Seat No.: _____ **Enrolment No._____**

GUJARAT TECHNOLOGICAL UNIVERSITY

BE - SEMESTER–III (OLD) - EXAMINATION – SUMMER 2017

Subject Code: 130504 **Date: 05/06/2017**

Subject Name: Process Calculation

Time: 10:30 AM to 01:30 PM **Total Marks: 70**

Instructions:

1. **Attempt all questions.**
2. **Make suitable assumptions wherever necessary.**
3. **Figures to the right indicate full marks.**
4. **Atomic Mass: H:1, O:16, S:32, P:31, Cl:35.5, K:39, Mn:55, C:12, N:14, Zn:65.4, S:32**

Q.1 (a) In a double effect evaporator plant, the second effect is maintained under vacuum of 345 torr. Find the absolute pressure in kgf/cm^2, kPa, atm, N/m^2, bar, psi and mm Hg. **07**

(b) Convert the following: **07**
(1) 300 g/l H_2SO_4 to normality (2) 2.75 N H_3PO_4 to g/l
(3) 150 g/L HCl to molarity (4) 3 M $KMnO_4$ to normality

Q.2 (a) A gas mixture has the following composition by volume: **07**
Ethylene: 35.6%, Benzene: 24.5%, Oxygen: 1.3%, Methane: 15.5%, Ethane 20.0%, Nitrogen: 3.1%.
Find: (a) the average molar mass of the gas mixture, (b) the composition by mass and (c) the density of gas mixture in kg/m^3 at NTP.

(b) The average molar 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 30.08, the other engineer, using an incorrect value of 14, calculates the average molar mass to be 18.74. (i) Calculate the vol% 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**

OR

(b) A weight of 1.10 kg of carbon dioxide occupies a volume of 33 liter at 300 K. Using the Van der Waals equations of state, calculate the pressure. **07**
Data: For CO_2, take a = 3.60 [(m^3)^2.kPa]/(kmol)^2 and b = 4.3 x 10^{-2} m^3/kmol.

Q.3 (a) In the Deacon process for manufacturing chlorine, hydrochloric acid gas is oxidized with air. The reaction taking place is: **07**

$$4HCl + O_2 = 2Cl_2 + 2H_2O$$

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.

(b) The shift reaction is a very important reaction in the gas processing industry. **07**

$$CO + H_2O = CO_2 + H_2$$

If *a* and *b* are the percent carbon monoxide in the dry inlet and outlet gas mixtures to and from the shift converter respectively. Prove that moles of CO converted (x) per 100 moles of inlet gas mixture can be calculated by using the formula.

$$x = 100(a - b)/[100 + b]$$

OR

Q.3 (a) Zinc sulphide ore containing 74% ZnS and 26% inerts are roasted in a burner. Assume complete combustion of the ore to SO_2 with dry air at 300K and 750 mm Hg. The burner is supplied with 55% excess air over the stoichiometric amount required for the complete roasting of the ore. The gases are passed through V_2O_5 catalyst bed were nearly 98% of SO_2 gets converted to SO_3. The **14**

converter gases are passed through an absorption tower where all SO_3 is absorbed in the form of H_2SO_4 of 90% strength. It is desired to produce 1000 kg/h of 90% acid by spraying pure water at the top of absorption tower.
Calculate: (a) the analysis of the burner gases, (b) the analysis of the converter gases, (c) the quantity of the ore to be roasted per hour and (d) the volumetric flow rate of the air entering the converter in m^3/h.

Q.4 (a) The heat capacity of carbon monoxide is given by the following equation. **06**

$$C_p = 6.395 + 6.77 \times 10^{-4}\, T + 1.3 \times 10^{-7}\, T^2$$

where C_p = cal/(gmol)C, T = ^{0}C

What is the enthalpy change associated with heating carbon monoxide from 500 ^{0}C to 1000 ^{0}C?

(b) Obtain the expression relating the heat of reaction and the temperature of reaction. **08**

$$SO_{2(g)} + \tfrac{1}{2} O_{2(g)} = SO_{3(g)}$$

Also calculate the heat of reaction at 700 K using the following C_p^0 data. $C_p^0 = a + bT + cT^2$ KJ/Kmol K

	ΔH^0_{f298} (KJ/gmol-K)	a	b x 10^3	c x 10^6
SO_2	-296.81	24.77	62.95	-44.26
O_2	0.0	26.026	11.755	-2.3426
SO_3	-395.72	22.04	121.6	-91.87

OR

Q.4 (a) A solution of ethyl alcohol containing 8.6% alcohol is fed at the rate of 1000 kg/hr to a continuous distillation column. The product (distillate) is a solution containing 95.5% alcohol. The waste solution from the column carries 0.1% of alcohol. All percentages are by weight. Calculate (a) the mass flow rate of top and bottom products in kg/hr and (b) the percentage loss of alcohol. **07**

(b) Isothermal and isobaric absorption of SO_2 is carried out in a packed tower containing Raschig rings. The gases enter the bottom of the tower containing 14.8% SO_2 by volume. Water is distributed at the top of the column at the rate of 16.5 liter per second. The total volume of the gas handled at 101.3 kPa and 303 K is 1425 m^3/hr. The gases leaving the tower are found to contain 1% SO_2 by volume. Calculate the %SO_2 by weight in the outlet water. **07**

Q.5 (a) A fuel gas constitutes of CO_2: 3.4%, C_2H_4: 3.7%, C_6H_6:1.5%, O_2: 0.3%, CO:17.4%, H_2: 36.8%, CH_4: 24.9% and N_2:12.0% (on mole basis). It is burnt with air in a furnace. The Fyrite analyzer indicated 10 mole% CO_2 (on dry basis) in the flue gases. Find: (a) the percent excess air used and (b) the complete Orsat analysis. **07**

(b) Oil is to be extracted from meal by a continuous counter-current extractor. The unit is charged with 1000 kg/hr meal based on oil-free solids. Untreated meal contains 0.4 kg oil and 0.025 kg benzene per kg oil free meal. Fresh solvent is benzene containing 1.5% oil (mass%). The ratio of fresh solvent to the oil fresh meal is kept at 0.665 kg/kg. The solid meal retains 0.507 kg solution per kg solid. The solution retained by the meal contains 11.83% oil (by mass). Make the complete material balance and find the composition and amount of overflow from the extractor. **07**

OR

Q.5 (a) Discuss in detail about proximate and ultimate analysis of coal. **07**

(b) Define Dry bulb temperature, Wet bulb temperature, Dew point, Absolute humidity, Relative humidity, Humid heat and Humid volume for air-water contact operation. **07**

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