ResearchGate

See discussions, stats, and author profiles for this publication at: https://www.researchgate.net/publication/231269081

Virtual Inorganic Pedagogical Electronic Resource Learning Objects in Organometallic Chemistry

ARTICLE *in* JOURNAL OF CHEMICAL EDUCATION · DECEMBER 2011

Impact Factor: 1.11 · DOI: 10.1021/ed200200w

CITATIONS
3

READS
44

7 AUTHORS, INCLUDING:

Joanne L Stewart
Hope College
26 PUBLICATIONS **128** CITATIONS

SEE PROFILE

Nancy Scott Burke Williams
The Claremont Colleges
24 PUBLICATIONS **635** CITATIONS

SEE PROFILE

Laurel Goj Habgood
Rollins College
15 PUBLICATIONS **418** CITATIONS

SEE PROFILE

Hilary J Eppley
DePauw University
33 PUBLICATIONS **1,086** CITATIONS

SEE PROFILE

Available from: Joanne L Stewart
Retrieved on: 02 February 2016

JOURNAL OF CHEMICAL EDUCATION

Report

pubs.acs.org/jchemeduc

Virtual Inorganic Pedagogical Electronic Resource Learning Objects in Organometallic Chemistry

Barbara A. Reisner,*,[†] Joanne L. Stewart,[‡] B. Scott Williams,[§] Laurel A. Goj,[∥] Patrick L. Holland,[⊥] Hilary J. Eppley,[#] and Adam R. Johnson[∇]

[†]Department of Chemistry and Biochemistry, James Madison University, Harrisonburg, Virginia 22807, United States

[‡]Department of Chemistry, Hope College, Holland, Michigan 49422-9000, United States

[§]W. M. Keck Science Center, Claremont, California 91711, United States

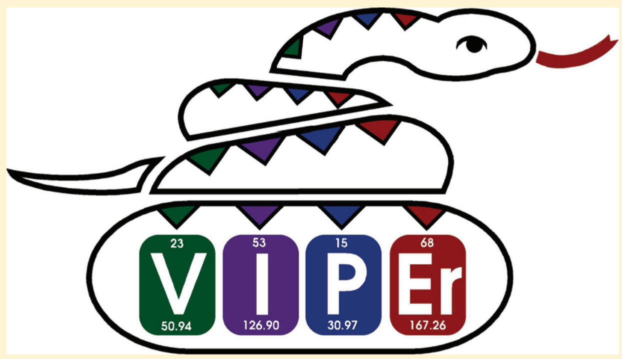
[∥]Department of Chemistry, Rollins College, Winter Park, Florida 32789, United States

[⊥]Department of Chemistry, University of Rochester, Rochester, New York 14627, United States

[#]Department of Chemistry and Biochemistry, DePauw University, Greencastle, Indiana 46135, United States

[∇]Department of Chemistry, Harvey Mudd College, Claremont, California 91711, United States

ABSTRACT: Four Virtual Inorganic Pedagogical Electronic Resource (VIPEr) learning objects featuring organometallic chemistry are highlighted.



KEYWORDS: *Graduate Education/Research, Second-Year Undergraduate, Upper-Division Undergraduate, Inorganic Chemistry, Organic Chemistry, Computational Chemistry, Crystals/Crystallography, MO Theory, Periodicity/Periodic Table*

The contemporary importance of organometallic chemistry is well appreciated. In the past decade alone, three Nobel Prizes have been awarded in this area.[1−3] Alas, in the undergraduate curriculum, organometallic chemistry often gets short shrift. It may be taught hurriedly at the end of a one-semester introductory inorganic course, or it may be given slightly more in-depth treatment in an advanced inorganic or organic chemistry course. Because the field of inorganic chemistry includes topics ranging from solids to siderophores, organometallic chemistry may lie outside of many instructors' comfort zones or they might benefit from seeing how organometallic chemists present the topic in their own classes. Virtual Inorganic Pedagogical Electronic Resource (VIPEr) was founded as a virtual space where specialists in all of the subfields of inorganic chemistry could come together to share teaching materials and discuss pedagogical approaches to teaching this subject.[4] The VIPEr Web site features exemplary teaching materials.[5]

This report highlights teaching materials, specifically learning objects, in the field of organometallic chemistry. Organometallic chemistry introduces students to a new world of "sandwich" compounds, olefin complexes, carbenes, oxidative addition reactions, and more. Many students encounter metal−carbon bonding for the first time. Students must master electron counting in order to be able to write reasonable mechanisms for organometallic reactions; students must also understand the orbitals and energies of both the metal and the organic fragment in order to understand bonding. They must learn to write sophisticated catalytic cycles for seemingly disparate chemical reactions such as polymerization, metathesis, and carbon−carbon bond formation.

Surprisingly few papers in the *Journal* provide examples of how to introduce organometallic chemistry in a setting other than the laboratory. Since 2001, when Knowles, Noyori, and Sharpless received their Nobel Prize for their work on chirally catalyzed hydrogenation and oxidation reactions,[1] only a single *Journal* article has focused on approaches to teaching organometallic chemistry in the lecture classroom.[6] Several articles have provided examples where organometallic compounds have been used to teach other chemical concepts[7−9] or have reviewed classes of organometallic compounds.[10,11] Most activities published in the *Journal* provide examples of incorporating organometallic chemistry in a laboratory course.

Here we present four examples of activities for lecture or discussion. One of the benefits of teaching organometallic

Published: December 20, 2011

© 2011 American Chemical Society and Division of Chemical Education, Inc.

chemistry either late in the semester of an introductory inorganic course or in an advanced course is that it allows the instructor to ask students more integrative, complex chemistry questions, as well as to engage students with the chemical literature. The organometallic learning objects discussed represent such advanced approaches. In Organometallics and Named Reactions,[12] Goj uses named reactions as a vehicle to engage students with the chemical literature. Holland's Electron Counting and a Catalytic Reaction[13] is an exercise in electron counting and catalytic cycles. Eppley's Bonding and Electronic Structure of a 14-electron W(II) bound to 4-electron π-donors[14] uses a paper from the chemical literature to teach students about π-complexes while building on their electron counting abilities. Finally, Johnson describes a fun and challenging outdoor activity where students must integrate their knowledge of electron counting and reaction mechanism in Catalytic Cycles and Artistry: Chalk Drawing 101.[15]

■ ORGANOMETALLICS AND NAMED REACTIONS

Organometallics and Named Reactions[12] was developed as an in-class activity to introduce students to the synthetic utility of a variety of transition metal complexes while developing students' research and communication skills. The three learning outcomes are (i) students will be able to use SciFinder Scholar to perform a basic literature search; (ii) students will be able to describe a reaction in terms of the substrate, reagents used, products formed, and overall bond breakage and bond formation; and (iii) students will improve their visual and oral communication skills. Students are provided with a choice of 30 named reactions and instructions on the expected content and format of the in-class presentation.

This learning object is suitable for a second-semester or more advanced organic course, as well as an inorganic chemistry course offered after the general chemistry sequence. With organic chemistry students, the instructor would encourage the students to compare and contrast the organometallic reagents with the classic organic methods that they are currently learning. In an inorganic chemistry course, the instructor would steer the discussion toward the choice of ligands, electron counting, and possible mechanisms. A brief description of the activity, learning goals, implementation strategy with assessment methods, and the student handout are available on the VIPEr Web site.[12]

■ ELECTRON COUNTING AND A CATALYTIC REACTION

Electron Counting and a Catalytic Reaction[13] was developed to give small groups of students an opportunity to practice the calculation of formal oxidation states and total electron counts. Students debate their answers within groups and together correct common misconceptions using four related rhodium complexes. These complexes were specifically chosen because they are a part of a well-known catalytic cycle—the Monsanto acetic acid process. By looking at the reactions in each step, students also are exposed to some of the fundamental ideas in catalysis. This exercise enables the students to discover the rationale behind the terms "oxidative addition" and "reductive elimination" by using the logic of electron counting.

This activity is designed for an advanced undergraduate inorganic chemistry course. In a single activity, students work with classmates to see catalytic cycles and basic organometallic mechanisms, while practicing electron counting. The learning object on the VIPEr Web site includes a description of the activity and a handout for students.[13]

■ BONDING AND ELECTRONIC STRUCTURE OF A 14-ELECTRON W(II) BOUND TO 4-ELECTRON π-DONORS

Bonding and Electronic Structure of a 14-electron W(II) bound to 4-electron π-donors[14] was developed collaboratively by Hilary Eppley at DePauw University, Joanne Stewart at Hope College, and Margret Geselbracht at Reed College. The goal of this activity was to use an article from the primary literature to facilitate the discussion of bonding modes for π-ligands. After learning about electron counting and the interaction of π-ligands with metal orbitals, students read a *J. Am. Chem. Soc.* communication by Jackson and co-workers that dealt with modes of bonding in π-ligands that the students had not seen before.[16] Student learning goals for the activity include being able to count electrons, describe the molecular orbitals involved in 4 e^- π-bonding to alkynes or nitriles, and explain the structural parameters and bonding in 4 e^- complexes of imines, ketones, and aldehydes. The learning object also broadens students' perspectives on science by requiring them to connect the science in the paper to overall research goals, locate additional information about the article's authors, and place the work within the context of a larger body of work by the author.

This learning object was used in the organometallics unit of a junior−senior level inorganic chemistry course and is appropriate for advanced students. The literature discussion is assigned about one week ahead of time and requires one class period to complete. The learning object on the VIPEr Web site consists of a link to the original literature article, learning goals, a downloadable handout of discussion questions, and some tips and common problems encountered by the students.[14]

■ CATALYTIC CYCLES AND ARTISTRY: CHALK DRAWING 101

Catalytic Cycles and Artistry[15] was developed to close the organometallics unit in an inorganic chemistry course. After teaching electron counting and major catalytic reactions and illustrating several important catalytic cycles, the teacher has the students spend one day drawing mechanisms on the sidewalk. The students work in groups of three to five, and work to propose reasonable mechanisms for catalytic reactions given the substrate, product, and catalyst identities. Student learning outcomes include (i) to understand the cyclic nature of catalysis; (ii) to apply knowledge of basic mechanistic steps to a new problem; and (iii) to propose a realistic mechanism based on elementary reactions. These activities prepare students to answer questions in which they need to either propose a mechanism or identify elementary reaction steps.

This activity is designed for students in a junior−senior level course in advanced inorganic chemistry. Each catalytic cycle requires about 20 min to complete. The learning object on the VIPEr Web site consists of a brief description of the activity, learning goals, a downloadable handout, and some tips and common problems encountered by the students.[15] The answer key is also available for faculty who log in to the site.

■ AUTHOR INFORMATION

Corresponding Author

*E-mail: reisneba@jmu.edu.

ACKNOWLEDGMENTS

The National Science Foundation (DUE-0737030) is acknowledged for funding the development of VIPEr.

REFERENCES

(1) The Nobel Prize in Chemistry 2001. http://nobelprize.org/nobel_prizes/chemistry/laureates/2001/ (accessed Dec 2011).

(2) The Nobel Prize in Chemistry 2005. http://nobelprize.org/nobel_prizes/chemistry/laureates/2005/ (accessed Dec 2011).

(3) The Nobel Prize in Chemistry 2010. http://nobelprize.org/nobel_prizes/chemistry/laureates/2010/ (accessed Dec 2011).

(4) Virtual Inorganic Pedagogical Electronic Resource. http://www.ionicviper.org/ (accessed Dec 2011).

(5) Benatan, E.; Eppley, H. J.; Geselbracht, M. J.; Johnson, A. R.; Reisner, B. A.; Stewart, J. L.; Watson, L.; Williams, B. S. *J. Chem. Educ.* **2009**, *86*, 766–767.

(6) Duncan, A. P.; Johnson, A. R. *J. Chem. Educ.* **2007**, *84*, 443–446.

(7) Cass, M. E. *J. Chem. Educ.* **2004**, *81*, 1144–1146.

(8) Steinborn, D. *J. Chem. Educ.* **2004**, *81*, 1148–1154.

(9) Battle, G. M.; Allen, F. H.; Ferrence, G. M. *J. Chem. Educ.* **2010**, *87*, 813–818.

(10) Grimes, R. N. *J. Chem. Educ.* **2004**, *81*, 657–672.

(11) Bowman, D. C. *J. Chem. Educ.* **2006**, *83*, 735–739.

(12) Goj, L. A. *Organometallics and Named Reactions VIPEr Learning Object.* https://www.ionicviper.org/class-activity/organometallics-and-named-reactions (accessed Dec 2011).

(13) Holland, P. L. *Electron Counting and a Catalytic Reaction VIPEr Learning Object.* https://www.ionicviper.org/class-activity/electron-counting-and-catalytic-reaction (accessed Dec 2011).

(14) Eppley, H. J. *Bonding and Electronic Structure of a 14-electron W(II) bound to 4-electron pi-donors VIPEr Learning Object.* https://www.ionicviper.org/literature-discussion/bonding-and-electronic-structure-14-electron-w-ii-bound-4-electron-pi-donors (accessed Dec 2011).

(15) Johnson, A. R. *Catalytic Cycles and Artistry: Chalk Drawing 101 VIPEr Learning Object.* https://www.ionicviper.org/class-activity/catalytic-cycles-and-artistry-chalk-drawing-101 (accessed Dec 2011).

(16) Jackson, A. B.; Schauer, C. K.; White, P. S.; Templeton, J. S. *J. Am. Chem. Soc.* **2007**, *129*, 10628–10629.