1-36

3rd. I

Exam. Code: 0907
Sub. Code: 6691

1128

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 Psychometric chart steam tables is allowed.

x-x-x

Q.1. Answer the following questions in one word/ one line

a) Calculate the number of moles of oxygen present in the container having 48 g of NaOH, 56 g of H_2O and 184 g of H_2SO_4.

b) For the given inorganic chemical reaction
$HCl\ (aq) + NaOH\ (aq) \rightarrow NaCl\ (aq) + H_2O\ (l)$
If HCl is present in excess and the amount of NaOH is doubled, number of moles of NaCl will be _____

c) Differentiate between a recycle stream, purge stream and bypass stream.

d) If for the given reaction $N_2 + 3H_2 \rightarrow 2NH_3$
The feed contains x moles of N_2 and y moles of H_2. If N_2 is the limiting reactant, then (write the correct option)
(i) x=y (ii) 3x<y (iii) x>y (iv) 3x>y

e) What is the mass fraction of Na in NaOH molecule?

f) For a mixture of NO_3 and SO_2, having 25 moles of NO_3 and 100 moles of SO_2, Calculate the partial pressure of NO_3 and SO_2 respectively. The total pressure exerted by the gases is 100 atm.

g) Density of a material is an intensive or extensive property?

h) Work is negative when _____ performs a work on the _____

i) At 100% RH the wet bulb temperature will be equal to _____.

j) Explain Hess's law. (10)

SECTION-A

Q.2a) A seed crystal of diameter D (mm) is placed in a solution of dissolved salt, and new crystals are observed to nucleate at a constant rate r (crystals/min). Experiments with seed crystals of different sizes show that the rate of nucleation varies with the seed crystal diameter as $r\ (crystals/min) = 200D - 10D^2$ (D in mm)

(i) What are the units of the constants 200 and 10?
(ii) Calculate the crystal nucleation rate in crystals/s corresponding to a crystal diameter of 0.050 inch.
(iii) Derive a formula for r (crystals/s) in terms of D (inches). (4)

b) A 0.50-molar aqueous solution of sulfuric acid flows into a process unit at a rate of 1.25 m^3/min. The specific gravity of the solution is 1.03. Calculate (i) the mass concentration of H_2SO_4 in Kg/m^3, (ii) the mass flow rate of H_2SO_4 in Kg/s and (iii) the mass fraction of H_2SO_4 (4)

P.T.O.

c) How many of each of the following is contained in 100 g of CO_2?
(i) mol CO_2 (ii) lb-moles O (iii) g O and (iv) molecules of CO_2. (2)

Q.3. In order to recover crystalline K_2CrO_4 from aqueous solution, 4500 kilograms per hour of a solution that is one-third K_2CrO4 by mass is joined by a recycle stream containing 36.4% K_2CrO4, and the combined stream is fed into an evaporator. The concentrated stream leaving the evaporator contains 49.4% K_2CrO4; this stream is fed into a crystallizer in which it is cooled (causing crystals of K_2CrO4 to come out of solution) and then filtered. The filter cake consists of K_2CrO4 crystals and a solution that contains 36.4% K_2CrO4 by mass; the crystal account for 95% of the total mass of the filter cake. The solution that passes through the filter, also 36.4% K_2CrO4, is the recycle stream.

i) Calculate the rate of evaporation, the rate of production of crystalline K_2CrO4, the feed rates that the evaporator and the crystallizer must be designed to handle, and the recycle ratio mass of recycle/mass of fresh feed.

ii) Suppose that the filtrate were discarded instead of being recycled. Calculate the production rate of crystals. (10)

Q.4 a) Propane is dehydrogenated to form propylene in a catalytic reactor

$$C_3H_8 \rightarrow C_3H_6 + H_2$$

The process is to be designed for a 95% overall conversion of propane. The reaction products are separated into two streams: the first, which contains H_2, C_3H_6, and 0.555% of C_3H_8 that leaves the reactor, is taken off as product; the second, which contains the balance of the unreacted propane and 5% of the propylene in the first stream, is recycled to the reactor. Calculate (a) the composition of the product, (b) the ratio: (moles recycled)/(moles fresh feed), and (c) the single-pass conversion. (6)

b) Acetylene is hydrogenated to form ethane. The feed to the reactor contains 1.50 mol H_2/mol C_2H_2. (i) Calculate the stoichiometric reactant ratio (mol H_2 react/mol C_2H_2 react) and the yield ratio (kmol C_2H_6 formed/kmol H_2 react). (ii) Determine the limiting reactant and calculate the percentage by which the other reactant is in excess. (iii) Calculate the mass feed rate of hydrogen (kg/s) required to produce 4 × 106 metric tons of ethane per year, assuming that the reaction goes to completion and that the process operates for 24 hours a day, 300 days a year. (4)

SECTION-B

Q.5a) A gas containing nitrogen, benzene, and toluene is in equilibrium with a liquid consisting of 36 mole% benzene and 65 mole% toluene at 85°C and 10 atm. Estimate the nitrogen gas mole% using Raoult's law and assuming ideal gas behavior. (3)

b) A stream of air at 100°C and 5260 mmHg contains 10% water by volume. (a) Calculate dew point temperature of the stream. (b) Calculate the percentage of the vapor that condenses and the final composition of the gas phase if the air is cooled to 80°C at constant pressure. (c) Calculate the percentage condensation and the final gas-phase composition if, instead of being cooled, the air is compressed isothermally to 8500 mmHg. (7)

Q.6a) A turbine discharges 200 kg/h of saturated steam at 10 bar absolute. It is desired to generate steam at 250°C and 10 bar by mixing the turbine discharge with a second stream of superheated steam of 300°C and 10 bar. (i) If 300 kg/h of the product steam is to be

generated, how much heat must be added to the mixer? (ii) If instead the mixing is carried out adiabatically, at what rate is the product steam generated? (4)

b) Two streams of water are mixed to form the feed to a boiler. Process data are as follows:
Feed stream 1 - 120 kg/min 30°C
Feed stream 2 - 175 kg/min 65°C
Boiler pressure 17 bar (absolute)
The exiting steam emerges from the boiler through a 6-cm ID pipe. Calculate the required heat input to the boiler in kilojoules per minute if the emerging steam is saturated at the boiler pressure. Neglect the kinetic energies of the liquid inlet streams. (6)

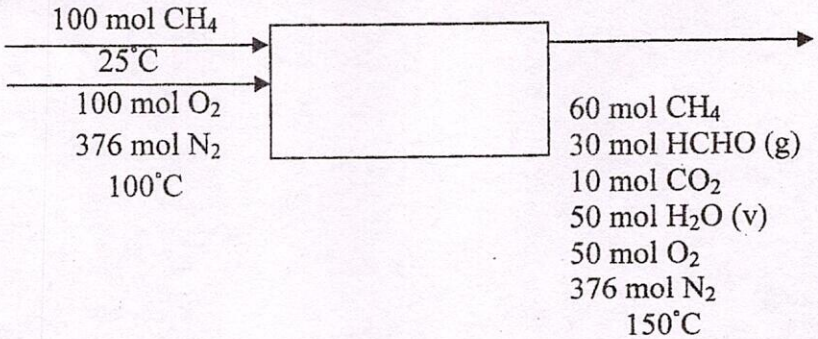
Q.7a) An open vessel containing 0.205 lbm of liquid water is placed in an empty room 5 ft wide, 4 ft deep, and 7 ft high, which initially contains dry air at 90°F. All the water evaporates without changing the room temperature. Use the psychrometric chart to estimate the final relative humidity, wet-bulb temperature, humid volume, dew-point temperature, and specific enthalpy of the room air. Take the molecular weight of dry air to be 29.0, and for simplicity, assume the mass of dry air in the room stays constant at its initial value. (5)

b) Methane is oxidized with air to produce formaldehyde in a continuous reactor. A competing reaction is the combustion of methane to form CO_2.

$$CH_4\,(g) + O_2 \rightarrow HCHO\,(g) + H_2O\,(v)$$

$$CH_4\,(g) + 2O_2 \rightarrow CO2 + 2H_2O\,(v)$$

A flowchart of the process for an assumed basis of 100 mol of methane fed to the reactor is shown here. How much heat is added or removed from the system?



(5)

x-x-x