Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2023/2024

COURSE NAME	:	MASS AND ENERGY BALANCE
COURSE CODE	:	DAK 12903
PROGRAMME CODE	:	DAK
EXAMINATION DATE	:	JANUARY / FEBRUARY 2024
DURATION	:	3 HOURS
INSTRUCTIONS	:	1. ANSWER ALL QUESTIONS 2. THIS FINAL EXAMINATION IS CONDUCTED VIA ☐ Open book ☒ 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 **SIX (6)** PAGES.

Q1 (a) Define the following terms.

(i) Specific gravity.

(ii) Molecular weight.

(iii) Temperature.

(3 marks)

(b) Convert $\frac{15(in)(cm^2)}{(week)(s)(lb_m)(ft^2)}$ to all SI units.

(7 marks)

(c) As an engineer, you are tasked to design a desalination plant supplying 20,000 kg of freshwater per month. The seawater contains 93.5 wt% water, 4.5 wt% salt, and 2 wt% of ultrafine sand particles. At the first stage of the desalination process, 100 % of the ultrafine sand particles will be removed via multi-media filters. The filtered seawater containing only water and salt will then be pressurized up to 1000 psi to allow the water to pass through the reverse osmosis membranes to produce clean water (H_2O). However, the reverse osmosis process can only convert 40 wt% of the seawater into pure water, while 60 wt% of unrecovered water will be discharged together with the salt.

(i) Draw the mass balance diagram for this process.

(5 marks)

(ii) Determine the mass flow rate for all streams in this process in kg/month.

(10 marks)

Q2 Candy production started when a flavoured sugar solution was dried using a single evaporator (E), followed by two crystallizers (C_1 and C_2). The process begins when 1000 kg/h of feed solution (F) containing 20 wt% sugar is fed to an evaporator, which evaporates some water at 453K to produce 63 wt% of sugar solution. This solution is then provided to the first crystallizer (C_1) at 297K, where candy containing 73 wt% sugar is produced. A saturated solution containing 30 wt% sugar is recycled back to the evaporator in this first crystallizer. Next, the candy is fed to the second crystallizer (C_2), where candy containing 93 wt% sugar is produced. A saturated solution containing 30 wt% sugar is recycled back to the first crystallizer in this second crystallizer.

(a) Draw a diagram based on the problem above.

(7 marks)

(b) Calculate all the flowrate involved in the production of candy.

(14 marks)

(c) Solve the recycle ratio at evaporator (E) and first crystallizer (C_1). Given recycle ratio is mass of recycle/mass of fresh feed.

(4 marks)

Q3 Chemical reactions play a crucial role in various fields of science and technology. A good understanding and manipulation of chemical reactions are essential for advancements in the production of chemical-based products.

(a) The oxidation of ethylene (C_2H_4) using oxygen (O_2) to produce ethylene oxide C_2H_4O occurs in a catalytic reactor. The inlet feed contains 100g of C_2H_4 and 250 g of O_2. [MW: $C_2H_4 = 28$, $O_2 = 32$ g/mol]

(i) Construct and balance the chemical equation for the reaction.

(2 marks)

(ii) Solve the number of moles for ethylene and oxygen.

(4 marks)

(iii) Determine the limiting reactant based on the calculation of actual and stoichiometric ratios.

(4 marks)

(b) The reactions occur within a continuous reactor operating at a steady state.

$$C_2H_6 \longrightarrow C_2H_4 + H_2$$

$$C_2H_6 + H_2 \longrightarrow 2CH_4$$

A 100 mol of input comprises 75.0 mole% C_2H_6, with the remaining portion being inert gases (I). The fractional conversion of C_2H_6 is 0.545, and the fractional yield of C_2H_4 is 0.425.

(i) Find the maximum possible yield of C_2H_4.

(2 marks)

(ii) Calculate the molar composition of the product gas using the extent of reaction formula.

(11 marks)

(iii) Determine the selectivity in the production of C_2H_4 over CH_4.

(2 marks)

Q4 The concepts of an ideal gas and energy balance are relevant and have practical applications in various aspects. Hence, there are numerous industries and fields where the principles of ideal gas behaviour and energy balance are crucial for efficient operation.

(a) Ethane (C_2H_6) flows into the reactor at 4 atm and 127 °C. The mass flow rate is 300 kg/h. [C = 12, H = 1 (kg/kmol)]

[Standard condition: Ps =1atm, Ts = 273K, V/n = 22.415 L/mol]

(i) Find the temperature in Kelvin.

(2 marks)

(ii) Determine the molecular weight of ethane.

(3 marks)

(iii) Solve the molar flow rate of ethane inside the stream.

(2 marks)

(iv) Calculate the volumetric flow rate of the stream in m^3/hr.

(3 marks)

(b) A turbine is powered by 400 kg/h. The steam is introduced into the turbine at 32 atm of pressure and a temperature of 400 °C, with a linear speed of 70 m/s. It exits the turbine 7 meters below the inlet, at atmospheric pressure, and a velocity of 220 m/s. The turbine generates shaft work at a rate of 80 kW, and it is estimated that the heat loss from the turbine amounts to 12,000 kcal/hr.

(Given g = 9.81 m/s^2)

(i) Convert the value of heat loss into kJ/s.

(2 marks)

(ii) Determine the rate of enthalpy change in kJ/s.

(8 marks)

(iii) Calculate the specific enthalpy change associated with the process in kJ/s.

(3 marks)

(iv) Calculate the specific enthalpy change associated with the process in kJ/kg.

(2 marks)

- END OF QUESTIONS -

APPENDIX 1

FORMULA

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

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

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

$Q = v.A$

$\frac{P.\ \dot{V}}{P_s\ .\hat{V}_s}\ n\frac{T}{T_s}$

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

$n_i = n_o \pm V.\xi$

$PV = nRT$

$\Delta U + \Delta E_k + \Delta E_p = Q\text{-}W$

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

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

$\Delta\dot{H} = \dot{m}.\Delta\hat{H}$

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

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

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

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

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

$C_p = C_v + R$

APPENDIX B

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