Seat No.: ________ Enrolment No.

GUJARAT TECHNOLOGICAL UNIVERSITY

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

Subject Code: 3133606 **Date: 26/11/2019**

Subject Name: Fundamentals of Material & Energy Balance Calculations

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)** Discuss Proximate and Ultimate analysis of coal. **03**

(b) Give Classification of material balance problems and explain it briefly. **04**

(c) A natural gas has the following composition on mole basis: CH_4= 84%, C_2H_4=13% and N_2= 3% **07**

Calculate the heat added to heat 10 kmol of natural gas from 298 K to 523 K using heat capacity dat given below:

$$Cp= a + bT+ cT^2+dT^3 \quad kJ/(kmol.K)$$

Gas	a	b×10³	c×10⁶	d×10⁹
CH_4	19.2494	52.1135	11.973	-11.3173
C_2H_6	5.4129	178.0872	-67.3749	8.7147
N_2	29.5909	-5.141	13.1829	-4.968

Q.2 **(a)** A gas containing 25 % CO, 5% CO_2, 2% O_2 and the rest is N_2 is burnt with 20% excess air. If the conversion is 80% complete, calculate the composition by volume of the flue gases considering the given compositions of gas to be on mole basis. **03**

(b) Limestone mixed with coke is being burnt in a kiln. An average analysis of the limestone is $CaCO_3$= 84.5%, $MgCO_3$= 11.5 % and the rest is inerts. The coke contains 76% carbon 21% ash and 3% moisture. The calcination of $CaCO_3$ is only 95 % complete and that of $MgCO_3$ is 90%. The carbon in the coke is completely burnt to CO_2. The kiln is fed with one kg of coke per 5 kg of limestone. Calculate the weight percent of CaO in the product leaving the kiln. Assume that the moisture in the feed is completely vaporized. **04**

(c) Pure methane is heated from 303.15K to 523.15 K at atmospheric pressure. Calculate the heat added per kmol methane, using date given below: **07**

a	b×10³	c×10⁶	d×10⁹
19.2494	52.1135	11.973	-11.3173

OR

(c) Calculate the heat of reaction at 298.15 K of the following reaction: **07**

$3CaSO_{4(s)} + SiO_{2(s)} \quad 3\,CaO.SiO_{2(s)} + SO_{2(g)} + 3/2\,O_{2(g)}$

Component	ΔH^0_f, kJ/mol at 298.15 K (25^0 C)
$CaSO_{4(s)}$	-1432.7
$SiO_{2(s)}$	-903.5
$3\,CaO.SiO_{2(s)}$	-2879
$SO_{2(g)}$	-296.81
$O_{2(g)}$	0.0

Q.3 **(a)** Define following terms (a) Yield (b) limiting reactant and (c) Molality **03**

(b) What are the methods of expressing the composition of mixtures and solutions? **04**

(c) The waste acid from a nitrating process containing 20% HNO_3, 55% H_2SO_4 and 25% H_2O by weight is to be concentrated by addition of concentrated sulphuric acid containing 90% HNO_3 to get desired mixed acid containing 26% HNO_3 and 60% H_2SO_4. Calculate the quantities of waste and concentrated acids required for 1000 kg of desired mixed acid. **07**

OR

Q.3 **(a)** Define (a) Adiabatic saturation temperature (b) Wet bulb Temperature (c) Molal humidity **03**

(b) Define NCV and GCV. **04**

(c) A Feed containing 50% benzene and 50% toluene is fed to a distillation column at the rate of 5000 kg/h. The top product contains 95% benzene and bottom product contains 92% toluene by weight. Calculate (a) the mass flow rates of top and bottom products and (b) the percent recovery of benzene. **07**

Q.4 **(a)** 98 grams of sulphuric acid are dissolved in water to prepare one litre of solution. Find normality and molarity of solution. **03**

(b) Write down statement of Amagat's law with mathematical expression. **04**

(c) A mixture of acetone vapour and nitrogen contains 14.8% acetone by volume. Calculate the following at 293 K and a pressure of 99.33 kPa. **07**

(a) Partial pressure of acetone.
(b) Moles of acetone per mole of nitrogen.
(c) Relative saturation of mixture at 293 K.
(d) Percentage saturation of mixture at 293 K.

Data: Vapour pressure of acetone at 293 K = 24.638 kPa

OR

Q.4 **(a)** Write in brief about selectivity. **03**

(b) Brief about raoult's law and henry's law for gas-liquid system. **04**

(c) A mixture of benzene vapour and nitrogen gas at 297 K and 100 kPa has a relative humidity of 60%. It is desired to recover 80% of benzene by cooling a mixture to 283 K and compressing to a suitable pressure. Find out the pressure required for above duty. **07**

Data: Vapour pressure of benzene at 297 K = 12.2 kPa

Q.5 **(a)** 2000 kg of wet solids by weight are fed to a tray dryer where it is dried by hot air. The product finally obtained is found to contain 1 % moisture by weight, calculate: **03**

(a) The kg of water removed from solids,
(b) The kg of product obtained.

(b) Acetone is recovered from an acetone-air mixture containing 25% (volume) acetone by scrubbing with water. Assuming that air is insoluble in water, determine the percent of acetone in the entering gas that is absorbed if the gas leaving the scrubber analyzes 5% acetone. **04**

(c) Explain orsat analysis with diagram. **07**

OR

Q.5 **(a)** Draw neat sketch of Recycle, bypass and purge operations with explanation. **03**

(b) A continuous distillation column is used to regenerate solvent for use in a solvent extraction unit. The column treats 200 kmol/hr of a feed containing 10 % mole ethyl alcohol and the rest is water. The overhead product is 89% mole alcohol and the bottom product is 0.3% mole alcohol. The overhead product is sent to the extraction unit and the bottom is wasted. What is the daily requirement of make-up alcohol in the solvent extraction unit? **04**

(c) A purified brine at the rate of 50 kg/h is sent to an electrolytic cell for producing chlorine: **07**

$$2NaCl + 2H_2O \longrightarrow 2NaOH + Cl_2 + H_2$$

Only 50 % of NaCl in the charge is electrolyzed. The gases leaving the cell carry with them water vapour in the ratio 0.03 mol/mol gas formed. The solution leaving the cell contains 10%NaOH which is concentrated to 50% NaOH in evaporators. The NaCl present in the solution fed to the evaporator is crystallized and removed so that the concentrate leaving the evaporators contain only 1.5% NaCl. Calculate the following :

(a) The rate of production of 50% NaOH in kg/h
(b) The rate of production of chlorine and hydrogen gas
(c) The rate at which NaCl is crystallized in kg/h.

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