

NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

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

TCE1101 Chemical Engineering Calculations

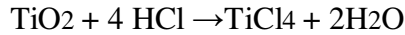
Duration of Examination 3 Hours

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.
-

- 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 H₃PO₄.
(MW H₃PO₄ = 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.



For 1 kg of TiCl_4 produced, determine:

- the kg of TiO_2 ore fed.
- the kg of 45 wt % HCl solution fed.
- 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 $5 \cdot 14 \times 10^{-2} \text{ m}^3$ at a maximum temperature of 45°C . Calculate the pressure inside the cylinder by:

- assuming that the mixture obeys the ideal gas laws;
- 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: $a = 9.24 \times 10^6 \text{ atm} \left(\frac{\text{cm}^3}{\text{gmol}} \right)^2$, $b = 90.7 \left(\frac{\text{cm}^3}{\text{gmol}} \right)$ **(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 , $\Delta\hat{H} = 1179 \text{ Btu/lb}$

Water 150°F $\Delta\hat{H} = 117.87 \text{ Btu/lb}$, water 60°F $\Delta\hat{H} = 28.07 \text{ Btu/lb}$ **(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)

COMPRESSIBILITY CHARTS ...

