UNIVERSITY OF TORONTO
Faculty of Applied Science and Engineering
Final Examination, April 1995
First Year - Programs
CHE112S-CHEMISTRY
Examiners: B. Saville and Staff

DATA: R = 8.314 kPa L mol^{-1} K^{-1} or Pa m3 mol^{-1} K^{-1} or J mol^{-1} K^{-1}

$$\frac{RT}{nF} \ln Q = \frac{0.059}{n} \log Q \text{ at } 25°C$$

F =96485 Coul/mol e^-

1. (a) Sulfur dioxide (SO_2) occurs in polluted air. [i] What are the principal sources of atmospheric SO_2? [ii] What harmful effects does SO_2 in the atmosphere cause?

(b) The exhaust gas from a combustion process contains some SO_2. A sample of this exhaust gas, having a volume of 10.00 L measured at 99.5 kPa and at 22.8°C, is passed through an aqueous solution of volume 185 mL, which absorbs all the SO_2 from the sample. A standard solution of potassium permanganate ($KmnO_4$) is made by dissolving 1.250 g $KmnO_4$ in water to make 1.000 L of solution. The solution containing the SO_2 is then titrated with the standard $KMnO_4$ solution. 18.26 mL of the $KMnO_4$ solution are needed to oxidize all the SO_2, according to the equation

$$5\ SO_2 + 2\ MnO_4^- + 2H_2O = 5SO_4^{2-} + 2Mn^{2+} + 4H^+.$$

How many parts per million of SO_2 (by volume) did the exhaust gas contain?

Atomic masses In g/mol: H 1.008, O 16.00, S 32.07, K 39.10, Mn 54.94

2. The composition of dry air In mol % is 78.04% N_2, 20.99% O_2, 0.937% argon and other noble gases, and 0.033% CO_2. A system for separation and purification of gases takes In 5.000 m^3 of dry air, measured at 103.0 kPa and at 18.0°C. It recovers 99.99% of the nitrogen as pure N_2 and 99.98% of the oxygen as pure Os. The remainder of the air is discharged as byproduct gas at 97.0 kPa and at 40.0°C. [i] What is the volume of this byproduct gas? [ii] How many moles of argon and other noble gases does it contain? [iii] What Is the partial pressure of CO_2 in it?

3. It is desired to manufacture MgO by heating and decomposing one of two magnesium salts, $MgCO_3$ to release CO_2, or $Mg(OH)_2$ to release H_2O. Given the thermodynamic data below answer the following:

(a) Write the stoichiometric equations and calculate ΔH (or each decomposition process at 25°C (kJ/mol salt). Are they endo or exothermic?

(b) Will any of these reactions proceed spontaneously at 25°C under standard conditions?

(c) At what approximate temperature (°C) will each reaction just proceed spontaneously under standard conditions?

(d) In your opinion, which is the preferred process? Why?

Data at 25°C	$\Delta H_f°$ (kJ/mol)	S°(J/mol/K)
$MgCO_{3\,(s)}$	-1113	66
$Mg(OH)_{2\,(s)}$	-925	61
$MgO_{\,(s)}$	-602	27
$CO_{2\,(g)}$	-394	214
$H_2O_{\,(g)}$	-242	189

4. A chemical of formula C_8H_{10} is used as a jet fuel yielding CO_2, and H_2O gases as combustion products. Assuming that the pressure is constant at 101.3 kPa and that the gases are ideal:

(a) What is the stoichiometric equation for reaction with oxygen and, what is the heat of combustion (kJ/mol) of the fuel from both its liquid and vapour states at 25°C?

(b) How much heat is required (kJ) to convert 1 mol of fuel from liquid state at 10°C to vapour state at 225°C?

(c) What are Δ(PV) and Δ(internal energy) (I.e., ΔE or All] (kJ/mol) for combustion of the vapour in (a) above?

Data at 25°C	$\Delta H_f°$ kJ/mol	C_f J/mol K
C_8H_{10} (g)	19	129
C_8H_{10} (l)	-24	184
CO_2 (g)	-394	34
H_2O (g)	-242	36
O_2 (g)	-	29

5. (a) Calculate the pH of a 0.15M solution of NH_4Cl in water.

(b) How many mg of solid NaOH must be added to 100.0 mL of the solution in part(a) to raise its pH to 9.50?

Given: K_b of $NH_3 = 1.8 \times 10^{-5}$; $K_w = 1.0 \times 10^{-4}$; MW of NaOH = 40.0 g/mol.

6. A quantity of phosgene gas ($COCl_2$) was placed in an evacuated, sealed container and heated to 724 K until the following reaction had reached equilibrium:

$COCl_2\ (g) \Longleftrightarrow CO(g) + Cl_2(g)$

If the total pressure at equilibrium was one bar, and the density of the gas was 1.16 g/L at equilibrium, determine:

(a) the equilibrium constant for the reaction, assuming Ideal gas behavior

(b) the percentage dissociation of phosgene under these conditions

(c) if the above system, at equilibrium, is compressed to a pressure of 2 bar at a constant temperature, and allowed to re-equilibrate, will the gas density be greater than or less than 2.32 g/L (i.e. twice the original value)? Explain your answer.

Data: Atomic masses in g/mol: C 12.01; O 16.00; Cl 35.45

7. Given an electrochemical cell consisting of Cr/Cr^{3+} and Zn/Zn^{2+} half cells where $E° (Cr^{3+}/Cr) = -0.744V$ and $e° (Zn^{2+}/Zn) = -0.762V$

(a) Assuming standard conditions,

(i) write the equations describing the reactions at the anode and at the cathode (clearly label which one is for the anode and which for the cathode in this galvanic cell). State the direction of current flow in the external circuit.

(ii) write the equation describing the whole cell

(b) calculate the cell emf at 25°C for

$[Zn^{2+}] = 0.0090$ M, and $[Cr^{3+}] = 0.0070$ M.

8. a) A solution of glucose in water freezes at -1°C. What is the vapor pressure of this solution at 100°C? The molal freezing point constant for water, K_f, is 1.85°C/molal. Assume that there is 1 kg of solvent present.

b) What mass of NaCl must be added to 1 kg of water to produce an aqueous solution which freezes at -1°C?

Data: MW glucose = 180g/mol
MW NaCl = 58 g/mol