Seat No.: _____ Enrolment No._____

GUJARAT TECHNOLOGICAL UNIVERSITY

BE - SEMESTER– III (New) EXAMINATION – WINTER 2019

Subject Code: 3130508 Date: 3/12/2019

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.**

			Marks
Q.1	**(a)**	A mixture of nitrogen and carbon dioxide at 298 K and 101.325 kPa has an average molecular weight of 31. Calculate the partial pressure of nitrogen.	**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)	Discuss the importance of recycling and bypassing operation	**07**
Q.2	**(a)**	A sample of well water contains 140 gm/m^3 Ca^+ ions and 345 gm/m^3 Na^+ ions. Express the hardness of the water sample in terms of equivalent of $CaCO_3$ in gm/m^3. (Atomic weight of Ca = 40, Na = 23,C = 12 and O = 16)	**03**
	(b)	Describe the material balance of drying operation.	**04**
	(c)	A solution of NaCl in water contains 15 % NaCl (by mass) at 335 K. The density of the solution is 1.127 kg/lit. Determine the molarity, normality and molality of the solution.	**07**
		OR	
	(c)	A gaseous mixture has the following composition by volume. SO_2 = 6 %, O_2 = 9%, CO = 1.5% and CO_2 = 4.5 % and remaining is nitrogen. Calculate (a) the density of gas mixture at a temperature of 425 K and at a pressure of 202.65 kPa g and (b) Composition by weight.	**07**
Q.3	**(a)**	Describe the material balance of liquid – liquid extraction.	**03**
	(b)	In a paper mill, a wash liquor containing 3% (by weight) solid is concentrated in an evaporator to yield a lye containing 30% (by weight) solids. Calculate the quantity of water evaporated per 100 kg of feed?	**04**
	(c)	A coke is known to contain 90% carbon and 10% non combustible ash by weight. (a) Calculate the moles of oxygen are theoretically required to burn 100 kg of coke completely? (b) If 50 % excess air is supplied calculate the analysis of gases at the end of combustion.	**07**

OR

Q.3 **(a)** List out the classification of material balance problems. **03**

(b) The orsat analysis of a flue gas is CO_2 = 12.7 %, O_2 = 7.1% N_2 = 80.2 %. Determine the percentage excess air used in combustion. The nitrogen present in the flue gas is contributed by air only. **04**

(c) In a production of chlorine gas by oxidation of hydrochloric acid gas, air is used 30 % in excess of that theoretically required. Based on 4 kmol HCl, Calculate; (a) The weight ratio of air to HCl gas in feed. (b) If oxidation is 85 % complete, calculate the composition off product stream on mole basis. **07**

Q.4 **(a)** Calculate the standard heat of reaction of the following reaction using std. heat of formation data. **03**

$$C_5H_{12\,(l)} + 8O_{2\,(g)} \rightarrow 5CO_{2\,(g)} + 6H_2O_{(l)}$$

Component	ΔH_f^0 = kJ/mol @25°C
C_5H_{12} (l)	-173.49
CO_2 (g)	-393.51
H_2O (l)	-285.83

(b) A feed to a continuous fractionating column (Distillation column) analyses by weight 28 % benzene and 72 % toluene. The analysis of the distillation shows 52 % (weight) benzene and 5 % (weight) benzene was found in the bottom product. Calculate the amount of distillation and bottom product per 1000 kg of feed per hour. Also calculate the recovery of benzene. **04**

(c) Pure CO is mixed with 100 % excess air and burnt. Only 80% of CO is burns. The reactants are at 100 °C and the products are at 300 °C. Estimate the amount of heat added or removed per kmol of CO fed to the reactor. **Data:** Mean molal specific heat between 25 °C and T °C in kJ/kmol K are as follows. **07**

Gas	T = 100 °C	T = 300 °C
CO	29.22	30.61
CO_2	-	43.77
O_2	29.64	43.77
N_2	29.17	29.66

Standard heat of formation at 25 °C are:
CO = -110524 kJ/kmol and CO_2 = -393514 kJ/kmol

OR

Q.4 **(a)** Calculate the enthalpy change (std. heat of reaction) between reactants and products if both are at 298.15 K and if 10 mol of formaldehyde is produced according to the following reaction. **03**

$$CH_{4\,(g)} + O_{2\,(g)} \rightarrow HCHO_{(g)} + H_2O_{(g)}$$

Component	ΔH_C^0 = kJ/mol @25°C
CH_4(g)	-890.65
HCHO	-563.46

(b) The spent acid from a nitrating process contains 15% HNO_3, 65% H_2SO_4 and 20% H_2O by weight. This acid is to be concentrated to contain 25 % HNO_3 and 58 % H_2SO_4 by addition of concentrated sulphuric acid containing 93% H_2SO_4 and concentrated nitric acid **04**

containing 90% HNO_3. Calculate the weights of spent acid, concentrated sulphuric acid and concentrated nitric acid that must be combined to obtain 100 kg of the desired mixture.

(c) 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

Q.5 **(a)** Define. (a) Adiabatic flame temperature (2) Latent heat (c) Excess air requirement. **03**

(b) A liquid fuel is found to contain 83% C, 15% hydrogen and 2% Sulphur. Calculate the net calorific value (NCV) of liquid sample at 298 K. **04**

Data: Gross calorific value of fuel at 298 K is 45071 kJ/kg of liq fuel.

Latent heat of water vapour at 298K =2442.5 kJ/kg.

(c) Discuss classification of fuels and define calorific values of fuels. **07**

OR

Q.5 **(a)** Define. (1) Heat capacity (2) Calorie (3) Humidity **03**

(b) Calculate the calorific value at 298K of a sample of fuel oil having C/H ratio of 9.33 (by weight) and containing sulphur to the extent of 1.3 % by weight. **04**

Data:

The Gross calorific value (GCV) of fuel oil at 298 K = 41785 kJ/kg.

Latent heat of water vapour (25 °C) = 2442.5 kJ/kg

(c) Discuss Ultimate analysis and proximate analysis of coal. **07**

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