Exam. Code: 0907
Sub. Code: 33351

2124

B.E. (Biotechnology) Third Semester
BIO-311: Process Calculations

Time allowed: 3 Hours **Max. Marks: 50**

NOTE: ***Attempt five questions in all, including Question No. I which is compulsory and selecting two questions from each Section. Use of a psychometric chart and steam table is allowed.***

x-x-x

Q.1.a) A liquid has a specific gravity of 0.50. What is the mass of 3 cm^3 of this liquid?

b) Convert 825 kCal/h to kJ/s.

c) 100 kg/h of molecular hydrogen (H_2) is fed into a reactor. What is the molar flow rate of this stream in g moles/h.

d) A gas sample has a volume of 4.2 L, a pressure of 3.0 atm, and a temperature of 310 K. Calculate the number of moles of gas using the ideal gas law equation.

e) What does Hess's Law state? (10)

SECTION-A

Q.2.a). A mixture of gases has the following composition by mass: O_2 – 16%, CO- 4%, CO_2- 17%, N_2- 63%. Calculate the molar composition of the gaseous mixture.

b). Consider the dimensionally homogeneous equation $D\ (ft) = 3t(s) + 4$. Derive an equation for distance in meters in terms of time in minutes. (5,5)

Q.3.a). 500 kg/h of a mixture of benzene and toluene containing 50% benzene by mass is separated in a distillation column into two fractions. The mass flow rate of benzene in the top stream is 225 kg/h and that of toluene in the bottom stream is 235 kg/h. Calculate the unknown component flow rates in the output streams.

b). A 100 kg aqueous solution of NaOH contains 20% NaOH by mass. It is desired to produce 8% NaOH solution by diluting a stream of the 20% solution with a stream of pure water. Calculate (i) Liters of water/kg feed solution (ii) kg product solution/kg feed solution. (4,6)

Q.4. Acrylonitrile is produced in the reaction of propylene, ammonia and oxygen as

$$C_3H_6 + NH_3 + \frac{3}{2}O_2 \rightarrow C_3H_3N + 3\,H_2O$$

The feed contains 10 mole% propylene, 12% ammonia and 78% air. A fractional conversion of 30% of the limiting reactant is achieved. Taking 100 mol feed as the basis, determine (i) limiting reactant (ii) percentage by which the other reactant is in excess (iii) molar composition of the product gas constituents for a 30% conversion of the limiting reactant. (10)

P.T.O.

SECTION-B

Q.5.a). A gas containing nitrogen (N), benzene (B), and toluene (T) is in equilibrium with a liquid consisting of 35 mol% benzene and 65 mol% toluene at 85°C and 10 atm. Estimate the gas composition (mole fraction) using Raoult's law and assuming ideal gas behavior. Given

$$\log(P_B^*)\ (mm\ Hg) = 6.906 - \frac{1211}{T(°C) + 220.8}$$

$$\log(P_T^*)\ (mm\ Hg) = 6.9533 - \frac{1344}{T(°C) + 219.4}$$

b). 525 Kg/h of steam enters a turbine at 48 atm and 450°C at a linear velocity of 55 m/s and leaves at a point 3 m below the turbine inlet at atmospheric pressure and a velocity of 350 m/s. The turbine delivers shaft work at a rate of 65 kW and the heat loss from the turbine is estimated to be 10.6 kW. Calculate the specific enthalpy change associated with the process. (5,5)

Q.6.a). A turbine discharges 200 kg/h of saturated steam at 10 bar absolute ($\hat{H} = 2776\ kJ/kg$). The turbine discharge is mixed with superheated steam at 300°C and 10 bar ($\hat{H} = 3052\ kJ/kg$) to generate steam at 250°C and 10 bar ($\hat{H} = 2943\ kJ/kg$). Calculate the amount of heat that must be added to the mixer to generate 300 kg/h of the product steam.

b). Air is at a dry bulb temperature of 40°C and 30% relative humidity. Use the psychrometric chart to estimate (i) absolute humidity (ii) wet bulb temperature (iii) dew point and (iv) humid volume. Calculate the amount of water in 150 m^3 of air at these conditions. (4,6)

Q.7. Steam enters a steam chest, segregated from the biomass, at 200°C saturated, and is completely condensed in the steam chest. The rate of the heat loss from the steam chest to the surroundings is 2.5 kJ/s. The reactants are placed in the vessel at 10°C and at the end of the heating the material is at 85°C. If the charge consists of 180 kg of material with an average heat capacity of Cp= 3 J/g K, determine how many kilograms of steam are needed per kilogram of charge? The charge remains in the reaction vessel for 30 min. (10)

x-x-x