國立清華大學 100 學年度碩士班入學考試試題

系所班組別：化學工程學系

考試科目（代碼）：輸送現象及單元操作(0901)

　　*請在【答案卷　】作答

Problem1(20%) An experimental setup for curtain coating is displayed in the figure. A Newtonian liquid with viscosity M is coated on a substrate that is moving with a constant speed V horizontally. The coating thickness is H. The rectangular tank that delivers the coating solution is closed with gas pressure Pa above the liquid level. Some relevant parameters are given in the figure. W is the width of the slot gap that controls the coating flow. There may exist two vortices in the tank as shown in the figure. The input volumetric flow rate into the tank is Q.

(I) Which of the following statement(s) is(are) correct? Please write down the number(s) of the correct statement(s), if you miss any of the correct statement, you will not get any points.(10%)

(1) When vortices appear, the flow in the tank becomes turbulent.

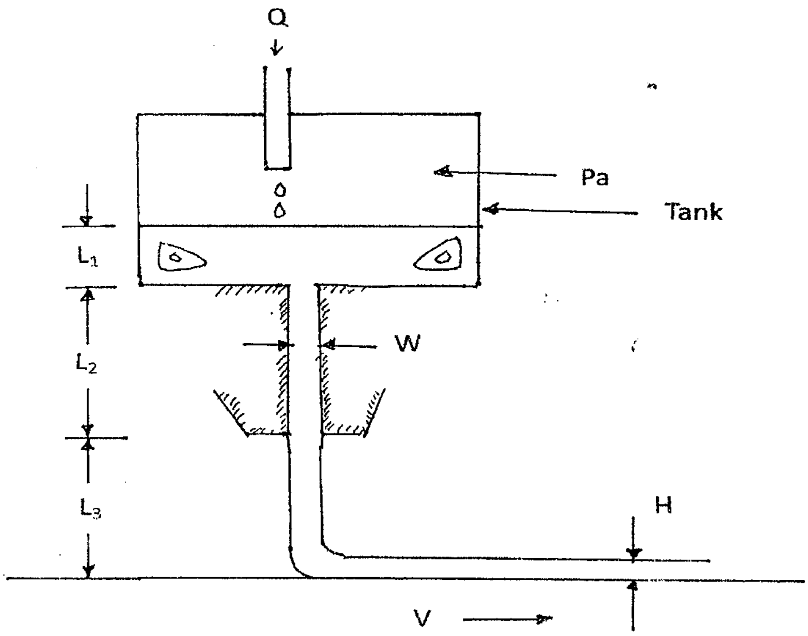
(2) Both of the vortices are rotating in counter-clockwise direction.

(3) When the coating speed V is too high, air bubbles may be trapped into the coating solution, increasing L_3 may postpone this phenomenon.

(4) If the input volumetric flow rate Q is steady and fixed, the coating thickness H is fixed, too.

(5) There exists a minimum slot gap Wm, below which coating is not possible.

(II) Assuming one-dimensional and steady flow exists in the system; derive H as a function of other parameters. List your assumptions.(10%)



Problem2(20%)

(a) Write down the correct physical quantity (involved in energy transport) with the SI unit of

(i) [m^2s^{-1}] (2%)

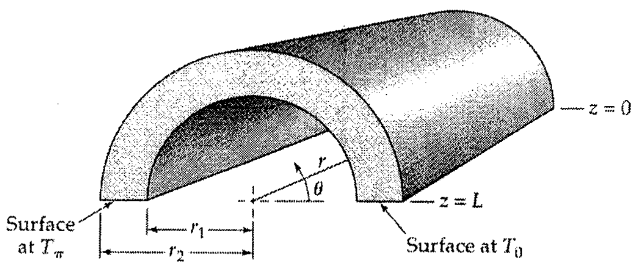
(ii) [$Jm^{-1}s^{-1}K^{-1}$] (2%)

(iii) [$Jm^{-2}s^{-1}K^{-1}$] (2%)

(b) What are the important dimensionless groups governing the Nusselt number in forced convection? (2%)

(c) What are the important dimensionless groups governing the Nusselt number in natural (free) convection? (2%)

(d) The curved surfaces and the end surfaces (both shaded in the figure shown below) of the solid in the shape of a half-cylindrical shell are insulated. The surface θ =0, of area $(r_2-r_1)L$, is maintained at temperature T_0, and the surface at $\theta = \pi$, also of area $(r_2-r_1)L$, is kept at temperature T_π. The thermal conductivity of the solid varies linearly with temperature from k_0 at $T = T_0$ to k_π at $T = T_\pi$. Find the steady-state temperature distribution. (10%)



Problem3(20%)

Multiple choice (please pick only one answer for each question)

3-1. What is the counterpart of mass diffusivity in momentum transfer?　(2%)

(1) viscosity,

(2) thermal diffusion coefficient,

(3) Reynolds number,

(4) kinematic viscosity,

(5) none of the above.

3-2. Which of the following statement is correct? (2%)

(1) Prandtl number = mass diffusivity / thermal diffusion coefficient.

(2) Schmidt number = kinematic viscosity / mass diffusivity.

(3) Most of the limiting Schmidt numbers of gas pairs at 1 atm are far greater than 1.

(4) The S.I. unit of Prandtl number is 1/sec.

(5) None of the above.

3-3. What is the SI unit of mass diffusivity?　(2%)

(1) kg/s,

(2) kg/m^2,

(3) m^2/s,

(4) kg/(s m),

(5) none of the above.

3-4. Which statement about eddy diffusivity is correct?　(2%)

(1) Eddy diffusivity is not a fluid property, but a flow parameter.

(2) Eddy diffuvisity is not a fluid property and not a flow parameter.

(3) Eddy diffusivity is a fluid property and a flow parameter.

(4) Eddy diffusivity is a fluid property, but not a flow parameter.

(5) Non of the above.

3-5. Give the order for the following four diffusion situations in their magnitudes of mass diffusivity: (A) Ar in Ni at 293K, (B) He in Ni at 293K, (C) He in Ni at 500K, and (D) Ar in O_2 at 293K.　(3%)

(1) A>B>C>D,

(2) D>C>B>A,

(3) D>A>B>C,

(4) C>B>A>D,

(5) None of the above.

3-6. What can the Chilton-Colburn analogy be used for?　(3%)

(1) to decide which free-convection correlation to use,

(2) to estimate the mass transfer coefficient from the heat transfer coefficient for the same geometry,

(3) to predict the length/diameter effects for friction factors,

(4) to estimate thermal radiation losses,

(5) non of the above.

3-7. Species A diffuses from a solid to a semi-infinite body of liquid B above it. Assume the density and mass diffusivity are constants. This diffusion process can be described by the one-dimensional version of Fick's second law. Initially, there is no A present in liquid B, and the concentration of A at the solid-liquid interface is C_{A0}. Let z be the coordinate with its origin located at the solid-liquid interface and its positive direction pointing into liquid B. Let D be the mass diffusivity of the binary system and t be the time. The concentration profile of A is:

[Note: you can figure out the answer without derivations. Here, erf(x) is the error function and erfc(x) the corresponding complementary error function.]　(3%)

(1) $\frac{C_A}{C_{A0}} = 1 - \text{erfc}\,(z/\sqrt{4Dt})$,

(2) $\frac{C_A}{C_{A0}} = \text{erf}\,(\sqrt{4Dt}/z)$,

(3) $\frac{C_A}{C_{A0}} = 1 - \text{erf}\,(\sqrt{4Dt}/z)$,　(接下頁)

(續前頁)

(4) $\frac{C_A}{C_{A0}} = \text{erf}\,(z/\sqrt{4Dt})$,

(5) $\frac{C_A}{C_{A0}} = 1 - \text{erf}\,(z/\sqrt{4Dt})$.

3-8. Continued from question 3-7. The interfacial molar flux is:
[Note: you can figure out the answer without derivations.]　(3%)
(1) $C_{A0}\sqrt{D/\pi t}$,
(2) $\sqrt{D/\pi C_{A0} t}$,
(3) $\sqrt{DC_{A0}/\pi t}$,
(4) $C_{A0}\sqrt{Dt/\pi}$,
(5) $C_{A0}\sqrt{t/\pi D}$.

Problem4(20%)

(1)請解釋如何利用「液側境膜溫度法」估計套管式熱交換器之熱傳係數(6%)，並解釋如何以所獲得之熱傳係數評估壁垢厚度。(3%)
註: 請圖示套管式熱交換器，標示與定義所用參數，否則不與計分。

(2)
a. 請圖示套管式熱交換器，標示與定義操作參數。(4%)
b. 請圖示平板式熱交換器，標示與定義操作參數。(4%)
c. 一般熱交換器的能量交換計算，會假設熱交換器在絕熱之下操作。相較於熱交換器的操作環境 (i.e., ambient environment) ，要如何評估熱交換器是否在絕熱之下操作？(3%)

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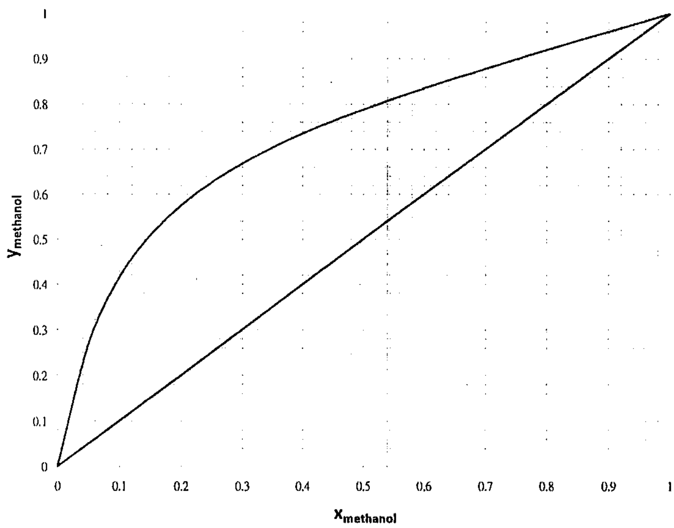
Problem5(20%)

(a)(5%)

Henry's Law constant of gas A in solvent B is 2 and Henry's Law constant of gas A in solvent C is 0.5. Which is a better solvent for A?

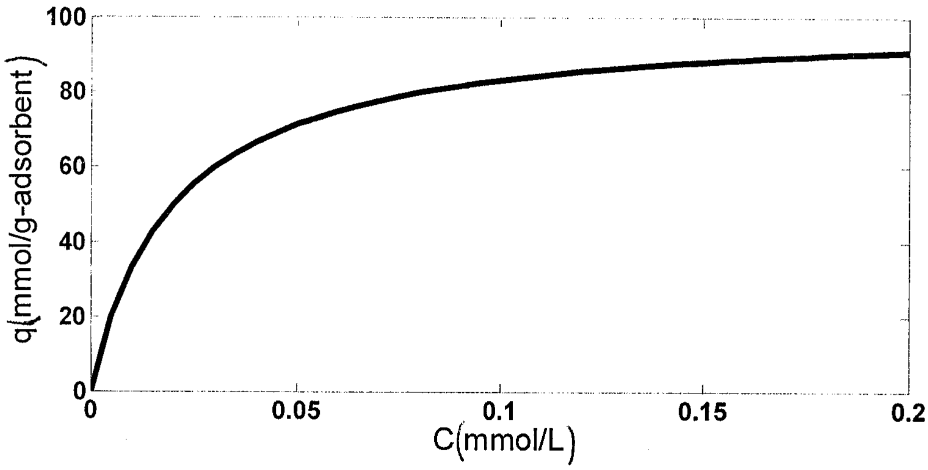
(b)(5%)

A distillation column is designed to separate methanol and water continuously. The feed is a saturated liquid that contains 50 mol% of methanol and 50 mol% of water. A distillate containing 90 mol% of methanol and a bottom containing 10 mol% of methanol is desired. Find the minimum number of stages required for the separation.



(c)(5%)

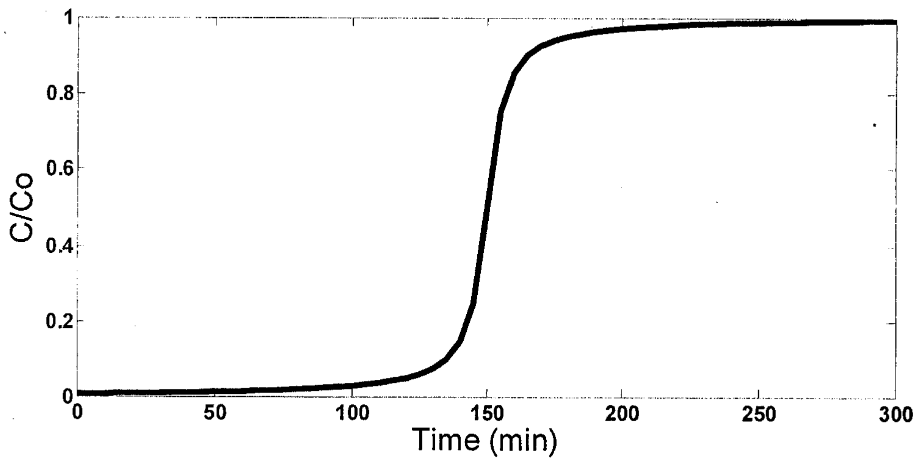
A valuable drug product A is separated from a solution that using adsorption. The equilibrium between amount of A adsorbed on the adsorbent and the concentration of A in the solution is given by following diagram



If 0.2g of this adsorbent is added to 10 L of initial solution that contains 0.1 mmol/L of A, how much A (in mmols/g) will be absorbed on the adsorbent.

(d)(5%)

Ion-exchange adsorption of salicylic acid by strongly-base anion exchange resin PUROLITE A-400 was investigated using an adsorption column. The following breakthrough curve was obtained with an initial concentration of C_o=0.6 g/L. The flow rate of the solution is 8.5 ml/min.



The saturation time is approximately 150 min. The break-through time, which is defined as the time when outlet concentration reaches 5% of the initial concentration, is approximately 100 min.

Suppose a new experiment is conducted in the same column, with the same initial concentration, but with a flow rate of 5.5 ml/min.

(i) What is the saturation time?

(ii) If effects of mass transfer and axial dispersion are negligible, what is the break-through time

(iii) If effects of mass transfer and axial dispersion cannot be neglected, do you expect the break-time to decrease, increase or unchanged?