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:

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

   where $Z$ is the compressibility factor, $\underline{V}$ 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°C and $P_C$ = 46.0 bar. $R$ is the gas constant [= 83.1439 bar cm$^3$/(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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## PART Ⅱ. 化工動力學 (50%)

1. (10 points total) For the reaction A ↔ 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 $k_f = 0.5\ min^{-1}$, $k_b = 0.1\ min^{-1}$, $C_{A0} = 2\ mol/L$, $C_{B0} = 0$, and feed rate is $4\ L/min$.

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

   $$A \xrightarrow{+H_2O} B$$

   With a first-order rate constant of $2.5 \times 10^{-3}$ $min^{-1}$.
   (a) What is the steady-state fractional conversion of ***A*** if the feed rate is 0.3 L/sec and the feed concentration $C_{A0}$=0.12 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 → R, $r_i = k_i C_A$
   A+R → B+C+R, $r_p = k_p C_A C_R$
   R → X, $r_t = k_t C_R$
   (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 *mol/L*, $k_i$= 0.001 $sec^{-1}$, $k_p$= 20 $L/mol \cdot sec$, and $k_t$= 0.1 $sec^{-1}$. (5 points)
   (d) What are $C_R$ and $C_X$ for this conversion? (5 points)