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RN-8043

B. E. - II (Sem. III) (Chemical) Examination

May / June – 2010

Process Calculation

Time : **3** Hours] [Total Marks : **100**

Instructions :

(1)

નીચે દર્શાવેલ ☛ નિશાનીવાળી વિગતો ઉત્તરવહી પર અવશ્ય લખવી.
Fillup strictly the details of ☛ signs on your answer book.

Name of the Examination :

☛ **B. E. - 2 (Sem. 3) (Chemical)**

Name of the Subject :

☛ **Process Calculation**

☛ Subject Code No. : **8 0 4 3** ☛ Section No. (1, 2,.....) : **1&2**

Seat No. :

Student's Signature

(2) Attempt **all** questions.
(3) Assume suitable data necessary.
(4) Figure to the right indicates full marks.
(5) Atomic weight N = 14, H = 1, C = 12, O = 16, Cl = 35.5 Mg = 24.
(6) Use the separate answer-sheet for each section.

SECTION - I

1 (a) Answer following questions : **8**

(i) Find nitrogent (N) content of urea sample containing 96.43% urea. **2**

(ii) Define selectivity. **1**

(iii) Convert a volumetric flowrate of 2 m^3/s to *l*/hr. **1**

(iv) Explain Dalton's law. **1**

(v) Ammonia is produced by following reaction : **2**

$N_2 + 3H_2 \rightarrow 2NH_3$

Calculate molal flowrate of hydrogen corresponding to nitrogen feed rate of 25 kmol/h if they are fed in stoichiometric proportion.

(vi) Define yield. **1**

(b) In the production of formaldehyde, methanol is fed to a steam heated horizontal vaporizer, which produces vapours at 358 K (85°C) and 0.123 MPa g. Air is introduced with the help of blower. Compressed air is heated to 343 K(70°C) and mixed in a controlled ratio with methanol vapours. The mixture contains approximately one volume of air for each volume of methanol vapours. Mixed gas is passed into the reactor and hot product gases from the reactor are cooled and scrubbed in a scrubber. Gases free from methanol and formaldehyde have following molar composition : **12**

CO_2 = 4.8%, CO = 0.3%, CH_4 = 0.3%, O_2 = 0.3%, H_2 = 20.2% and N_2 = 74.2%

The major reactions taking place in the reactor are :

$$CH_3OH \rightarrow HCHO + H_2$$

$$HCHO \rightarrow CO + H_2$$

$$CH_3OH + \tfrac{1}{2}O_2 \rightarrow CO_2$$

$$CH_3OH \rightarrow CH_4 + \tfrac{1}{2}O_2$$

Calculate :

(a) The % conversion of methanol

(b) Yield of formaldehyde.

2 Attempt any **two** : **8×2=16**

(i) (a) The diameter and height of a vertical cylindrical tank are 5 ft and 6 ft 6 in respectively. It is full upto 75% height with carbon tetrachloride (CCl_4) the density of which is 1.6 kg/l. Find mass in kilograms.

(b) Glycerin, weighing 600 mg is dissolved in pure water to make a final solution of 1 litre. Find the TOC and Thod of the solution.

(ii) An aqeous solution of monoethanolamine contains 20% MEA (by weight). It is utilized for the absorption of CO_2. Rich solution from the absorber contains 40 volumes CO_2. Calculate CO_2 loading in terms of moles CO_2 dissolved per mole MEA assuming that density of the solution is 1.011 kg/l.

(iii) Nitrogen hydrogen mixture with a molar ratio of 1:3 is used for the manufacture of NH_3. Where 18% conversion is achieved. After separating NH_3 from product the unconverted gases are recycled. The feed contains 0.2 mole of argon per 100 moles of N_2-H_2 mixture. The toleration limit of argon entering the reactor is 6 parts to 100 parts of N_2-H_2 mixture by volume. Calculate :

(a) The fraction of recycle that must be continually purged.

(b) The overall yield of ammonia.

3 Attempt any **two** : **7×2=14**

(i) The analysis of a sample of Babul bark yields 5.8% moisture, 12.6% tannin, 8.3% soluble non-tannin organic matter and the rest lignin. In order to extract tannin out of the bark, a counter current extraction process is employed. The residue from the extraction process is analysed and found to contain 0.92% tannin and 0.65% soluble non-tannin organic matter on a dry basis. Find the percentage of tannin recovered on the basis of original tannin present in the bark. All analysis are given on weight basis.

(ii) Limestone is a mixture of calcium and magnesium carbonates and inert material. Lime is made by calcining the carbonates i.e. heating them until CO_2 is driven off by the reactions :

$CaCO_3 \rightarrow CaO + CO_2$

$MgCO_3 \rightarrow MgO + CO_2$

When 100 kg of limestone is calcined, 44 kg of CO_2 is obtained. If the limestone contains 10% inerts, calculate the complete analysis.

(iii) A gas mixture has the following composition by volume :

Ethylene	30.6%
Benzene	24.5%
Oxygen	1.3%
Methane	15.5%
Ethane	25.0%
Nitrogen	3.1%

Find :

(a) The average molecular weight of gas mixture

(b) The composition by weight

(c) The density of mixture in kg/m^3 at NTP.

SECTION - II

4 (a) Answer the following questions briefly : **4×1=4**

(i) Define calorific values - GHV and NHV of fuel.

(ii) Write the Watson equation used in computing the latent heat of vaporization.

(iii) Enumerate the applications of Hess's law.

(iv) What is recycle ratio?

(b) Answer the followings : **2×3=6**

(i) Explain the proximate analysis of coal.

(ii) The gross calorific value of gaseous propane is 2219.71 kJ/mol at 298 K. Calculate its net calorific value if the latent heat of vaporization of water is 2442.5 kJ/kg at this temperature.

(c) Solve the followings : **2×5=10**

(i) Temperature of 1 mole of pure oxygen is raised from 350 K to 1500 K. Calculate the heat required using C_p° data.

$$C_p^\circ = a + bT + cT^2 + dT^3 \text{ kJ/(k mol K)}$$

Where $a = 26.0257$

$b = 11.7551 \times 10^{-3}$

$c = -2.3426 \times 10^{-6}$

$d = -0.5623 \times 10^{-9}$

(ii) Calculate the latent heat of vaporization of o-xylene at its normal boiling point using Riedel equation. Normal boiling point of o-xylene is 417.5 K. The critical temperature and critical pressure of o-xylene are 630.3 K and 3730 kPa.

5 Attempt any **two** : **2×8=16**

(i) A fuel gas has the following composition by volume :

Species	% by volume
$C_{2.5}H_{4.2}$ (illuminants)	7.0
$C_{1.2}H_{4.4}$ (paraffins)	11.2
CO_2	2.1
CO	33.8
H_2	40.6
O_2	0.5
N_2	4.8

(a) Calculate the theoretical number of moles of oxygen for the combustion of 1 mole of the gas.

(b) Calculate % molar composition of the flue gases formed by burning the fuel gas with 30% excess air. Assume all the combustile components are burnt to CO_2 and H_2O.

(ii) Monochloroacetic acid (MCA) is manufactured in a Semibatch reactor by the action of glacial acetic acid with chlorine gas at 373 K. MCA thus formed will further react with chlorine to form dichloroacetic acid (DCA). To prevent the formation of DCA, excess acetic acid is used. A small-scaled unit which produces 5000 kg/day MCA requires 4536 kg/day of chlorine gas. Also, 263 kg/day of DCA is separated in the crystallizer to get almost pure MCA product.

Find :

(a) % conversion

(b) % yield of MCA and

(c) Selectivity.

Reactions :

$$CH_3COOH + Cl_2 \rightarrow \underset{(MCA)}{CH_2ClCOOH} + HCl$$

$$CH_2\ Cl\ COOH + Cl_2 \rightarrow \underset{(DCA)}{CHCl_2\ COOH} + HCl$$

(iii) A coal with the following specifications is burnt with 100% excess air :

Constituents of coal	% by weight
C	50.22
H	2.79
S	0.37
N	2.05
O	18.04
Moisture	7.0

Calculate (a) The theoretical requirement of O_2 per kg of the coal (b) Flue gas analysis.

6 Attempt any **two** : **2×7=14**

(i) In a water cooling tower, air enters at height of 1 mt above the ground level and leaves at the height of 7 mt. Inlet and outlet velocities of air are 20 m/s and 30 m/s. Water enters the tower at 8 mt from the ground level and leaves the tower at height 0.8 mt. Temperature of water at entry and exit of the tower is 80°C and 50°C respectively. Cooling tower is well insulated and a fan of 2.25 kW drives the air through the cooler. Calculate the amount of air required per sec for 1 kg/sec flow of water through the cooler. Specific heats of water and air are 4.186 kJ/(kg K) and 1.005 kJ/(kg K) respectively.

(ii) Liquid Benzene at 303 K is mixed and dissolved continuously with liquid toluene which is at 373 K in the molar ratio 3:2 (Benzene: toluene) in an insulated tank. If the heat of mixing is assumed to be zero, what is the temperature of the mixed solution? Molecular weights of benzene and toluene are 78 kg/kmol and 92 kg/kmol respectively. The heat capacity C_p of these liquids follows :

$C_p = a + b_t$ where T is absolute temperature.

Data :

$T_{(K)}$	C_p of Benzene kJ/kg·K	C_p of Toluene kJ/kg·K
283	1.591	1.524
338	2.018	—
358	—	2.236

(iii) Evaluate heat of reaction for $SO_2 + \frac{1}{2}O_2 \rightarrow SO_3$ occurring at 1 atm. pressure and 775 K. The heat capacity follows $C_p^\circ = a + bT + cT^2 + dT^3$ in kJ/(kmol K). Heat of reaction at 298.15 K is –98910 kJ/kmol of SO_2 used up.

Species	a	$b \times 10^3$	$c \times 10^6$	$d \times 10^9$
SO_2	24.771	62.9481	–44.2582	11.122
O_2	26.0257	11.7551	–2.3426	–0.5623
SO_3	22.0376	121.624	–91.8673	24.3691