國立雲林科技大學 103 學年度 碩士班招生考試試題

系所：化材系

科目：單元操作與輸送現象

1. The air at 25°C flows over a steel plate (40 cm x 50 cm, thickness = 2.5 cm), of which top-side temperature is 275°C. The convective heat transfer coefficient is 40 W/m^2-K. (shown as following Figure 1).
   (a) Please calculate the heat loss from the top-side of steel. (10%)
   (b) Please determine the temperature of bottom-side of steel under the condition of above air flow and additional radiation heat loss of 380 W from the steel. The thermal conductivity of steel is 45 W/m-K. (10%)

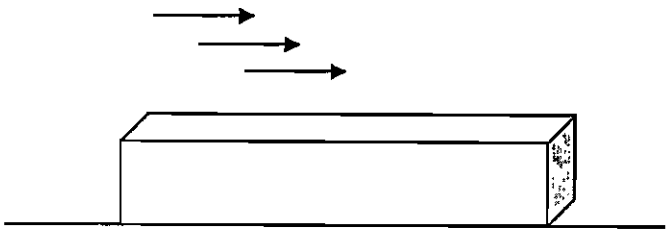

Figure 1

2. In a heat exchanger, the oil is cooled from 250°F to 180°F, of which flow rate is 1.0 kg/s. The water is used as coolant at 50°F, of which flow rate is 0.5 kg/s. The heat capacities of oil and water are 1880 J/kg-K and 4177 J/kg-K, respectively. The overall heat transfer coefficient is 270 W/m^2-K. Please calculate the heat transfer areas for (a) cocurrent flow and (b) countercurrent flow, respectively. (1 W = 1 J/s) (20%)

3. Describe and explain the following:
   (a) Write down and explain the physical meaning of the equations of continuity for incompressible and compressible flow, respectively. (6%)
   (b) Write down and explain the physical meaning of Reynolds number. (4%)
   (c) Write down the Fick's 1st law of diffusion in terms of N_A (the molar flux relative to a stationary coordinate) for a binary system with species A and B, and explain the physical meaning of each terms appeared in the equation. (6%)
   (d) Physical meaning of the operation and equilibrium lines in the distillation operation with reflux based on the McCabe-Thiele method. (4%)

4. Referring to Figure 2, consider a Gas A dissolves in, diffuses into and reacts with a liquid B, and the concentration A at the gas/liquid interface is C_{A0}. If assume the reaction rate per unit volume $r_A = -kC_A$, find (a) the steady concentration distribution, $C_A(z)$ (12%), and the

average concentration, $\bar{C}_A$ (8%), of A in B. Assume constant physical properties, small concentration of A, and that the product of reaction does not interfere with the diffusion of A through B.

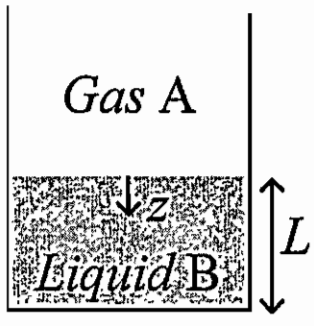

Figure 2

5. Referring to Figure 3, consider a laminar, fully-developed flow of an incompressible Newtonian fluid with viscosity μ and density ρ in a vertical cylindrical tube of Length L and diameter D under the influence of a pressure gradient $(p_0 - p_L)/L$. Find (a) the momentum flux distribution (8%), (b) the velocity distribution (6%), and (c) and the volume flow rate (6%) **using the shell momentum balance method.**

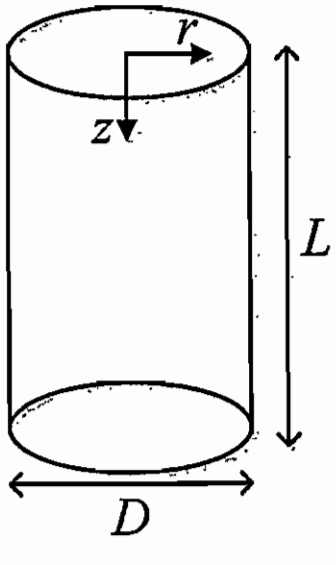

Figure 3

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1. (17 分)

An adiabatic turbine is operating with an ideal gas of constant heat capacity C_p at fixed inlet temperature T_1 and pressure P_1, and at fixed exit pressure P_2. If the turbine operates reversibly, derive

(a) The minimum outlet temperature T_2. (10 分)

(b) The maximum work that can be extracted from the turbine. (7 分)

2. (18 分)

An inventor has devised a piston/cylinder device in which one mole of an ideal gas is compressed isothermally but irreversibly at 145°C from 3 bar to 8 bar. The net effects of the process are claimed to be:

- The work required is 25% greater than the work of reversible, isothermal compression.
- The heat transferred from the gas during compression flows to a heat reservoir at 115°C.

Justify whether or not the claimed device is possible, and list required calculations.

3. (15 分)

A binary system is composed of species 1 and 2. At 35°C, the vapor pressure of pure species 1 is 120.2 kPa, and the vapor pressure of pure species 2 is 73.9 kPa. For a liquid composition of species 1 (x_1) at 0.389, total pressure (P) is 108.6 kPa.

(a) Determine whether or not the system is ideal ? (5 分)

(b) Estimate the vapor-phase composition and total pressure at 35°C for an equimolar liquid mixture for this binary system. (10 分)

Data:

Assume a one-parameter model is applied for the activity coefficients (γ) of the binary system,

$\ln \gamma_1 = 0.68 x_2^{\,2}$ and $\ln \gamma_2 = 0.68 x_1^{\,2}$.

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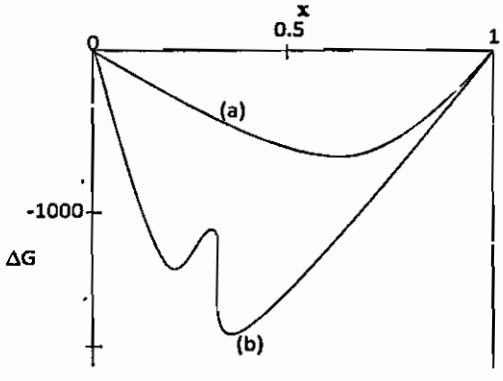
4. (20 分).

(a)What is Raoult's law ? (4 分) (b)Please show how to obtain it.(6 分) (c)If a binary system A and B conforms closely to Raoult's Law. Vapor pressures for pure species are given by the following equations:

$\ln P_A^{sat}/kPa = 14.3 - \frac{2945}{t/^\circ C + 220}$, $\ln P_B^{sat}/kPa = 14.2 - \frac{2970}{t/^\circ C + 210}$, prepare a graph showing P vs. x_1 (0, 0.2, 0.4, 0.6, 0.8, 1) and P vs. y_1 for a temperature of 80℃. (10 分)

5. (15 分)

(a)For thermodynamic property M, we can know nM = M(T, P, n_1,n_2, ..n_i...), please show us how to obtain M=$\sum_i x_i \overline{M_i}$ and $\sum_i x_i d\overline{M_i}$=0 at constant T and P. (5 分)(b)What is Gibbs energy change of mixing? (3 分)(c)Which curve may appear phase separation in the following figure? (3 分)(d)And explain why a phase separation happened?(4 分)



6. (15 分)

(a) Please write the general form of the first law for open, non-simple system. (3 分)(b) Please write the general form of the first law for close, a simple system. (Do not only write the equation and please explain the meaning for each item)(3 分)(c) An ideal gas is compressed from a initial 1 bar and 25℃ to a final state of 5 bar and 25℃ by three different mechanically reversible process (1) heating at constant volume followed by cooling at constant pressure (2) Adiabatic compression followed by cooling at constant volume. Please calculate the required work, heat transferred, and the changes in internal energy, enthalpy, and entropy of ideal gas for each process.(9 分)

1. For the parallel reactions

$$A + B \rightarrow D \qquad r_D = k_1 C_A^{\alpha_1} C_B^{\beta_1}$$
$$A + B \rightarrow U \qquad r_U = k_2 C_A^{\alpha_2} C_B^{\beta_2}$$

How to control the concentrations of A and B for the following four conditions: (1) $\alpha_1 < \alpha_2, \beta_1 < \beta_2$; (2) $\alpha_1 > \alpha_2, \beta_1 > \beta_2$; (3) $\alpha_1 < \alpha_2, \beta_1 > \beta_2$; (4) $\alpha_1 > \alpha_2, \beta_1 < \beta_2$ to make $S_{D/U}$ as large as possible (4%)? Select possible reactors and schemes from Figure 1 (a) ~ (i) that will maximize $S_{D/U}$ of above four conditions (9%).

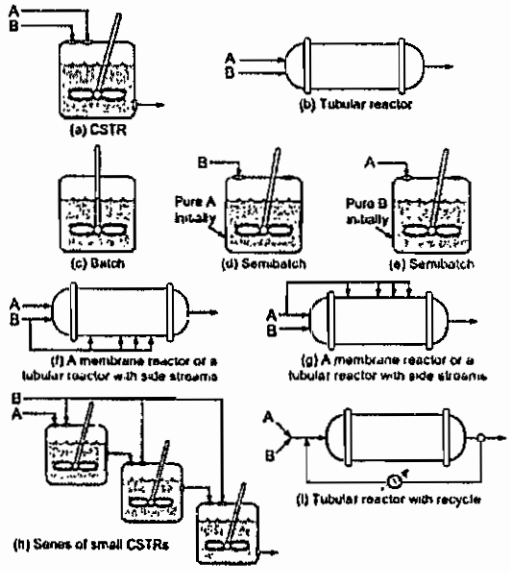


Figure 1. Various reactors and schemes for maximizing $S_{D/U}$.

2. The following reactions were carried out in a CSTR (or PFR).

$3A \rightarrow B + C \qquad -r_{1A} = k_{1A} C_A$

$2C + A \rightarrow 3D \qquad r_{2D} = k_{2D} C_C^2 C_A$

$4D + 3C \rightarrow 3E \qquad r_{3E} = k_{3E} C_D C_C$

(a) Please write down the mole balances and rate law equations of components A, C, and D when the reactions were carried out in a liquid phase CSTR. (6%)

(b) Please write down the mole balances and rate law equations of components A, B, C, D, and E when the reactions were carried out in a gas phase PFR. (6%)

3. The gas phase reaction A → B + C follows an elementary rate law and is to be carried out first in a PFR and then in a separate experiment in a CSTR. When pure A is fed to a 10 dm^3 PFR at 290 K and a volumetric flow rate of 5 dm^3/s , the conversion is 80 %. When a mixture of 50 % A and 50 % inert (I) is fed to a 10 dm^3 CSTR at 330 K and a volumetric flow rate of 5 dm^3/s , the conversion is also 80 %. What is the activation energy in cal/mol? (10%)

4. The reversible reaction of A to B,

$$A \Leftrightarrow 2B$$

is to be carried out at constant temperature. The feed consists of pure A at 340 K and 202.6 kPa (2 atm). The concentration equilibrium constant, K_c, at 340 K is 0.1 mol/dm^3 and the rate constant k_A is 0.5 min^{-1}. (15%)

(a) Derive an equation relating the X_e (equilibrium conversion of A), K_c, and C_{A0} in a constant-volume batch reactor.

(b) Derive an equation relating the X_e (equilibrium conversion of A), K_c, and C_{A0} in a flow reactor.

(c) Assuming the reaction is elementary, express the rate of reaction solely as a function of conversion for a flow system and for a batch system.

(d) Determine the CSTR volume necessary to achieve 70% of the equilibrium conversion of 49% for a molar feed rate of A of 2 mol/min.

5. The irreversible elementary liquid-phase reaction, A +B → 2C, reacts in an isothermal steady-state flow reactor. The change in volumetric flow rate can be negligible. The entering concentrations of A (C_{A0}) and B (C_{B0}) are 1.0 and 2,0 M, respectively ($C_{A0} = 1.0\,M$, $C_{B0} = 2.0\,M$), and the effluent concentration of A (C_{A1}) is 0.5 M ($C_{A1} = 0.5\,M$). Find the effluent concentration (C_{B1}) and the conversion (X_B) of B. (15%)

6. Use the below data with the entering molar flow rate $F_{A0} = 50$ kmol/hr to answer the following question

Conversion, X	0	0.1	0.2	0.4	0.6
$-r_A$ (kmol/m^3 · hr)	80	65	56	48	41

(a) Calculate the volume necessary to achieve 0.6 conversion in a CSTR (10%)

(b) Calculate the volume necessary to achieve 0.6 conversion in a PFR (10%)

7. The elementary gas-phase reaction, A → B + C, is carried out isothermally in a PFR with no pressure change. The entering molar flow rate F_{A0} is 3 mol/min, the entering concentration C_{A0} is 0.5 mol/L, and the rate constant k is 0.05 min^{-1}. Calculate the reactor volume and space time to achieve 80% conversion. (15%)

1. Calculate the reversible work done by a perfect gas when 50 g of iron (55.85 $g\,mol^{-1}$) reacts with hydrochloric acid in an open beaker at 298.15 K. (12 %)

$$Fe_{(s)} + 2\,HCl_{(aq)} \rightarrow FeCl_{2(aq)} + H_{2(g)}$$

2. Calculate the AgCl solubility in an ideal solution of the following reactions at 25℃ from standard potential data: (10 %)

$$Ag^{+}_{(aq)} + e^{-} \Rightarrow Ag_{(s)} \quad E^{o} = 0.80\ V$$

$$AgCl_{(s)} + e^{-} \Rightarrow Cl^{-}_{(aq)} + Ag_{(s)} \quad E^{o} = 0.22\ V$$

3. The following consecutive reactions are elementary:

$$A \xrightarrow{k_a} I \xrightarrow{k_b} P$$

If the initial concentration of A is $[A]_0$, and no I & P are present initially. Find the rate of formation of P by using the steady-state approximation. (16 %)

4. The vapour pressure of benzene is 53.3 kPa at 60.6℃, but it fell to 51.5 kPa when 19 g of an involatile organic compound was dissolved in 500 g of benzene (78.11 $g\,mol^{-1}$). We assume that the solution is ideal. Calculate the molar mass ($g\,mol^{-1}$) of the involatile organic compound. (12 %)

5. The constant-pressure heat capacity of a sample of a perfect gas was found to vary with temperature: $C_p/(\mathrm{J\,K^{-1}}) = 10 + 2(T/\mathrm{K})$. Calculate q, w, ΔU and ΔH when the temperature is increased from 100℃ to 200℃ at constant volume. (10%)

6. Calculate the change in the entropies of the system and the surroundings, and the total change in entropy, when the volume of a sample of argon gas of mass 20 g at 300 K and 2.0 bar increases from 1.0 $\mathrm{dm^3}$ to 5.0 $\mathrm{dm^3}$ in an isothermal irreversible expansion against $p_{ex} = 0$. The molecular weight of argon is 40 $\mathrm{g\,mol^{-1}}$. (12%)

7. A solution of polyurethane in dimethylformamide contains 3 $\mathrm{g\,L^{-1}}$. The equilibrium height of the column of solution (density 0.95 $\mathrm{g\,cm^{-3}}$) in the osmometer corrected for capillary rise is 4.2 cm at 20℃. What is the number average molar mass of the polyurethane, assuming the solution is ideal? (12%)

8. A reaction $2\mathrm{A} \rightarrow \mathrm{P}$ has a third-order rate law with $k_r = 7.6\times10^4\ \mathrm{dm^6\ mol^{-2}\ min^{-1}}$. (a) Derive the integrated rate low for the chemical equation. (b) How long does it take for the concentration of A to decrease from $5.6\times10^{-2}\ \mathrm{mol\,dm^{-3}}$ to $8.8\times10^{-4}\ \mathrm{mol\,dm^{-3}}$? (16%)

1. Which would you expect to be the stronger acid? Explain your reasoning in each instance.
   (a) CH_2ClCO_2H or $CHCl_2CO_2H$ (5%)
   (b) CCl_3CO_2H or $CHCl_2CO_2H$ (5%)

2. Define the following stereochemical terms:
   (a) Meso compound (5%)
   (b) Chiral center (5%)

3. Which would you expect to be the stronger nucleophile in a polar aprotic solvent?
   (a) $CH_3CO_2^-$ or CH_3O^- (5%)
   (b) H_2O or H_2S (5%)

4. Which product (or products) would you expect to obtain from each of the following reactions? In each part give the mechanism (S_N1, S_N2, E1, or E2) by which each product is formed and predict the relative amount of each product.

   (a) 3-Chloropentane $\xrightarrow[\text{MeOH, 50°C}]{\text{MeO}^-}$ (5%)

   (b) (S)-3-Bromo-3-methylhexane $\xrightarrow[\text{MeOH}]{\text{25°C}}$ (5%)

5. Outline a synthesis of propene from each of the following:
   (a) Propyl alcohol (5%)
   (b) 1,2-Dibromopropane (5%)

6. Write structural formulas for each of the following: 12%
   (a) 2-merthyl-2-propanol (b) m-fluoroaniline
   (c) allyl phenyl ketone (d) 3,3-dimethyl-1-butene
   (e) tert-butyl phenyl ether (f) 4-ethyl-2-methylhexane

7. Show how you might prepare 2-bromobutane from: 10%
   (a) 2-Butanol (b) 1-Butanol

8. What products would be formed from the reaction of isobutyl bromide under each of the following condition? 9%
   (a) OH^-, H_2O (b) CN^-, ethanol (c) MeONa, MeOH

9. Explain why cyclopentadiene is more acidic than 1.3-cyclohexadiene. 10%

10. Write major organic product would you expect to obtain when succinic anhydride reacts with each of the reagents: 9%
    (a) NH_3 (b) $CH_3CH_2CH_2OH$ (c) C_6H_6 and $AlCl_3$