國立中央大學113學年度碩士班考試入學試題

所別：化學工程與材料工程學系 碩士班 甲組(一般生)

科目：化工熱力學及化學反應工程

＊本科考試可使用計算機，廠牌、功能不拘

Problem 1　　計算題應詳列計算過程，無計算過程者不予計分

There is an adiabatic exothermic irreversible gas-phase reaction.

$$2A+B \rightarrow 2C$$

is to be carried out in a flow reactor for an equimolar feed of A and B.

A Levenspiel plot for above reaction is shown in figure below.

(a) What PFR volume is necessary to achieve 50% conversion? **(2 points)**

(b) What CSTR volume is necessary to achieve 50% conversion? **(2 points)**

(c) What is the volume of a second CSTR added in series to the first CSTR (part b) necessary to achieve an overall conversion of 80%? **(2 points)**

(d) What PFR volume must be added to the first CSTR (part b) to raise the conversion to 80%? **(2 points)**

(e) What conversion can be achieved in a 6×10^4 m^3 CSTR and also in a 6×10^4 m^3 PFR? **(2 points)**

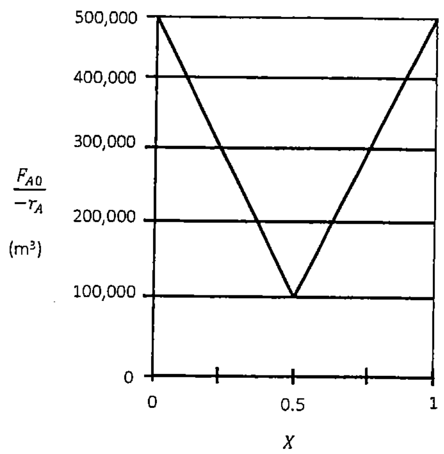

Figure. Levenspiel plot.

Problem 2

The gas phase reaction:

$$CH_3\text{-}CH_3 \rightarrow CH_2{=}CH_2+H_2$$

follows an elementary rate law and is to be carried out first in a PFR and then in a separate experiment in a CSTR. When pure CH_3-CH_3 is fed to a 10 dm^3 PFR at 300K and a volumetric flow rate of 5 dm^3/s, the conversion is 80%. When mixture of 50% CH_3-CH_3 and 50% inert (I) is fed to a 10 dm^3 CSTR at 320K and a volumetric flow rate of 5 dm^3/s, the conversion is 80%. What is the activation energy in cal/mol? **(10 points)**

注意：背面有試題

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Problem 3

In NCU company, you are an engineer who is assigned to design a CSTR for the elementary consecutive gas-phase reactions.

$$A \xrightarrow{k1} B \xrightarrow{k2} C$$

The feed conditions and desired product specifications are known (as shown in Table below), together with the temperature of the heating medium. Now, it's your job to design the reactor, that is, to specify the rector volume and the area of the heating coil inside the reactor. The ratio C_B/C_C in the product is equal to 10 and 50 % of A in the feed is converted. The feed is gas-phase and pure A with a molar flow rate of 0.05 lb mol/s and a volumetric flow rate of 7.85 ft^3/s. The entering temperature is 400 °F and the entering pressure in the reactor is 4 atm. The heating medium is saturated high-pressure steam at 350 °F and the overall heat-transfer coefficient between the heating medium and the reaction mixture is 400 Btu/h ft^2 °F.

Note that the heat capacities are $C_{P,A} = C_{P,B} = C_{P,C}$ =25 Btu/lb·mole· °F.

Ideal gas constant=1.986 Btu/lb·mol·[R] (the [R] here is Rankine temperature scale; [R]=°F+459.67)

Reaction 1	Reaction 2
$A_1=2\times10^9$ s^{-1}	$A_2=1\times10^{11}$ s^{-1}
E_1=31,000 Btu/lb·mol	E_1=40,000 Btu/lb·mol
ΔH_{Rx1}=15,000 Btu/lb·mol A	ΔH_{Rx2}=-20,000 Btu/lb·mol C

(a) Calculate the desired operating temperature inside the reactor **(10 points)**

(b) Calculate the volume of the reactor **(5 points)**

(c) Calculate the area of the heating coil **(5 points)**

Problem 4

The formation of component C on the catalytic surface is believed to proceed by the following mechanism

$$A_2 + 2S \rightleftharpoons 2A \bullet S$$

$$B + A \bullet S \rightarrow C \bullet S$$

$$C \bullet S \rightarrow C + S$$

Suggest a rate-limiting step and derive a rate law. **(10 points)**

注意：背面有試題

Problem 5

The following equation of state has been proposed for fluid

$$P = \frac{RT}{V} - b - \frac{a}{TV^2}$$

where a and b are constant

(a) Determine a and b parameters in terms of the critical temperature and pressure of the fluid. **(5 points)**

(b) Determine the constant-volume heat capacity and internal energy as function of temperature, volume, critical temperature and pressure. **(5 points)**

Problem 6

A binary solution containing methanol (M) and ethanol (E), whose vapor pressures of M and E are given by Antoine Equation:

$$\ln P_M^{sat}(kPa) = 16.5785 - \frac{3638.27}{t\,(°C) + 239.500}$$

$$\ln P_E^{sat}(kPa) = 16.8958 - \frac{3795.17}{t(°C) + 230.918}$$

(a) Prepare a P-x-y diagram for this binary solution for a temperature of 70°C. **(5 points)**

(b) A subcooled solution contains 75% M and 25% E in a cylinder at 70°C. The pressure in this system starts reducing reversibly until this subcooled liquid become superheated vapor. Determine the composition of the bubble point and the dew point when this subcooled solution becomes superheated vapor. **(5 points)**

Problem 7

The Flory–Huggins theory (FHT) has been a predominant approach in comprehending the thermodynamics and phase characteristics of polymer blends for an extended period. The core of the theory revolves around the formulation of free energy of mixing, derived from a lattice model. This theory encompasses combinatorial entropy components linked to the configurations of polymer chains within the lattice, along with an enthalpic contribution arising from interactions among diverse species. The enthalpic aspect is significantly influenced by the Flory–Huggins interaction parameter, χ_{12}, which describes the strength of attraction or repulsion between segments of either species.

(a) Please derive **(10 points)**

$$\Delta G_{mix} = RT(n_1 \ln \phi_1 + n_2 \ln \phi_2 + n_1 \phi_2 \chi_{12})$$

where 1 and 2 indicates solvent and polymer, respectively

(b) What is the physical meaning of ΔG_{mix} in polymer solution? **(5 points)**

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Problem 8

Please prove the residual-entropy and mention the condition for the following equation **(15 points)**

$$\frac{S^R}{R} = -T\int_0^P \left(\frac{\partial Z}{\partial T}\right)_P \frac{dP}{P} - \int_0^P (Z-1)\frac{dP}{P}$$

注意：背面有試題