

Textbooks and Kinetic Metastability

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J. Chem. Educ. DOI: 10.1021/acs.jchemed.5b00569

ABSTRACT: This letter calls attention to the coverage of kinetic metastability in the introductory textbooks and accompanying online materials written by the author and his coauthors.

KEYWORDS: *First-Year Undergraduate/General, Textbooks/Reference Books, Thermodynamics, Kinetics, Nomenclature/Units/Symbols*

The article by William B. Jensen on kinetic metastability in the April issue of this *Journal*¹ argues that this topic ought to be included in freshman textbooks and also argues against the use of the adjective “spontaneous” when referring to a reaction with $K > 1$. I and my coauthors of the textbooks, *The Chemical World: Concepts and Applications*² and *Chemistry: The Molecular Science*,³ agree on both counts.

With respect to “spontaneous”, the 1994 edition of *The Chemical World* contains this statement on page 238, “Here we will categorize reactions that produce appreciable quantities of products as product-favored systems.” That terminology has persisted through the second edition of that book and for the five editions of *Chemistry: The Molecular Science*. In the most recent edition of the latter, the reactant-/product-favored terminology is used in the chapter on equilibrium (page 525) as well as in the chapter on thermodynamics. On page 695, a section headed “Reactant-Favored and Product-Favored Processes” begins. This note appears in the margin: “We prefer “product-favored” to “spontaneous” because some reactions do begin spontaneously, but produce only tiny quantities of products when equilibrium is reached. Also, the nonscientific usage of “spontaneous” implies a rapid change; if a product-favored reaction is very slow it does not appear spontaneous at all.”

With respect to kinetic metastability, Dr. Jensen’s statement that the few explicit examples of kinetic metastability cited in most introductory textbooks, “are isolated and never generalized under the rubric of kinetic metastability, thus leaving the student with the false impression that they are relatively uncommon.” is true only insofar as our textbooks have used the terms “thermodynamic stability” and “kinetic stability” instead of “kinetic metastability”. Thus, the 1994 edition of *The Chemical World* has a section headed “Thermodynamic and Kinetic Stability” (page 320) that cites an article in *American Scientist* by Roald Hoffmann on stability.⁴ The section says, “There are actually two kinds of stability. A thermodynamically stable substance does not undergo product-favored reactions.... A kinetically stable substance may have the potential to undergo product-favored reactions, but it does this so slowly that it remains essentially unchanged for a long time.” In the most recent edition of *Chemistry: The Molecular Science*, there is a nearly 3-page section headed “Thermodynamic and Kinetic Stability” (pp 733–735) that includes a Problem-

Solving Example that deals with kinetic (meta)stability of NO and the need for catalysts in automobile exhaust systems. Dr. Jensen’s examples of Al and C (diamond) are both given in this section, as is the example of the human body, much of which is thermodynamically unstable with respect to decomposition to CO₂, water, and minor quantities of other substances. In addition, the online material (OWLv2) accompanying the textbook includes a simulation titled “Thermodynamic and Kinetic Stability” that enables students to adjust Gibbs free energies of A, B, and C as well as transition-state energies for a hypothetical system $A \rightleftharpoons B \rightleftharpoons C$ and observe the results using plots of concentration vs time. In a series of carefully scaffolded steps, the simulation leads students to recognize how thermodynamic stability and kinetic (meta)stability affect chemical reactions.

Thus, at least one general chemistry textbook has been making the important distinctions championed by Dr. Jensen for at least 20 years.

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Notes

The authors declare the following competing financial interest(s): I am a coauthor (as disclosed in both the abstract and manuscript) of the two textbooks that are exceptions to Dr. Jensen’s statement that kinetic (meta)stability is not included in textbooks. I will therefore receive royalties from sales of those textbooks should readers of this letter to the editor choose to adopt one of them.

REFERENCES

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