Seat No.: ________ Enrolment No.___________

GUJARAT TECHNOLOGICAL UNIVERSITY

BE – SEMESTER VI – • EXAMINATION – SUMMER 2014

Subject Code: 163502 **Date: 21-05-2014**

Subject Name: Material & Energy Balance Calculations

Time: 10:30 am to 01:00 pm **Total Marks: 70**

Instructions:

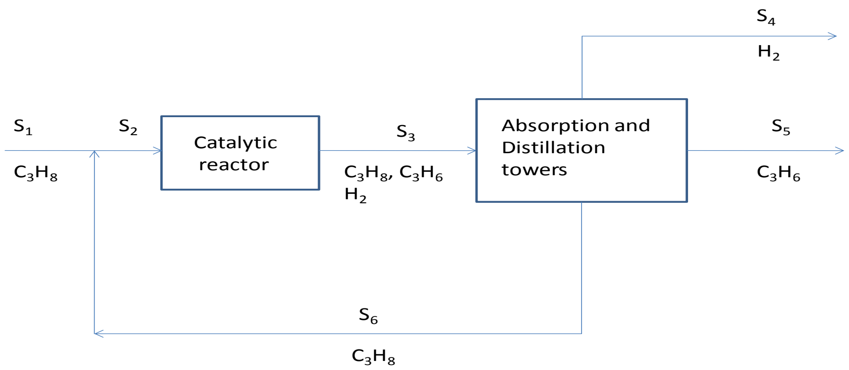
1. **Attempt all questions.**
2. **Make suitable assumptions wherever necessary.**
3. **Figures to the right indicate full marks.**

Q.1 **(a)** The heat capacity of sulphur is Cp = 15.2 + 2.68T , where Cp is in J/(gmol K) and T is in K. Convert that Cp is in cal/(gmol ^{0}F) with T in ^{0}F. **07**

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

(1) Yield
(2) Selectivity
(3) Molarity
(4) Molality
(5) Normality
(6) Extensive properties
(7) Intensive properties

Q.2 **(a)** The process schematic of a propane dehydrogenation plant is shown in figure. It is desire to set up a simplified version of material balance for this plant. Assume that only reaction is the dehydrogenation of propane to propylene; there are no side reactions. The yield of propylene per pass is 30 %. Assume that the amount of carbon formed on the catalyst is negligible. The product flow rate (stream S_5) is 100 kmol/hr. Calculate the flow rate of all the other streams. Notice that all streams except streams. Notice that all streams except stream S_3 are pure. **07**



(b) In the Deacon process for the manufacturing chlorine, hydrochloric acid gas is oxidized with air. The reaction taking place is **07**

$$4HCl + O_2 \rightarrow 2Cl_2 + 2H_2O$$

If the air is used in excess of 30 % of that theoretically required, and if the oxidation is 90 % complete, calculate the composition by volume of dry gases leaving the reaction chamber.

OR

(b) In an electrochemical cell, the current is passed at the rate of 1130 amperes for 18 000 s through a solution containing copper sulphate. At the end of the process, 1.12 m^3 of oxygen (at NTP) is collected. Find (a) amount of copper liberated, and (b) the current efficiency of the cell. **07**

Q.3	**(a)**	A saturated solution containing 1500 kg of potassium chloride at 360 K is cooled in an open tank to 290 K. If the specific gravity 1.2, the solubility of KCl per 100 parts of water is 53.55 at 360 K and 34.5 at 290 K, calculated (a) The capacity of the tank required (b) The weight of crystals obtained neglecting the loss of the water by evaporation	**07**
	(b)	Two tanks which are connected to each other is initially sealed off one another by means of a valve. Tank I initially contain 1 m^3 of air at 600 kPa and 70 ^{0}C. Tank II contains a mixture of oxygen and nitrogen 95 % (mole) nitrogen at 1200 kPa and 90 ^{0}C. The valve is now opened and the contents of the tanks are allowed to mix. After complete mixing, the tank contained 85 % (mole) nitrogen. Calculate the volume of tank II.	**07**
		OR	
Q.3	**(a)**	The atmosphere in the morning during a humid period is at 313 K and is 70% saturated. During the night the temperature falls to 303 K. The pressure is 101.3 kPa. The vapour pressure of water at 303 K is 4.24 kPa and 7.38 kPa at 313K. What percent of water in the afternoon air is deposited as dew during the night?	**07**
	(b)	Waste acid from a nitrating process contain 25 % HNO_3 , 55 % H_2SO_4 and 20 % H_2O by weight. This is to be concentration to get fortified acid containing 27 % HNO_3, 60 % H_2SO_4, and 13 % water. This is done by adding concentration H_2SO_4 of strength 93 % H_2SO_4 and concentration H_2SO_4 and concentration HNO_3 of strength 90 % HNO_3 in suitable quantities to the waste acid. If 1000 kg fortified acid is to be produced, calculated the kg of the various solutions mixed?	**07**
Q.4	**(a)**	Heat capacity for gaseous SO_2 is given by the following equation: $C_P^0 = 43.458 + 10.634\times10^{-3}T - \dfrac{5.945\times10^5}{T^2}$ kJ/(kmol) (K) Calculated the heat required to raise the temperature of 1 kmol pure SO_2 from 300 K and 1000 K.	**07**
	(b)	Steam (that is used to heat a biomass) enters the steam chest, which is segregated from the biomass, in the reactor, at 250 ^{0}C saturated, and is completely condensed in the steam chest. The rate of the heat loss from the steam chest to the surrounding is 1.5 kJ/s. The reactants are placed in the vessel at 20 ^{0}C and at the end of the heating the material is at 100 ^{0}C. If the charge consists of 150 kg of material with an average heat capacity of Cp = 3.26 J/(g) (K), how many kilograms of steam are needed per kilogram of charge? The charge remains in the reaction vessel for 1 hr. The heat of vapourization of saturated steam at 250 ^{0}C is 1701 kJ/kg.	**07**
		OR	
Q.4	**(a)**	Calculated the enthalpy of zinc vapour at 1200 ^{0}C and atmosphere pressure, relative to solid at 10 ^{0}C. Data: Melting point of Zn = 419 ^{0}C (at 1 atm) Boiling point of Zn = 907 ^{0}C (at 1 atm) Mean C_p of solid Zn = 0.105 kcal/kg ^{0}C Mean C_p of liquid Zn = 0.109 kcal/kg ^{0}C Heat of fusion of Zn = 1660 kcal/kgmole Heat of vaporization of Zn = 26900 kcal/kgmole Mean Cp of Zinc vapour = 4.97 kcal/kgmole ^{0}C Atomic weight of Zn = 65.4 kg/kgmole	**07**
	(b)	Using Watson equation, calculate latent heat of vaporization of (a) Acetone at 313K (b) Carbon disulphide (CS_2) at 413 K.	**07**

T1 (boiling point temp)	Component	Latent heat of vap 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)** Define the following terms **07**

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

(b) Dry methane is burned with dry air. Both are at 25^0C initially. The flame temperature is 1300 ^{0}C. If the complete combustion is assumed, how much excess air is used? **07**

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

Standard heat of reaction is -8.028 x 10^5 J/mole of methane reacted. Mean molal heat capacities of gases between 25 ^{0}C and 1300 ^{0}C in J/mol K are: 51.88 for CO_2, 34.01 for O_2, 40.45 for H_2O and 32.21 for N_2.

OR

Q.5 **(a)** Pure CO is mixed with 100 % excess air and burned. Only 80% of CO burns. The reactants are at 100 ^{0}C and the products at 300 ^{0}C. Calculate the amount of heat to be added or removed per kmol of CO fed to the reactor. Standard heats of formation in kJ/mol at 298 K are -110.6 for CO and -393.51 for CO_2. The mean molal heat capacity between 25 ^{0}C and T^0C in kJ/kmol K are **07**

Gas	T = 100^0C	T = 300^0C
CO	29.22	30.61
CO_2		43.77
O_2	29.84	30.99
N_2	29.17	29.66

(b) Calculate the heat of reaction at 700 K using the following. **07**

$$SO_2 + \frac{1}{2}O_2 \rightarrow SO_3$$

$Cp^0 = a + bT + cT^2$ KJ/Kmol K

Comp.	$\Delta H^0_{f298\ kJ/mol}$	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

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