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Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2016/2017

COURSE NAME	:	MASS AND ENERGY BALANCES
COURSE CODE	:	BNQ 20903
PROGRAMME CODE	:	BNN
EXAMINATION DATE	:	DECEMBER 2016/JANUARY 2017
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

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THIS QUESTION PAPER CONSISTS OF **SIX (6)** PAGES

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Q1 (a) Chemical engineer technologist usually deals with chemical process.

(i) Define the 'Chemical Process' term.

(2 marks)

(ii) List **FOUR (4)** industries that chemical engineer technologist could work for.

(4 marks)

(b) Identify **THREE (3)** types of separation processes and separating agents based on a solid agent.

(3 marks)

(c) Illustrate the membrane separation and heat exchanger processes and list **TWO (2)** applications in real life or industry.

(6 marks)

(d) 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)

(e) Supposed the equipment involved in industry will apply the mass balance concept which is total mass input equal to the total mass output. However, there are possibilities for the equipment to produce different total mass output. List **FIVE (5)** possible reasons of the discrepancy that you can think of.

(5 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)

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:

$$CH_4 + O_2 \rightarrow HCHO + H_2O$$
$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

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, ξ_1 and ξ_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 2.487×10^3 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, $\acute{\upsilon}$ = 0.606 m^3/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^3/s) that needs to be supplied to the exchanger.

(10 marks)

- END OF QUESTION –

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Unit Conversion

R value

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

Liquid water properties at 4 °C (277.2 K)

Density (ρ) = 1000 kg/m^3
= 1 g/cm^3
= 62.43 lb_m/ft^3

Temperature

K = °C + 273.15
°F= 32 + 1.8(°C)
°R= °F + 459.67
100 °C = 212 °F + 373.15 K = 671.67 °R
0 °C = 32 °F = 273.15 K = 491.67 °R

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FACTORS FOR UNIT CONVERSIONS

Unit Conversion Factors

Quantity	Equivalent Values
Mass	1 kg = 1000 g = 0.001 metric ton = 2.20462 lb_m = 35.27392 oz 1 lb_m = 16 oz = 5×10^{-4} ton = 453.593 g = 0.453593 kg
Length	1 m = 100 cm = 1000 mm = 10^6 μm = 10^{10} Å 1 m = 39.37 in = 3.2808 ft = 1.0936 yd = 0.0006214 mile 1 ft = 12 in = 1/3 yd = 0.3048 m = 30.48 cm
Volume	1 m^3 = 1000 liters = 10^6 cm^3 = 10^6 ml 1 m^3 = 35.3145 ft^3 = 220.83 imperial gallons = 264.17 gal = 1056.68 qt 1 ft^3 = 1728 in^3 = 7.4805 gal = 0.028317 m^3 = 28.317 liters = 28317 cm^3
Force	1 N = 1 kg·m/s^2 = 10^5 dynes = 10^5 g·cm/s^2 = 0.22481 lb_f 1 lb_f = 32.174 lb_m·ft/s^2 = 4.4482 N
Pressure	1 atm = 1.01325×10^5 N/m^2 (Pa) = 101.325 kPa = 1.01325 bars 1 atm = 1.01325×10^6 dynes/cm^2 1 atm = 760 mmHg at 0°C (torr) = 10.333 m H_2O at 4°C = 14.696 lb_f/in^2 (psi) 1 atm = 33.9 ft H_20 at 4°C = 29.921 inHg at 0°C
Energy	1 J = 1 N·m = 10^7 ergs = 10^7 dyne·cm = 2.778×10^{-7} kW·h 1 J = 0.23901 cal = 0.7376 ft-lb_f = 9.486×10^{-4} Btu
Power	1 W = 1 J/s = 1.341×10^{-3} hp

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