Chemistry 2720 Fall 2003 Test 2

Aids allowed: Calculator, one $8\frac{1}{2} \times 11$-inch sheet of notes

Time: 75 minutes

Total marks: 52

Useful data is given at the end of this paper.

1. Consider the following reaction occurring in aqueous solution:

$$H_2O_{(l)} + A_{(aq)} \rightarrow P_{(aq)}.$$

   Suppose that this reaction is nonspontaneous under some particular conditions, but only just. In other words, suppose that the free energy change is just slightly positive. Holding all other conditions constant, we add an inert salt to the solution. Can this make the reaction spontaneous? Why or why not? [6 marks]

2. The vapor pressure of ice at 0°C is 0.006 025 atm. Given that the enthalpy of sublimation (vaporization of the solid) of ice at this temperature is 50.92 kJ/mol, calculate the vapor pressure of ice at -12°C. [6 marks]

3. Mercury (I) chloride (Hg_2Cl_2, molar mass 472.09 g/mol) has a solubility of 0.0020 g/L in water at 25°C. The mercury (I) ion has a peculiarity: It does not exist as a free ion in aqueous solution. Rather, one obtains the mercurous ion Hg_2^{2+}. Calculate the standard free energy of formation of the mercurous ion. [12 marks]

4. Calculate the equilibrium constant for the reaction

$$Hg^{2+}_{2(aq)} \rightleftharpoons Hg_{(l)} + Hg^{2+}_{(aq)}$$

   at 25°C. Which of the two aqueous ions will be more abundant under equilibrium conditions? (Metallic mercury is insoluble in water, so it precipitates out.) [8 marks]

5. Suppose that we want to make calcium chloride from calcium oxide by passing a stream of chlorine gas over a sample of calcium oxide. In our experimental apparatus, $P_{Cl_2} = 0.8$ bar, $P_{O_2} = 0.2$ bar, and $T = 85$°C. Will this work? The standard enthalpy of formation of calcium chloride is $-795.80\,\mathrm{kJ/mol}$. [20 marks]

Useful data

To convert degrees Celsius to Kelvin, add 273.15.

$$\mathcal{F} = 96\,485.342\ \text{C/mol}$$
$$R = 8.314\,472\ \ \text{J K}^{-1}\text{mol}^{-1}$$

$$1\ \text{atm} = 101.325\ \text{kPa}$$
$$1\ \text{bar} = 100\ \text{kPa}$$

Standard thermodynamic properties at 25°C			
Species	$\Delta\bar{H}_f^\circ$ (kJ/mol)	$\Delta\bar{G}_f^\circ$ (kJ/mol)	$\bar{C}_P$ ($\text{J K}^{-1}\text{mol}^{-1}$)
$CaO_{(s)}$	−634.92	−603.30	42.8
$Cl^-_{(aq)}$	−167.080	−131.218	
$Hg_2Cl_{2(s)}$	−265.37	−210.72	101.7

Standard Entropies at 25°C and 1 bar	
Species	$\bar{S}^\circ$ $\text{J K}^{-1}\text{mol}^{-1}$
$Ca_{(s)}$	41.6
$CaCl_{2(s)}$	104.62
$Cl_{2(g)}$	223.081

Standard reduction potentials at 25°C	
Reduction process	$\mathcal{E}^\circ$ (V)
$Hg^{2+}_{(aq)} + 2e^- \rightarrow Hg_{(l)}$	0.851
$Hg^{2+}_{2(aq)} + 2e^- \rightarrow 2Hg_{(l)}$	0.7973