Challenge Problem: NeauPayne Pharmaceutical Series – Stoichiometry, Acid/Base and Thermochemistry

This is a five-part challenge problem with a "pharmaceutical" theme. It is intended for a General Chemistry II audience.

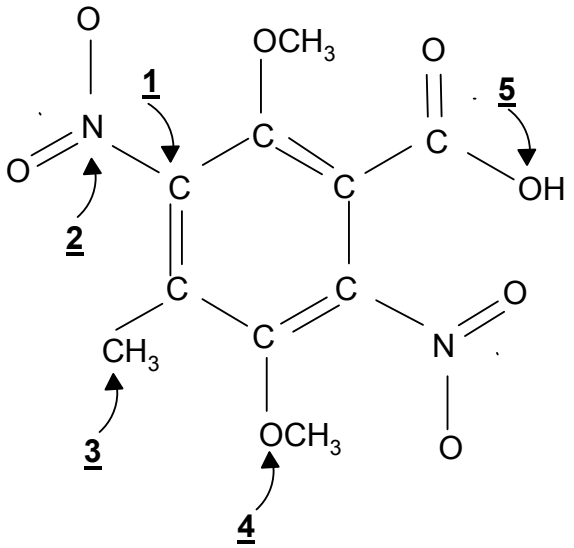
1. You have recently been hired by NeauPayne Pharmaceuticals, Inc. as a research and development chemist to formulate new drugs. From deep in the Amazon jungle, your expedition team collected a number of plants from which you have extracted and isolated a compound that shows good analgesic properties, and it is given the product name, CHON-el #6. This compound is found to contain the elements carbon, hydrogen, oxygen and nitrogen. A 1.000 gram of the sample of the compound was combusted and gave the following amount of products: 1.538 grams of carbon dioxide, 0.3154 grams of water, 0.3215 grams of nitrogen dioxide. From this data, determine the percentage composition and empirical formula of CHON-el #6.

Comments to the instructor: This challenge problem requires students to apply stoichiometry skills in determining the percent composition and empirical formula. Notice you do not need the balanced equation to determine the composition, or data for oxygen. This realization requires some critical thinking on the part of the student. The compound will be further characterized in a series of problems. Also, there are numerous ways to work this problem. The solution presented is in the author's opinion, the most lucid (available on request.)

2. (1) CHON-el #6 has been found to have acidic properties. Before the drug can be placed on the market, its properties must be characterized. Assume it is a monoprotic acid. If 2.710 grams of CHON-el #6 is neutralized by 45.61 mL of 0.2076 M NaOH, what is the molecular weight of CHON-el #6? (2) Using the data from the previous problem, what is the molecular formula of CHON-el #6? (3) If the pH of a 0.20 M solution is 2.67, what is the K_a of CHON-el #6? (4) Which indicator(s) would be recommended for titration of CHON-el #6?

Comments to the instructor: This is a continuation of "pharmaceutical problem". Concepts emphasized are titration, acid/base theory and acid/base equilibrium concepts. Also, stoichiometry is reinforced.

3. A sample of CHON-el #6 was sent to the x-ray crystallography department for structural analysis. Their results produced a partially completed structure of CHON-el #6 is shown below. Please complete the structure and provide the hybridization, shape and bond angles around the atom identified with arrows. For reasons to be investigated later, you are a little nervous about this structure.



Comments to the instructor: Students often do not encounter a larger Lewis structure until organic chemistry. Introducing such structures earlier will show relevance.

4. (1) When 3.258 grams of CHON-el #6 is combusted, 100.0 g of water with an initial temperature of 23.7 C reaches a final temperature of 31.8 C. What is the enthalpy of combustion? (2) Is it endothermic or exothermic? (3) Using the combustion data, and standard heats of formation of the products and the other reactant, determine the standard molar enthalpy of formation of CHON-el #6. Note: Useful information is found in Problems #1 and #2 of this series. In addition, a balanced chemical reaction will be quite useful! (4) Preliminary clinical studies on the effectiveness of CHON-el #6 as an analgesic yielded disappointing results. Based on the structure of CHON-el #6, can you suggest an alternative use for this compound? Recall you were a little nervous about the structure (from problem #3).

Comments to the instructor: This problem will have students searching the literature and/or their textbooks for appropriate data. It involves many aspects of thermo-chemistry, including calorimetry, enthalpy and Hess' Law.

5. What is the chemical equation for the standard enthalpy of formation? Using the structure in Problem #3, calculate the standard molar enthalpy of formation, this time, using bond energies. You may have to "uncondense" or expand portions of the structure to determine the bonds in some parts of the molecule. For graphite, use 611 kJ/mol as the bond dissociation energy (the BDE of a C=C).

Comments to the instructor: At this introductory level, we are not considering resonance stabilization energies and will approximate the dissociation of the 10 moles of graphite to be equivalent to five carbon-carbon double bond energies.