注意：考試開始鈴響前，不得翻閱試題，

並不得書寫、畫記、作答。

國立清華大學 111 學年度碩士班考試入學試題

系所班組別：化學工程學系

科 目 代 碼 ：0902

考 試 科 目 ：化工熱力學及化學反應工程

—作答注意事項—

1. 請核對答案卷（卡）上之准考證號、科目名稱是否正確。
2. 考試開始後，請於作答前先翻閱整份試題，是否有污損或試題印刷不清，得舉手請監試人員處理，但不得要求解釋題意。
3. 考生限在答案卷上標記「由此開始作答」區內作答，且不可書寫姓名、准考證號或與作答無關之其他文字或符號。
4. 答案卷用盡不得要求加頁。
5. 答案卷可用任何書寫工具作答，惟為方便閱卷辨識，請儘量使用藍色或黑色書寫；答案卡限用 2B 鉛筆畫記；如畫記不清（含未依範例畫記）致光學閱讀機無法辨識答案者，其後果一律由考生自行負責。
6. 其他應考規則、違規處理及扣分方式，請自行詳閱准考證明上「國立清華大學試場規則及違規處理辦法」，無法因本試題封面作答注意事項中未列明而稱未知悉。

國立清華大學 111 學年度碩士班考試入學試題

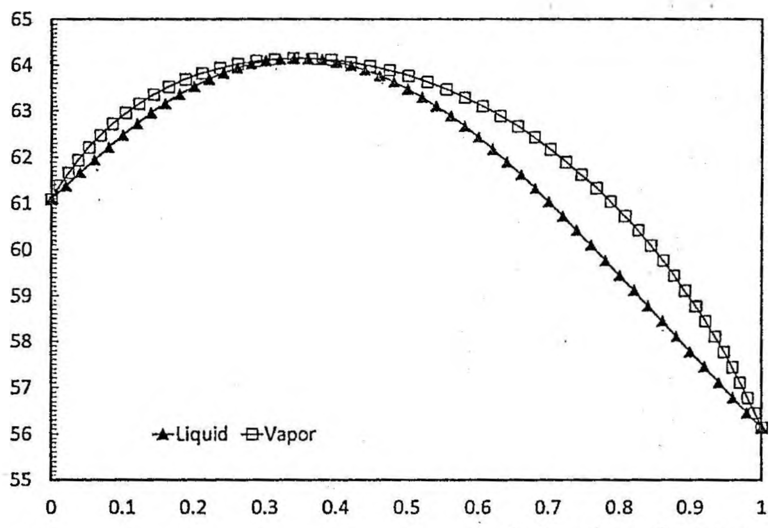
系所班組別：化學工程學系碩士班

考試科目（代碼）：化工熱力學及化學反應工程（0902）

　　*請在【答案卡】作答

Problem 1 (10%)

Each sub-question is 2% in score.



The T-x-y diagram of acetone in chloroform is given above.

1. What is the boiling point of chloroform?
(A) 56.1 °C
(B) 59.9 °C
(C) 61.1 °C
(D) 62.2 °C
(E) 64.1 °C

2. What is the boiling point of acetone?
(A) 56.1 °C
(B) 59.9 °C
(C) 61.1 °C
(D) 62.2 °C
(E) 64.1 °C

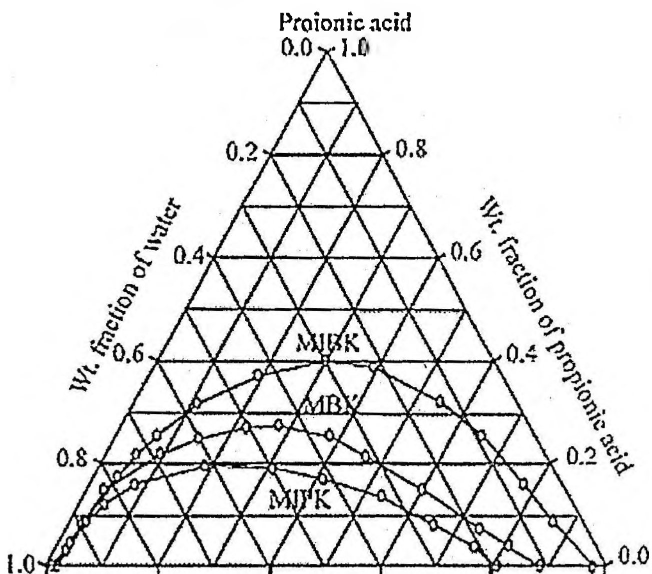
3. What is bubble point of a mixture of containing 70% of acetone?
(A) 56.1 °C
(B) 59.9 °C
(C) 61.1 °C
(D) 62.2 °C
(E) 64.1 °C

4. What is dew point of a mixture of containing 70% of acetone?
(A) 56.1 ℃
(B) 59.9 ℃
(C) 61.1 ℃
(D) 62.2 ℃
(E) 64.1 ℃

5. What is aeotropic point of a mixture acetone?
(A) 56.1 ℃
(B) 59.9 ℃
(C) 61.1 ℃
(D) 62.2 ℃
(E) 64.1 ℃

<u>Problem 2 (10%)</u>

Each sub-question is 2% in score.



The ternary liquid-liquid equilibrium diagram of water-n-propionic acid and three solvents MIBK, MBK MIPK are given above

6. What is the solubility of water MIBK in water?
(A) ~0.01
(B) ~0.8
(C) ~0.9
(D) ~0.98
(E) ~0.5

7. What is the solubility of water in MBK in water?
(A) ~0.01
(B) ~0.8
(C) ~0.9
(D) ~0.98
(E) ~0.5

8. What is the solubility of water in MIPK?
(A) ~0.01
(B) ~0.8
(C) ~0.9
(D) ~0.98
(E) ~0.5

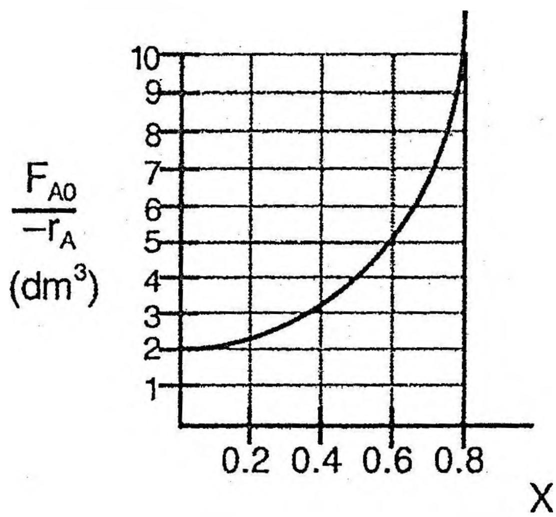
9. What is the solubility of MIPK in water?
(A) ~0.01
(B) ~0.8
(C) ~0.9
(D) ~0.98
(E) ~0.5

10. Which of the following is true?
(A) A mixture containing 20%water/20%PropionicAcid/60%MIBK is a two-phase liquid
(B) A mixture containing 20%water/20%PropionicAcid/60%MBK is a two-phase liquid
(C) A mixture containing 20%water/20%PropionicAcid/60%MIPK is a two-phase liquid
(D) None of above
(E) All of above

Problem 3 (8%)

Each sub-question is 2% in score.

Consider the following Levenspiel plot



11. The equilibrium conversion is

(A) $X_e<0.6$

(B) $X_e=0.8$

(C) $X_e>0.8$

(D) Cannot tell from the information given.

12. The flow rate to an 8 dm^3 CSTR corresponding to above Figure where 80% conversion is achieved is

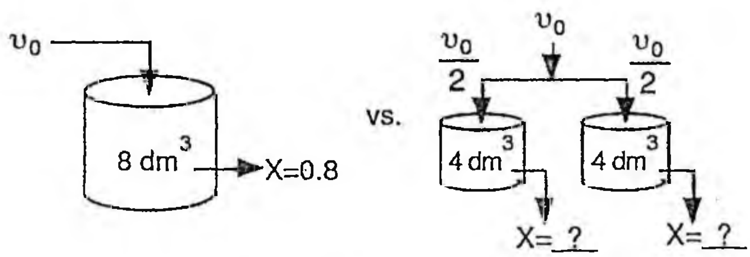
(A) $F_{A0}=0.8$ mol/s

(B) $F_{A0}=10$ mol/s

(C) $F_{A0}=1$ mol/s

(D) Cannot tell from the information given.

13. If the conversion achieved in a single 8 dm^3 CSTR is 80%, what would the conversion be if the flow is equally divided into to two CSTRs in parallel with first reactor having a volume of 4 dm^3 each (same total volume).



The total reactor volume is constant at 8 dm^3. The conversion for the two reactors in parallel is

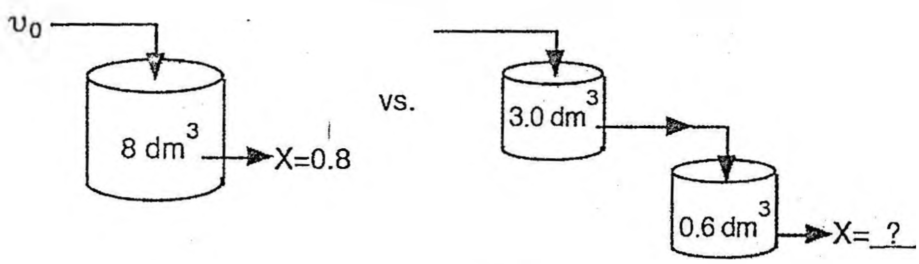
(A) X > 0.8

(B) X < 0.8

(C) X = 0.8

(D) Can't tell from the information given

14. If the conversion achieved in a single 8 dm^3 CSTR is 80%, what would the conversion be if two CSTRs are connected in series with first reactor having a volume of approximately 3.0 dm^3 and the second reactor having a volume of 0.6 dm^3.



The conversion for the two reactors in series is

(A) X > 0.8

(B) X < 0.8

(C) X = 0.8

(D) Can't tell from the information given

Problem 4 (12%)

Each sub-question is 4% in score.

15. The reaction A+ B→2C takes place in an unsteady CSTR. The feed is only A and B in equimolar proportions. Which of the following set of equations gives the correct mole balances on A, B and C. Species A and B Species A and B are disappearing and Species C is being formed

(A) $F_{B0} - F_A - \int^V r_A dV = \frac{dN_A}{dt})$

$F_{B0} - F_B - \int^V r_A dV = \frac{dN_B}{dt})$

$-F_C + 2\int^V r_A dV = \frac{dN_C}{dt})$

(B) $F_{A0} - F_A + \int^V r_A dV = \frac{dN_A}{dt})$

$F_{A0} - F_B + \int^V r_A dV = \frac{dN_B}{dt})$

$-F_C - 2\int^V r_A dV = \frac{dN_C}{dt})$

(C) $F_{A0} - F_A + \int^V r_A dV = \frac{dN_A}{dt})$

$F_{A0} - F_B + \int^V r_A dV = \frac{dN_B}{dt})$

$F_C + \int^V r_C dV = \frac{dN_C}{dt})$

(D) $F_{B0} - F_A - \int^V r_A dV = \frac{dN_A}{dt})$

$F_{B0} - F_A - \int^V r_A dV = \frac{dN_B}{dt})$

$-F_C + \int^V r_C dV = \frac{dN_C}{dt})$

16. Consider the gas-phase elementary reaction R → 2S which takes place in a PFR in which R and inert I are fed. If the entering concentration of R is cut by a factor of 5 while maintaining a constant entering volumetric flow rate, υ_0, how will the conversion change?

(A) X won't change

(B) X will increase

(C) X will decrease

(D) Cannot tell from the information given.

17. The liquid phase reaction A + B→3C follows an elementary rate law and is carried out in a constant volume batch reactor with stoichiometric feed. For a batch reaction time of one hour the conversion is 50%. If the same reaction is carried out in a PFR at the same temperature in which there is no pressure drop, for the same space time of one hour would the conversion be

(A) $X > 50\%$

(B) $X < 50\%$

(C) $X = 50\%$

(D) Insufficient information to answer definitively

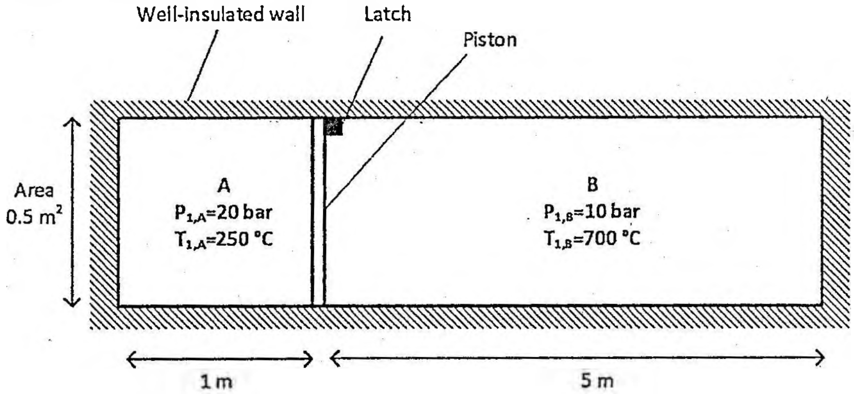
Problem 5 (10%)

Consider a well-insulated and rigid container including two compartments A and B filled with ideal gas as shown below. A thin metallic piston between Compartment A and B is initially held in place by a latch. After the latch is removed, the piston moves until the pressure the temperature of the two compartments reach equilibrium. Please determine:

(a) the distance the piston moved *(3%)*

(b) final temperature *(3%)*

(c) final pressure *(4%)*

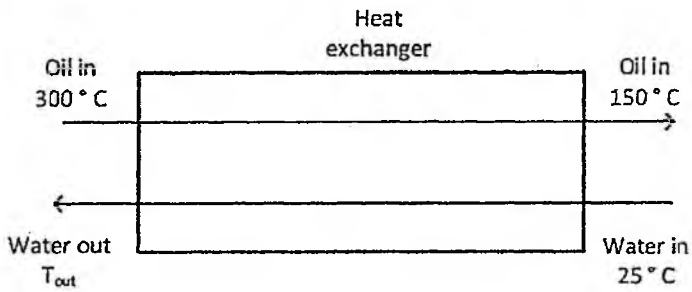


Notes:

1. Before removing the latch, Compartment A is 1 m long at 20 bar and 250 °C
2. Before removing the latch, Compartment B is 5 m long at 10 bar and 700 °C
3. The cross-sectional area of the container is 0.5 m^2
4. Ideal gas heat capacity $C_v = \frac{5}{2}R$
5. Assume the thickness of piston is negligible

Problem 6 (10%)

A heat exchanger is used to cool hot oil using cooling water as shown below. Please demonstrate whether the heat transfer process is reversible or irreversible by calculating the entropy change.



Notes:
1. Oil flow rate: 5 kg/min
2. Oil heat capacity:2.5 kJ/(kg-K)
3. Water flowrate: 10 kg/min
4. Water heat capacity: 4.2 kJ/(kg-K)

Problem 7 (10%)

Reactant A decomposes by three simultaneous reactions in a CSTR to form three products, one that is desired, B, and two that are undesired, X and Y. These gas-phase reactions, along with the appropriate rate laws, are called the *Trambouze* reactions.

(i) $A \rightarrow X,\ r_X = k_1 = 0.0001 \frac{\text{mol}}{\text{dm}^3 * \text{s}}$ (zero order)

(ii) $A \rightarrow B, r_B = k_2 C_A = (0.0015\ s^{-1}) * C_A$ (first order)

(iii) $A \rightarrow Y,\ r_Y = k_3 C_A^2 = \left(0.008 \frac{\text{dm}^3}{\text{mol} * \text{s}}\right) * C_A^2$ (second order)

Please calculate the CSTR reactor volume that would maximize the instantaneous selectivity of species B for an entering concentration of species A of 0.4 M and a volumetric flow rate of 2.0 dm^3/s.

Problem 8 (10%)

The gas-phase reactions: $3A \rightarrow 2B + C$ was carried out in a constant volume batch reactor. $t_{1/10}$ was the time necessary for the concentration of A to fall to 1/10 of its initial concentration. Run1 through 4 were carried out at 80 °C. Please determine the reaction order.

Run	1	2	3	4
Initial concentration $C_{A0} \frac{mol}{l}$	0.090	0.150	0.245	0.41
$t_{1/10}$ (min)	109.2	40.2	14.8	5.4

Problem 9 (10%)

In chemical processes, the choice of reactor is an important task to maximize productivity and selectivity. The common types of reactions can be categorized as follows:

Single reactions:

Feed→Product; $r = kC^{a}_{Feed}$

Multiple reactions in parallel producing byproducts:

Feed→Product; $r_1 = k_1 C^{a1}_{Feed}$

Feed→Byproduct; $r_2 = k_2 C^{a2}_{Feed}$

Mixed parallel and series reactions in series producing byproducts:

Feed→Product; $r_1 = k_1 C^{a1}_{Feed}$

Product →Byproduct; $r_2 = k_2 C^{a2}_{Product}$

(a) For a single reaction, which type of reactor is not preferred and why? *(3%)*
(b) For multiple reactions in parallel producing byproducts, which type of reactor is preferred? (Please discuss both the case of $a_2>a_1$ and $a_2<a_1$) *(3.5%)*
(c) For multiple reaction in series producing byproducts, which type of reactor is preferred? *(3.5%)*

Problem 10 (10%)

For the following reaction:

$$A+B \leftrightarrow C+D$$

Experimental data was collected using a batch reactor at 60 °C with pure A and B feed. Base on the best fitting results, a second order model (with respect to A) for the forward reaction and first order model (with respect to C) for the reverse reaction is concluded with:

$$k_a = 0.002688\ \text{m}^3\cdot\text{kmol}^{-1}\cdot\text{min}^{-1}$$
$$k_{-a} = 0.004644\ \text{min}^{-1}$$

For a plant producing 10 tons of product C per day, calculate the volume required by a CSTR operating at 60 °C. Assume no product is recycled to the reactor and the reaction feed in a equimolar mixture of A and B (8.33 kmol·m^{-3}). Also, assume the reactor conversion to be 95 % of the equilibrium conversion.

(a) Based on the kinetic parameters and information provided, what is equilibrium conversion? *(2.5%)*
(b) What is the size of the CSTR if 10 tons of C is to be produced per day (the molecular weight of C is 88.1 g/mol) with a feed concentration of 8.33 kmol·m^{-3} of pure A and pure B. *(5%)*
(c) If the production of 10 tons of C per day is to be carried out in a PFR, what would be the required retention time? Is the volume of the PFR greater or smaller than the CSTR *(2.5%)*