Enrollment No./Seat No.:

GUJARAT TECHNOLOGICAL UNIVERSITY

Bachelor of Engineering - SEMESTER - III EXAMINATION - WINTER 2025

Subject Code: BE03005031 **Date: 19-12-2025**

Subject Name: Material and Energy Balance Computation

Time: 10:30 AM TO 01:00 PM **Total Marks: 70**

Instructions

1. **Attempt all questions.**
2. **Make suitable assumptions wherever necessary.**
3. **Figures to the right indicate full marks.**
4. **Simple and non-programmable scientific calculators are allowed.**
5. **Atomic Weights: C:12, H:1, O:16, S:32, Cl:35.5, N:14, Ca:40, K:39, Cu:63.5, Fe:55.8, Na:23**

			Marks
Q.1	**(a)**	How many kilograms of carbon disulphide will contain 3.5 kmol carbon?	**03**
	(b)	The flow rate of water through a pipe is reported as 20 ft^3/ min. Convert the volumetric flow rate into the mass flow rate in kg/s. Density of water is 1 gm/cc.	**04**
	(c)	A gas mixture has the following composition by volume | C_2H_4 | C_6H_6 | O_2 | CH_4 | C_2H_6 | N_2 | | 30.60% | 24.50% | 1.30% | 15.50% | 25.00% | 3.10% | Determine (a) the average molecular weight of the gas mixture, (b) the density of the gas mixture in kg/m^3 NTP. (c) the composition by mass	**07**
Q.2	**(a)**	A sample of milliolite limestone, obtained from Porbandar, Gujarat, is found to contain 54.5% CaO (by mass). If this CaO is present as $CaCO_3$ in the limestone, find the content of $CaCO_3$ in the limestone.	**03**
	(b)	An aqueous solution of acetic acid of 35% concentration (by mass) has density 1.04kg/L at 298.15. Find the molarity of the solution.	**04**
	(c)	Crystals of $MgCl_2.6H_2O$ have a solubility of 190 g per 100 g ethanol at 25 ^oC. It is desired to make 1000 kg of saturated solution. Calculate the quantities of crystals and ethanol required to make the above solution. Also determine the composition of the saturated solution by mass.	**07**
		OR	
	(c)	In a constant pressure reactor where the gas-phase reaction A → 2B + C occurs, starting with 75% A and 25% inerts, the volume is observed to double. Calculate the conversion of A. Then analyze how the presence of inerts influences the observed volume change, and predict how the conversion would differ if no inerts were present.	**07**
Q.3	**(a)**	Explain the steps and reasoning involved in solving material balance problems for systems without chemical reactions	**03**

(b) Explain the recycling and bypassing operation with appropriate examples **04**

(c) Selective dehydrogenation of alkanes to alkenes is a well-established process. In this process, dehydrogenation of i-butane is carried out on a platinum impregnated catalyst at 50kPa g and 773 K. The feed to the reactor is pure i-butane along with 0.75kmol H_2 per kmol of i-butane. Hydorgen stream contains 90% H_2 and 10% methane (by mole). Following reactions are known to take place. **07**

$$\underset{\text{i-butane}}{\text{i-}C_4H_{10}} \longrightarrow \underset{\text{i-butylene}}{\text{i-}C_4H_8} + H_2$$

$$\underset{\text{i-butane}}{\text{i-}C_4H_{10}} \longrightarrow \underset{\text{propylene}}{C_3H_6} + CH_4$$

Literature reports 50% per pass conversion in a battery of three reactors with 88% yields of i-butylene. Calculate the composition of the product stream leaving the final reactor.

OR

(a) Describe following terms **03**

(1) Stoichiometric Ratio, (2) Limiting Reactant & (3) Excess Reactant

(b) Explain process flow diagram (PFD) and process block diagram (PBD) for chemical process industries. **04**

(c) A pilot plant reactor was charged with 50 kg of naphthalene ($C_{10}H_8$) and 200 kg (98% by mass) of H_2SO_4. The reaction was carried out for 3 hours at 160°C (433 K). The reaction goes to near completion. The product distribution was found to be 18.6% monosulphonate naphthalene and 81.4% disulphonate naphthalene. Calculate (a) the quantities of monosulphonate (MSN) ($C_{10}H_7SO_3H$) and disulphonate (DSN) ($C_{10}H_6(SO_3H)_2$) products, and (b) the complete analysis of the product. **07**

Q.4 **(a)** Define following terms with suitable examples **03**

Conversion, Yield and Selectivity.

(b) Liquid Ammonia is stored at 705 kPa a in a tank. It is discharged to an atmospheric storage. Calculate the percentage flash vapours produced letting down the pressure. **04**

Pressure, kPa a	Saturation temperature, °C (K)	Enthalpy, kJ/kg Sensible h	Enthalpy, kJ/kg Total H	Enthalpy, kJ/kg Latent λv
705	14 (287.15)	265.56	1475.1	1209.6
101.3	–33.3 (239.82)	49.1	1418.7	1369.6

[Reference state: h = 200 kJ/kg at 0°C (273.15 K)]

(c) Using Watson equation, Calculate latent heat of vaporization of **07**

(a) acetone at 313K (40^{o}C) (b) carbon disulphide (CS_2) at 413 K

T1 (Boiling point temp) K	component	Latent heat of vap at T1, K (kJ/kmol)	Tc (K)	n
329.4	Acetone(C3H6O)	29121	508.1	0.38
319.0	CS_2	26736	552.0	0.38

OR

(a) In the production of sulfuric acid from anhydrous, gypsum is roasted with clay to obtain sulfur dioxide and cement clinker. The reaction proceeds as follows: **03**

$3\ CaSO_4(s) + SiO_2(s) = 3\ CaO{\cdot}SiO_2(s) + 3\ SO_2(g) + (3/2)\ O_2(g)$

Calculate the heat of reaction at 25°C (298.15 K).

Component	Phase	ΔH°f at 25°C (298.15 K) kJ/mol
$CaSO_4$	Solid	–1432.7
SiO_2	Solid (amorphous)	–903.5
$3\ CaO{\cdot}SiO_2$	Solid (clinker)	–2879.0
SO_2	Gas	–296.81
O_2	Gas	0.0

(b) Define the following terms **04**

1. Dry bulb temperature
2. Wet bulb temperature
3. Absolute humidity
4. Relative humidity

(c) A mixture of isomeric diphenyl-diphenyloxides (Diphyl DT) is used as a thermic fluid in a liquid phase heating system. The thermic fluid enters an indirect fired heater at 180 ^{o}C and leaves at 260 ^{o}C. The heat capacity of the fluid is given by **07**

$C_l = 1.436+0.00218\ T$ kJ/(kg.K) where T is in K.

(a) Calculate the supply of heat in the heater per kg of liquid heated (b) if the heat capacity of Diphyl DT at 180 ^{o}C and 260 ^{o}C are 2.424 and 2.598 kJ/kg. K, respectively, how much error will be involved in the computation of heat load using the mean heat capacity value?

Q.5 (a) Explain following terms **03**

Hess's law, Heat of formation and Heat of Combustion

(b) Discuss Proximate and Ultimate analysis of coal. **04**

(c) Isothermal and isobaric absorption of SO_2 is carried out in a packed tower containing Raschig rings. The gases enter the bottom of the tower containing 14.8% SO_2 by volume. Water is distributed at the top of the column at the rate of 16.5 L/s. The total volume of the gas handled at 101.3 kPa (760 Torr) and 30°C (303 K) is 1425 m^3/h. The gases leaving the tower are found to contain 1% SO_2 by volume on dry basis. Calculate the % SO_2 by mass in the outlet water. **07**

OR

(a) Describe How Energy Balance Determines the Heat Requirement for Drying **03**

(b) Describe the meanings of Gross Calorific Value (GCV) and Net Calorific Value (NCV), and explain the principles behind the different methods used to determine them. **04**

(c) The Orsat analysis of the flue gases shows CO_2: 12.4%, CO: 3.1%, O_2: 5.4% and N_2: 79.1% (by volume). All the hydrogen but only 85% of the carbon in the (solid) fuel appears in the flue gases. Calculate the per cent excess air used. Assume that negligible oxygen and nitrogen are present in the fuel. **07**

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