Chemistry 2740 Spring 2021 Test 1

Total marks: 32

Submission: From the time you open the test in Crowdmark, you have a total of **2 hours** to complete the test **and upload your answers to Crowdmark**.

Data: Much of the data you will need is contained in the appendices of the textbook. Some additional data is given at the end of the test. Please use data from the textbook and from this test paper and **not** from other sources.

Instructions: Under no conditions are you to discuss the contents of this test with, or obtain assistance from, any person by any means prior to the submission deadline of **7:00 p.m. Friday, January 29th**. You may however email me to clear up minor issues you run into while doing the test. Note that I can't watch my email every minute of the day, so last-minute questions may not receive timely answers.

You can use any resources you like (textbook, web resources, etc.), and any computational tools (calculator, spreadsheet, etc.). However, the point of this test is to evaluate your understanding of the material so you must give full details of any work or reasoning. **Answers without detailed work will receive <u>NO</u> credit.**

Make sure to use a sufficiently dark pencil or pen so that your work will scan or photograph well. Also, verify the quality of your images before uploading them. If I can't read it, I can't mark it. Color is permitted if you think it would be useful. While the test is intended to be hand-written—neatly please!—I don't mind computer (word processor, spreadsheet) output if you think it's helpful for some problems. (I think this is unlikely in this test.)

Keep in mind the **firm** deadlines: **two hours, ending before 7:00 p.m.**

1. (a) Write down the formation reaction for an aqueous ammonium ion ($NH^+_{4(aq)}$). [2 marks] **4 marks**

   (b) Calculate the entropy of formation of an aqueous ammonium ion, i.e. the entropy change for the reaction you wrote down in part (a). [2 marks]

   (This quantity is sometimes useful in free energy calculations.)

2. The molar heat capacity of solid silicon is well described by the equation[1] **9 marks**

$$C_{p,m} = 23.698 + 3.305 \times 10^{-3} T - \frac{4.354 \times 10^5}{T^2}.$$

In this equation, $C_{p,m}$ is in $\mathrm{J\,K^{-1}mol^{-1}}$ and T is in Kelvin. Calculate the molar entropy of silicon at 1200 °C. [9 marks]

Note: Use the expression above for the heat capacity of silicon. Do not use the heat capacity from appendix A of the textbook.

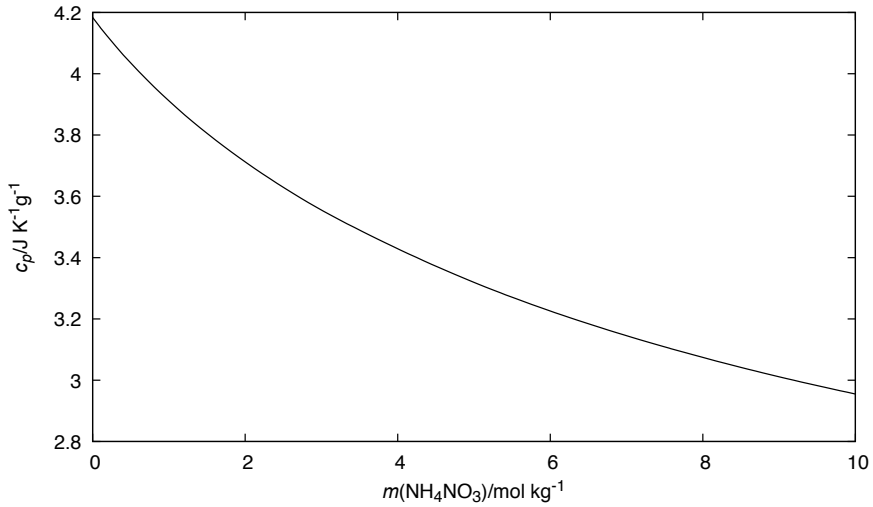
3. In problem 5.7#3, which we discussed in class, we estimated that, to make a cold pack that would cool from 20 to 2 °C, we would want 59 g of ammonium nitrate to be dissolved in 250 mL of water. In this problem, we will reexamine this estimate. **19 marks**

   (a) For high-accuracy thermodynamic work, we do not use molarity concentrations. Instead, we use molal concentrations, defined as the number of moles of *solute* per kilogram of *solvent*. Accurately calculate the molality of a solution made by dissolving 59 g of ammonium nitrate in 250 mL of water (measured at 20 °C). [6 marks]

   Note: The molality is usually denoted by the symbol m, which is unfortunate since we also use m for mass.

   (b) The graph at the top of the next page gives the specific heat capacity of an ammonium nitrate solution as a function of molality. Use this graph to determine the specific heat capacity of the solution described in part (a). Try to read the graph reasonably accurately. (I will of course allow reasonable variances in your answers.) [2 marks]

[1] Glasov and Pashinkin, *High Temp.* **39**, 413 (2001)



Data from Gucker et al., *J. Am. Chem. Soc.* **58**, 2118 (1936).

(c) The specific heat capacity determined in part (b) is in units of joules per Kelvin per gram of *solution*. Calculate the temperature to which the solution described in part (a) will cool if the water and ammonium nitrate are mixed at an initial temperature of 20 °C. The enthalpy of solution of ammonium nitrate in water is 25.69 kJ mol^{-1}. [10 marks]

(d) If we want the cold pack to drop in temperature from 20 to 2 °C when activated, should we increase or decrease the amount of ammonium nitrate used from our initial estimate of 59 g? [1 mark]

Standard entropies

Species	S° / J K^{-1}mol^{-1}
$H_{2(g)}$	130.680
$N_{2(g)}$	191.609
$NH^+_{4(aq)}$	111.2
$Si_{(s)}$	18.82