

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/231268645>

Infrared Spectroscopy as a Preview of Coming Attractions: Teaching Chemistry with Instrumental Methods at Two-Year Colleges

ARTICLE *in* JOURNAL OF CHEMICAL EDUCATION · APRIL 2010

Impact Factor: 1.11 · DOI: 10.1021/ed100175b

CITATIONS

2

READS

10

1 AUTHOR:



David Brown

Southwestern College

15 PUBLICATIONS 459 CITATIONS

SEE PROFILE

Instrumentation Topics for the Teaching Laboratory

edited by
Michelle Bushey
Trinity University
San Antonio, TX 78212-7200

Infrared Spectroscopy as a Preview of Coming Attractions: Teaching Chemistry with Instrumental Methods at Two-Year Colleges

by David R. Brown

Department of Chemistry, Southwestern College, Chula Vista, California 91910
dbrown@swccd.edu

The nation's two-year colleges (2YCs) are a major contributor to the undergraduate science education enterprise in America. In 2006, of 15.4 million undergraduates, approximately 6.4 million (about 42%) were enrolled in 2YCs (1). These statistics are essentially mirrored when focusing exclusively on the education of undergraduate chemistry majors. Data compiled in 2003 indicate that 42% of bachelor's graduates and 37% of master's graduates in chemistry reported attending a 2YC at some point on the way to completion of their respective degrees (2).

Although the fundamental mission of 2YC chemistry departments is to educate students in lower-division classes such as general chemistry and organic chemistry, it is important to recognize that the majority of students in those classes will ultimately transfer to four-year institutions. A subset of those students will choose chemistry as a major at their transfer institutions and will encounter upper-division courses such as inorganic chemistry and physical chemistry. While this group of future chemistry majors may constitute a minority of the students in a typical class of 2YC general chemistry students, they can surely benefit from exposure to a preview of physical chemistry in their general chemistry laboratory course. This article describes the use of molecular spectroscopy as a vehicle to deliver a preview of concepts in physical chemistry to students in general chemistry at a two-year college.

Giving 2YC Students a Preview of Physical Chemistry

Determining a Bond Length with FTIR Spectroscopy

Student access to analytical instrumentation in 2YC chemistry programs can vary widely. Some departments are quite well equipped, while others may have little or no instrumentation. This is largely because of financial restrictions and insufficient campus infrastructure and facilities to support the use of sophisticated instruments. However, one of the less-expensive instruments that has a minimal impact on a departmental supply budget is a Fourier transform infrared (FTIR) spectrometer. This is one of the more common instruments likely to be found in a 2YC chemistry department.

Numerous experiments employing FTIR spectroscopy and suitable for adaptation in 2YC laboratory curricula have been reported in this *Journal*. Examples include the gas phase analyses of N_2O (3); automobile exhaust (4); cigarette smoke (5); the study of lead binding by EDTA (6); and the investigation of protein secondary structure (7). With regard to the current discussion, however, students in second-semester general chemistry at Southwestern College use an

FTIR spectrometer to acquire the IR spectrum from gas phase HCl, with the ultimate goal of determining the HCl bond length (Figure 1). Students perform a version of the classic physical chemistry laboratory experiment (8) that has been reduced in complexity to match the level of preparation of general chemistry students.

Providing a full account of this experiment is beyond the purview of this column. Nonetheless, this forum is an appropriate place to discuss what 2YC students may gain from conducting the experiment. Another hope is that this account of a simplified physical chemistry experiment may encourage other 2YC instructors to make creative use of available instrumentation by adapting upper-level chemistry experiments for the benefit of their general chemistry students.

Concepts Introduced by Determining the HCl Bond Length

Through this experiment, students can be introduced to a wide variety of fundamental concepts in physical chemistry, including selection rules, harmonic and anharmonic molecular vibrations, molecular rotations, reduced masses, and molecular moments of inertia. Further, this experiment offers students an opportunity to get early, hands-on experience with an instrument that traditionally is not introduced until organic chemistry. Having more opportunities to use sophisticated instrumentation benefits the students and increases their confidence for using instruments in future laboratory courses or undergraduate research projects.

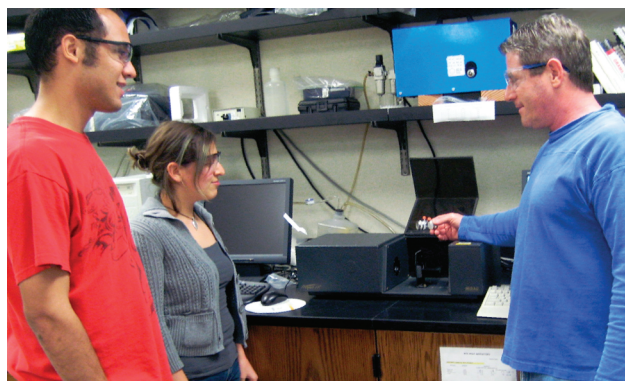


Figure 1. Instructor introducing students to using an FTIR spectrometer to acquire spectra from gas phase HCl, which the students use to determine the HCl bond length.

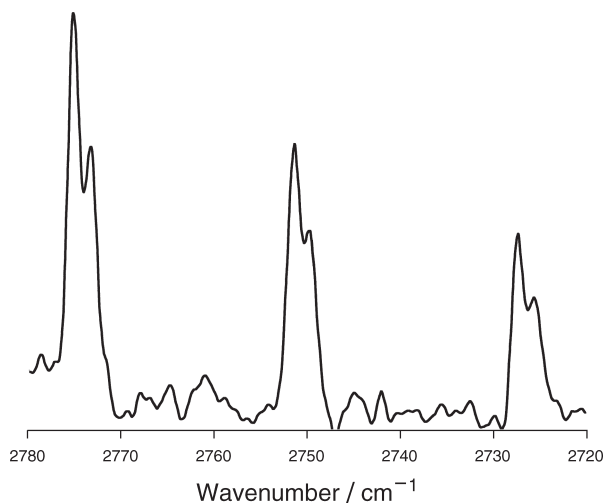


Figure 2. Selected portion of gas phase IR spectrum of HCl at 1 cm^{-1} resolution illustrating isotope effects.

This experiment also offers students an opportunity to address the concept of natural abundances of isotopes. Students in general chemistry are taught that the atomic mass for a given element found on the periodic table is the result of a weighted average of the masses of all the individual isotopes of that element. As an exercise, students can be provided the isotopic masses of an element along with their respective abundances and calculate an atomic mass that closely matches the value found on a periodic table. However, although solving a problem such as this has inherent value by illustrating the origin and nature of the atomic masses on the periodic table, the simultaneous existence of multiple isotopes remains an abstract, intangible concept for students. If a gas phase IR spectrum of HCl is collected with sufficient resolution (e.g., 1 cm^{-1} or less), then the contributions of the two species H^{35}Cl and H^{37}Cl become apparent. The effects of individual isotopes manifest themselves in spectra the students personally collect and analyze, offering them an opportunity to directly observe such phenomena. Figure 2 shows a portion of a spectrum acquired with 1 cm^{-1} resolution that reveals easily observed isotope effects.

Although not currently done at Southwestern College, the experiment can be enhanced to include an investigation of isotope effects attributable to the presence of deuterium. Several

methods for the production of HCl–DCl gas mixtures have been reported in this *Journal* (9–12).

Student Outcomes and Impressions

The method of analyzing gas phase IR spectra of HCl to determine its bond length is quite accurate. Feedback from students indicates they experience a sense of pride on successfully performing a physical measurement as fundamental as determining a molecular bond length. This level of pride is enhanced by the fact that bond length values, as determined by the students, rarely differ by more than a few percent from the literature value of approximately 1.29 Å (13, 14). Although the experiment itself is brief, the impact of acquiring and analyzing the IR spectrum of gas phase HCl can be significant and lasting. Hopefully the effects may last for years, until the time when the student arrives better prepared for a future physical chemistry laboratory course.

Literature Cited

1. National Science Foundation, Division of Science Resources Statistics. *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2009*; NSF: Arlington, VA, January 2009; NSF 09-305. <http://www.nsf.gov/statistics/wmpd/> (accessed Apr 2010).
2. National Science Foundation, Division of Science Resources Statistics. *Characteristics of Recent Science and Engineering Graduates: 2003*; NSF: Arlington, VA, 2006; NSF 06-329. <http://www.nsf.gov/statistics/nsf06329> (accessed Apr 2010).
3. Bryant, M.; Reeve, S.; Burns, W. J. *Chem. Educ.* **2008**, *85*, 121–124.
4. Seasholtz, M.; Pence, L.; Moe, O. J. *Chem. Educ.* **1988**, *65*, 820–823.
5. Ford, A.; Burns, W.; Reeve, S. J. *Chem. Educ.* **2004**, *81*, 865–867.
6. Fitch, A.; Dragan, S. J. *Chem. Educ.* **1998**, *75*, 1018–1021.
7. Olchowicz, J.; Coles, D.; Kain, L.; MacDonald, G. J. *Chem. Educ.* **2002**, *79*, 369–371.
8. Garland, C.; Nibler, J.; Shoemaker, D. *Experiments in Physical Chemistry*, 8th ed.; McGraw-Hill: Boston, 2008; Chapter 37.
9. Mayer, S.; Bard, R.; Cantrell, K. J. *Chem. Educ.* **2008**, *85*, 847–848.
10. Furlong, W.; Grubbs, W. J. *Chem. Educ.* **2005**, *82*, 124.
11. Lawrence, B.; Zanella, A. J. *Chem. Educ.* **1996**, *73*, 367.
12. Buettner, G. J. *Chem. Educ.* **1985**, *62*, 524.
13. Huber, K.; Herzberg, G. *Molecular Spectra and Molecular Structure—IV. Constants of Diatomic Molecules*; Van Nostrand Reinhold Company: New York, 1979; p 716.
14. Woods, R.; Henderson, G. J. *Chem. Educ.* **1987**, *64*, 921–924.