

**UNIVERSITY COLLEGE TATI (UC TATI)****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<sup>2</sup> to its equivalent in kg.cm/s<sup>2</sup> (2 marks)
  - ii. An acceleration of 1 cm/s<sup>2</sup> to its equivalent in km/yr<sup>2</sup>. (2 marks)

## ELEMENTARY PRINCIPLES OF CHEMICAL PROCESS(DTC 1063)

---

**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)

## ELEMENTARY PRINCIPLES OF CHEMICAL PROCESS(DTC 1063)

**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)

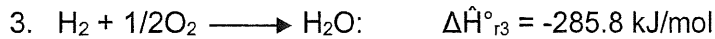
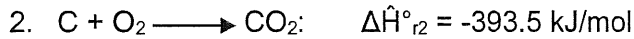
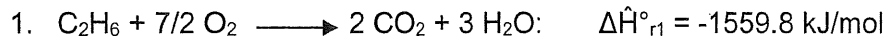
## ELEMENTARY PRINCIPLES OF CHEMICAL PROCESS(DTC 1063)

**QUESTION 4**

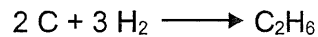
- (a) Define the following:
- i. Kinetic Energy (2 marks)
  - ii. Potential Energy (2 marks)
  - iii. Internal Energy (2 marks)
- (b)
- i. State the general energy equation for close system. (2 marks)
  - ii. Describe the condition for adiabatic and isothermal process. (4 marks)
- (c) A horizontal cylinder equipped with a frictionless piston contains  $785 \text{ cm}^3$  of steam at  $400 \text{ K}$  and  $125 \text{ kPa}$ . 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  $125 \text{ kPa}$ .
- 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 ( $C_p$ ) 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)



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



## ELEMENTARY PRINCIPLES OF CHEMICAL PROCESS(DTC 1063)

## APPENDIX

## A. Factor for unit conversion

Quantity	Equivalent Values
Mass	$1 \text{ kg} = 1000 \text{ g} = 0.001 \text{ metric ton} = 2.20462 \text{ lb}_m = 35.27392 \text{ oz}$ $1 \text{ lb}_m = 16 \text{ oz} = 5 \times 10^{-4} \text{ ton} = 453.593 \text{ g} = 0.453593 \text{ kg}$
Length	$1 \text{ m} = 100 \text{ cm} = 1000 \text{ mm} = 10^6 \text{ microns } (\mu\text{m}) = 10^{10} \text{ angstroms } (\text{\AA})$ $= 39.37 \text{ in.} = 3.2808 \text{ ft} = 1.0936 \text{ yd} = 0.0006214 \text{ mile}$ $1 \text{ ft} = 12 \text{ in.} = 1/3 \text{ yd} = 0.3048 \text{ m} = 30.48 \text{ cm}$
Volume	$1 \text{ m}^3 = 1000 \text{ L} = 10^6 \text{ cm}^3 = 10^6 \text{ mL}$ $= 35.3145 \text{ ft}^3 = 220.83 \text{ imperial gallons} = 264.17 \text{ gal}$ $= 1056.68 \text{ qt}$ $1 \text{ ft}^3 = 1728 \text{ in.}^3 = 7.4805 \text{ gal} = 0.028317 \text{ m}^3 = 28.317 \text{ L}$ $= 28,317 \text{ cm}^3$
Force	$1 \text{ N} = 1 \text{ kg}\cdot\text{m/s}^2 = 10^5 \text{ dynes} = 10^5 \text{ g}\cdot\text{cm/s}^2 = 0.22481 \text{ lb}_f$ $1 \text{ lb}_f = 32.174 \text{ lb}_m\cdot\text{ft/s}^2 = 4.4482 \text{ N} = 4.4482 \times 10^5 \text{ dynes}$
Pressure	$1 \text{ atm} = 1.01325 \times 10^5 \text{ N/m}^2 \text{ (Pa)} = 101.325 \text{ kPa} = 1.01325 \text{ bar}$ $= 1.01325 \times 10^6 \text{ dynes/cm}^2$ $= 760 \text{ mm Hg at } 0^\circ\text{C (torr)} = 10.333 \text{ m H}_2\text{O at } 4^\circ\text{C}$ $= 14.696 \text{ lb}_f/\text{in.}^2 \text{ (psi)} = 33.9 \text{ ft H}_2\text{O at } 4^\circ\text{C}$ $= 29.921 \text{ in. Hg at } 0^\circ\text{C}$
Energy	$1 \text{ J} = 1 \text{ N}\cdot\text{m} = 10^7 \text{ ergs} = 10^7 \text{ dyne}\cdot\text{cm}$ $= 2.778 \times 10^{-7} \text{ kW}\cdot\text{h} = 0.23901 \text{ cal}$ $= 0.7376 \text{ ft}\cdot\text{lb}_f = 9.486 \times 10^{-4} \text{ Btu}$
Power	$1 \text{ W} = 1 \text{ J/s} = 0.23901 \text{ cal/s} = 0.7376 \text{ ft}\cdot\text{lb}_f/\text{s} = 9.486 \times 10^{-4} \text{ Btu/s}$ $= 1.341 \times 10^{-3} \text{ hp}$

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

Table B.2 Heat Capacities<sup>a</sup>

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 <sub>3</sub> COCH <sub>3</sub>	58.08	l	1	°C	123.0	18.6	-12.78	34.76	-30-60
Acetylene	C <sub>2</sub> H <sub>2</sub>	26.04	g	1	°C	71.96	20.10	-5.033	18.20	0-1200
Air		29.0	g	1	°C	42.43	6.053	0.3191	-1.965	0-1500
Ammonia	NH <sub>3</sub>	17.03	g	1	K	28.94	0.4147	0.4799	-1.965	273-1800
Ammonium sulfate	(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	132.15	g	1	°C	28.09	0.1965	0.4421	-6.686	0-1200
Benzene	C <sub>6</sub> H <sub>6</sub>	78.11	c	1	K	35.15	2.954			275-328
Isobutane	C <sub>4</sub> H <sub>10</sub>	58.12	g	1	°C	215.9	23.4			6-67
<i>n</i> -Butane	C <sub>4</sub> H <sub>10</sub>	58.12	g	1	°C	126.5	23.4	-25.20	77.57	0-1200
Isobutene	C <sub>4</sub> H <sub>8</sub>	56.10	g	1	°C	74.06	32.95	-18.91	49.87	0-1200
Calcium carbide	CaC <sub>2</sub>	64.10	g	1	°C	89.46	30.13	-15.47	34.98	0-1200
Calcium carbonate	CaCO <sub>3</sub>	100.09	g	1	°C	92.30	27.88	-17.27	50.50	0-1200
Calcium hydroxide	Ca(OH) <sub>2</sub>	74.10	c	2	K	82.88	25.64	-8.66 × 10 <sup>10</sup>		298-720
Calcium oxide	CaO	56.08	c	2	K	68.62	1.19	-12.87 × 10 <sup>10</sup>		273-1033
Carbon	C	12.01	c	2	K	82.34	4.975			276-373
Carbon dioxide	CO <sub>2</sub>	44.01	c	2	K	41.84	2.03	-4.52 × 10 <sup>10</sup>		273-1173
Carbon monoxide	CO	28.01	g	1	°C	11.18	1.095	-4.891 × 10 <sup>10</sup>		273-1373
Carbon tetrachloride	CCl <sub>4</sub>	153.84	g	1	°C	36.11	4.233	-2.887	7.464	0-1500
Chlorine	Cl <sub>2</sub>	70.91	g	1	K	28.95	0.4110	0.3548	-2.220	0-1500
Copper	Cu	63.54	g	1	°C	93.39	12.98	-1.607	6.473	273-343
			c	1	K	33.60	1.367			0-1200
						22.76	0.6117			273-1357

<sup>a</sup>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)



**Physical Property database**  
Quickly integrates  
tabulated heat  
capacities