NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF INDUSTRIAL TECHNOLOGY
BACHELOR OF ENGINEERING (HONS) DEGREE
Part One Examination January 2011

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)** Air is flowing through a duct under a draft of 4.0 cm H_2O. The barometer indicates that the atmospheric pressure is 730mm Hg. What is the absolute pressure of the air in inches of mercury? **(6 marks)**

b) Fuels other than gasoline are being eyed for motor vehicles because they generate lower levels of pollutants than does gasoline. Compressed propane is one such proposed fuel. Suppose that in a test 20 kg of C_3H_8 is burned with 400 kg of air to produce 44 kg of CO_2 and 12 kg of CO. What was the percent excess air? **(7 marks)**

c) The vapor pressure of benzene is measured at two temperatures, with the following results:

$T_1 = 7.6^\circ C$ $\quad\quad$ $p_1^* = 40 mmHg$

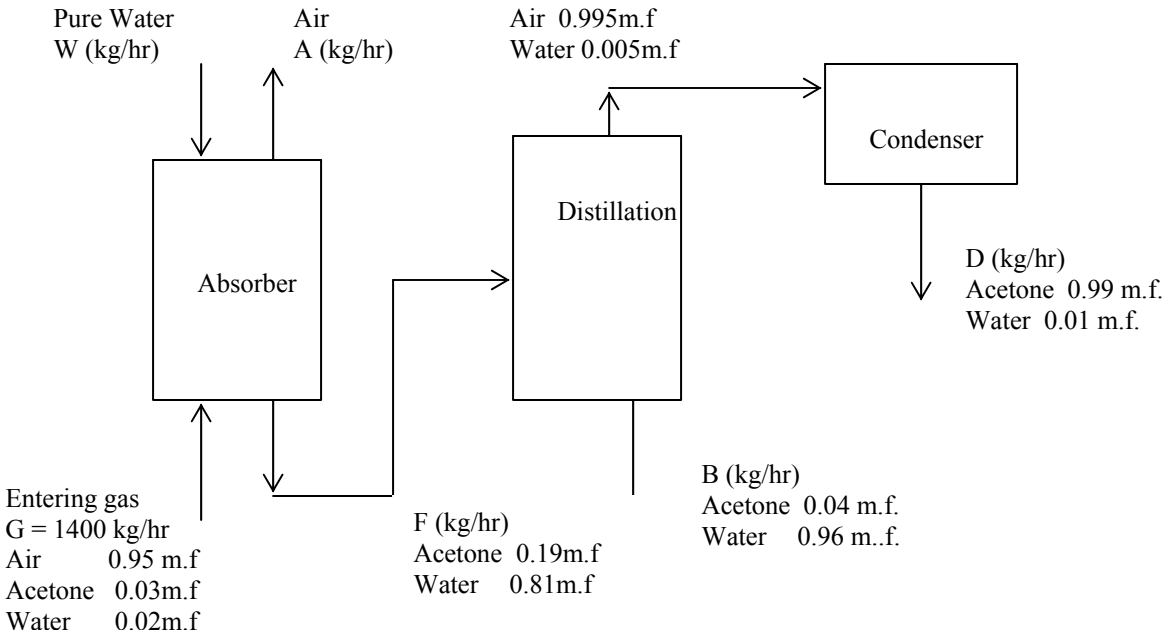
$T_2 = 15.4^\circ C$ $\quad\quad$ $p_2^* = 60 mmHg$

Calculate the latent heat of vaporization and the parameter B, in the Clausius-Clapeyron equation and then estimate $p^* at\ 42.2^\circ C$ using this equation. **(7 marks)**

2. A contact sulfuric acid plant produces 98.0 % sulfuric acid, by absorbing SO_3 into a 97.3% sulfuric acid solution. A gas containing 8.00 % SO_3 (remainder inerts) enters the SO_3 absorption tower at the rate of 28 lb mol per hour. 98.5 % of the SO_3 is absorbed in this tower. 97.3 % sulfuric acid is introduced into the top of the tower and 95.9 % sulfuric acid from another part of the process is used as make - up acid. The flow sheet is given in the figure with all of the known data on it. Calculate the

a. Tons/day of 95.9 % H_2SO_4 make-up acid solution required. **(7 marks)**
b. Tons/day of 97.3 % H_2SO_4 solution introduced into the top of the tower. **(7 marks)**
c. Tons/day of 98 % H_2SO_4 solution produced. **(6 marks)**

3. Acetone is used in the manufacture of many chemicals and also as a solvent. You are asked to design an acetone recovery system having the flowsheet illustrated below. All the concentrations of gases and liquids are specified in weight % (mass %). Calculate A, F, W, B and D per hour given G = 1400 kg/hr. **(20 marks)**



4. **a)** A gaseous mixture has the following composition in mole percent: methane (CH_4) 20, ethylene (C_2H_4) 30, nitrogen (N_2) 50 at 90atm pressure and 100°C. Compare the volume per mole as computed by methods of:

(i) ideal gas law **(5 marks)**
(ii) the pseudo–reduced technique, or Kay's method. **(10 marks)**

b) A cylinder 0.150m^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)**

5. **a)** What is the change in internal energy when 10 kgmol of air is cooled from 60 to 30°C in a constant volume process? ($C_{v,air} = 2.1\times10^4\ J/(kgmol^\circ C)$) **(5 marks)**

b) A gas is contained in a cylinder fitted with a movable piston. The initial gas temperature is 25°C. The cylinder is placed in boiling water with the piston held in a fixed position. Heat in the amount of 2 kcal is absorbed by the gas, which equilibrates at 100°C (and a higher pressure). The piston is then released, and the

gas does 100 J of work in moving the piston to its new equilibrium position. The final gas temperature is 100^{o}C.

Write an energy balance equation for each of the two stages of this process, and in each case solve for the unknown energy term in the equation. In solving this problems, consider the gas in the cylinder to be the system, neglect the change in potential energy of the gas as the piston moves vertically, and assume the gas behaves ideally. Express all energies in joules. **(15 marks)**