# Chemistry 2740 Spring 2022 Test 1

**Total marks:** 45

**Submission:** From the time you open the test in Crowdmark, you have a total of **75 minutes** to complete the test **and upload your answers to Crowdmark**.

**General instructions:** Under no conditions are you to discuss the contents of this test with, or obtain assistance from, any person by any means while the test is open. You may however email me to clear up minor issues you run into while doing the test.

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 NO credit.**

Please only use data on this test paper and in the textbook. **Do not** use data obtained from other sources as this might cause your answers to differ from mine.

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 I'm not very fussy about significant figures—that's Wayne's job—I am picky about a couple of things:

- You should give answers to a reasonable number of decimal places given the input data. Don't give me answers to eight decimal places if the data aren't that accurate, and don't round your final answer so much that I can't tell if it's right or wrong. Use reasonable judgement. Of course, you can't go wrong following the significant figure rules.
- All the digits in your final answer should be correct, which generally means that you should store intermediate results in calculator memories. Alternatively, keep a few extra digits in intermediate steps.

1. 1.05 mol of nitrogen initially at equilibrium in a piston at 80.08 °C and occupying a volume of 10.0 L is expanded adiabatically against a constant external pressure of 1.18 bar to a final volume of 20.0 L. Calculate **6 marks**

   (a) $q$ [1 mark]
   (b) $w$ [4 marks]
   (c) $\Delta U$ [1 mark]

2. Dodecane ($C_{12}H_{26}$) is a liquid at room temperature with a standard entropy of 490.66 J K$^{-1}$mol$^{-1}$ and a constant-pressure heat capacity of 375.1 J K$^{-1}$mol$^{-1}$. It melts at 263.1 K with an enthalpy of fusion of 35.7 kJ mol$^{-1}$. Calculate the entropy of solid dodecane at its melting point. **7 marks**

3. A large café mocha (one of my favorite things) from a well-known Canadian company contains 33 g of sugar. Assume that this sugar is all sucrose ($C_{12}H_{22}O_{11}$, molar mass 342.30 g mol$^{-1}$), and let's try to put this number into perspective. The overall reaction for the oxidation of sugars by oxygen in aerobic metabolism generates carbon dioxide and water. The reactions occur in solution. **15 marks**

   (a) Assuming that the oxidation can be harnessed with perfect efficiency, what is the maximum muscle work that could be obtained from the oxidation of 33 g of sucrose[1] at 25 °C? Assume the following intracellular concentrations: [sucrose] = 2.2 mmol L$^{-1}$, [$O_2$] = 1.2 mmol L$^{-1}$, [$CO_2$] = 25 mmol L$^{-1}$; also assume that the activity of water in a cell is close to 1. [11 marks]

   (b) To what height could a 90 kg mass (which might be the mass of a person we won't name who enjoys mochas) be raised by this amount of work? [2 marks]

   (c) The oxidation of sugars is carried out in many steps in a cell, and not as a direct reaction of oxygen. What principle allows us to ignore all of the intermediate steps and to focus on the overall reaction in a calculation of the maximum work? [2 marks]

   Bonus: Redo the above calculations at 37 °C. [6 marks]

4. 1.0832 g of tyrosine ($C_9H_{11}NO_{3(s)}$, molar mass 181.1885 g mol$^{-1}$) is burned in a bomb calorimeter with a heat capacity of 10.84 kJ K$^{-1}$, resulting in a temperature rise of 2.436 K. The experiment was initiated using 10.3 cm of fuse wire with a combustion energy of −9.6 J cm$^{-1}$. When a nitrogen-containing compound is burned in a bomb calorimeter, $N_2$ is formed. Calculate **17 marks**

   (a) The molar enthalpy of combustion of tyrosine [13 marks]
   (b) The standard enthalpy of formation of tyrosine [4 marks]

[1] If you know something about the biochemistry of sugars, you might object that cells don't oxidize sucrose directly. Sucrose is first hydrolyzed to glucose and fructose, and those sugars can then be oxidized. The point of this question is to illustrate how much free energy is stored in sucrose, and not to get into the detailed biochemistry.