

## 國立臺灣科技大學102學年度碩士班招生試題

系所組別：化學工程系碩士班

科目：化工熱力學與動力學

(總分為100分)

**Part I. 化工熱力學 (50%)**

1. (20 points total) Explain concisely the following terms:

- (a) **Cubic equations state** (5 points)
- (b) **Departure properties** (5 points)
- (c) **Excess properties** (5 points)
- (d) **Principle of corresponding states** (5 points)

2. (15 points total) A cylinder containing 50 L of methane stores at room temperature (25°C). The pressure in the cylinder is indicated by a pressure gauge, 10 atm.

Please answer the following questions:

- (a) Is there any liquid methane in the cylinder? Why? (3 points)
- (b) How many moles of methane in the cylinder, if the properties of the methane vapor should be estimated by the two-term virial equation:

$$Z = 1 + \frac{B(T)}{V}$$

where  $Z$  is the compressibility factor,  $V$  is molar volume, and  $T$  is temperature.The second virial coefficient  $B$  of methane can be estimated from the following equation:

$$\frac{BP_C}{RT_C} = 0.1445 - (0.330/T_r) - (0.1385/T_r^2)$$

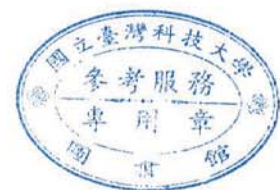
where  $T_r = (T/T_C)$ . The critical properties of methane are  $T_C = -82.75^\circ\text{C}$  and  $P_C = 46.0$  bar.  $R$  is the gas constant [ $= 83.1439$  bar  $\text{cm}^3/(\text{mol K}) = 8.31439$  J/(mol K)]. (12 points)

3. (15 points total) The sublimation pressure of ice ( $P^{sub}$ ) and the vapor pressure of water ( $P^{vap}$ ) varying with temperature can be expressed, respectively, by the following two equations:

$$\ln P^{sub} (\text{Pa}) = 28.8926 - 6140.1/T (\text{K})$$

$$\ln P^{vap} (\text{Pa}) = 26.3026 - 5432.8/T (\text{K})$$

- (a) If a closed vessel contains water-ice-steam simultaneously, what is the degree of freedom of this system? (2 points)
- (b) Estimate the coexisting temperature and pressure of this three-phase system. (5 points)
- (c) Estimate the heat of fusion at the triple point of water. (8 points)



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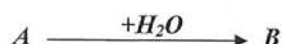
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## PART II. 化工動力學 (50%)

1. (10 points total) For the reaction  $A \leftrightarrow B$ ,  $r = k_f C_A - k_b C_B$ , find the residence times for 50% conversion:
- (a) in a continuous stirred tank reactor (CSTR) and (5 points)
- (b) in a plug flow reactor (PFR) (5 points)
- if  $k_f = 0.5 \text{ min}^{-1}$ ,  $k_b = 0.1 \text{ min}^{-1}$ ,  $C_{A0} = 2 \text{ mol/L}$ ,  $C_{B0} = 0$ , and feed rate is  $4 \text{ L/min}$ .

2. (20 points total) The following liquid-phase hydration reaction occurs in a 10,000L CSTR (assuming constant density):



With a first-order rate constant of  $2.5 \times 10^{-3} \text{ min}^{-1}$ .

- (a) What is the steady-state fractional conversion of  $A$  if the feed rate is  $0.3 \text{ L/sec}$  and the feed concentration  $C_{A0} = 0.12 \text{ mol/L}$ ? (8 points)
- (b) If the feed rate suddenly drops to 70% of its original value and is maintained there, what is the fractional conversion of  $A$  after 60 minutes, and what is the new steady-state fractional conversion of  $A$ ? (7 points)
- (c) What is the ratio of the steady-state productivity (mol/time) of  $B$  for case (b) relative to case (a)? (5 points)
3. (20 points total) Consider the following chain reaction in a CSTR (assuming constant density):
- $$A \rightarrow R, \quad r_t = k_t C_A$$
- $$A + R \rightarrow B + C + R, \quad r_p = k_p C_A C_R$$
- $$R \rightarrow X, \quad r_i = k_i C_R$$
- (a) Write the mass-balance equations for  $A$ ,  $B$ ,  $R$ , and  $X$  in a CSTR. (5 points)
- (b) What is the overall reaction rate with respect to  $C_A$ ? (5 points)
- (c) Find the residence time ( $\tau$ ) for 90% conversion of  $A$  in a CSTR assuming pseudo steady state if the feed concentration  $C_{A0} = 2 \text{ mol/L}$ ,  $k_t = 0.001 \text{ sec}^{-1}$ ,  $k_p = 20 \text{ L/mol} \cdot \text{sec}$ , and  $k_i = 0.1 \text{ sec}^{-1}$ . (5 points)
- (d) What are  $C_R$  and  $C_X$  for this conversion? (5 points)

