INDUSTRIAL STOICHIOMETRY
(BIOT 2102)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) The line that helps to calculate the ratio of amount of vapour to amount of liquid in a vapour-liquid mixture is known as
(a) Equilibrium line (b) Operating line
(c) Tie line (d) None of these.

(ii) Which of the following mole ratio is NOT appropriate to the equation $6CO_2 + 6H_2O = C_6H_{12}O_6 + 6O_2$?
(a) 6 moles H_2O / 6 moles $C_6H_{12}O_6$ (b) 6 moles CO_2 / 6 moles H_2O
(c) 6 moles CO_2 / 1 mole $C_6H_{12}O_6$ (d) 6 moles CO_2/ 6 moles O_2

(iii) Recycling in a chemical process facilitates
(a) increased yield (b) enrichment of product
(c) heat conservation (d) all of the three.

(iv) A gas sample contains 16.0 g of CH_4, 16.0 g of O_2, 16.0 g of SO_2, and 33.0 g of CO_2. What is the total number of moles of gas in the sample?
(a) 2.25 moles (b) 2.50 moles
(c) 2.75 moles (d) 3.00 moles.

(v) With reference to the following reaction, if 100 g of N_2 and 100 g of H_2O are mixed and the maximum possible reaction occurs, what mass of O_2 is produced?
$2N_2 + 6H_2O = 4NH_3 + 3O_2$
(a) 100 (b) 171
(c) 88.9 (d) 2.78.

(vi) Degree of freedom of a binary mixture of ethanol and water is
(a) more than one (b) less than one
(c) one (d) indeterminate.

(vii) Calculate the heat gained by one kmol of a gas when heated from 400K to 800K whose heat capacity is given by $C_p = a + bT$ KJ/(kmol.K) where a = 50 and b = 0.02.
(a) 24800KJ (b) 24800KW
(c) 2160KW (d) 21600KJ.

(viii) Heat of formation of water is
(a) -242.81KJ/mol (b) -393.51KJ/mol
(c) 0 (d) none of the above.

(ix) Calculate the degree of reduction of sucrose
(a) 4 (b) 6 (c) 2 (d) none of the above.

(x) A reaction is A + 2B -> 3C, if 2 moles of A and 4 moles of B entered the system, what are the number of moles of C formed?
(i) 2 (ii) 4 (iii) 6 (iv) 8.

Group – B

2. A solution of NaCl in water contains 230 gm of NaCl per litre at 20°C. The density of the solution at this temperature is 1.148 gm per litre. Calculate the following:
(i) Composition in weight %
(ii) Volumetric % of water.
(iii) Composition in mole %.

(4 + 4 + 4) = 12

3. Produce a log-log plot for the following data, show it obeys a power law and extract the law from the data.

x	2	30	70	100	150
y	4.24	16.4	25.1	30	36.7

12

Group – C

4. N_2-H_2 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 mol of Argon per 100 moles of N_2-H_2 mixture. The tolerance limit of Argon entering the reactor is 6 parts to 100 parts of N_2-H_2 mixture by volume. Calculate:
(i) Fraction of recycle that must be continuously purged.
(ii) The overall yield of NH_3.

(8 + 4) = 12

5. Hydrogen can be obtained from methane by the steam methane reforming reaction:
   $CH_4 + H_2O \rightarrow CO + 3H_2$
   A gas mixture containing 53 mol% methane and 47 mol% water is fed into a reactor.
   (i) Determine which component in the gas mixture is the limiting reactant.
   (ii) Determine the percentage by which the other reactant is in excess.
   (iii) Determine the amount of each gas exiting the reactor, if the conversion of the limiting reactant is 25%.

(4 + 4 + 4) = 12

Group – D

6. Temperature of pure oxygen is raised from 350K to 1500K.
   (i) Calculate the amount of heat supplied for raising the temperature of 1kmol oxygen using the following C_p data and absolute enthalpies. Absolute enthalpies at 350K and 1500K are 10129 KJ/Kmol and 49273 KJ/Kmol respectively.
   (ii) Calculate the error % in calculating using absolute enthalpies.
   $C_p = a + bT + cT^2 + dT^3$ kJ/(kmol.K)

a	b × 10^3	c × 10^6	d × 10^9
26.02	11.75	-2.342	-0.5623

(9 + 3) = 12

7. (a) Water is pumped from the bottom of a well 75m deep at the rate of 1Lps into an atmospheric storage tank 15m above the ground. To prevent freezing in the winters, a heater puts 65kW into the water during its transfer from the well to the storage tank. Heat is lost from the whole system at the constant rate of 25kW. A 1.8kW pump is used to pump the water. About 60% of the rated power goes into the work of pumping and the rest is dissipated as heat to the atmosphere. Assume the change in kinetic energy to be negligible. Calculate the changes in the internal energies between the storage tank and the bottom of the well.

   (b) How much heat must be added in order to raise the temperature of a 20% (w/w) caustic soda solution from 280K to 360K?
   C_l at 280K = 3.56kJ/(kg.K)
   C_l at 360K = 3.71kJ/(kg.K)

8 + 4 = 12

Group – E

8. (a) Nitrogen is sometimes bubbled into fermenters to maintain anaerobic conditions. It does not react, and leaves with the fermenter off-gas. However, it can strip water from the fermenter, so that water vapour also leaves in the off-gas. In a continuous fermenter operated at 33°C, 20g/h water is evaporated in this way. How much heat must be put into the system to compensate for evaporative cooling? (Latent heat of vaporization of water at 33°C is 2430.7kJ/kg)

   (b) Fumaric acid and water are produced from malic acid using the enzyme, fumarase. Calculate the standard heat of reaction for the above enzyme transformation.
   Heat of combustion of:
   Malic acid = -1328.8kJ/gmol
   Fumaric acid = -1334.0kJ/gmol.

6 + 6 = 12

9. Glucose is used as carbon source and ammonia is used as the nitrogen source to grow yeast anaerobically in a continuous reactor at 30°C. A mixture of ethanol and glycerol is produced along with cells, water and carbon-di-oxide. At steady state, mass flows to and from the reactor at steady state are as follows:
   Glucose in: 49kg/h
   NH_3 in: 0.9kg/h
   Cell out: 5.61k/h
   Glycerol out: 6.95kg/h
   Ethanol out: 12.9kg/h
   CO_2 out: 24.6kg/h
   H_2O out: 15kg/h
   Estimate the cooling requirements.
   Heat of combustion of glucose = -2805kJ/mol
   Heat of combustion of NH_3 = -382.6kJ/mol
   Heat of combustion of glycerol = -1655.4kJ/mol
   Heat of combustion of ethanol = -1366.8kJ/mol
   Heat of combustion of yeast = -21.2kJ/g
   Molecular weight of glycerol is 92.

12