

Seat No.: _____

Enrolment No. _____

GUJARAT TECHNOLOGICAL UNIVERSITY

B.E. Sem-IV Examination June 2010

Subject code: 140504

Subject Name: FUNDAMENTAL CHEMICAL ENGINEERING CALCULATIONS & STOICHIOMETRY

Date: 21 /06 /2010

Time: 10.30 am – 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.

- Q.1**
- (a) In a double effect evaporator plant, the second effect is maintained under vacuum of 400 torr (mm Hg). Find the absolute pressure in kPa and psi. **02**
- (b) The diameter and height of a vertical cylindrical tank are 5 ft and 6 ft 6 in respectively. It is full up to 75% height with carbon tetrachloride, the density of which is 1.6 kg/L. Find the mass in kilograms and pounds. **04**
- (c) In the case of liquids, the local heat-transfer coefficient for long tubes and using bulk-temperature properties is expressed by the empirical equation **08**
- $$h = 0.023 G^{0.8} \times k^{0.67} \times c_p^{0.33} / (D^{0.2} \times \mu^{0.47})$$
- where h = heat-transfer coefficient, Btu/(sec-ft²-degF)
 G = mass velocity of liquid, lb/(ft²-sec)
 c_p = heat capacity, Btu/(lb-deg F)
 k = thermal conductivity, Btu/(sec-ft-deg F)
 D = diameter of tube, ft and
 μ = viscosity of liquid, lb/(ft-sec)

Convert the empirical equation into SI units. Will the above equation change when consistent SI unit are used? Why?

- Q.2**
- (a) Convert the following: **07**
- (1) 294 g/l H₂SO₄ to normality (2) 5 N H₃PO₄ to g/l
(3) 54.75 g/L HCl to molarity (4) 3 M K₂SO₄ to normality
- (b) Cracked gas from a petroleum refinery has the following composition by volume: methane: 41%, ethane: 12%, ethylene : 22%, propane:5%, n-butane: 20%. **07**
- Find (i) average molar mass of the gas mixture, (b) the composition by mass and (c) density of the gas mixture at 101.325 KPa pressure and 300 K.

OR

- (b) An aqueous solution of acetic acid of 35% concentration (by mass) has density 1.04 kg/l at 298.15 K. Find the molarity, normality and molality of the solution. **07**

- Q.3 (a)** 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. **07**

- (i) Calculate the volume % of nitrogen in the flue gases,
- (ii) If the remaining components of the flue gases are CO_2 and O_2 , calculate the volume % each of them.

- (b)** A spent solution of Chloroacetic acid (Mol. Wt.: 94.5) in ether (Mol. Wt.: 74.0) contains 20 mole % chloroacetic acid. It is desired to make 500 kg of a saturated solution at 298 K. Find the quantities of spent solution and Chloroacetic acid required to make the above solution. **07**

Data: The solubility of Chloroacetic acid in ether is 190g/ 100g ether at 298 K.

OR

- Q.3 (a)** The analysis of the gas entering the secondary converter in a contact sulphuric acid plant is 4% SO_2 , 13% O_2 and 83% N_2 (on volume basis). The gas leaving the converter contains 0.45% SO_2 on SO_3 -free basis (by volume). Calculate the percentage of SO_2 entering the converter getting converted to SO_3 . **07**

- (b)** In a silver electroplating plant, silver nitrate is used. When 1130 amperes were passes through $AgNO_3$ solution for 32400 sec, it was found that $2.0 m^3$ oxygen (at NTP) was liberated at the anode. Calculate: (a) the amount of silver liberated in kg, and (b) the current efficiency of the cell. **07**

Data: Equivalent mass of silver: 108

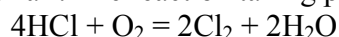
- Q.4 (a)** Pure methane is heated from 303 K to 523 K at atmospheric pressure. Calculate the heat added per kmol methane using the following data: **04**

$$C_p = 19.2494 + 52.1135 \times 10^{-3}T + 11.973 \times 10^{-6}T^2 - 11.3173 \times 10^{-9}T^3 \text{ KJ/(Kmol-K)}$$

- (b)** Using Antoine equation calculate the vapour pressure of acetic acid at 316 K. **04**

Data: A=6.5127 B= 1533.30 C= -50.8500

- (c)** In the Deacon process for manufacturing chlorine, hydrochloric acid gas is oxidized with air. The reaction taking place is: **06**

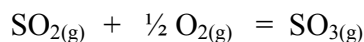


If the air is used in excess of 30% of that theoretically required and if the oxidation is 80% complete, calculate the composition by volume of dry gases leaving the reaction chamber.

OR

- Q.4** The analysis of the limestone gives 60% $CaCO_3$, 33.5% $MgCO_3$ and rest inerts. It is treated with 12% aqueous sulphuric acid (by weight) to obtain pure CO_2 . An excess of 15% of the acid over the stoichiometric amounts is used to ascertain that the reaction goes to near completion. Based on the treatment of 500 kg limestone, calculate: (a) the amount of 100% (by weight) sulphuric acid required, (b) the amount of the residue, (c) the analysis of the residue left in the vessel and (d) the moles of CO_2 produced. **14**

- Q.5 (a)** Obtain the expression relating the heat of reaction and the temperature of reaction. **07**



Also calculate the heat of reaction at 700 K using the following C_p^0 data.

$$C_p^0 = a + bT + cT^2 \text{ KJ/Kmol K}$$

	ΔH_{f298}^0	a	b x 10 ³	c x 10 ⁶
(KJ/gmol-K)				
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

- (b)** Isothermal and isobaric absorption of SO₂ is carried out in a packed tower containing Raschig rings. The gases enter the bottom of the tower containing 14.8% SO₂ 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 m³/hr. The gases leaving the tower are found to contain 1% SO₂ by volume. Calculate the %SO₂ by mass in the outlet water. **07**

OR

- Q.5 (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% alcohol. All percentage are by mass. Calculate (a) the mass flow rates of top and bottom products in kg/hr and (b) the percentage loss of alcohol. **07**
- (b)** It is required to make 1000 kg mixed acid containing 60% H₂SO₄, 32% HNO₃ and 8% water by blending (i) spent acid containing 11.3% HNO₃, 44.4% H₂SO₄ and 44.3% H₂O, (ii) aqueous 90% HNO₃ and (iii) aqueous 98% H₂SO₄. All percentage are by mass. Calculate the quantities of each of three acids required for blending. **07**
