國立臺北科技大學 102 學年度碩士班招生考試

系所組別：3510 化學工程研究所甲組

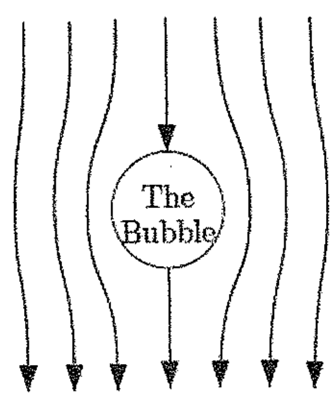
第一節　單元操作與輸送現象　試題

注意事項：

1. 本試題共五題，配分共 100 分。
2. 請標明大題、子題編號作答，不必抄題。
3. 全部答案均須在答案卷之答案欄內作答，否則不予計分。

1. Alcohol solution containing 16.67 wt % of ethanol flows at a fixed rate of 10 kg/min into a 2000-liter tank, initially filled with 500-liter fresh water. The density of the incoming alcohol solution is 0.97 kg/L. The solution in tank, kept uniform by stirring, flows out at a fixed rate of 5 kg/min. (a) Derive an equation of mass balance relating the outlet withdrawal concentration of solution as a function of time. Also, (b) how much weights of solution will there be in the tank at the end of 2 h? and (c) calculate its concentration of ethanol. (d) What is the upper limit for the number of kilograms of ethanol in the tank if the process continues?　(a 配分 10 分，b, d 各配分 4 分，c 配分 2 分，共計 20 分)

2. Float glass is made by floating molten glass on top of molten tin. Entrapped bubbles are a major problem in making float glass with a very flat surface and uniform thickness. The method of removing bubbles out of molten glass by flotation is explained schematically as follows. The bubble is floating up, and in its frame of reference the liquid is flowing down



(a) Derive a mathematical expression for terminal velocity υ_t of spherical bubbles rising through a liquid in Stokes flow. Assume the drag force for a floating bubble conforms to the modified Stokes law, which may be written below:

$$F_D = 3\pi\mu_f \upsilon D_p \left(\frac{1 + \dfrac{2\mu_f}{3\mu_p}}{1 + \dfrac{\mu_f}{\mu_p}} \right)$$

Given the glass with viscosity $\mu_f = 10$ Pa·s and density $\rho_f = 2500$ kg/m^3, it measures 0.007 m thick in a container, and the entrapped gas bubble has very small viscosity μ_p as compared with μ_f. (b) Balance drag and buoyancy forces to determine the diameter D_p of the largest bubble remaining in a container of molten glass after a certain time of floating, for instance, 1.5 minutes. (c) How much time does it take to float while the size of allowable largest bubble changes from (b) to one fourth? $D_p' / D_p = 0.25$. (d) Verify the values of Reynolds number and drag coefficient whether Stokes flow still applies for both cases (b) and (c)?　(a, b 各配分 5 分，c 配分 2 分，d 配分 4 分，共計 16 分)

3. A hydrocarbon oil at 307 K enters inside a copper pipe with an inside diameter of 0.025 m and a length of 15.0 m with a flow rate of 136 kg/hr. The inside pipe surface is assumed constant at 373 K since steam is condensing outside the pipe wall and has a very large heat-transfer coefficient, h_o. (a) Predict the heat-transfer coefficient h_i, and (b) the oil outlet temperature T_L. The properties of oil to be used are as follows:

T, K	ρ, kg/m^3	C_p, J/kg·K	k, W/m·K	μ, Pa·s
300	910	1840	0.133	0.0414
310	897	1920	0.131	0.0228
340	870	2000	0.130	0.00789
370	865	2130	0.128	0.00372

(a 配分 12 分，b 配分 8 分，共計 20 分)

(A) Convective heat-transfer correlations in tubular laminar flow

$$\mathrm{Nu} = \frac{hD}{k} = 1.86\left(\mathrm{Re}\,\mathrm{Pr}\frac{D}{L}\right)^{1/3}\left(\frac{\mu_b}{\mu_w}\right)^{0.14}; \quad \mathrm{Re} < 2100$$

(B) In transition region

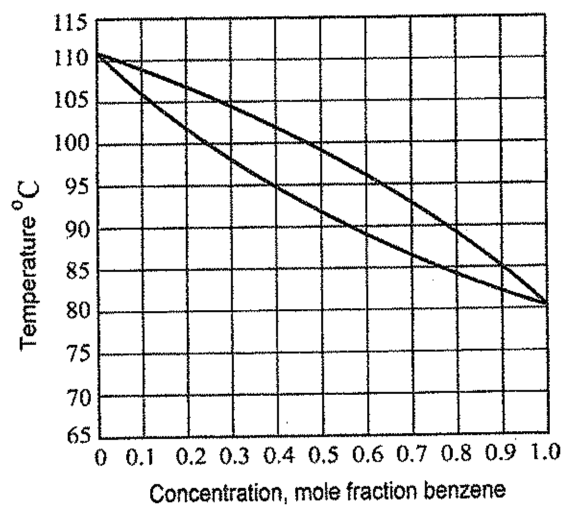
$$\mathrm{Nu} = \frac{hD}{k} = 1.62\left(\mathrm{Re}\,\mathrm{Pr}\frac{D}{L}\right)^{1/3}\left(\frac{\mu_b}{\mu_w}\right)^{0.14}; \quad 2100 < \mathrm{Re} < 6000$$

注意：背面尚有試題

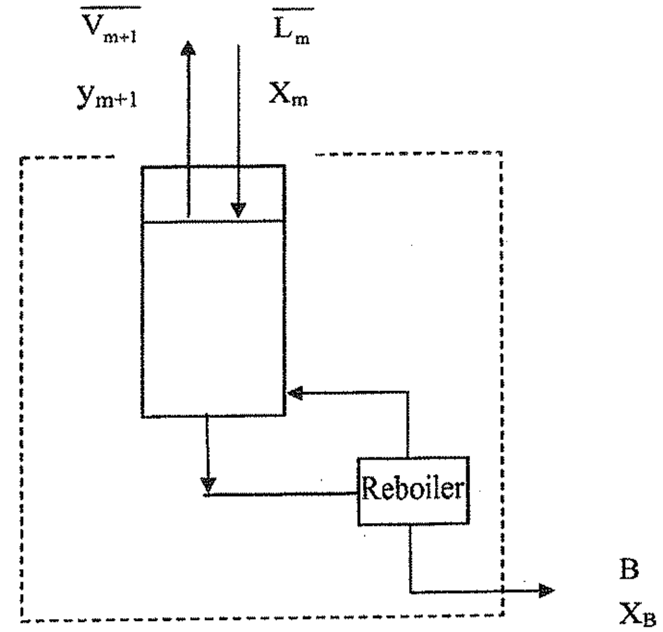
(C) In turbulent flow

$$Nu = \frac{hD}{k} = 0.023 Re^{0.8} Pr^{1/3} \left(\frac{\mu_b}{\mu_w} \right)^{0.14} ; \quad Re > 6000$$

4. A continuous fractionating distillation column is to be designed at 1.0 atm to separate 216 kg mol/h of a mixture of 60 mol% benzene (M_A= 78) and 40 mol% toluene (M_B= 92) into an overhead product containing 95 mol% benzene and a bottom product containing 95 mol% toluene, respectively. The feed is liquid at the boiling temperature, and the q-line has an infinite slope. Assuming the reflux is a saturated liquid and a reflux ratio of R_D = 2.5 mol to 1 mol of overhead product is to be used. Vapor-liquid equilibrium data of benzene-toluene binary mixture at 1 atm to be used are given below: x and y in mole fraction benzene in liquid and vapor phases, respectively.



(a) What is the average relative volatility of benzene to toluene α_{AB} between 90~100°C? (b) Compute the mole rates of overhead product and bottom product per hour? (c) If steam at 20 psig is used for reboiler heating, the molar latent heats of benzene, toluene and steam are 7360, 7960 and 9396 cal/mol, respectively. How much steam is required in kilograms per hour, neglecting heat loss? (d) If the bottom product from the reboiler is to be elevated 10 m high to a second distillation column unit without cooling the toluene solution before it enters the pump. The pressure in the reboiler of the first distillation unit is 1.1 atm and the pressure in the second unit is atmospheric. The friction loss in the overall suction and discharge line is 40 kPa; and the velocity of toluene solution in the pump discharge line is 2.5 m/s. The density of toluene solution is 566 kg/m^3. Calculate the brake horsepower required to drive the pump with an efficiency of 60%. (1 BHP = 745.7 W)
(a, c 各配分 5 分，b, d 各配分 6 分，共計 22 分)



5. A gas containing 3.0 mole percent of acetone is passed through a packed tower with a diameter of 0.4 m to remove 90% of acetone by absorption in water. The absorber will operate at 25°C and 1 atm, assuming the aqueous acetone solution follows Henry's law: y_e = 1.2 x in mole fraction. The gas and liquid flow rates are to be 20 kg mol/h and 100 kg mol/h, and mass-transfer coefficients are given below:

$$k_y a = 0.0378 \text{ kg mol/s} \cdot \text{m}^3 \cdot \text{unit mol fraction.}$$
$$k_x a = 0.0616 \text{ kg mol/s} \cdot \text{m}^3 \cdot \text{unit mol fraction.}$$

(a) Based on the two-resistance theory, find the overall mass-transfer coefficient $K_y a$ and the percent of the total resistance in the gas phase, assuming isothermal operation and neglecting changes in gas and liquid flow rates. (b) Calculate the height of a transfer unit H_{oy}, the number of transfer units N_{oy}, and the total tower height Z_T. (c) If using the same flow rates under the conditions of part (a), re-calculate N_{oy} for operation at 2 atm and at 4 atm. (d) What is the effect of pressure on H_{oy}?
(a, c 各配分 5 分，b 配分 9 分，d 配分 3 分，共計 22 分)