Seat No.: _____ Enrolment No._____

GUJARAT TECHNOLOGICAL UNIVERSITY

BE - SEMESTER– III(NEW) EXAMINATION – WINTER 2022

Subject Code:3130508 Date:27-02-2023

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.**

Q.1 **(a)** Define the following terms: **03**
i) standard heat of reaction, ii) standard heat of formation, and iii) sensible heat

(b) In a double effect evaporator plant, the second effect is maintained under vacuum of 475 torr (mm Hg). Find the absolute pressure in kPa, bar and psi. **04**

(c) A gas mixture contains 65% CH_4, 20% C_2H_6, 10% C_3H_8, 3% N_2 and 2% O_2. Calculate (i) Average molecular mass of gas mixture and (ii) Volume occupied by this gas mixture at 405.3 KPa and 303 K. **07**

Q.2 **(a)** Explain the derived quantity and give units of the following in terms of fundamental quantities: force and work. **03**

(b) Explain the importance of recycling, bypassing and purging operations with a diagram. **04**

(c) A solution of caustic soda in water contains 20% NaOH (by weight) at 333 K (60°C). The density of the solution is 1.196 kg/l. Find the molarity, normality, and molality of the solution. **07**

OR

(c) The conductance of a fluid flow system is defined as the volumetric flow rate, to a pressure of one torr (133.233 Pa). For an orifice, the conductance C can be computed from **07**

$$C = 89.2A\sqrt{\frac{T}{M}}\ ft^3/s$$

where, A = area of opening, ft^2, T = temperature, °R, M = Molar mass
Convert the empirical equation in SI units.

Q.3 **(a)** Describe Raoult's law with its applications and limitations. **03**

(b) Explain i) Boyle's law, and ii) Dalton's law. **04**

(c) It is required to make 1000 kg mixed acid containing 60% H_2SO_4, 32% HNO_3, and 8% water by blending (i) the spent acid containing 11.3% HNO_3, 44.4% H_2SO_4, 44.3% H_2O, (ii) aqueous 90% HNO_3 and (iii) aqueous 98% H_2SO_4. All % are by weight. Calculate the quantities of each of the three acids required for mixing. **07**

OR

Q.3 **(a)** Find % excess of H_2 for $N_2 + 3H_2 \rightarrow 2NH_3$ reaction if for 100 kg of NH_3 production, H_2 fed is 30 kg. **03**

(b) Explain the following terms with reference to air-water humidification operation: **04**
i) dry-bulb temperature, ii) absolute humidity, iii) dew point, and iv) wet-bulb temperature

(c) Heat capacity data for gaseous SO_2 are reported in standard data book by the following equation: **07**

$C_p^0 = 43.458 + 10.634 \times 10^{-3}\ T - 5.945 \times 10^5/T^2$ ($kJ.kmol^{-1}.K^{-1}$)

Calculate the heat required to raise the temperature of 1 kmol pure SO_2 from 300 to 1000 K, using the above equation.

Q.4 **(a)** Explain the following terms with reference to the chemical processes: i) process flow sheet, ii) P & I diagram, and iii) degree of freedom **03**

(b) Discuss the various methods involved for solving material balance problems without chemical reactions. **04**

(c) Obtain an expression relating the heat of reaction and the temperature of the reaction $SO_{2\,(g)} + ½\ O_{2\,(g)} \rightarrow SO_{3\,(g)}$. Using the same expression, calculate the heat of reaction at 800K. **07**

The heat capacity data is given below:

$C_p^o = a + bT + cT^2 + dT^3$ where C_p^o = Ideal gas heat capacity at 101.325 kPa, kJ/(kmol.K) and T = Absolute temperature, K

Compound	a	b x 10^3	c x 10^6	d x 10^9
Sulphur dioxide (SO_2)	24.7706	62.9481	-44.2582	11.122
Oxygen (O_2)	26.0257	11.7551	-2.3426	-0.5623
Sulphur trioxide (SO_3)	22.0376	121.624	-91.8673	24.3691

The standard heat of formation data is given in the following table:

Component	ΔH_f^o at 298.15 K, kJ/mol
$SO_{2\,(g)}$	-296.81
$SO_{3\,(g)}$	-395.72

OR

Q.4 **(a)** Describe the following equations with their terminology: **03**
i) Watson equation ii) Riedel equation iii) NIST equation

(b) The (GHV) gross heating value of gaseous propane is 2219.71 kJ/mol at 298.15 K. Calculate its NHV (net heating value) in kJ/mol and kJ/kg. Latent heat of water vapor at 298.15 K = 2442.5 kJ/kg. **04**

(c) 100 kg of Cadmium at 27^0C is to be melted. The heat is supplied by steam. Calculate mass of steam to be supplied. **07**

Data:
Melting Point of Cadmium is 320.9 ^{0}C.
Atomic weight of Cadmium = 112.
$C_p = 6 + 0.005T$ kcal/kmol^{0}C where T is in ^{0}C.
Latent heat of fusion = 2050 kcal/kmol
Latent heat of steam = 210 kcal/kg

Q.5 **(a)** Describe excess reactant, limiting reactant and recycle ratio. **03**

(b) In the production of sulphur trioxide, 100 kmol of SO_2 and 100 kmol of O_2 are fed to a reactor. If the percent conversion of SO_2 to SO_3 is 80%, Calculate the composition of product stream on mole basis. **04**

(c) Give classification of fuel in brief. Define GCV and NCV for fuels. Give its importance. **07**

OR

Q.5 **(a)** Describe the material balance of liquid – liquid extraction. **03**

(b) 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. **04**

(c) Discuss ultimate analysis of coal. Give Dulong formula and Calderwood equation with nomenclature. **07**

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