國　立　清　華　大　學　命　題　紙

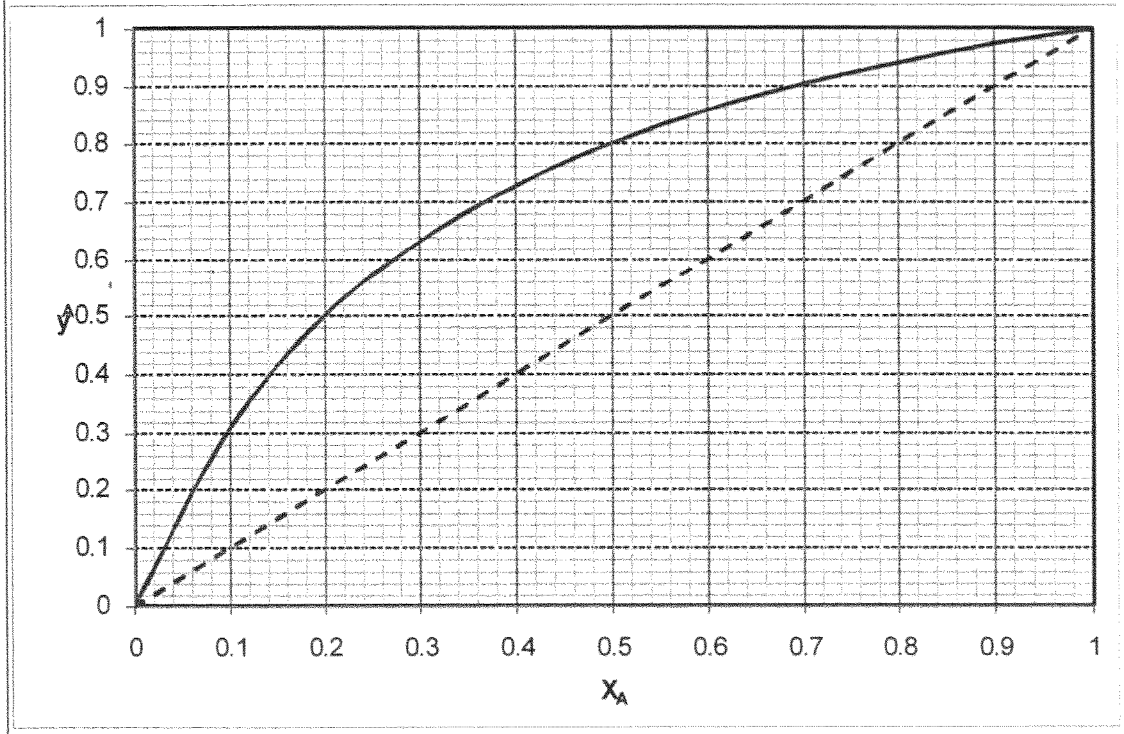
98 學年度__化學工程學__系（所）____________組碩士班入學考試

科目__輸送現象及單元操作_ 科目代碼__0701__共_4_頁第_1_頁 *請在【答案卷卡】內作答

1. (I) The below is a y-x diagram of a binary liquid mixture containing a component A and a component B. A mixture of 60 mol% A is separated into a stream containing 90mol% A, and another stream containing 10 mol% A.

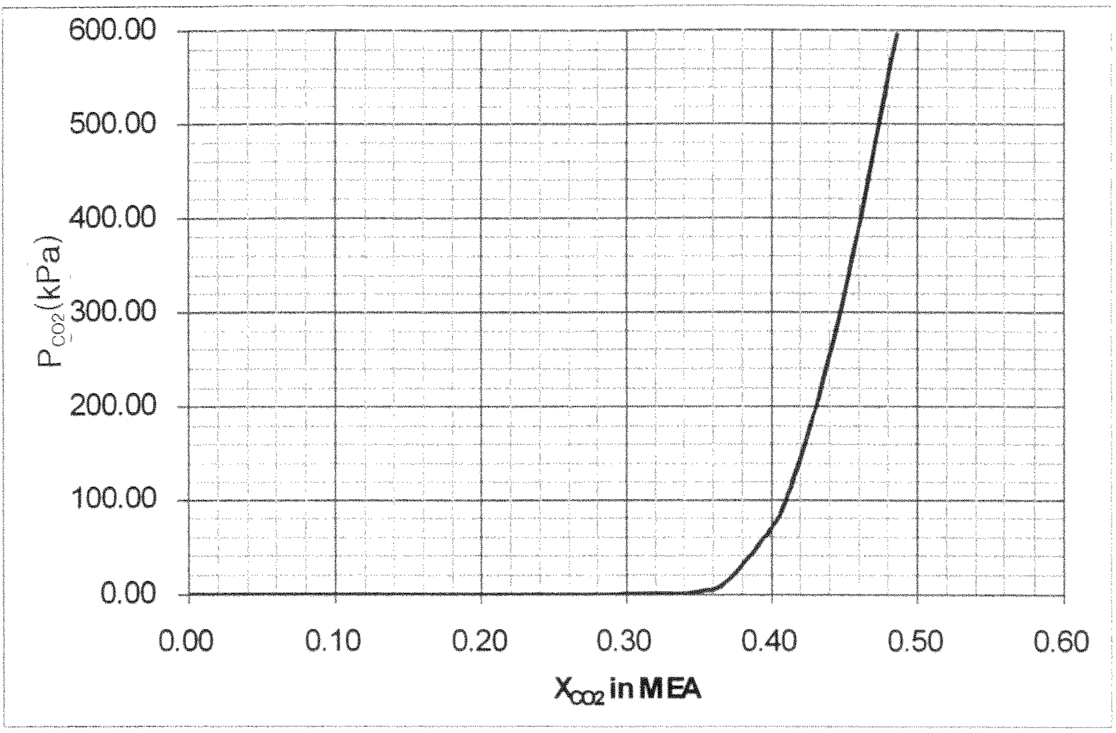
- What is the minimum number of stage required if the feed is a saturated liquid? (2%)
- What is the minimum number of stage required if the feed is a saturated vapor? (2%)
- What is the minimum reflux ratio required if the feed is a saturated liquid? (3%)
- What is the minimum reflux ratio required if the feed is a saturated vapor? (3%)

Illustrate your answer with sketches.



(II) The below is the absorption equilibrium curve of CO_2 in a chemical solvent MEA. Suppose the solvent is used to remove nearly all CO_2 from a feed air stream at 1 MPa with an inlet CO_2 partial pressure of 400 kPa, what is the minimum amount of solvent per mole of feed air stream required if

- fresh solvent is available? (5%)
- only recycled solvent containing 20 mol% of CO_2 is available? (5%)



2. (I) Answer the following questions regarding mass transport:

(a) Define the Schmidt, Lewis, and Sherwood numbers. State their physical meanings. (5%)

(b) The following equation is useful for interrelating expressions of fluxes in mass units and those in molar units in the two-component systems:

$$\frac{\mathbf{j}_A}{\rho w_A w_B} = \frac{\mathbf{J}_A{}^*}{c x_A x_B}$$

where ρ is the total mass concentration, c is the total molar concentration, w_i (i = A or B) is the mass fraction, x_i (i = A or B) is the molar fraction, $\mathbf{j}_A$ is the molecular mass flux and $\mathbf{J}_A^*$ is the molecular molar flux. Verify the correctness of this relation. (5%)

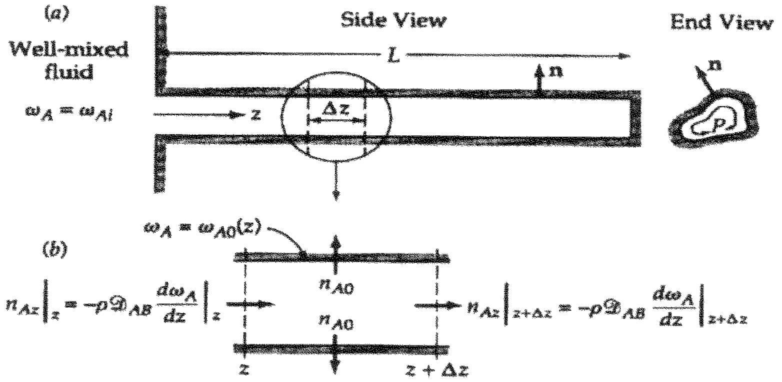
(II) A slender cylindrical pore of length L, cross-sectional area S, and perimeter P, is in contact at its open end with a large body of well-mixed fluid consisting of species A and B (see the figure below). Species A, a minor constituent of this fluid, diffuses into the pore along z direction and reacts with the walls of the pore. The rate of this reaction may be expressed as $(\mathbf{n} \bullet \mathbf{n}_A)\big|_{surface} = f(w_{A0})$; that is, at the wall the mass flux normal to the surface is some function of the mass fraction, w_{A0}, of A in the fluid adjacent to the solid surface. The mass fraction w_{A0} depends on z. Because A is present in low concentration, the fluid temperature and density may be considered constant and the diffusivity may also be regarded as a constant. Moreover, because the pore is long compared to its lateral dimension, concentration gradients in the lateral direction may be neglected.

(a) Show by means of a shell balance that at steady state, (4%)

$$-\frac{dn_{Az}}{dz}=\frac{P}{S}f(w_{A0})$$

(b) Obtain the concentration profile of A for the special case that $f(w_{A0}) = k_1'' w_{A0}$. To obtain a boundary condition at $z = L$, neglect the rate of reaction on the closed end of the cylindrical pore. (4%)

(c) Develop an expression for the total rate W_A of disappearance of A in the cylindrical pore. (2%)



3.Professor Lee and his graduate student Mr. Lin are working on a heat transfer project. They want to study the temperature variations of a hot iron sphere with diameter D. They assume that the temperature of the sphere is uniform spatially but varies with time as the sphere exchanges heat by convection with its surroundings. The temperature of the sphere is To initially and the surrounding temperature is fixed at Ta. The density and heat capacity of the sphere are constant. Professor Lee predicts that the following equation is valid:

$$X = \exp(-Y) \qquad (1)$$

Here X and Y are dimensionless temperature and time, respectively.

(I) If you were Mr. Lin, could you prove that Professor Lee is correct by properly defining X and Y? (8%)

(II) Mr. Lin tries to evaluate a convective heat transfer coefficient h that may be needed in Eq.(1) above. Professor Lee suggests that if Mr. Lin studies the steady heat transfer from the surface of the iron sphere to the surrounding air strictly through conduction in the radial direction to infinity (mathematically speaking), he will find the corresponding Nusselt number Nu is a constant. Nu is defined as:

$$Nu = hD/Ka$$

Here Ka is the thermal conductivity of air. Then he can determine h.

Professor Lee claims that Nu should be less than 4, can you find the lowest value of Nu?(8%)

(III) The weather is hot and humid, so Mr. Lin opens the window to enjoy the gentle breeze that makes the experimental site more comfortable, then he finds Nu is around 10, why?(4%)

4. A layer of insulation with a thermal conductivity of k is installed around the outside of a cylinder, as shown below, whose radius r_1 is fixed with a length of L. The cylinder has a high thermal conductivity and the inner temperature T_1 at point r_1 outside the cylinder is fixed. The outer surface of the insulation at T_2 is exposed to an environment at T_0 where convective heat transfer occurs. It is not obvious if adding more insulation will decrease or increase the heat-transfer rate, q.

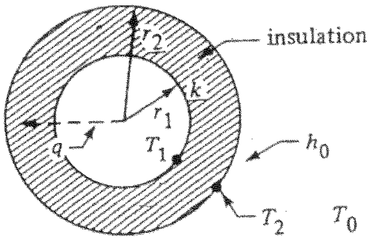
(a) We need to determine the effect of the thickness of insulation on q. Please derive the critical radius, $(r_2)_{cr}$, when the hear transfer rate is a maximum. (8%)

(b) An electric wire having a diameter of 1.5 mm and covered with a plastic insulation (thickness = 2.5 mm) is exposed to air at 300 K and $h_0 = 20$ W/m^2 · K. The insulation has a k of 0.4 W/m · K. It is assumed that the wire surface temperature is constant at 400 K and is not affected by the covering.

(i) Calculate the value of the critical radius, $(r_2)_{cr}$. (2%)

(ii) Calculate the heat loss per meter of wire length with no insulation. (5%)

(iii) Repeat (ii) for the insulation present. (5%)



5. Short questions: (5% each)

(a) What are the three physical quantities whose transport phenomena are studied in the course of "Transport Phenomena"? Why are these three topics put together in the course for chemical engineering students? (3+2%)

(b) What are the SI units of Re, viscosity, kinematic viscosity, friction factor, and dissipation function? (5%)

(c) When the distribution of a certain physical quantity, c, reaches a steady state, which of the following time derivatives become zero, partial time derivative, total time derivative, and substantial time derivative? Explain. (3+2%)

(d) Arrange the following three flow disturbances in the order of increasing e_v (friction loss factor): 90° elbow, 45° elbow, and orifice. Explain. (3+2%)