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FINAL EXAMINATION QUESTION BOOKLET

COURSE CODE	:	DTC1063
COURSE	:	ELEMENTARY PRINCIPLES OF CHEMICAL PROCESS
SEMESTER/SESSION	:	2 - 2022/2023
DURATION	:	3 HOURS

Instructions:

1. This booklet contains **5** questions. Answer **ALL** questions.
2. All answers should be written in answer booklet.
3. Write legibly and draw sketches wherever required.
4. If in doubt, raise up your hands and ask the invigilator.

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO

THIS BOOKLET CONTAINS 8 PRINTED PAGES INCLUDING COVER PAGE

QUESTION 1

(a) List out three (3) base unit (3 marks)

(b) Give three (3) examples of derive unit (Quantity and Unit). (3 marks)

(c) Use the conversion table provided to convert the following:

i. 23 $lbm.ft/min^2$ to its equivalent in $kg.cm/s^2$ (2 marks)

ii. An acceleration of 1 cm/s^2 to its equivalent in km/yr^2. (2 marks)

QUESTION 2

(a) Define the following terms:

i. Mass flow rate (2 marks)
ii. Molar concentration (2 marks)
iii. ppm (2 marks)

(b) Explain the differences between absolute pressure, gauge pressure and atmospheric pressure. (6 marks)

(c) A mixture is 10.0 mole % ethyl alcohol (C_2H_5OH), 75.0 mole % ethyl acetate ($C_4H_8O_2$), and 15.0 mole % acetic acid (CH_3COOH).

Solve the following

i. The mass fraction of each compound (3 marks)
ii. The average molecular weight of the mixture (3 marks)

QUESTION 3

(a)
i. State the general material balance equation for single unit process (2 marks)
ii. Define the continuous process. (2 marks)
iii. List one (2) example of batch process (2 marks)

(b)
i. Explain the main difference between recycle and bypass stream (2 marks)
ii. Clarify what will happen to mass total and mass fraction when a stream is recycle. (2 marks)
iii. Draw and label a flow chart that illustrate the process ethanol purification (separate water) using a distillation column. (3 marks)

(c) A liquid mixture containing 30.0 mole % benzene (B), 25.0 mole % toluene (T), and the balance xylene (X) is fed to a distillation column. The bottoms product contains 98.0 mole % X and no B, and 96.0% of the X in the feed is recovered in this stream. The overhead product is fed to a second column. The overhead product from the second column contains 97.0% of the B in the feed to this column. The composition of this stream is 94.0 mole % B and the balance T.

i. Draw and label a flowchart of this process. (3 marks)
ii. Calculate the molar ratio of the benzene at the overhead product of second column to the feed of the first column. (7 marks)

QUESTION 4

(a) Define the following:

i. Kinetic Energy (2 marks)

ii. Potential Energy (2 marks)

iii. Internal Energy (2 marks)

(b) i. State the general energy equation for close system. (2 marks)

ii. Describe the condition for adiabatic and isothermal process. (4 marks)

(c) A horizontal cylinder equipped with a frictionless piston contains 785 cm^3 of steam at 400 K and 125 kPa. A total of 83.8 joules of heat is transferred to the steam, causing the steam temperature to rise and the cylinder volume to increase. A constant restraining force is maintained on the piston throughout the expansion, so that the pressure exerted by the piston on the steam remains constant at 125 kPa.

Calculate

i. the final cylinder volume (3 marks)

ii. the final temperature (3 marks)

(d) i. By definition, what are C_v and C_p? (2 marks)

ii. State the phase change of the following process:

a. Vaporization (2 marks)

b. Sublimation (2 marks)

QUESTION 5

(a) Use the data in Table B.2 to calculate the following:

i. The heat capacity (Cp) of liquid benzene at 40 °C (2 marks)
ii. The heat capacity at constant pressure of benzene vapor at 40 °C (2 marks)
iii. The heat capacity at constant pressure of solid carbon at 40 °C (2 marks)

(b) Define the following terms:
i. Exothermic process (2 marks)
ii. Endothermic process (2 marks)
iii. Heat of formation (2 marks)

(c) i. Give two (2) examples of exothermic and endothermic process (4 marks)
ii. Explain the two (2) methods that can be used for solving energy balance for reactive process (may use flow chart for explanations). (3 marks)

(d) The standard heats of the following combustion reactions have been determined experimentally. (6 marks)

1. $C_2H_6 + 7/2\ O_2 \longrightarrow 2\ CO_2 + 3\ H_2O$: $\Delta\hat{H}^\circ_{r1} = -1559.8$ kJ/mol
2. $C + O_2 \longrightarrow CO_2$: $\Delta\hat{H}^\circ_{r2} = -393.5$ kJ/mol
3. $H_2 + 1/2O_2 \longrightarrow H_2O$: $\Delta\hat{H}^\circ_{r3} = -285.8$ kJ/mol

Use Hess's law and the given heats of reaction to determine the standard heat of the following reaction:

$$2\ C + 3\ H_2 \longrightarrow C_2H_6$$

APPENDIX

A. Factor for unit conversion

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 microns (μm) = 10^{10} angstroms (Å) = 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 L = 10^6 cm^3 = 10^6 mL = 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 L = 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 = 4.4482×10^5 dynes
Pressure	1 atm = 1.01325×10^5 N/m^2 (Pa) = 101.325 kPa = 1.01325 bar = 1.01325×10^6 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 = 2.778×10^{-7} kW·h = 0.23901 cal = 0.7376 ft-lb_f = 9.486×10^{-4} Btu
Power	1 W = 1 J/s = 0.23901 cal/s = 0.7376 ft·lb_f/s = 9.486×10^{-4} Btu/s = 1.341×10^{-3} hp

Example: The factor to convert grams to lb_m is $\left(\frac{2.20462\ lb_m}{1000\ g}\right)$.

Physical Property database
Quickly integrates tabulated heat capacities

Table B.2 Heat Capacities[a]

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)
Acetone	CH_3COCH_3	58.08	l	1	°C	123.0	18.6			−30–60
			g	1	°C	71.96	20.10	−12.78	34.76	0–1200
Acetylene	C_2H_2	26.04	g	1	°C	42.43	6.053	−5.033	18.20	0–1200
Air		29.0	g	1	°C	28.94	0.4147	0.3191	−1.965	0–1500
			g	1	K	28.09	0.1965	0.4799	−1.965	273–1800
Ammonia	NH_3	17.03	g	1	°C	35.15	2.954	0.4421	−6.686	0–1200
Ammonium sulfate	$(NH_4)_2SO_4$	132.15	c	1	K	215.9				275–328
Benzene	C_6H_6	78.11	l	1	°C	126.5	23.4			6–67
			g	1	°C	74.06	32.95	−25.20	77.57	0–1200
Isobutane	C_4H_{10}	58.12	g	1	°C	89.46	30.13	−18.91	49.87	0–1200
n-Butane	C_4H_{10}	58.12	g	1	°C	92.30	27.88	−15.47	34.98	0–1200
Isobutene	C_4H_8	56.10	g	1	°C	82.88	25.64	−17.27	50.50	0–1200
Calcium carbide	CaC_2	64.10	c	2	K	68.62	1.19	-8.66×10^{10}	—	298–720
Calcium carbonate	$CaCO_3$	100.09	c	2	K	82.34	4.975	-12.87×10^{10}	—	273–1033
Calcium hydroxide	$Ca(OH)_2$	74.10	c	1	K	89.5				276–373
Calcium oxide	CaO	56.08	c	2	K	41.84	2.03	-4.52×10^{10}		273–1173
Carbon	C	12.01	c	2	K	11.18	1.095	-4.891×10^{10}		273–1373
Carbon dioxide	CO_2	44.01	g	1	°C	36.11	4.233	−2.887	7.464	0–1500
Carbon monoxide	CO	28.01	g	1	°C	28.95	0.4110	0.3548	−2.220	0–1500
Carbon tetrachloride	CCl_4	153.84	l	1	K	93.39	12.98			273–343
Chlorine	Cl_2	70.91	g	1	°C	33.60	1.367	−1.607	6.473	0–1200
Copper	Cu	63.54	c	1	K	22.76	0.6117			273–1357

[a] Adapted in part from D. M. Himmelblau, *Basic Principles and Calculations in Chemical Engineering,* 3rd Edition, © 1974, Table E.1. Adapted by permission of Prentice-Hall, Inc., Englewood Cliffs, NJ.

(*continued*)