Reg. No. | | | | | | | | | | | | | |

B. E / B. TECH.DEGREE EXAMINATION, MAY/JUNE 2023

Third Semester

CH18301 – CHEMICAL PROCESS CALCULATIONS

(Chemical Engineering)

(Regulation 2018 & 2018A)

(USE OF PSYCHROMETRIC CHART IS PERMITTED)

TIME: 3 HOURS **MAX. MARKS: 100**

CO1	Interpret the data presented in different unit systems and apply various gas laws to calculate the unknowns in a given system
CO2	Build basic knowledge on various unit operations and processes and perform material balances for steady and unsteady state chemical systems.
CO3	Provide insight into the concepts and calculations associated with gases which involves two phase systems.
CO4	Perform energy balance calculations for steady and unsteady state chemical processes.
CO5	Implement various methods used for analyzing combustion process and demonstrate the ability to understand process simulators.

PART- A (10x2=20Marks)

(Answer all Questions)

		CO	RBT LEVEL
1.	Relate the partial pressure of a pure component to its vapour pressure.	1	2
2.	Explain Molarity and Molality.	1	2
3.	Identify the limiting reactant and excess reactant when 30 kg of Calcium reacts with 40 kg of Oxygen to form Calcium Oxide.	2	3
4.	Construct the recycle, bypass and purge operations.	2	3
5.	Develop the relationship between absolute and molal humidity.	3	3
6.	'High humidity makes us feel hotter than actual air temperature' – Explain.	3	2
7.	Outline the application of Hess's law of constant heat summation.	4	2
8.	Illustrate the application of Kopp's rule with an example.	4	2
9.	Compare Gross Calorific value and Net Calorific value.	5	2
10.	Write a short note on process simulators.	5	2

Q. Code: 779747

PART- B (5x 14=70Marks)

			Marks	CO	RBT LEVEL
11. (a)	**(i)**	At 298 K, the solubility of methyl chloride in methanol is 44 kg per 100 kg. Determine the weight fraction and mole fraction of methanol in the saturated solution.	(7)	1	3
	(ii)	Compare the pressures given by the ideal gas and Van der Waals equation for 1 mole of CO_2 occupying a volume of 381 x 10^{-6} m^3 at 40 °C. Data: a = 0.3646 Pa $(m^3)^2/mol^2$; b = 4.28 x 10^{-5} m^3/mol	(7)	1	3
		(OR)			
11. (b)	**(i)**	A gas mixture contains 0.274 kmol of HCl, 0.337 kmol of N_2 and 0.089 kmol of O_2. Calculate the Average molecular weight of the gas, partial pressure of each component and the volume occupied by this mixture at 405.3 kPa and 303 K.	(7)	1	3
	(ii)	A gas mixture has the following composition by volume: SO_2 – 8.5 %, O_2 – 10 % and the remaining N_2. Estimate the composition by weight and the density of the gas mixture at a temperature of 473 K and 202.65 kPa gauge pressure.	(7)	1	3
12. (a)		Methanol is produced by the reaction of CO with H_2 according to the equation $CO + 2H_2 \longrightarrow CH_3OH$. Only 20% of the CO entering the reactor is converted to methanol. The methanol product is condensed and separated from the unreacted gases, which are recycled. The feed to the reactor contains 2 kmoles of H_2 for 1 kmol of CO. The fresh feed enters at 35 °C and 300 atm. Estimate the volume of fresh feed gas and recycle ratio to produce 6000 kg/h of methanol.	(14)	2	3
		(OR)			
12. (b)		Wet solids containing 50 % water and 50 % solids are to be dried to get solids with 5 % water by weight. Fresh air contains 0.0010 kg water vapour per kg of dry air and the air leaving the dryer contains 0.05 kg water vapour per kg dry air. If 100 kg of dry air enters the dryer for every kg of dry solids, calculate the quantity of fresh air, the fraction of the air recirculated and the recycle ratio.	(14)	2	3

13. (a) An air – water sample has a dry bulb temperature of 50 °C and a wet bulb temperature of 35 °C. Estimate the following properties at a total pressure of 1 atm. **(14)** **3** **3**

i) kg of water vapour/kg of dry air ii) % humidity iii) % relative saturation iv) Dew point v) Humid heat vi) Enthalpy in kJ/kg dry air vii) Humid volume.

Data: Vapour pressure of water at 50 °C = 92.51 mm Hg

λ_0 = 2502 kJ/kg

(OR)

13. (b) An air – water vapour mixture has a relative humidity of 80 % at 293 K and 100 kPa pressure. Calculate the following: **(14)** **3** **3**

i) Molal humidity of the air.
ii) Molal humidity of air if its temperature is reduced to 283 K and the pressure is increased to 174.65 kPa condensing out some water.
iii) The weight of the water condensed from 500 kg of original wet air.
iv) Final volume of the wet air at after condensation of water vapour.

14. (a) A natural gas has the following composition on mole basis: CH_4 – 84 %, C_2H_6 – 13 % and N_2 – 3 %. Formulate an empirical expression for heat to be added and calculate the heat to be added to raise the temperature of 10 kmol of natural gas from 298 K to 523 K using heat capacity data given below. **(14)** **4** **5**

$Cp° = a + bT + CT^2 + dT^3$, 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	8.7149
N_2	29.5909	-5.141	13.1829	-4.968

(OR)

14. (b) Formulate an empirical expression relating the heat of reaction and the temperature of the reaction for the gas phase oxidation of sulphur-di-oxide to sulphur-tri-oxide. Using the same expression, calculate the heat of reaction at 773 K. **(14)** **4** **5**

Data: $\Delta H_f°$ of SO_3 and SO_2 are -395720 and -296810 kJ/kmol respectively.

$Cp° = a + bT + CT^2 + dT^3$, kJ/kmol.K

Gas	a	b x 10^3	c x 10^6	d x 10^9
SO_3	22.036	121.624	-91.867	24.369
SO_2	24.771	62.948	-44.258	11.122
O_2	26.026	11.755	-2.343	-0.562

15. (a) A fuel gas contains 70 % methane, 20 % ethane and 10 % oxygen. The fuel – air mixture contains 200 % excess oxygen before combustion. 10 % of the hydrocarbon remains unburnt. 90 % of the total carbon burnt forms CO_2 and the rest forms CO. Analyze the composition of the flue gas on wet and dry basis. **(14)** **5** **4**

(OR)

15. (b) The ultimate analysis of a coal sample is given below. **(14)** **5** **4**

Carbon – 61.5 %, Hydrogen – 3.5 %, Sulphur – 0.4 %, ash – 14.2 %, nitrogen – 1.8 % and rest oxygen. Determine the theoretical oxygen requirement, theoretical dry air requirement per unit weight of coal. Analyze the composition of flue gas when coal is burned with 90 % excess dry air by Orsat method.

PART- C (1x 10=10Marks)

(Q.No.16 is compulsory)

Marks **CO** **RBT LEVEL**

16. Estimate the theoretical flame temperature of a gas containing 20 % CO and 80 % N_2 when burnt with 100 % excess air. Both air and gas are initially at 25 °C. **(10)** **4,5** **4**

Data:

$C_p\ CO_2 = 6.339 + 10.14 \times 10^{-3}\ T – 3.415 \times 10^{-6}\ T^2$

$C_p\ O_2 = 6.117 + 3167 \times 10^{-3}\ T – 1.005 \times 10^{-6}\ T^2$

$C_p\ N_2 = 6.457 + 1.389 \times 10^{-3}\ T – 0.069 \times 10^{-6}\ T^2$

ΔH_{rxn} at 25 °C = - 67,636 kJ

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