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-ft^2-degF)
G= mass velocity of liquid, lb/(ft^2-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 H_2SO_4 to normality (2) 5 N H_3PO_4 to g/l
(3) 54.75 g/L HCl to molarity (4) 3 M K_2SO_4 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**

$Cp = 19.2494 + 52.1135 \times 10^{-3}T + 11.973 \times 10^{-6} T^2 - 11.3173 \times 10^{-9} T^3$ 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**

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

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.

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**

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

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

(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 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% H_2SO_4, 32% HNO_3 and 8% water by blending (i) spent acid containing 11.3% HNO_3, 44.4% H_2SO_4 and 44.3% H_2O, (ii) aqueous 90% HNO_3 and (iii) aqueous 98% H_2SO_4. All percentage are by mass. Calculate the quantities of each of three acids required for blending. **07**

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