Group – E

8. (a) Nitrogen is sometimes bubbled into fermenters to maintain anaerobic conditions. It does not react, and leaves in 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, 20 g/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 = 2430.7 kJ/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 = -1328.8 kJ/gmol and
   Fumaric acid = -1334.0 kJ/gmol.

6 + 6 =12

9. *Aspergillus niger* is used to produce citric acid in a batch reactor operated at 30°C. Over a period of three days, 4500 kg glucose and 1050 kg oxygen are consumed to produce 3000 kg citric acid, 1000 kg biomass and other products. Ammonia is used as nitrogen source. Power input to the system by mechanical agitation of the broth is about 15 kW; approximately 200 kg water is evaporated over the culture period. Estimate the cooling requirements. Latent heat of vapourization of water at 30°C is 2430.7 kJ/kg.

12

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) Which of the following does the concept of material balance based upon?
   (a) Conservation of mass (b) Conservation of energy
   (c) Conservation of momentum (d) Conservation of volume.

   (ii) 10 moles of O_2 is added to 10 moles of H_2, how many moles of H_2O will it produce?
   (a) 5 (b) 10 (c) 15 (d) 20.

   (iii) A combustion reaction has reactants 1 mole of C_xH_y and 2 moles of O_2 and products 1 mole of CO_2 and 2 mole of H_2O, what is x + y?
   (a) 1 (b) 3 (c) 4 (d) 5.

   (iv) 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?
   (a) 2 (b) 4 (c) 6 (d) 8.

   (v) There were 15 moles of a substance present initially in a system, 25 moles were added to it and a reaction occurred so that its moles are reduced by 50%, what are the final moles of a substance in the system?
   (a) 10 (b) 15 (c) 20 (d) 40.

   (vi) Number of available electrons in ethanol is
   (a) 12 (b) 4 (c) 6 (d) indeterminate.

   (vii) Ideal liquid solution follows
   (a) Henry's law (b) Boyle's Law
   (c) Charles' Law (d) Raoult's Law

   (viii) Heat of formation of carbon di-oxide is
   (a) -242.81 kJ/mol (b) -393.51 kJ/mol
   (c) 0 (d) none of (a), (b) and (c).

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

(x) When the temperature of a binary mixture is more than its bubble point but less than its dew point then it is a
(a) saturated liquid mixture (b) equilibrium vapour liquid mixture
(c) saturated vapour mixture (d) subcooled liquid mixture.

Group – B

2. In 1000 ft^3 of a mixture of H_2, N_2 and CO_2 at 250°F, the partial pressure are 0.26 atm, 0.32 atm and 1.31 atm respectively. Assuming ideal gas behaviour, find
(i) lb mole of H_2
(ii) mole fraction of H_2
(iii) pressure fraction of H_2
(iv) partial volume of H_2
(v) volume fraction of H_2
(vi) weight of H_2
(vii) average molecular weight of gas mixture
(viii) weight fraction of H_2
(ix) density of gas mixture (kg/m^3).

(2 + 1 + 1 + 1 + 1 + 1 + 1 + 2 + 2) = 12

3. Air is pumped through an orifice immersed in liquid. The size of the bubbles leaving the orifice depends on the diameter of the orifice and the properties of the liquid. The equation representing the situation is :

$$\frac{g(\rho_L-\rho_G){D_b}^3}{\sigma Do} = 6;$$

Where,
g = gravitational acceleration, 32.174 ft/sec^2
ρ_L = Liquid density, 1 gm/cm^3
ρ_G = Gas density , 0.081 lb/ft^3
D_b = Bubble diameter
σ = Gas liquid surface tension =70.8 dyne/cm
D_o = orifice diameter = 1 mm
Calculate the bubble diameter D_b.

12

Group – C

4. Production of single cell protein from hexadecane is described by the following reaction equation:

$$C_{16}H_{34} + a\,O_2 + bNH_3 \rightarrow cCH_{1.66}O_{0.27}N_{0.20} + dCO_2 + eH_2O$$

Where, $CH_{1.66}O_{0.27}N_{0.20}$ represents the biomass. If RQ = 0.43, determine the stoichiometric coefficients.

12

5. Antimony is obtained by heating pulverised stibnite (Sb_2S_3) with scrap iron and drawing antimony (Sb) from the bottom of the reactor vessel.

$$Sb_2S_3 + 3Fe \rightarrow 2Sb + 3FeS$$

Suppose that 0.600 Kg of stibnite (Sb_2S_3, MW = 340) and 0.25 kg of Fe (MW = 56) are heated together to give 0.20 kg of Sb metal (MW = 121.8), determine.
(i) Which reactant is limiting reactant?
(ii) % excess reactant.
(iii) Degree of completion (fraction).
(iv) % conversion with respect to stibnite.
(v) The yield of Sb.

3 + 3 + 2 + 2 + 2 = 12

Group – D

6. Temperature of pure oxygen is raised from 350°K to 1500°K.
(i) Calculate the amount of heat supplied for raising the temperature of 1 kmol oxygen using the following C_p data and absolute enthalpies.
(ii) Calculate the error % in calculating using absolute enthalpies.

$$C_p = a + bT + cT^2 + dT^3 \; kJ/(kmol.K)$$

Absolute enthalpy at 350°K = 10,129 kJ/kmol and at 1500°K = 49,273 kJ/kmol.

a	$bx10^3$	$cx\,10^6$	$dx10^9$
26.02	11.75	-2.342	-0.5623

8 + 4 =12

7. (a) Water is pumped from the bottom of a well 75 m deep at the rate of 1 Lps into an atmospheric storage tank 15 m above the ground. To prevent freezing in the winters, a heater puts 65 kW 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 25 kW. A 1.8 kW 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 280°K to 360°K?
C_l at 280°K= 3.56 kJ/(kg.K)
C_l at 360°K= 3.71 kJ/(kg.K)

8 + 4 = 12