八十八學年度 化學工程學 系（所） 組碩士班研究生招生考試

科目 輸送現象及單元操作 科號2401 共3 頁第1 頁 *請在試卷【答案卷】內作答

Problem 1 (20%)

Short questions:

(a) A steel sphere of radius 0.25 cm falls with a speed of $8x10^{-3}$ m/s in a Newtonian liquid when its terminal velocity has been reached. What would be the terminal velocity if the radius of the steel sphere were 0.125 cm? Assume creeping flows. (6%)

(b) Can one use the Navier-Stokes equation to describe the flow behavior of polystyrene melt? Why? (4%)

(c) Put the following four fluids in an order according to the magnitude of viscosity: CO_2(20C, 1 atm), CO_2(100C, 1 atm), H_2O(10C), H_2O(80C). Explain. (6%)

(d) For pipe flows, which of the following two flow conditions gives more uniform cross-sectional velocity distribution: laminar flow or turbulent flow? Explain. (4%)

Problem 2 (20%)

This is a problem about friction factor and its relation to Reynolds number. Consider the steady state flow of an incompressible fluid in one of the two systems: (a) the fluid flows inside a pipe with a uniform cross section area; (b) the fluid flows around a submerged sphere. The friction factor is defined as:

$$f = F_k/(A\,K)$$

where F_k is the drag force exerted on the solid surface, A is a characteristic surface area and K is a characteristic kinetic energy per unit volume of the fluid. Under the conditions of small Reynolds number:

(a) Derive the relation between friction factor and *Re* for flow inside a pipe. (8 points)

(b) Derive the relation between friction factor and *Re* for flow around a submerged sphere. (8 points)

(c) It is known that the friction factor defined by Darcy is four times that by Fanning, i.e., $f_D = 4\,f_F$. What is the difference between these two definitions? (4 points)

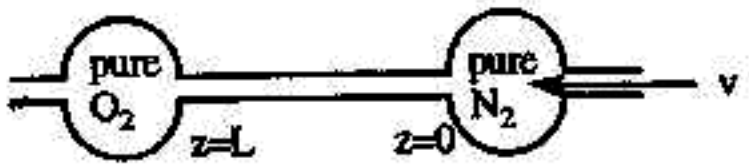
Problem 3 (20%)

Prove that it is possible to add a layer of material to a pipe of outside radius r and length L to increase the heat lost rate from the pipe. The temperature of the outer surface of the pipe is T and that of the surrounding air is T_a.

Problem 4 (20%)

(a) Two gases are initially separated into two bulbs connected by a narrow diameter capillary. Pure N_2 then flows from right to left, as shown below. Assume that the volumes at two ends ($z = 0$ and $z = L$) are so large that each remains nearly pure. Derive the concentration distribution of N_2 along the capillary. What would the equation of concentration distribution be reduced to in the limit of very small value of vL/D_{AB} (D_{AB} = diffusion coefficient)?

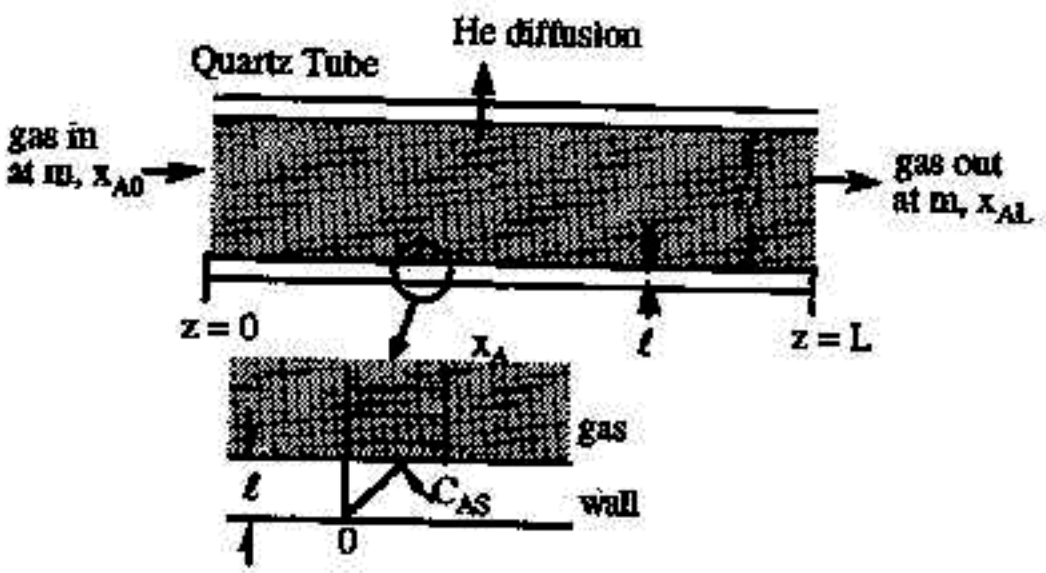
(10%)

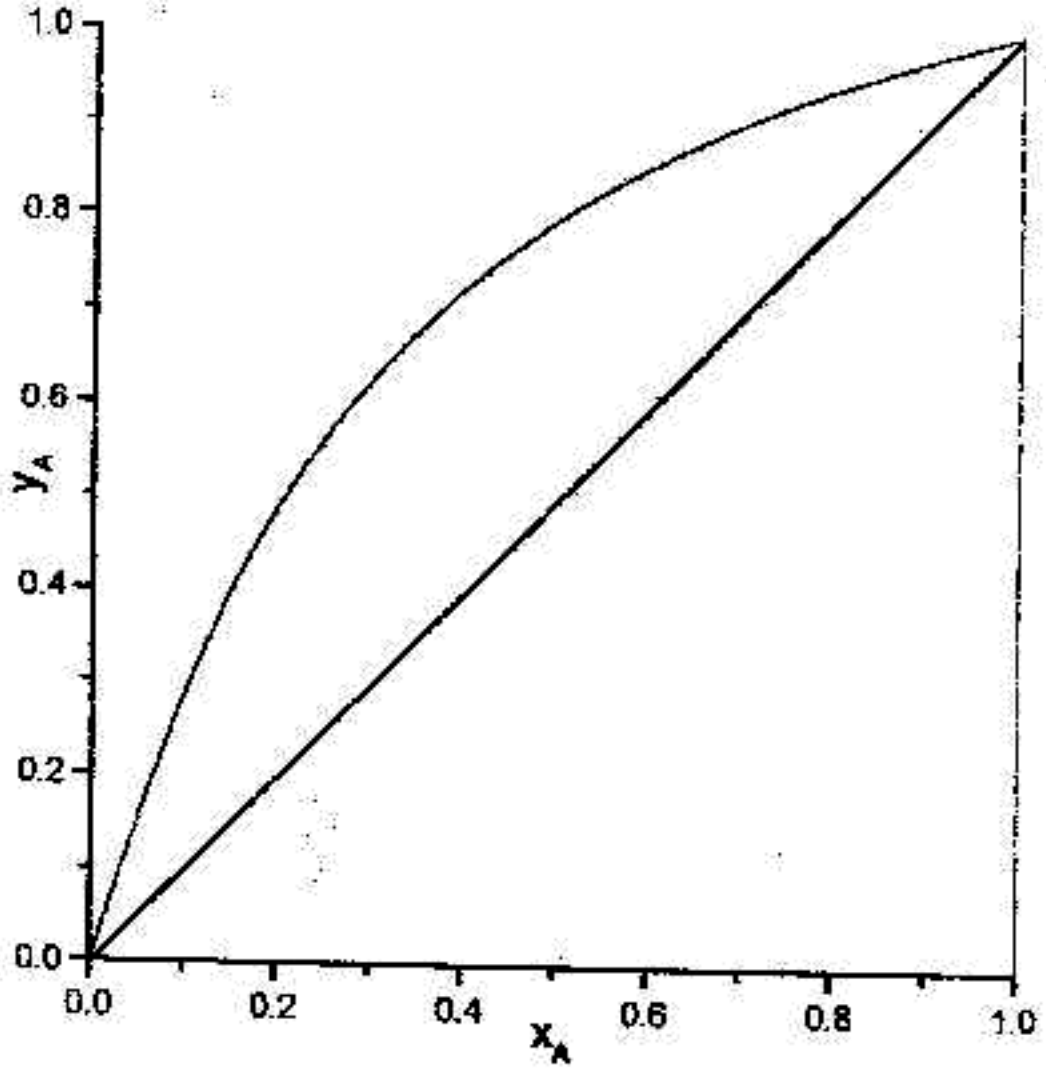


(b) A methane-helium gas mixture with a low helium concentration x_{A0} flows through a long quartz tube, as shown below. The tube has a length L, inner diameter D, and wall thickness $\ell(<< D)$. Helium can diffuse through quartz but methane cannot. Because of the low helium concentration, the molar flow rate, m, of the gas mixture remains essentially constant throughout the tube. The flow rate is fast enough that mass transfer in the axial direction is dominated by convection. Furthermore, since the diffusion coefficient is much smaller in the wall than in the gas, the radial composition gradient is negligible as compared to that in the wall. Determine the helium concentration, x_{AL}, at the tube exit and the rate of helium loss by diffusion at steady state. The concentration of helium at the solid/gas interface is

(10%)

$$c_{AS} = K_x x_A$$





Problem 5 (20%)

The equilibrium *y-x* diagram of a binary system A and B is given in the above figure.

(a) Determine the relative volatility of the system at $x_A = 0.5$. (4%)

(b) If a **saturated liquid feed** containing 30 mol% of A is separated into a distillate that recovers 90% of A in the feed and a bottom that recovers 80% of B in the feed, what are the mole fractions of the distillate and the bottom. (4%)

(c) Determine the minimum number of stage required for the separation. (4%)

(d) Determine the minimum boilup ratio required for the separation. (4%)

(e) If the latent heat of A and B are ΔH_A and ΔH_B , respectively, estimate the minimum energy required in the reboiler. (4%)

Write down the equations if you are unable to calculate numerical results. Sketch graphical solution on your answer sheet.