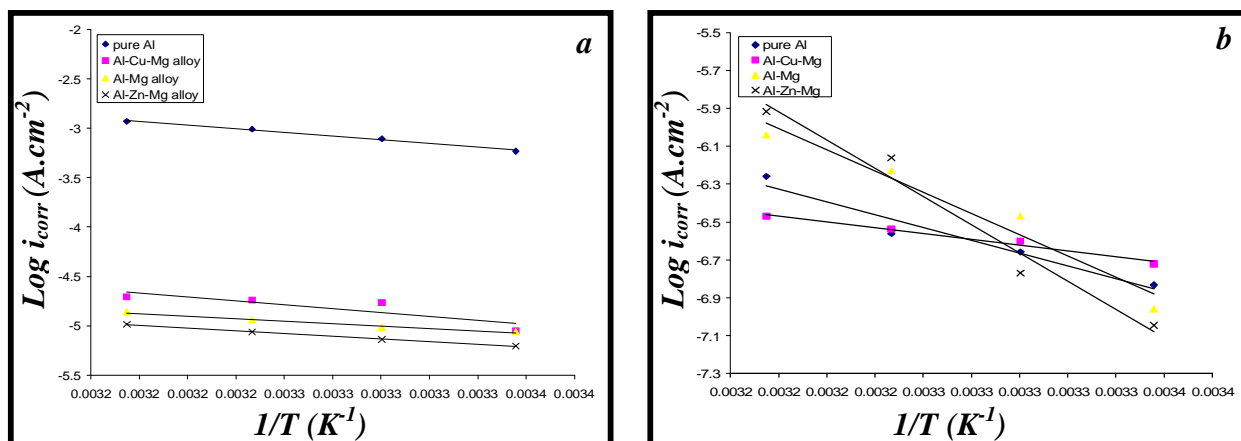
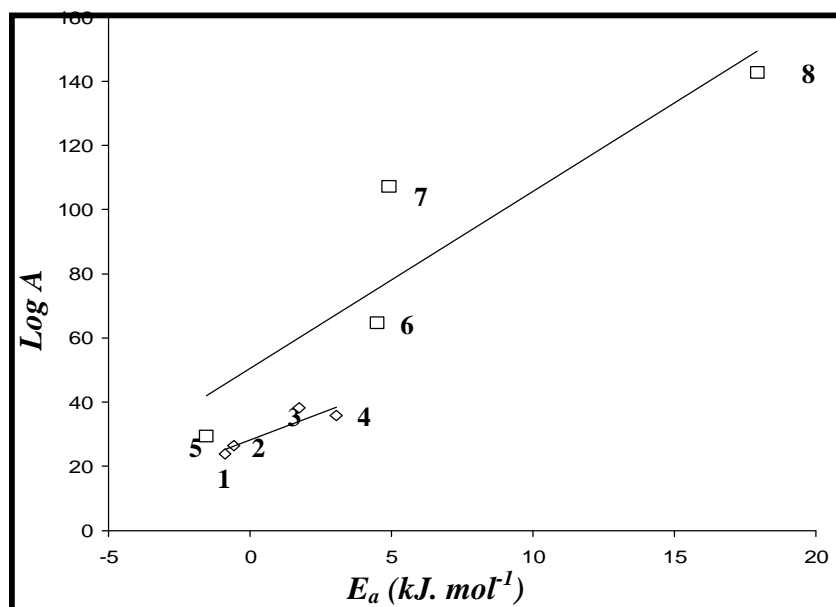


Fig. (4) : Arrhenius plots, relating( $\log i_{corr}$ ) values to  $(1/T)$  for the corrosion of pure Al and its alloys in  $1 \times 10^{-3} \text{ mol.dm}^{-3}$  NaOH solution  
 (a) Aerated solution, (b) Deaerated solution.



- 1-Al-Mg in aerated solution
- 2-Al-Zn-Mg in aerated solution
- 3-Al-Cu-Mg in aerated solution
- 4-pure Al in aerated solution
- 5-Al-Cu-Mg in deaerated solution
- 6-pure Al in deaerated solution
- 7-Al-Mg in deaerated solution
- 8-Al-Zn-Mg in deaerated solution.

Fig. (5) : Log A values plotted against  $E_a$  for pure Al and its alloys in  $1 \times 10^{-3} \text{ mol.dm}^{-3}$  NaOH solution.