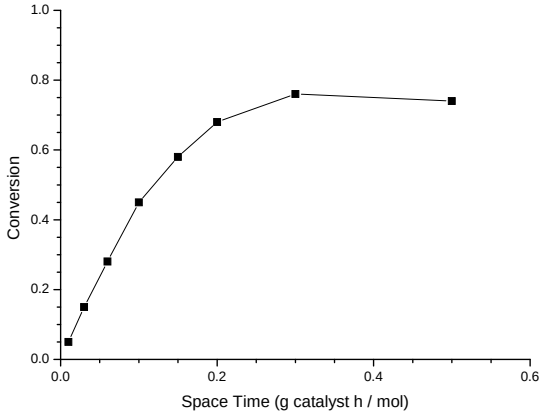
經濟部所屬台灣中油股份有限公司 100 年新進博士級人員甄試試題

類　　別：化學工程(B)
專業科目：化工原理

注意事項	
	1.本試題共 4 頁（A4 紙 4 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、For a catalytic reaction, A → B, experimental data from an isothermal packed bed reactor (PBR) are plotted as shown below. Interpret the data as much as you can, e.g., possible reasons of such curve shape, the catalyst activity. (共 10 分)



二、The pyrolysis of acetaldehyde (Ac) is believed to take place according to the following sequence:

$$CH_3CHO \xrightarrow{k_1} CH_3\bullet + CHO\bullet$$

$$CH_3\bullet + CH_3CHO \xrightarrow{k_2} CH_3\bullet + CO + CH_4$$

$$CHO\bullet + CH_3CHO \xrightarrow{k_3} CH_3\bullet + 2CO + H_2$$

$$2CH_3\bullet \xrightarrow{k_4} C_2H_6$$

(共 15 分)

(1) Use pseudo steady state hypothesis (PSSH) theorem to derive the rate expression for the rate of the disappearance of acetaldehyde, $-r_{Ac}$. (10 分)

(2) Under what conditions does it reduce to $-r_{Ac} = kC_{Ac}^{3/2}$. (5 分)

三、The questions in this section refer to the design and operation of a Continuous-flow Stirred Tank Reactor (CSTR). (共 15 分)

(1) Why is the volume of the reactor tank measured after the stirrer has been working? (3 分)

(2) What error might arise from determining the value of the rate constant on one day and then using the value on another day to make predictions about the operation of the CSTR? (2 分)

(3) How does the composition of the output stream from a CSTR compared with that of its contents? (2 分)

(4) What is meant by the mean residence time of a CSTR? State two quantities whose values influence the value of the mean residence time. (4 分)

(5) For most chemical manufacturing processes, continuous reactors are preferred to batch reactors. Suggest two circumstances under which a batch reactor would be preferable. (4 分)

四、Answer the following questions. (共 2 分)

(1) For a fluid flowing in a tube with an inside diameter of D, please define the Nusselt number. (1 分)

(2) For a fully developed turbulent flow in a smooth tube, does Nusselt number increase or decrease with fluid flow rate? (1 分)

五、To diffuse through oxygen gas at the same temperature, the same total pressure, and the same concentration gradient, which gas will have a higher diffusivity, carbon dioxide gas or helium gas? (2 分)

六、(1)能量傳送(heat transfer)有那三種不同的機制? (3 分)

(2)上述各種機制(mechanism)的能量傳送速率式(heat transfer rate formula)為何? (3 分)

七、熱交換器的功能在於交換(傳送)冷熱流體之間的能量，有一單程逆流(single pass counterflow)的套管式(double-pipe)熱交換器，其總傳熱面積為 A，總傳熱係數為 U，熱交換器兩端冷熱流體的溫度差分別為$\triangle T_1$及$\triangle T_2$。 (共 4 分)

(1)試寫出對數平均溫度差(logarithmic mean temperature difference，LMTD，$\triangle T_L$)。(1 分)

(2)試寫出此熱交換器的總熱交換速率式。 (1 分)

(3)使用對數平均溫度差有何假設? (2 分)

八、An engineer planned to pump out the liquid toluene at 50°C in a storage tank by a centrifugal pump. The piping between the outlet of the tank and the entrance to the pump is shown in the figure below. The pump was sat at an elevation which is 11 m higher than the free surface of the liquid toluene. The designated flow rate for the pumping is 2.5×10^{-3} m^3/s. The pipe's inside diameter, D, in the piping system was 3 inch. The pipe is made of smooth steel and the system included two 90° elbows. The number of velocity heads for the elbows was 0.7 (K_f). The form friction loss for the elbow is $K_f \cdot (v^2/2)$. The total piping length, L, before the entrance to the pump was 20 m. At 50°C toluene has a viscosity, μ, of 4.12×10^{-4} Pa·s, a density, ρ, of 820 kg/m^3 and a vapor pressure of 98 mmHg. Calculate the frictional loss, that is, the energy loss per unit mass of toluene due to friction, travelling through this piping system before entering the pump. For this calculation you can use $f = 16/Re$ for laminar flow and $f = 0.0791/Re^{1/4}$ for turbulent flow, where $f = 0.5(D/L)(\Delta P/\rho v^2)$ is the Fanning friction factor , ΔP is the pressure drop along the tube, v is the average velocity in the tube and the skin friction loss per unit mass in a tube is related to the friction factor as $h_f = 4f\,(L/D)(v^2/2)$. v is average velocity in the pipe. The friction loss in the tank can be neglected. (共 14 分)

(1) Calculate the Reynolds number, Re, for liquid toluene at 50°C in this piping system. (2 分)

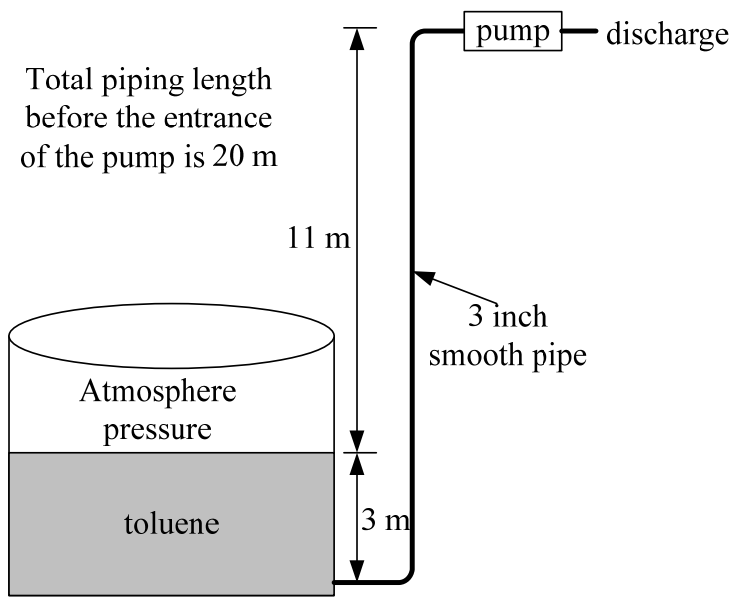
(2) Calculate the friction factor defined in the problem. (1 分)

(3) Calculate the skin friction loss of the fluid flowing in the pipe. (2 分)

(4) Calculate the form friction loss of the fluid flowing in the elbows. (1 分)

(5) Calculate the static pressure of the fluid at the entrance of the pump. (6 分)

(6) Could the choice of the pump position avoid cavitation occurring in this pumping system? Please answer the last question based on your calculation. Simply answering "yes" or "no" to the question gets no score. (2 分)



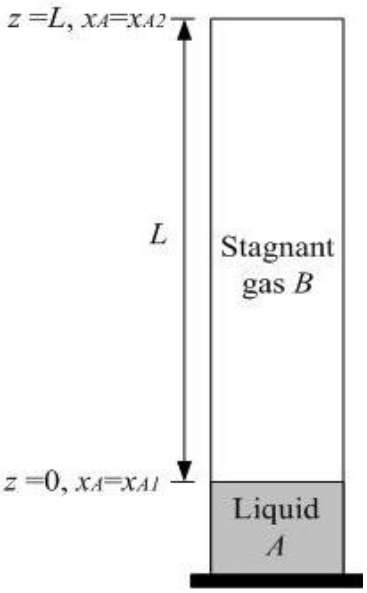
九、Consider the diffusion of vapor of a volatile liquid A through a stagnant gas B in a long cylinder as shown in the schematic plot below. The mole fraction of vapor A at the liquid-gas interface is x_{A1} and at the top of the cylinder the mole fraction of vapor A is kept at x_{A2}. The level of the liquid-gas interface was kept constant by continuous refilling (i.e. the liquid level can be regarded as constant). Please answer the following questions. The molecular diffusivity (D_{AB}) and mixture concentration (C) can be assumed to be constant. (共 15 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) Write down the mass balance equation. (2 分)

(3) Write down the molar flux equation relating mole fraction of component A [ie., $N_A=f(x_A)$]. (3 分)

(4) Derive the relation that describes the mole fraction of vapor A in the gas column as a function of the height (z). (9 分)



十、Radioactive waste material (k_r = 20 W/m·K) is stored in a cylindrical stainless steel (k_s = 15 W/m·K) container with inner radius and outer radius of r_i=1.0 m and r_o=1.2 m, respectively. The length of the container is 1 meter. Thermal energy is generated uniformly within the radioactive waste material at a volumetric rate of 2×10^5 W/m^3 steadily. The outer container surface is exposed to water at T_∞ = 25 °C, with a heat transfer coefficient of h = 1000 W/m^2·K. The ends of the cylindrical assembly are insulated so that all heat transfer occurs in the radial direction. The heat transfer process can be regarded as steady-state. For this situation, to determine： (共 17 分)

(1) the heat generate rate (Watt) from the radioactive waste material. (2 分)

(2) the steady-state temperature at the outer surfaces of the stainless steel (T_2). (2 分)

(3) the steady-state temperature at the inner surfaces of the stainless steel (T_1). (2 分)

(4) the two thermal boundary conditions of the radioactive waste material. (2 分)

(5) the shell energy balance within the radioactive waste material. (2 分)

(6) the temperature distribution within the radioactive waste material. (6 分)

(7) the temperature at the center of the radioactive waste material (T_o). (1 分)