Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2022/2023

COURSE NAME	:	MASS AND ENERGY BALANCE
COURSE CODE	:	DAK 12903
PROGRAMME CODE	:	DAK
EXAMINATION DATE	:	FEBRUARY 2023
DURATION	:	3 HOURS
INSTRUCTIONS	:	1. ANSWER **ALL** QUESTIONS
		2. THIS FINAL EXAMINATION IS CONDUCTED VIA **CLOSED BOOK.**
		3. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

THIS QUESTION PAPER CONSISTS OF **SEVEN (7)** PAGES

Q1 (a) A 0.9 mol/L (M) aqueous solution of nitric acid (HNO_3) flows into a process unit at a rate of 2.65 m^3/min. The specific gravity of the solution is 1.5. (Given ρ_{water}=1000kg/m^3, MW_{HNO3} = 63.02 g/mol).

(i) Calculate the mass concentration of HNO_3 in kg/m^3

(2 marks)

(ii) Determine the mass flow rate of HNO_3 in kg/s

(2 marks)

(iii) Find the mass fraction of HNO_3

(6 marks)

(b) An inlet stream that contains 20 mole% of water vapor and 80 mole% of dry air enters a condenser. Dry air may be taken to contain 21mole% of oxygen, with the balance nitrogen. The condensation process occurs whereby a 90% of the water vapor in the inlet stream is condensed and found to be 225 L/h of pure water. Another outlet stream of condenser removes the same component as the inlet stream. (Given ρ_{water} = 1000kg/m^3, MW_{water} = 18.0 kg/kmol).

(i) Determine the molar flow rates for all streams

(9 marks)

(ii) Calculate the mole fractions of oxygen, nitrogen and water in the outlet stream.

(6 marks)

Q2 (a) 5000 kg/h of a solution that is 40% of sodium chloride (NaCl) by mass is joined by a recycle stream containing 45% of NaCl, and the combined stream is fed into an evaporator. The condensed stream contains a pure water whereas the concentrated stream leaving the evaporator contains 50% NaCl and this stream is fed into a crystallizer in which it is cooled, causing the crystals of NaCl to come out of solution and then filtered. The filter cake consists of pure NaCl crystals and a solution that contains 45% NaCl by mass. The crystals account for 95% of the total mass of the filter cake. The solution that passes through the filter also contains of 45% NaCl.

(i) Draw the process flow diagram.

(4 marks)

(ii) Determine the rate of evaporation at the condensed stream.

(9 marks)

(iii) Calculate the feed rates to the evaporator and crystallizer.

(9 marks)

(iv) Solve the recycle ratio (mass of recycle/mass of fresh feed)

(3 marks)

Q3 (a) Copper (II) sulphate is produced in the reaction of copper (II) oxide with sulphuric acid.

$$CuO + H_2SO_4 \longrightarrow CuSO_4 + H_2O$$

100 mol of feed contains 45 mole% of copper (II) oxide and 55 mole% of sulphuric acid. In this reaction, a fractional conversion of 30% of the limiting reactant is achieved.

(i) Determine the limiting reactant.

(4 marks)

(ii) Solve the percentage of excess reactant.

(4 marks)

(iii) Calculate the molar amounts of all products.

(7 marks)

(b) A 100 mol/h of butane (C_4H_{10}) and 5000 mol/h of air (21% of oxygen) fed into a combustion reactor. The reaction process occurs between the butane and oxygen producing carbon dioxide (CO_2) and water (H_2O) as the outlet products.

(i) Write the balance combustion reaction of butane and oxygen.

(2 marks)

(ii) Find the molar flow rates of theoretical oxygen and air.

(5 marks)

(iii) Calculate the percentage of excess air.

(3 marks)

Q4 (a) In a 6L of flask, carbon dioxide at an initial pressure of 5 bar is cooled from 110°C to 40°C. Assume the cooling process occurs in an ideal gas behavior. The heat capacities (Cp) values were given in **Table Q4**.
[Given R = 8.314 x 10^{-3} kJ/(mol.°C) = 0.08314 L.bar/(mol.K)]

(i) State the value of specific heat at constant volume in function of temperature.

(2 marks)

(ii) Calculate the internal energy inside the system

(4 marks)

(iii) Find the number of moles at the initial condition

(2 marks)

(iv) Determine the heat transferred during the cooling process.

(2 marks)

(b) A stream containing 10% ammonia (NH_3) and 90% air by volume is to be heated from 30°C to 250°C. The molar flow rate for the inlet and outlet streams of every component remains constant throughout the process. The flow rate of the gas is 4.00 x 10^3 liters (STP)/min. Given the specific molar volume at STP is 22.4 L(STP)/mol whereas the specific enthalpy of air at the inlet and outlet streams are -0.15kJ/mol and 8.17 kJ/mol, respectively as per tabulated data in **Table Q4(b)**. The heat capacities (Cp) values were given in Table **Q4**.

(i) Calculate the molar flow rate of the ammonia and air.

(6 marks)

(ii) Determine the specific enthalpy of ammonia at the outlet stream.

(4 marks)

(iii) Solve the required rate of heat for this operation in kilowatts.

(5 marks)

-END OF QUESTIONS-

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Table Q4

Compound	a x 10^{-3}	b x 10^{-5}	c x 10^{-8}	d x 10^{-12}
Ammonia	35.15	2.954	0.4421	-6.686
Carbon Dioxide	36.11	4.233	-2.887	7.464

Table Q4 (b)

References: NH_3 (g, 20°C, 1atm), air (g, 25°C, 1atm)

Substance	n_{in} (mol/min)	$\hat{H}_{in}$ (kJ/mol)	n_{out} (mol/min)	$\hat{H}_{out}$ (kJ/mol)
Ammonia	n_{NH3}	0	n_{NH3}	$\hat{H}$
Air	n_{Air}	-0.15	n_{Air}	8.17

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FORMULA

$SG = \frac{\rho_{substance}}{\rho_{reference}}$

$\rho = \frac{m}{v}$

$\dot{m} = \rho.Q$

$Q = v.A$

$F = m.a$

$P = \frac{F}{A}$

$n_i = n_o + V.\xi$

$PV = nRT$

$\Delta U + \Delta E_k + \Delta E_p = Q - W$

$\hat{H} = \hat{U} + P\hat{V}$

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

$\dot{W} = \dot{W}_s + \dot{W}_{fl}$

$\Delta E_k = m\frac{{V_2}^2 - {V_1}^2}{2}$

$\Delta E_p = mg(z_2 - z_1)$

$\Delta U = \int_{T_1}^{T_2} C_v(T)\, dT$

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

$C_p = a + bT + cT^2 + dT^3$

$C_p = C_v + R$

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CONVERSION OF UNITS

Mass	1 kg	= 1000 g = 0.001 metric ton = 2.20462 lb_m = 35.27392 oz
	1 lb_m	= 16 oz = 5 x 10^{-4} ton = 453.593 g = 0.453593 kg
Length	1 m	= 100 cm = 1000 mm = 10^6 microns (μm) = 10^{10} angstroms ($\overset{0}{A}$)
		= 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
		= 35.3145 ft^3 = 220.83 imperial gallons = 264.17 gal
		= 1056.68 qt
	1ft^3	= 1728 in^3 = 7.4805 gal = 0.028317 m^3 = 28.317 liters
		= 28 317 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 = 4.4482 x 10^5 dynes
Pressure	1 atm	= 1.01325 x 10^5 N/m^2 (Pa) = 101.325 kPa = 1.01325 bars
		= 1.01325 x 10^6 dynes/cm^2
		= 760 mm Hg at 0°C (torr) = 10.333 m H_2O at 4°C
		= 14.696 lb_f/in^2 (psi) = 33.9 ft H_2O at 4°C
		= 29.921 in Hg at 0°C
Energy	1 J	= 1 N.m = 10^7 ergs = 10^7 dyne.cm
		= 2.778 x 10^{-7} kW.h = 0.23901 cal
		= 0.7376 ft-lb_f = 9.486 x 10^{-4} Btu
Power	1 W	= 1 J/s = 0.23901 cal/s = 0.7376 ft.lb_f/s = 9.486 x 10^{-4} Btu/s
		= 1.341 x 10^{-3} hp