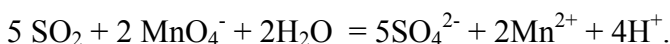


UNIVERSITY OF TORONTO  
 Faculty of Applied Science and Engineering  
 Final Examination, April 1995  
 First Year - Programs  
 CHE112S-CHEMISTRY  
 Examiners: B. Saville and Staff

DATA:  $R = 8.314 \text{ kPa L mol}^{-1} \text{ K}^{-1}$  or  $\text{Pa m}^3 \text{ mol}^{-1} \text{ K}^{-1}$  or  $\text{J mol}^{-1} \text{ K}^{-1}$   
 $\frac{RT}{nF} \ln Q = \frac{0.059}{n} \log Q$  at  $25^\circ\text{C}$   
 $F = 96485 \text{ Coul/mol e}^-$

1. (a) Sulfur dioxide ( $\text{SO}_2$ ) occurs in polluted air. [i] What are the principal sources of atmospheric  $\text{SO}_2$ ? [ii] What harmful effects does  $\text{SO}_2$  in the atmosphere cause?

(b) The exhaust gas from a combustion process contains some  $\text{SO}_2$ . A sample of this exhaust gas, having a volume of 10.00 L measured at 99.5 kPa and at  $22.8^\circ\text{C}$ , is passed through an aqueous solution of volume 185 mL, which absorbs all the  $\text{SO}_2$  from the sample. A standard solution of potassium permanganate ( $\text{KMnO}_4$ ) is made by dissolving 1.250 g  $\text{KMnO}_4$  in water to make 1.000 L of solution. The solution containing the  $\text{SO}_2$  is then titrated with the standard  $\text{KMnO}_4$  solution. 18.26 mL of the  $\text{KMnO}_4$  solution are needed to oxidize all the  $\text{SO}_2$ , according to the equation



How many parts per million of  $\text{SO}_2$  (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%  $\text{N}_2$ , 20.99%  $\text{O}_2$ , 0.937% argon and other noble gases, and 0.033%  $\text{CO}_2$ . A system for separation and purification of gases takes In  $5.000 \text{ m}^3$  of dry air, measured at 103.0 kPa and at  $18.0^\circ\text{C}$ . It recovers 99.99% of the nitrogen as pure  $\text{N}_2$  and 99.98% of the oxygen as pure  $\text{O}_2$ . The remainder of the air is discharged as byproduct gas at 97.0 kPa and at  $40.0^\circ\text{C}$ . [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  $\text{CO}_2$  in it?

3. It is desired to manufacture MgO by heating and decomposing one of two magnesium salts,  $\text{MgCO}_3$  to release  $\text{CO}_2$ , or  $\text{Mg(OH)}_2$  to release  $\text{H}_2\text{O}$ .

Given the thermodynamic data below answer the following:

(a) Write the stoichiometric equations and calculate  $\Delta H$  (or each decomposition process at  $25^\circ\text{C}$  (kJ/mol salt). Are they endo or exothermic?

(b) Will any of these reactions proceed spontaneously at  $25^\circ\text{C}$  under standard conditions?

(c) At what approximate temperature ( $^\circ\text{C}$ ) will each reaction just proceed spontaneously under standard conditions?

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

Data at $25^\circ\text{C}$	$\Delta H_f^\circ$ (kJ/mol)	$S^\circ$ (J/mol/K)
$\text{MgCO}_3$ (s)	-1113	66
$\text{Mg(OH)}_2$ (s)	-925	61
$\text{MgO}$ (s)	-602	27
$\text{CO}_2$ (g)	-394	214
$\text{H}_2\text{O}$ (g)	-242	189

4. A chemical of formula  $\text{C}_8\text{H}_{10}$  is used as a jet fuel yielding  $\text{CO}_2$ , and  $\text{H}_2\text{O}$  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  $25^\circ\text{C}$ ?

(b) How much heat is required (kJ) to convert 1 mol of fuel from liquid state at  $10^\circ\text{C}$  to vapour state at  $225^\circ\text{C}$ ?

(c) What are  $\Delta(PV)$  and  $\Delta(\text{internal energy})$  (I.e.,  $\Delta E$  or  $\Delta U$ ) (kJ/mol) for combustion of the vapour in (a) above?

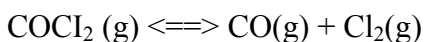
Data at $25^\circ\text{C}$	$\Delta H_f^\circ$ kJ/mol	$C_f$ J/mol K
$\text{C}_8\text{H}_{10}$ (g)	19	129
$\text{C}_8\text{H}_{10}$ (l)	-24	184
$\text{CO}_2$ (g)	-394	34
$\text{H}_2\text{O}$ (g)	-242	36
$\text{O}_2$ (g)	-	29

5. (a) Calculate the pH of a 0.15M solution of  $\text{NH}_4\text{Cl}$  in water.

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

Given:  $K_b$  of  $\text{NH}_3 = 1.8 \times 10^{-5}$ ;  $K_w = 1.0 \times 10^{-14}$ ; MW of  $\text{NaOH} = 40.0$  g/mol.

6. A quantity of phosgene gas ( $\text{COCl}_2$ ) was placed in an evacuated, sealed container and heated to 724 K until the following reaction had reached equilibrium:



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  $\text{Cr}/\text{Cr}^{3+}$  and  $\text{Zn}/\text{Zn}^{2+}$  half cells where  $E^\circ(\text{Cr}^{3+}/\text{Cr}) = -0.744\text{V}$  and  $E^\circ(\text{Zn}^{2+}/\text{Zn}) = -0.762\text{V}$

(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  $25^\circ\text{C}$  for

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

8. a) A solution of glucose in water freezes at  $-1^{\circ}\text{C}$ . What is the vapor pressure of this solution at  $100^{\circ}\text{C}$ ? The molal freezing point constant for water,  $K_f$ , is  $1.85^{\circ}\text{C/molal}$ . 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  $-1^{\circ}\text{C}$ ?

Data: MW glucose =  $180\text{g/mol}$

MW NaCl =  $58\text{ g/mol}$