09-1 311

SE (chemical) (Sem III) (R) May 09 (139)
Process Calculations 3/6/09

2873–09. **(REVISED COURSE)** **VR–3378**

(3 Hours) **[Total Marks : 100**

(1) Question No. 1 is **compulsory**.
(2) Attempt any **four** questions from remaining **six** questions.
(3) Assume **suitable** data wherever **necessary**.
(4) **Figures** to the **right** indicate **full** marks.

1. (a) How many moles of K_2CO_3 will contain 117 kg 'K' ? **5**

(b) A sample of gas having volume of 1 m^3 is compressed to half of its original volume. The operation is carried out for a fixed mass of gas at constant temperature. Calculate the percent increase in pressure. **5**

(c) It is desired to make up 1000 kg of a solution containing 35% by weight of a substance, 'A'. Two solutions are available, one containing 10 weight % 'A' and other containing 50 weight % 'A'. How many kilograms of each solution will be required ? **5**

(d) The dry bulb temperature and dew point of ambient air were found to be 302 K and 291 K respectively. Barometer reads 100 kPa. Calculate : (i) absolute molal humidity and (ii) absolute humidity. **5**
Data : Vapour pressure of water at 291 K = 2·0624 kPa
Vapour pressure of water at 302 K = 4·004 kPa.

2. (a) A vent stream from an ethylbenzene plant has a composition : 66% H_2, 33% CH_4 and 1% other components, ($CO + C_2H_6 + C_2H_4$ etc.). It is passed through a PSA unit where hydrogen is recovered as 98% pure stream with 2% CH_4 as an impurity. Recovery of hydrogen is 85% at feed pressure of 50 bar. Calculate the composition of reject stream. **12**

(b) A feed to a continuous fractionating column analyses by weight 28% benzene and 72% toluene. The analysis of the distillate shows 52 weight % benzene and 5 weight % benzene was 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. **8**

3. The fresh feed to a methanol synthesis unit contains 32 mole % CO, 64 mole % H_2 and 4 mole % N_2 and flows at a rate of 100 mol/h. The fresh feed is mixed with recycle feed flowing at a rate of 400 mol/h to produce a reactor feed containing 13 mole % N_2. The product stream leaving the condensor (after reactor) contains only liquid methanol. For preventing a build up of nitrogen in the system, a purge stream is withdrawn from the gas stream leaving the condenser. The gases not purged constitute the stream recycled to the reactor. Compute the production rate of methanol (mol/h), the molar flow rate and composition of the purge gas, and the overall and single pass conversion. **20**

4. (a) In production of chlorine gas by oxidation of hydrochloric acid gas, air is used 30% in excess of that theoretically required. Based on 4 kmol HCl, Calculate : **12**
(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.

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(b) A sample of fuel oil has C/H ratio 9·33 (by weight) and contains 1·3% Sulphur (weight basis). The net calorific value of the fuel oil is 39685 kJ/kg at 298 K. Calculate its gross calorific value using latent heat of water at 298 K. $\lambda_{water\ vapour}$ at 298 K = 2442·5 kJ/kg.

5. (a) A closed vessel contain a mixture of 40% NO_2 and 60% N_2O_4 at a temperature of 311 K and a pressure of 531·96 kPa. When the temperature is increased to 333 K, some of N_2O_4 dissociates to NO_2 and a pressure rises to 679·95 kPa. Calculate the composition of gases at 60°C by weight.

(b) A feed containing 60 mole % A, 30 mole % B and 10 mole % inerts enters a reactor. The product stream leaving the reactor is found to contain 2 mole % A. Reaction taking place is : $2A + B \rightarrow C$.
Find the percentage of original 'A' getting converted to 'C'.

6. (a) The dry bulb temperature and dew point of ambient air were found to be 303 K and 289 K respectively. Calculate (i) the absolute molal humidity, (ii) the absolute humidity, (iii) the % RH (iv) the % saturation and (v) the humid heat.
Data : Vapour pressure of water at 289 K = 1·818 kPa
Vapour pressure of water at 303 K = 4·243 kPa.
Barometric pressure = 100 kPa.

(b) Temperature of oxygen is raised from 350 K to 1500 K. Calculate the amount of heat that must be supplied for raising the temperature of 1 kmol oxygen using the C_p° data given below : $C_p^\circ = a + bT + cT^2 + dT^3$

Gas	a	$b \times 10^3$	$c \times 10^6$	$d \times 10^9$
O_2	26·0257	11·7551	–2·3426	–0·5623

7. (a) Calculate the heat of formation of ethane gas at 298·15 K from its elements using Hess's law.
Data : Heat of formation of $CO_{2(g)}$ = –393·51 kJ/mol
Heat of formation of $H_2O_{(l)}$ = –285·83 kJ/mol
Heat of combustion of ethane gas at 298·15 K = –1560·69 kJ/mol.

(b) A natural gas has the following composition on mole basis :
CH_4 = 84%, C_2H_6 = 13%, and N_2 = 3%
Calculate :
(i) The heat added to heat 2 kmol of gas mixture from 311 K to 533 K.
(ii) The heat to be added to heat 200 kg of natural gas from 311 K to 533 K
Data : C°_{pm} Values in kJ/(kmol. K)

Gas	C°_{pm} (311–298 K)	C°_{pm} (533–298 K)
CH_4	36·0483	41·7800
C_2H_6	53·5240	67·4954
N_2	29·1317	29·3578