Seat No.: _____ Enrolment No._____

# GUJARAT TECHNOLOGICAL UNIVERSITY

**B.E. Sem-III Remedial Examination March 2010**

**Subject code: 130504** **Subject Name: PROCESS CALCULATION**

**Date: 11 / 03 /2010** **Time: 11.00 am – 02.00 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)** Iron metal weighing 500 lb occupies a volume of 29.25 liter. Calculate the density of iron in $kg/m^3$. **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

$\mu$ = 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)** A solution of sodium chloride in water contains 20% NaCl (by mass) at 333 K. The density of the solution id 1.127 kg/L. Find the molarity, normality and molality of the solution. Atomic mass: Na: 23, Cl:35.5. **07**

**(b)** Cracked gas from a petroleum refinery has the following composition by volume: methane: 45%, ethane: 10%, ethylene : 25%, propane:7%, propylene:8%, n-butane: 5%. **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 KPaa pressure and 273 K.

**OR**

**(b)** A gas mixture has the following composition by volume: **07**

Ethylene: 30.6%, Benzene : 24.5%, Oxygen : 1.3%,

Methane : 15.5%, Ethane : 25.0%, Nitrogen : 3.1%

Find: (a) the average molar mass of the gas mixture,

(b) the composition by mass, and

(c) the density of the mixture in $kg/m^3$ at NTP.

**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 lye sample obtained from a soap-making unit contains 9.6% glycerol and 10.3% salt (NaCl). It is concentrated at the rate of 5000 kg/hr in a double effect evaporator until the final solution contains 80% glycerol and 6% salt. Assume that about 4.5% of initial glycerol is lost by entrainment. All percentage are by mass. **07**

Find: (a) the evaporation taken place in the system; and (b) the amount of salt crystallized out in the salt box of the evaporator.

**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)** Ina 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**

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

**(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)** Define in reference to air-water system: **06**

(1) Dry-bulb temperature
(2) Absolute humidity
(3) Relative humidity
(4) Humid heat
(5) Humid volume
(6) Wet bulb temperature

**OR**

**Q.4** Acetaldehyde ($CH_3CHO$) is oxidized over silica gel with the help of air. The mixture is passed over the catalyst at 387 K. The outgoing dry gases are found to contain 4.85% $CO_2$, 8.65% acetaldehyde, 14.9% acetic acid, 2.55% $O_2$ and 69.05% $N_2$ by volume (on dry basis). For carrying out dry analysis, water was first removed from the mixture. During the water removal, some acetic acid is also condensed. Calculate: **14**

(a) the percentage conversion of acetaldehyde,
(b) the percentage yield of acetic acid,
(c) the mass ratio of air to acetaldehyde in the incoming feed,
(d) the percentage removal of acetic acid during the removal of water and
(e) the actual analysis of gases leaving the reactor.

Assume that following are the reactions occurring:

$$CH_3CHO + \tfrac{1}{2} O_2 = CH_3COOH$$

$$CH_3CHO + 5/2\ O_2 = 2CO_2 + 2H_2O$$

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

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

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

| | $\Delta H^0_{f298}$ (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 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)** Explain the Proximate and Ultimate analysis of coal. **07**

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