GIET MAIN CAMPUS AUTONOMOUS GUNUPUR – 765022

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4th Semester Regular Examination-April-May 2019

BCHPC4050- CHEMICAL PROCESS CALCULATION

(Regulations 2017) CHEMICAL ENGG.

Time : 3 Hours Maximum : 100 Marks

Answer ALL Questions

The figures in the right hand margin indicate marks.

PART – A: (Multiple Choice Questions) 10 x 2=20 Mark

Q.1. Answer *All* Questions.

a. A mixture of FeO and Fe_3O_4 was heated in air and is found to gain 5 % in its mass. What is the composition of FeO in initial mass? [CO1] [PO1]
a. 30% b. 25% c. 20% b. 35%

b. How much Super Phosphate fertilizer can be made from one tonne of calcium phosphate of 93.5 % purity? The reaction is $Ca_3(PO_4)_2 + 2\ H_2SO_4 \rightarrow\ CaH_4(PO_4)_2 + 2\ Ca_2SO_4$? [CO2] [PO1]
a. 1200 kg b. 1594 kg c. 1683 kg d. 1358 kg

c. A bypass stream for a process is useful because [CO3] [PO2]
A. it improves conversion B. it increases the product yield
C. it removes impurities buildup D. it ensures better control over the process

d. Kopp's rule deals with; [CO4] [PO1]
A. heat capacities B. thermal conductivity C. flame temperature D. viscosities

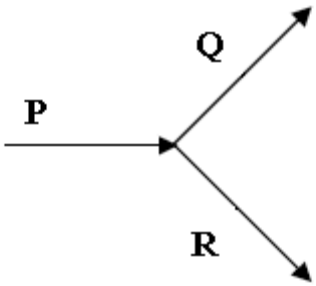
e. At eutectic point the number of phases present is; A. one B. two C. three D. four [CO2] [PO1]

f. The heat capacities of the substances; [CO4] [PO1]
A. decrease with increase in temperature B. increase with increase in temperature
C. temperature has no effect D. none of the above

g. Recycle stream is purged for; A. limiting the inerts B. increase the product yield C. better control over the process D. improve conversion [CO3] [PO2]

h. For a gas phase cracking reaction A → B + C at 300°C, the Gibbs free energy of the reaction at this temperature is $\Delta G° = -2750$ J/mol. The pressure is 1 bar and the gas phase can be assumed to be ideal. The universal gas constant R = 8.314 J/mol.K. The fractional molar conversion of A at equilibrium is: A. 0.44 B. 0.50 C. 0.64 D. 0.80 [CO4] [PO3]

i. A liquid mixture of ethanol and water is flowing as inlet stream P into a stream splitter. It is split into two streams, Q and R, as shown in the figure below. [CO1] [PO1]



The flowrate of P, containing 30 mass % of ethanol, is 100 kg/h. What is the least number of additional specification(s) required to determine the mass flowrates and compositions (mass %) of the two exit streams? A. 0 B. 1 C. 2 D. 3

j. Water is heated at atmospheric pressure from 40ºC to 80ºC using two different processes. In process I, the heating is done by a source at 80ºC. In process II, the water is first heated from 40ºC to 60ºC by a source at 60ºC, and then from 60ºC to 80ºC by another source at 80ºC. [CO4] [PO2]
Identify the correct statement.
A. Enthalpy change of water in process I is greater than enthalpy change in process II
B. Enthalpy change of water in process II is greater than enthalpy change in process I
C. Process I is closer to reversibility
D. Process II is closer to reversibility

PART – B: (Short Answer Questions)10x2=20 Marks

Q.2. Answer *ALL* questions

a. What is the weight of 1 liter of methane under standard conditions? [CO1] [PO1]

b. What do you mean by vapour pressure of a liquid? Mention assumptions used in the derivation of Clausius-Clapeyron equation. [CO3] [PO1]

c. How relative humidity does differs from % humidity. [CO4] [PO2]

d. State the basic principle underlying steam distillation. [CO2] [PO1]

e. A solution of acetic acid in water contains 20% acetic acid by weight. Find the molality of the solution. [CO1] [PO1]

f. Write short note on Wet- and dry-bulb thermometry. [CO4] [PO1]

g. Humid air at a temperature of 75^0C, 1.1 bar and 30% relative humidity is fed to a process at a rate of 1000 m^3/hr. Determine the molar flow rate of water. VP of water at 75^0C is 38.5 kPa. [CO4] [PO2]

h. State Roult's law and Henry's law. [CO3] [PO1]

i. Give the difference between theoretical and actual flame temperature, heat of formation and heat of combustion. [CO2] [PO1]

j. Explain recycle, bypass and purging. [CO3] [PO1]

PART – C: (Long Answer Questions) 15x4=60 Marks

Answer *ALL* questions

Q.3

a. A natural gas has the following composition by volume in percentage, methane – 85, ethane – 6, propane – 4, butane – 1, hydrogen sulphide – 1, nitrogen – 3. Determine the composition by wt %, the average molecular weight, the density at 30^oC and one atmosphere in kg/m^3, the theoretical oxygen demand treating hydrogen sulphide as non-combustible and total carbon content. 10 [CO2] [PO1]

b. A compound whose molecular weight is 103 analyses as following (percentage weight basis): C – 81.5; H – 4.9; N – 13.6. What is its formula? 5 [CO1] [PO1]

OR

c. Carburated water gas has the following composition by volume in percentage H_2 - 35.2, CH_4 – 14.8, C_2H_4 – 12.8, CO_2 – 1.5, CO – 33.9 and rest nitrogen. The gas is available at 500^oC and 3 atm (g) pressure. Find the molar volume using Vander wall's equation of state. Given the critical properties as: 9 [CO1] [PO1]

Gas:	H_2	CH_4	C_2H_4	CO_2	CO	N_2
T_c, ^{o}K:	33.2	190.55	282.36	304.19	132.92	126.2
P_c,atm:	12.8	45.44	49.66	72.85	34.52	33.5

d. Octane is burnt with 10% excess air. Calculate: (i) Air/fuel ratio by weight. (ii) Air/fuel ratio by volume. (iii) Weight of dry exhaust gas formed per unit weight of fuel. 6 [CO2] [PO1]

Q.4

a. A solvent recovery system delivers a gas saturated with Benzene vapor which analyses on a Benzene free basis as CO - 15%, O_2 - 4%, and N_2 – 81%. The gas is at 21.1^0C and 100 kPa. It is compressed to 506 kPa and cooled to 21.1^0C after compression. How many kg of Benzene are condensed by this process per 1000m^3 of original mixture? Take VP of Benzene 10 kPa. 7 [CO3] [PO2]

b. Moist air contains 0.0109 kg water vapour per cubic meter of the mixture at 300 K and 101.3 kPa. Calculate: (a) the relative saturation, (b) the absolute humidity, (C) the percent saturation, (d) the temperature to which the mixture be heated so that its percent saturation becomes 10%. 8 [CO4] [PO1]

OR

c. A mixture of acetone vapour and nitrogen gas at 101.3 kPa and 310 K contains acetone vapour to the extent that it exerts a partial pressure of 15 kPa. The vapour pressure of acetone in kPa is given by the Antoine equation: $\ln P^S = 14.5463 - \frac{2940.46}{T - 49.19}$, where temperature is in K. Determine the following:
(i) The weight fraction of acetone in the mixture, (ii) The absolute humidity, (iii) The molal saturation humidity, (iv) The absolute saturation humidity. 8 [CO4] [PO3]

d. Bottled liquid gas containing n-Butane (50 mol %), Propane (45 mol %) and Ethane (5 mol %) with vapor pressures at 30^0C in bar as 3.4, 10.8, 46.6 respectively sold for household use. Determine the pressure of the system and the equilibrium vapor composition at 30^0C. 7 [CO3] [PO3]

Q.5

a. A drier is fed with wet solid to reduce the moisture content from 80% to 15%. The product leaving the drier is admitted to an oven which further brings down the moisture to 2%. If the drier can handle 1000 kg of wet solid per hour, calculate: [CO2] [PO1] 8
(i) The weight of water evaporated in the drier and in the oven per hour.
(ii) The percentage of original water that is removed in the drier and the oven.

b. An aqueous solution of Na_2CO_3 contains 15% carbonate by weight. 80% of the carbonate is recovered as $Na_2CO_3.10H_2O$ by evaporation of water and subsequent cooling to 278 K. The solubility of Na_2CO_3 at 278 K is 9% (weight). On the basis of 100 kg of solution treated, determine the following: [CO1] [PO2] 7
(a) the quantity of crystal formed
(b) the amount of water evaporated.

OR

c. The spent acid from a nitrating process contains 33% H_2SO_4, 36% HNO_3 and 31% water by weight. This acid is to be strengthened by the addition of concentrated sulphuric acid containing 95% H_2SO_4 and concentrated nitric acid containing 78% HNO_3. The strengthened mixed acid is to contain 40% H_2SO_4 and 43% HNO_3. Calculate the quantities of spent and concentrated acids that should be mixed together to yield 1500 kg of the desired mixed acid. 6 [CO2] [PO1]

d. Carbon monoxide and hydrogen reacts to give methanol: $CO + 2H_2 \rightarrow CH_3OH$. [CO2] [PO2]
The conversion of CO entering the reactor is only 20%. A feed stream consisting of 33% CO, 66.5% H_2 and 0.5% CH_4 is mixed with a recycle stream and sent to a reactor. The methanol leaving the reactor is separated and the unconverted gases are recycled. To prevent the accumulation of CH_4 and keep its concentration in the recycle stream at 3%, a portion of the recycled stream is blown off. For 100 moles of fresh feed, determine the following:
(a) The moles of recycle stream (b) The moles of purge stream (c) The moles of methanol produced 9

Q.6

a. A magnetite ore containing 100% Fe_3O_4 is subjected to reduction by pure carbon in an externally heated retort. 95% of the Fe_3O_4 present is reduced to the metallic state while the remaining 5% is converted to FeO, according to the reaction. [CO2] [PO3]

$Fe_3O_4 + 4C \rightarrow 3Fe + 4CO$ …(i)

$Fe_3O_4 + C \rightarrow 3FeO + CO$ …(ii)

The amount of carbon to be charged is 300% in excess of that required according to the eqn. (i). The reactants enter at a temperature of 250^0C and the products, both the solids and the gas leave at a temperature of 950^0C. 15

Estimate the heat requirements for the process based on 100 kg of magnetite charged. Following data are available:

Specific heat kcal/kg ^{0}C,

Fe_3O_4 – 0.18, FeO – 0.18, Fe – 0.13, C – 0.30, CO – 0.27.

Standard heat of formation, $\Delta H_f{}^0$ at 25 ^{0}C in kcal/g mol

Fe_3O_4 (s) = -267, FeO (s) = -64.3, CO (g) = -26.4

OR

c. The heat capacity of carbon dioxide is given by the following relation 7 [CO2] [PO3]

$$C_P = 26.540 + 42.454 * 10^{-3} T - 14.298 * 10^{-6} T^2$$

where C_p is in Kj/kmol; K and T is in K.

(a) How much heat is required to heat 1 kg of CO_2 from 300 K to 1000 K?

(b) Obtain the relation expressing the heat capacity in kcal/kmol °C and temperature in °C.

d. Hydrogen gas is burned in an adiabatic reactor with two times the theoretical quantity of air, both air and hydrogen being at 298 K initially. What will be the temperature of the reaction products? The standard heat of formation of gaseous water is -241.826 kJ/mol. The heat capacities (kJ/kmol K) of the gases are given below: [CO2] [PO2] 8

Water vapour: $C_P = 30.475 + 9.652 * 10^{-3} T + 1.189 * 10^{-6} T^2$

Nitrogen: $C_P = 27.034 + 5.815.454 * 10^{-3} T - 0.2889 * 10^{-6} T^2$

Oxygen: $C_P = 25.611 + 13.260 * 10^{-3} T - 4.2077 * 10^{-6} T^2$

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