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Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2019/2020

COURSE NAME	:	MASS AND ENERGY BALANCE
COURSE CODE	:	DAK 12903 / DAK 22903
PROGRAMME	:	DAK
EXAMINATION DATE	:	DECEMBER 2019 / JANUARY 2020
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

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

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Q1 (a) There are **five (5)** general classification of separation techniques in chemical plant.

(i) List all of them.

(5 marks)

(ii) Explain and give one example for each of them.

(10 marks)

(b) Most processes for production high energy content gas or gasoline from coal include some types of gasification step to make hydrogen or synthesis gas. Pressure gasification is preferred because of its greater yield of methane and higher rate of gasification. Given that a 50 kg test run of gas averages 10.0% H_2, 40.0% CH_4, 30.0% CO and 20.0% CO_2. Calculate:

(i) The mole fraction for each component.

(8 marks)

(ii) The average molecular weight of the mixture

(2 marks)

Q2 (a) One hundred kilograms per minute of a mixture containing 60% oil and 40% water by mass are fed into a settling tank that operates at a steady state. Two products streams emerge from the settler, the top one contains pure oil, and the bottom one is 90% water by mass.

i. Draw a diagram for this process.

(4 marks)

ii. Determine the flowrate for the two product streams.

(6 marks)

(b) In a distillation column, a liquid hydrocarbon containing 20% ethane (C2), 40% propane (C3) and 40% butane (C4) is to be fractionated into essentially pure components as shown in the **Figure Q2 (b).** By referring to that figure, calculate the value of E, A, P, B and the composition of C2, C3 and C4 at A.

(15 marks)

Q3 Ethylene glycol ($HOCH_2CH_2OH$), used as an antifreeze, is produced by reacting ethylene oxide (C_2H_4O) with water (H_2O). A side reaction produce an undesirable dimer ($HOCH_2CH_2OCH_2CH_2OH$). The reactor feed is 100 mol/s ethylene oxide and 100 mol/s water.

$$C_2H_4O + H_2O \longrightarrow HOCH_2CH_2OH$$
$$HOCH_2CH_2OH + C_2H_4O \longrightarrow HOCH_2CH_2OCH_2CH_2OH$$

(a) Draw a diagram for this process.

(4 marks)

(b) Derive the expression for the product stream component flow rates in terms of the two extents of reaction, ξ_1 and ξ_2.

(4 marks)

(c) If the fractional conversion of ethylene oxide (C_2H_4O) is 0.9 and the fractional yield for ethylene glycol ($HOCH_2CH_2OH$) is 0.45, calculate the reactor outlet composition and determine the selectivity of ethylene glycol ($HOCH_2CH_2OH$) relative to dimer ($HOCH_2CH_2OCH_2CH_2OH$).

(17 marks)

Q4 (a) Define the term below:

(i) Energy.
(ii) Kinetic energy.
(iii) Potential energy.
(iv) Internal energy.

(8 marks)

(b) The cracking process of ethane (C_2H_6) to form ethylene (C_2H_4) is shown below:

$$C_2H_6\,(v) \longrightarrow C_2H_4\,(v) + H_2\,(g) \qquad \Delta \hat{H}_r = +136.95 \text{ kJ/mol}$$

300 mol/s of ethane (C_2H_6) vapor is fed to the reactor at the temperature 400°C and a conversion 60% of C_2H_6 is achieved. The product gas emerges at 100°C. (Assume reference temperature is 400°C).

(i) Prepare the inlet-outlet enthalpy table.

(4 marks)

(ii) Find the required heat cooling rate.

(13 marks)

– END OF QUESTION –

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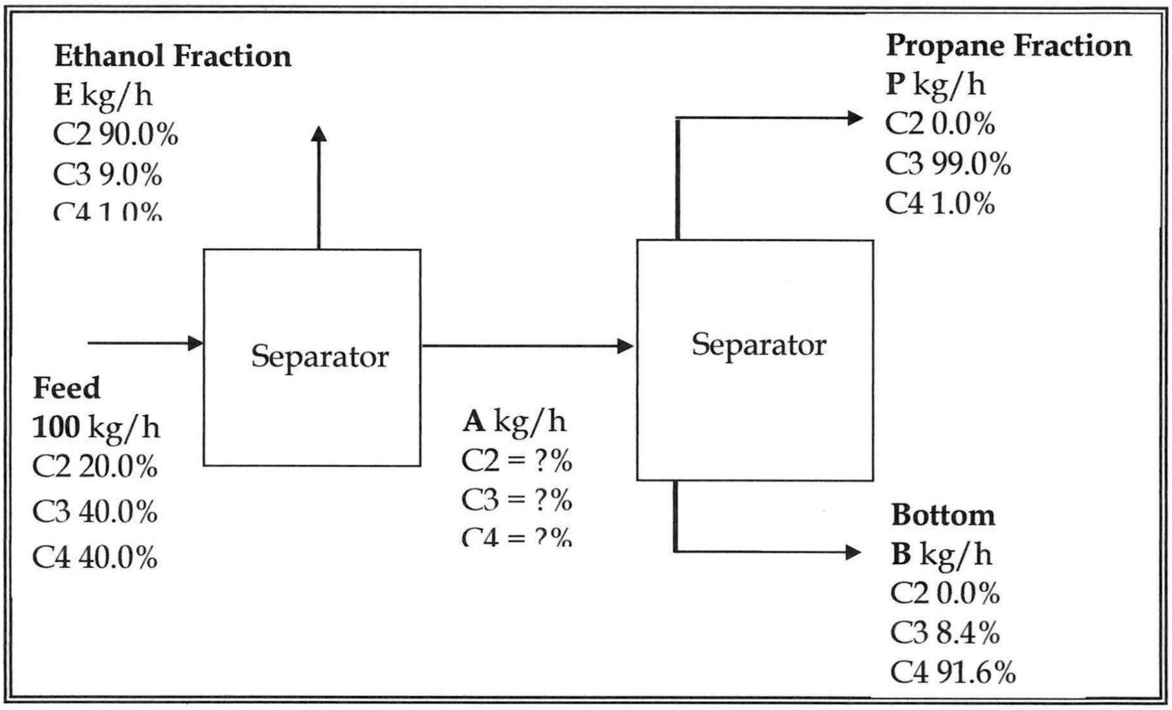

FIGURE Q2 (b)

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List of Formula

Water density = 1000 $kg.m^{-3}$

Molecular weight, O = 16 g/mol, H = 1 g/mol, N = 14 g/mol, C = 12 g/mol

101,325 Pa = 760 mmHg

1 m^3 = 1000 L

1 kJ/s = 1 kW

R (gas constant) = 0.08206 L.atm/ mol.K

$$\dot{Q} = \dot{m} \hat{C}_{p,i}(T_2 - T_1)$$

$$\Delta \hat{H}_R = \sum v_i \times \hat{H}_R \ (product) - \sum v_i \times \hat{H}_R \ (reac \tan t)$$

$$Q = \sum n_{out} \overset{\Delta}{H}_{out} - \sum n_{in} \overset{\Delta}{H}_{in}$$

$$Q = \sum n_{out} \overset{\Delta}{H}_{out} - \sum n_{in} \overset{\Delta}{H}_{in} + \xi \overset{\Delta}{H}_r$$

$$\int C_p dT = \int_{T_1}^{T_2} a*10^{-3} + b*10^{-5}T - c*10^{-8}T^2 + d*10^{-12}T^3 dT$$

$$fractional\ conversion = \frac{moles\ in - moles\ out}{moles\ in}$$

$$\Delta H = \dot{n} \Delta \hat{H}$$

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List of Physical Property Tables

Compound	Formula	Mol. Wt.	SG (20°/4°)	T_m(°C)[b]	$\Delta\hat{H}_m(T_m)$[c,e] kJ/mol	T_b(°C)[d]	$\Delta\hat{H}_v(T_b)$[c,e] kJ/mol	T_c(K)[f]
Chloroform	$CHCl_3$	119.39	1.489	−63.7	—	61.0		536.0
Copper	Cu	63.54	8.92	1083	13.01	2595	304.6	—
Cupric sulfate	$CuSO_4$	159.61	3.606[15°]			Decomposes > 600°C		
Cyclohexane	C_6H_{12}	84.16	0.779	6.7	2.677	80.7	30.1	553.7
Cyclopentane	C_5H_{10}	70.13	0.745	−93.4	0.609	49.3	27.30	511.8
n-Decane	$C_{10}H_{22}$	142.28	0.730	−29.9	—	173.8	—	619.0
Diethyl ether	$(C_2H_5)_2O$	74.12	0.708[25°]	−116.3	7.30	34.6	26.05	467
Ethane	C_2H_6	30.07	—	−183.3	2.859	−88.6	14.72	305.4
Ethyl acetate	$C_4H_8O_2$	88.10	0.901	−83.8	—	77.0	—	523.1
Ethyl alcohol (Ethanol)	C_2H_5OH	46.07	0.789	−114.6	5.021	78.5	38.58	516.3
Ethyl benzene	C_8H_{10}	106.16	0.867	−94.67	9.163	136.2	35.98	619.7
Ethyl bromide	C_2H_5Br	108.98	1.460	−119.1	—	38.2	—	504
Ethyl chloride	C_2H_5Cl	64.52	0.903[15°]	−138.3	4.452	13.1	24.7	460.4
3-Ethyl hexane	C_8H_{18}	114.22	0.717	—	—	118.5	34.27	567.0
Ethylene	C_2H_4	28.05	—	−169.2	3.350	−103.7	13.54	283.1
Ethylene glycol	$C_2H_6O_2$	62.07	1.113[19°]	−13	11.23	197.2	56.9	—
n-Heptane	C_7H_{16}	100.20	0.684	−90.59	14.03	98.43	31.69	540.2
n-Hexane	C_6H_{14}	86.17	0.659	−95.32	13.03	68.74	28.85	507.9
Hydrogen	H_2	2.016	—	−259.19	0.12	−252.76	0.904	33.3
Hydrogen bromide	HBr	80.92	—	86	—	−67	—	—
Hydrogen chloride	HCl	36.47	—	−114.2	1.99	−85.0	16.1	324.6
Hydrogen cyanide	HCN	27.03	—	14	—	26	—	—
Hydrogen fluoride	HF	20.0	—	83	—	20	—	503.2

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List of Physical Property Tables

Form 1: C_p[kJ/(mol·°C)] or [kJ/(mol·K)] = $a + bT + cT^2 + dT^3$
Form 2: C_p[kJ/(mol·°C)] or [kJ/(mol·K)] = $a + bT + cT^{-2}$

Example: $(C_p)_{acetone(g)} = 0.07196 + (20.10 \times 10^{-5})T - (12.78 \times 10^{-8})T^2 + (34.76 \times 10^{-12})T^3$, where T is in °C.

Note: The formulas for gases are strictly applicable at pressures low enough for the ideal gas equation of state to apply.

Compound	Formula	Mol. Wt.	State	Form	Temp. Unit	$a \times 10^3$	$b \times 10^5$	$c \times 10^8$	$d \times 10^{12}$	Range (Units of T)
Cumene (Isopropyl benzene)	C_9H_{12}	120.19	g	1	°C	139.2	53.76	−39.79	120.5	0–1200
Cyclohexane	C_6H_{12}	84.16	g	1	°C	94.140	49.62	−31.90	80.63	0–1200
Cyclopentane	C_5H_{10}	70.13	g	1	°C	73.39	39.28	−25.54	68.66	0–1200
Ethane	C_2H_6	30.07	g	1	°C	49.37	13.92	−5.816	7.280	0–1200
Ethyl alcohol (Ethanol)	C_2H_5OH	46.07	l	1	°C	103.1				0
			l	1	°C	158.8				100
			g	1	°C	61.34	15.72	−8.749	19.83	0–1200
Ethylene	C_2H_4	28.05	g	1	°C	+40.75	11.47	−6.891	17.66	0–1200
Ferric oxide	Fe_2O_3	159.70	c	2	K	103.4	6.711	-17.72×10^{10}	—	273–1097
Formaldehyde	CH_2O	30.03	g	1	°C	34.28	4.268	0.0000	−8.694	0–1200
Helium	He	4.00	g	1	°C	20.8				0–1200
n-Hexane	C_6H_{14}	86.17	l	1	°C	216.3				20–100
			g	1	°C	137.44	40.85	−23.92	57.66	0–1200
Hydrogen	H_2	2.016	g	1	°C	28.84	0.00765	0.3288	−0.8698	0–1500
Hydrogen bromide	HBr	80.92	g	1	°C	29.10	−0.0227	0.9887	−4.858	0–1200
Hydrogen chloride	HCl	36.47	g	1	°C	29.13	−0.1341	0.9715	−4.335	0–1200
Hydrogen cyanide	HCN	27.03	g	1	°C	35.3	2.908	1.092		0–1200
Hydrogen sulfide	H_2S	34.08	g	1	°C	33.51	1.547	0.3012	−3.292	0–1500
Magnesium chloride	$MgCl_2$	95.23	c	1	K	72.4	1.58			273–991
Magnesium oxide	MgO	40.32	c	2	K	45.44	0.5008	-8.732×10^{10}		273–2073
Methane	CH_4	16.04	g	1	°C	34.31	5.469	0.3661	−11.00	0–1200
			g	1	K	19.87	5.021	1.268	−11.00	273–1500