# Chemistry 4000/5000/7001 Spring 2009 Test 2

**Time:** 50 minutes

**Questions:** 6

**Marks:** 40

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

**The use of communications software or devices of any kind, including web browsers, is strictly prohibited.**

**You may not open any pre-existing files on your computer.**

**Instructions:** All answers should be written in the booklets provided.

If you use software to answer a question, explain what you did and show all relevant equations. You don't necessarily need to reproduce every command you entered, but someone who has used the software should have a good idea of how you solved the problem. For example, if you used software to solve an integral, it is generally enough to display the integral and answer, and indicate that you solved the integral using (e.g.) Maple. Note that you do not need to reproduce every digit generated by your calculator or computer. Just give me a few decimal places so that I can assess whether you have done the calculation correctly.

**Useful data:**

$k = 1.380\,650\,4 \times 10^{-23}\,\mathrm{J/K}$

$N_A = 6.022\,141\,79 \times 10^{23}\,\mathrm{mol^{-1}}$

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

1. In the section of the course dealing with statistical thermodynamics, we found that the molar internal energy of an ideal monatomic gas was $\frac{3}{2}RT$. Rederive this equation using equations from the kinetic theory of gases. [4 marks]

2. (a) What is an ideal rubber? [2 marks]

   (b) In an ideal rubber, elasticity is due to an entropic effect. How can entropy cause a restoring force? [6 marks]

3. Sketch the Maxwell-Boltzmann speed distribution. Show on your sketch the most probable, average and root-mean-squared speeds. [5 marks]

4. What is the probability that a molecule of nitrogen has a speed greater than 800 m/s at 1000 K? The molar mass of molecular nitrogen is 28.0134 g/mol. [5 marks]

   Maple hints: Rather than use assumptions, since you want a numerical answer in this problem, it is probably easiest to enter all of the constants in your Maple worksheet before doing any calculations. Don't forget that $\pi$ is `Pi` in Maple.

5. You want to build a molecular beam apparatus that produces a cold molecular beam of hydrogen molecules. The beam will be produced by effusion through a circular aperture of radius 0.2 mm from a container (ballast) kept at 77 K.

   (a) What is the average speed of the hydrogen molecules? Consider only molecules of $^1H_2$, with molar mass 2.015 650 064 g/mol. [2 marks]

   (b) A small number of molecules in the gas may be HD instead of $H_2$. The molar mass of HD is 3.021 926 810 g/mol. How fast do these molecules travel on average? [2 marks]

   (c) Suppose that we want $10^{16}$ molecules to be emitted through the aperture per second. At what pressure should we hold the ballast? Assume that all the molecules are $^1H_2$. [4 marks]

6. The lattice model of polymer solubility involves a number of assumptions and approximations. Explain these assumptions and approximations, and discuss how reasonable they are. [10 marks]