Y/K/TX

Reg. No: 23BCM0051

VIT
Vellore Institute of Technology

Final Assessment Test – November 2024

Course: BCHE203L - Chemical Process Calculations
Class NBR(s): 2651
Time: Three Hours
Slot: A1+TA1+TAA1
Max. Marks: 100

- KEEPING MOBILE PHONE/ANY ELECTRONIC GADGETS, EVEN IN 'OFF' POSITION IS TREATED AS EXAM MALPRACTICE
- DON'T WRITE ANYTHING ON THE QUESTION PAPER

Answer ALL Questions
(10 X 10 = 100 Marks)

1. Natural gas has the following composition by weight CH_4 = 94.1%, C_2H_6 = 3%, N_2 = 2.9%. The gas is piped from the well at a temperature of 27 °C, and an absolute pressure of 4 bar. Assuming that ideal gas law is applicable, calculate:
   a) Partial pressure of each component
   b) pure component volume of the component
   c) density of mixtures at the given conditions

2. A process gas flowing at a rate of 550 m^3/h at 101.3 kPa and 93 °C contains H_2S with a partial pressure of 0.2026 kPa. The gas passes to a scrubber in which 92% of H_2S is removed. Calculate the H_2S removal rate in kg/h.

3. An air – water vapour mixture has relative humidity of 80% at 293 K (20 °C) temperature and 100 kPa pressure. Calculate:
   a) Molal humidity of air
   b) Molal humidity of air if its temperature is reduced to 283 K (10° C) and the pressure is increased to 174.65 kPa condensing out some of the water
   c) The weight of water condensed from 500 kg of original wet air in the process of part (b)

   Data:

   Vapour pressure of water at 293 K (20° C) = 2.40 kPa
   Vapour pressure of water at 283 K (10° C) = 1.266 kPa

4. A crystallizer in a chemical industry is charged with 6400 kg of an aqueous solution containing 29.6% anhydrous Na_2SO_4. The solution is cooled and 10% of the initial H_2O is lost by evaporation. Crystals are obtained in the form of $Na_2SO_4.10\ H_2O$. If the mother liquor is found to contain 18.3%. Na_2SO_4, calculate the weight of the mother liquor and crystals.

5. 1000 kg of a 30% (*w/w*) solution of acetone in water is contacted with pure MIBK (methyl isobutyl ketone) to extract acetone in a mixer-settler. The operating temperature is 25°C. From the settler, the two phases separated are withdrawn separately. Find the quantity of MIBK that must be fed to the process to reduce the acetone concentration in the water rich phase to 5%. Also, calculate the percentage of acetone in the original feed solution which remains unextracted.

   Composition of phases:

   Raffinate phase: 5% acetone, 92.5% H_2O, and 2.5% MIBK

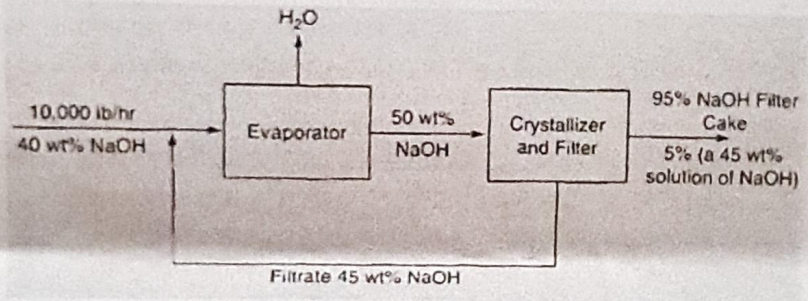
   Extract phase: 10% acetone, 87% MIBK, and 3% H_2O

6. Sulphur trioxide is manufactured by the reaction of SO_2 and O_2. 120 kmol of SO_2 and 120 kmol O_2 are fed to the reactor. If the conversion of SO_2 is 60%, calculate the composition of product stream on mole basis.

7. A process for the production of flake NaOH used in households to clear plugged drains. The fresh feed to the process is 10,000 lb/hr of a 40% aqueous NaOH solution. The fresh feed is combined with the recycled filtrate from the crystallizer, and fed to the evaporator where water is removed to produce a 50% NaOH solution, which in turn is fed to the crystallizer. The crystallizer produces a filter cake that is 95% NaOH crystals and 5% solution that itself consists of 45% NaOH. The filtrate contains 45% NaOH.

a. Determine the flow rate of water removed by the evaporator, and the recycle rate for this process.

b. Assuming that the same production rate of NaOH flakes occurs but the filtrate is not recycled, what would be the total feed rate of 40% NaOH? Assume that the product solution from the evaporator still contains 50% NaOH.



8. 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 95% overall conversion of propane. The reaction products are separated into two streams: (i) The first stream contains H_2, C_3H_6, and 0.555% of the propane that leaves the reactor & is taken off as product; (ii) The second stream contains the balance of the unreacted propane and 5% of the propylene in the product stream is recycled to the reactor.

Calculate the composition of the product (wt%), recycle ratio and single pass conversion. All the percentages are in mole %.

9.a) The Orsat analysis of the flue gases from a boiler house chimney gives CO_2 = 11.4%; O_2 = 4.2%; and N_2 = 84.4% (mole%). Assuming that complete combustion has taken place:

(i) Calculate the % excess air.

(ii) Find the C: H ratio in the fuel.

OR

9.b) Blast furnace gas having the composition (*v/v*): CO_2 = 13%, CO = 25%, H_2 = 3.5%, N_2 = 58.5% is burned in a furnace. Calculate the percent excess air when the dry flue gas contain CO_2 = 19.5%, O_2 = 5.8% and N_2 = 74.7%.

10.a) Dry methane is burnt with dry air and both are initially at 25°C. The adiabatic flame temperature is 1350 °C. If combustion is assumed to be complete, how much excess air is used? The following data is provided:

Heat of reaction, $\Delta H_R^\circ = -0.2 \times 10^5$ cal

$(C_{pm})_{CO2} = 12.37$ cal/mol. °C; $(C_{pm})_{H2O} = 9.6$ cal/mol. °C

$(C_{pm})_{N2} = 7.68$ cal/mol. °C; $(C_{pm})_{air} = 7.44$ cal/mol. °C

OR

10.b) Combustion of solid wastes produces a gas of the following analysis: $CO_2 = 9\%$, $CO = 2\%$, $O_2 = 7\%$, and $N_2 = 82\%$. Find the difference in enthalpies for this gas between the bottom and top of the stack if the temperature of the gas at the bottom is 600 K and that at the top is 375K. The heat capacities C_P (kJ/kmol.K) and T (K) of the gas are mentioned in the table below:

$C_P^\circ = a + bT + cT^2$

Component	a	b	c
CO	26.586	7.582×10^{-3}	-1.120×10^{-6}
Co_2	26.540	42.45×10^{-3}	-14.29×10^{-6}
O_2	25.74	12.98×10^{-3}	-3.864×10^{-6}
N_2	27.03	5.815×10^{-3}	-0.289×10^{-6}

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