BASICS OF MATERIALS & ENERGY BALANCE
(CHEN 2103)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) Solutions having same osmotic pressure are called
(a) ideal solution (b) isotonic solution
(c) saturated solution (d) supersaturated solution

(ii) A vapour whose partial pressure is less than its equilibrium pressure is called
(a) Saturated vapour (b) superheated vapour
(c) supersaturated vapour (d) none of these

(iii) The vapor pressure of pure water at 100°C is
(a) 100 Pa (b) 13.6 mm of Hg
(c) 760 torr (d) 1 m water column

(iv) 1 cP is equivalent to
(a) 1 gm/cm. s (b) 1 kg/m.s
(c) 2.42 lb/ft. hr (d) 2.42 lb/ft. s

(v) The reference temperature during enthalpy calculation
(a) may be the lowest temperature of all the streams in the plant
(b) may be the highest temperature of all the streams in the plant
(c) may not be same for all the streams of the plant
(d) is always taken at 273K temperature

(vi) Enthalpy of a vapour gas mixture may be increased by increasing the
(a) temperature at constant humidity (b) humidity at constant temperature
(c) temperature and humidity (d) all (a), (b) & (c)

(vii) Critical point is the _____ temperature possible where liquid and gas can coexist.
(a) lowest (b) highest
(c) optimum (d) none of above

(viii) The degree of superheat is the difference between the actual temperature and _____ at a given pressure
(a) critical temperature (b) Bubble point temperature
(c) Saturated temperature (d) None of above

(ix) An equimolar mixture of gas containing CO_2, H_2, O_2 and N_2 has the average molecular weight equal to:
(a) 106 (b) 53
(c) 79.5 (d) 26.5

(x) The heat of vaporization _____ with the increase in pressure
(a) increases (b) decreases
(c) becomes zero at critical pressure (d) both (b) and (c)

Group - B

2. (a) A natural gas has the following composition, all figures are in volumetric percent: Methane, CH_4 83.5%, Ethane, C_2H_4 12.5%, Nitrogen, N_2 = 4.0. Calculate the average molecular weight and density of the gas mixture at 35^0C and 1.5 atm. [(CO5) (Analyze/IOCQ)]

(b) The equation for the economic nozzle diameter is given by $D = 0.059\frac{w^{0.45}}{\rho^{0.31}}$, where, D = economic nozzle diameter, inch, *w* = mass flow rate of fluid, lb / hr, and ρ = density of fluid, lb / ft^3. Transform the equation into a new form $D' = \alpha'\frac{w'^{0.45}}{\rho'^{0.31}}$ where, D' = economic nozzle diameter in mm, *w*'= mass flow rate of fluid in kg/hr and ρ' = density of fluid in kg /m^3. Determine the value of α. Data: 0.3048 m = 1 foot and 0.4536 kg = 1 lb. [(CO3) (Understand/LOCQ)]

5 + 7 = 12

3. (a) In a continuous kraft pulp bleaching unit, caustic soda is required at a concentration of 15% NaOH (by wt) and a flow rate of 1kg/s. The solution is prepared by introducing 50% caustic lye (by wt) and diluted with water continuously in a 2500 lt tank, equipped with an agitator and withdrawing water continuously at desired rate of 15% NaOH. Suddenly, the inflow of caustic lye fails. Assuming that the volume of liquid in the tank is constant, calculate the time required for the effluent concentration to fall to 10% NaOH. Given, NaOH sp.gr. in the range of 15 to 10% concentration to be approximately constant at 1.1. [(CO2) Evaluate/HOCQ]

(b) An evaporator system containing 5% (by weight) caustic soda is designed to produce a lye containing 25% (by weight) solution. Calculate the ratio between solvent vaporized and feed rate. [(CO2) (Understand/LOCQ)]

9 + 3 = 12

Group - C

4. (a) In the oxidation of SO_2 to SO_3, the conversion is 75% by using 70% excess air. Calculate a) composition of gases leaving the reactor in mole basis b) kg mole air fed per kg mole SO_2. [(CO2) (Understand/LOCQ)]

   (b) Iron pyrites FeS_2 is burnt with air 100 % in excess of that required to oxidize all iron to Fe_2O_3 and all sulphur to sulphur dioxide. Calculate the composition of the exit gases in mole% and weight %, if 80% of sulphur is oxidized to sulphur dioxide and the rest to sulphur trioxide. All iron is oxidized to Fe_2O_3. [(CO2) Analyze/IOCQ]

6 + 6 = 12

5. (a) The composition of a sample of bituminous coal by weight is found to be 75% C, 5% H_2, 12% O_2, 3% N_2, 1% S, and 4% Ash. Calculate the minimum volume of air necessary at NTP for complete combustion of 1 kg coal and composition of dry flue gas by volume if 20% excess air is supplied. [(CO2) (Analyze/IOCQ)]

   (b) A sample of dry flue gas has the following composition by volume: CO_2 – 13.4%, N_2 – 80.5%, O_2 – 6.1%. Calculate the excess air supplied assuming the fuel contains no nitrogen and oxygen. [(CO2) (Evaluate/HOCQ)]

8 + 4 = 12

Group - D

6. (a) Define the following related to psychrometric chart: (i) absolute humidity, (ii) saturation humidity, (iii) relative humidity, (iv) percentage humidity. [(CO5) (Remember/LOCQ)]

   (b) 40 kg/h of water is to be removed in a dryer. Air is supplied to drying chamber at a temperature of 65°C, a pressure of 101 kPa, and a dew point of 5°C. If air leaves the drier at a temperature of 35°C, a pressure of 100kPa, and a dew point of 25°C, calculates the volume of air that must be supplied per hr at the initial conditions. Given: vapour pressure of water at 5°C and 24°C are 0.87 kPa and 2.98 kPa respectively. [(CO2) (Analyze/IOCQ)]

6 + 6 = 12

7. (a) The relation between the friction factor, *f*, and Reynolds number, *Re*, during fluid flow through pipe line is of the form

$$f = a\,\mathrm{Re}^{m}$$

From the experimental data on pressure drop through pipe lines, the calculated values of *f* as a function of *Re* are given below.

Re	4530	5010	5780	9600	12600	15600
f	0.0097	0.0095	0.0092	0.0081	0.0075	0.0071

Determine the values of *a* and *m* by using a suitable graph. [(CO3)(Analyze/IOCQ)]

(b) Justify the values thus obtained in the previous problem by applying least square regression formula for straight line. [(CO3) (Evaluate/HOCQ)]

6 + 6 = 12

Group - E

8. (a) Calculate the heat required to bring 150 mol / hr of a stream containing 60 % C_2H_6 and 40 % C_3H_8 by volume from 0^0C to 400^0C.

Data: For C_2H_6, $C_P = 0.04937 + 13.92 \times 10^{-5} T - 5.816 \times 10^{-8} T^2 + 7.280 \times 10^{-12} T^3$

For C_3H_8, $C_P = 0.06803 + 22.59 \times 10^{-5} T - 13.11 \times 10^{-8} T^2 + 31.71 \times 10^{-12} T^3$

Where, C_P is in kJ / mol. ^{0}C and T = temperature in ^{0}C.

[(CO2) (Understand/LOCQ)]

(b) The standard heats of the following combustions reactions have been determined experimentally.

$C_2H_6 + 7/2\ O_2 \rightarrow 2CO_2 + 3H_2O$ $\Delta H_1 = -1559.8$ kJ / mol

$C + O_2 \rightarrow CO_2$ $\Delta H_2 = -393.5$ kJ / mol

$H_2 + 1/2\ O_2 \rightarrow H_2O$ $\Delta H_3 = -285.8$ kJ / mol

Use Hess's law to determine the heat of formation of ethane.

[(CO2) (Analyze/LOCQ)]

6 + 6 = 12

9. (a) Calculate the theoretical flame temperature of a gas containing 20% CO and 80% N_2 when burned with 100% excess air, both air and gas initially being at 25^0C.

Data: Heat capacity (C_P) = a + b T, Kcal / kmol. K

The values of the coefficients for different materials are as follows:

Material	a	b x 10^3
CO_2	6.339	10.14
O_2	6.117	3.167
N_2	6.457	1.389

The standard heat of formation of CO_2 (ΔH^0_{298K}) = - 67636 kcal /mol.

[(CO2) (Evaluate/HOCQ)]

(b) A well stirred batch reactor wrapped in an electrical heating mantle is charged with a liquid reaction mixture. The reactant must be heated from an initial temperature of 25^0C to 250^0C before the reaction can take place at a measurable rate. Using the data given below determine the time required for this heating to take place.

Reactant: mass = 1.5 Kg, C_V = 0.90 Kcal / Kg. ^{0}C

Reactor: mass = 3.0 Kg, C_V = 0.12 Kcal / Kg. ^{0}C

Heating rate(Q) = 500 W

Negligible reaction and no phase change during heating. Negligible energy added to the system by the stirrer. [(CO2) (Analyze/IOCQ)]

8 + 4 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	35.4%	36.4%	28.2%

Course Outcome (CO):

After completion of the course students will be able to:

1. Generate ability to handle elementary flow-sheeting given a specific process.
2. Identify skills to develop equations for energy and mass balance given a specific process.
3. Analyze any physical phenomena to obtain a functional relation between dimensionless numbers associated with the process.
4. Identify recycle, bypass and purge points in a chemical process and perform calculations with them.
5. Describe equations of state and properties of gases and liquids, including phase transition.

*LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question

Department & Section	Submission Link
CHE	https://classroom.google.com/c/NDAxOTQ4MzM1Mjc3/a/NDY3Nzg3ODEyMDUz/details