Closed Book

Birla Institute of Technology & Science, Pilani

Pilani Campus

First Semester 2023-2024

Comprehensive Examination (Regular)

ID No. _____ Name _____

Course No. _____ Course Title _____Section No._____

Instructor's Name _____ Room No. _____ Date_____

Verified:
Signature of Invigilator:

INSTRUCTIONS

1. Enter all the required details on the cover of every answer booklet.
2. Write on both sides of the sheet in the answer book. Rough work, if any should be done at the bottom of the page. Finally cross out the rough work and draw a horizontal line to separate it from the rest of the material on the page. Also, cross out all blank pages in the answer booklet.
3. Any answer crossed out by the student will not be examined by the examiner.
4. No sheet should be torn from the answer booklet.
5. Mobile phones or any electronic communication/storage device of any kind is prohibited in the examination hall.
6. Use of any unfair means will make the candidate liable to disciplinary action.
7. Student should not leave the examination hall without submitting the answer booklet to invigilator on duty.
8. Student must abide by all the instructions given by the invigilator(s) on duty.

I have carefully read and understood all the instructions.

I do understand that any attempt to use unfair means of any kind in an examination is a serious and punishable offence.

I hereby declare that I will not attempt to do any malpractice in the examination.

Signature of the student

BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI

Department of Chemical Engineering

First Semester 2023-2024

Comprehensive Examination (Closed Book)

CHE F211: CHEMICAL PROCESSS CALCULATIONS

DATE: 13.12.2023 **Maximum Marks: 120**

***Note*:** The question paper consists of two parts. **Part A** is of 36 marks and of 60 minutes duration. **Part B** question paper can be collected only after submission of Part A answer sheet.

Time: 1 hour **PART – A** **Marks: 36**

Write your answers/solutions in the space provided. Each question carries four marks. The data booklet of Tables and Charts is allowed.

Atomic weights:- Na:23, Cl:35.5, O:16, C:12, H:1, Sb:122, Fe:56, S:32.

1. Find the molecular formula for the solid compound which contains 22% sodium, 33% chlorine and 45% oxygen.

2. Find the extent of reaction and the mole fractions of the products for the reaction A → 3B if conversion is 60%.

3. If 12 kg of C_7H_{16} is burnt to give 15 kg of CO_2, what is the percentage conversion?

4. For the reaction, $Sb_2S_3 + 3\ Fe \rightarrow 2\ Sb + 3FeS$, if 650 g of stibnite ($Sb_2S_3$) and 200 g of iron turnings (Fe) are heated together to give 200 g of antimony (Sb) metal, what is the limiting reactant? Find the % excess of the excess reactant and the yield of Sb based on feed.

5. Suppose that in a text 22 kg of C_3H_8 is burned with 415 kg of air to produce 44 kg of CO_2 and 14 kg of CO. What was the percentage excess air?

6. One hundred kmol per hour of a mixture (F) of 40 mol% methanol in water at 30°C and 1 atm is to be separated by distillation at the same pressure into a top liquid distillate (D) containing 96 mol% methanol and a bottom liquid product (W) containing 94 mol% water. Find the molar rates of top and bottom products, D and W, respectively.

7. A mixture of 60% H_2 and 40% N_2 is combined in a tank at 800 atm and -70°C. Estimate the specific volume of the mixture (in cm^3/gmol) using Kay's method for generalized equation of state. Given T_c(K): H_2=33 & N_2=126.2 and P_c(atm): H_2=12.8 & N_2=33.5.

8. Moist air at 40°C and 45% relative humidity is heated in a furnace to 85°C. How much heat is added per kg of dry air and what is the final dew point of the air. Given λ_0 = 2502 kJ/kg H_2O.

9. What is the heat absorbed for isothermal reaction, C_4H_{10} (g) → C_2H_4 (g) + C_2H_6 (g); at 298 K and 1 atm pressure. Standard heat of combustion, kJ /mol:
C_4H_{10} (g) = -2873.5; C_2H_4 (g) = -1411.80 ,C_2H_6 (g) = -1561.0

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BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI
Department of Chemical Engineering
First Semester 2023-2024
Comprehensive Examination (Closed Book)
CHE F211: CHEMICAL PROCESS CALCULATIONS

Date: 13.12.2023 **Maximum Marks: 120**

Time: 2 hours **PART – B** **Marks: 84**

Atomic weights:- Na:23, Cl:35.5, O:16, N:14, C:12, H:1, Sb:122, Fe:56, S:32, Ca:40 , Mg:24.

1. (a) (7 Marks) Define/explain the following terms:
   Dulong-Petit's law, Kopp's rule, Trouton's Rule, molal humidity, relative humidity, saturation humidity, absolute humidity.
   (b) (7 Marks) An air-water vapor sample has a dry-bulb temperature of 70ºC and 10% relative humidity at 1 std atm pressure. Determine (analytically): humidity, molal humidity, humid heat, dew point and humid volume. Obtain the wet-bulb temperatue from the humidity chart.

2. (20 Marks)
   Pure CO_2 may be prepared by treating limestone with aqueous sulphuric acid. The limestone used contained anhydrous calcium carbonate ($CaCO_3$) and anhydrous magnesium carbonate ($MgCO_3$) and some inert insoluble materials (I). The acid used contained 15% sulphuric acid (H_2SO_4) by weight. The residue from the process had the following composition by weight: calcium sulphate ($CaSO_4$) 12.00%, magnesium sulphate ($MgSO_4$) 4.00%, sulphuric acid (H_2SO_4) 1.20%, inert (I) 0.50%, carbon dioxide (CO_2) 0.20% (trapped), and water (H_2O) 82.10%. During the process, the mass was warmed, and carbon dioxide and water vapor were removed. The reactions are:

   $$CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + H_2O + CO_2$$
   $$MgCO_3 + H_2SO_4 \rightarrow MgSO_4 + H_2O + CO_2$$

   Calculate
   (a) The composition (in %) of the lime stone used
   (b) The % excess acid used
   (c) The mass of water vaporized and removed per 100 kg of residue
   (d) The mass of carbon dioxide obtained per 100 kg of limestone.

3. (30 Marks) Dry air (only O_2 and N_2) and toluene ($C_6H_5CH_3$) vapor are mixed and fed to a reactor at 197°C and 1 atm. Air is supplied in 120% excess of the toluene fed to the reactor. 23% of toluene reacts to form benzaldehyde (C_6H_5CHO) and 2% reacts with oxygen to form CO_2 and CO. The ratio of CO_2 to CO formed is 7:3. Water vapor is formed in both the reactions:

   $$C_6H_5CH_3 + O_2 \rightarrow C_6H_5CHO + H_2O$$
   $$20\ C_6H_5CH_3 + 159\ O_2 \rightarrow 98\ CO_2 + 42\ CO + 80\ H_2O$$

   The product gases leave the reactor at 205°C and 1 atm. Water is circulated through a jacket surrounding the reactor, entering at 20°C and leaving at 47°C. If 100 kg mole toluene is fed to the reactor and all gaseous materials are behaving as ideal gas, then answer the following questions:

(a) Draw a suitable flow diagram with proper labelling. How many unknowns are here? What are they?
(b) Calculate the volumetric flow (m^3) of the combined feed stream to the reactor.
(c) Calculate the volumetric flow (m^3) of the combined product gases.
(d) Calculate the heat transfer from the reactor (kJ).

Data:

$\Delta\hat{H}_f^o\left(\frac{kJ}{gmol}\right)$: $C_6H_5CH_3$ (g) = 50; C_6H_5CHO (g) = -40; CO_2 = -394; CO = -111; H_2O (g)= -242.

$C_p\left(\frac{J}{gmol.^oC}\right) = a + bT + cT^2 + dT^3$ where T is in ^oC

Compound	a	b $\times 10^2$	c $\times 10^5$	d $\times 10^9$
$C_6H_5CH_3$ (g)	94.18	38.00	-27.86	80.33
C_6H_5CHO (g)	74.06	32.95	-25.20	77.57
O_2 (g)	29.10	1.158	-0.607	80.33
N_2 (g)	29.00	0.2199	0.5723	-2.87
CO_2 (g)	36.11	4.233	-2.88	7.464
CO (g)	28.95	0.411	0.3548	-2.22
H_2O (g)	33.46	0.688	0.76	-3.593

4. (20 *Marks*)
Calculate the theoretical flame temperature (outlet temperature of the adiabatic reactor) for CO gas burned at constant pressure with 150% excess air, when the reactants enter at 100°C and 1 atm. Given $\Delta\hat{H}_f^o\left(\frac{kJ}{gmol}\right)$: CO= -111, CO_2= -394;

$C_{p,m}\left(\frac{kJ}{gmol.^oC}\right)$: CO =0.029, O_2 = 0.031, N_2 =0.030, CO_2 = 0.046.

~ All the Best ~