Seat No.: _____ Enrolment No._____

GUJARAT TECHNOLOGICAL UNIVERSITY

BE - SEMESTER–IV EXAMINATION – WINTER 2015

Subject Code: 140504 Date:06/01/2016

Subject Name: Fundamental Chemical Engineering Calculations & Stoichiometry

Time: 02:30pm to 05:00pm 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)** Find out the value of the universal gas constant R in following units: **04**

i) atm.lit/gmol.K
ii) J/gmol.K
iii) cm^3.atm/kmol.K
iv) kPa.m^3/kmol.K

(b) Briefly explain fundamental units and derived units. Also explain dimensional consistency. **03**

(c) A natural gas has the following composition by volume: CH_4: 82%, C_2H_6: 12% and N_2: 6%. **07**

Find: i) the average molecular weight of the gas mixture,
ii) the composition by weight, and
iii) the density of the gas mixture in kg/m^3 at 101.325 kPa and 273 K.

Q.2 **(a)** The empirical equation for laminar flow heat transfer to flat plate is given by **07**

$$h_x = \left[0.332\, k^{2/3}\, C_p^{1/3}\, u_0^{1/2}\, \zeta^{1/2} \right] / \left[x^{1/2}\, \mu^{1/6} \sqrt[3]{1-\left(\frac{x_0}{x}\right)^{\frac{3}{4}}} \right]$$

Where h_x = heat transfer coefficient, Btu/(s.ft^2.^oF)
C_p = heat capacity, Btu/(lb.^0F)
U_o = fluid velocity of approaching fluid, ft/s
ζ = density I, lb/ft^3
k = thermal conductivity, Btu/(s.ft. ^0F)
μ = viscocity of liquid, (lb/ft.s)
x = distance from leading edge of plate or from the tube entrance, ft
x_0 = distance at heated section, ft

Convert the empirical equation into SI units.

(b) It is required to make 1000 kg mixed acid containing 60% H_2SO_4, 32% HNO_3, and 8% water by blending **07**

i) the spent acid containing 11.3% HNO_3, 44.4% H_2SO_4, 44.3% H_2O,
ii) aqueous 90% HNO_3 and
iii) aqueous 98% H_2SO_4.

All % are by weight. Calculate the quantities of each of the three acids required for mixing.

OR

(b) A weight of 1.10 kg of carbon dioxide occupies a volume of 33 litre at 300 K. Using the Van der Waals equation 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)** Explain the concept of recycling and bypassing operation with diagrams. **07**

(b) Ethyl alcohol is industrially produced by fermentation of molasses. A sample of molasses contains 45% (wt./wt.) fermentable sugars (in the form of sucrose). The reactions taking place in the fermenter are as follows: **07**

$$\underset{\text{(sucrose)}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow{\text{invertase}} \underset{\text{(d-Glucose)}}{C_6H_{12}O_6} + \underset{\text{(d-Fructose)}}{C_6H_{12}O_6}$$

$$\underset{\text{(monosaccharide)}}{C_6H_{12}O_6} \xrightarrow{\text{zymase}} \underset{\text{(alcohol)}}{2C_2H_5OH} + 2CO_2$$

Calculate the theoretical production of alcohol (having density of 0.785 kg/l) in liters per tonne of molasses.

OR

Q.3 **(a)** Methanol and ethanol at 100^0C have vapor pressure of 2710 mm and 1635 mm Hg respectively. Calculate the total pressure and composition of the vapor in contact with a liquid containing 30% by weight methanol and rest ethanol at 100^0 C. **07**

(b) In a silver electroplating plant, silver nitrate is used. When 1130 amperes were passed through $AgNO_3$ solution for 32,400 sec, it was found that 2.0 m^3 O_2 (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**

Q.4 **(a)** Define the following terms: **07**
- i) Relative humidity
- ii) Dew point
- iii) Humid heat
- iv) Dry-bulb temperature
- v) Absolute humidity
- vi) Wet-bulb temperature
- vii) Humid volume

(b) Using the following Antoine equation, calculate the vapour pressure of n-hexane at 305 K. **03**

$$\log_{10} p = 5.9951 - \frac{1168.7}{T - 48.95}$$

where p = vapour pressure in kPa and
T = absolute saturation temperature in K

(c) Discuss methods of solving material balance problems without chemical reaction. **04**

OR

Q.4 **(a)** What will be the composition of gases obtained by burning pure FeS_2 with 60% excess air? Assume that the reaction proceeds in the following manner. **07**

$$4FeS_{2(s)} + 11O_{2(g)} \longrightarrow 2Fe_2O_{3(s)} + 8SO_{2(g)}$$

(b) With a neat sketch show the material balance for the following unit operations: **07**
i) distillation and ii) evaporation

Q.5 **(a)** Crystals of $MgCl_2.6H_2O$ have a solubility of 190 g per 100 g ethanol at 298.15 K. It is desired to make 1000 kg of saturated solution. Calculate the quantities of the crystals and ethanol required to make above solution. **07**

(b) With a typical example, explain the terms: Conversion, Yield, Selectivity, Limiting component and Excess component. **07**

OR

Q.5 **(a)** Pure methane is heated from 303K to 523K at atmospheric pressure. Calculate the heat added per kmol methane using C_p data. **07**

Data for methane:

$C_p = a + bT + cT^2 + dT^3$

Where a = 19.2494, $b \times 10^3 = 52.1135$, $c \times 10^6 = 11.973$, $d \times 10^9 = -11.3173$

(b) A multiple contact counter-current extractor is employed to extract oil from halibut livers with the help of ethyl ether. The fresh livers are charged to the extractor at the rate of 1000 kg/h and contain 25.7% oil. Pure ether enters the bottom of the extractor. The overflow from the extractor contains 70% oil. The underflow rate is 0.23 kg solution/kg of oil-free solids and is known to contain 12.8% oil. Based on these operating conditions, make the complete material balance and find the flow rate of ether to the extractor. Also compute the percentage recovery of oil. All percentage are by mass. **07**

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