# INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR
## End-Autumn Semester 2018-19

Date of Examination: 20/11/2018 Session (FN/AN) AN Duration 3 hrs Full Marks: 50
Subject No.: CH21103 Subject: CHEMICAL PROCESS CALCULATIONS
Department/~~Center/School~~: CHEMICAL ENGINEERING
Specific charts, graph paper, log book etc., required: NO.
Special Instructions (if any):
Answer all questions. Assume, if necessary, clearly stating them. No queries will be entertained during the examination.

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**PART A (25 Marks)**

1. **[8 marks]** 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. **(5+1+2)**

2. **[7 marks]** The oxidation of nitric oxide takes place in an isothermal batch reactor.

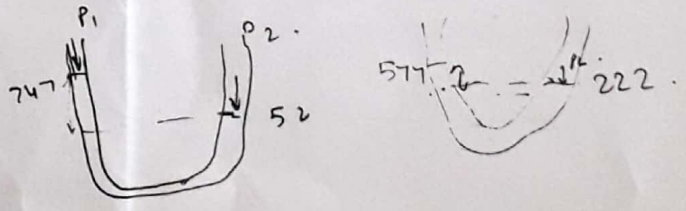
$$NO + 1/2\,O_2 \rightleftharpoons NO_2$$

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%. **(3+1)**
b. Suppose the pressure in the reactor eventually equilibrates at 360 kPa. What is the equilibrium percent conversion of NO? **(3)**

3. **[10 marks]** Pure chlorobenzene is contained in a flask attached to an open-end mercury manometer. When the flask contents are at 58.3 °C, the height of the mercury in the arm of the manometer connected to the flask is 747 mm and that in the arm open to the atmosphere is 52 mm. At 110 °C, the mercury level is 577 mm in the arm connected to the flask and 222 mm in the other arm. Atmospheric pressure is 755 mm Hg.

a. Using the Clausius–Clapeyron equation to estimate the vapor pressure of chlorobenzene at 130 °C. **(3)**
b. Now consider air saturated with chlorobenzene at 130 °C and 101.3 kPa is cooled to 58.3 °C at constant pressure. Estimate the percentage of the chlorobenzene originally in the vapor that condenses. **(5)**
c. Summarize the assumptions you made in doing the calculation of part (b). **(2)**




$P_A - P_c = 695$
$P_A - P_c' = 355$
$P_c' - P_c = 340$



4-2-1-1
4+1-2-1
4+1-1-1

**PART – B (25 Marks)**

***Specific Instruction Related to Part B***

**B1. Please detach the Psychrometric chart from the question paper. Answer questions 4 and 5 on the same chart. Answers must be written on the answer script (NOT on the chart).**

**B2. 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.**

4. **[10 marks]**

(a) Given Standard Heat of formation of $CO_2$ (g) is– 393.51 KJ/gmole C and Heat of Oxidation of CO (g) is – 282.99 KJ/gmole CO. Justify how you can find the standard heat of formation of CO (g). Find it. **(2)**

(b) Find out the Heat of Formation of **Na+** ion. Given $\Delta H_f^\circ$ of water is – 68.317 Kcal and Heat of Neutralization between a strong acid and a strong base is – 13.36 Kcal. State all assumptions clearly. **(2)**

(c) What is double decomposition of salt? **(1)**

(d) How is **percent saturation** related to **Relative Humidity**? Show it. **(2)**

(e) "Polar Liquids have higher vapour pressure" - is the statement true or false? Justify. **(2)**

(f) With suitable figure give example of a system that exhibits both flow work and Mechanical work. **(1)**

5. **[5 marks]**

a) Draw and mark a typical solid – liquid – vapour phase diagram (Axes are Temperature and Pressure). What will be unique about the solid – liquid boundary if it represents water. (3)

**(b)** Write down the **Clapeyron Equation**. From it, state the assumptions and derive the **Clausius Clapeyron Equation**. (2)

6. **[5 marks]**

a) Process air for a specific plant has **Dry Bulb Temperature** of 82°C and **Specific Humidity** of 0.045 (Kg Water/ Kg Bone dry air). What are the **Wet Bulb Temperature, Relative Humidity,** Dew point, Specific Volume and Specific enthalpy of this air? Please care to write the answers clearly on your answer script. **(3)**

b) If 1000 Kg of this Humid air (initial condition stated above) is cooled to 32 °C ($T_{DB}$), how much water will condense out? Draw the cooling step on the Psychrometric Chart. **(2)**

7. **[5 marks]**

500 Kg/ hr of air with **4% RH** enters a two stage Humidifier at 98°C. It is first cooled ***adiabatically*** to 80% saturation. Then water is sprinkled into the air stream so that it can isothermally attain complete saturation. Find out

(a) Mark the entire process on the chart. (1)

(b) **Dry Bulb Temperature, Wet Bulb Temperature** and **Specific Humidity** of outlet air after the adiabatic cooling step. (2)

(c) **Final moisture content of air after the second stage.** **(1)**

(d) Hourly rate of water uptake during the entire process. (1)