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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Seat No.: _____ Enrolment No._____

GUJARAT TECHNOLOGICAL UNIVERSITY

BE- SEMESTER–III (NEW) EXAMINATION – WINTER 2020

Subject Code:3130508 Date:05/03/2021

Subject Name:Material & Energy Balance Computation

Time:10:30 AM TO 12:30 PM Total Marks:56

Instructions:

1. **Attempt any FOUR questions out of EIGHT questions.**
2. **Make suitable assumptions wherever necessary.**
3. **Figures to the right indicate full marks.**

			Marks
Q.1	**(a)**	Define Fundamental and Derived Units with example	**03**
	(b)	In double effect evaporator plant the second effect is maintain under vacuum of 475torr (mmHg).find the absolute pressure in kpa	**04**
	(c)	A gas contain in a closed vessel at pressure of 121.59 kPa g and 299 K (29 ^{O}C) gas heated to temperature of 1273 K (1000 ^{O}C) Find the pressure to which a closed vessel should be designed.	**07**
Q.2	**(a)**	Describe (1) Stoichiometric Ratio (2) Stoichiometric Proportion (3) Excess Reactant	**03**
	(b)	Discuss about By Pass operations	**04**
	(c)	A solution of caustic soda in water contains 20% NaOH (by weight) at 333 K. The density of the solution is 1.196kg/l. Find the molarity, normality and molality of the solution	**07**
Q.3	**(a)**	Explain the methods for solving problems of material balance without chemical reactions	**03**
	(b)	A combustion reactor is fed with 50 kmol/ of butane and 2100kmol/h air calculate the % excess air used.	**04**
	(c)	It is required to make 1000 kg mixed acid containing 60% H2SO4, 32% HNO3 and 8% water by blending (i) the spent acid containing 11.3 % HNO3, 44.4% H2SO4 and 44.3 % H2O. (ii) Aqueous 90% HNO3 and (iii) aqueous 98 % H2SO4. All percentages are by mass. Calculate the quantities of each of the three acids required for blending	**07**
Q.4	**(a)**	Define : Drying, Evaporation, crystallization	**03**
	(b)	(A) In Manufacture of chlorine, feed containing HCL acid gas and air are fed to an oxidizer the product gases leaving the oxidizer are found to contain 13.2 % HCL, 6.3% O_2, 42.9% N_2, 30% CL_2, 7.6% H_2O Calculate A) The percent excess air used. B) The composition by weight of gases entering the oxidizer	**04**

(c) Soybean seeds are extracted with hexane in batch extractors. The flaked seeds contains 18.6 % oil, 69.0 % solids & 12.4 % moisture cake. At the end of the extraction process the cake is separated from the hexane oil mixture. The cake analysis yields, 0.8 % oil, 87.8%solids and 11.5 % moisture. Find the% recovery of oil .All percentage is on weight basis **07**

Q.5 **(a)** Describe Importance of energy balance in chemical industry. **03**

(b) Definematerial balance and explain methods solving material balance without chemical reaction. **04**

(c) Temperature of pure Oxygen is raised from 350 to 1500 K. calculate the amount of heat to be supplied for raising the temperature of 1 kmol oxygen using the following Cpo data **07**

Cpo = a + bT +cT2 +dT3 KJ/ (Kmol. K)

Gas	a	b x 10^3	c x 10^6	d x 10^9
0_2	26.0257	11.7551	-2.3426	-0.5623

Q.6 **(a)** Define the following terms: **03**

(1) Heat of formation
(2) Heat of combustion
(3) Heat of reaction

(b) In Production of SO_3, 100 kmol of SO_2, And 200 kmol of O_2 are fed to a reactor. The Product stream is found to contain 80 kmol SO_3. Find the Percentage conversion of SO_2 **04**

(c) Pure methane gas is heated from 303K to 523K at atmospheric pressure. Calculate the heat added per kmole methane using Cp^0 data given below **07**

Cp^o = a + bT +cT2 +dT3 KJ/ (Kmol. K)

Gas	a	b x 10^3	c x 10^6	d x 10^9
$C0_2$	19.2494	52.1135	11.973	-11.3173

Q.7 **(a)** In manufacture of acetic acid by oxidation of acetaldehyde, 100kmol of acetaldehyde is fed to a reactor per hour. The product leaving the reactor contain 14.81% acetaldehyde, 59.29% acetic acid , and rest of oxygen. Find percentage conversion of acetaldehyde **03**

(b) The GHV(gross heating value) of gaseous n- butane is 2877.40 kj/ mol at 298 K. calculate its NHV (net heating value) in KJ/kg **04**

(c) Explain Air Requirement for fuel and used method of theoretical oxygen, theoretical, air Excess air **07**

Q.8 **(a)** In Production of SO_3, 100 kmol of SO_2, And 200 kmol of O_2 are fed to a reactor. The Product stream is found to contain 80 kmol SO_3. Calculate the composition of the product stream on mole basis **03**

(b) Crude oil is analyzed to contain 87% carbon , 12.5% hydrogen and 0.5 % sulphur calculate net calorific value of crude oil at 298 K. **04**

(c) Discuss about proximate and ultimate analysis of fuel **07**

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Seat No.: _____ Enrolment No._____

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	**(a)**	A bag filter of 5 micron rating is designed for a pressure drop of 0.05 lb_f/in^2 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 m^3/hr.	**03**
	(b)	Heat capacity of sulphuric acid is given by $C_p^0 = 23.06 + 2.071 \times 10^{-2} T$ Where, C_p^0 = Heat Capacity in Btu/ (lb-mol ^0R) and T = Temperature in ^0R What is the equivalent expression if heat capacity is given in kJ/ (kmol K) and T is in K.	**04**
	(c)	Acetaldehyde is oxides 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% CO_2, 8.65% acetaldehyde, 14.9% acetic acid, 2.55% O_2 and 69.05% N_2 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.	**07**
Q.2	**(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	**03**
	(b)	Aqueous solution of triethanolamine (TEA) i.e. $N(CH_2CH_2OH)_3$ contains 50% TEA by weight. Find the molarity of the solution if the density of the solution is 1.05 kg/liter.	**04**
	(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	**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. **07**

$$CH_3OH \longrightarrow HCHO + H_2$$

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 SO_2 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 (C_4H_6) at 298.15 K (25 ^{0}C) using the following dada: **04**
Standard heat of formation of CO_2 (g) = -393.51 kJ/mol
Standard heat of formation of H_2O (l) = -285.83 kJ/mol
Heat of combustion of liquid 1-3 butadiene (C_4H_6) 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^o, kJ/mol
NH_3 (g)	-49.94
NH_4OH (l)	-361.20
H_2O (l)	-285.83

OR

Q.4 **(a)** 125 kg/h of methanol liquid at a temperature of 35 ^{0}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 ^{0}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 ^{0}C. SO_2 = 7.09% O_2 = 10.55% SO_3 = 0.45% N_2 = 81.91% **07**
Calculate the heat amount of 1 kmol gas mixture over 25 ^{0}C using the heat capacity data given below.

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/m^3 at 298 K of the gas having following composition by volume: **07**

CH_4: 74.4 %, C_2H_6 : 8.4 %, C_3H_8 : 7.4 %, i-C_4H_{10} : 1.7 %, n-C_4H_{10} : 2.0 %, i-C_5H_{12} : 0.5 %, n-C_5H_{12} : 0.4 %, N_2 : 4.3 %, CO_2: 0.9 %

Data:

Component	GCV, kJ/mol	NCV, kJ/mol
CH_4	890.65	802.62
C_2H_6	1560.69	1428.64
C_3H_8	2219.17	2043.11
i-C_4H_{10}	2868.20	2648.12
n-C_4H_{10}	2877.40	2657.32
i-C_5H_{12}	3528.83	3264.73
n-C_5H_{12}	3535.77	3271.67

Specific volume of the gas at 25 ^{0}C and 101.3 kPa = 24.465 m^3/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**

CO_2: 11.4%, O_2: 4.2%, and N_2: 84.4%

Assuming complete combustion,

(1) Calculate the % excess air

(2) Find the C:H ratio in the fuel

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Seat No.: _____ Enrolment No._____

GUJARAT TECHNOLOGICAL UNIVERSITY

BE - SEMESTER–III (NEW) EXAMINATION – SUMMER 2021

Subject Code:3130508 Date:06/10/2021

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.**

Q.1 **(a)** Define the following terms with reference to air-water humidification operation: i) dry-bulb temperature, ii) wet-bulb temperature, iii) dew point **03**

(b) A solution containing 55% benzene, 28% toluene and 17% xylene by weight is in contact with its vapour at 373 K. Calculate the total pressure and molar composition of the liquid and vapour. **04**

Data: vapour pressure at 373 K:
benzene: 178.6 kPa, toluene: 74.6 kPa, xylene: 28 kPa

(c) In case of liquids, the local heat-transfer coefficient for long tubes and using bulk-temperature properties is expressed by the following empirical equation: **07**

$$h = 0.023\, G^{0.8} k^{0.67} C_p^{\,0.33} / (D^{0.2} \mu^{0.47})$$

where h = heat-transfer coefficient, Btu/(h.ft^2.^{o}F)
G = mass velocity of liquid, lb/(ft^2.s)
C_p = heat capacity, Btu/(lb.^{o}F)
k = thermal conductivity, Btu/(h.ft.^{o}F)
D = diameter of tube, ft and
μ = viscosity of liquid, lb/(ft.s)

Convert the equation into SI units.

Q.2 **(a)** Discuss the importance of recycling, parallel and bypassing operations. **03**

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

(c) The dry bulb temp & dew point of ambient air were found to be 302 K & 291 K respectively. The barometer reads 100 kPa. Calculate: i) the absolute molal humidity, ii) the absolute humidity, iii) % RH, iv) % saturation, v) humid heat, and vi) humid volume. **07**

Data: vapour pressure of water at 291 K = 2.0624 kPa
vapour pressure of water at 302 K = 4.004 kPa

OR

(c) The average molecular mass of a flue gas sample is calculated by two different engineers. One engineer uses the correct molar mass of 28 for N_2 and determines the average molar mass to be 30.8, the other engineer, using an incorrect value of 14, calculates the average molar mass to be 20.3. i) Calculate the volume % of N_2 in the flue gases, ii) If the remaining components of the flue gases are CO_2 and O_2, calculate the volume % of each of them. **07**

Q.3 **(a)** Explain normality, molarity and molality. **03**

(b) 5000 kg of benzene and toluene containing 50 mol% benzene is distilled to get an overhead product containing 95 mol% benzene and a residue containing 90 mol% toluene. Calculate benzene and toluene in feed, distillate and residue. **04**

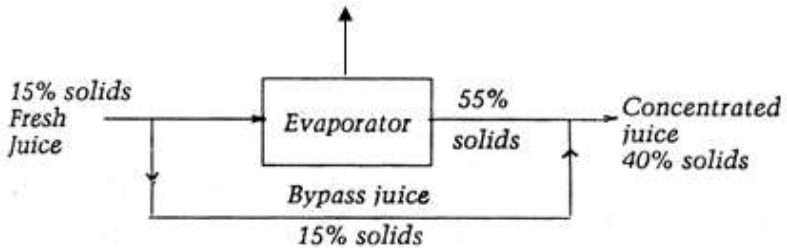
(c) A mixed acid is to be prepared from spent acid, 99% H_2SO_4, 95% HNO_3 and water, if necessary. Determine the mass of sulphuric acid, nitric acid and water necessary to convert 1000 kg of spent acid containing 40% H_2SO_4, 20% HNO_3, 40% H_2O into a mixed acid containing 50% H_2SO_4, 40% HNO_3, 10% H_2O. All percentages are on mass basis. **07**

OR

Q.3 **(a)** Explain the importance of a process flowsheet. **03**

(b) With a typical example, explain the following terms: **04**
Conversion, yield, selectivity and limiting component.

(c) Fresh juice contains 15% solids and 85% water (by wt.) is to be concentrated to contain 40% solids. In a single evaporation system, it is found that volatile constituents of juice escape with water leaving the concentrated juice with a flat taste. To overcome this problem, part of the fresh juice bypasses the evaporator operation as shown schematically in the figure. **07**



Analyze the diagram and calculate:
i) The fraction of juice that bypasses the evaporator
ii) The concentrated juice produced (containing 40% solids) per 100 kg of fresh juice fed to the process.

Q.4 **(a)** Explain the following: **03**
i) Watson equation ii) Riedel Equation

(b) In the Deacon process for manufacturing chlorine, hydrochloric acid gas is oxidized with air. The reaction taking place is: **04**
$4HCl + O_2 \rightarrow 2Cl_2 + 2H_2O$
If the air is used in excess of 30% of that theoretically required and if the oxidation is 80% complete, calculate the composition by volume of dry gases leaving the reaction chamber.

(c) Tallow is essential glyceryl tristearate. It is desired to saponify the tallow with caustic soda. For 100 kg of tallow, calculate i) the theoretical requirement of caustic soda, and ii) the amount of glycerin liberated. **07**
Data:
Molecular weight of glyceryl tristearate = 890 kg/kmol
Molecular weight of caustic soda = 40 kg/kmol
Molecular weight of sodium stearate = 306 kg/kmol
Molecular weight of glycerin = 92 kg/kmol

OR

Q.4 **(a)** Explain the material balance in electrochemical reactions. **03**

(b) Define and explain the following terms: **04**
i) latent heat of vaporization ii) latent heat of condensation
iii) latent heat of sublimation iv) latent heat of fusion

(c) A mixture of aniline and water containing 11.8% by weight of aniline is cooled from 100 ^oC to 40 ^oC with the help of cooling water. Find the amount of heat removed by cooling 100 kg of aniline mixture. **07**
The specific $C_p = a + bT + cT^2$ (kcal/kg.^oC)
where constants a, b, c are:
For aniline: a = 1.407, b = 2.467 x 10^{-3}, c = -6.08 x 10^{-6}
For water: a = 0.6741, b = 2.8 x 10^{-3}, c = 8.3 x 10^{-6}

Q.5 **(a)** State Hess's law of constant heat summation. **03**

	(b)	Why is excess air provided for combustion process? Write a short note on orsat analysis.	**04**
	(c)	The ultimate analysis of coal sample by weight is given below: Carbon: 61.5%, H_2: 3.5%, S: 0.4%, ash: 14.2%, N_2: 1.8% and rest O_2 Calculate: i) theoretical oxygen requirement per unit weight of coal, ii) theoretical dry air requirement per unit weight of coal, and iii) the orsat analysis of flue gases when coal is burnt with 90% excess dry air.	**07**
		OR	
Q.5	**(a)**	Define GCV and NCV for fuels and discuss their importance.	**03**
	(b)	Define and distinguish the following: i) Sensible heat and latent heat ii) Endothermic and exothermic reactions	**04**
	(c)	Discuss Ultimate analysis of coal. Give Dulong formula and Calderwood equation with nomenclature.	**07**

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Seat No.: _____ Enrolment No._____

GUJARAT TECHNOLOGICAL UNIVERSITY

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

Subject Code:3130508 Date:18-07-2022

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)** What is derived quantity? Give units of the following in terms of fundamental quantities: density and pressure. **03**

(b) Discuss importance of recycling and bypassing operations. **04**

(c) The average molecular mass of a flue gas sample is calculated by two different engineers. One engineer uses the correct molar mass of 28 for N_2 and determines the average molar mass to be 30.8, the other engineer, using an incorrect value of 14, calculates the average molar mass to be 20.3. i) Calculate the volume % of N_2 in the flue gases, ii) If the remaining components of the flue gases are CO_2 and O_2, calculate the volume % of each of them. **07**

Q.2 **(a)** Define the following terms: **03**
i) sensible heat ii) latent heat iii) heat capacity

(b) A force equal to 192.6 N is applied on a piston with a diameter of 5 cm. Find the pressure exerted by the piston in kPa, bar and psi. **04**

(c) Cracked gas from a petroleum refinery has the following composition by volume; methane 40%, ethane 10%, ethylene 25%, propane 10%, propylene 10%, n-butane 5%. Find: **07**
i) average molecular weight of the mixture,
ii) the composition by wt%, and
iii) density of the gas mixture

OR

(c) In case of liquids, the local heat-transfer coefficient for long tubes and using bulk-temperature properties is expressed by the empirical equation **07**

$$h = 0.023\, G^{0.8} k^{0.67} C_p^{\,0.33} / (D^{0.2} \mu^{0.47})$$

where h = heat-transfer coefficient, Btu/(h.ft^2.^{o}F)
G = mass velocity of liquid, lb/(ft^2.s)
C_p = heat capacity, Btu/(lb.^{o}F)
k = thermal conductivity, Btu/(h.ft.^{o}F)
D = diameter of tube, ft and
μ = viscosity of liquid, lb/(ft.s)

Convert the equation into SI units.

Q.3 **(a)** A sample of milliolite limestone, obtained from Porbandar, Gujarat, is found to contain 45.5% 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) A H_2SO_4 solution has a molarity of 11.24 and molality of 94. Calculate the density of the solution. **04**

(c) The feed to a continuous fractionating column analyzes by weight 28% benzene and 72% toluene. The analysis of the distillate shows 52% benzene and 5% benzene was **07**

found in the bottom product. Calculate the amount of distillate and bottom product per 1000 kg/h of feed. Also calculate the % recovery of benzene.

OR

Q.3 **(a)** Write the following equations with description of their terms: **03**
i) Watson equation ii) Riedel equation iii) NIST equation

(b) Aqueous solution of triethanolamine (TEA) of molar mass 149 contains 60% TEA by mass. Find the molarity of the solution if density of the solution is 1.5 kg/lit. **04**

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

Q.4 **(a)** Define percentage conversion, percentage yield and selectivity. **03**

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

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

OR

Q.4 **(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) 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) A mixture of aniline and water containing 11.8% by weight of aniline is cooled from 100 ^oC to 40 ^oC with the help of cooling water. Find the amount of heat removed by cooling 100 kg of aniline-water mixture. **07**
The specific $C_p = a + bT + cT^2$ (kcal/kg.^oC)
where constants a, b, c are:
For aniline: a = 1.407, b = 2.467 x 10^{-3}, c = -6.08 x 10^{-6}
For water: a = 0.6741, b = 2.8 x 10^{-3}, c = 8.3 x 10^{-6}

Q.5 **(a)** With a neat sketch show the material balance for the following unit operations: **03**
i) Gas absorption, and ii) liquid-liquid extraction

(b) The feed water to reverse osmosis plant has dissolved solids to the extent of 5000 mg/L. The feed to product ratio (by mass) is 4:3. The treated water from the plant contains 600 mg/L of solids. Find the dissolved solids in the reject stream. **04**

(c) For o-xylene, calculate: **07**
i) latent heat of vaporization at T_B using Riedel equation, and
ii) latent heat of vaporization at 25 ^oC using Watson equation.
Data: P_C = 3732 kPa, T_C = 630.3 K, T_B = 417.6 K

OR

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

(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^oC 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^oC. atomic weight of Cadmium is 112.
$C_P = 6 + 0.005T$ kcal/kmol.^oC where T is in ^oC
latent heat of fusion = 2050 kcal/kmol
latent Heat of steam = 210 kcal/kg

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