經濟部所屬台灣中油股份有限公司 100 年新進博士級人員甄試試題

類　　別：化學工程(A)
專業科目：化工原理

注意事項	
	1.本試題共 3 頁（A4 紙 3 張）。 2.本試題共 10 題，合計 100 分，各題配分標示於題後。須用藍、黑色鋼筆或原子筆**答案卷指定範圍內標題號（不必抄題）**依題目順序作答，於本試題或其他紙張作答者不予計分。 3.考試結束前離場者，試題須隨答案卷繳回，俟該節考試結束後，始得索取。 4.考試時間：150 分鐘。

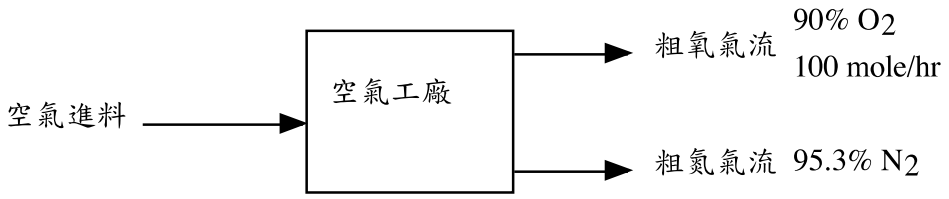
一、解釋名詞。 (共 10 分)

(1)超臨界萃取 (supercritical extraction)。(3 分)

(2)蒸汽重組反應 (steam reforming reaction)。(3 分)

(3)生質醇類汽油。(4 分)

二、空氣工廠分離氣體，示意圖如下，如欲生產每小時 100 mole, 90%的粗氧氣供工業用，計算需要空氣進料流量 (mole/hr)，粗氧氣流的成分和粗氮氣流量 (mole/hr)。其中空氣成分氮氣 (N_2)=78.08%，氧氣(O_2)=20.98%，氬氣(Ar)=0.94%，且分析發現粗氮氣流中不含氬氣。(15 分)



三、This part of the question concerns the operation of a Continuous Stirred Tank Reactor (CSTR). The design equation for a first order reaction in a CSTR is

$$V/u = ([A]_0 - [A])/ k[A]$$

(共 15 分)

(1) Why is it important that the temperature should remain constant during the run of the experiment? (2 分)

(2) Why is it important that mixing should be as near perfect as possible during the experiment? (2 分)

(3) In a given reactor it is intended to convert 43% of reactant A into products. Calculate the total flow rate (u) given that V=1.5 dm^3 and k=0.15 min^{-1}. (3 分)

(4) What would be the effect on the percentage conversion if the total flow rate was less than expected? Justify your answer. (3 分)

(5) What is meant by the 'mean residence time' of the reactant A in a CSTR? Give the equation which defines it. (2 分)

(6) In operating a CSTR commercially, computer control of flow rates is more effective than it would be with a batch reactor. Why is this so? (3 分)

四、The viscosity of air at 20°C and 1 atm has a value of 1.8×10^{-4} poise. Answer the following questions： (共 4 分)

(1) Will the viscosity of air at 200°C and 1 atm be higher or lower than 1.8×10^{-4} poise? (2 分)

(2) Will the viscosity of air at 20°C and 10 atm be higher or lower than 1.8×10^{-4} poise? (2 分)

五、Answer the following questions： (共 3 分)

(1) Define the Prandtl number. (1 分)

(2) At 20°C and 1 atm, which will have a larger Prandtl number, water or mercury liquid?（2 分）

六、簡答下列問題： (共 4 分)

(1)質量傳送(mass transfer)有那兩種不同的機制(mechanism)? (2 分)

(2)上述各種機制的質量傳送速率式(transfer rate formula)為何? (2 分)

七、Using dimensional analysis and the Buckingham Pi theorem, demonstrate many important conclusions. Please answer the following questions. (共 5 分)

(1) Which dimensionless group is related to the friction factor for pipe flow? (1 分)

(2) What kind of dimensionless groups are related to Nusselt number (Nu) for forced convection? (1 分)

(3) What kind of dimensionless groups are related to Nusselt number (Nu) for natural convection? (1 分)

(4) What kind of dimensionless groups are related to Sherwood number (Sh) for forced convection? (1 分)

(5) What kind of dimensionless groups are related to Sherwood number (Sh) for natural convection? (1 分)

八、Consider a spherical droplet of liquid water suspended in the air. Still air surrounds the droplet. At an infinitely long distance from the gas film, the concentration of water vapor in the air is effectively zero. At a constant temperature of T = 30°C and 1 atm total pressure, the evaporation rate of the droplet is controlled by the rate of molecular diffusion through the still air. Please answer the following questions: (共 16 分)

(1) Is the case equimolar counter diffusion (等莫耳相對擴散)or unicomponent diffusion (單成份擴散)? (1 分)

(2) Derive the molar flux (N_A) of evaporation of water as the function of P_A, D_{AB}, T, dP_A/dr. (4 分)

(3) Derive the molar flow rate (F_A) of evaporation of water as the function of P_A, D_{AB}, T, P. (3 分)

(4) Derive the equation of time required for the water droplet to completely evaporate. (5 分)

(5) Determine the time it will take for the water droplet to completely evaporate at 30°C (T) and 1 atm total system pressure (P) if the initial droplet radius is 5 mm (r_1). (3 分)

Note：The vapor pressure of water (P_A) is 4.2 kPa and the diffusivity of water vapor (D_{AB}) is 0.26 cm^2/s at 30°C. M_A：molecular weight of water. ρ_A：density of water. P：total pressure.

九、A common type of tube-flow viscometer for liquids consists of a relatively large reservoir with a very slender outlet tube, the rate of outflow being determined by timing the fall in the surface level. The liquid level of the reservoir can be regarded as constant at the short time. (共 17 分)

(1) Write down the energy balance equation for the fluid flowing in the tube. (2 分)

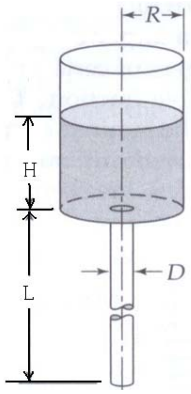
(2) Write down the Fanning friction equation (汎寧方程式) for the fluid flowing in the tube. (3 分)

(3) Write down the Fanning friction factor for the fluid laminar flowing in the circular tube. (2 分)

(4) Derive the Hagen-Poiseuille equation (Hint: Energy balance equation for laminar flow) for the tube flow. The gravity effect must be included. (6 分)

(5) If oil with a constant density flows out of the tube-flow viscometer at the rate of 0.273 cm^3/s, what is the bulk velocity of the fluid? The tube diameter is D = 0.18 cm, H = 8 cm and L = 55 cm. (1 分)

(6) What is the kinematic viscosity of the fluid? (3 分)



十、A cylindrical copper tube with an outside diameter of 10 cm and an inside diameter of 7.5 cm is submerged into a stirring water bath at 60°C. Inside the tube, a coolant at 18°C flows through the tube to maintain the tube temperature steady. The length of the tube in contact with water is 10 m, which gives the water-tube interface area of 3.14 m^2. Neglect the heat transfer through the two ends. The heat transfer coefficient between the tube and water is 950 $W \cdot m^{-2} \cdot K^{-1}$, while the heat transfer coefficient between copper and coolant is 1250 $W \cdot m^{-2} \cdot K^{-1}$. Please answer the following questions. (共 11 分)

(1) How many heat resistances are there for this system if neglecting the fouling resistances? (1 分)

(2) Derive the expression of overall heat transfer coefficient (U_o) based on the outside area of the copper tube (A_o). (4 分)

(3) Write down the expression of heat removed rate for this system. (1 分)

(4) Calculate the rate of heat removed by the coolant to keep the temperature of the tube at steady state. (5 分)

Note：The followings are properties of copper that may relate to the calculation：

thermal conductivity = 400 $W \cdot m^{-1} \cdot K^{-1}$；heat capacity =385 $J \cdot kg^{-1} \cdot K^{-1}$；density = 894 $kg \cdot m^{-3}$.

T_o：the temperature of water, T_i：the temperature of coolant. L：tube length.

R_o：the outside radius of the copper tube. R_i：the inside radius of the copper tube.