國立臺灣科技大學
113學年度碩士班招生
試題

系所組別：0600化學工程系碩士班

科　　目：化工熱力學與動力學

<<506002>>

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(總分為100分；所有試題務必於答案卷內頁依序作答，否則不予計分)

PART (I) 化工動力學

1.

1-1. What are the advantages and disadvantages of using fine catalysts in a packed bed reactor for gas-phase reaction, respectively? (4pt)

1-2. We use a CSTR to carry out a biological reaction (Nutrient + cells→ product (metabolite) + more cells), what is the change in cell concentration in the reactor as the liquid nutrient flow rate ($\upsilon_{nutrient}$) is gradually increased? Please draw a schematic diagram and explain the reasons. (4pt)

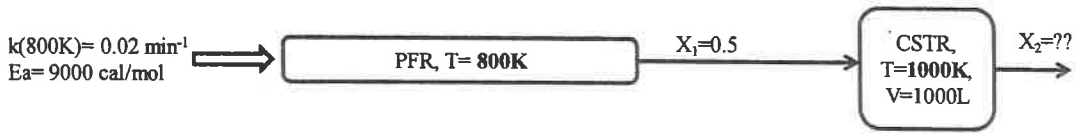
1-3. An elementary reversible reaction, A↔B, is carried out in a 10m-PFR, where the quartz wool is covered on stainless steel pipes for adiabatic purpose. The reactant is introduced at room temperature. ((Feed: pure A, C_{A0}) Several phenomena have been observed: (1) The fastest reaction rate occurs at 1.5 meters, not at the inlet; (2) After 5 meters, the temperature reaches 100°C and does not increase with reactor length; (3) Removing the quartz wool from 6 to 10 meters, however, increases the conversion rate. Please explain the reasons for these three phenomena with using equation of reaction rate and proper statement. (8pt)

2.The gas-phase reaction, 2A → B +5C, proceeds in two isothermal reactors.

(a) What is the volume of 1st **PFR**? (Feed: pure A, v_0= 10 L/min) (7pt)

(b) Estimate the X_2 after 2nd **CSTR**. (7pt)

The pressure drop can be neglected. R= 1.987 cal/mol-K



$$\int_0^x \frac{1+\varepsilon x}{1-x}\,dx = (1+\varepsilon)\ln\frac{1}{1-x} - \varepsilon x$$

3.The autocatalytic liquid-phase reaction, 2A + R → 3R, is carried out in an isothermal CSTR. Please design the proper reactor volume for maximun reaction rate of A. (7pt)

($-r_A = 0.0139 * C_A C_R$ (mol/L-min), F_{A0} = 5 mol/min, F_{R0} = 1 mol/min, volumetric flow rate = 2.5 L/min).

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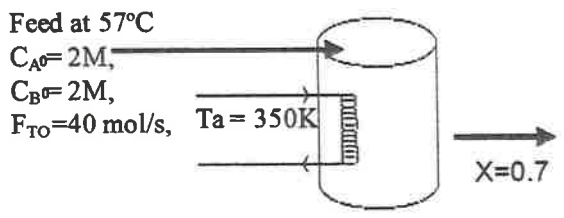
PART (I) 化工動力學

4.The elementary liquid-phase reaction (**2A+B → 2C**) is carried out in a CSTR, as shown in the following figure. Please **calculate the V as X=0.7.** (13pt)

Additional information: $Q = UA(T_a-T)$, $U= 50\ J/m^2\ s\ K$, $A=2\ m^2$, $W_s = 0$

$\Delta H_{Rxn}(298K) = 10{,}000\ J/mol\text{-}A$, $Cp_A = Cp_B = 200\ J/mol\text{-}K$, $Cp_C = 150\ J/mol\text{-}K$

$E=8300\ J/mol$, $k_{A,300K} = 0.08\ L^2/mol^2\text{-}s$, $R=8.3\ J/mol\text{-}K = 0.082\ L*atm/mol*K$



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PART (II) 化工熱力學

5. (20%) For an ideal solution under a given temperature T and pressure P, answer the following questions.

(1) **(4%)** When there are n_1 molecules of solvent and n_2 molecules of solute in a solution that can accommodate $n_1 + n_2$ molecules, find the total number of molecular arrangements (Ω) in the solution.

(2) **(6%)** Using the connection established by Boltzmann between entropy S and Ω, as $S = k \ln\Omega$, where k is the Boltzmann's constant, find the entropy change before and after mixing of solute and solvent. Ω = 1 before mixing, and molar ratio of solvent $x_1 = n_1/(n_1 + n_2)$, molar ratio of solute $x_2 = n_2/(n_1 + n_2)$. Please use Stirling's approximation as $\ln n! = n \ln n - n, when\ n \gg 1$.

(3) **(6%)** What is the enthalpy change of mixing (ΔH_{mix}) for the ideal solution? What is the Gibbs energy change of mixing (ΔG_{mix})? Is ΔG_{mix} positive or negative?

(4) **(4%)** If the chemical potential of molecule 1 in the mixture is $\mu_1 = [\frac{\partial G}{\partial n_1}]_{T,P,n_2}$, find the chemical potential change for the addition of 1 molecule of solvent ($\Delta n_1 = 1$).

6. (20%) For a Carnot cycle traversed by a working fluid in its ideal-gas state in a Carnot engine as shown below, answer the following questions.

(1) **(10%)** Express the work done by the cycle as a function of the two operating temperatures and the entropy change between the step b→c. Also sketch the regions representing the heat received from the hot reservoir (Q_H), the heat released to the cold reservoir (Q_C), and the work done by the engine (W) using the Carnot cycle in TS-diagram (temperature versus entropy diagram).

(2) **(10%)** In a real engine, both internal and external irreversibility can occur. Sketch the T-S diagram of the Carnot cycle containing each irreversibility and the two simultaneously.

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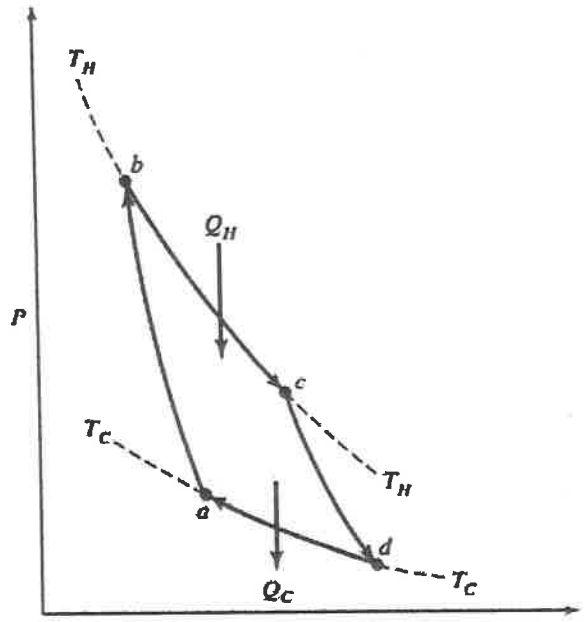

PV diagram showing a Carnot cycle for a working fluid in the ideal gas state.

7. (10%) Currently, power devices using compound semiconductor such as silicon carbide (SiC) are becoming increasingly important due to their low operating on-resistance. A SiC-MOSFET (a kind of power switching device) with an on-resistance of 40 milliohms (mΩ) is operating under a continuous drain current of up to 60A. The device temperature during operation is 348 K and the environment is 298 K.

(1) **(3%)** What is the power dissipation of this device?

(2) **(7%)** Calculate the rate of entropy generation for the device and environment. What is the total rate of entropy generation $\dot{S}_G$?