B.TECH/CHE/3RD SEM/CHEN 2104(BACKLOG)/2020

INDUSTRIAL STOICHIOMETRY
(CHEN 2104)

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

(ii) The SI unit of the ratio of kinematic viscosity to thermal diffusivity of a material is/has
(a) m (b) m^2/s (c) W/m^2K (d) no unit

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

(iv) 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

(v) The vapour pressure temperature relation given by $\ln\frac{P}{P_0}=\frac{\lambda}{R}(\frac{1}{T_0}-\frac{1}{T_1})$ is known as:
(a) Kirchoff's equation (b) Claussius- Clapeyron equation
(c) Berthelot equation (d) Clapeyron equation

(vi) A gas mixture contains 28kg N_2, 16kg O_2 and 17kg NH_3. The volume fraction of oxygen in the mixture is
(a) 0.262 (b) 0.20 (c) 0.355 (d) 0.25

(vii) 1 cm / s^2 is equivalent to
(a) 9.95×10^9 km/yr^2 (b) 2.34×10^5 km/yr^2
(c) 5.5×10^8 km/yr^2 (d) 9.81 km/yr^2

(viii) 1 torr is equal to _____ mm of Hg column
(a) 1 (b) 0.1 (c) 10 (d) 100

(ix) The value of universal gas constant R is 8.314
(a) kJ/mol K (b) cal/mol K (c) J/kmol K (d) kJ/kmol K

(x) Oxygen percentage by weight in atmospheric air is
(a) 32 (b) 23 (c) 21 (d) 16

Group – B

2. (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.

(b) Then justify the values thus obtained by applying least square regression formula for straight line.

7 + 5 = 12

3. (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.

(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. Data: 0.3048 m = 1 foot and 0.4536 kg = 1 lb.

4 + 8 = 12

Group – C

4. (a) Develop steady state material and energy balance equation for a continuous binary distillation column having only top and bottom product.

(b) An absorber operating at 40°C and 106.6 kPa is used for removing benzene from vapour and gas mixture by wash oil (M.W. 260). The flow rate of vapour and gas mixture is 3600 m^3/h. The concentration of benzene at the inlet of the absorber is 2% by volume and 90% of the inlet benzene is absorbed. The benzene content in the wash oil entering the absorber is 0.2% by mol. The flow rate of the absorbing

oil is 10000 kg/h. Determine the rate of absorption of benzene and also determine the benzene concentration in wash oil leaving the absorber.

4 + 8 = 12

5. (a) Sea water is to be desalinised by reverse osmosis using the scheme given in fig. 6 Based on fresh feed flow rate 1000 kg/h, determine (i) rate of desalinised water produced (D) and (ii) the recycle ratio (R/B) of the process.

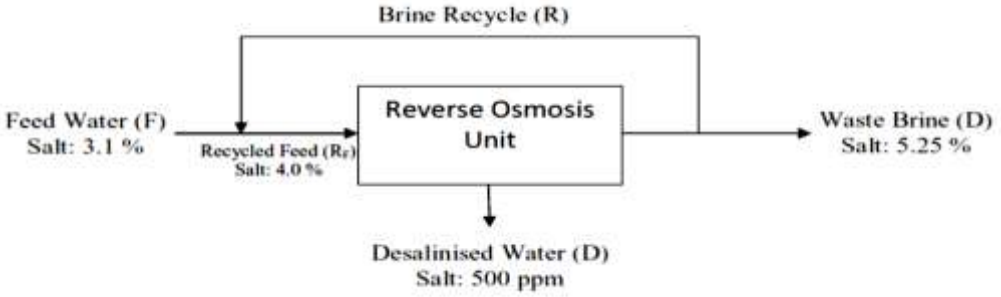

Fig. 6

(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.

9 + 3 = 12

Group – D

6. (a) In the oxidation of SO_2 to SO_3, the conversion is 75% by using 70% excess air. Calculate (i) composition of gases leaving the reactor in mole basis (ii) kg mole air fed per kg mole SO_2.

(b) 10 kg of PbS and 3 kgs of O_2 react to yield 6 kgs of Pb and 1 kg of PbO_2 according to the reaction

$$PbS + O_2 \longrightarrow Pb + SO_2$$
$$PbS + 2O_2 \longrightarrow PbO_2 + SO_2$$

Calculate (i) the amount of PbS that does not react, (ii) percentage excess O_2 based on the amount of PbS that actually reacts, (iii) amounts of SO_2 formed (iv) percentage conversion of PbS to Pb.

6 + 6 = 12

7. (a) Methanol may be produced by the reaction of carbon dioxide and hydrogen.

$$CO_2 + 3H_2 \rightarrow CH_3OH + H_2O$$

The fresh feed to the process contains hydrogen and carbon dioxide in stoichiometric proportion, and 0.5 mole% inerts (I). The reactor effluent passes to a condenser, which removes essentially the entire methanol and water formed, none of the reactants or inerts. The latter substances are recycled to the reactor. To avoid build-up of the inerts in the system, a purge stream is withdrawn from the recycle. The feed to the reactor contains 2% inerts, and the single-pass conversion is 60%. Calculate the molar flow rates of the fresh feed, the total feed to the reactor, and the purge stream for methanol production rate of 1000 mol/h.

(b) A stack gas contains 60 mole% N_2, 15% CO_2, 10% O_2, and the balance H_2O. Calculate the molar composition of the gas on a dry basis.

9 + 3 =12

Group – E

8. (a) Find the heat of formation of chloroform ($CHCl_3$) from the following data:

H_2 (g) + ½ O_2 (g) = H_2O (l), ΔH_1 = - 68317.4 cal

C (β) + O_2 (g) = CO_2 (g), ΔH_2 = - 94051.8 cal

1/2H_2 (g) + ½ Cl_2 (g) = HCl (aq), ΔH_3 = - 40023 cal

$CHCl_3$(g) + ½ O_2 (g) + H_2O (aq) = CO_2 (g) + 3 HCl (aq), ΔH_4 = - 121800 cal

(b) Pyrites fines are roasted for making sulfuric acid. The gases leaving the roaster are at 775K and have molar composition SO_2: 7.09%, O_2: 10.55%, SO_3: 0.45%, and N_2: 81.91%. Calculate the heat content of 1 kmol gas mixture over 298K.
$C_P = A + BT + CT^2$ kJ / kmol. K and T is in K.

Component	A	B × 10^3	C × 10^6
SO_2	24.7706	62.9481	- 44.2582
O_2	26.0257	11.7551	- 2.3426
SO_3	22.0376	121.6240	- 91.8673
N_2	29.5909	- 5.1410	13.1829

6 + 6 = 12

9. (a) The standard heat of reaction for the oxidation of ammonia is given below:
$4NH_3 + 5O_2 \longrightarrow 4NO + 6\ H_2O$, ΔH_{25} = - 904.7 kJ / mol.

100 mol NH_3 / sec and 200 mol O_2 / sec at 25^0C are fed into a reactor in which the ammonia is completely consumed. The product gas emerges at 300^0C. Calculate the rate at which heat must be transferred to or from the reactor, assuming operation at 1 atm.

Data: Enthalpy of O_2 at 300^0C = 8.470 kJ / mol
Enthalpy of NO at 300^0C = 8.453 kJ / mol
Enthalpy of H_2O at 300^0C = 9.570 kJ / mol

(b) A natural gas contains 85% CH_4 and 15 % C_2H_6 by volume. The heats of combustion CH_4 and C_2H_6 at 25^0C and 1 atm with water vapour asw the assumed product are given below:

$CH_4(g) + 2\ O_2(g) \longrightarrow CO_2\ (g) + 2\ H_2O\ (v)$, ΔH_c^0 = - 802 kJ / mol

$C_2H_6 + \frac{7}{2} O_2\ (g) \longrightarrow 2\ CO_2\ (g) + 3\ H_2O\ (v)$, ΔH_c^0 = - 1428 kJ / mol

Calculate the higher heating value (kJ/gm) of the natural gas.

6 + 6 = 12

Department & Section	Submission Link
CHE	https://classroom.google.com/c/Mjk4MDUyOTE4NDM1/a/Mjk4MDUyOTE5ODQz/details