Q. P. Code: 24091

(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 mixture of CH_4 and C_2H_6 has density 1.0 kg/m^3 at 273 K and 101.325 kPa pressure. Calculate the mole% and weight% of CH_4 and C_2H_6 in the mixure. 5

b) The waste acid from a nitrating process is containing 30% H_2SO_4, 35% HNO_3 and 35% H_2O by weight. The acid is to be concentrated to contain 39% H_2SO_4, and 42% HNO_3 by addition of concentrated sulphuric acid containing 98% H_2SO_4, and concentrated nitric acid containing 72% HNO_3 (by weight). Calculate quantities of three acids to be mixed to get 1000 kg of desired mixed acid. 5

c) Calculate the net calorific value at 298 K at a sample of fuel oil having C/H ratio 9.33 (by weight) and containing sulphur to the extent of 1.3 % by weight. 5
Data: The GCV of the fuel oil at 298 K = 41785 kJ/kg
Latent heat of water vapour at 298 K = 2442.5 kJ/kg

d) Calculate the heat of formation of liquid ethyl acetate ($C_4H_8O_2$) at 298 K. Standard heat of formation of CO_2 (g) = - 393.51 kJ/mol;Standard heat of formation of H_2O (l) = - 285.83 kJ/mol 5
Standard heat of combustion of liquid ethyl acetate = -2230.91 kJ/mol

2. a) Dryer system handles 1000 kg/day of wet solids. Wet solids containing 50% solids and 50% water are fed to the first dryer. From the first dryer the product that comes out has 20% moisture. This is further admitted to the second dryer from which the product coming out has 2% moisture. Calculate the % or original water that is removed in each dryer and final weight of the product. 10

b) Final purification stage in the preparation of the reaction A → 2B + C takes place in a catalytic reactor. The reactor effluent is sent to a separator. The overall conversion of A is 95%. The product stream from the separator consists of B, C and 0.5% of A entering the separator, while the recycle stream consists of the remainder of the unreacted A and 1% of B entering the separator. Calculate (i) the single pass % of A in the reactor. (ii) the molar ratio of recycle to feed. 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 10

Turn Over

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.

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) Calculate the heat of formation of liquid ethyl acetate ($C_4H_8O_2$) at 298 K. Standard heat of formation of CO_2 (g) = - 393.51 kJ/mol;Standard heat of formation of H_2O (l) = - 285.83 kJ/mol 10
Standard heat of combustion of liquid ethyl acetate = -2230.91 kJ/mol

5 a) Cl_2 is manufactured by burning HCl gas using air. The reaction taking place in the burner is: 10
$4\ HCl\ (g) + O_2\ (g) \Longrightarrow 2Cl_2(g) + 2H_2O\ (g)$
Air is used in 35% excess of that theoretically required. Assuming that the oxidation is 80% complete and dry air and HCl gas enter the burner at 298 K(25°C), calculate the adiabatic reaction temperature of the product gas stream.
$\Delta H_{f,H2O\ (g)} = -241.82$ kJ/mol; $\Delta H_{f,HCl(g)} = -92.31$ kJ/mol

$C_p^o = a + bT + cT^2 + dT^3$ (kJ/kmol-K)

Component	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
HCl	30.3088	-7.609	13.2608	-4.3336
H_2O	29.5909	-5.141	13.1829	-4.968

b) Calculate the number of kilocalories required to heat from 500 K to 1500 K per m^3 of gas measured at 1 atm and 0°C having composition CO_2 20%; N_2 50%; $O_2$20% and H_2 10% by volume. 10

$C_p^o = a + bT + cT^2$ (kcal/kmol-K)

gas	a	b x 10^3	c x 10^6
CO_2	6.339	10.14	-3.415
N_2	6.457	1.389	-0.069
O_2	6.117	3.167	-1.005
H_2	6.946	-0.196	0.4757

6. a) A quadruple- effect evaporator is fed with 1060 kg/h of 4% (by mass) causticsoda solution in a textile mill. It is concentrated to 25% (by mass) lye. The saturated steam at 7 bar g is fed to the first effect. The cold feed also enters the first effect at 30ºC. The final effect operates at 50.6 kPa a (vacuum of 380 torr). The operating pressure in first, second and third effect are observed to be 3.7, 2.35 and 0.8 bar g, respectively. Neglect the boiling point elevation effects and assume that no heat loss due to radiation takes place from the evaporator bodies. 10

Heat capacity of feed (C_{1F}) = 4.04 kJ/(kg.K)
Solution leaving first effect (C_{11}) = 3.977 kJ/(kg.K)
Solution leaving second effect (C_{12}) = 3.936 kJ/(kg.K)
Solution leaving third effect (C_{13}) = 3.894 kJ/(kg.K)
Solution leaving fourth effect (C_{14}) = 3.873 kJ/(kg.K)
Latent heat of steam at 700 kPa g = 2046.3 kJ/kg
Evaluate the (steam economy and specific steam consumptionof the system.

Effect no.	P (kPa g)	Saturation T (ºC)	Latent heat of steam (kJ/kg)
1st	370	149.6	2114.4 (λ_{v1})
2nd	235	137.5	2151.5 (λ_{v2})
3rd	80	117.2	2210.2 (λ_{v3})
4th	-50.66	81.7	2304.6 (λ_{v4})

b) A vapour at 411 K and standard atmospheric pressure, containing 0.72 mole fraction benzene and 0.28 mole fraction toluene serves as a feed to a fractionating column in which it is separated into a distillate containing 0.995 mole fraction benzene and bottoms with 0.97 mole fraction toluene. The reflux ratio is desired to be 1.95 kmol/kmol distillate product. For a feed of 100 kmol, compute heat load of reboiler. Assume that there is no heat loss to the surrounding and heat of solution is negligible. 10

Data: Enthalpy of vapours (overhead) = 42170 kJ/kmol mixture
Enthalpy of liquid (overhead) = 11370 kJ/kmol mixture
Specific enthalpy of bottom product = 18,780 kJ/kmol mixture
Enthalpy of feed = 44,500 kJ/kmol
