Exam. Code: 0907
Sub. Code: 33351

2125

**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) The volumetric flow rate of $CCl_4$ ($\rho = 1.595\ g/cm^3$ ) in a pipe is 100 $cm^3$/min. Calculate the mass flow rate in kg/h.

b) Calculate the amount of heat required to heat 10 kg of oil from 40°C to 90°C. Given the specific heat of oil is 2.1 kJ/kg °C.

c) Wet pulp contains 70% water. After drying, 100 kg of water is removed, and now the pulp contains only 30% water. What was the weight of the pulp before drying?

d) 2 moles of a gas occupy a volume of 1 L at a pressure of 40 bar. Calculate the temperature of the gas using Van der Waals equation of state. Given the constants a = 1.39 $L^2$bar/$mol^2$ and b= 0.039 L/mol.

e) Explain single pass conversion and overall conversion. (10)

## SECTION-A

Q.2.a). The volume of a microbial culture is observed to increase exponentially according to the formula $V\ (cm^3) = 2e^{5t}$ where t is in seconds. Calculate the expression for V ($m^3$) in terms of t (h). What must be the units of 2 and 5?

b). A gas mixture contains the following components by mass: $CO_2$ – 40%, $O_2$ – 20%, and $N_2$ – 40%. Calculate the molar composition (mole percent) of the gaseous mixture. (5,5)

Q.3.a). A 150 kg aqueous solution of potassium hydroxide (KOH) contains 25% KOH by mass. It is desired to produce a 10% KOH solution by diluting it with a stream of pure water. Calculate (a) the mass of water (kg) that must be added to dilute the feed to 10% KOH. (b) mass of the final diluted solution (kg).

b). 1000 kg/h of a mixture containing equal parts by mass of methanol and water is distilled. Product stream leaves the top and the bottom of the distillation column. The flow rate of the bottom stream is measured to be 673 kg/h and the overhead stream is analyzed to contain 96 wt% methanol. Calculate the mole fraction of methanol and the molar flow rates of methanol and water in the bottom product stream. (4.6)

Q.4. The reaction between ethylene and hydrogen bromide to form ethyl bromide is carried out in a continuous reactor.

$$C_2H_4 + HBr \rightarrow C_2H_5Br$$

The product stream is analyzed and found to contain 51.7 mole% $C_2H_5Br$ and 17.3% HBr. The feed to the reactor contains only ethylene and hydrogen bromide. Calculate the fractional conversion of the limiting reactant and the percentage by which the other reactant is in excess. If the molar flow rate of the feed stream is 165 mol/s, what is the extent of reaction? (10)

## SECTION-B

Q.5.a). An equimolar liquid mixture of benzene and toluene is in equilibrium with its vapor at 30°C. Calculate the total pressure and the composition of the vapor. Given: the vapor pressure of benzene at this temperature is 15.9 kPa and that of toluene is 5.01 kPa.

b). 1200 kg/h steam enters the turbine at 30 bar and 400°C at a linear velocity of 25 m/s and leaves at a point 10 m below the turbine inlet at 0.1 bar pressure and a velocity of 250 m/s. The turbine delivers shaft work at a rate of 150 kW, and the heat loss from the turbine is estimated to be 1507 kJ/h. Calculate the specific enthalpy change associated with the process. (4,6)

Q.6.a). Air is at a dry bulb temperature of 29°C and absolute humidity 0.01 kg/kg dry air. Use the psychrometric chart to estimate (i) relative humidity (ii) wet bulb temperature (iii) dew point and (iv) humid volume (v) specific enthalpy.

b). Calculate the amount of heat required to raise 200 kg of nitrous oxide from 20°C to 150°C in a constant volume vessel. The constant volume specific heat capacity of $N_2O$ in this temperature range is given by $C_v\ (kJ/kg°C) = 0.855 + 9.42 \times 10^{-4}T$ (5,5)

Q.7a). Explain the difference between saturated steam and superheated steam.

b). Superheated steam at 300°C and 1 atm ($\hat{H} = 3074\ kJ/kg$) is produced by mixing an available stream of saturated steam at 1 atm discharged from a turbine at a rate of 1150 kg/h ($\hat{H} = 2676\ kJ/kg$) with a second stream of superheated steam at 400°C and 1 atm ($\hat{H} = 3278\ kJ/kg$. The mixing may be considered adiabatic. Calculate the amount of superheated steam at 300°C produced and the required volumetric flow rate of the 400°C steam. Specific volume of steam at 400°C and 1 atm is 3.11 m$^3$/kg. (3,7)

x-x-x