

Note : i) Q.No 1 is compulsory.**ii) Answer any three of the remaining five question.****Q1. a) Give material balance equation for evaporation operation? (5 Marks)****b) Discuss the general energy balance procedure? (5 Marks)****c) A mixture of nitrogen and carbon dioxide at 293K and 101.325 kPa has an average molecular weight of 31. What is the partial pressure of nitrogen? (5 Marks)****d) Calculate the heat of formation of ethane gas at 298.15 K from its element using Hess's law.**Data: Heat of formation of CO₂ (g) = -393.51 kJ/mol, Heat of formation of H₂O (l) = -285.83 kJ/mol

Heat of combustion of ethane gas at 298.15 K = -1560.69 kJ/mol.

(5 Marks)**Q2. a) For a mixture of ideal gases prove that i) $P_A = X_A P$ and ii) $V_A = X_A V$. (15 Marks)****b) Write the general energy balance procedure? (5 Marks)****Q3. a) An evaporator system concentrating a weak liquor from 5% to 50% solids handles 100 kg of solids per hour. If the same system is to concentrate a weak liquor from 4% to 35%, find the capacity of the system in terms of solids that can be handled per hour assuming water evaporation capacity to be same in both the cases. (10 Marks)****b) Flue gases leaving the boiler stack at 523 K have the following composition: (10 Marks)**CO₂ = 11.31%, H₂O = 13.04%, O₂ = 2.17% and N₂ = 73.48% (by volume). Calculate the heat lost in 1 kmol of gas mixture above 298K, using the heat capacity data given below :Cp° = a + bT + cT² + dT³, kJ/kmol.K

Gas	a	b*10 ³	c*10 ⁶	d*10 ⁹
CO ₂	21.3655	64.2841	-41.0506	9.7999
O ₂	26.0257	11.7551	-2.3426	-0.5623
H ₂ O	32.4921	0.0796	13.2107	-4.5474
N ₂	29.5909	-5.141	13.1829	-4.968

Q4. a) A gas has the following composition by volume: SO₂ = 8.5%, O₂ = 10% and N₂ = 81.5%Find i) the density of gas mixture at a temperature of 473K and 202.65 kPa g and ii) composition by weight. **(10 Marks)****b) In the synthesis of methanol, fresh feed containing 32% CO, 64% H₂ and 4% inerts (by volume) is mixed with the recycle feed. Mixed feed entering the reactor results in 20% per pass conversion of CO. The product stream from the reactor is fed to a condenser where all methanol formed gets condensed and the gases from the condenser are recycled. In order to prevent build up of inerts in the recycle loop, a small portion of the gases leaving the condenser is continuously purged. If the mixed feed contains 13 mole% inerts, calculate :****i) the recycle ratio and ii) the purge ratio. (10 Marks)**

Q5. 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 v) the humid heat. Given data : vapour pressure of water at 298 K = 1.818 kPa, vapour pressure of water at 304 K = 4.243 kPa and barometric pressure = 100 kPa. (15 Marks)

b) Write short notes on bypass and purge operation **(5 Marks)**

Q6. a) Define

i) Normality ii) Molarity iii) Molality iv) Ideal gas law v) Stoichiometric proportion **(10 Marks)**

b) In the shift reaction $\text{CO} + \text{H}_2\text{O} \longrightarrow \text{CO}_2 + \text{H}_2$, a and b are mole % of CO in the inlet and dry outlet gas mixture to and from the reactor respectively. Prove that moles of CO converted (x) per 100 moles of inlet gas mixture can be calculated using the following relation :

$$x = \frac{a(100-b)}{100+b} \quad \text{(10 Marks)}$$
