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) How many g moles of S are there in 22 g of H_2SO_4?
(a) 0.4489 (b) 0.2245 (c) 0.1256 (d) 0.3256

(ii) There were 10 moles of a substance present initially in a system, 5 moles were added to it and a reaction occurred so that its moles are reduced by 20%, what are the final moles of a substance in the system?
(a) 10 (b) 12 (c) 15 (d) 18

(iii) What is the average molecular weight of a gas containing 20% N_2 (molecular wt. = 28) and 80% SO_2 (molecular wt. = 64)?
(a) 28.4 (b) 56.8 (c) 24.4 (d) 48.8

(iv) According to the balances on steady-state processes, the accumulation is equal to?
(a) 1 (b) 0 (c) 100 (d) 2

(v) Two statements are given as
I: Specific density is dimensionless.
II: When salt is added to water, density of the solution will increase.
Number of correct statement is
III. Mole% of a gas in an ideal gaseous mixture is dimensionless.
(a) 0 (b) 1 (c) 2 (d) 3

(vi) Heat of formation of water vapour is
(a) -242.81KJ/mol (b) -393.51KJ/mol
(c) 0 (d) None of the above

(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) Degree of reduction of $CH_{1.8}O_{0.5}N_{0.2}$ with respect to nitrogen is
(a) 4.8 (b) 4.2 (c) 4 (d) Indeterminate

(ix) For a gaseous mixture, composition of the components in volume fraction is equal to their composition
(a) in weight fraction (b) in mole fraction
(c) in partial pressure fraction (d) both (b) and (c)

(x) Enthalpy change accompanying a reaction where a compound is synthesized elements is called
(a) Heat of reaction (b) Heat of combustion
(c) Heat of formation (d) Heat of mixing.

Group- B

2. (a) Thermal conductivity of a material is 50 Btu/(hr.ft. ^oF). Convert the value to Watt/(m^oC). [(CO1) (Understand/LOCQ)]
(b) A solution of NaCl in water contains 20% NaCl (by mass) at 333K. The density of the solution is 1.127 Kg/L. Find the molarity, normality and molality of the solution. [(CO2) (Calculate /IOCQ)]

6 + 6 = 12

3. Produce a log-log plot for the following data. Show it obeys a power law ($y=Ax^n$) and find the values of A and n from the data. [(CO1) (Calculate /HOCQ)]

X	2	30	70	100	150
Y	4.24	16.4	25.1	30	36.7

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. [(CO3) (Evaluate/HOCQ)]

12

5. (a) The chlorination of methane occurs by the following reaction

$$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$$

Determine the product composition in mol% if the conversion of the limiting reactant is 67%, and the feed contains 40 gmol CH_4, 50 gmol Cl_2, and 10 gmol N_2. [(CO2) (Evaluate/IOCQ)]
(b) Define: (i) limiting reactant
(ii) % excess
(iii) yield factor. [(CO2) (Remember/LOCQ)]

6 + (2 + 2 + 2) = 12

Group - D

6. Combustion of solid wastes produces a flue gas of the following composition: CO_2=9%, CO=2%, O_2=7% and N_2=82%. Find the difference in enthalpies for this gas between the bottom and the top of the stack if the temperature of the gas at the bottom is 600K and that at the top is 375K. The heat capacities of the gas are:

   CO: $C_p = 26.586 + 7.582\times10^{-3}T - 1.12\times10^{-6}T^2$

   CO_2: $C_p = 26.540 + 42.454\times10^{-3}T - 14.298\times10^{-6}T^2$

   O_2: $C_p = 25.74 + 12.987\times10^{-3}T - 3.864\times10^{-6}T^2$

   N_2: $C_p = 27.03 + 5.815\times10^{-3}T - 0.289\times10^{-6}T^2$

   Where C_p is in KJ/(Kmol.K) and T is in K. [(CO1)(Analyze/IOCQ)]

12

7. (a) Derive an expression for the internal energy change in a steady state flow process of an incompressible fluid. [(CO4) (Understand/LOCQ)]

   (b) Calculate the heat of formation of n-heptane at 298K using heat of combustion data.
   Standard heat of combustion of hydrogen= -241.82KJ/mol.
   Standard heat of combustion of carbon=-393.51KJ/mol.
   Standard heat of combustion of n-heptane= -4501.3KJ/mol.
   [(CO4) (Calculate/IOCQ)]

6 + 6 = 12

Group - E

8. *Aspergillus niger* is used to produce citric acid in a batch reactor operated at 30°C. Over a period of three days, 4500kg glucose and 1050kg oxygen are consumed to produce 3000kg citric acid, 1000kg biomass and other products. Ammonia is used as nitrogen source. Power input to the system by mechanical agitation of the broth is about 15kW; approximately 200kg water is evaporated over the culture period. Estimate the cooling requirements. Latent heat of vaporization of water at 30°C is 2430.7kJ/kg. [(CO6)(Analyse/IOCQ)]

12

9. (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, 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 = 2430.7kJ/kg).
   [(CO5)(Analyse/IOCQ)]

   (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. (CO5) (Understand/LOCQ)]

6 + 6 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	25	50	25

Course Outcome (CO):

After the completion of the course students will be able to

1. Solve problems related to units and conversions and fit the given data using the methodologies.
2. Able to make *material balances* on unit operations and processes.
3. Understand stoichiometry of microbial growth and product formation.
4. Solve problems related to energy balance for steady state processes.
5. Determine the heat of reaction for processes with biomass and secondary metabolite production.
6. Design simultaneous material and energy balances in biochemical processes.

*LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question

Department & Section	Submission Link
BT	https://classroom.google.com/c/NDYyNjI3MDQ2NjE1/a/NDc1MTQ5MzMyODY3/details