Name:

Enrolment No:

UPES

End Semester Examination, May 2025

Programme Name: B. Tech. (Chemical Engineering) **Semester : II**
Course Name : Materials and Energy Balance Calculations **Time : 3 hrs**
Course Code : CHCE 2029 **Max. Marks: 100**
Nos. of page(s) : 02
Instructions : Assume any missing data. Draw the diagrams, wherever necessary.

SECTION-A
(5Q × 4M = 20 marks)

1	A mixture of gases has the following composition by weight N_2=34 Cl_2 = 22 % Br_2 = 25% and O_2 = 19%. **Identify** (i) Composition of the gas mixture by volume % (ii) Density of the gas mixture in kg/m^3 at 25^{O}C & 740 mm Hg.	**4**	**CO1**
2	Carbon monoxide combines with chlorine in the presence of a suitable catalyst to give phosgene as CO + Cl_2 -----→ $COCl_2$. After reaction the product contains 12 moles of phosgene, 3 moles of chlorine when 8 moles of carbon monoxide is considered. **Identify** limiting reactant and calculate % excess reactant used.	**4**	**CO1**
3	10 kg of CH_4 is burnt with 10% excess air. **Identify** the volume of air used for the combustion if air is at 30°C and 1.3 atm pressure?	**4**	**CO2**
4	In the process of production of PCl_5, 4.25 g of Cl_2 with 2.20 g of P_4 produces 4.28 g of PCl_5. According to the following reaction. ***Predict*** the following. P_4 + 10Cl_2 ---> 4PCl_5 (1)Limiting reactant (2) % excess reactant	**4**	**CO3**
5	The heat capacity of silicon carbide is given by $C_P = 37.221 + 1.22X10^{-3}T - 1.189X10^5T^{-2}$ where Cp is in KJ/Kmol K and T is in K. **Analyze** the enthalpy change in silicon carbide in the range 0 to 1000 K.	**4**	**CO4**

SECTION-B
(4Q × 10M = 40 marks)

6	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). **Recognize** a relation between the dimensionless groups using dimensional analysis. **OR** The **drag force** F experienced by a small sphere moving slowly through a fluid depends on the **radius** of the sphere r (in meters), the **velocity** v of the sphere (in meters per second), and the **viscosity** of the fluid η (in kilogram per meter per second). Using **dimensional analysis**, find a formula for F in terms of r, v, and η.	**10**	**CO1**
7	A producer gas made from coke has the following composition by volume. Item | CO | O_2 | CO_2 | N_2 Composition | 28 | 0.5 | 3.5 | 68 This gas is burned with 20% excess air. If the combustion is 98% complete, calculate the weight and composition of the stack gases formed per 100 lb of gas burned. **Express** the composition of stack gases in weight percent and mole percent.	**10**	**CO2**
8	A fresh pressed juice contains 5% of total solids and it is desired to raise this percentage to 10% of total solids by evaporation and then to add sugar to give 2% of added sugar in	**10**	**CO3**

	the concentrated juice. ***Compute*** the quantity of water that must be removed and of sugar that must be added with respect to each 100 kg of pressed juice.		
9	One kg of H_2O is heated from 250 K to 400 K at 1 atm pressure. ***Calculate*** the amount of heat required for this? The mean heat capacity of ice between 250 K to 273 K is 2.037 kJ/kg-K, the mean heat capacity of liquid water between 273 K to 373 K is 75.726 kJ/kg-K and the heat capacity of water vapor (kJ/kmol-K) is $C_p = 30.475 + 9.652 \times 10^{-3} T + 1.189 \times 10^{-6} T^2$ where T is in K. the latent heat of fusion and vaporization of water are 6012 kJ/kmol and 40608 kJ/kmol, respectively.	**10**	**CO4**
SECTION-C **(2Q × 20M = 40 marks)**			
10	Fresh feed stream flowing at 100 kg/h contains 20% by weight KNO_3 in H_2O. The fresh feed stream is combined with a recycle stream and is fed to an evaporator. The concentrated liquid solution exited the evaporator contains 50% KNO_3 is fed to a crystallizer. The crystals obtained from the crystallizer are 96% KNO_3 and 4% water. The liquid from the crystallizer constitutes the recycle stream and contains 0.6 kg KNO_3 per 1.0 kg of H_2O. ***Compute*** all stream flow rate values and compositions.	**20**	**CO3**
11	Hydrogen gas is burned in an adiabatic reactor with two times the theoretical quantity of air, both air and hydrogen initially at 298 K. ***Analyze*** the temperature of the reaction products? The standard heat of formation of gaseous water is –241.826 kJ/mol. The heat capacities (kJ/kmol-K) of the gases are given below: Water vapor $C_p = 30.475 + 9.652 \times 10^{-3} T$ Nitrogen $C_p = 27.034 + 5.815 \times 10^{-3} T$ Oxygen $C_p = 25.611 + 13.26 \times 10^{-3} T$ **OR** A solution of 10% (weight) acetone in water is subjected to fractional distillation at a rate of 1000 kg/h to produce a distillate containing 90% acetone and a bottom product containing not more than 1% acetone. Feed enters at 340 K; distillate and residue leave the tower at 300 K and 370 K, respectively. A reflux ratio of 8 kg/h of liquid reflux to kg/h of distillate product is employed. The rise in temperature of 30 K is permitted for the cooling water circulated in the condenser employed for condensing the vapours into the distillate product and the reflux. Saturated steam at 276 kPa is available for supplying heat of vaporization in the reboiler. Latent heat of steam at 276 kPa is 2730 kJ/kg. Heat losses from the column may be neglected. The heat capacity of acetone is 2.2 kJ/kg-K and that of water is 4.2 kJ/kg-K. The boiling point of 90% acetone-water solution is 332 K. The latent heat of acetone at 332 K is 620 kJ/kg and that of water is 2500 kJ/kg. C***alculate*** the following: (a) the cooling water circulation rate (b) the rate of circulation of steam	**20**	**CO4**