UNIVERSITY OP TORONTO •
FACULTY OF APPLIED SCIENCE AND ENGINEERING

FINAL EXAMINATIONS, DECEMBER 1994
First Year - Programs 1,2,3,4,6,7,8,9
CHE112F. CHEMISTRY
Examiners • Chemical Engineering Staff

DATA: R = 8.314 J/mol/K
F =96485 Coul/mol e^-

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

1 atm = 101.3 kPa

1. From the following data, calculate the standard molar enthalpy of formation of solid calcium carbide ($CaC_{2(s)}$).

i) $Ca(s) + 2H_2O_{(l)} \rightarrow Ca(OH)_{2(s)} + H_{2(g)}$ $\Delta H^\circ = -414.8$ kJ
ii) $2C_{(s,graphite)} + O_{2(g)} \rightarrow 2CO_{(g)}$ $\Delta H^\circ = -221.0$ kJ
iii) $CO_{2(g)} \rightarrow CO_{(g)} + 1/2O_{2(g)}$ $\Delta H^\circ = +284.0$ kJ
iv) $CaO_{(s)} + H_2O_{(l)} \rightarrow Ca(OH)_{2(s)}$ $\Delta H^\circ = -65.2$kJ
v) $H_{2(g)} + 1/2O_{2(g)} \rightarrow H_2O_{(l)}$ $\Delta H^\circ = -286.0$ kJ
vi) $CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$ $\Delta H^\circ = +177.5$kJ
vii) $CaC_{2(s)} + CO_{(g)} \rightarrow CaO_{(s)} + 3C_{(s,graphite)}$ $\Delta H^\circ = -462.3$kJ

2. a) Calculate the ΔG° for the reaction:

$$2CaCO_{3(s)} \rightarrow 2CaO_{(s)} + 2CO_{2(g)}$$

b) Under what condition might you expect the above reaction to become spontaneous? Explain your answers mathematically.

Given data: ΔG°_f for $CaO_{(s)}$ = -604kJ/mol
ΔG°_f for $CaCO_{3(s)}$ = -1129kJ/mol
ΔG°_f for $CaO_{2(g)}$ = -386kJ/mol

[NOTE: DATA W QUESTION 1 WILL BE NEEDED FOR THIS QUESTION.]

c) Calculate the equilibrium constant (K) for the reaction in part (a).

3. Metallic copper is prepared from the mineral chalcopyrite ($CuFeS_2$) by a series of high temperature reactions in which the chalcopyrite is first oxidized to copper (I) sulphide (Cu_2S), iron (III) oxide (Fe_2O_3) and sulphur dioxide (SO_2), followed by reduction of the copper (I) sulphide to metallic copper. How many kilograms of pure copper can be obtained from 1000 kg of an ore containing 28.88 wt% chalcopyrite?

Data: Molar Masses (g/mol) - Fe 55.8, Cu 63.5, S 32.0, O 16.0

4. A nickel ore is quantitatively oxidized using 1.5 times the stoichiometric amount of air required for complete reaction. The equation for (his oxidation can be written as

$$4Ni_2Fe_2S_{8(s)} + 57O_{2(g)} \rightarrow 8NiO_{(s)} + 14Fe_2O_{3(s)} + 32SO_{2(g)}$$

Data: Molar Masses (g/mol) - O 16.0, N 14.0, S 32.0, Fe 55.8, Ni 58.7

(a) Assuming that air is 21 volume % O_2 and 70 volume % N_2, calculate the mol fraction of SO_2 in the product gas.

(b) How many m^3 of air at 1000 kPa and 25˚C are required to treat 1000 kg of ore under these conditions?

5. A dilute solution of dissolved ore contains 150 ppm zinc (mass basis) as Zn^{2+} and 250 ppm of cobalt as Co^{2+}. If this solution is electrolysed between inert electrodes at 298 K, what is the molar concentration of cobalt ions left in solution when the zinc ions are just starting to be deposited?

Assume solution densities of 1 g/mL, and that deposition of the metal ions occurs at the reversible potential (i.e., E = zero).

$Co^{2+}_{(aq)} + 2e^- \Leftrightarrow Co_{(s)}$ $\quad E^\circ = -0.277$ V
$Zn^{2+}_{(aq)} + 2e^- \Leftrightarrow Zn_{(s)}$ $\quad E^\circ = -0.763$ V

6. Although ethanol was used as an antifreeze addition to water in the winter for som lime, the primary ingredient of radiator antifreeze for automobiles is now ethylene glycol, which can be used it can be used in summer as well as winter. The following calculations will illustrate why that is so. (Assume ideal behaviour.)

Data:

	Ethanol (C_2H_5OH)	Water (H_2O)	Ethylene glycol (HOC_2H_4OH)
Equilibrium vapor pressure at 100˚C (kPa)	264	101	4.79
Molar mass (g/mol)	46.07	18.2	62.07
Density (g/mL)	0.789	1.00	1.109

The freezing point depression constant (K_f) for water is 1.86˚C/m.

a) Calculate the freezing point of a 50% by volume solution of ethylene glycol in water and of a 50% by volume solution of ethanol in water.

b) Calculate the equilibrium vapor pressure for these two solutions at 100'C.

7. A buffer was prepared by dissolving 10.7 g of NH_4Cl (MW = 53.5 g/mol) and 5.95g of NH_3 (MW = 17 g/mol) in water, making a 500mL solution.

a) Determine the pH of the buffer.

b) Determine the pH of the solution after 100mL of 0.25M NaOH is added to the 500mL buffer solution.

K_b for NH_3 =$1.8x10^{-5}$
K_w=$1.0xl0^{-14}$

8. Graphite ($C_{(s)}$) was added to a vessel containing carbon dioxide ($CO_{2(g)}$) at 1000 K and 50 kPa, resulting in the formation of carbon monoxide ($CO_{(g)}$. The equilibrium constant for the reaction (based upon 1 mol of CO_2) is 1.75.

a) Determine the equilibrium partial pressures of CO and CO_2.

b) Predict and explain any changes in the equilibrium position if this system was compressed to one-half of its original volume.