

# CHG 8191L

## **Assignment # 3**

### **Solutions**

## Problem 1 (solution)

$$\text{Re} = \frac{\omega r^2}{\nu} = \frac{(2 \cdot \pi \cdot 16)(0.2)^2}{0.01} = 402 \quad \text{Re}_{\text{cr}} < 2000 \quad \Rightarrow \quad \text{laminar}$$

$$k_d = 0.62 (5 \cdot 10^{-6})^{2/3} \cdot (2\pi \cdot 16)^{1/2} \cdot (0.01)^{-1/6} = \underline{4 \cdot 10^{-3} \text{ cm s}^{-1}}$$

$$\text{Sc} = \frac{\nu}{D} = \frac{0.01}{5 \cdot 10^{-6}} = 2'000 \quad \delta = \frac{D}{k_d} = \frac{5 \cdot 10^{-6}}{4 \cdot 10^{-3}} = \underline{0.0013 \text{ cm}}$$

$$\text{Sh} = 0.62 \text{Sc}^{0.33} \text{Re}^{0.5} = 0.60(2'000)^{0.33}(402)^{0.5} = \underline{157}$$

## Problem 2 (solution)

$$\left. \begin{aligned} Sh_{av} &= 0.023 Re^{0.8} Sc^{1/3} \\ Re &= 20'000 \\ Sc &= \frac{v}{D} = \frac{0.01}{5 \cdot 10^{-6}} = 2'000 \end{aligned} \right\} Sh_{av} = 0.023(20'000)^{0.8} (2000)^{1/3} = 779$$

$$I_{lim} = z \cdot F A c_b \cdot Sh_{av} \cdot \frac{D}{d_e}$$

$$d_e = 4Ac / P = 4(100 \times 1) / 2(100 + 1) = 1.98 \text{ cm}$$

$$A = 100 \times 100 = 10000 \text{ cm}^2$$

$$I_{lim} = (2) \cdot (96500) \cdot (0.1 \cdot 10^{-3}) \cdot (10000)(779) \cdot \frac{5 \cdot 10^{-6}}{1.98} = 379.98 \text{ A}$$

## Problem 3 (solution)

The overall chemical reaction for Aluminum reaction is:



The theoretical amount of Al produced in 30 days will be equal to:

$$\begin{aligned} M_{\text{theor}} &= \frac{M * I * (24 * 30 \text{ days})}{(Z * F)} \\ &= \frac{(26.98 \text{ g/mol} * 65\,000 \text{ A} * 24 \text{ hr/day} * 30 \text{ days} * 150)}{(3 * 26.8 \text{ A hr /mol})} \\ &= 2355716 \text{ kg} = 2356 \text{ Tons} \end{aligned}$$

**The Faradic efficiency**

$$\varphi = \frac{2090 * 0.995}{2356} * 100\% = 88.3 \%$$

The specific energy consumption is:

$$P = \frac{I V}{M \text{ actual} * \text{Purity}} = \frac{65\,000 * 718 * 24 * 30}{2090 * 0.995} = 16158 \text{ kWh / ton Al}$$

## Problem 4 (solution)

Assumption: Faradaic efficiency is 100 %

Data: Density of Zn deposit is  $d_{Zn} = 7.13 \text{ g/cm}^3$

The surface area of metallic objects:

$$A = \text{Mass} * A_s = 15 \text{ kg} * 19.2 \text{ m}^2 / \text{kg} = 288 \text{ m}^2$$

Mass of Metal deposited for all objects:

$$\text{Mass Zn} = A * \delta * \rho_{Zn} \Rightarrow \text{Mass Zn} = 2880000 \text{ cm}^2 * 0.0015 \text{ cm} * 7.13 \text{ g/cm}^3$$

$$\text{Mass Zn} = 30801.6 \text{ g}$$

The time of process:

$$\text{Time} = \frac{\text{Mass Zn} * Z * F}{I * M_{wt} \text{ Zn} * \varphi} = \frac{30801.6 \text{ g} * 2 * 26.8 \text{ A.h/mol}}{80 \text{ A} * 65.39 \text{ g/mol} * 1} = 316 \text{ h (or 13 days)}$$