

GUJARAT TECHNOLOGICAL UNIVERSITY**BE - SEMESTER-III (NEW) EXAMINATION – WINTER 2021****Subject Code:3130508****Date:23-02-2022****Subject Name:Material & 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.

- | | | Marks |
|------------|---|--------------|
| Q.1 | <p>(a) A bag filter of 5 micron rating is designed for a pressure drop of 0.05 lb_f/in² per US gallon per minute of water solution in clean conditions. Calculate the pressure drop in kPa from the filter for water flow rate of 10 m³/hr.</p> | 03 |
| | <p>(b) Heat capacity of sulphuric acid is given by</p> $C_p^0 = 23.06 + 2.071 \times 10^{-2} T$ <p>Where, C_p^0 = Heat Capacity in Btu/ (lb-mol ⁰R) and
 T = Temperature in ⁰R</p> <p>What is the equivalent expression if heat capacity is given in kJ/ (kmol K) and T is in K.</p> | 04 |
| | <p>(c) Acetaldehyde is oxidized over silica gel with the help of air. The mixture is passed over the catalyst at 387 K. The outgoing dry gases are found to contain 4.85% CO₂, 8.65% acetaldehyde, 14.9% acetic acid, 2.55% O₂ and 69.05% N₂ by volume on dry basis. For carrying out dry analysis, water was first removed from the mixture. During the water removal, some acetic acid is also condensed. Calculate (1) the percentage conversion of acetaldehyde (2) the percentage yield of acetic acid (3) the wt ratio of air to acetaldehyde in incoming feed (4) the percentage removal of acetic acid during removal of water (5) the actual analysis of gases leaving the reactor.</p> | 07 |
| Q.2 | <p>(a) Calculate the vapour phase composition at 60 ⁰C in equilibrium with a liquid mixture containing 40 mole% benzene and 60 mole% toluene.
 Data: Vapour pressure of benzene at 60 ⁰C= 385 torr; Vapour pressure of toluene at 60 ⁰C= 140 torr</p> | 03 |
| | <p>(b) Aqueous solution of triethanolamine (TEA) i.e. N(CH₂CH₂OH)₃ contains 50% TEA by weight. Find the molarity of the solution if the density of the solution is 1.05 kg/liter.</p> | 04 |
| | <p>(c) Cracked gas from a petroleum refinery has the following composition by volume: 45% methane, 10% ethane, 25% ethylene, 7% propane, 8% propylene, 5% n-butane</p> | 07 |

Find (1) the average molar mass of the gas mixture (2) the composition by mass, and (3) specific gravity of the gas mixture.

OR

- (c) The composition of a gas mixture in the manufacture of nitric acid at a pressure of 0.709 MPa g and at a temperature of 923 K is as follows: $N_2 = 70.5\%$, $O_2 = 18.8\%$, $H_2O = 1.2\%$ and $NH_3 = 9.5\%$ Calculate the density of the gas mixture using an ideal gas law. **07**

- Q.3 (a)** A waste acid from a nitrating process contains 23% HNO_3 , 57% H_2SO_4 and 20% water by weight. This acid is to be concentrated to contains 27% HNO_3 , 60% H_2SO_4 by the addition of concentrated sulphuric acid containing 93% H_2SO_4 and concentrated nitric acid 90% HNO_3 . All percentages are on weight basis. Calculate the amounts in kg of waste and concentrated acids that must be combined to obtain 1000 kg of desired mixture. **03**

- (b) Define (1) Stoichiometric Ratio (2) Limiting Reactant (3) Excess reactant (4) Selectivity **04**

- (c) A gas mixture containing 15 mole% 'A' and 85 mole% inert is fed to an absorption tower where it is contacted with liquid solvent 'B' which absorbs 'A'. The mole ratio of solvent to gas entering tower is 2:1. The gas leaving the absorber contains 2.5% 'A', 1.5% 'B' and rest inert on mole basis. Calculate (a) the percentage of the original solute 'A' that remains unrecovered (b) the fraction of solvent ('B') fed to tower lost in gas leaving the tower. During process same solvent evaporates and gets added in gas leaving the tower. **07**

OR

- Q.3 (a)** A multiple effect evaporator system has a capacity of processing one tone per day of solid caustic soda when it concentrates weak liquor from 4 to 25% (both on weight basis). When the plant is fed with 5% weak liquor and if it is concentrated to 50% (by weight). Find the capacity of plant in terms of solid caustic soda assuming the water evaporating capacity to be same in both cases. **03**

- (b) What is the difference between recycling and bypassing operation in chemical industry? Discuss the importance of recycling and bypassing operation in chemical industry. **04**

- (c) Formaldehyde is produced by dehydrogenation of methanol. $CH_3OH \longrightarrow HCHO + H_2$ **07**
The per pass conversion is 67%. The product leaving the reactor is fed to separation unit battery where formaldehyde is separated from methanol and hydrogen. The separated methanol is recycled to the reactor. If the production rate of formaldehyde is 1000 kg/h, calculate: (1) Combined feed ratio and (2) Flow rate of methanol required to the process as fresh feed.

- Q.4 (a)** Heat Capacity data for gaseous SO₂ is given by the following equation: **03**

$$C_p^0 = 43.458 + 10.634 \times 10^{-3} T - 5.945 \times \frac{10^5}{T^2}$$

Calculate the heat needed to raise the temperature of 1 kmol pure sulphur dioxide from 300 K to 1000 K.

- (b)** Calculate the standard heat of formation of liquid 1-3 butadiene (C₄H₆) at 298.15 K (25 °C) using the following data: **04**

Standard heat of formation of CO₂ (g) = -393.51 kJ/mol

Standard heat of formation of H₂O (l) = -285.83 kJ/mol

Heat of combustion of liquid 1-3 butadiene (C₄H₆) at 298.15 K (25 °C) = - 2520.11 kJ/mol

- (c)** Calculate the standard heat of reaction at 298.15 K when gaseous ammonia is dissolved in water to form 2% by weight ammonia solution. **07**

Data

Component	ΔH_f° , kJ/mol
NH ₃ (g)	-49.94
NH ₄ OH (l)	-361.20
H ₂ O (l)	-285.83

OR

- Q.4 (a)** 125 kg/h of methanol liquid at a temperature of 35 °C is to be obtained by removing heat from saturated methanol vapour. Find out the amount of heat to be removed in kJ/sec. **03**

Data:

Boiling point of menthol = 64.8 °C

Latent heat of condensation of methanol= 1101.7 kJ/kg

Specific heat of methanol = 2.7235 kJ/ (kg K)

- (b)** Define the following terms: (1) Heat of formation (2) Heat of combustion (3) Heat of reaction **04**

- (c)** The gas having the following composition by volume is at temperature of 502 °C. SO₂ = 7.09% O₂ = 10.55% SO₃ = 0.45% N₂ = 81.91% Calculate the heat amount of 1 kmol gas mixture over 25 °C using the heat capacity data given below. **07**

Gas	a	b x 10 ³	c x 10 ⁶	d x 10 ⁹
SO ₂	24.7706	62.9481	-44.2582	11.122
O ₂	26.0257	11.7551	-2.3426	-0.5623
SO ₃	22.0376	121.624	-91.8673	24.3691
N ₂	29.5909	-5.141	13.1829	-4.968

- Q.5 (a)** What is ultimate analysis and proximate analysis of coal? **03**

- (b)** Define **04**

(1) Absolute Humidity (2) Relative Humidity (3) Percentage Humidity (4) Wet bulb temperature

- (c) Calculate the GHV and NHV in kJ/mol, kJ/kg & kJ/m³ at 298 K of the gas having following composition by volume: 07

CH₄: 74.4 %, C₂H₆ : 8.4 %, C₃H₈ : 7.4 %, i-C₄H₁₀ : 1.7 %, n-C₄H₁₀ : 2.0 %, i-C₅H₁₂ : 0.5 %, n-C₅H₁₂ : 0.4 %, N₂ : 4.3 %, CO₂: 0.9 %

Data:

Component	GCV, kJ/mol	NCV, kJ/mol
CH ₄	890.65	802.62
C ₂ H ₆	1560.69	1428.64
C ₃ H ₈	2219.17	2043.11
i-C ₄ H ₁₀	2868.20	2648.12
n-C ₄ H ₁₀	2877.40	2657.32
i-C ₅ H ₁₂	3528.83	3264.73
n-C ₅ H ₁₂	3535.77	3271.67

Specific volume of the gas at 25 °C and 101.3 kPa = 24.465 m³/kmol

OR

- Q.5 (a)** A sample from Godavari Colliery has the following analyses: 03

Component	Mass%
Carbon	50.22
Hydrogen	2.79
Sulphur	0.37
Nitrogen	2.05
Ash	19.53
Oxygen	18.04
Moisture	7.00

Calculate GCV based on the Dulong formula

- (b) The dry bulb temperature and dew point of ambient air were found to be 303 K and 289 K respectively. Calculate (1) the absolute molal humidity (2) the % RH (3) the humid heat. 04

Data: Vapour pressure of water at 289 K = 1.818 kPa

Vapour pressure of water at 303 K = 4.243 kPa

Barometric pressure =100 kPa

- (c) The Orsat analysis of the flue gases from a boiler house chimney by volume is as given below: 07

CO₂: 11.4%, O₂: 4.2%, and N₂: 84.4%

Assuming complete combustion,

- (1) Calculate the % excess air
- (2) Find the C:H ratio in the fuel
