THE OHIO STATE UNIVERSITY

CHEMISTRY 6086 –Advanced Chemistry Knowledge for Educators: Atomic Structure, Energy, and Quantum Mechanics.

5 Credit hours

Available: May 12- July 30; May 12- July 2; June 8- July 30

Instructor Information

Instructor:	Dr. Ted M. Clark	Office:	N/A
Email:	Clark.789@osu.edu	Office Hours:	By arrangement

Course Description: For professionals and educators seeking an advanced understanding of General Chemistry content knowledge with consideration of how this understanding informs teaching and learning in College Credit Plus Chemistry courses. Topics typically found in the first semester of General Chemistry will be investigated, including scientific measurement and error analysis, the historical underpinnings of atomic structure leading to a quantum mechanical model, and thermodynamics and energy

Prerequisites: Enrollment in Advanced Chemistry Knowledge for Educators Certificate Program.

Required General Chemistry Textbooks

- Chemistry, The Central Science (14th Ed.) electronic textbook by Brown, LeMay, Bursten, Murphy, Woodward, & Stoltzfus, paired with the online homework system MasteringChemistry, will be provided.

How This Course Works

Mode of delivery: This course is 100% online. There are not required sessions when you must be logged in to Carmen at a scheduled time.

Pace of online activities: The course is divided into modules which are completed in order. The suggested schedule provides guidance for completing all of the assignments in the available time.

8 week course	Course Module & Assignment	Within Module	Lesson Plan	Reflection Paper
Week 1	Topic 0, Introduction	X	--	--
Week 1	Topic 1, Measurement	X	X	X
Week 2	Topic 2, Atomic structure	X	X	X
Week 3	Topic 3, Stoichiometry & Reactions	X	X	X
Week 4 & 5	Topic 4, Thermodynamics & Energy	X	X	X
Week 6	Topic 5, Quantized Energy	X	X	X
Week 7	Topic 6, Quantum Mechanics	X	X	X
Week 8	Revise & Resubmit Assignments	--	--	--

Each module includes **Instructional** resources, **Chemical Education** resources, and **Deeper Dive** content. Students will complete tasks within each area, but will frequently be able to choose material that interests them. Available content is listed at the end of this syllabus.

Credit hours and work expectations: This is a 5-credit-hour course. According to OSU guidelines, expect to spend 15-20 hours on coursework/week to receive an average grade. In this graduate course an average grade is a B grade.

Attendance and participation: Attendance is based on your online activity. During most weeks you will probably log in to the course in Carmen multiple times. Office hours and any live sessions are optional.

Discussion forum: Students will use a program (called Perusall) to annotate and discuss class readings. This is a place where you can share ideas, comments, and questions with the instructor and your classmates.

Course Objectives

Upon successful completion of this course, you should:

- Synthesize methods, practices, and resources appropriate for teaching undergraduate General Chemistry with a deep understanding of fundamental topics that inform pedagogical decisions.
- Demonstrate an awareness of the range and depth of topics in undergraduate General Chemistry courses, along with mastery of these topics.
- Adapt educational resources to support General Chemistry instruction based on one's learning objectives and the setting in which the resources are to be used.
- Use primary research articles to connect an advanced understanding of scientific ideas with their teaching and learning in General Chemistry.

Grading

Grades are based on completion-based tasks within a module, including surveys, quizzes, and article annotations (50% of total score), and Lesson Plans and Reflection Papers (combined 50%).

A > 92%   A- = 90.0 – 91.9%

B+ = 88.0 – 89.9%   B = 82.0 – 87.9%   B- = 80.0 – 81.9%

C+ = 78.0 – 79.9%   C = 75.0 – 77.9%

Course Information & Policies

Title IV Attendance Requirement: Federal policy requires that attendance for all university students be verified during the first week of classes

STANDARDS OF ACADEMIC CONDUCT IN GENERAL CHEMISTRY

Violations of academic standards in General Chemistry will be referred to the University Committee of Academic Misconduct (COAM) as required by Faculty Rules. It is the responsibility of COAM to investigate all reported cases of student academic misconduct; illustrated by, but not limited to, cases of plagiarism and any dishonest practices in connection with examinations, quizzes, and graded assignments. Instructors shall report all instances of alleged academic misconduct to the committee (Faculty Rule 3335-5-487). For additional information see the Code of Student Conduct: studentlife.osu.edu/csc

Student Responsibilities: *Any graded material must represent your own work.* Unauthorized group efforts by students, use of another student's course materials, or assistance from individuals who already have taken the course, could place you in jeopardy of violation of the standards for the course. In some courses, group work is acceptable on certain activities (as explicitly stated by your instructor). In these cases, it is important that you know and understand where authorized collaboration (working in a group) ends and collusion (working together in an unauthorized manner) begins. Identical answers indicate copying or unacceptable group efforts - always answer questions in your own unique words. It is important that you consult with your instructor for clarification on whether or not collaboration is appropriate on an activity. *You should not assist others in violating academic standards*. Students supplying materials for others to "look at" may be charged with academic misconduct.

Commitment to Diversity: The Department of Chemistry and Biochemistry promotes a welcoming and inclusive environment for all students and staff, regardless of race, gender, ethnicity, national origin, disability or sexual orientation. There is no tolerance for hateful speech or actions. All violations of this policy should be reported to the OSU Bias Assessment and Response Team (BART, studentaffairs.osu.edu/bias). The Department encourages diversity at all levels, particularly among the next generation of scientists. Students are encouraged to participate in organizations that provide support specifically for science and engineering students who are African-American, Asian, disabled, Hispanic, LGBTQ or women. These organizations are listed on the Colleges of Arts and Sciences (artsandsciences.osu.edu/stem-organizations) and Engineering (engineering.osu.edu/studentorgs) websites.

Disability Services: The University strives to make all learning experiences as accessible as possible. If you anticipate or experience academic barriers based on your disability (including mental health, chronic or temporary medical conditions), reasonable accommodations can be established. Students should first register with Student Life Disability Services, then meet with the General Chemistry SLDS Coordinator in the Undergraduate Studies Office (Holly Wheaton) who will assist you in establishing your accommodations in the course.

Contact SLDS
Email: slds@osu.edu
Phone: 614-292-3307
Address: 098 Baker Hall
Website: slds.osu.edu

Contact Holly Wheaton
Email: genchem@osu.edu
Phone:614-292-6009
Address:110 Celeste Lab

Available Course Content

Topic 1. Introduction to Matter and Measurement

Instructional

Readings	**Video**
Chapter 1. Matter, Energy, and Measurement. Brown, T. L., LeMay, H. E., Bursten, B. E., Murphy, C.J., Woodward, P.M., Stoltzfus, M.W. (2018). *Chemistry: the central science, 14th edition,* Englewood Cliffs, NJ: Prentice Hall. Chapter 1 Reading Guide	Chapter 1, Part 1. Chapter 1, Part 2.

Chemical Education

Readings	**Video**
Metz, P. A., & Pribyl, J. R. (1995). Measuring with a purpose: Involving students in the learning process. *Journal of chemical education*, *72*(2), 130. Pacer, R. A. (2000). How can an instructor best introduce the topic of significant figures to students unfamiliar with the concept? *Journal of Chemical Education*, *77*(11), 1435. Caballero, J. F., & Harris, D. F. (1998). There seems to be uncertainty about the use of significant figures in reporting uncertainties of results. *Journal of chemical education*, *75*(8), 996. Clark, T. M., Cervenec, J., & Mamais, J. (2011). "The Price is Right" for Your Classroom. *Journal of Chemical Education*, *88*(4), 428-431. Crute, T. D. (2005). Teaching significant figures using age conversions. *Journal of Chemical Education*, *82*(10), 1507.	Chemical Education Research: Measurement.

Deeper Dive

Readings	**Video**
Harvey, D. (2000). Chapter 4 Evaluating Analytical Data, in *Modern analytical chemistry; Chapter 4A-4C*. Boston: McGraw-Hill Companies, Inc.	Evaluating Analytical Data
Buffler, A., Lubben, F., & Ibrahim, B. (2009). The relationship between students' views of the nature of science and their views of the nature of scientific measurement. *International Journal of Science Education*, *31*(9), 1137-1156. Allie, S., Buffler, A., Lubben, F., & Campbell, B. (2001). Point and set paradigms in students' handling of experimental measurements. In *Research in Science Education-Past, Present, and Future* (pp. 331-336). Springer, Dordrecht.	Nature of Science and the Point-Set Paradigm for Measurement

Topic 2. Atomic Structure

Instructional

Readings	Video
Chapter 2. Atoms, Molecules, and Ions. Brown, T. L., LeMay, H. E., Bursten, B. E., Murphy, C.J., Woodward, P.M., Stoltzfus, M.W. (2018). *Chemistry: the central science, 14th edition,* Englewood Cliffs, NJ: Prentice Hall. Chapter 2 Reading Guide	Chapter 2, Part 1. Chapter 2, Part 2.

Chemical Education

Readings	Video
Gilbert, T. R., Kirss, R. V., Foster, N., & Davies, G. (2013). Chapter 2, in *Chemistry: The science in context*. *Chapter 2*. WW Norton & Company.	Inclusion of Mass Spectrometry in General Chemistry
Pearson, E. F. (2005). Revisiting Millikan's oil-drop experiment. *Journal of chemical education*, *82*(6), 851.	

Deeper Dive

Readings	Video
Weinberg, S. (1990). Cathode Rays, in *The Discovery of Subatomic Particles*	Thomson and Cathode Rays The Plum Pudding Model, Part 1. The Plum Pudding Model, Part 2.
Crease, R.P. (2004). Chapter 8. Seeing the electron: Millikan's Oil-Drop Experiment, in *The Prism and the Pendulum: The Ten Most Beautiful Experiments in Science*. Jennings, R. C. (2004). Data selection and responsible conduct: Was Millikan a fraud? *Science and engineering ethics*, *10*(4), 639-653.	Millikan's Oil Drop Experiment
Crease, R.P. (2004). Chapter 9. Dawning Beauty: Rutherford's Discovery of the Atomic Nucleus, in *The Prism and the Pendulum: The Ten Most Beautiful Experiments in Science.* Weinberg, S. (1990). The Discovery of the Nucleus, in *The Discovery of Subatomic Particles.* Weinberg, S. (1990). Radioactivity, in *The Discovery of Subatomic Particles.* Weinberg, S. (1990). Appendix J, Rutherford Scattering, in *The Discovery of Subatomic Particles.*	Rutherford's Investigation of Radioactivity and Scattering
Knight, R. D. (2017). Chapter 37. The foundations of modern physics, in *Physics for scientists and engineers*. Pearson Higher Ed..	

Topic 3. Stoichiometry and Aqueous Reactions

Instructional

Readings	**Video**
Chapter 3. Chemical Reactions and Reaction Stoichiometry and Chapter 4. Reactions in Aqueous Solutions, in Brown, T. L., LeMay, H. E., Bursten, B. E., Murphy, C.J., Woodward, P.M., Stoltzfus, M.W. (2018). *Chemistry: the central science, 14th edition,* Englewood Cliffs, NJ: Prentice Hall. Chapter 3 and Chapter 4 Reading Guides	Chapter 3, Part 1. Chapter 3, Part 2. Chapter 4, Part 1. Chapter 4, Part 2. Chapter 4, Part 3.

Chemical Education

Readings	**Video**
Gulacar, O., Eilks, I., & Bowman, C. R. (2014). Differences in general cognitive abilities and domain-specific skills of higher-and lower-achieving students in stoichiometry. *Journal of Chemical Education*, *91*(7), 961-968. Taskin, V., & Bernholt, S. (2014). Students' Understanding of Chemical Formulae: A review of empirical research. *International Journal of Science Education*, *36*(1), 157-185 Horvat, S., Segedinac, M. D., Milenković, D. D., & Hrin, T. N. (2016). Development of procedure for the assessment of cognitive complexity of stoichiometric tasks. *Macedonian Journal of Chemistry and Chemical Engineering*, *35*(2), 275-284.	Stoichiometry and a Particle-Level Representation
Taasoobshirazi, G., & Glynn, S. M. (2009). College students solving chemistry problems: A theoretical model of expertise. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *46*(10), 1070-1089. Heckler, A. F. (2011). 8 The Ubiquitous Patterns of Incorrect Answers to Science Questions: The Role of Automatic, Bottom-up Processes. *Psychology of Learning and Motivation-Advances in Research and Theory*, *55*, 227.	Approaches for Solving Acid-Base Problems: What do Successful and Unsuccessful Students Do?

Deeper Dive

Readings	**Video**
	Conductivity of Aqueous Solutions
Suchocki, J. A. (2013). Chapter 3 Discovering the Atom and Subatomic Particles, in *Conceptual chemistry*. Pearson Higher Ed. Nash, L. K. (1950). *The atomic-molecular theory* (Vol. 4). Harvard University Press. Weinberg, S. (1990). The atomic scale, in *The Discovery of Subatomic Particles.*	Atoms & Stoichiometry for Dalton & Gay-Lussac Avogadro's Hypothesis and Specific Heat The Dumas Method, Greater Uncertainty, & Cannizzaro's Solution.

Topic 4. Thermodynamics and Energy

Instructional

Readings	Video
Chapter 5. Thermochemistry. Brown, T. L., LeMay, H. E., Bursten, B. E., Murphy, C.J., Woodward, P.M., Stoltzfus, M.W. (2018). *Chemistry: the central science, 14th edition.* Chapter 5 Reading Guide	Chapter 5, Part 1. Chapter 5, Part 2.

Chemical Education

Readings	Video
Galley, W. C. (2004). Exothermic bond breaking: A persistent misconception. *Journal of chemical education*, *81*(4), 523. Doige, C. A., & Day, T. (2012). A typology of undergraduate textbook definitions of 'heat' across science disciplines. *International Journal of Science Education*, *34*(5), 677-700. Cooper, M. M., & Klymkowsky, M. W. (2013). The trouble with chemical energy: Why understanding bond energies requires an interdisciplinary systems approach. *CBE—Life Sciences Education*, *12*(2), 306-312. Becker, N. M., & Cooper, M. M. (2014). College chemistry students' understanding of potential energy in the context of atomic–molecular interactions. *Journal of Research in Science Teaching*, *51*(6), 789-808. Nilsson, T., & Niedderer, H. (2014). Undergraduate students' conceptions of enthalpy, enthalpy change and related concepts. *Chemistry Education Research and Practice*, *15*(3), 336-353. Nagel, M. L., & Lindsey, B. A. (2015). Student use of energy concepts from physics in chemistry courses. *Chemistry Education Research and Practice*, *16*(1), 67-81. Kohn, K. P., Underwood, S. M., & Cooper, M. M. (2018). Energy connections and misconnections across chemistry and biology. *CBE—Life Sciences Education*, *17*(1), ar3.	Investigating Potential, Kinetic, and Internal Energy with PhET sims

Deeper Dive

Readings	Video
Crease, R.P. (2009). Chapter 5. The Scientific Equivalence of Shakespeare: The Second Law of Thermodynamics, in *The Great Equations: Breakthroughs in Science from Pythagoras to Heisenberg.*	Reversible PV Work
Noggle, J.H.(1980) Chapter 1 Properties of Matter, in *Physical Chemistry, 2nd edition.* Noggle, J.H.(1980) Appendix II Partial Derivatives, in *Physical Chemistry, 2nd edition*	States, State Functions, & Equations of State.
Noggle, J.H.(1980) Chapter 2 The First Law of Thermodynamics, in *Physical Chemistry, 2nd edition.*	What is Enthalpy? Explaining and **Predicting** Heat Capacity Values.

Topic 5 Quantized Energy and the Electronic Structure of Atoms

Instructional

Readings	**Video**
Chapter 6. Electronic Structure, in Brown, T. L., LeMay, H. E., Bursten, B. E., Murphy, C.J., Woodward, P.M., Stoltzfus, M.W. (2018). *Chemistry: the central science, 14th edition.* Chapter 6 Reading Guide	Chapter 6, Part 1. Chapter 6, Part 2.

Chemical Education

Readings	**Video**
Crease, R.P. (2004). Chapter 6. Light a wave: Young's lucid analogy, in *The Prism and the Pendulum: The Ten Most Beautiful Experiments in Science.*	Waves and Wave Interference Wave Particle-Duality
Moore, E. B., Chamberlain, J. M., Parson, R., & Perkins, K. K. (2014). PhET interactive simulations: Transformative tools for teaching chemistry. *Journal of Chemical Education*, *91*(8), 1191-1197. McKagan, S. B., Perkins, K. K., & Wieman, C. E. (2008). Why we should teach the Bohr model and how to teach it effectively. *Physical Review Special Topics-Physics Education Research*, *4*(1), 010103. Clark, T. M., & Chamberlain, J. M. (2014). Use of a PhET interactive simulation in general chemistry laboratory: Models of the hydrogen atom. *Journal of Chemical Education*, *91*(8), 1198-1202.	
Goldhaber, A.S. and Crease, R.P. (2014). Max Planck Introduces the Quantum, in *The Quantum Moment: How Planck, Bohr, Einstein, and Heisenberg Taught Us to Love Uncertainty*.	Introduction to Black-body Radiation

Deeper Dive

Readings	**Video**
Baggott, J. (2011). Chapter 1 The most strenuous work in my life, in *The Quantum Story: A History in 40 Moments,* Oxford University Press. Kuhn, T. S. (1987). Afterword: Revisiting Planck, in *Black-body theory and the quantum discontinuity, 1894-1912*. University of Chicago Press.	Black-body Radiation
Baggott, J. (2011). Chapter 2 Annus mirabilis; Chapter 3 A little bit of reality; Chapter 4 la Comedie Francais; Chapter 5 A Strangely Beautiful Interior in *The Quantum Story: A History in 40 Moments,* Oxford University Press.	
Wheaton, B. R. (1978). Philipp Lenard and the photoelectric effect, 1889-1911. *Historical Studies in the Physical Sciences*, *9*, 299-322.	Particles and Light, Part 1
Stuewer, R. H. (1970). Non-Einsteinian interpretations of the photoelectric effect. Millikan, R. A. (1916). A direct photoelectric determination of Planck's" h". *Physical Review*, *7*(3), 355. Knight, R. D. (2017). Chapter 39. Quantization, in *Physics for scientists and engineers*. Pearson Higher Ed.	Particles and Light, Part 2

Topic 6. Quantum Mechanics

Instructional

Chapter 6. Electronic Structure, continued, in Brown, T. L., LeMay, H. E., Bursten, B. E., Murphy, C.J., Woodward, P.M., Stoltzfus, M.W. (2018). *Chemistry: the central science, 14th edition.*	Chapter 6, Hydrogen atom

Chemical Education

Readings	**Video**
Dick-Perez, M., Luxford, C. J., Windus, T. L., & Holme, T. (2016). A quantum chemistry concept inventory for physical chemistry classes. *Journal of Chemical Education*, *93*(4), 605-612. Niaz, M., & Fernandez, R. (2008). Understanding quantum numbers in general chemistry textbooks. *International Journal of Science Education*, *30*(7), 869-901. Shiland, T. W. (1997). Quantum mechanics and conceptual change in high school chemistry textbooks. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *34*(5), 535-545. Taber, K. S. (2005). Learning quanta: Barriers to stimulating transitions in student understanding of orbital ideas. *Science Education*, *89*(1), 94-116. Tsaparlis, G., & Papaphotis, G. (2002). Quantum-chemical concepts: Are they suitable for secondary students? *Chemistry Education Research and Practice*, *3*(2), 129-144.	

Deeper Dive

Readings	**Video**
	Atomic model: Bohr to de Broglie Particle in a Box (de Broglie) Particle in a Box (Schrödinger) Particle in a Box: Applications and Implications
Crease, R.P. (2009). Chapter 9. "The Basic Equation of Quantum Theory": Schrödinger's Equation, in *The Great Equations: Breakthroughs in Science from Pythagoras to Heisenberg.* Crease, R.P. (2004). Chapter 10. The only mystery: The quantum interference of single electrons, in *The Prism and the Pendulum: The Ten Most Beautiful Experiments in Science*.	Wavefunctions & Quantum Numbers
	Depicting Atomic Orbitals
Niaz, M., & Cardellini, L. (2011). What Can the Bohr− Sommerfeld Model Show Students of Chemistry in the 21st Century?. *Journal of Chemical Education*, *88*(2), 240-243.	Quantum numbers & Angular momentum
	Magnetic quantum number and the Zeeman Effect
Friedrich, B., & Herschbach, D. (2003). Stern and Gerlach: How a bad cigar helped reorient atomic physics. *Physics Today*, *56*(12), 53-59.	Spin

Baggott, J. (2011). Chapter 5 A strangely beautiful interior; Chapter 6 The self-rotating electron; Chapter 7 A late erotic outburst; Chapter 8 Ghost field; Chapter 9 All this damned quantum jumping; Chapter 10 The uncertainty principle; Chapter 11 The 'Kopenhagener Geist', in *The Quantum Story: A History in 40 Moments,* Oxford University Press.	
Herbert, N. (1993). Chapter 5. Quantum reality: What do we suppose matter really looks like?, in *Elemental mind: Human consciousness and the new physics*. New York: Dutton.	