B.TECH/CHE/3RD SEM/CHEN 2104/2016

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) Heat of _____ of a fuel is called its heating value
(a) formation (b) reaction
(c) vaporization (d) combustion.

(ii) A vapour whose partial pressure is less than its equilibrium pressure is called
(a) saturated vapour (b) superheated vapour
(c) supersaturated vapour (d) unsaturated vapour.

(iii) Percentage saturation of a vapour bearing gas is always _____ the relative saturation.
(a) higher than
(b) less than
(c) equal to
(d) either (a) or (b) depending on amount of vapour.

(iv) For the equation D (m/s) = **a** t (s) + b the units of **a** are
(a) m (b) m/s^2 (c) s/m (d) none of the above.

(v) Air contains 21 mol% O_2 (mol. wt. = 32) and 79 mol% N_2 (mol. wt = 28). The average molecular weight of air is
(a) 28.84 (b) 30.00 (c) 25.24 (d) 27.50.

(vi) 'Partial pressure of a solute gas is proportional to the mole fraction of the solute in the solution' is referred to as
(a) Raoult's law (b) Dalton's law
(c) Henry's law (d) Gay–Lussac's law.

(vii) A sample of saline water contains 5000 ppm of chloride which can be expressed as:
(a) 5 gm/liter (b) 50 gm/liter
(c) 50 kg/m^3 (d) 500 gm/m^3.

(viii) Enthalpy of a vapour gas mixture may be increased by increasing the
(a) temperature at constant humidity
(b) humidity at constant temperature
(c) pressure at constant temperature
(d) none of these.

(ix) Air is essentially a mixture of oxygen and nitrogen in the volume percent of 21 and 79 respectively. The weight percent of oxygen in air will be
(a) 21% (b) less than 21%
(c) greater than 21% (d) none of these.

(x) In a chemical process, the recycle stream is purged for
(a) increasing the yield (b) enriching the product
(c) limiting the inert (d) increasing the selectivity.

Group – B

2. (a) Using Buckingham's π theorem show that the volumetric discharge of a centrifugal pump (Q) is given by:

$$Q = ND^3 f\left[\frac{gH}{N^2D^2}.\frac{\mu}{ND^2\rho}\right]$$

Where, N is the speed of the pump in revolution per minute, D, the diameter of impeller, g, the acceleration due to gravity, μ the viscosity of the fluid, ρ the density of the fluid and H the head of fluid.

(b) Over a short temperature ranges, the viscosity of a liquid appears to follow the relationship given below:

$$\mu = A\exp\left(\frac{B}{T}\right)$$

Determine the values of A and B from the following data for CCl_4.

T, (in K)	303	313	323	333	345
μ, (in mPa.S)	0.843	0.739	0.651	0.585	0.524

6 + 6 = 12

3. (a) A gas mixture has the following composition by volume: Ethylene 30.6%, Benzene 24.5%, Oxygene 1.3%, Methane 15.5%, Ethane 25.0%, Nitrogen 3.1%. Find (i) the average molecular weight of the gas mixture, (ii) the composition by weight, and density of the mixture in kg/m^3 at NTP.

(b) The resisting force (F) of a supersonic plane during flight can be considered as dependent upon the length of the aircraft (l), velocity (v), air viscosity (μ), air density (ρ) and bulk modulus of air (K) If the dimensions of K are $ML^{-1}T^{-2}$, express the functional relationship between these variables.

4 + 8 = 12

Group – C

4. (a) A solution of potassium dichromate in water contains 15% $K_2Cr_2O_7$ by weight. 1000 Kg of this solution is fed to an evaporator where it is cooled to 20°C after evaporation. If the yield of $K_2Cr_2O_7$ crystals is 80%. Calculate the amount of water evaporated. Given: Solubility of $K_2Cr_2O_7$ at 20°C is 11.47.

(b) In a particular drying operation, it is necessary to hold the moisture content of feed to a dryer to 15% (w/w) to prevent lumping of materials. This is accomplished by mixing the feed having 30% moisture content with the recycle stream of dried materials having 3% moisture content. Calculate the fraction of the dried materials that must be recycled for the purpose.

6 + 6 = 12

5. (a) Ammonium sulphate is to be crystallized from a solution containing 45% ammonium sulphate by cooling it in a counter flow crystallizer from 85 to 35°C. During cooling the amount of water that evaporates is 5% of the mass of the feed solution. If the feed rate is 1000 kg/h, calculate (i) rate of formation of crystals, (ii) cooling water rate if it is heated from 18 to 29°C.
Data given: solubility of ammonium sulphate at 35°C = 75; Sp heat of 48% ammonium sulphate = 2.97 kJ/kg K; Heat of crystallization is 75.2 kJ/kg; latent heat of vaporization of water is 2414 kJ/kg.

(b) A continuous fractionating column operating at a pressure of 100 kPa is to be used to separate 1000 kg/h of solution of benzene and toluene containing 0.4 mass fraction of benzene, into an overhead product containing 0.97 mass fraction of benzene and a bottom

product containing 0.02 mass fraction of benzene. A reflux ratio 3.5 is to be used. Calculate (i) the quantity of top and bottom product formed per hour; (ii) condenser and re-boiler heat load.
Data given: enthalpy of feed = 171 kJ/kg; enthalpy of distillate = 67 kJ/kg; enthalpy of residue = 200 kJ/kg; enthalpy of saturated vapour from the top of the column = 540 kJ/kg.

6 + 6 = 12

Group – D

6. (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.

(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.

8 + 4 = 12

7. (a) During synthesis of ammonia a 1:3 N_2-H_2 mixture is fed to the converter resulting in a 30% conversion to ammonia. The ammonia formed is separated by condensation and unconverted gases are recycled to the reactor. The initial N_2-H_2 mixture contains 0.25 parts of argon per 100 part of N_2-H_2 mixture. The tolerance limit of argon entering the reactor is 8 parts per 100 parts of N_2-H_2 mixture. Estimate the fraction of recycle that is continuously to be purged.

(b) A pyritic ore is reduced with hydrogen according to the following reaction:

$$FeS_2 + 2H_2 = Fe + 2H_2S$$

The ore contains 15% inert solid (gangue). Twenty five percent excess hydrogen is used, and the cinder (solid residue) remaining contains 5% FeS_2 by weight. Calculate the volume of furnace gases (at 400ºC and 1 atm) per 100 kg of ore charged.

6 + 6 = 12

Group – E

8. (a) The standard heat of reaction of ammonia oxidation is given below:

$$4\,NH_3 + 5\,O_2 = 4\,NO + 6\,H_2O, \qquad \Delta H_{25} = -904.7\ KJ$$

One hundred mol NH_3 / s and 200 mol O_2 / s at 25^{0}C are fed into a

reactor in which the ammonia is completely consumed. The product gas emerges at 300^{0}C. Calculate the rate at which heat must be transferred to or from the reactor assuming operation at 1 atm. Data:

Material	Enthalpy at 300^{0}C, KJ / mol
O_2	8.470
NO	8.453
H_2O	9.570

(b) The exhaust gases from a pyrites roasting furnace leaves at 600^{0}C and has the following composition by volume: SO_2 = 7.05%, O_2 = 10.5%, SO_3 = 0.79% and N_2 = 81.66. If one kmol of the gas mixture is cooled to 77^{0}C, calculate the total quantity of heat released. The specific heats of individual components expressed in kJ/kmol are $C_P = A + BT + CT^2$.

Component	A	B x 10^2	C x 10^5
SO_2	25.74	5.80	-3.81
O_2	28.19	0.63	-0.075
SO_3	25.44	9.85	-4.06
N_2	27.34	0.62	-0.078

6 + 6 = 12

9. (a) On the basis of the data and the chemical reactions given below, find the heat of formation of $ZnSO_4$ from elements.

$Zn + S = ZnS$, H_1 = - 44 kcal/kmol

$2\ ZnS + 3\ O_2 = 2\ ZnO + 2\ SO_2$ H_2 = -221.88 kcal/kmol

$2\ SO_2 + O_2 = 2\ SO_3$ H_3 = -46.88 kcal/kmol

$ZnO + SO_3 = ZnSO_4$ H_4 = -55.10 kcal/kmol

(b) In a mechanically agitated batch reactor preheating of 2 Kg reactant from 25^{0}C to 200^{0}C is to be carried out by condensing saturated steam in the jacket. The reactor, made of stainless steel 316 weighs 3.5 Kg. If the heating rate is 450 W, find the time required to achieve this heating.

Data: Heat capacities of reactant and reactor vessel material are respectively 0.90 and 0.12 $\frac{Kcal}{Kg.^0C}$. Take negligible reaction and no phase change during heating and negligible energy added to the system by the stirrer.

6 + 6 = 12