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**UNIVERSITI TUN HUSSEIN ONN MALAYSIA**

**FINAL EXAMINATION  
SEMESTER I  
SESSION 2019/2020**

COURSE NAME : MASS AND ENERGY BALANCES  
COURSE CODE : BNQ 20903  
PROGRAMME CODE : BNN  
EXAMINATION DATE : DECEMBER 2019/JANUARY 2020  
DURATION : 3 HOURS  
INSTRUCTION : ANSWER ALL QUESTIONS

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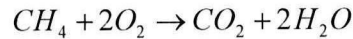
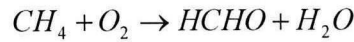
THIS QUESTION PAPER CONSISTS OF FIVE (5) PAGES

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- Q1** (a) Ali is very excited when he was offered the Chemical Engineering Technology course in UTHM. He thought that the course is about chemistry, the subject that he interested when he was in form 5. However, the course is very different from what he thought.
- (i) In your own word, describe in detail about Chemical Engineering Technology course and the advantages of this course. (5 marks)
- (ii) List **FOUR (4)** industries that chemical engineer technologist could work for. (4 marks)
- (b) Illustrate with an explanation on the absorption and liquid-liquid extraction processes and list **TWO (2)** applications in real life or industry for each of the processes. (8 marks)
- (c) As a chemical engineer technologist, propose the best way to cool the circulating water used in oil refineries. Include the explanation of the basic concept of this process. (5 marks)
- (d) Differentiate between open and close system in energy balance. (3 marks)
- Q2** Wet air containing 4.0 mol% water vapor is passed through a column of calcium chloride pellets. The pellets adsorb 97.0% of the water in the feed and none of the other constituents of the air. The pellets were initially dry and had a mass of 3.40 kg. After 5.0 hours of operation, the pellets are reweighed and found to have a mass of 3.54 kg.
- (a) Sketch and label in detail the process, including the unknown and equipment involved for the above statement. (5 marks)
- (b) Determine the water adsorption rate by the calcium chloride pellets. (5 marks)
- (c) Calculate the molar flow rate (mol/h) of the feed gas and the mol fraction of water vapor in the product gas. (10 marks)
- (d) (i) The mol fraction of water in the product gas is monitored and found to have the value calculated in part **Q2(a)** for the first 10 hours of operation, and after that it begins to increase. Predict the most likely cause of the increase. (3 marks)
- (ii) If the process in **Q2(d)(i)** continues to run, estimate the final mole fraction of water in the product gas. (2 marks)

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- Q3** Methane and oxygen react in the presence of a catalyst to form formaldehyde. In a parallel reaction, methane is oxidized to carbon dioxide and water as described by the following equations:



The feed to the reactor contains equimolar amounts of methane and oxygen. Assume a basis of 100 mol feed/s. The fractional conversion of methane is 0.900 and the fractional yield of formaldehyde is 0.855.

- (a) Draw and label a flowchart for the process mentioned above. (5 marks)
- (b) List the equations for the product stream component flow rates in terms of the two extents of reaction,  $\xi_1$  and  $\xi_2$ . (5 marks)
- (c) Calculate the molar composition of the reactor output stream. (7 marks)
- (d) Determine the selectivity of formaldehyde production relative to carbon dioxide production. (8 marks)

- Q4** Saturated steam at a gauge pressure of 2 bars is to be used to heat a stream of ethane. The ethane enters a heat exchanger at 16°C and 1.5 bar gauge at a rate of  $2.487 \times 10^3$  kg/min and is heated at constant pressure to 93°C. The steam condenses and leaves the exchanger as a liquid at 27°C. The specific enthalpy of ethane at the given pressure is 941 kJ/kg at 16°C and 1073 kJ/kg at 93°C. The enthalpy and specific volume of the vapor and liquid are listed below:  
 Enthalpy of saturated vapor:  $H_1 = 2724.7$  kJ/kg.  
 Enthalpy of liquid at 27°C:  $H_2 = 113.1$  kJ/kg.  
 Specific volume of steam,  $\hat{v} = 0.606$  m<sup>3</sup>/kg.

- (a) Sketch and label in detail the process and unknown involved in the above statement. (5 marks)
- (b) Calculate the energy (kW) that needs to be transferred to the ethane in order to heat it from 16°C to 93°C. (10 marks)
- (c) Assuming that all the energy transferred from the steam goes to heat the ethane, determine the steam rate (in m<sup>3</sup>/s) that needs to be supplied to the exchanger. (10 marks)

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- END OF QUESTION -

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**Unit Conversion****R value**

$$R = 8.31451 \text{ J K}^{-1} \text{ mol}^{-1} = 8.20578 \times 10^{-2} \text{ L atm K}^{-1} \text{ mol}^{-1} = 8.31451 \times 10^{-2} \text{ L bar K}^{-1} \text{ mol}^{-1} = \\ 8.31451 \text{ Pa m}^3 \text{ K}^{-1} \text{ mol}^{-1} = 62.364 \text{ L Torr K}^{-1} \text{ mol}^{-1} = 1.98722 \text{ cal K}^{-1} \text{ mol}^{-1}$$

**Liquid water properties at 4 °C (277.2 K)**

$$\begin{aligned} \text{Density } (\rho) &= 1000 \text{ kg/m}^3 \\ &= 1 \text{ g/cm}^3 \\ &= 62.43 \text{ lb}_m/\text{ft}^3 \end{aligned}$$

**Temperature**

$$\begin{aligned} \text{K} &= \text{°C} + 273.15 \\ \text{°F} &= 32 + 1.8(\text{°C}) \\ \text{°R} &= \text{°F} + 459.67 \\ 100 \text{ °C} &= 212 \text{ °F} + 373.15 \text{ K} = 671.67 \text{ °R} \\ 0 \text{ °C} &= 32 \text{ °F} = 273.15 \text{ K} = 491.67 \text{ °R} \end{aligned}$$

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## FACTORS FOR UNIT CONVERSIONS

## Unit Conversion Factors

Quantity	Equivalent Values
Mass	$1 \text{ kg} = 1000 \text{ g} = 0.001 \text{ metric ton} = 2.20462 \text{ lb}_m = 35.27392 \text{ oz}$ $1 \text{ lb}_m = 16 \text{ oz} = 5 \times 10^{-4} \text{ ton} = 453.593 \text{ g} = 0.453593 \text{ kg}$
Length	$1 \text{ m} = 100 \text{ cm} = 1000 \text{ mm} = 10^6 \mu\text{m} = 10^{10} \text{ \AA}$ $1 \text{ m} = 39.37 \text{ in} = 3.2808 \text{ ft} = 1.0936 \text{ yd} = 0.0006214 \text{ mile}$ $1 \text{ ft} = 12 \text{ in} = 1/3 \text{ yd} = 0.3048 \text{ m} = 30.48 \text{ cm}$
Volume	$1 \text{ m}^3 = 1000 \text{ liters} = 10^6 \text{ cm}^3 = 10^6 \text{ ml}$ $1 \text{ m}^3 = 35.3145 \text{ ft}^3 = 220.83 \text{ imperial gallons} = 264.17 \text{ gal} = 1056.68 \text{ qt}$ $1 \text{ ft}^3 = 1728 \text{ in}^3 = 7.4805 \text{ gal} = 0.028317 \text{ m}^3 = 28.317 \text{ liters} = 28317 \text{ cm}^3$
Force	$1 \text{ N} = 1 \text{ kg}\cdot\text{m}/\text{s}^2 = 10^5 \text{ dynes} = 10^5 \text{ g}\cdot\text{cm}/\text{s}^2 = 0.22481 \text{ lb}_f$ $1 \text{ lb}_f = 32.174 \text{ lb}_m\cdot\text{ft}/\text{s}^2 = 4.4482 \text{ N}$
Pressure	$1 \text{ atm} = 1.01325 \times 10^5 \text{ N}/\text{m}^2 \text{ (Pa)} = 101.325 \text{ kPa} = 1.01325 \text{ bars}$ $1 \text{ atm} = 1.01325 \times 10^6 \text{ dynes}/\text{cm}^2$ $1 \text{ atm} = 760 \text{ mmHg at } 0^\circ\text{C (torr)} = 10.333 \text{ m H}_2\text{O at } 4^\circ\text{C} = 14.696 \text{ lb}_f/\text{in}^2 \text{ (psi)}$ $1 \text{ atm} = 33.9 \text{ ft H}_2\text{O at } 4^\circ\text{C} = 29.921 \text{ inHg at } 0^\circ\text{C}$
Energy	$1 \text{ J} = 1 \text{ N}\cdot\text{m} = 10^7 \text{ ergs} = 10^7 \text{ dyne}\cdot\text{cm} = 2.778 \times 10^{-7} \text{ kW}\cdot\text{h}$ $1 \text{ J} = 0.23901 \text{ cal} = 0.7376 \text{ ft}\cdot\text{lb}_f = 9.486 \times 10^{-4} \text{ Btu}$
Power	$1 \text{ W} = 1 \text{ J}/\text{s} = 1.341 \times 10^{-3} \text{ hp}$

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