Seat No.: ________ Enrolment No.___________

GUJARAT TECHNOLOGICAL UNIVERSITY

BE - SEMESTER–III • EXAMINATION – WINTER • 2014

Subject Code: 2133606 **Date: 20-12-2014**

Subject Name: Material and Energy Balance Calculations

Time: 02.30 pm - 05.00 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 weight: H: 1, C: 12, N: 14, O: 16, S: 32, Cl: 35.5, Cu=63.5.**

Q.1 **(a)** The Antoine equation predicts the effect of temperature on vapour pressure by the relation: **07**

$$\ln P^s = A - \frac{B}{T - C}$$

Where, A, B and C are Antoine constants. For water, the values of the constants when the vapour pressure is in kPa and temperature is in K are found to be A = 16.26205, B = 3799.887 and C = 46.854. What are these values when Vapour pressure is in mm Hg and temperature in ^{0}C.

(b) A weight of 1.10 kg of Carbon dioxide occupies a volume of 33 liter at 300 K. Using the Van der Waals equation of state, calculate the pressure. Data: For CO_2 , take a = 3. 60 [$(m^3)^2$-kPa]/$(kmol)^2$and b = 4.3 x 10^{-2} m^3/kmol. **07**

Q.2 **(a)** Explain Recycle, Purge, bypass with suitable diagram and also define the overall and single pass fraction conversion. **07**

(b) The gaseous reaction A = 2B + C takes place isothermally in a constant-pressure reactor. Starting with a mixture of 75 % A and 25 % inerts (by volume), in a specified time the volume double. Calculate the conversion achieved. **07**

OR

(b) 1 kg nitrogen is mixed with 3.5 m^3 of hydrogen at 300 K and 101.3 kPa and sent to the ammonia converter. The product leaving the converter analyzed 13.7 % ammonia, 70.32 % hydrogen and 15.98 % nitrogen. **07**

i. Identity the limiting reactant.
ii. What is the present excess of excess reactant?
iii. What is the present conversion of the limiting reactant?

Q.3 **(a)** Air at 298 K, 55% saturated with water vapour, is initially at 100 kPa. It is then compressed to 1000 kPa and cooled to a temperature so that 90% of the water vapour is condensed. Calculated the following: **07**

i. The final temperature of the air
ii. The volume of final air per cubic meter of original air

Data: The vapour pressure (kPa) of water is given by

$$\ln P^s = 16.26205 - \frac{3799.887}{T - 46.854}$$

Where T is in K.

(b) The average molecular weight of the flue gas sample is calculated by two different engineers. One engineer used the correct molecular weight of N_2 as 28, while the other used an incorrect value of 14. They got the average molecular weight as 30 and the incorrect one as 18.74. Calculate the % volume of N_2 in the flue gases. If the remaining gases are CO_2 and O_2 calculated their compositions also. **07**

OR

Q.3 **(a)** A tank holds 100 m^3 of a water-salt solution in which 4 kg of salt is dissolved. Water runs into tank at the rate of 5 m^3/min and salt solution overflows at the same rate. If the mixing in the tank is adequate to keep the concentration of salt in the tank uniform at all times, how much salt is in the tank at the end of 50 min. Assume that the density of the salt solution is essentially the same as that of water. **07**

(b) A weak acid containing 12.5 % H_2SO_4 and the rest water is fortified by adding 500 kg of concentrated acid containing 80 % H_2SO_4. Determine the amount of the solution obtained if it contains 18.5 % H_2SO_4? **07**

Q.4 **(a)** Air is being compressed from 100 kPa and 255 K (where it has an enthalpy of 489 kJ/kg) to 278 K (where it has an enthalpy of 509 kJ/kg). The exit velocity of air from the compressor is 60 m/s. what is the power required (in kW) for the compressor if the load is 100 kg/hr of air ? **07**

(b) Estimate the heat of vaporization of methyl chloride at -30 ^{0}C from the Clapeyron equation assuming ideal behavior for the vapour phase. The vapour pressure (kPa) is given by **07**

$$\ln P^s = 14.2410 - \frac{2137.72}{T - 26.72}$$

Where T is in K.

OR

Q.4 **(a)** Coal is burnt to a gas of the following compositions: CO_2: 9.2%, CO: 1.5 %, O_2: 7.3 %, N_2: 82 %. What is the enthalpy difference for this gas between the bottom and the top of the stack if the temperature at the bottom is 550 ^{0}F and at the top is 200 ^{0}F? The heat capacity equations are (T in ^{0}F ; C_p = Btu/ (lbmol ^{0}F)) **07**

C_p of $N_2 = 6.895 + 0.7624 \times 10^{-03}\ T - 0.7 \times 10^{-07}\ T^2$

C_p of $O_2 = 7.104 + 0.7851 \times 10^{-03}\ T - 0.5528 \times 10^{-07}\ T^2$

C_p of $CO_2 = 8.448 + 5.757 \times 10^{-03}\ T - 21.59 \times 10^{-07}\ T^2 + 3 \times 10^{-10}\ T^3$

C_p of CO $= 6.865 + 0.8024 \times 10^{-03}\ T - 0.736 \times 10^{-07}\ T^2$

(b) Using Watson equation, calculate latent heat of vaporization of **07**

(a) Acetone at 313K

(b) Carbon disulphide (CS_2) at 413 K.

T_1 (boiling point temp)	Component	Latent heat of vaporization at T_1, K (KJ/kmol)	T_c	n
329.4	Acetone (C_3H_6O)	29121	508.1	0.38
319	CS_2	26736	552.0	0.38

Q.5 **(a)** Calculate the theoretical flame temperature of gas having 20 % CO and 80 % N_2 burnt with 150 % excess air. Both air and gas are being at 25 ^{0}C. **07**

Data: heat of formation of CO_2 = -94,052 cal /gmol , CO = -26,412 cal/ gmol at 25 ^{0}C.

C_{pm} : CO_2 = 12.1 , O_2 = 7.9 , N_2 = 7.55 cal/ gmol K.

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

i. Dry-bulb temperature
ii. Wet bulb temperature
iii. Latent heat
iv. Absolute humidity
v. Percentage humidity
vi. Dew point
vii. Humid heat

OR

Q.5 **(a)** Pure CO is mixed with 100 percent excess air and completely burned at constant pressure. The reactants are originally at 400 K. Determine the heat added or removed if the products leave at 600 K. The standard heat of reaction at 298 K is 282.99 kJ per mol CO burned. The mean specific heats applicable in the temperature range of this problem are 29.10, 29.70 and 41.45 J / mol K respectively for CO, O_2, N_2 and CO_2. **07**

(b) The heat of combustion of methane, carbon and hydrogen are -890.4 kJ/mol, -393.51 kJ/mol and -285.84 kJ/mol respectively. Calculate the heat of formation of methane. **07**

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