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) What is the unit of mole fraction?
(a) Kg/m^3 (b) N/m^3
(c) m^{-2} (d) None of the mentioned

(ii) If the mole fraction of 4.5 moles of solute is 0.5, what is the number of moles of solvent?
(a) 9 (b) 4.5 (c) 1.5 (d) 3

(iii) $[ML^{-1}T^{-2}]$ is the dimensional formula of
(a) force (b) coefficient of friction
(c) modulus of elasticity (d) energy

(iv) The temperature at which the first drop of liquid is formed is known as
(a) Bubble point (b) Dew point
(c) Critical point (d) Supercritical point

(v) How many milliliters of 2 M NaCl solution are required to make 1 liter of 0.4 M NaCl solution?
(a) 5000 ml (b) 800 ml
(c) 200 ml (d) 0.2 ml

(vi) 2 litres of nitrogen at N.T.P. weighs _____ gms.
(a) 2.5 (b) 1.25 (c) 28 (d) 14

(vii) 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

(viii) Consider the following balanced equation:
$4NH_3 + 5O_2 = 4NO + 6H_2O$
How many grams of O_2 (formula wt = 32.0) are required for the complete reaction of 162 g of NH_3 (formula wt = 17.0)?
(a) 108 (b) 381 (c) 244 (d) None of these

(ix) Which of the following statement is false?
(a) Change in internal energy equals the heat added in a constant volume process
(b) In constant pressure process heat transferred is equal to the enthalpy of the body
(c) CpdT= dE+PdV, E is internal energy
(d) CvdT =dE+ PdV, E is the internal energy.

(x) Calculate the heat gained by one kmol of a gas when heated from 300K to 500K whose heat capacity is given by C_p = a+ bT KJ/(kmol.K) where a= 5 and b= 0.2.
(a) 17000kW (b) 17000kJ (c) 1700kW (d) None of the above

Group – B

2. (a) The effective heat capacity of a mixture of gases is given by $Cp=7.13+0.577\times10^{-3}\ T + 0.0248 \times 10^{-6}T^2$ Where Cp is in Btu/(lb-mol.^{0}F) and T is in ^{0}F. Change the equation into the form in which Cp is given in KJ/(Kmol. K) and the temperature is in K.

(b) A natural gas has the following composition by volume percent: CO_2: 0.8%, N_2: 3.2% and CH_4: 96%. Calculate: i) The composition in weight percent. ii) The average molecular weight of gas. iii) The density at standard conditions in Kg/m^3.

6 + (2 + 2 + 2) = 12

3. (a) 2m^3 of O_2 at 200 KPa and 280K is mixed with 10kg of N_2 at 95KPa and 300K and the resulting mixture is brought to 110KPa and 280 K.
i) What is the partial pressure of O_2 in the final mixture?
ii) What is the final volume of the mixture?

(b) Prove that volume composition of an ideal gas mixture is same as molar composition of that mixture.

(4 + 4) + 4 = 12

Group – C

4. In a process of Cl_2 manufacture, a dry mixture of HCl gas and air is passed over a heated catalyst which promotes oxidation of the acid. Air is used in 20% excess of that stoichiometrically required.

$$4HCl + O_2 \rightarrow 2Cl_2 + 2H_2O$$

Calculate
(i) Weight of air supplied per kg of acid.
(ii) Composition by weight of gas entering the reaction chamber.

(iii) Assuming that 60% of the acid is oxidised in the process, calculate the composition by weight of the gas leaving the chamber.

4 + 4 + 4 = 12

5. Carbon monoxide combines with chlorine in the presence of a suitable catalyst from phosgene according to the following reaction.

$$CO(g) + Cl_2(g) \rightarrow COCl_2\ (g).$$

After reaction, the product contained 12 moles of phosgene, 3 moles of chlorine and 8 moles of carbon monoxide. Assuming that the original reactant mixture is free of phosgene, calculate the following.

i) The percentage excess reactant used.
ii) The present conversion of the limiting reactant.
iii) The moles of total product per mole of reactant mixture fed to the reactor.

Define (i) Limiting reactant (ii) percentage conversion of reactant

(3 + 3 + 3) + 3 = 12

Group – D

6. (a) Calculate the energy required to dissociate a kilogram of sodium bicarbonate into sodium carbonate, carbon-di-oxide and water at 298K.

(b)

Heat of formation of sodium bicarbonate, kJ/mol	Heat of formation of sodium carbonate, kJ/mol	Heat of formation of carbon di oxide, kJ/mol	Heat of formation of water, kJ/mol
-950.81	1130.68	-393.51	-241.82

Water is pumped from the bottom of a well 50m deep at the rate of 1L/s into an atmospheric storage tank 10m above the ground. To prevent freezing in the winters, a heater puts 52KW 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 21KW. A 1.5KW pump is used to pump the water. About 55% 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 change in internal energies between the storage tank and the bottom of the well.

4 + 8 = 12

7. 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: $C_p = 26.586 + 7.582\times10^{-3}T - 1.1210^{-6}T^2$

CO_2: $C_p = 26.540 + 42.454\times10^{-3}T - 14. \times298\times10^{-6}T^2$

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.

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Group – E

8. 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=0.9Cal/(g.˚C), how much steam is required?

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9. A crude fermenter is set up in a shed in the backyard of a suburban house. Under anaerobic conditions with ammonia as nitrogen source, about 0.45g ethanol are formed per g of glucose consumed. At steady state, the production rate of ethanol averages 0.4kg/h. The owner of this enterprise decides to reduce her electricity bill by using the heat released during the fermentation to warm water as an adjunct to the household hot-water system. 2.5L/h cold water at 10˚C is fed into a jacket surrounding the fermenter. To what temperature is the water heated? Heat losses from the system are negligible. Use a biomass composition of $CH_{1.75}O_{0.58}N_{0.18}$ plus 8% ash. (Given data: q=115KJ/gmol of available electrons, heat of combustion of ethanol=-1366KJ/gmol, heat of combustion of glucose= -2805KJ/gmol)

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Department & Section	Submission Link
BT	https://classroom.google.com/c/MjQwNjIyMDI5NzU3/a/Mjc1NTE3MDQ5NDg4/details