

**BIRLA INSTITUTE OF TECHNOLOGY, MESRA, RANCHI
(END SEMESTER EXAMINATION)**

CLASS: B.TECH/BSc.

BRANCH: CHEMICAL ENGG., FOOD TECH., BSc. CHEMISTRY

SUBJECT: CL24205 / CL217 CHEMICAL PROCESS CALCULATIONS

SEMESTER : III

SESSION : MO/2025

TIME: 3 Hours

FULL MARKS: 50

INSTRUCTIONS:

1. The question paper contains 5 questions each of 10 marks and total 50 marks.
 2. Attempt all questions.
 3. The missing data, if any, may be assumed suitably.
 4. Before attempting the question paper, be sure that you have got the correct question paper.
 5. Tables/Data hand book/Graph paper etc. to be supplied to the candidates in the examination hall.
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		CO	BL
Q.1(a) Convert 23 lbm.ft/min ² to its equivalent in kg.cm/s ² .	[2]	1	2
Q.1(b) The oxidation of ethylene to produce ethylene oxide proceeds according to the equation $2C_2H_4 + O_2 \rightarrow 2C_2H_4O$. The feed to a reactor contains 100 kmol C ₂ H ₄ and 100 kmol O ₂ . Determine: (i) limiting reactant, (ii) percentage excess of the other reactant, (iii) composition of mixture, if the reaction proceeds to a point where the fractional conversion of the limiting reactant is 50%.	[3]	1	3
Q.1(c) The primary means of synthesizing acrylonitrile is ammoxidation of propylene: $C_3H_6 + NH_3 + 1.5O_2 \rightarrow C_3H_3N + 3H_2O$ The feed to a propylene ammoxidation process contains 10.0 mole% propylene, 12.0% ammonia, and 78.0% air. A fractional conversion of 30.0% of the limiting reactant is achieved. Taking 100 mol of feed as a basis, determine which reactant is limiting, the percentage by which each of the other reactants is in excess, and the molar amounts of all product gas constituents for a 30% conversion of the limiting reactant.	[5]	1	3
Q.2(a) An equimolar liquid mixture of benzene (B) and toluene (T) is in equilibrium with its vapor at 30°C. What is the system pressure and the composition of the vapor? Vapor pressure of benzene and toluene are 119 mmHg and 36.7 mmHg at 30°C.	[2]	2	3
Q.2(b) An ideal-gas mixture at 10 bar absolute and 200°C in a 100-m ³ tank contains 50 mole% H ₂ and 50 mole% N ₂ . What is the partial pressure of H ₂ ? What is the pure-component volume of H ₂ ? What would happen to p _{H2} and v _{H2} if the temperature were raised?	[3]	2	3
Q.2(c) A mixture of acetone vapour and nitrogen gas at 101.3 kPa and 295 K contains acetone vapour to the extent that it exerts a partial pressure of 15 kPa. The vapour pressure of acetone at 295 K is 26.36 kPa. Determine the following: (a) the molal humidity, (b) the absolute humidity, (c) the molal saturation humidity, (d) the absolute saturation humidity, (e) the percent saturation.	[5]	2	3
Q.3(a) The raw feed to a sulfur removal process contains 15 wt.% CO ₂ , 5 wt.% H ₂ S, and 1.5 wt.% CO, and the balance is CH ₄ . The original absorber design placed a maximum flow rate limit of 80 kg/h. Any feed flow rate in excess of 80 kg/h is bypassed. The product stream (mixture of bypass stream and top stream of absorber) of the whole process contains 1% H ₂ S, 0.3% CO, and the balance is carbon dioxide and methane. The absorber absorbs hydrogen sulfide and carbon monoxide only. If the fresh feed to the unit is 100 kg/h. Make a neat flow diagram of the process and perform a degree of freedom analysis for absorber, mixer (mixing point of bypass stream and top stream of absorber), and overall process. Note: Perform only degrees of freedom analysis; do not carry out material balance calculations.	[5]	3	3
Q.3(b) A fresh feed stream contains liquid mixture containing 35.0 mol% toluene (T), 27.0 mol% xylene (X), and the remainder benzene (B) is fed to a distillation column. The fresh feed molar flow rate is 100 kmol/h. The bottom product contains 97.0 mol% X and no B, and 93.0% of the xylene in the feed is recovered in this stream. The overhead product is fed to a second column. The overhead product from the second column contains 5.0 mol% T and no X, and 96.0% of the benzene fed to the system is recovered in this stream. Calculate (i) the composition of the bottoms stream from the second column, and (ii) the percentage of toluene contained in the process feed that emerges in the bottom product from the second column.	[5]	3	3

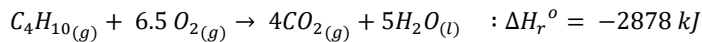
Q.4(a) A gas stream contains nitrogen, hydrogen, and 0.2 mol% argon (Ar) as an impurity. Nitrogen and hydrogen are in stoichiometric proportion. If we do only recycling, then Ar concentration will build up and eventually shut down the reaction. To avoid this, we purge a portion of the recycle stream so that the level of Ar in the recycle stream is maintained at 7.0%. The reactor single pass fractional conversion is 0.25. How much nitrogen is required to produce 245 kmol/h of ammonia? What is the flow rate of the recycle stream? What is the flow rate of the purge stream? [5] 4 3

Q.4(b) Propane can be dehydrogenated to form propylene in a catalytic reactor:
 $C_3H_8 \rightarrow C_3H_6 + H_2$ [5] 4 3

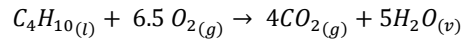
A process is to be designed for a 95% overall conversion of propane. The reaction products are separated into two streams: the first, which contains H₂, C₃H₆ and 0.555% of the propane that leaves the reactor, is taken off as product; the second stream, which contains the balance of the unreacted propane and propylene in an amount equal to 5% of that in the first stream, is recycled to the reactor. Calculate the composition of the product, the ratio (moles recycled)/(moles fresh feed) and the single pass conversion.

Q.5(a) A stream of 100 kg/h of methanol vapor is condensed to liquid methanol at 30°C by removing heat from saturated methanol vapor. The boiling point of methanol is 64.8°C. The latent heat of condensation of methanol is 1101.7 kJ/kg, and the specific heat of liquid methanol is 2.7235 kJ/(kg·°C). Determine the amount of heat in kW that must be removed. [2] 5 3

Q.5(b) The standard heat of the combustion of n-butane vapor is [3] 5 3

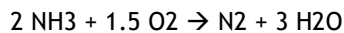
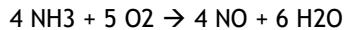


The heats of vaporization of n-butane and water at 25°C are 19.2 kJ/mol and 44.0 kJ/mol, respectively. Calculate the standard heat of the reaction below.

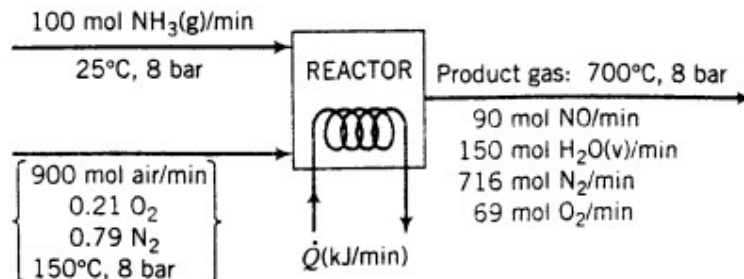


Also, calculate ΔH if 2400 mol/s of CO₂ is produced in this reaction and the reactants and products are all at 25°C.

Q.5(c) Ammonia is oxidized with air to form nitric oxide in the first step of the production of nitric acid. Two principal reactions occur: [5] 5 3



A flowchart of the reactor as follows.



Taking elemental species [N₂(g), O₂(g) and H₂(g)] at 25°C as references, calculate the required rate of heat transfer to or from the reactor (KW). Below equation can be utilized.

$$\hat{H}_i = \Delta \hat{H}_{fi}^o + \int_{25}^T C_{pi} dt$$

Given:

(ΔH_f)NH₃ = -46.19 KJ/mol, (ΔH_f)NO = 90.37 KJ/mol,

HH₂O (@ 700°C) = -216.91 KJ/mol, HN₂ (@ 700°C) = 20.59 KJ/mol,

HO₂ (@ 700°C) = -21.86 KJ/mol,

The specific heat of NO is calculated by following equation:

$$CP(NO) = (2.950 \times 10^{-2}) + (8.188 \times 10^{-6})T - (2.925 \times 10^{-9})T^2 + (3.652 \times 10^{-13})T^3$$