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) In chemical process, the recycle stream is purged for
(a) increasing the yield (b) enriching the product
(c) limiting the inerts (d) energy conservation.

(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) 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).

(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) The total volume occupied by a gaseous mixture is equal to the sum of the pure component volumes. This is
(a) Dalton's law (b) Amgat's law
(c) Gay Lussaxc's law (d) Avogadro law.

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

(ix) Limiting reactants is one which decides the _____ of the chemical reaction.
(a) equilibrium constant (b) conversion
(c) rate constant (d) speed.

(x) Unit of mass velocity
(a) kg/h (b) kg/m^2 h (c) kg/m^2 (d) kg/m h.

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) Check the dimensional consistency of the following empirical equation for heat transfer coefficient

$h = 0.023\ G^{0.8}\ k^{0.67}\ Cp^{0.33}\ D^{-0.2}\ m^{-0.47}$

where h = heat transfer coefficient, G = mass velocity, k = thermal conductivity, C_p= specific heat, D = diameter, m = absolute viscosity.

(b) A chimney gas has the following composition by volume: CO_2 9.5%, CO 0.2%, O_2 9.6%, N_2 80.7%. Assuming ideal gas law calculate its composition by weight and the density of the gas mixture at 27^0C and 750 mm Hg.

6 + 6 = 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 abso … the wash oil entering the absorber is 0.2% … sorbing oil is 10000 kg/h. Determine the … and also determine the benzene concent … sorber.

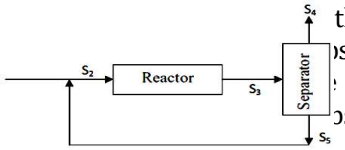

Figure1

4 + 8 = 12

5. (a) Define relative humidity, percentage humidity, humid volume and humid heat of moist air.

(b) Iron pyrites FeS_2 is burnt with air 100% in excess of that required for complete combustion to Fe_2O_3 and 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.

5 + 7 = 12

(b) 45 kg/h of water is to be removed in a drier. 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 the air leaves the drier at a temperature of 35°C, a pressure of 100 kPa and a dew point of 24°C, calculate the volume of air that must be supplied per hour at the initial conditions.

(The vapour pressure of water at 5°C and 24°C are 0.87 and 2.98 kPa respectively.)

Group – E

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

$H_2 (g) + ½ O_2 (g) = H_2O (l)$,	$\Delta H_1 = -68317.4$ cal
$C (\beta) + O_2 (g) = CO_2 (g)$,	$\Delta H_2 = -94051.8$ cal
$1/2H_2 (g) + ½ Cl_2 (g) = HCl (aq)$,	$\Delta H_3 = -40023$ cal
$CHCl_3(g) + ½ O_2 (g) + H_2O (aq) = CO_2 (g) + 3 HCl (aq)$,	$\Delta H_4 = -121800$ cal

4 + 8 = 12

Group – D

6. (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. 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) The gases leaving the roaster are at 775K and have molar composition SO_2: 7.00%, O_2: 10.55%, SO_3: 0.45% and N_2: 81.91%. Calculate the heat content of 1 kmol gas mixture over 298K temperature. Cp = A + BT + CT² kJ/kmol. K and T is in K.

Component	A	B × 10³	C × 10⁶
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	29.5902	5.1410	13.1829

6 + 6 = 12

9. (a) Calculate the enthalpy of 1 kg of Zinc vapour at 1000^0C and atmospheric pressure, relative to the solid at 0°C. Zinc melts at 419°C and boils under atmospheric pressure at 907°C.

(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.

Data: Mean heat capacity of solid Zinc = 0.105 kcal / kg. ^{0}C

Mean heat capacity of liquid Zinc = 0.109 kcal / kg. ^{0}C

The heat of fusion of Zn = 25 kcal / kg

The heat of vaporization of Zn at normal boiling point = 412 kcal / kg

Mean heat capacity of Zn vapour = 4.97 kcal / kmol.

9 + 3 = 12

7. (a) A feed stream (S_1) at 100 kg/h and containing only component A mixes with the recycle stream S_5 before entering the reactor as shown in figure 1 below where the reaction $A \rightarrow B$ takes place. The stream S_3 leaving the reactor is separated without phase or composition change into stream S_4 and S_5. If the mass fraction of B in S_4 is 0.95 and total flow rate of S_5 is 10 kg/h, then determine the ratio S_3 to S_5 and the flow rate of A in S_3. Find the conversion of A in the reactor.

(b) 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.)

4 + 8 = 12