Name: Enrolment No:	UPES UNIVERSITY WITH A PURPOSE

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES
End Semester Examination, December 2021

Programme Name: B. Tech. (APE-Gas/ CERP) **Semester : III**
Course Name : Material and Energy Balance Computations **Time : 3 hrs**
Course Code : CHCE 2013 **Max. Marks: 100**
Nos. of page(s) : 04
Instructions : Assume any missing data. Draw the diagrams, wherever necessary.

SECTION A
(6X10=60 marks)

S. No.		Marks	CO
1	(a) A mixture of gas has the following composition by mass **O_2- 16%**, **CO- 4%**, **CO_2- 8%** and rest **N_2**, **tabulate** the molar composition and average molecular weight? (b) Power required in an agitator is a function of rotational speed (**n**), impeller diameter (**d**), fluid properties like density (**ρ**), viscosity (**μ**), and acceleration due to gravity (**g**). Obtain a relation between the dimensionless groups using dimensional analysis.	**5** **5**	**CO1**
2	(a) Aluminum sulfate can be made by reacting crushed bauxite ore with sulfuric acid, according to the following equation $$Al_2O_3 + 3\,H_2SO_4 ----\rightarrow Al_2(SO_4)_3 + 3H_2O$$ The bauxite ore contains **55.4%** by weight aluminum oxide, the reminder being impurities. The sulfuric acid solution contains **77.7% H_2SO_4**, the rest being water. To produce crude aluminum sulfate containing **1798 lb** of pure aluminum sulfate, **1080 lb** of bauxite ore and **2510 lb** of sulfuric acid solution are used. i. Identify the excess reactant ii. What percent of excess reactant was consumed iii. What was the degree of completion of the reactant? (b) Brief about **Raoult's law** and its applications	**7** **3**	**CO2**
3	The vapor pressure of Benzene is measured at two temperatures, with the following results, **T_1 = 7.6 ^{O}C** **p_1* = 40 mm Hg** **T_2 = 15.4 ^{O}C** **p_2* = 60 mm Hg** **Determine** the latent heat of vaporization and the parameter **B** in **Classius-Clapeyron** equation and then estimate p^* at **42.2** in ^{O}C using this equation.	**10**	**CO3**

$$lnp^* = -\frac{\Delta Hv}{RT} + B$$

p^* = saturation vapor pressure ΔH_v = latent heat of vaporization

B = constant   T = absolute Temperature

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4 | Marks: **10** | **CO4**

Moist air contains **0.0109 kg** water vapor per cubic feet of the mixture at **300 K** and **101.325 kPa**. Calculate the following,

a) Partial pressure of water vapour
b) The relative saturation
c) Absolute humidity of the air
d) The percentage saturation

The vapor pressure of water is approximated by the following Antoine equation

$$lnp^* = 16.26205 - \frac{3799.887}{T - 46.854} \quad where\ T\ in\ K\ and\ p*\ in\ kPa.$$

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5 | Marks: **10** | **CO5**

A tank holds **10000 kg** of saturated solution of **$NaHCO_3$** at **60^o C**. You want to crystallize **400 kg of $NaHCO_3$**. To what temperature the solution must be cooled? The solubility data for **$NaHCO_3$** as a function of temperature is given in the following table:

Temperature, ^{0}C	**60**	**50**	**40**	**30**	**20**	**10**
$\frac{g\ of\ NaHCO_3}{100\ g\ of\ water}$	**16.4**	**14.5**	**12.7**	**11.1**	**9.6**	**8.15**

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6 | Marks: **10** | **CO6**

A natural gas stream has the following composition on mole basis:

CH_4 – 84%, C_2H_6 – 13% and N_2 – 3%.

Calculate the heat to be added to heat **10 kmol** of natural gas from **298 K** to **523 K** using the heat capacity data given below.

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

Gas	a	b x 10^3	c x 10^6	d x 10^9
CH_4	**19.2494**	**52.1135**	**11.973**	**-11.3173**
C_2H_6	**5.4129**	**178.0872**	**-67.3749**	**8.7147**
N_2	**29.5909**	**-5.141**	**13.1829**	**-4.968**

SECTION B

(2 X 20=40 marks)

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7 | Marks: **18** | **CO5**

(a) 4500 kg/h of a solution that is **one-third K_2CrO_4** by mass is joined by a recycle stream containing **36.4% K_2CrO_4**, and the combined stream is fed into an evaporator. The concentrated stream leaving the evaporator contains **49.4% K_2CrO_4**; this stream is fed into a crystallizer in which it is cooled (causing crystals of **K_2CrO_4** to come out of solution) and then filtered. The filter cake consists of **K_2CrO_4** crystals and a solution of **36.4% K_2CrO_4** by mass. The crystals account

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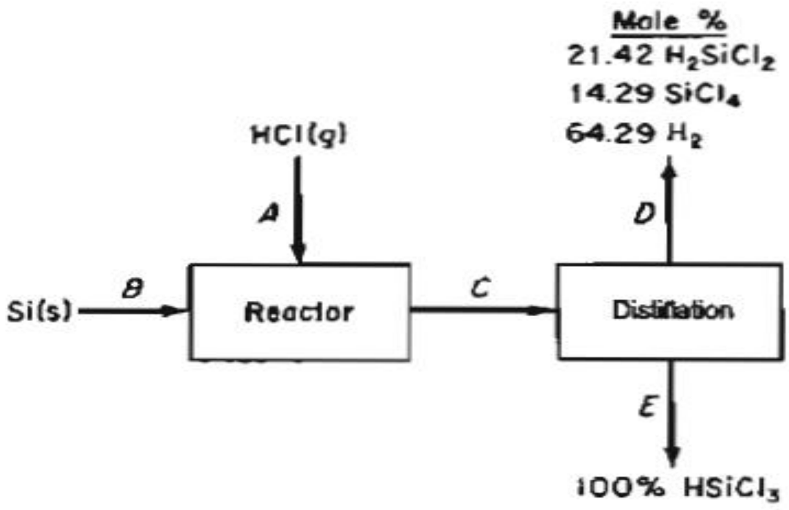
<td>for 95% of the total mass of the filter cake. The solution that passes through the filter, also 36.4% K_2CrO_4 is the recycle stream.

Calculate the rate of evaporation, the rate of production of crystalline K_2CrO_4 , the feed rates that the evaporator and the crystallizer must be designed to handle and the recycle ratio

(b) Define crystallization

OR

Metallurgical grade silicon is purified to electronic grade for use in semiconductor industry by chemically separating it from its impurities. The Si metal reacts with varying degrees with hydrogen chloride gas at 300^{O} C to form several polychlorinated silanes. Trichorosilane is liquid at room temperature and is easily separated by fractional distillation from the other gases. If 100 kg of silicon reacted as shown in figure, how much Trichorosiane is produced?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<td>2

20</td>
<td>CO5</td>
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<td>The conversion of solid waste to innocuous gases can be accomplished in incinerators in an environmentally acceptable fashion, However the hot exhaust gases must be cooled or diluted with air. An economic feasibility study indicates that solid municipal waste can be burnt to a gas of the following composition (on a dry basis). 9.2% CO_2, 1.5% CO, 7.3% O_2 and the rest is N_2.
What is the enthalpy difference for this gas per lb mol between the bottom and top of the stack if the temperature at the bottom of the stack is 550 ^{o}F and the temperature at the top of the stack is 200 ^{o}F. Ignore the water vapor in the gas. Because these are ideal gases, you can neglect any energy effects resulting from the mixing of the gaseous components.</td>
<td>20</td>
<td>CO6</td>
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The heat capacity equation is $C_p = A + B\,T - C\,T^2 + D\,T^3$ where C_p is in Btu/lbmol ^{0}F and T in ^{0}F. The values of constants are as given in the table.

Component	A	B	C	D
N_2	6.895	0.7624×10^{-3}	0.7009×10^{-7}	-
O_2	7.104	0.7851×10^{-3}	0.5528×10^{-7}	-
CO_2	8.448	5.757×10^{-3}	21.59×10^{-7}	3.059×10^{-10}
CO	6.865	0.8024×10^{-3}	0.7367×10^{-7}	-

OR

(a) The standard heats of formation at **298 K** are **-110.6 kJ/mol** for **CO**, **-238.64 kJ/mol** for **CH_3OH**. The latent heat of vaporization of **methanol** at **298 K** is **37.98 kJ/mol**. The specific heats are **(J/mol. K)** are given by: **18** **CO6**

$C_p\,(CH_3OH) = 18.382 + 101.564 \times 10^{-3}\,T - 28.683 \times 10^{-6}\,T^2$

$C_p\,(CO) = 28.068 + 4.631 \times 10^{-3}\,T - 2.5773 \times 10^{-4}\,T^2$

$C_p\,(H_2) = 27.012 + 3.509 \times 10^{-3}\,T - 6.9006 \times 10^{-4}\,T^2$

calculate the standard heat of reaction at **1073 K**

(b) Define **Standard Heat of Reaction** **2**