Electrochemical Engineering CHG 8191L Winter 2016

Assignment 2 solutions

Problem #1

The values of α_a and α_c are provided = 0.5

J_0= 20 mA/cm^2 = 0.02 A/cm^2

You are required to use Tafel Equation, then the linear approximation to calculate J, then compare between the two values for each η value (1 mV = 0.001 V and 100 mV= 0.1 V). Since the overpotential values are positive, only anodic reaction will be considered here.

(a) Tafel Equation:

At η = 1 mV or 0.001 V

$$J = J_0[\exp(\propto \frac{aF\eta}{RT})]$$

$$J = 0.02[\exp(\frac{0.5(96500)(0.001)}{8.314(298)})]$$

J = J_{anodic}= 20.393 mA/cm^2

Now at η = 100 mV or 0.1 V, and using the same approach,

J = J_{anodic}= 140.219 mA/cm^2

(b) Linear Approximation:

J=J_0fη   where, f= F/RT= 38.92 V^{-1}

At η= 1 mV or 0.001 V

J=0.02(38.92)(0.001) = 0.778 mA/cm^2

Now at η = 100 mV or 0.1 V, and using the same approach,

J= 77.899 mA/cm^2

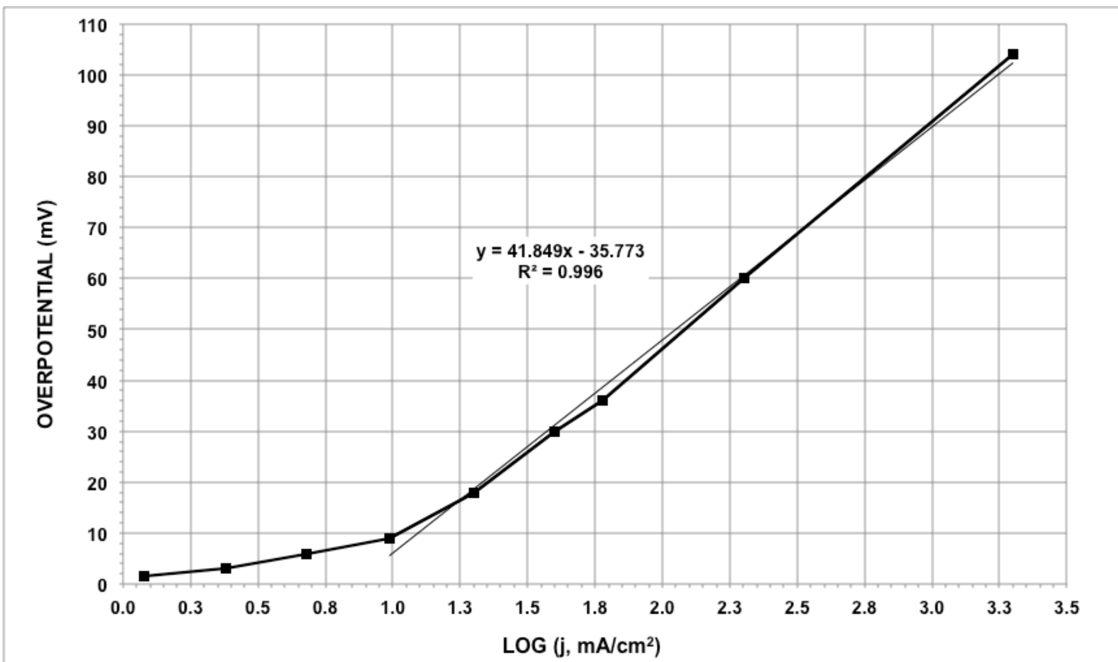
Comparison in J values for both methods:

Overpotential Values, η	Tafel (mA/cm^2)	Linear Approximation (mA/cm^2)	Difference (mA/cm^2)	Percentage Error (%)
1 mV	20.393	0.778	19.614	96.18
100 mV	140.219	77.899	62.320	44.44

Problem # 2

The question statement says copper dissolution at 25 °C, this means that the number of electrons = 2 and anodic reaction.

So the current densities and the overpotential values are provided. We can draw the data as shown below:



From the above Tafel plot, slope = 41.849 mV and intercept = -35.773 mV.

Tafel equation: $\eta = 2.303\ RT/n\alpha F \log j - 2.303\ RT/n\alpha F \log j_0$

So, slope = 41.849 mV = 2.303 RT/nαF where, n=2 and T=298 K

Hence, $\underline{\alpha = 0.7064 = \alpha_a}$

And, intercept = -35.773 mV = $-\ 2.303\ RT/n\alpha F \log j_0$

$\log j_0 = 0.8548$

Therefore, $j_0 = 7.157\ mA/cm^2$

Problem # 3

Hydrogen is being evolved from an electrolyte at pH = 5.

Hence, the EQUILIBRIUM potential of hydrogen is then defined from the following equation (comes from Nernst)

$E_{0\ (Equilibrium)} = E_{standard} - 0.059\ pH$

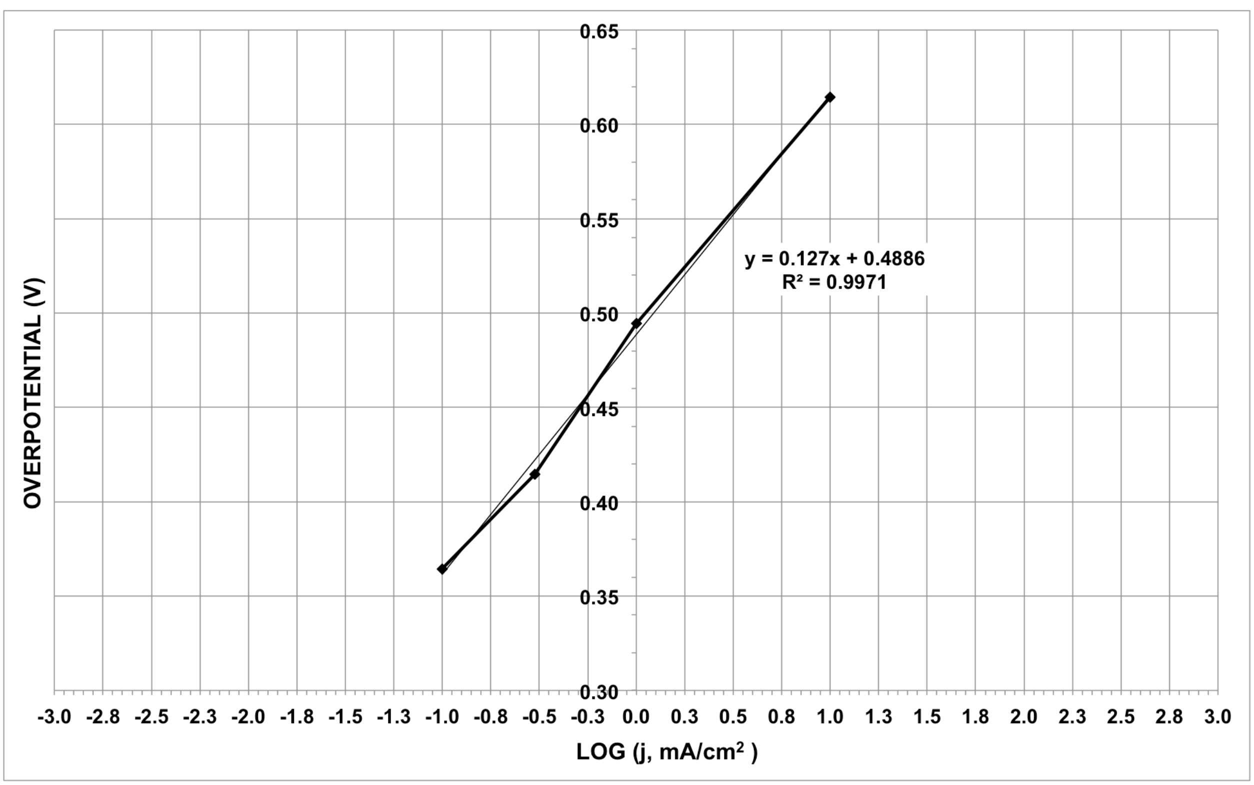
Please note that $E_{standard}$ for hydrogen = 0 (at standard temperature and pressure)

So , $E_{0\ (Equilibrium)} = - 0.059\ pH$

$E_{0\ (Equilibrium)} = - 0.2955\ V$ (for hydrogen at these conditions)

We need to find the overpotential η

And $\eta = E_{0\ (Equilibrium)} - E_{measured}$ or $E_{measured} - E_{0\ (Equilibrium)}$



From the above Tafel plot, slope = 0.127 V and intercept = 0.4886 V.

η (V)	j (mA/cm^2)
0.615	10
0.495	1
0.415	0.3
0.365	0.1

Sample calculations:

For the first reading,

Then, $\eta = E_{0\ (Equilibrium)} - E_{measured}$ = -0.2955-(-0.91)= 0.6145 V or -0.6145 V

From the above Tafel plot, slope = 41.849 mV and intercept = -35.773 mV.

Tafel equation: $\eta = 2.303\ RT/n\alpha F \log j - 2.303\ RT/n\alpha F \log j_0$

So, slope = 0.127 V = 2.303 RT/nαF where, n=1 (for H^+ formation) and T=298 K

$\alpha = 0.4656 = \alpha_c$

Hence, $\alpha_a = 0.5344 = 1 - |\alpha_c|$

And, intercept = 0.4886 V = - 2.303 RT/nαF $\log j_0$

$\log j_0 = -3.847$

Therefore, $j_0 = 1.421 \times 10^{-4}\ mA/cm^2$

Problem # 4

You need to identify the three polarization regions on each fuel cell curve. Then subtract potentials as shown below.

	Activation Overpotential	**Ohmic Drop**
Fuel Cell 1	η_{act} = 1.22 - 0.68 = 0.54 V	η_{ohm} = 0.68 - 0.64 = 0.04 V
Fuel Cell 2	η_{act} = 1.22 - 0.5 = 0.72 V	η_{ohm} = 0.5 - 0.46 = 0.04 V
Fuel Cell 3	η_{act} = 1.22 - 0.38 = 0.84 V	η_{ohm} = 0.38 - 0.34 = 0.04 V