Total number of printed pages - 04

B.TECH
PCE3I001

3rd Semester Regular Examination 2016 - 17
CHEMICAL PROCESS CALCULATIONS
BRANCH : Chemical
Time : 3 Hours
Max Marks : 100
Question Code : Y690

Answer Part-A which is compulsory and any four from Part-B.
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.

Part – A (Answer all the questions)

1. **Answer the following questions :** 2 x 10

(a) If two bottles A and B are filled with 100 g each of HNO_3 and H_2SO_4 respectively, which bottle contains more molecules?
  i. A
  ii. B
  iii. both A and B contains same number of molecules
  iv. none of these

(b) The molarity of water in pure water is _____.
  i. 5.5
  ii. 55.5
  iii. 555.5
  iv. None of these

(c) A wet paper pulp contains 75 % water. After 100 kg of water is removed in a dryer, it is found that the pulp contains 30 % water. The weight of the original pulp is _____ kg.
  i. 185.5
  ii. 175.5
  iii. 165.5
  iv. 155.5

(d) The MW of an ideal gas is 40. What will be the volume occupied by 0.2 kg of this gas at STP ?
  i. 112 cm^3
  ii. 112 m^3
  iii. 112 lit
  iv. 112 gallons

(e) The saturation temperature of a pure substance is known as the _____.
  i. Triple point

       ii.   Critical point
       iii.   Dew point
       iv.   Boiling point

(f) In a dilute solution _____ obeys Henry's law.
       i.   solvent
       ii.   solute
       iii.   both solvent and solute
       iv.   none of these

(g) With the increase in MW, the vapour pressure of chemically similar liquids at any given temperature _____.
       i.   increases
       ii.   decreases
       iii.   remains unchanged
       iv.   may increase, may decrease

(h) Purging operation is performed on recycle streams to _____.
       i.   increase yield
       ii.   remove inerts
       iii.   control T & P
       iv.   all of these

(i) With the increase in pressure, the heat of vaporization of liquids _____.
       i.   increases
       ii.   decreases
       iii.   remains unchanged
       iv.   may increase, may decrease

(j) Heat capacity of a solid compound is found by _____.
       i.   Kopp's rule
       ii.   Trouton's rule
       iii.   Hess's law
       iv.   Amagat's law

2. **Answer the following questions :**   **2 x 10**

(a) Define Basis.
(b) What do you understand by Yield and Selectivity ?
(c) Write the van der Walls' equation and their constant.
(d) Write the Clausius-Clapeyron equation and mention the assumptions.
(e) Discuss the Henry's law in relation to gas solubility.
(f) Define adiabatic saturation temperature.
(g) Why recycle operations are carried out in process industries ?
(h) Define Hess' s law of constant heat summation.
(i) Write the Kistyakowsky equation.
**(j)** What is Orsatanalysis ?

Part – B (Answer any four questions)

3. **(a)** A body weighs 1.0 kg in air, 0.90 kg in water, and 0.82 kg in a liquid. What is thespecific gravity of the liquid?   **04**

    (b) What is the specific gravity on the Baumé scale for a 100^0 Tw solution?   **03**

(c) $250\ m^3$ of 30^0 API gas oil is blended with $1000\ m^3$ of 15^0 API fuel oil. What is the density of the resultant mixture in kg/m^3? The density of water at $288.5\ K = 999\ kg/m^3$. Assume no volume change on mixing. **08**

4. (a) In the vapour-phase hydration of ethylene to ethanol, diethyl ether is obtained as a by-product as per the reactions:

$$C_2H_4 + H_2O \rightarrow C_2H_5OH$$
$$2C_2H_4 + H_2O \rightarrow (C_2H_5)_2O$$
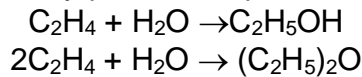
A feed mixture consisting of 60% ethylene, 3% inerts, and 37% water is sent to the reactor. If the product contain 53.89% ethylene, 14.37% ethanol, 1.80% ether, 26.35% water, and 3.59 % inerts, calculate:
  i.   the conversion of ethylene, and
  ii.   yield of ethanol and ether based on ethylene. **05**

(b) Chlorine is produced by the oxidation of hydrogen chloride gas with air as per the reaction:

$$4HCl + O_2 \rightarrow 2Cl_2 + 2H_2O$$
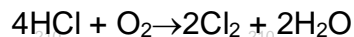
The reaction is carried out at $1.2 \times 10^5\ N/m^2$ and 400 K. 50 % excess air is used and the reaction is only 80 % complete. Calculate the following:
  i.   the volume of air admitted per $100\ m^3$ of HCl if both air and HCl enter the reactor at 1.0 bar and 290 K;
  ii.   the volume of gases leaving the reactor per $100\ m^3$ of HCl entering;
  iii. kg of Cl_2 produced per $100\ m^3$ of HCl entering, and
  iv.   % composition by volume of exit gas on a dry basis. **10**

5. (a) Mixtures of n-heptane (A) and n-octane (B) are expected to behave ideally. The total pressure over the system is 101.325 kPa. Using the following vapour pressure data construct the boiling point diagram.

T (K)	371.4	378	383	388	393	398.6
p_A^{sat} (kPa)	101.325	125.3	140.0	160.0	179.9	205.3
p_B^{sat} (kPa)	44.4	55.6	64.5	74.8	86.6	101.325

10

(b) Discuss about the equal-temperature reference-substance plots. **05**

6. (a) An adiabatic drier is used to dry a wet material. The drying air enters at 380.7 K and 101.325 kPa with a dew point of 298 K. Measurements show that 2.25 kg of water is evaporated per $100\ m^3$ of wet inlet air. Calculate using humidity chart:
  i.   the humidity of air entering the drier;
  ii.   the exit air humidity and percent humidity;
  iii. the exit air wet-bulb and dry-bulb temperatures; and
  iv.   the volume of exit air per $100\ m^3$ of inlet wet air. **10**

(b) A crystallizer is charged with 100 kg of a solution containing 25% $Ba(NO_3)_2$ in water. On cooling 10% of the original water

present evaporates. Calculate the yield of crystals when thesolution is cooled to 283 K. The solubility at 283 K is 7.0 kg $Ba(NO_3)_2$/100 kg total water. **05**
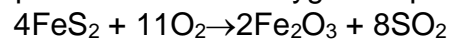
7. Air at 320 K saturated with water vapour is dehumidified by cooling to 285 K and byconsequent condensation of water vapour. Air leaving the dehumidifier, saturated at 285 K is mixedwith a part of the original air which is bypassed. The resulting air stream is reheated to 320 K. It isdesired that the final air contains water vapour not more than 0.03 kg per kg of dry air.Calculate:

    i.   the mass of dry air (in kg) bypassed per each kg of dry air sent through the dehumidifier;

    ii.   the mass of water vapour (in kg) condensed in the dehumidifier per 100 m^3 ofair sent through it; and

    iii.   the volume of final air obtained per 100 m^3 of air passed through the dehumidifier.

The total pressure is atmospheric and the vapour pressures of water are 1.4 kPa at 285 K and 10.6 kPaat 320 K. **15**

8. In a sulphuric acid plant, sulphur dioxide is obtained by the roasting of iron pyritescontaining 80.0% FeS_2 and 20% gangue. Iron sulphide reacts with oxygen as per the reaction:
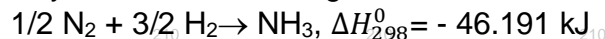$$4FeS_2 + 11O_2 \rightarrow 2Fe_2O_3 + 8SO_2$$
The cinder formed on the combustion analyzes 5.0% FeS_2. Determine the standard heat of reaction per kg of ore.

Data: The standard heat of formation values at 298 K are:

$FeS_2(s) = -178.02$kJ/mol, $Fe_2O_3(s) = -822.71$ kJ/mol, and $SO_2(g) = -296.9$ kJ/mol. **15**

9. **(a)** Discuss the effect of temperature on standard heat of reaction. **05**

    (b) Ammonia is synthesized according to the reaction:
$$1/2\ N_2 + 3/2\ H_2 \rightarrow NH_3,\ \Delta H^0_{298} = -46.191\ kJ$$
The specific heats of the components are:
$$c_P = a + bT + cT^2,\ J/mol.K.$$
The constants are:

Molecules	a	b x 10^3	c x 10^6
N_2	27.31	5.2335	- 4.1868 x 10^{-3}
H_2	29.09	- 0.8374	2.0139
NH_3	25.48	36.89	- 6.305

Determine the heat of reaction at 700 K. **10**