



UNIVERSITI KUALA LUMPUR
MALAYSIAN INSTITUTE OF CHEMICAL & BIOENGINEERING TECHNOLOGY

FINAL EXAMINATION
OCTOBER 2025 SEMESTER

COURSE CODE	: CPB 12204
COURSE TITLE	: MATERIAL & ENERGY BALANCE
PROGRAMME NAME	: BACHELOR OF CHEMICAL ENGINEERING TECHNOLOGY
DATE	: 28 JANUARY 2026
TIME	: 09.00 AM – 12.00 PM
DURATION	: 3 HOURS

INSTRUCTIONS TO CANDIDATES

1. Please read the instructions given in the question paper **CAREFULLY**.
2. This question paper is printed on both sides of the paper.
3. This question paper consists of **ONE** section.
4. Section A consists of five questions. Answer **FOUR (4)** questions only.
5. Please write your answer on the answer booklet provided.
6. Please answer all questions in English only.
7. Refer to the attached Formula / Appendices.

SECTION A (Total: 100 marks)

Answer FOUR (4) questions.

Please use the answer booklet provided.

Question 1

- (a) A mixture with an average molecular weight of 52.22 contains 45 mol% acetaldehyde with the remaining, acetone and acetic acid. It is found that the volume of acetaldehyde in the mixture is 100 cm^3 .
- Calculate the mole fractions for acetone and acetic acid in the mixture.
(4 marks)
 - Determine the number of moles of each compound in the mixture.
(4 marks)
 - Determine the volume of acetic acid and acetone (in cm^3).
(4 marks)
- b) A fresh feed stream consists of solid and water is fed into an evaporator at a rate of 75 kg/hr. Before entering the evaporator, a fraction of the fresh feed bypasses the evaporator and rejoins the evaporator concentrate stream while the other stream enters the evaporator at the rate of 60 kg/hr. In addition, water is evaporating at a rate of 20 kg/hr. The final product contains 30 wt% solid and the balance water. The process flow diagram is shown in Figure 1.

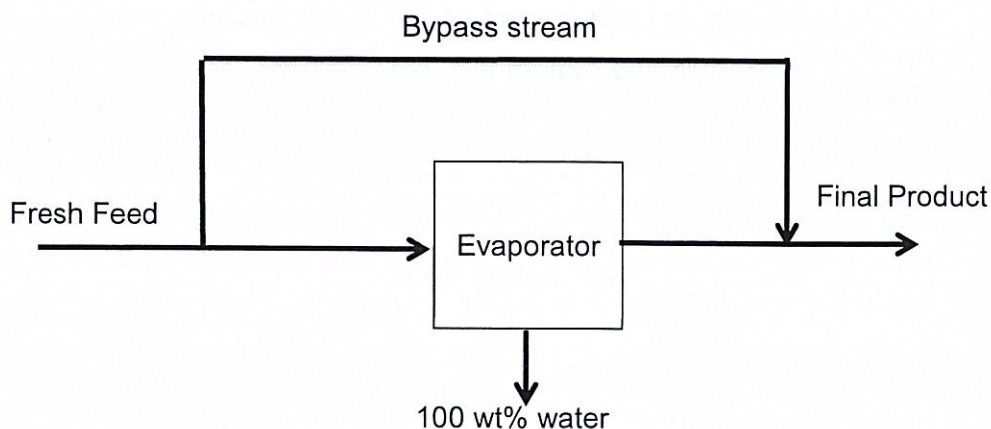


Figure 1: Evaporation Process

- i. Calculate the ratio of the bypass stream to the fresh feed stream.
(3 marks)
- ii. Calculate the mass flow rate of solid and water in the bypass stream.
(6 marks)
- iii. Determine the mass fraction of solid and water in the stream leaving the evaporator.
(4 marks)

Question 2

- (a) The *Reynolds number* (Re) is a dimensionless quantity that is used to help predict flow patterns in different fluid flow situations. If the calculated Reynolds number is less than 2100, the flow is defined as laminar flow. On the other hand, if the Reynolds number is above 2100, the flow is defined as turbulent flow. The equation is defined as below

$$Re = \frac{Dv\rho}{\mu}$$

Where D is pipe diameter, v is fluid velocity, ρ is the fluid density, and μ is fluid viscosity. Liquid methanol flows through a pipe with the diameter of 3.5 inches at the velocity of 550 ft/min. At fluid temperature of 20°C, the specific gravity (SG) of liquid methanol is given as 0.792 and the viscosity as 5.94×10^{-4} kPa.s. Evaluate the flow pattern of the liquid methanol by determining its Reynolds Number.

(10 marks)

- (b) A vapor mixture of 45 mol% 1-Propanol (C_3H_8O) and the balance 2-Propanol (C_3H_8O) is in equilibrium with its liquid mixture at 65°C. The gas-liquid mixture exhibits ideal solution behavior. Solve the system total pressure and the composition of the liquid mixture in mole %.

(9 marks)

- (c) Humid air at 87°C and 1 atm with relative humidity of 94% is cooled to 25°C at constant pressure.

- i. Calculate the dew point
(3 marks)
- ii. Calculate degrees of superheat of the air at 87°C.
(3 marks)

Question 3

- (a) A scuba tank contains 1500 total moles of a gas mixture that consists of oxygen (O_2) gas with a pressure of 0.45 atm and helium (He) gas at 16.53 psi. Solve the number of moles (in mole) of O_2 and He in the tank.

(7 marks)

- (b) 5.0 kmol of methane (CH_4) is placed in a 2.0 m^3 cylinder at 30°C .

- i. Estimate the cylinder pressure in atm if it is assumed methane behaves as an ideal gas in the system.

(5 marks)

- ii. Determine the cylinder pressure in atm using Soave-Redlich-Kwong equation of state if methane behaves as a non-ideal gas in the system.

(13 marks)

Question 4

A condenser is used to condense substances from gaseous to liquid state, typically by cooling it. In this problem, a stream of humid air consisting of 40 mol% air (air consists of 21 mol% O_2 and the balance N_2) and the balance water enters a condenser at 200°C . 80% of the water vapor in the feed is condensed and removed as pure liquid water. Both gas and liquid phase streams, which are in equilibrium with each other at 40°C , are separated and discharged as separate streams. O_2 gas leaves the condenser at the rate of 5.04 mol/s .

- (a) Draw and label a flowchart of the process.

(4 marks)

- (b) Solve the total flow rate of the feed stream and both streams leaving the condenser.

(3 marks)

- (c) Calculate the composition of the gas phase stream (in mol%) leaving the condenser.

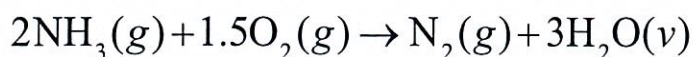
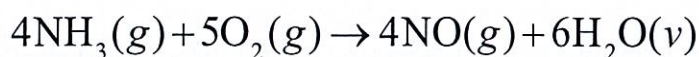
(4 marks)

- (d) Taking [N_2 (g, 40°C), O_2 (g, 40°C), and H_2O (v, 40°C)] as reference for enthalpy calculations, prepare and fill in the inlet-outlet enthalpy table and determine the heat transferred from the condenser in kilowatts (KW). (Neglect the effects of pressure changes on enthalpies).

(14 marks)

Question 5

In the first step of the nitric acid production, ammonia (NH_3) must be oxidized with excess air to form nitric oxide (NO) and H_2O . However, NH_3 oxidation also produces N_2 and H_2O in another reaction. 25 mol/s of NH_3 enters the reactor at 25°C and 1 atm. On the other hand, the pre-heated air enters as a separate inlet stream at 300°C and 1 atm at the rate of 250 mol/s (assume air consists of 21 mol% O_2 and the balance N_2). The gas mixtures leaves the reactor at 900°C and 1 atm. Selectivity of the desired, NO relative to the undesired, N_2 is 0.16 with 25% conversion of NH_3 .



- (a) Draw and label a flowchart of the process. (4 marks)
- (b) Solve the molar flow rate of all the compounds in the gas mixtures leaving the reactor using atomic balance method. (10 marks)
- (c) Taking elemental species [$\text{O}_2(g)$, $\text{H}_2(g)$, and $\text{N}_2(g)$] at 25°C and 1 atm as reference for enthalpy calculations, fill in and complete the inlet-outlet enthalpy table below (Table 1) and subsequently determine the heat transferred to the reactor in kilowatts.

Table 1: Inlet-outlet enthalpy table

Substance	INPUT		OUTPUT	
	n_{in} (mol/s)	H_{in} (kJ/mol)	n_{out} (mol/s)	H_{out} (kJ/mol)
$\text{N}_2(g)$		8.12		27.19
$\text{O}_2(g)$		8.47		28.89
$\text{NH}_3(g)$				
$\text{H}_2\text{O}(v)$				
$\text{NO}(g)$				

(11 marks)

END OF EXAMINATION PAPER

APPENDICES

A. List Of Formulations

$$1. SG_i = \frac{\rho_i}{\rho_{ref}}; \rho_{ref} = 1.000 \frac{g}{cm^3} = 1000.0 \frac{kg}{m^3} = 62.43 \frac{lbm}{ft^3}$$

$$2. \bar{M} = \sum y_i M_i; \frac{1}{\bar{M}} = \sum \frac{x_i}{M_i}$$

$$3. n_i = n_{io} + v_i \xi$$

$$4. \text{Overall Conversion} = \frac{\text{Reactant input to process} - \text{Reactant output from process}}{\text{Reactant input to process}} \times 100\%$$

$$5. \text{Single-Pass Conversion} = \frac{\text{Reactant input to reactor} - \text{Reactant output from reactor}}{\text{Reactant input to reactor}} \times 100\%$$

$$6. \% \text{ Excess Air} = \frac{(n_{air,feed}) - (n_{air,theoretical})}{(n_{air,theoretical})} \times 100\%; \% \text{ Excess} = \frac{n - n_s}{n_s} \times 100\%$$

$$7. \dot{Q} - \dot{W}_s = \Delta \dot{H} + \Delta \dot{E}_k + \Delta \dot{E}_p$$

$$8. \Delta \hat{H} = \int_{T_1}^{T_2} C_p(T) dT$$

$$9. \Delta \dot{H} = \sum_{out} \dot{n}_i \hat{H}_i - \sum_{in} \dot{n}_i \hat{H}_i$$

$$10. \Delta H = \xi \Delta \hat{H}_r^0 + \sum_{out} n_{out} \hat{H}_{out} - \sum_{in} n_{in} \hat{H}_{in}$$

$$11. \xi = \frac{|n_{A,out} - n_{A,in}|}{|v_A|}$$

$$12. PV = nRT; P\hat{V} = zRT$$

$$13. \hat{V} = \frac{V}{n}; V_r^{ideal} = \frac{\hat{V} P_c}{RT_c}$$

$$14. P_r = \frac{P}{P_c}; T_r = \frac{T}{T_c}$$

$$\text{The SRK equation of state: } P = \frac{RT}{\hat{V} - b} - \frac{\alpha a}{\hat{V}(\hat{V} + b)}$$

$$a = 0.42747 \frac{(RT_c)^2}{P_c}; b = 0.08664 \frac{RT_c}{P_c}; m = 0.48508 + 1.55171\omega - 0.1561\omega^2; \alpha = \left[1 + m(1 - \sqrt{T_r})\right]^2$$

$$\text{The virial equation of state truncated after the second term: } \frac{P\hat{V}}{RT} = 1 + \frac{B}{\hat{V}}$$

$$B = \frac{RT_c}{P_c} (B_o + \omega B_1); B_o = 0.083 - \frac{0.422}{T_r^{1.6}}; B_1 = 0.139 - \frac{0.172}{T_r^{4.2}}$$

$$15. p_i = y_i P = p_{i(T)}^*$$

$$16. p_i = y_i P = p_{i(T_{\text{dewpoint}})}^*$$

$$17. p_A = y_A P = x_A p_{A(T)}^*$$

$$18. p_A = y_A P = x_A H_{A(T)}$$

$$19. s_r(h_r) = \frac{p_i}{p_{i(T)}^*} \times 100\%$$

$$\frac{1.8^\circ F}{1^\circ C}; \frac{1.8^\circ R}{1^\circ K}; \frac{1^\circ F}{1^\circ R}; \frac{1^\circ C}{1^\circ K}$$

B. Gas Constant

$$\begin{aligned} R &= 8.314 \frac{\text{m}^3 \cdot \text{Pa}}{\text{mol} \cdot \text{K}} = 0.08314 \frac{\text{L} \cdot \text{bar}}{\text{mol} \cdot \text{K}} = 0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} = 62.36 \frac{\text{L} \cdot \text{mmHg}}{\text{mol} \cdot \text{K}} \\ &= 0.7302 \frac{\text{ft}^3 \cdot \text{atm}}{\text{lb mol} \cdot ^\circ \text{R}} = 10.73 \frac{\text{ft}^3 \cdot \text{psia}}{\text{lb mol} \cdot ^\circ \text{R}} \\ &= 1.987 \frac{\text{cal}}{\text{mol} \cdot \text{K}} = 8.3144 \frac{\text{J}}{\text{mol} \cdot \text{K}} = 1.987 \frac{\text{Btu}}{\text{lb mol} \cdot ^\circ \text{R}} \end{aligned}$$

C. Standard Conditions for Gases

System	T _s	P _s	V _s	n _s
SI	273 K	1 atm	0.022415 m ³	1 mol
CGS	273 K	1 atm	22.415 L	1 mol
American Engineering	492°R	1 atm	359.05 ft ³	1 lb-mole