Chemistry 2740 Spring 2011 Test 1

Time: 50 minutes
Marks: 36
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. Give one example of an intensive state variable or state function, and one example of an extensive state variable or state function. [2 marks]

2. The bomb calorimetry experiment is generally carried out in two steps: (i) burn a sample of known heat of combustion, and (ii) burn an unknown sample.

   (a) What do you actually measure in a calorimetry experiment? [2 marks]

   (b) What is the purpose of step (i)? [1 mark]

   (c) What quantity can you calculate after step (ii)? [1 mark]

3. Give an example of a process that is permitted by the first law of thermodynamics, but forbidden by the second law. [2 marks]

4. A protein is made up of a string of amino acids, sometimes called "residues". Two of the bonds along the "backbone" of a protein can rotate freely, as can some of the bonds in the side chains. As a result, proteins can adopt many conformations. At physiological temperatures, many proteins have a unique overall fold, called the native fold, which includes a small number of closely related conformations. For the sake of argument in this question, assume that the native fold consists of just one conformation. Proteins can be unfolded, resulting in more-or-less random conformations, by heating to high temperatures.

   (a) In a series of investigations, Makhatadze and Privalov measured the entropy of unfolding of proteins at 125 °C.[1] All of these values tend to fall into a narrow range, with an average of $52\,\mathrm{J\,K^{-1}(mol\ residues)^{-1}}$. How many conformations per residue does this value imply for the unfolded proteins? [6 marks]

   (b) If the native fold corresponded to many conformations, what effect would this have on the calculation of part (a)? [2 marks]

[1] These investigations were summarized in G. I. Makhatadze and P. L. Privalov, *Protein Sci.* **5**, 507 (1996).

5. A typical person at rest in a warm room emits heat at a rate of about 100 W. This is a reasonable measurement of a person's resting metabolic rate.

   (a) Suppose that most of the heat originates from oxidizing glucose to carbon dioxide and water. How much glucose (in moles) would this person oxidize per minute? [8 marks]

   Note: Biological oxidations occur in solution phase.

   (b) How many moles of oxygen would be required? [1 marks]

   (c) An average breath brings in about 0.5 L of air containing 21% oxygen. About 25% of the oxygen taken into the lungs is absorbed into the bloodstream. How many breaths per minute would be required by a person at rest to maintain their resting metabolic rate? Assume that the air has a temperature of 20 °C and a pressure of 1 atm. [7 marks]

   (d) How much work is done by the chest muscles each minute expanding the lungs by 0.5 L per breath against a constant external pressure of 1 atm? [4 marks]

Useful data

$k_B = 1.380\,650\,3 \times 10^{-23}$ J/K
$L = 6.022\,142\,0 \times 10^{23}\,\text{mol}^{-1}$
$R = 8.314\,472\,\text{J}\,\text{K}^{-1}\text{mol}^{-1}$
To convert degrees Celsius to Kelvin, add 273.15.
1 atm = 101 325 Pa
$1\,\text{m}^3 = 1000\,\text{L}$
1 W = 1 J/s

Standard thermodynamic data at 298.15 K		
Species	$\frac{\Delta_f H^\circ}{\text{kJ mol}^{-1}}$	$\frac{C_{p,m}}{\text{J K}^{-1}\text{mol}^{-1}}$
$C_6H_{12}O_{6(aq)}$ (α-D-glucose)	−1263.06	
$CO_{2(aq)}$	−413.26	
$H_2O_{(l)}$	−285.830	75.40
$O_{2(aq)}$	−12.09	