7 + 5 =12

Group – E

8. Glucose is used as carbon source and ammonia is 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: 49 kg/h
NH_3 in: 0 9 kg/h
Cell out: 5 61 k/h
Glycerol out: 6 95 kg/h
Ethanol out: 12 9 kg/h
CO_2 out: 24 6 kg/h
H_2O out: 15 kg/h
Estimate the cooling requirements.
Heat of combustion of glucose = -2805 kJ/mol
Heat of combustion of NH_3 = -382 6 kJ/mol
Heat of combustion of glycerol = -1655 4 kJ/mol
Heat of combustion of ethanol = -1366 8 kJ/mol
Heat of combustion of yeast = -21 2 kJ/g
Molecular weight of glycerol is 92. **12**

9. *Aspergillus niger* is used to produce citric acid in a batch reactor operated at 30°C. Over a period of three days, 4 500 kg glucose and 1050 kg oxygen are consumed to produce 3000 kg citric acid, 1 000 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) For the given unbalanced reaction $CaSO_4 + NaCl \rightarrow CaCl_2 + Na_2SO_4$. How many $CaSO_4$ in kg is required for producing 1 mole of Na_2SO_4? Assume NaCl in excess.
(a) 136 kg (b) 156 kg (c) 176 kg (d) 196 kg.

(iv) When 32 gms of CH_4 is burned with excess oxygen, how many grams of CO_2 are produced?
(a) 44 (b) 88 (c) 132 (d) 176.

(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) The line that helps to calculate the ratio of amount of vapour to amount of liquid in a VLE curve is known as
(a) bubble point (b) dew point
(c) critical point (d) tie line.

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

(viii) 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) 24800 KJ (b) 24800 KW
(c) 2160 KW (d)21600 KJ.

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

(x) For a gaseous mixture, composition of the components in volume percent is equal to their composition
(a) in weight % (b) in mole %
(c) both (d) none.

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. The following data has been gathered from an experiment to determine the relationship which exist between the diameter of a ring (d) and its period of oscillation (T) as a pendulum:

Ring dia (d) (cm)	3.51	7.26	13.7	28.5	38.7
Time period (T)(sec)	0.376	0.532	0.768	1.08	1.32

If the relationship existing between T and d is given as $T=Ad^n$, then find out the value of A and n using log-log graph paper.

12

Group – C

4. Production of single cell protein from hexadecane is described by the following reaction equation:
$C_{16}H_{34} + aO_2 + bNH3 \rightarrow cCH_{1.66}O_{0.27}N_{0.20} + dCO_2 + eH_2O$
where, $CH_{1.66}O_{0.27}N_{0.20}$ represents the biomass. If RQ= 0.43, determine the stoichiometric coefficients.

12

5. (a) Pure sulphur is burnt in air. Even when 20% excess dry air passed only 30% of the S burns to SO_3 and the remaining goes to SO_2. S to SO_3 is the desired reaction. What is the analysis of the resulting gases?

(b) In continuation of the above problem, the gases from the burner are passed through a converter where SO_2 is converted to SO_3 (without addition of any more air). If the gases leaving the converter have 4.3% SO_2, calculate the molar ratio of SO_3 to SO_2 in the exit gas.

$S + O_2 \longrightarrow SO_2$
$S + 1.5\ O_2 \rightarrow SO_3$

6 + 6 = 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 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 350K= 10,129 KJ/kmol and at 1500K= 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) A heat exchanger for cooling a hot hydrocarbon liquid uses 10,000kg/h of cooling water, which enters the exchanger at 294K. The hot oil at the rate of 5000kg/h enters at 423K and leaves at 338K and has an average heat capacity of 2.51kJ/(kg.K). Calculate the outlet temperature of water.
C_p of water= $a + bT + cT^2 + dT^3$ kJ/(kmol.K)

a	$bx10^3$	$cx\ 10^6$	$dx10^9$
50.845	213.08	-631.398	648.746

(b) Calculate the heat of formation of n-heptane at 298K using heat of combustion data.
Standard heat of combustion of hydrogen= -241.82 KJ/mol.
Standard heat of combustion of carbon=-393.51 KJ/mol.
Standard heat of combustion of n-heptane= -4501.3 KJ/mol.