CH 241 EXPERIMENT #4
WEEK OF NOVEMBER 2, 2015
MOLECULAR MODELING PART II

Introduction

In this lab you will continue to refine your computational modeling skills using the GaussView and Gaussian programs while exploring several key concepts discussed in class and comparing the results with known experimental data. As always, the goal here is not to simply get the "right" or "expected" answer, but to gain an appreciation for the techniques that organic chemists employ to solve problems.

Review your notes from Molecular Modeling I (experiment #2) to reacquaint yourself with the programs and basic commands so that you can be self-sufficient this week. For all parts except part V this week you should optimize the geometry using the semi-empirical AM1 method after building the appropriate molecule.

Part I. Substituted cyclohexanes

In this part, you will explore the relative stabilities and chirality of several substituted cyclohexanes. Be sure to rotate the structures around and draw Newman projections as needed to see the interactions that might stabilize or destabilize each individual conformer. The cyclohexane template provided under the "Rings" menu can be useful for building structures.

• Build both chair conformations of methylcyclohexane and record their energies. Using the difference in the energies, calculate the amount of each species present at equilibrium. Repeat this calculation for tert-butylcyclohexane. Refer to problem 5.11 and section 7.4a in your text if you are unsure how to proceed. Also, see question 3 in Problem Set 5. For your calculations, assume \( \Delta G \sim \Delta E \), and set them up so that \( K = [\text{equatorial}]/[\text{axial}] \).

• Build both chair conformations of cis-1,3- and trans-1,3-dimethylcyclohexane. As before, record their energies and compute the equilibrium ratios of the conformers for each compound. Note how these structures are related to each other and determine whether each structure is chiral.

Part II. Investigating relative acidities

As you might expect, a hydrogen atom in a stronger acid has a greater partial positive charge than one in a weaker acid. In other words, a stronger acid has a more "electron poor" hydrogen than a weaker one. In this exercise, you will assess the acidity of various compounds by examining their Mulliken charges.

• Compare acidities of ethane, ethylene, and acetylene by building these three compounds. After each calculation is done, request charge distribution, click on show numbers, and record the value of the charge on the hydrogen for each compound.

• Build acetic acid, trifluoroacetic acid, and trichloroacetic acid to explore the effect of substituents on acidity. Submit the calculations as before and record the charge value on the carboxyl hydrogen for each compound.

• To compare the acidity of alcohols versus phenols, repeat the same calculations for ethanol and phenol and record the appropriate values for each.
Part III. Relative stabilities of cations

Build models of 1°, 2°, and 3° butyl cations, being sure to specify that each molecule has a positive charge before submitting its job. Record the energy for each cation.

Part IV. Bridgehead alkenes and cations

Build the four species shown below and record the energy for each. Also note the sizes of the three angles around the positively charged carbon in the bridgehead cation. For the bridgehead alkene, record the two H-C=C-C dihedral angles.

Part V. Model of ibuprofen and acetaminophen

Build and clean models of (S)-ibuprofen and acetaminophen, but do not submit calculations for them. Check with the program that you have built the stereocenter correctly. Have your structures checked by the lab instructor.

PRELAB PREPARATIONS

1. Record the pKa values and structures of ethane, ethylene, acetylene, acetic acid, trifluoroacetic acid, trichloroacetic acid, ethanol, and phenol.
2. Draw the structures of (S)-ibuprofen and acetaminophen.

WHAT SHOULD BE IN YOUR NOTEBOOK?

1. An entry of the title, date, and page number in your table of contents.
2. An entry of the title and date on the first page of your experiment.
3. All the items that you were asked to record for each individual part of this lab.

WHAT SHOULD BE IN YOUR LABORATORY REPORT?

Do not exceed a total of two pages of text, supplemented with one page of pictures and references (please print this double-sided and send an electronic copy to Ed Klinkerch)

1. Title of the experiment with your name, lab section, and date.
2. Introduction (1 paragraph)
3. Results and Discussion, including an analysis of the data for each part. For parts I through IV, compare the calculated values with those available in your textbook, and explain the trends. Use tables to display data clearly and concisely when appropriate.
4. ChemBioDraw structures and/or tables as needed to understand your results and discussion.
5. Conclusion (1 paragraph)