One year with the ACS textbook *Chemistry*

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Choosing and Using the Chemistry Textbook
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http://quantum.bu.edu/DanDill/talks/OneYearWithTheACSTextbookChemistry.pdf
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Abstract

The ACS textbook *Chemistry* was used in the large (~650 students) general chemistry course at Boston University (CH101/2) for the first time in 2004/5. The experience has transformed our view of the general chemistry syllabus and our roles as course faculty. *Chemistry* takes a fundamentally different approach compared to other high-end texts. It is exquisitely integrated so that nothing is left unused elsewhere in the book, enabling students to see at nearly every turn the great breadth of applicability of concepts and ideas that are developed in ways that are meaningful to their present and future interests. The conceptual and numerical problems become means to an end rather than ends in themselves. Most important, we feel *Chemistry* gives our students the foundation to find their way through chemical questions they may meet in their future studies. In this sense, *Chemistry* is the most sophisticated general chemistry text that we have ever used. We must say, however, that students do not seem to like *Chemistry*, although they are stimulated to ask quite sophisticated questions in lecture, discussion, and via e-mail. They may be disconcerted by a text that is so different from those they may have used in high school. Perhaps they are challenged by a text that must be read closely, sentence by sentence, rather than used primarily as a source for examples that serve as templates to mimic the solving of end-of-chapter problems.

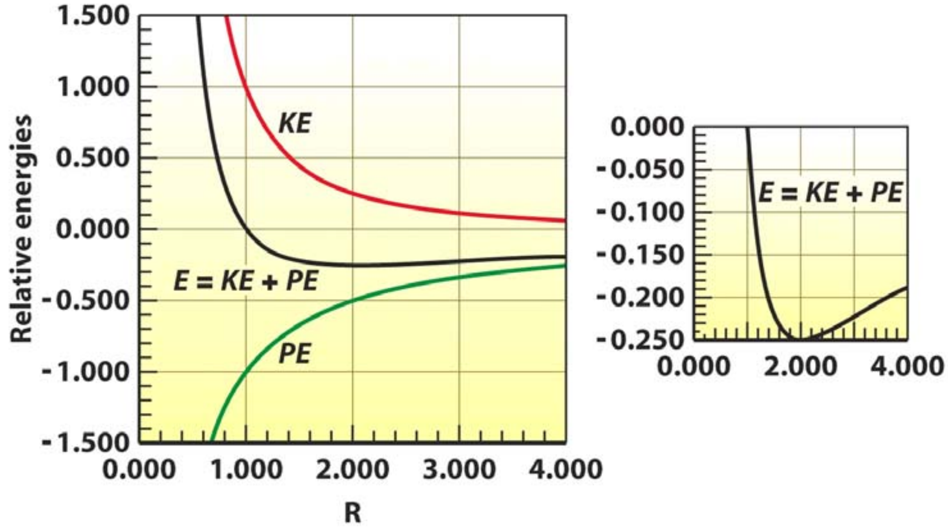
Initial reaction

In our main general chemistry course (for science majors and premedical students) we have a lot of experience and comfort with texts such as Oxtoby, Gillis & Nachtrieb, *Principles of Modern Chemistry*/5e, Petrucci, Harwood & Herring, *General Chemistry*/8e, and Zumdahl, *Chemical Principles*/5e. In this context, my initial reaction to the ACS text Chemistry after a five minute glance was that it was not a good text for a "serious" general chemistry course. My colleague Mort Hoffman encouraged me to have second look.

For this I decided to look at the text's *Web Companion*, http://snipurl.com/h9xd. The very first animation is of molecular motion in liquid water, and it asked whether the relationship of molecules to each other appears rnasom or ordered. With the alternative example of ice in mind, I chose "random," which displayed the message "Incorrect: ... replay the movie to see how the hydrogen- and oxygen-ends are oriented towards one another." This unexpected level of required attention to detail at the very outset really yanked me to attention, and so I decided to look at the exposition much more closely.

A closer look—quantum concepts

Quantum aspects of chemistry can be the most challenging to treat well, since we and our students have no everyday intuition about quantum behaviors. Looking over how ACS *Chemistry* handled things, I came across Figure 4.27, illustrating why atoms don't collapse.



ACS *Chemistry* Figure 4.27, illustrating the energies for a spherical electron attracted to a positive nucleus.

My first reaction was that something was wrong, since an s (spherical) electron has no orbital momentum and so cannot experience any centrifugal repulsion (what I interpreted the *KE* to be), since for it $-\ell(\ell + 1)/r^2 = 0$. I finally decided to actually read the text, and there learned that what was being illustrated was the contribution of the of the "motion" of the electron to its total energy. The text used a very clear, compact argument based on the inverse relation between de Broglie wavelength, λ, (in this example, a proxy for the size of the atom, R) and linear momentum, p: The smaller the atom, the large the linear momentum and so the larger the kinetic energy, $p^2/(2\,m)$.

I had never seen this kind of illustration, and it got me to thinking what a fully quantum mechanical version of it would be. It gave me great pleasure to understand that what was varying was the shape of the s electron wavefunction, and that the optimum shape is the one that gives the best balance of kinetic annd potential energy. That is, ACS *Chemistry* Figure 4.27 is really illustrating the variational treatment of ground state energies. The details are described in

http://quantum.bu.edu/notes/GeneralChemistry/WhyAtomsDon%27tCollapse.pdf

It is most unusual that a general chemistry text gets me to think about things I know well in a different way. This experience is one of many, many others.

A closer look—spontaneity

The treatment of spontaneity is based exclusively on counting, of molecular arrangements in mixtures and of energy arrangements among molecules. The result is that spontaneity is the result og nothing more or less than blind chance, to paraphrase Munowitz's comments in the introduction to *Principles of Chemistry*.

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A closer look—in class exploration

A hallmark of ACS Chemistry is is it extensive activities embedded in the exposition and meant to be done by students in class (rather than as a separate laboratory). This approach turns around the usual one of giving the tools first and then applying them to examples, with the benefit that the many times puzzling observations motivate students to want to understand their basis. A particularly rich activity determines whether alternative mixtures of $Co^{2+}(aq)$ and $PO_4^{3-}(aq)$ form a precipitate. Without benefit preliminary analysis, the results are puzzling. Only after ideas and tools of stoichiometry and limiting reagent are used do things finally make sense. Working from facts to understanding is the way science is done, and ACS Chemistry continually reinforces this. Traditional texts, in my experience, instead work from recipes to predicitons, that is, emphasis the end result.

Student reactions

Conclusion

and it has truned out to be a metaphor for the level and care throughout the entire text.

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