

國立清華大學命題紙

99 學年度 化學工程學系 碩士班入學考試

*請在【答案卷卡】作答

科目 化工熱力學及化學反應工程 科目代碼 0702 共 3 頁，第 1 頁

1.

- A steady stream of air at 400 K and 5 Bar flows through an adiabatic reversible device and leaves at 1 Bar. What is the final temperature (2%)? How much work per kmol of air can be obtained (3%)?
- A steady stream of air at 400 K and 5 Bar flows through an adiabatic device and leaves at 300 K and 1 Bar. How much work per kmol of air can be obtained (2%)? Is the process reversible (3%)?

You can assume that air is an ideal gas with

$$c_p = 30 \frac{\text{kJ}}{\text{kmol} \cdot \text{K}}$$

and

$$R = 8.314 \frac{\text{kJ}}{\text{kmol} \cdot \text{K}}$$

2.

According to thermodynamic relations

$$C_p - C_v = T \left(\frac{\partial P}{\partial T} \right)_v \left(\frac{\partial V}{\partial T} \right)_P$$

- Estimate $C_p - C_v$ for an ideal gas (4%)
- Estimate $C_p - C_v$ for a gas obeying the following equations of states (6%)

$$P = \frac{nRT}{V - nb}$$

- 3.(10%) Binary A-B system conforms to Raoult's law. At 50°C, the vapor pressures of pure A and B are 12.3 and 36.1 kPa, respectively. (a) Draw a schematic P - x (pressure-composition) phase diagram of the binary A-B system at 50°C with pressure ranging from 1 to 40 kPa. (b) What are the pressure and the composition of the gas phase in equilibrium with a liquid phase of 60at%B at 50°C? (c) Draw a schematic $\hat{f}_B^{liquid} - x_B^{liquid}$ (fugacity of B in the liquid phase - composition of B in the liquid phase) diagram at 50°C of the liquid phase.

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4. (10%) A vessel, divided into two parts by a partition, contains 5 moles of A gas at 350K and 35 bar at one side and 3 moles of B gas at 400K and 24 bar on the other. The partition is then removed, and the gases mix adiabatically and completely. (a) What are the temperature and the pressure of the system? (b) What is the change in enthalpy? (c) What is the change in entropy? (Just the equation, and do not have to get the exact numerical values). Assume A to be an ideal gas with $C_v=1.5R$ and the B to be an ideal gas with $C_v=2.5R$.

5. (10%)

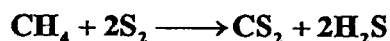
A reversible reaction, $A \xrightleftharpoons[k_2]{k_1} Q$, with rate constants following the Arrhenius Law, please show that the difference of activation energy between forward (k_1) and backward (k_2) rate constants is equal to the reaction enthalpy; i.e., $E_1 - E_2 = \Delta H$ where E_1 and E_2 indicate the activation energy of the forward and backward rate constants, respectively.

6. (10%)

A liquid-phase irreversible reaction: $A + B \rightarrow C + D$ is carried out in a series of three, equal volume CSTRs. The temperature is the same in all reactors. The volume flow rate to the first reactor is 10,000 L/h and the concentrations of A and B in the feed to the first reactor are the same ($C_{A,0} = C_{B,0} = 1.2$ mol/L). The rate law for this reaction is: $-r_A = kC_A C_B$ with $k = 3.50$ L/mol-h at the operation temperature. The final conversion is 0.75. What is the total volume of these three reactors?

7. (10%)

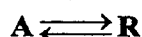
(A) The following reaction was carried out in a laboratory tubular reactor with a volume of 35.2 ml.



The reactor was operated at 600°C and 1atm. The feeding rates of S_2 and CH_4 were 0.236 and 0.119 g-mole/hr, respectively. The resulting production rate of CS_2 was 0.0079 g-mole/liter. The reaction is first order with respect to S_2 and first order with respect to CH_4 . Please determine the rate constant.

(5%)

(B) The following data were taken in a laboratory batch reactor for the following liquid phase first-order reversible reaction



Initially, pure A was presented

t (hr)	A (g-mol/l)
0	1.0
1	0.6
∞	0.4

Determine the forward and reverse rate constants.(5%)

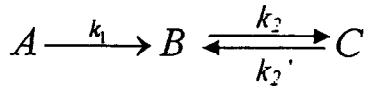
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8. (10%) An olefin (B) produced by dehydrogenation of a saturated hydrocarbon (A) undergoes isomerization to produce by-product (C). From the following batch reactor data determine the appropriate rate constant, assuming 1st order kinetics.



Time, min	Concentration, mol/liter		
	A	B	C
0	100	0	0
0.2	90.5	8.5	1.0
0.4	81.5	14.6	3.5
0.6	74.1	19.3	6.6
0.8	67.0	23.0	10.0
1.0	60.7	26.0	13.3
1.5	47.2	31.8	31.0
2.0	36.8	35.9	27.3
2.5	28.7	39.7	31.6
3.0	22.3	41.9	35.8
4.0	13.5	44.8	41.7
5.0	8.2	46.9	44.9
6.0	5.0	48.1	46.9
7.0	3.0	48.6	48.4
8.0	0.7	49.7	49.6
10.0			

Note:

$$\frac{dy}{dt} + p y = Q$$

$$y e^{\int p dx} = \int Q e^{\int p dx} dx + \text{constant}$$

You may use numerical method instead of using above formulas.

9. The elementary reaction $2A \rightleftharpoons B + C$ (reversible reaction) is to be carried out at 760°C, the feed is pure A in gas phase at a total pressure of 5 atm and 760°C. The forward rate constant is 1.8 l/mol-s and the equilibrium constant is 0.3 at 760°C.
- What is the equilibrium conversion? (10%)
 - Calculate the reactor volume necessary to achieve 98% of the equilibrium conversion of A in a PFR ($F_A = 10$ mole/min) (10%)