

Chemistry 2740 Spring 2010 Test 1

Time: 50 minutes

Marks: 41

Aids allowed: calculator, 8.5×11 -inch formula sheet

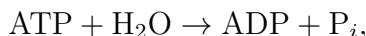
Useful data is given on the reverse of this page.

Instructions: You can answer the questions in any order, but make sure that you clearly label each of your answers with the question number in your exam booklet(s).

1. Briefly explain any *three* of the following concepts [3 marks each]:

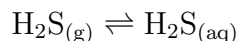
- (a) Coupled reactions
- (b) Indirect calorimetry
- (c) Microstate
- (d) Third law of thermodynamics
- (e) Vapor pressure

2. ATP (adenosine 5'-triphosphate) is the major energy carrier in cells. Energy is mainly released from ATP in the hydrolysis reaction



where ADP is adenosine 5'-diphosphate, and P_i represents “inorganic phosphate”, i.e. one of the protonation states of the phosphate anion. For this reaction, $\Delta_r H_m = -30.88 \text{ kJ/mol}$. In a turtle hepatocyte (liver cell) with a volume of 10^{-11} L , $7 \times 10^{-13} \text{ mol}$ of ATP are consumed per hour. Assume that a cell is mostly water with a density of about 1 kg/L and a heat capacity of about $4.2 \text{ J K}^{-1} \text{ g}^{-1}$. Now suppose that we could put a little insulated jacket around a hepatocyte. Considering only this one reaction, how long would it take for the temperature to rise by 5°C ? [6 marks]

3. (a) The equilibrium constant for dissolving hydrogen sulfide in water



is 0.087 at 298.15 K. What is the standard free energy of formation of an aqueous hydrogen sulfide molecule? [4 marks]

- (b) The slope of a graph of $\ln K$ vs T^{-1} for the above solubility process is 2100 K. What is the standard enthalpy of formation of aqueous hydrogen sulfide? [4 marks]
- (c) The standard entropy of gaseous H_2S at 298.15 K is $205.77 \text{ J K}^{-1} \text{ mol}^{-1}$. What is the standard entropy of aqueous H_2S ? [4 marks]

4. Gallium nitride (GaN) is a solid semiconductor used in light-emitting diodes. Jacob and Rajitha have recently reviewed the available data on the thermodynamic properties of GaN.¹ They found that the standard free energy of formation of GaN over the temperature range was well fit by the equation

$$\Delta_f G^\circ = -131\,530 + 117.4T, \quad (1)$$

over the temperature range 800 to 1400 K, where $\Delta_f G^\circ$ is in J/mol and T is in K.

- (a) Over this temperature range, what is the standard enthalpy of formation of GaN? [1 mark]
- (b) What does the coefficient of T in equation 1 represent? [2 marks]
- (c) At high temperatures, gallium nitride decomposes into its elements. Predict the temperature above which this would happen when GaN is kept in 1 bar of N_2 . [3 marks]
- (d) Above what temperature would GaN decompose into its elements if kept in 20 bar of N_2 ? Does the difference between your answers to this and the previous question agree with Le Chatelier's principle? Explain briefly. [8 marks]

Note: Gallium melts at 302.9 K and boils at 2477 K, so it is a liquid over the temperature range for which equation 1 is valid.

Useful data

$$k_B = 1.380\,650\,3 \times 10^{-23} \text{ J/K}$$

$$L = 6.022\,142\,0 \times 10^{23} \text{ mol}^{-1}$$

$$R = 8.314\,472 \text{ J K}^{-1} \text{ mol}^{-1}$$

Standard thermodynamic data at 298.15 K			
Species	$\frac{\Delta_f H^\circ}{\text{kJ mol}^{-1}}$	$\frac{\Delta_f G^\circ}{\text{kJ mol}^{-1}}$	$\frac{C_{p,m}}{\text{J K}^{-1} \text{ mol}^{-1}}$
$H_2S_{(g)}$	-20.50	-33.33	34.20

¹K. T. Jacob and G. Rajitha, *J. Cryst. Growth* **311**, 3806 (2009).