

Bachelor of Metallurgical Engineering 3rd Year 1st Semester Examination, 2017 (Supplementary)

Chemical Kinetics and Mass Transfer

Time: Three Hours

Full Marks-100

Answer any Five questions.

- 1. i) The rate of a 2nd-order reaction is given as

r_A = 4 C_A^2, mol/liter.hr 5

What is the value and unit of the rate constant? If the rate is expressed in mol/cm^3.sec and concentration in mol/cm^3, how will the value and unit of the rate constant change?

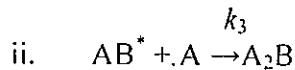
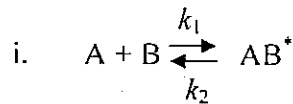
- ii) The total pressure in a closed reactor in which pure AB fed at 1 atm undergoes the 2nd-order irreversible reaction



decreases to 0.8 atm in 5 mintes at 500 K. Determine k.

- iii) After 8 minutes in a batch reactor, reactant (C_A0 = 1 mol/liter) is 80% converted; after 18 minutes, conversion is 90%. Find a rate equation representing this reaction. (Note, A trial and error solution may be necessary.) 8

- 2. i) Consider a gas phase reaction 2A + B -> A2B which takes place according to the following 2-step mechanism:



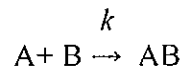
If the initial concentrations are C_A0 = 10 mol/m^3 and C_B0 = 5 mol/m^3, find the value of C_A2B at t = 30 sec, when the reaction is carried out in a constant-volume batch reactor at temperature T. Given, k1 = 0.02 m^3/mol.sec, k2 = 3 sec^-1 and k3 = 6 m^3/mol.sec. 15

- ii) Establish the following design equations for a steady-state mixed flow reactor:

$$\frac{V}{F_{A0}} = \frac{\tau}{C_{A0}} = \frac{X_A}{-r_A}$$

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3. i) Consider the following 2nd-order homogeneous reaction:



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Using the following data, determine the activation energy (E) of the reaction.

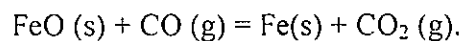
T, K	$C_A, \text{ mol/lit}$	$C_B, \text{ mol/lit}$	$-dC_A/dt, \text{ mol/lit.min}$
1000	5	3	0.3
1500	5	2	1.0

- ii) Consider the evaporation of liquid Zn taken in a rectangular tube into the stagnant film of argon formed by pure argon flowing over the tube at 764.0°C and 1 atm. Given, the saturated vapor pressure of liquid Zn at 764.0°C is 0.5 atm, $Z_2 - Z_1 = 0.02 \text{ m}$, and $D_{\text{Zn-Ar}}$ (at 764.0°C) = $1.43 \times 10^{-4} \text{ m}^2/\text{s}$. Find

- a) $J_{\text{Ar}(Z_1-Z_2)}$
 b) V_{Zn, Z_1}

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4. Consider the reduction of a dense cylindrical FeO sample ($L \gg r$) with a flowing mixture of CO-CO₂ mixture, which is controlled by 1-dimensional pore diffusion in the r -direction through the product (Fe) layer. The reduction reaction is



- i) Show that the molar rate of reduction of FeO, $-dn_{\text{FeO}}/dt$, can be expressed as follows:

$$-dn_{\text{FeO}}/dt = \frac{2\pi L(C_{\text{CO},b} - C_{\text{CO},e})D_{\text{pore}}}{\ln(r_{\text{FeO}}^0/r_{\text{FeO}})}$$

where r_{FeO}^0 is the initial radius of the cylinder having the length L .

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- ii) Show that the progress of the reduction can be expressed as

$$X_{\text{FeO}} + (1 - X_{\text{FeO}}) \ln(1 - X_{\text{FeO}}) = \frac{4D_{\text{pore}}(C_{\text{CO},b} - C_{\text{CO},e})t}{\rho_{\text{m,FeO}}(r_{\text{FeO}}^0)^2}$$

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5. i) The following table shows the data for the half-life period ($t_{1/2}$) versus the initial concentration of reactant A (C_{A0}) for the reaction, $A \rightarrow \text{Products}$.

$\log C_{A0}$	10	20	30
$\log t_{1/2}$	30	35	40

Find the order of the reaction.

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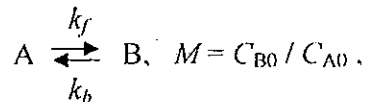
- ii) Refer to the problem of dissolution of a flat plate (A) in a flowing fluid (B). If the local Sherwood Number at $x = 0.5$ m is 1000 and $D_{AB} = 1.2 \times 10^{-8}$ m²/s, determine the steady rate of dissolution W_{Ay} (mole/time) of the plate. Given,

$$L = 1 \text{ m} \quad W \text{ (width of the plate)} = 0.3 \text{ m}$$

$$C_{As} = 40 \text{ mol/m}^3 \quad C_{A\infty} = 0.$$

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- iii) Considering the following 1st-order reversible reaction



derive the rate equation

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$$-\ln \left(\frac{C_A - C_{Ae}}{C_{A0} - C_{Ae}} \right) = At, \quad \text{where } A = f(k_f, C_{A0}, M, C_{Ae}).$$

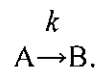
6. i) Give the two basic postulates, one thermodynamic and the other kinetic, of the activated complex theory. 3
- ii) Give one metallurgical example for
- series reactions
 - parallel reactions
- 3
- iii) Give an example in which the term "order" does not apply in the rate equation of the reaction. 3
- iv) Superimpose the $\ln k$ vs $1/T$ plots for the two reactions, $P \rightarrow Q$ and $M \rightarrow N$, for each of the following two cases:

(a) $A_{P \rightarrow Q} = A_{M \rightarrow N}$, $E_{P \rightarrow Q} < E_{M \rightarrow N}$

(b) $E_{P \rightarrow Q} = E_{M \rightarrow N}$, $A_{P \rightarrow Q} < A_{M \rightarrow N}$.

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v) Consider the half-order nonelementary homogeneous reaction



Find its integrated form of rate equation (X_A vs t). Explain with the help of a suitable plot how you will find out the rate constant k .

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