Register No.: ..... Name: .....

SAINTGITS COLLEGE OF ENGINEERING (AUTONOMOUS)

(AFFILIATED TO APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY, THIRUVANANTHAPURAM)

THIRD SEMESTER B.TECH DEGREE EXAMINATION (R,S), DECEMBER 2023
CHEMICAL ENGINEERING
(2020 SCHEME)

Course Code : 20CHT203

Course Name: Chemical Process Principles

Max. Marks : 100 **Duration: 3 Hours**

Any missing data may be suitably assumed. Attested copy of Psychrometric chart can be permitted.

PART A

(Answer all questions. Each question carries 3 marks)

1. Convert kgf/cm^2 & lbf/in^2 to N/m^2.
2. How real gases are different from ideal gases.
3. Write Raoult's law and Henry's law with its mathematical expression and its significance.
4. Differentiate relative humidity and percent humidity. Also write the relation between two.
5. State and explain the law of conservation of mass.
6. Differentiate steady state and unsteady state operation with example.
7. Define limiting reactant and excess reactant with example.
8. Differentiate Gross Calorific Value and Net Calorific Value.
9. Differentiate standard heat of combustion and standard heat of formation.
10. What is specific heat capacity? Write an expression for calculating heat capacity of a mixture of gases.

PART B

(Answer one full question from each module, each question carries 14 marks)

MODULE I

11. a) Iron reacts with steam according to the following reaction: (5)
$3Fe + 4H_2O \rightarrow Fe_3O_4 + 4H_2$
(Molecular weight of Fe = 55.85)
i) How many kilograms of iron and steam are required to produce 100 kg of hydrogen?
ii) What volume will the hydrogen occupy at standard condition?

b) The molarity of an aqueous solution of $MgCl_2$ at 300 K is 4. The specific gravity of the solution is 1.3 at 300 K (MW of Mg – 24.3). Determine the following: (9)
i) The concentration of $MgCl_2$ in weight fraction.
ii) The concentration of $MgCl_2$ in mole fraction.

iii) The molality of the solution.
iv) The normality of the solution at 300 K.
v) Express the concentration in ppm.

OR

12. a) The molar volume of a gas mixture analyzing 40% nitrogen and 60% ethane at 325 K is 4.5 x 10^{-4} m^3/mol. Determine the pressure of the gas by: (6)
i) The ideal gas equation
ii) The Van der Waals equation
The Van der Waals constants: Nitrogen (a = 0.1365 N m^4/mol^2 and b = 3.86 x 10^{-5} m^3/mol), Ethane (a = 0.557 N m^4/mol^2 and b = 6.51 x 10^{-5} m^3/mol)

b) A mixture of gas is piped from a tank at 298 K and 340 kPa. The gas is found to contain 63% methane, 12% ethane, 8% propane and the rest is nitrogen. Calculate the following: (8)
i) The partial pressure of nitrogen.
ii) The pure component volume of ethane in 5 m^3 of the gas.
iii) The density at standard conditions in kg/m^3.
iv) The average molecular weight of the gas.

MODULE II

13. a) Explain the boiling point diagram in detail with an example of ethanol-water solution. (7)

b) At 300 K, the vapour pressures of two pure liquids A & B are 80 kPa and 50 kPa respectively. The concentration of A in the vapour in equilibrium with a solution of A and B is found to be 35 % (mol). Calculate the composition of the liquid and the total pressure of the vapour. (7)

OR

14. a) The vapour pressure of ethyl ether at 273 K is 25 kPa and its latent heat of vapourization is 4.185 x 10^2 kJ/kg. Calculate the vapour pressure of ethyl ether at 293 K and 308 K. (5)

b) An air-water vapour sample at atmospheric pressure has an absolute humidity of 0.025 kg water vapour/kg dry air, and a wet bulb temperature of 306 K. Calculate the following using psychrometric chart: (9)
Absolute saturation humidity, Molal saturation humidity, Partial pressure of water vapour, Percent saturation, relative saturation, Dew point of the system, Humid volume and Enthalpy of wet air.

MODULE III

15. a) Hydrogen sulphide is absorbed from a gaseous mixture containing 26% H_2S and 74% inerts by a solution in a tower. The tower operates at 4 bar and 330 K. The gases leave the tower with an H_2S content of 8%. Assuming that H_2S is alone removed and nothing is added as the gas passes through the tower and if the feed to the tower is 3000 m^3/hr, calculate the amount of H_2S removed from the gas. And also calculate the percentage recovery of H_2S. (7)

b) A 35% (by weight) Na_2SO_4 solution in water, initially at 50 ^{0}C is fed to a crystallizer at 20 ^{0}C. The product stream contains hydrated crystals of $Na_2SO_4.10H_2O$ in equilibrium with a 20% (by weight) Na_2SO_4 solution. Calculate the feed rate of 35% solution required to produce 500 kg/hr of hydrated crystal. (7)

OR

16. a) A feed containing 60% (by weight) benzene and 40% (by weight) toluene is passing to a binary distillation column. The purity of benzene in the distilled product is 95% (by weight) and the purity of toluene in the residue is 97%. (8)
i) Calculate the amount of feed required to produce a 3000 kg/hr distillate.
ii) If the reflux ratio is 2.5, what will be the amount of vapour condensed in the condenser / kg of distillate

b) A batch of leather leaving a drier weighs 1000 kg and contains 5% moisture. During drying the leather losses 50% of its original weight. Determine the following: (6)
i) The moisture content of the leather entering the drier on a dry basis.
ii) The amount of moisture removed per kg of dry leather.
iii) Water removed as percent of original water present.

MODULE IV

17. a) A fuel containing 70% carbon by weight and the rest combustible hydrogen and moisture is burned with excess air. The flue gas analyzed 9% CO_2, 2% CO, 3% O_2, and 86% N_2. Calculate: (14)
i) The percent of excess air.
ii) The ratio of carbon to combustible hydrogen in the fuel on weight basis.
iii) The ratio of carbon to total hydrogen in the fuel on weight basis.
iv) The percentage of combustible hydrogen and moisture in the fuel.
v) The mass of moisture present in the flue gas per kg of oil burned.

OR

18. a) A gas containing only CH_4 and N_2 is burned with air yielding a flue gas that has an Orsat analysis of CO_2 = 8.7%, CO = 1% O_2 = 2% and N_2 = 88.3%. Calculate the following: (7)
i) The percent composition of the fuel.
ii) The percent excess air used.

b) Coal containing 80% carbon and 6% ash by weight when burned leaves a cinder which contains 90% ash, and 10% carbon. If 100 kg of coal is charged, calculate the weight of the cinder produced and the percent of fuel value wasted. (7)

MODULE V

19. a) Explain the effect of temperature on heat of reaction. (10)

b) Define Kopp's rule. Determine the heat capacity of $Na_2SO_4.10H_2O$ at room temperature using Kopp's rule. The atomic heat capacities of elements (J/g-atom K) are 26.04 for Na, 22.6 for S, 16.8 for O and 9.6 for H. (4)

OR

20. a) State and explain Hess's law. Write the mathematical expression for Hess's law. (4)

b) (10)

Using Hess's law calculate the heat of formation of chloroform ($CHCl_3$) with the following data.

$CHCl_3 + 0.5\ O_2 + H_2O \rightarrow CO_2 + 3HCl$	ΔH^0_{298} = - 281.67 kJ
$H_2 + 0.5\ O_2 \rightarrow H_2O$	ΔH^0_{298} = - 285.84 kJ
$C + O_2 \rightarrow CO_2$	ΔH^0_{298} = - 393.51 kJ
$0.5\ H_2 + 0.5\ Cl_2 \rightarrow HCl$	ΔH^0_{298} = - 92.311 kJ

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