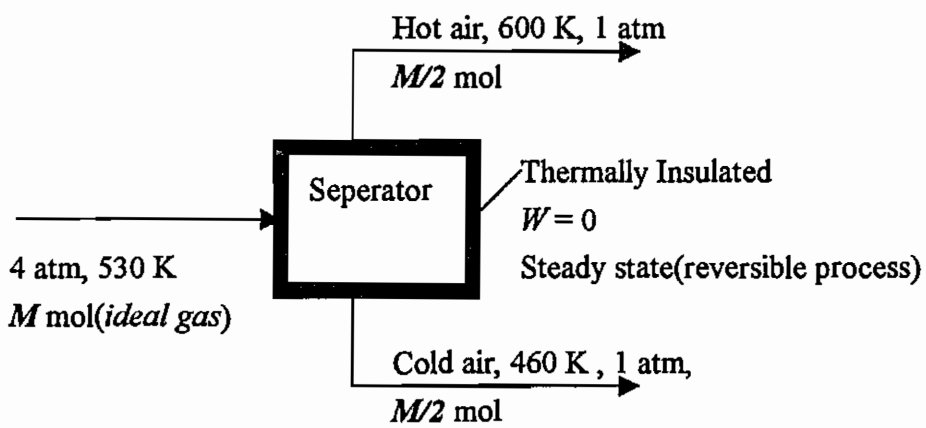
國立雲林科技大學
九十二學年度碩士班入學招生考試試題

系所：化工系
科目：化工熱力學

1. Calculate the work done on the ideal gas closed system consisting of 50.00 g of argon, if it is reversibly cooled at constant volume of 5.00 L from 298.15 K to 150.00 K, then reversibly expanded from 5.00 L to 10.00 L at a constant temperature of 200.0 K and then reversibly heated at a constant volume of 10.00 L from 150.0 K to 298.15 K. [15%]

2. Is the following process possible? Please make your judgement according to the $2^{nd}$ law of thermodynamics. [15%]




3. Calculate the entropy change for the following process: A sample containing 2,000 mol of helium gas originally at 298.15 K and 1.000 bar is cooled to its normal boiling temperature of 4 K, condensed to a liquid and then cooled further to 2 K, where it undergoes another phase transition to a second liquid form, called liquid helium II. This liquid phase is suddenly vaporized by a beam of laser light, and the helium is brought to a temperature of 298.15 K and a pressure of 0.500 bar. [10%]

4. The third law defines no new property but allows absolute values of the entropy to be determined. Please state the third law of thermodynamics from this aspect. Give the formula for calculating the absolute value of the entropy of a substance that is gaseous at the temperature $T_1$. [10%]

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5. (15%)

The activity coefficients ($\gamma$) of a binary A-B equilibrium system can be expressed as a function of species mole fraction (x).

$$\ln \gamma_A = 0.5\, x_B^2$$
$$\ln \gamma_B = 0.5\, x_A^2$$

The vapor pressures of A and B at 80°C are 900 mmHg and 600 mmHg, respectively. It is known that there is an azeotrope in the system at 80°C, calculate

(a) the azeotrope pressure (mmHg) ? (5%)

(b) the azeotrope mole fraction composition ? (10%)

Hint: ln 3 = 1.0986, ln 2 = 0.6931

6. (15%)

The behavior of a fluid system follows the truncated virial equation of state

$$\frac{P\underline{V}}{RT} = 1 + \frac{B(T)}{\underline{V}}$$

where *B(T)* is the second virial coefficient. If the fluid is to be thermodynamically stable, please obtain the constraint on *B(T)*. List all assumptions you may use.

7. (20%)

Pure nitrogen tetroxide ($N_2O_4$) is diluted with nitrogen and heated to 25 °C and 1 bar where the dissociation reaction (e.g., $N_2O_{4(g)} \leftrightarrow 2\, NO_{2(g)}$) can occur. The standard state Gibbs free energies of formation for $N_2O_{4(g)}$ and $NO_{2(g)}$ are 97.89 kJ/mole and 51.31 kJ/mole, respectively. If the initial mole fraction of $N_2O_4$-nitrogen mixture before dissociation begins is 0.20, calculate

(a) the chemical equilibrium constant ? (6%)

(b) the extent of the decomposition ? (6%)

(c) the mole fractions of $NO_2$ and $N_2O_4$ present at equilibrium ? (8%)

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系所：化工系
科目：化工動力學

1. Please explain the following terms:(20%)
   (A) elementary and nonelementary reaction
   (B) autocatalytic reaction
   (C) Arrhenius law
   (D) space velocity

2. A homogeneous gas reaction A $\rightarrow$ 3P has a reported rate at 500K

$$-r_A = 0.02C_A \quad [\text{mol/ (liter-sec)}]$$

Find the space-time needed for 80% conversion of a 50% A — 50% inert feed to a plug flow reactor operating 500 K and 5 atm ($C_{A0}$= 0.5 mol/liter) (20%)

3. 10 gram moles of P are produced hourly from a feed consisting of a saturated solution of A ($C_{A0}$= 0.1 mol/liter) in a mixed flow reactor. The reaction is

$$A \rightarrow P \qquad r_R = (0.2\text{hr}^{-1})\, C_A$$

Cost of reactant at $C_{A0}$= 0.1 mol/liter is \$ 5 / mol A

Cost of reactor including installation, auxiliary equipment, instrumentation, Overhead, labor, depreciation, etc, is \$ 0.1 / hr-liter. What is reactor size、feed rate and conversion should be used for optimum operations? (20%)

4. Gas mixture of 72% of air and 28% of A is charged to a flow reactor that A is oxidized. The reaction is a gas reaction.

$$2A + O_2 \rightarrow 2AO$$

(A) Express the flow rate (moles/ sec) as function of conversion ($X_A$) for species of A, $O_2$, AO and $N_2$. (5%)

(B) $-r_A = k\, C_A C_B$ Where k= 200 $dm^3$/ (mol ·sec) and B = $O_2$, calculate the concentration of A, $O_2$, AO and $N_2$ when conversion $X_A$ = 0.5 at the total pressure is 1485 kPa and 227 $^0$C. Constant pressure and constant temperature are assumed. (10%)

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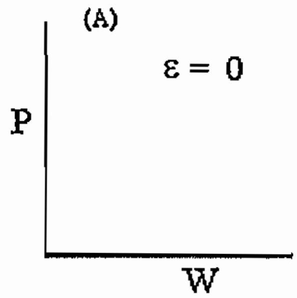
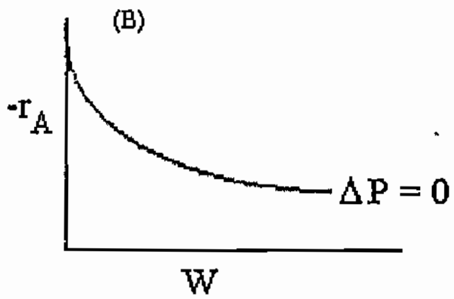
（C） Draw the $(1/-r_A)$ vs. $X_A$ curve for $X_A$ = 0.0, 0.25, 0.5 and 0.75. (5%)

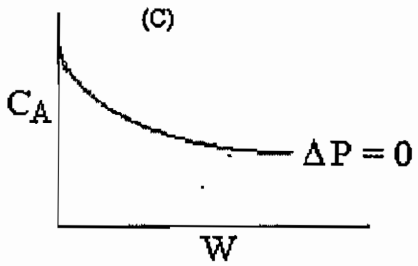
5. Differential form of Ergun equation for the pressure drop in packed beds is expressed:

$$dP/dW = (-\alpha/2)\,(T/T_0)\,[P_0/(P/P_0)]\,(1+\varepsilon X)$$

where, $\alpha$ is constant and $\alpha > 0$; $T_0$ and $P_0$ are inlet temperature and pressure; $\varepsilon$ is defined as (change in total number of moles for complete conversion / total number of moles fed to reactor); W is the weight of catalyst. For gas-phase reaction, the species are catalyzed and flow through in a packed bed reactor. Please answer the followed questions:
(a) If $\varepsilon = 0$, isothermal operation and with initial condition of $P = P_0$ at $W = 0$, please derive the equation $(P/P_0)$ as function of W and draw the qualitative curve on Fig. (A) (10 %)
(b) With the result of (a), for gas reaction ($A \rightarrow B$; $-r_A = k\,C_A^{\,2}$) and conditions of (a); please draw the qualitative curves of $\Delta P > 0$ on Figs. (B) and (C), and explain the reasons. (10 %)



1、(10%) For a turbulent fluid flows in the z direction of a horizontal circular tube (see Figure 1), the velocity at a distance y from the tube wall, $v_z(y)$, to the centerline velocity, $v_c$, is:

$$\frac{v_z(y)}{v_c} = \left(\frac{y}{R}\right)^{1/7}$$

where R is the radius of circular tube. Calculate average velocity of this turbulent flow = ?   (in terms of $v_c$)

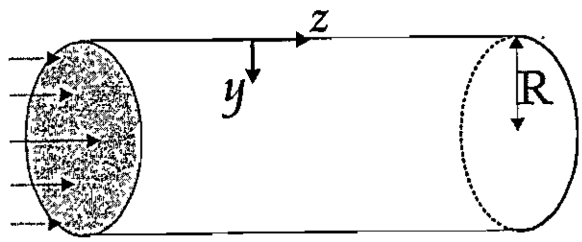



Figure 1

2、 For a incompressible creeping flow over a sphere (with a radius R, see Figure 2), fluid approaches from below with velocity $v_\infty$

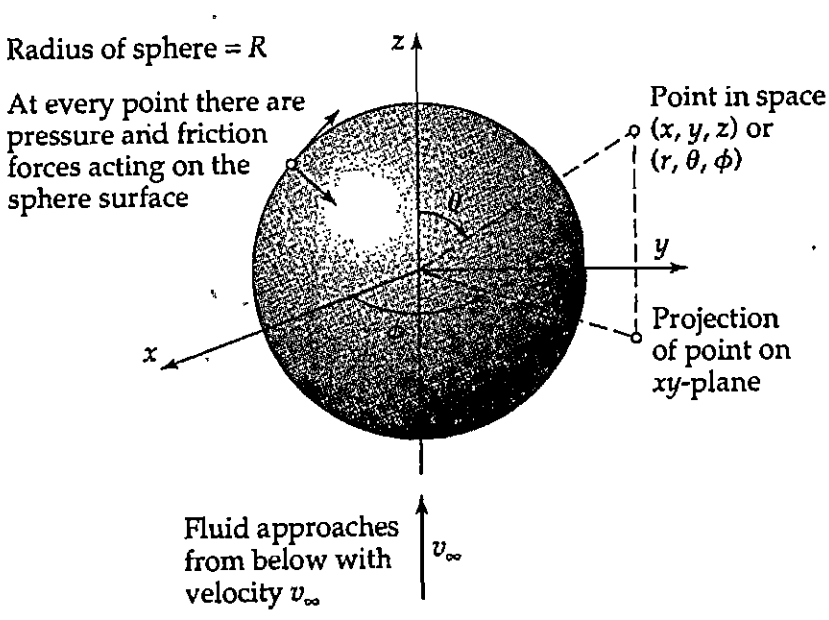



Figure 2

If the equation of motion for a steady, creeping flow is

$$\left[\frac{\partial^2}{\partial r^2} + \frac{\sin\theta}{r^2}\frac{\partial}{\partial\theta}\left(\frac{1}{\sin\theta}\frac{\partial}{\partial\theta}\right)\right]^2 \psi = 0$$ , where $\psi$ is the stream function.

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and if the equation of continuity for spherical coordinates is

$$\frac{\partial \rho}{\partial t}+\frac{1}{r^2}\frac{\partial(\rho r^2 v_r)}{\partial r}+\frac{1}{r\sin\theta}\frac{\partial(\rho v_\theta \sin\theta)}{\partial \theta}+\frac{1}{r\sin\theta}\frac{\partial(\rho v_\phi)}{\partial \phi}=0.$$

and the velocity in r-direction is $v_r=-\dfrac{1}{r^2\sin\theta}\dfrac{\partial\psi}{\partial\theta}$

(5%) (1)If the first boundary condition is r =R, $v_r$=0, the second boundary condition is r =R, $v_\theta=0$, derive the third boundary condition for the equation of motion. ( in terms of $\psi(v_\infty, r, \theta)$)

(5%) (2)If $v_\phi=0$, derive the velocity in $\theta$-direction, $v_\theta=$ ? (in terms of $\psi$, $r$ and $\theta$)

(10%) (3)If the solution of equation of motion is $\psi(r,\theta)=f(r)\sin^2\theta$,

and $f(r)=\left(-\dfrac{v_\infty R^3}{4}\dfrac{1}{r}+\dfrac{3v_\infty R}{4}r-\dfrac{v_\infty r^2}{2}\right)$, find $v_r$ *and* $v_\theta$.

3、 A hollow sphere of outside radius $r_2$ is covered with thermal insulation having an outside radius of $r_3$. The temperature of the outer surface of the sphere, $T_2$, and the temperature of the surrounding air, $T_0$ are fixed. The radius of insulation associated with the maximum energy transfer for a hollow sphere is called the critical radius. Assume the thermal conductivity is k and the convective heat transfer coefficient is h.

(15%)(1) Derive the critical radius ($r_{3\,critical}$) for a hollow sphere.

(5%) (2) If k=0. 0962 W/(m · K) and h=34 W/($m^2$ · K), find critical radius ($r_{3\,critical}$)= ? m

4. A tube 1 cm in inside diameter that is 20 cm long is filled with $CO_2$ and $H_2$ at 2 atm total pressure at 0℃. The diffusion coefficient of the $CO_2$-$H_2$ system under these conditions is $0.275 cm^2s^{-1}$. If the partial pressure of $CO_2$ is 1.5 atm at one end and 0.5 atm at the other end, find the rate of diffusion for (a) steady-state equimolar counter diffusion (15%) and (b) steady-state diffusion of $CO_2$ through stagnant $H_2$. (15%)

5. Oil is to be extracted from meal by means of benzene using a continuous countercurrent extractor. The unit is to treat 1000 kg of meal (based on completely exhausted solid) per hour. The untreated meal contains 400 kg of oil and 25 kg of benzene. The fresh solvent mixture contains 10 kg of oil and 655 kg of benzene. The exhausted solids are to contain 60 kg of unextracted oil. Experiments carried out under conditions identical with those of the projected battery show that the solution retained depends on the concentration of the solution, as shown in Table 1. Find (a) the concentration of the strong solution, or extract ; (5%) (b) the concentration of the solution adhering to the extracted solids ; (5%) (c) the mass of solution leaving with the extracted meal ; (5%) (d) the mass of extract. (5%) All quantities are given on an hourly basis.

Table 1

| concentration, kg oil/kg solution | solution retained, kg/kg solid | concentration, kg oil/kg solution | solution retained, kg/kg solid |
|---|---|---|---|
| 0.0 | 0.500 | 0.4 | 0.550 |
| 0.1 | 0.505 | 0.5 | 0.571 |
| 0.2 | 0.515 | 0.6 | 0.595 |
| 0.3 | 0.530 | 0.7 | 0.620 |