# 國立中央大學114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

計算題　請詳列計算過程。

**Problem 1 (10 pts)**

Hydrogen gas flows steadily through a horizontal, insulated pipe with an internal diameter of 4 cm. A pressure drop occurs as the gas passes through a partially opened valve. Upstream of the valve, the pressure is 700 kPa, the temperature is 120°C, and the average velocity is 10 m/s. If the pressure just downstream from the valve is 20 kPa, what is the temperature? Assume for nitrogen that PV/T is constant, $C_v$=2.5 R and $C_P$=3.5 R.

**Problem 2 (20 pts)**

An insulated container consists of two compartments separated by a partition. One compartment contains 5 moles of an ideal gas at a pressure of $P_1$=15 bar and a temperature of T=300 K. The adjoining compartment contains 3 moles of an ideal gas at a pressure of $P_2$=8 bar (initially under evacuation) and a temperature of T=240 K. When a valve is opened, the system is allowed to reach equilibrium, resulting in equilibrium temperature and pressure. Assume for nitrogen that $C_v$ is 2.5 R and $C_P$ is 3.5 R.

(a) Calculate the final pressure P of mixture

(b) Calculate the entropy change when the gases are identical

(c) Calculate the entropy change when the gases are different

(d) What is minimum amount of work required to separate the mixture in (c) into two different gases, each at equilibrium temperature T and pressure P

**Problem 3 (10 pts)**

Prepare a P-$x_1$-$y_1$ diagram and $x_1$-$y_1$ diagrams for a binary system of cyclohexanone (C) and phenol (P) at 200 °C by calculating P and $y_1$ at five different compositions $x_1$=0, 0.2, 0.4, 0.7, 1.0. The vapor phases are assumed as an idea gas.

$$\frac{G^E}{RT} = -3.5x_1x_2\ (independent\ of\ temperature\ and\ pressure)$$

$$\ln P_C^{sat}(kPa) = 15.0886 - \frac{4093.3}{T\ (°C) + 236.12}$$

$$\ln P_P^{sat}(kPa) = 14.4130 - \frac{3490.885}{T\ (°C) + 174.569}$$

**Problem 4 (10 pts)**

Prove that in a binary system, if one component follows Henry's Law, then the other component follows Lewis-Randall Law.

注意:背面有試題

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**Problem 5** (15 pts)

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 the 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?

$$\int_0^x \frac{dx}{1-x} = \ln\left(\frac{1}{1-x}\right)$$

$$\int_0^x \frac{dx}{(1-x)^2} = \frac{x}{1-x}$$

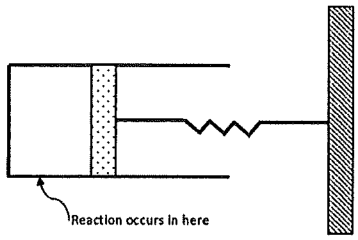
$$\int_0^x \frac{(1+\varepsilon x)dx}{1-x} = (1+\varepsilon)ln\frac{1}{1-x} - \varepsilon x$$

**Problem 6** (15 pts)

Consider a cylindrical batch reactor with one end fitted with a frictionless piston attached to a spring (as shown in the figure below). The reaction

$$A + B \rightarrow 8C$$

The gas reaction is second order in A and first order in B.




(a) Writing the rate law solely as a conversion function, evaluating all possible symbols numerically. (10 pts)

(b) What is the conversion and rate of reaction when V = 0.2 $ft^3$? (5 pts)

*Additional information:*

Equal moles of A and B are present at the beginning (t = 0)

Initial volume: 0.15 $ft^3$.

Value of $k_1$: 1.0 $(ft^3/lb\ mol)^2 \cdot s^{-1}$

The relationship between the volume of the reactor and pressure within the reactor is

V = (0.1) P (V in $ft^3$ and P in atm)

Temperature of the system (considered constant): 140°F

Gas constant: 0.73 $ft^3 \cdot$ atm/lb mol °R

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**Problem 7 (10 pts)**

(a) An irreversible, liquid phase, second-order reaction, A→Product (s), proceeds to 50% conversion in a PFT operating isothermally, isobarically, and at a steady state. What conversion would be obtained if the PFR operated at ***double*** the original pressure (with all else unchanged)? (3 pts)

(A)>50% (B)<50% (C) 50% (D) insufficient information to answer definitively

(b) An irreversible, gas phase, second-order reaction, A→Product (s), proceeds to 50% conversion in a PFT operating isothermally, isobarically, and at a steady state. What conversion would be obtained if the PFR operated at ***double*** the original pressure (with all else unchanged)? (3 pts)

(A)>50% (B)<50% (C) 50% (D) insufficient information to answer definitively

(c) The rate constant for an irreversible, heterogeneously catalyzed, gas phase, second-order reaction, A→Product (s), was determined to be 0.234 from experimental data failed to include a large pressure drop in the reactor in his/her analysis. If the pressure drop were properly accounted for, the rate constant would be (4 pts)

(A)>0.234 (B)<0.234 (C) 0.234 (D) insufficient information to answer definitively

**Problem 8 (10 pts)**

Nitric acid is made commercially from nitric oxide. The gas-phase oxidation of ammonia produces nitric oxide.

$$4NH_3+5O_2 \rightarrow 4NO + 6H_2O$$

The feed consists of 15 mol% ammonia in air at 8.2 atm and 227°C.

(a) What is the total entering concentration?

(b) What is the entering concentration of ammonia?

(c) Set up a stoichiometric table with ammonia as your basis of calculation.

(d) Express the concentration, Ci, for each species as a conversion function for a constant-volume batch reactor. Express the total pressure as a function of X.

(e) Repeat (d) assuming the reaction is first order in $NH_4$ and half order in $O_2$

(1) Write the rate law in terms of molar flow rates.

(2) Write the combined rate law and mole balance solely in terms of conversion and rate law parameters for a batch reactor and a flow reactor.