Seat No.: _____ Enrolment No.______

GUJARAT TECHNOLOGICAL UNIVERSITY

B.E. Sem-III(Chemical Engg)Examination December 2009

Subject code:130504 **Subject Name: Process Calculations**

Date: 23 /12 /2009 **Time: 11.00 am – 1.30 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 Weights : C:12, H:1, O:16, S:32, Cl:35.5, N:14, Ca:40, K:39, Cu:63.5, Fe:55.8, Na:23, Zn : 65**

Q.1 **(a)** The empirical equation for laminar flow heat transfer to flat plate is given by **07**

$$h_x = [0.332\, k^{2/3}\, C_p^{\,1/3} u_o^{\,1/2}\ \zeta^{1/2}\ ]\ /\ [\, x^{1/2}\ \mu^{1/6}\ \sqrt[3]{1-\left(\frac{x_0}{x}\right)^{3/4}}\ ]$$

where h_x= heat transfer coefficient, Btu/(s.ft^2.^{o}F)
C_p= heat capacity, Btu/(lb. ^{o}F)
u_o = fluid velocity of approaching fluid, ft/s
ζ = density I, lb/ft^3
k =Thermal conductivity, Btu/(s .ft . ^{o}F)
μ = viscosity of liquid, (lb/ft. s)
x = distance from leading edge of plate or from the tube entrance, ft
x_o = distance at heated section, ft

Convert the empirical equation into metric units.

(b) An aqueous solution of K_2CO_3 is prepared by dissolving 43 gm K_2CO_3 in 100 gm water at 20^{o}C. Find molarity, normality and molality of the solution. Take density of solution as 1.3 gm/cm^3. **07**

Q.2 **(a)** A multiple-effect-evaporator system has a capacity of processing one tonne 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% (both on weight basis), find the capacity of the plant in terms of solid caustic soda, assuming water evaporating capacity to be same in both the cases. **07**

(b) Carbon dioxide is dissolved to the extent of 38 liters per liter of solution of 27.5% (by weight) DAPOL (diamino-iso-propanol [$C_3H_4OH(NH_2)_2$]. The volume of carbon dioxide gas measured at 101.325 kPa and 288.6 K. Find the weight % and mole% of carbon dioxide in the solution. If the density of DAPOL solution as 1.04 kg/l. **07**

OR

(b) Soya bean seeds are extracted with hexane in batch extractors. The flaked seeds contain 18.6% oil, 69%solids and 12.4% moisture. At the end of the extraction process, deoiled cake (DOC) is separated from the hexane oil mixture. DOC analysis yields 0.8% oil, 87.7% solids and 11.5% moisture. Find the percentage recovery of oil. All percentage are by weight. **07**

Q.3 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 was nearly 98% of SO_2 gets converted to SO_3. The 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. **14**

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.

OR

Q.3 **(a)** In the BASF oil quench process to manufacture acetylene, pure oxygen and pure methane are fed to the acetylene burner. The cracked gas from the burner has the following composition: **10**

H_2 : 56.5%, CH_4 :5.2%, C_2H_4 :0.3%, C_2H_2 :7.5%, C_3H_6 :0.5%,
CO:25.8%, CO_2 :4.0%, and O_2 : 0.2%(mole % on dry basis).

Assume that formation of other compounds, such as aromatics, is negligible.

For 100 kmol cracked gas, calculate (a) methane requirement, (b) oxygen requirement, (c) production of water, (d) conversion of methane (e) yield of acetylene production

(b) Discuss uses of recycling and bypassing operation **04**

Q.4 **(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 775 K using the following C_p^0 data.
$C_p^0 = a + bT + cT^2$ kJ/kmol .K

	ΔH^0_{f298} (kJ/mol)	a	b x 10^3	c x 10^6
SO_2	-296.81	24.771	62.948	-44.258
O_2	0.0	26.026	11.755	-2.343
SO_3	-395.72	22.036	121.624	-91.87

(b)(1) Using Antoine equation calculate the vapour pressure of acetic acid at 316 K. **03**

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

(2) Using Watson equation, calculate latent heat of vaporization of acetone at 313 K. **04**

Data: Latent heat of acetone at 329.4 K = 29121 kJ/kmol
Critical temperature of acetone = 508.1 K.

OR

Q.4 **(a)** A sample of coal is found to contain 67.2% carbon and 22.3% ash (weight basis). The refuse obtained at the end of combustion is analyzed to contain 7.1% carbon and the rest ash. Compute the % of the original carbon remaining unburnt in the refuse. **07**

(b) Define the following terms **07**

(1) Dry-bulb temperature
(2) Absolute humidity
(3) Percentage humidity
(4) Process flow sheet
(5) Dew point
(6) Humid heat
(7) Limiting component

Q.5 **(a)** 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 lit/s. The total volume of the gas handled at 101.325 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**

(b) 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 analyzer indicated 10.0 mole% CO_2 (on dry basis) in the flue gases. Find (a) percent excess air used and (b) the complete Orsat analysis. **07**

OR

Q.5 **(a)** A solution of ethyl alcohol containing 8.6% alcohol is fed at the rate of 1000 kg/h 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 mass. Calculate (a) the mass flow rates of top and bottom products in kg/h and (b) the percentage loss of alcohol. **07**

(b) Discuss Proximate and Ultimate analysis of coal. **07**

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