



INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

End-Autumn Semester Examination 2022-23

Date of Examination: 21/11/2022 Session: (FN/AN) AN Duration: 3 hrs. Full Marks: 50

Subject No.: CH21103 & CH21203

Subject: CHEMICAL PROCESS CALCULATIONS

Department/Center/School: Chemical Engineering

Specific charts, graph paper, log book etc., required: _____

Special Instructions (if any): All questions are compulsory

Assume, any missing data if necessary with justification.

Answer all parts of a question together. Also all questions in a part together.

Graph Papers will be provided in the examination hall.

No queries will be entertained during the examination.

PART A

1. A mixture of 75 mole% propane and 25 mole% hydrogen is burned with 25% excess air. Fractional conversions of 90% of the propane and 85% of the hydrogen are achieved. Out of the reacted propane, 95% reacts to form CO_2 and the balance reacts to form CO . Calculate the molar composition of the stack gas on a dry basis, the mole ratio of water to dry stack gas, and the concentration of CO (in ppm) in the stack gas. (6+2+2)
2. The oxidation of nitric oxide takes place in an isothermal batch reactor.
$$\text{NO} + 1/2 \text{O}_2 \rightleftharpoons \text{NO}_2$$

The reactor is charged with a mixture containing 20.0 volume percent NO and the balance air at an initial pressure of 380 kPa (absolute).

 - a. Assuming ideal gas behaviour, determine the composition of the mixture (component mole fractions) and the final pressure (kPa) if the conversion of NO is 90%. (4+2)
 - b. Suppose the pressure in the reactor eventually equilibrates at 360 kPa. What is the equilibrium percent conversion of NO ? (4)
3. A mixture of CH_4 and C_2H_6 has the average molecular weight 22.4. Find mole % of CH_4 and C_2H_6 in the mixture. (5)

PART B

Specific Instruction Related to Part B

- A1. Please detach the Psychrometric chart from the question paper. Answer all parts of questions 4 on the same chart. The Psychrometric chart must be submitted along with your answer script. Please do all markings on the Psychrometric chart with a Pen and write your roll number there. No marks will be given if the markings are not found on the chart.
 - A2. Use the steam table provided for solving both parts of Problem 5. Please mark the data that you have used for solving the questions.
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4. (a) Process air for a specific plant has Humid Volume of 1.20 m^3/Kg dry air and Relative Humidity 10%. Find out all other information that you can get from the Psychrometric Chart. (3 marks)
(b) If 600 Kg of the above mentioned Humid air is cooled to 40 $^\circ\text{C}$ (T_{DB}), how much water will condense out? Draw the cooling step on the Psychrometric Chart. (3 marks)
(c) How much water needs to be added to adiabatically cool Humid air from $T_{\text{DB}} = 90^\circ\text{C}$ and specific humidity 0.018 to 80% saturation. What is the initial & final wet bulb temperature of the system? (2 marks)
(d) A tank is half filled with water at room temperature (40 $^\circ\text{C}$). Then the tank is closed, and kept inside an insulated container. What will be the eventual temperature of water and air trapped inside the tank after significant duration of time, which is enough to acquire thermal equilibrium, if the Atmospheric Relative Humidity was 25%. Justify your answer. (2 + 3 = 5 marks)

2291

2406

0.7 + 7246 B

5. (a) Superheated steam in a vessel of volume 2 m^3 is at an initial temperature of 550°C and pressure 500 KPa . The temperature and the pressure of the Vessel are simultaneously reduced in such a way that 100% saturated steam (vapour) is obtained. Find out the final pressure and temperature. Also find out the total enthalpy change associated with the process. Use the attached steam table as necessary. (2+1=3 marks)
- (b) 9.805 gm of water is initially sealed in a capsule. The capsule is subsequently broken inside a chamber which has volume 0.075 m^3 . What temperature and pressure should be maintained in the chamber so that saturated vapour is obtained? (3 marks)

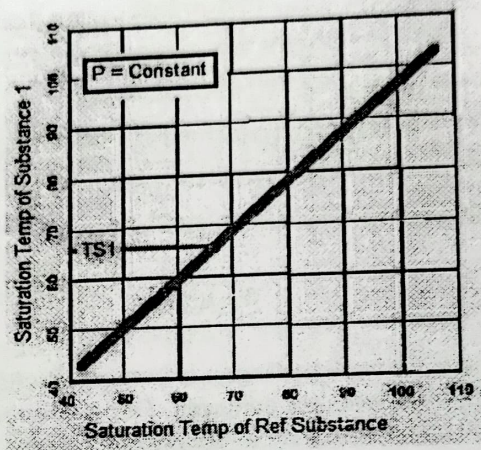


Figure 1

6. (a) You are provided a graph of the type shown in figure 1. How this graph can be useful in obtaining the Latent Heat of Vaporization of "substance 1" at Temperature $TS1$ as marked on the graph? (3 marks)
- (b) What is the formation reaction of CO(g) ? Please comment on the nature of this formation reaction. How can you circumvent this problem and calculate the Standard Heat of Reaction of CO(g) (please find the value)? [Given Standard Heat of formation of $\text{CO}_2 \text{ (g)}$ is $-393.51 \text{ KJ/gmole C}$ and standard Heat of Oxidation of CO (g) is $-282.99 \text{ KJ/gmole CO}$]. (0.5+0.5+2 = 3 marks)

Please do NOT forget to detach the Psychrometric Chart from the Question Paper and attach it to your answer script.

$$V = \frac{RT}{P}$$