Registration No.										

Total number of pages: 04 **B.Tech.**
PCE3I001

3rd Semester Regular/Back Examination 2017-18
CHEMICAL PROCESS CALCULATION
BRANCH : CHEM, PT
Time : 3 Hours
Max Marks : 100
Q.CODE : B1110

Answer Question No.1 and 2 which are compulsory and any four from the rest.

The figures in the right hand margin indicate marks.

Assume suitable notations and any missing data wherever necessary.
Use of Humidity Chart is permitted. Answer all parts of a question at a place.

1. Answer the following questions : (2x10)

(a) The molar composition of a gas is 10% H_2, 10% O_2, 30% CO_2 and balance H_2O. If 50% H_2Ocondenses, the final mole percent of H_2 in the gas on a dry basis will be:
i) 10%
ii) 5%
iii) 18.18%
iv) 20%

(b) A hydrocarbon oil is rated at 30°API. What is its specific gravity at 288.8 K?
i) 1.235
ii) 0.876
iii) 0.300
iv) 0.675

(c) 45 moles of oxygen is supplied for the combustion of 36 gatom of carbon. The %excess reactant supplied is:
i) 80%
ii) 33.3%
iii) 30%
iv) 25%

(d) A mixture of oxygen and sulphur dioxide is at 200 kPa. The average molecular weight of themixture is 44.8. The partial pressure of oxygen in the mixture is:
i) 89.6 kPa
ii) 120 kPa
iii) 101.3 kPa
iv) 80 kPa

(e) A liquid solution is in equilibrium with its vapour. The concentration of the more volatilecomponent in the vapour is maximum:
i) At the bubble point temperature
ii) At the dew-point temperature
iii) Between the bubble point and the dew-point temperatures
iv) At the normal boiling point of the mixture

(f) A vapour containing 70% A and 30% B is compressed at a constant temperature of 350 K. It isknown that A and B form ideal solutions and at 350 K the vapour pressures of A and B are respectively70 kPa and 30 kPa. What is the composition of the first drop of condensate?
i) 50% A, 50% B
ii) 30% A, 70% B

iii) 70% A, 30% B
iv) None of the above

(g) The absolute humidity of air at 101.3 kPa is measured to be 0.02 kg of water per kg of dry air.Determine the partial pressure of water vapour in the air.
i) 1.99 kPa
ii) 2.55 kPa
iii) 3.16 kPa
iv) 3.87 kPa

(h) With increase in pressure, the heat of vaporization of liquids
i) Decreases
ii) Increases
iii) Remain unchanged
iv) May increase or decrease

(i) The heat of reaction is
i) Independent of temperature and pressure
ii) Independent of temperature but changes with pressure
iii) Independent of the number of intermediate steps involved
iv) Independent of the state of aggregation of the reactants and products

(j) Trouton's ratio is the ratio of
i) Latent heat of vaporization to the normal boiling point
ii) The heat supplied to the absolute temperature
iii) The heat capacity of a substance to the heat capacity of water
iv) None of the above

2. Answer the following questions : (2x10)

(a) Prove that: Normality = Molarity x Valency.

(b) A sample of water contains 1575 ppm solids. Find the concentration of solids by weight percentage.

(c) A body weighs 1 kg in air, 0.9 kg in water, and 0.8 kg in a liquid. Find the specific gravity of the liquid.

(d) An aqueous solution of triethanolamine [TEA – $(CH_2CH_2OH)_3N$] contains 50% TEA by weight. If the density of this solution is 1.25 kg/l, find the molarity of this solution.

(e) Using the Clausius-Clapeyron equation, calculate the vapourpressure of water at 360 K if the vapour pressure at 373 K is 101.325 kPa. The mean heat of vaporization in this temperature range is 2275 kJ/kg.

(f) For air-water systems, prove that: $H = 0.6207 [p_A / (P - p_A)]$. Where, H = absolute humidity, p_A = partial pressure of water vapour, and P = total pressure of the system.

(g) Calculate the weight of sulphur dioxide in a vessel having 2 m^3volume at 98 kPa and 120^0C.

(h) State Trouton's rule and Kistyakowsky equation.

(i) Why purging operation is performed on recycle streams ?

(j) The GCV of gaseous n-butane is 2880 kJ/mol at 298 K. Calculate its NCV in kJ/mol and kJ/kg units using latent heat of water vapour at 298 K as 2442.5 kJ/kg.

3. (a) A compound whose molecular weight is 80contains 50 % N, 10 % H, 25 % C, and 15 % O on weight basis. Find its formula. **(5)**

(b) Ahydrochloric acid solution has a molarity of 20 and molality of 80. Calculate the density of the solution in kg/l. **(5)**

(c) CO_2 weighing 1 kg occupies a volume of 30litres at 303 K. Calculate the pressure using the van der Waals equation of state. Data: a = 3.6 $(m^3)^2$.kPa/$(kmol)^2$ and b = 4.3 x 10^{-2} m^3/kmol for CO_2. **(5)**

4. **(a)** A solution has a gravity of 100^0Twaddell. Calculate its specific gravity and its gravity in degrees Baume. **(3)**

(b) A fuel having composition C_nH_m and no inerts is fired in a furnace. If the mole fraction of oxygen in flue gas is "α" on dry basis, prove that: **(12)**

$$\% \text{ Excess Air} = \left[\frac{100\ \alpha}{1 - 4.762\ \alpha}\right]\left[\frac{19.048 + 3.762\ r}{4 + r}\right],$$

$$\text{where, } r = \frac{m}{n} = \frac{\text{atoms of hydrogen}}{\text{atoms of carbon}}.$$

5. **(a)** A security guard at an industrial park can work well upto an absolute humidity of 0.017 kg/kg dry air. On one hot summer day, the dry-bulb and wet-bulb temperatures are found to be 47^0C and 42^0C respectively. Can the guard workwell ? Give your comments. **(5)**

(b) Moist air of 35 m^3 volume at a total pressure of 101.325 kPa and 30^0C contains water vapour in such proportions that its partial pressure is 3.0 kPa. Without total pressure being changed, the temperature is reduced to 15^0C and some of the water vapour is condensed. After cooling, it is found that the partial pressure of water vapour is 1.5kPa. Calculate: volume of air at 15^0C and weight of water condensed. **(10)**

6. **(a)** A mixture of benzene vapour and nitrogen gas at 110 kPa and 325 K contains benzene vapour to the extent that it exerts a partial pressure of 14.5 kPa. The vapour pressure of benzene is given by the Antoine equation as: **(7)**

$$\ln p^0 = 13.9 - \frac{2788.5}{T - 52.4}$$

Determine: the mole fraction of benzene in the mixture, the weight fraction of benzene in the mixture, the molal humidity, the absolute humidity, and the molal saturation humidity.

(b) In a sulphuric acid plant, pyrites containing 50 % (weight) sulphur is burnt to give SO_2 which is subsequently converted to SO_3 in a converter. The analysis of the burner gas shows 9 % SO_2 and 7 % O_2. The cinder is analysed and it is found that it contains 3 % sulphur as SO_3. Assuming that all the sulphur in the feed is burnt, calculate the weight of pyrites burnt per 100 kmol SO_3-free burner gas. **(8)**

7. **(a)** Calculate the heat of formation of $ZnSO_4$ from elements by using Hess's law and following data: **(5)**

$Zn + S \rightarrow ZnS$	$\Delta H = -184.23$ kJ/mol
$2\ ZnS + 3\ O_2 \rightarrow 2\ ZnO + 2\ SO_2$	$\Delta H = -929.5$ kJ/mol
$2\ SO_2 + O_2 \rightarrow 2\ SO_3$	$\Delta H = -196.8$ kJ/mol
$ZnO + SO_3 \rightarrow ZnSO_4$	$\Delta H = -230.3$ kJ/mol

(b) The heat capacity of CO_2 is given by the equation: **(5)**

$$C_p = 26.54 + (42.45 \times 10^{-3}\ T) - (14.29 \times 10^{-6}\ T^2)$$

where, C_p is in kJ/kmol.K and T is in K. How much heat is required to heat 1 kg of CO_2 from 320 K to 980 K ?

(c) Calculate the heat of reaction for the esterification of ethyl alcohol with acetic acid if the standard heats of combustion are: ethyl alcohol (l), - 1367 kJ/mol; acetic acid (l), - 872 kJ/mol; and ethyl acetate (l), - 2275 kJ/mol. **(5)**

8. A theoretical producer gas (35% CO and 65% N_2) at 25^0C is burnt with 50% excess air (preheated to 200^0C). Assuming complete combustion, calculate the theoretical flame temperature.Data:Standard heat of formation of CO and CO_2 are –26.5 and–94.1 kcal/gmol respectively. **(15)**

$C_{p\,O2} = 6.94 + 0.000677\ T$

$C_{pN2} = 6.5 + 0.001413\ T$

$C_{pCO} = 6.35 + 0.00018\ T$

$C_{pCO2} = 9.1 + 0.0048\ T$

9. **Write short notes on :**

(a) Reference substance plots **(5)**

(b) Effect of temperature on heat of reaction **(5)**

(c) Van der Waal's theory **(5)**