Problem 1 (30 points)

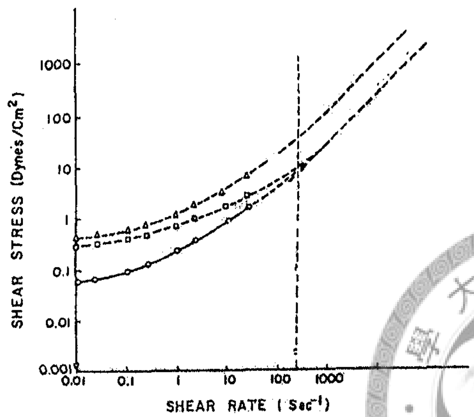
(a) (8 points)

Please give the SI units of the following terms:

(1) kinematic viscosity (2)NPSH (net positive suction head) (3)Grashof number (4)thermal diffusivity

(b) (5 points)

The following figure provides the shear stress-shear rate relationship for blood under a variety of conditions using capillary viscometer at ambient temperature. Different lines represent blood with different amount red blood cells.



Which one(s) of the following rheological behaviors of fluids is (are) shown in the figure?

1. Newtonian
2. Non-newtonian with yield stress
3. Pseudo-plastic
4. Dilatant

(c) (5 points)

Give the definition and physical meaning of the Nusselt number and Biot number for heat transfer.

(d) (5 points)

Give the definition and physical meaning of the Sherwood number and Peclet number for mass transfer.

(e) (7 points)

In a binary mixture of helium (He) and nitrogen (N_2), $D_{H\text{-}N}$ represents the diffusivity (diffusion coefficient) of He in N_2, and $D_{N\text{-}H}$ the diffusvity of N_2 in He. Which one is larger, $D_{H\text{-}N}$ or $D_{N\text{-}H}$? why?

Problem 2 (20 points)

A spherical particle settles under the action of gravity in a liquid. The settling velocity u_0 is a function of the following quantities:

particle diameter d
liquid density ρ
the effective density of the particle $(\rho_d - \rho)$ (ρ_d is the actual density of the particle)
liquid viscosity μ
gravitational acceleration g

a. Obtain a relationship for u_0 using dimensional analysis. (9 points)

b. The settling velocity is found experimentally to be inversely proportional to the viscosity of the fluid. What will be the effect of doubling the particle diameter? (5 points)

c. Please give the theoretical equation of the drag force for the particle under the condition in b. (6 points)

接背面

Problem 3 (25 points)

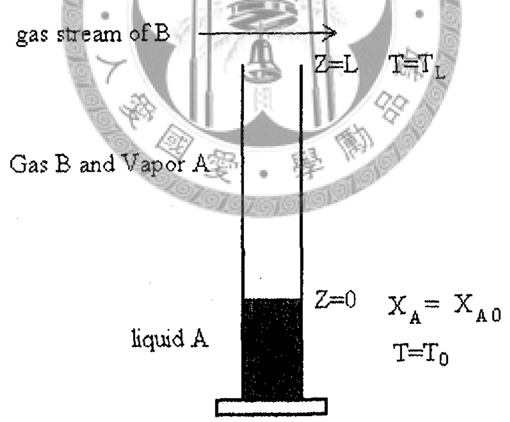
Liquid A is evaporating into gas B as described in the following figure. In the figure, X_A represents the mole fraction of vapor A in the gas phase, and T stands for the temperature. Gas stream of pure B is used to purge away vapor A. It is known that gas B cannot dissolve in liquid A, and the concentration of vapor A is not dilute. At Z=0 (the liquid-gas interface), $X_A = X_{A0}$, and $T=T_0$. At Z=L (the gas stream B) $T=T_L$. In such a system, the total molar concentration of A and B in the gas phase can be assumed as a constant (C). In the gas phase, the mutual diffusivity (diffusion coefficient) of A in B is D_{AB}, the thermal conductivity is K, and the heat capacity (per unit mole) is C_p. All these physical properties can be assumed to be constant and independent of temperature and concentration. It is also known that the assumption of steady one-dimensional heat and mass transfer in the Z direction is valid.

(a) Determine the molar flux of B in the Z direction.

(b) Determine the molar flux of A in the Z direction.

(c) Determine the molar average velocity in the Z direction.

(d) Determine the heat flux in the Z direction.

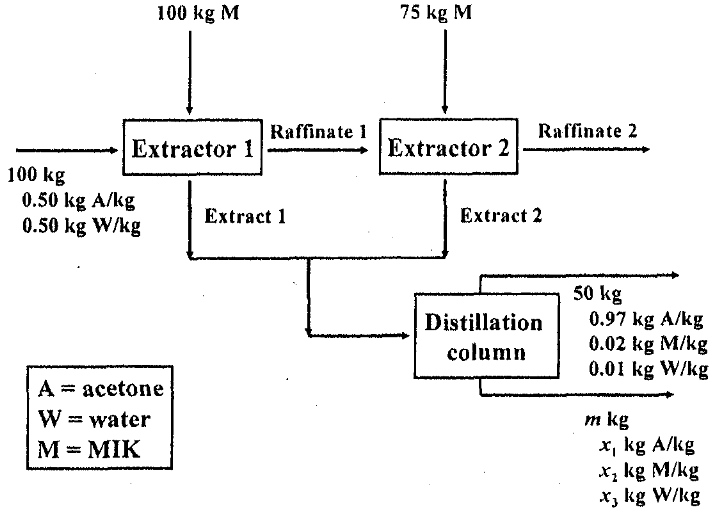


Problem 4 (25 points)

An extraction-distillation process

A mixture containing 50.0 wt% acetone and 50.0 wt% water is to be separated into two streams – one enriched in acetone, the other in water. The separation process consists of extraction of the acetone from the water into methyl isobutyl ketone (MIK), which dissolves acetone but is nearly immiscible with water. The extract is later separated by distillation. The process is shown schematically below.

接次頁



a. What are the amount and the composition of the raffinate 2? Please use the phase diagram in the answer sheet and plot on it. (10 points) （請於答案卷內所附相圖上作答）

b. What is the amount and composition of the bottom product of the distillation column? (7 points)
(If you don't know the answer in a, please use the following composition for raffinate 2 to solve the above problem. 5 points)

50 kg
0.90 kg W/kg
0.07 kg A/kg
0.03 kg M/kg

c. Using the following Fenske equation to calculate the number of plates in the distillation column under total reflux condition. (8 points)

$$N_{\min} = \frac{\ln[(x_{DL}/x_{BL})/(x_{DH}/x_{BH})]}{\ln \alpha_{L,K}} - 1$$

where x_{DL}: mole fraction of the light key component in overhead

x_{BL}: mole fraction of the light key component in bottom

x_{DH}: mole fraction of the heavy key component in overhead

x_{BH}: mole fraction of the heavy key component in bottom

$\alpha_{LK,HK}$: ratio of the K values (equilibrium ratio y_e/x_e) of light key component to that of heavy key component; assuming that under the column condition the K values for water, acetone and methyl isobutyl ketone are 1, 0.6, and 6, respectively)

(If you don't know the answer in b, please use the following composition for the bottom product from the distillation column to solve the above problem. 5 points)

178 kg
0.5 kg W/kg
0.1 kg A/kg
0.94 kg M/kg