NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF INDUSTRIAL TECHNOLOGY
BACHELOR OF ENGINEERING (HONS) DEGREE
Part One Examination April 2009

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) Gypsum (plaster of Paris : $CaSO_4 . 2H_2O$) is produced by the reaction of calcium carbonate and sulfuric acid. A certain lime stone analyzes: $CaCO_3$ 96.89 %; $MgCO_3$ 1.41 %; inerts 1.70 %. For 5 metric tons of limestone reacted completely, determine:
a) kg of anhydrous gypsum ($CaSO_4$) produced.
b) kg of sulfuric acid solution (98 wt%) required.
c) kg of carbon dioxide produced.
(MW : $CaCO_3$ 100.1; $MgCO_3$ 84.32; H_2SO_4 98; $CaSO_4$ 136; $MgSO_4$ 120; H_2O 18; CO_2 44) **(12 marks)**

b) Calcium carbonate is a naturally occuring white solid used in the manufacture of lime and cement. Calculate the number of lb mols of calcium carbonate in:
a. 50 g mol of $CaCO_3$.
b. 150 kg of $CaCO_3$.
c. 100 lb of $CaCO_3$. **(8 marks)**

2. a) Convert the ideal gas constant : R = 1.987 Cal/(gmol)(K) to Btu/(lb mol)(°R) **(4 marks)**

b) Find the value for the universal gas constant R, to match the following combinations of units: for 1 g-mol of ideal gas when the pressure is in atm and the volume is in cm^3 and temperature in K. At STP conditions and P = 1 atm V = 22.415 m^3/kgmol. **(6 marks)**

c) Gas at 15 °C and 105 kPa is flowing through an irregular duct. To determine the rate of flow of gas, CO_2 from the tank is passed into the gas stream. The gas analyzed 1.2% CO_2 by volume before and 3.4% CO_2 by volume after the addition. As the CO_2 that was injected left the tank, it was passed through a rotameter, and found to flow at a rate of 0.0917 m^3/min at 4 °C and 131 kPa. What was the rate of flow of the entering gas in the duct in m^3/min? **(10 marks)**

3. a) A mixture of gases has the following composition by mass:

O_2	20%
CO	4.0%
CO_2	13%
N_2	63%

What is the molar composition? **(10 marks**

b) A 0.6 molar aqueous solution of sulphuric acid flows into a process unit at a rate of 1.5 m^3/min. The specific gravity of the solution is 1.03

i. Calculate the mass concentration of H_2SO_4 in kg/m^3.
ii. The mass flow rate of solution in kg/s
iii. The mass flow rate of H_2SO_4 in kg/s
iv. The mass fraction of H_2SO_4
v. The molar flow rate of H_2SO_4 in kgmoles/s

(10 marks)

4. **a)** A 100-hp engine is used to pump ground water into an irrigation channel. Calculate the rate at which the pump is doing work in

(a) Btu/hr
(b) J/s
(c) kW. **(3 marks)**

b) A stream of hot water at 150 °F flowing at a rate of 50 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.

(3 marks)

c) Seven pounds of N_2 at 120°F are stored in a cylinder having a volume of 0.75 ft^3. Calculate the pressure in atmospheres in the cylinder

(a) assuming N2 to be an ideal gas
(b) assuming the pressure of N2 can be predicted by van der Waal's equation
(c) using the compressibility factor method
(d) using the Redlich-Kwong equation of state. **(14 marks)**

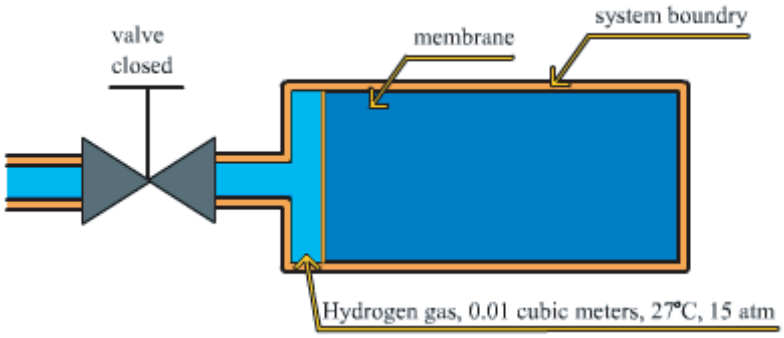
Take: $a = 1.347 \times 10^6 \left(\frac{cm^3}{gmol} \right)^2$ $b = 38.6 \left(\frac{cm^3}{gmol} \right)$ $T_C = 126.2K$ $P_C = 33.5atm$

5. **a)** Crude oil is pumped at a rate of 15.0 kg/s from a well 220m deep to a storage tank 20m above the ground level. Calculate the rate at which potential energy increases (J/s)

(5 marks)

b)) A shock tunnel uses hydrogen as its driving gas. The hydrogen at high pressure is restrained by a metallic membrane. When the membrane is ruptured, the hydrogen bursts into the evacuated section and a researcher can study high intensity shock waves. Given the data on the schematic diagram of the tunnel, determine the final temperature and

pressure of the gas. The process occurs quickly, before any appreciable heat transfer can occur between the gas and the walls of the chamber. **(15 marks)**



Basis: 0.01 m^3 of H_2 at 27°C, 15 atm.

Take: $T_C = 33.3K \quad P_C = 12.8atm$