(3 hours) Maximum marks: 80

N.B.

1. Question no. 1 is **compulsory**.
2. Attempt any **three** questions out of remaining **five** questions.
3. Assumptions made should be clearly stated.
4. Figures to the right indicate marks.

1. a) A gas mixture contains 0.274 kmol of HCl, 0.337 kmol of $N_2$ and 0.089kmol of $O_2$. Calculate (i) Average molecular weight of gas and (ii) Volume occupied by this mixture at 405.3 kPa and 303 K. (Given atomic weights: H = 1; Cl = 35.5; O = 16; N = 14). 5

   b) A spent lye sample obtained from a soap making unit contains 9.6 % glycerol and 10.3% salt (NaCl). It is concentrated at the rate of 4000 kg/h in a double effect evaporator until final solution contains 80% glycerol and 6% salt. Assume that about 5% of glycerol is lost by entrainment. Find a) the evaporation taken place in the system and b) the amount of salt crystallized in the box of the evaporator. All percentages are by weight. 5

   c) A sample of petrol contains 15% $H_2$ and 85% C by weight. Calculate the amount of air required for the complete combustion of 1 kg of petrol. Find the composition of the dry products on volume basis if 15 % excess air is supplied. 5

   d) Define (i) Adiabatic saturation temperature (ii) Percentage humidity. 5

2. a) Prove that for a ideal gas mixture mol% = volume% = pressure% 10

   b) Make the following conversions: i) 294g/l of $H_2SO_4$ to normality ii) 5N $H_3PO_4$ to g/l iii) 54.75 g/l HCl to molarity iv) 3M $K_2SO_4$ to g/l v) 4.8 mg/ml $CaCl_2$ to normality. (Given atomic weights: H = 1; Cl = 35.5; O = 16; P = 31; K = 39) 10

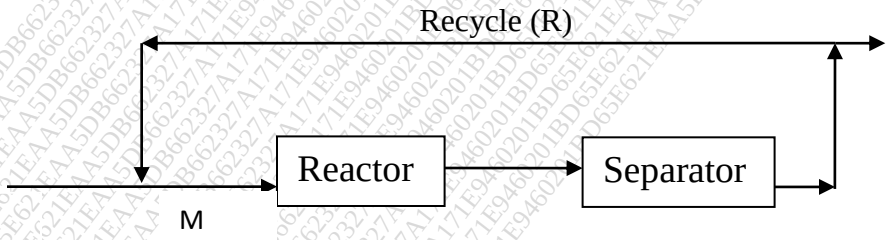
3. a) The waste acid from a nitrating process contain 55% $H_2SO_4$, 20% $HNO_3$and 25% $H_2O$ by weight. The acid is to be concentrated to contain 60% $H_2SO_4$ and 26% $HNO_3$ by addition of concentrated sulphuric acid containing 95% $H_2SO_4$ and concentrated nitric acid containing 90% $HNO_3$ (by wt.). Calculate the quantities of three acids to be mixed to get 1000 kg of desired mixed acid. 10

   b) A feed to a continuous fractionating column analyses by wt. 28% benzene and 72% tolune. The analysis of the distillate shows 52 wt% benzene and 5 wt.% benzene as found in the bottom product. Calculate the amount of distillate and bottom product per 1000 kg of feed per hour. Also calculate % recovery of benzene. 10

4. a) A storage tank of a demineralised water (DM) has a holding capacity of 1500 $m^3$upto an overflow point. The inflow of DM water to the tank is 25 l/s having silica (as $SiO_2$) content of 0.005 mg/l. The supply of DM water to the high pressure boilers from the tank amount to 25 l/s. With time, the DM water quality deteriorates and the silica content in the feed DM water increases to 0.02 mg/l. Assume that the inflow into and the outflow from the tank remains constant at 25 l/s. Calculate the time required for the silica content in the storage tank to increase to 0.01 mg/l. 10

   b) In production of chlorine gas by oxidation of HClgas , air is used 30% in excess of that theoretically required. Based on 4kmolHCl, Calculate i) the weight ratio of air to hydrochloric acid gas in feed. ii) if oxidation is 80% complete, find the composition of product stream on mole basis. 10

5 a) $N_2$-$H_2$ mixture with a molar ratio of 1:3 is used for the manufacture of $NH_3$ where 18% conversion is achieved. After separating $NH_3$ from the product, the unconverted gases are recycled. The feed contains 0.2 moles of argon per 100 moles of $N_2$-$H_2$mixure. The tolerance limit of argon entering the reactor ( i.e. in mixed feed) is 6 parts to 100 parts $N_2$-$H_2$mixure by volume. Calculate the fraction of recycle that must be continuously purged and overall yield of $NH_3$(F = feed; M = mixed feed). 10




   b) Air contains 21 mol% $O_2$ and 79 mol% $N_2$ is to be heated from 303 K to 423 K. Calculate the heat required to be added if the air flow rate is 3 $m^3$(NTP) per minute using data given below: 10

$$C_p^o = a + bT + cT^2 + dT^3 \quad (kJ/kmol\text{-}K)$$

| gas | a | b x $10^3$ | c x $10^6$ | d x $10^9$ |
|---|---|---|---|---|
| $O_2$ | 26.0257 | 11.7551 | -2.3426 | -0.5623 |
| $N_2$ | 29.5909 | -5.141 | 13.1829 | -4.968 |

6. a) Obtain an empirical equation for calculating the heat of reaction at any temperature T (K) for the reaction. 10

$CO\ (g) + 2\ H_2\ (g) \longrightarrow CH_3OH\ (g)$

Data: standard heat of reaction $\Delta H^o_R = -90.41$ KJ/mol;

$C_p$ data:

For $CO_2(g)$ $C_p = 29.03 - 2.82 \times 10^{-3}T + 11.64 \times 10^{-6}T^2$

For $H_2(g)$ $C_p = 28.61 + 1.02 \times 10^{-3}T - 0.15 \times 10^{-6}T^2$

For $CH_3OH\ (g)$ $C_p = 21.14+70.84 \times 10^{-3}T + 25.86 \times 10^{-6}T^2$

$C_p$ is in J/mol-K and T in K

b) Calculate the standard heat of formation of chloroform gas from its elements using Hess's law. 10

Data:

$C\ (s) + O_2\ (g) \longrightarrow CO_2\ (g)$ $\Delta H_1 = -393.51$ kJ/mol

$H_2\ (s) + 0.5\ O_2\ (g) \longrightarrow H_2O\ (l)$ $\Delta H_2 = -285.83$ kJ/mol

$0.5H_2\ (g) + 0.5Cl_2\ (g) \longrightarrow HCl\ (aq)$ $\Delta H_3 = -167.57$ kJ/mol

$CHCl_3\ (g) + 0.5O_2\ (g) + H_2O\ (l) \longrightarrow CO_2\ (g) + 3HCl\ (aq)$

$\Delta H^o_c = -509.95$ kJ/mol

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