

**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) 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
- (iii) When temperature of the vapour liquid mixture is more than its bubble point but less than its dew point, then it is a
(a) subcooled liquid mixture (b) saturated liquid mixture
(c) Equilibrium vapour liquid mixture (d) Saturated vapour mixture
- (iv) A reaction is as follows.
 $A + 2B \rightarrow 3C$
If 2 moles of A and 4 moles of B entered the system, how many of moles of C will be formed?
(a) 2 (b) 4 (c) 6 (d) 8
- (v) A vapor whose partial pressure is less than its equilibrium vapor pressure is called a _____ vapor.
(a) Saturated (b) Unsaturated
(c) Supersaturated (d) subcooled
- (vi) 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

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- (vii) A flue gas mixture has the following molar composition of CO₂= 10%, H₂O= 25%, O₂= 20% and N₂= 45%. What will be the molar composition of O₂ in the dry flue gas?
 (a) 26.67% (b) 20%
 (c) 13.33% (d) Cannot be determined
- (viii) Ideal liquid solution follows
 (a) Henry's law (b) Boyle's Law
 (c) Charles' Law (d) Raoult's Law
- (ix) When the temperature of a binary mixture is less than its bubble point then it is a
 (a) Saturated liquid mixture (b) Equilibrium vapour liquid mixture
 (c) Saturated vapour mixture (d) Subcooled liquid mixture
- (x) Calculate the degree of reduction of sucrose
 (a) 4 (b) 6 (c) 2 (d) none of the above.

Group - B

2. (a) Use the following data to predict the equation of best fit straight line by Least Square Analysis.

x	0	1	2	3	4
y	1	5	10	22	38

- (b) Define (i) absolute error (ii) relative error.

9 + 3 = 12

3. In 1000 ft³ of a mixture of H₂, N₂ and CO₂ at 250°F, the partial pressure are 0.26 atm, 0.32 atm and 1.31 atm respectively. Assuming ideal gas behaviour, find
- lb mole of H₂
 - mole fraction of H₂
 - pressure fraction of H₂
 - partial volume of H₂
 - volume fraction of H₂
 - weight of H₂
 - Average molecular weight of gas mixture
 - Weight fraction of H₂
 - Density of gas mixture (Kg/m³)

2 + 1 + 1 + 1 + 1 + 1 + 1 + 2 + 2 = 12

Group - C

4. (a) A weak H₂SO₄ contains 12.43% acid and rest water. If 200 kg of an H₂SO₄ solution containing 77.7% H₂SO₄ (and rest water) is mixed with the other solution mentioned and the final acid is 18.63% H₂SO₄, how many Kg of weak acid is being mixed?

(b) Define the following terms:

- (i) Limiting reactant
- (ii) Excess reactant
- (iii) %Selectivity
- (iv) Percentage yield

$$4 + (2 + 2 + 2 + 2) = 12$$

5. Determine the slope of the vapour pressure curve of water at 32°F and at an interval of 5°F from 35°F to 60°F by graphical differentiation method. The vapour pressure of water at different temperatures have been given below:

Temperature (°F)	32	35	40	45	50	55	60	65
Vapor pressure (psi)	0.089	0.100	0.122	0.147	0.178	0.214	0.256	0.306

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Group - D

6. (a) Combustion of solid wastes produces a flue gas of the following composition: CO₂=9%, CO=2%, O₂=7% and N₂=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:

$$\text{CO: } C_p = 26.586 + 7.582 \times 10^{-3}T - 1.12 \times 10^{-6}T^2$$

$$\text{CO}_2: C_p = 26.540 + 42.454 \times 10^{-3}T - 14.298 \times 10^{-6}T^2$$

$$\text{O}_2: C_p = 25.74 + 12.987 \times 10^{-3}T - 3.864 \times 10^{-6}T^2$$

$$\text{N}_2: C_p = 27.03 + 5.815 \times 10^{-3}T - 0.289 \times 10^{-6}T^2 \text{ where } C_p \text{ is in KJ/(Kmol.K) and } T \text{ is in K.}$$

(b) Explain vapour-liquid equilibrium of a binary mixture of n-pentane and n-hexane with the help of a phase diagram.

$$9 + 3 = 12$$

7. (i) Calculate the heat of formation of liquid 1,3-butadiene, where the heats of combustion of 1,3-butadiene, carbon and hydrogen are -2522.1KJ/mol, -393.51KJ/mol and -241.82KJ/mol respectively.

(ii) Water from a tank at a height Z₁m from the ground is pumped with a velocity U₁m/s into a reactor containing CaCO₃ resulting in an exothermic reaction. The product is transferred into a reservoir at a height Z₂m from the ground at a velocity of U₂m/s. Balance the energy components considering a steady flow process.

$$6 + 6 = 12$$

Group - E

8. (a) The maximum growth yield coefficient for *Bacillus subtilis* growing on methanol is 0.4g cells/ g methanol. The heat of combustion of cells is 21kJ/g cells and for methanol it is 7.3kCal/g. Determine the metabolic heat generated by the cells per unit mass of methanol consumption.

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(b) Derive an energy balance equation for production of citric acid by *Aspergillus niger* in a continuous stirred tank reactor.

7+5 = 12

9. Steam is used to heat nutrient medium in a continuous flow process. Saturated steam at 150°C enters a coil on the outside of the heating vessel and is completely condensed. Medium enters the vessel at 15°C and leaves at 44°C. Heat losses from the jacket to the surroundings are estimated as 0.22KW. If the flow rate of medium is 3250kg/h and the heat capacity is $C_p=0.9\text{Cal}/(\text{g}\cdot^\circ\text{C})$, how much steam is required?

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Department & Section	Submission Link
BT	https://classroom.google.com/c/MjQwNjIyMDI5NzU3/a/Mjc1NTE3MDQ5NTIx/details