NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF INDUSTRIAL TECHNOLOGY
BACHELOR OF ENGINEERING (HONS) DEGREE
Part One Examination February 2010

TCE1101 Chemical Engineering Calculations

Duration of Examination 3 Hours

Instructions to Candidates:

1. Answer ALL FIVE questions.
2. Each question carries equal marks.
3. Show all your steps clearly in your calculation.
4. Start the answers for each question on a new page.

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1. **a)** Phosphoric acid is a colorless deliquescent acid used in the manufacture of fertilizers and as a flavoring agent in drinks. For a given 10 wt % phosphoric acid solution of specific gravity 1.10 determine:
a. the mol fraction composition of this mixture.
b. the volume (in US gallons) of this solution which would contain 1 g mol H_3PO_4.
(MW H_3PO_4 = 97.97) **(8 marks)**

b) A U-tube manometer is used to determine the pressure drop across an orifice meter. The liquid flowing in the pipe line is a sulfuric acid solution having a specific gravity (60°/60°) of 1.250. The manometer liquid is mercury, with a specific gravity (60°/60°) of 13.56. The manometer reading is 5.35 inches, and all parts of the system are at a temperature of 60°F.
What is the pressure drop across the orifice meter in psi. **(12 marks)**

2. $TiCl_4$ can be formed by reacting titanium dioxide (TiO_2) with hydrochloric acid. TiO_2 is available as an ore containing 78 % TiO_2 and 22 % inerts. The HCl is available as 45 wt% solution (the balance is water). The per pass conversion of TiO_2 is 75 %. The HCl is fed into the reactor in 20 % excess based on the reaction. Pure unreacted TiO_2 is recycled back to mix with the TiO_2 feed.

$$TiO_2 + 4\ HCl \rightarrow TiCl_4 + 2H_2O$$

For 1 kg of $TiCl_4$ produced, determine:

a) the kg of TiO_2 ore fed.
b) the kg of 45 wt % HCl solution fed.
c) the ratio of recycle stream to fresh TiO_2 ore (in kg).

(MW : TiO_2 79.9; HCl 36.47; $TiCl_4$ 189.7) **(20 marks)**

3. **a)** A gas analyzes 60% methane and 40% ethylene by volume. It is desired to store 12.3 kg of this gas mixture in a cylinder having a capacity of $5{\cdot}14 \times 10^{-2}\ m^3$ at a maximum temperature of 45°C. Calculate the pressure inside the cylinder by:

(i) assuming that the mixture obeys the ideal gas laws;
(ii) using the compressibility factor determined by the pseudo critical point method.
(15 marks)

b) A cylinder $0.150 m^3$ in volume containing 22.7 kg of propane C_3H_8 stands in the sun. A gauge pressure shows that the pressure is 4790 kPa gauge. What is the temperature of the propane in the cylinder. Use van der Waal's equation of state.

Take: $a = 9.24\times10^6 atm\left(\frac{cm^3}{gmol}\right)^2$, $b = 90.7\left(\frac{cm^3}{gmol}\right)$ **(5 marks)**

4. **a)** A steel tank having a capacity of 25 m^3 holds carbon dioxide at 30°C and 1.6 atm. Calculate the weight, in grams, of the carbon dioxide. **(7 marks)**

b) A stream of hot water at 150 °F flowing at a rate of 50 US gal/min is to be produced by mixing water at 60 °F and steam at 30 psia and 280 °F in a suitable mixer. What are the required flow rates of steam and cold water. Assume Q = 0.

Take: Steam 30 psia, 280° F, $\Delta\hat{H} = 1179 Btu/lb$
Water 150°F $\Delta\hat{H} = 117.87 Btu/lb$, water 60°F $\Delta\hat{H} = 28.07 Btu/lb$ **(13 marks)**

5. Argon gas in an insulated plasma deposition chamber with a volume of 2 L is to be heated by an electric resistance heater. Initially, the gas, which can be treated as an ideal gas, is at 1.5 Pa and 300 K. The 1000-ohm heater draws current at 40V for 5 minutes (i.e., 480 J of work is done on the system by its surroundings). What is the final gas temperature and pressure in the chamber? The mass of the heater is 12 g and its heat capacity is 0.35 J/gK. Assume that the heat transfer through the walls of the chamber from the gas at this low pressure and in the short time period can be considered negligible.

Take : $C_{V,ideal\ gas} = 3/2R$, $C_V = C_P - R$, $C_P = 5/2R$ **(20 marks)**