Dr. Tapas Palai 12/12/2022

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Roll No._____

National Institute of Technology Hamirpur
Department of Chemical Engineering
Subject: CH 213 – Chemical Process Calculation
End Semester Examination, December 2022
Branch: Chemical Engineering
Class: B. Tech. | **Semester:** III | **Full Marks:** 50 | **Time:** 3 hours

Instructions:

- Answer all the questions. All parts (a, b, c) of any question must be answered in same place.
- Calculator is allowed but exchange the same with others is not allowed.
- **Psychrometric chart provided with the question paper is to be submitted with answer sheet.**
- Missing data may suitably be assumed, if any.

1. a) An airplane is normally fueled with 20000 gallons of jet fuel before take-off. The plane consumes 4000 gallons per hour in flight. One day the plane is mistakenly filled with 20000 kg of fuel. How long will the plane fly before running out of fuel? (3)
   Given: The specific gravity of jet fuel is 0.95.
   1 gallon = 3.785 L.

   b) Trace components can be used to measure flow rates in pipelines, process equipment, and rivers that might otherwise be quite difficult to measure. Suppose that the water analysis in a flowing creek shows 180 ppm of Na_2SO_4. If 10 kg of Na_2SO_4 is added to the stream uniformly over a 1 h period and the analysis of downstream (assume complete mixing) indicates 330 ppm of Na_2SO_4, calculate volumetric flow rate of water in m^3/h. Assume no Na_2SO_4 is lost in the streambed. (7)
   Given: density of water is 1000 kg/m^3.

2. Sodium hydroxide is usually produced from aqueous solution of common salt (NaCl) by electrolysis. The feed to the electrolysis unit is 30% NaCl. The essential elements of the system are shown in the Fig. 1 (compositions are in mass%). (10)
   a) Write down the balanced reaction occurring the electrolysis unit.
   b) What is the molar conversion of salt to NaOH?
   c) How much chlorine gas is produced per kg of product?
   d) Calculate the amount of water that must be evaporated in the evaporator?

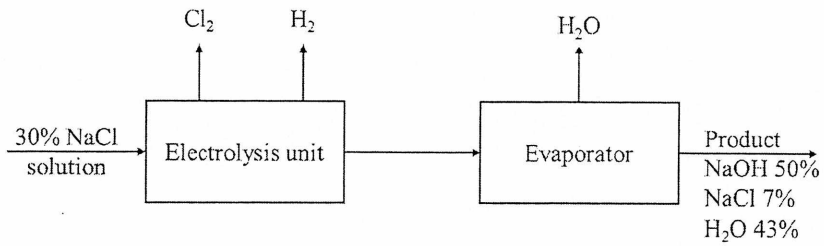

Fig. 1

3. a) On a particular day at Hamirpur, the following data were recorded: Pressure = 100 kPa, Dry bulb temperature = 35°C, Dew point = 21°C. Estimate: (4)
   i) Absolute and relative humidity
   ii) Wet-bulb temperature
   iii) Enthalpy of the air.

   b) Calculate the enthalpy change (in kJ/gmol) for 1 kg of water from – 30°C to 130°C at 1 atm. pressure. (6)

Given:

Latent heat of phase transition

ΔH_{fusion} (at 0°C) = 6.01 kJ/gmol

$\Delta H_{vaporization}$ (at 100°C) = 40.65 kJ/gmol

C_p for water: $C_p = a + bT + cT^2$

C_p for water (J/gmol. °C)	a	b × 10^2	c × 10^5
Solid	23.70	0.00	0.00
Liquid	18.30	47.21	−133.88
Vapour	33.46	0.69	0.70

4. a) A mixture of CH_4 and C_2H_6 has the average molecular weight 22.4. Find the composition of the mixture in mole%. (4)

   b) Steam flowing at a rate of 10 kg/h enters a steam turbine at a velocity of 50 m/s and leaves at a point 5 m below the inlet at a velocity of 300 m/s. The heat loss from the turbine is estimated to be 10 kW, and the turbine delivers shaft work at a rate of 70 kW. Calculate the change in internal energy during the process. (6)

5. Methane and oxygen at 25°C are fed to a continuous reactor in stoichiometric amounts according to the following reaction to produce formaldehyde: (10)

$$CH_4(g) + O_2(g) \rightarrow HCHO(g) + H_2O(g)$$

In a side reaction, methane is oxidized to carbon dioxide and water:

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

The product gases emerge at 400°C, and the effluent gas contains 0.15 gmol/s of CO_2. There is no remaining O_2 found in the effluent gas-stream.

a) From the degree of freedom analysis, identify the nature of the problem.

b) Determine the amount of heat removed from the reactor per mole of CH_4 fed to the reactor.

c) Calculate the outlet composition.

Data:

Average C_p values:

O_2 = 31.2 J/gmol.°C

H_2O = 35.3 J/gmole.°C

HCHO = 43.2 J/gmole.°C

CH_4 = 45.9 J/gmole.°C

CO_2 = 43.6 J/gmole.°C

Standard heat of formation:

$\Delta H_f^0(CH_4, 25°C, 1\ atm) = -74.85$ kJ/gmol

$\Delta H_f^0(HCHO, 25°C, 1\ atm) = -115.9$ kJ/gmol

$\Delta H_f^0(H_2O, 25°C, 1\ atm) = -241.83$ kJ/gmol

$\Delta H_f^0(CO_2, 25°C, 1\ atm) = -393.5$ kJ/gmol

---------- *All the best* ----------