Enrolment No./Seat No_____

GUJARAT TECHNOLOGICAL UNIVERSITY

BE - SEMESTER–III EXAMINATION – SUMMER 2025

Subject Code:3130508 Date:06-06-2025

Subject Name: Material & Energy Balance Computation

Time:02:30 PM TO 05:00 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)**	In a double effect evaporator, the second effect is maintained under vacuum of 475 torr (mm Hg). Find the absolute pressure in kPa, bar and psi.	**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/sec. Density of water is 1 gm/cc.	**04**
	(c)	In the case of fluids, the local heat-transfer coefficient for long tubes and using temperature properties is expressed by the empirical equation $$h = 0.023\, G^{0.8} \times k^{0.67} \times C_p^{0.33} / (D^{0.2} \times \mu^{0.47})$$ Where, h = heat transfer coefficient, Btu/(h·ft^2·°F) G = mass velocity of fluid, lb/(ft^2· s) C_p = heat capacity of fluid at constant pressure, Btu/(lb°F) k = thermal conductivity, Btu/(h· ft · °F) D = diameter of tube, ft μ = viscosity of liquid, lb/(ft · s) convert the empirical equation into SI unit.	**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)	Ethanol is present in the aqueous solution to the extent of 1200 mg/l. Find TOC and ThOD of the solution in mg/l.	**04**
	(c)	An aqueous solution of acetic acid of 35% concentration (by mass) has density 1.04kg/lit at 298.15. Find the molarity, normality and molality of the solution	**07**
		OR	
	(c)	A gas mixture has the following composition by volume.	**07**

C_2H_4	30.6%
C_6H_6	24.5%
O_2	1.3%
CH_4	15.5%
C_2H_6	25.0%
N_2	3.1%

Find (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

Q.3 **(a)** A solution of ethyl alcohol containing 8.6% alcohol is fed at the rate of 1000 kg/hr to a continuous distillation column. The product (distillate) is a solution containing 95.5% alcohol. The waste solution from the column carries 0.1% of alcohol. All percentages are by mass. Calculate (a) the mass flow rates of top and bottom products in kg/h and (b) the percentage loss of alcohol. **07**

(b) Define following with suitable examples **07**
PFD and P&ID diagram (2) Conversion and Yield

OR

Q.3 **(a)** Acetic acid is used as principal solvent extraction and chloroform is used as an auxiliary solvent. A particular oil is first treated with acetic acid. The acetic acid -oil mixture has a composition 63.4% acetic acid and 36.6% oil. The complex is separated into two coexisting liquid phases at room temperature having the composition shown in Table 1 **07**

Composition of Acetic Acid-oil Mixture.

	Composition by mass %	
	Acetic acid	oil
Complex	63.4	36.6
Upper layer	9.62	90.38
Lower layer	93.03	6.97

To the above complex, chloroform is added. The resultant mixture (a new complex) is separated again in two coexisting liquid phases at room temperature having the composition shown in Table 2.

	Composition by mass %		
	Acetic acid	Chloroform	oil
Complex	57.8	9.7	Balance
Upper layer	24.5	18.93	Balance
Lower layer	87.5	3.62	Balance

Calculate: (a) The mass ratio of two layer for Table 1 and Table 2. (b) The amount of complex added to the original mixture.

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

(c) Describe **03**
(1) Stoichiometric Ratio
(2) Limiting Reactant
(3) Excess Reactant

Q.4 **(a)** A liquid fuel is found to contain 83% C, 15% H_2 and 2% Sulphur. Calculate the net calorific value (NCV) of liquid sample at 298 K. Data: Gross calorific value of fuel at 298 K is 45071 kJ/kg of liq fuel. Latent heat of water vapor at 298K =2442.5 kJ/kg. **07**

(b) The analysis of limestone gives 60% $CaCO_3$, 33.5% $MgCO_3$ and rest inerts. It is treated with 12% aqueous sulphuric acid by mass to obtain pure CO_2. An excess of 15% of the acid over the stoichiometric amounts is used to ascertain that the reaction goes to completion. Based on the treatment of 500 kg limestone, calculate: (a) the amount of 100% (by mass) sulphuric acid required, (b) the amount of the residue, (c) the analysis of the residue left in the vessel, and (d) the moles of CO_2 produced. **07**

OR

Q.4 **(a)** The gaseous reaction A = 2B + C takes place isothermally in a constant pressure reactor. Starting with a mixture of 75% A and 25% inerts (by volume), in a specified time the volume double. Calculate the conversion achieved. **07**

(b) A pilot plant reactor was charged with 50 kg of naphthalene and 200 kg (98% by mass) of H_2SO_4. The reaction was carried out for 3 hours at 160°C. The reaction goes to near completion. The product distribution was found to be 18.6% monosuphonate naphthalene (MSN) and 81.4% disulphonate naphthalene (DSN). Calculate (i) the quantities of MSN and DSN products, and (ii) the complete analysis of the product. **07**

Q.5 **(a)** A gas mixture has the following composition on mole basis. CH_4:84%, C_2H_6:13% and N_2:3%. Calculate the energy to be added to heat the 15 kmol of gas mixture from 298 K to 523 K using heat capacity data given below. **07**

$C_P^0 = a + bT + cT^2 + dT^3$ where C_p^0 is in kJ/kmol K or J/mol K.

Component	**a**	**b x 10^3**	**c x 10^6**	**d x 10^9**
$CH_4(g)$	19.25	52.11	11.97	-11.32
$C_2H_6(g)$	5.41	178.19	-67.38	8.72
$N_2(g)$	29.59	-5.41	13.18	-4.97

(b) Calculate the heat of reaction of the following reaction. **07**

$4NH_3(g) + 5O_2(g) \longrightarrow 4NO(g) + 6H_2O(g)$

Data: Component ΔH_f^O cal/ gmol

$NH_3(g)$ -11020

NO(g) 21570

$H_2O(g)$ -57796

OR

Q.5 **(a)** Using Watson equation, calculate laten heat of vaporization of **07**
(a) acetone at 313K (40°C) (b) carbon disulphide (CS_2) at 413 K

T_1 (Boiling point temp)	component	Laten heat of vap at T_1, K (KJ/kmol)	T_c	n
329.4	Acetone(C_3H_6O)	29121	508.1	0.38
319.0	CS_2	26736	552.0	0.38

(b) The orsat analysis of the flue gases from a boiler house chimney gives CO_2 11.2%, O_2:4.2% and N_2 84.4 % (mole %). Assuming that complete combustion has taken place, (a) calculate the % excess air and (b) find the C: H ratio in the fuel. **07**

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