



Indiana Content Standards for Educators

SCIENCE—CHEMISTRY

Chemistry teachers are expected to have a broad and comprehensive understanding of the knowledge and skills needed for this educator license, and to use that knowledge to help students prepare for the challenges and opportunities of the twenty-first century. This requires the ability to identify, comprehend, analyze, synthesize, and evaluate the basic principles, fundamental concepts, and essential content defined in these standards, and to apply that knowledge to the tasks of planning and delivering effective instruction and assessment.

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Chemistry teachers have a broad and comprehensive understanding of the nature of science and the processes of scientific inquiry.

Standard 2: Central Concepts and Connections in Science

Chemistry teachers have a comprehensive understanding of the core ideas in other science disciplines and of the relationships between science, engineering, technology, and society.

Standard 3: Atomic Structure

Chemistry teachers have a broad and comprehensive understanding of the structure of atoms.

Standard 4: The Properties of Matter

Chemistry teachers have a broad and comprehensive understanding of the states of matter and their characteristic properties.

Standard 5: Chemical Bonding

Chemistry teachers have a broad and comprehensive understanding of the principles of chemical bonding and the characteristics of intermolecular forces.

Standard 6: Chemical Reactions

Chemistry teachers have a broad and comprehensive understanding of common inorganic chemical reaction types and the principles of chemical reactivity.

Standard 7: Thermochemistry

Chemistry teachers have a broad and comprehensive understanding of the laws of thermodynamics and how they apply to chemical systems.

Standard 8: Organic Chemistry and Biochemistry

Chemistry teachers have a broad and comprehensive understanding of organic chemistry and biochemistry.

Standard 9: Science Instruction and Assessment

Chemistry teachers have a broad and comprehensive understanding of content-specific instruction and assessment in science.

The Indiana Educator Standards for Science—Chemistry describe the knowledge and skills that teachers need to help students achieve the learning outcomes defined by the Indiana Revised Academic Standards for Science Grade 5–Grade 8, Chemistry I, and Integrated Chemistry and Physics. The Indiana Academic Standards can be found [here](#).

Standard 1: The Nature and Processes of Science

Chemistry teachers have a broad and comprehensive understanding of the nature of science and the processes of scientific inquiry, including:

- 1.1 the characteristics, assumptions, and goals of science
- 1.2 the tentative nature of scientific knowledge, which is subject to change as new evidence, new tools, or new ways of thinking become available
- 1.3 the formulation of testable hypotheses and the principles and procedures for designing and conducting scientific investigations
- 1.4 common tools, materials, and technology used in chemistry investigations
- 1.5 the collection, organization, analysis, interpretation, and communication of scientific data, including the use of technology
- 1.6 the safe execution of laboratory exercises and safe storage and disposal of chemicals
- 1.7 the role and applications of mathematics in science
- 1.8 the characteristics and uses of various sources of scientific information and the evaluation of scientific information, claims, and arguments
- 1.9 the role of peer review and critical evaluation of the results of scientific investigations, models, and explanations

Standard 2: Central Concepts and Connections in Science

Chemistry teachers have a comprehensive understanding of the core ideas in other science disciplines and of the relationships between science, engineering, technology, and society, including:

- 2.1 the unifying concepts and processes that cut across the sciences and engineering
- 2.2 the basic concepts and major principles of life science
- 2.3 the basic concepts and major principles of physics
- 2.4 the basic concepts and major principles of Earth and space science
- 2.5 the basic characteristics, principles, and goals of the engineering, or technological, design process
- 2.6 the interconnections between the various disciplines of science
- 2.7 the interrelationships between science and technology
- 2.8 the social, cultural, and ethical aspects of science and technology
- 2.9 the historical development of important ideas in science from different periods and cultures

Standard 3: Atomic Structure

Chemistry teachers have a broad and comprehensive understanding of the structure of atoms, including:

- 3.1 the mass, charge, and arrangement of subatomic particles
- 3.2 historical and contemporary models of atomic structure
- 3.3 electron configurations of atoms and ions and the relationship to chemical behavior
- 3.4 the relationship between subatomic particles and the organization of the periodic table
- 3.5 periodic trends in physical and chemical properties
- 3.6 the properties of radioactive materials, including nuclear stability, half-life, and the types of emissions resulting from radioactive decay
- 3.7 the nature of nuclear reactions and the processes of fission and fusion

Standard 4: The Properties of Matter

Chemistry teachers have a broad and comprehensive understanding of the states of matter and their characteristic properties, including:

- 4.1 the principles of kinetic molecular theory
- 4.2 the movement, arrangement, and interaction of particles in the solid, liquid, gas, and plasma states of matter
- 4.3 the characteristics of elements, molecules, ions, compounds, and mixtures
- 4.4 the chemical and physical properties of matter and the nature of chemical and physical changes of matter
- 4.5 the application of the gas laws to chemical systems
- 4.6 the composition of solutions, suspensions, and colloids
- 4.7 the colligative properties of solutions, the factors that affect solubility, and units of concentration
- 4.8 the rules of nomenclature for inorganic substances

Standard 5: Chemical Bonding

Chemistry teachers have a broad and comprehensive understanding of the principles of chemical bonding and the characteristics of intermolecular forces, including:

- 5.1 the characteristics of ionic bonds, covalent bonds, and metallic bonds and the principles of chemical bonding
- 5.2 the use of Lewis structures to represent the chemical bonding in a molecule
- 5.3 the application of the valence-shell electron-pair repulsion model (VSEPR), valence bond theory, and molecular orbital theory
- 5.4 the determination of molecular geometry of molecules and ions
- 5.5 the characteristics of different types of intermolecular forces such as dipole-dipole, dispersion, and hydrogen bonding
- 5.6 the relationship between intermolecular forces and the properties of matter

Standard 6: Chemical Reactions

Chemistry teachers have a broad and comprehensive understanding of common inorganic chemical reaction types and the principles of chemical reactivity, including:

- 6.1 the basic types of inorganic chemical reactions and the possible indications of a chemical reaction
- 6.2 the mole concept and its use in chemical calculations such as limiting reagents, theoretical yield, and percent yield
- 6.3 the law of conservation of mass and its application in balancing chemical equations
- 6.4 collision theory and the factors that affect reaction rates
- 6.5 chemical kinetics, including reaction rates, rate constants, rate laws, reaction order, and basic reaction mechanisms
- 6.6 the dynamic nature of chemical equilibrium, equilibrium constants, and the factors that affect chemical equilibrium
- 6.7 the Arrhenius, Brønsted-Lowry, and Lewis definitions of acids and bases and the determination of pH and pOH of strong and weak acids and bases
- 6.8 the workings of buffer systems and the principles and applications of acid-base titration
- 6.9 the principles and applications of electrochemistry, including electrolytic and galvanic cells, cell potentials, and cell equilibrium

Standard 7: Thermochemistry

Chemistry teachers have a broad and comprehensive understanding of the laws of thermodynamics and how they apply to chemical systems, including:

- 7.1 the principles and applications of the three laws of thermodynamics
- 7.2 forms of energy and the transformation of energy from one form to another
- 7.3 the concepts of heat and temperature
- 7.4 the use of calorimetry to determine the amount of heat absorbed or released in chemical reactions and physical processes
- 7.5 the energy changes associated with the formation and breaking of chemical bonds
- 7.6 the energy changes associated with chemical reactions and physical processes
- 7.7 free energy and the spontaneity of chemical reactions

Standard 8: Organic Chemistry and Biochemistry

Chemistry teachers have a broad and comprehensive understanding of organic chemistry and biochemistry, including:

- 8.1 the chemical bonding characteristics of the carbon atom, including single bonds, hybridization, and multiple bonds
- 8.2 the composition, structure, and properties of organic compounds
- 8.3 the naming of organic compounds and functional groups
- 8.4 the basic types of organic reactions and the reactants and products of common reaction types
- 8.5 cellular respiration, fermentation, photosynthesis, and major anabolic and catabolic pathways
- 8.6 the structure and properties of nucleic acids, amino acids, proteins, carbohydrates, lipids, and polymers and their role in biochemical processes

Standard 9: Science Instruction and Assessment

Chemistry teachers have a broad and comprehensive understanding of content-specific instruction and assessment in science, including:

- 9.1 the Indiana Revised Academic Standards for Science
- 9.2 the National Science Education Standards, the NCATE/NSTA Standards for Science Teacher Preparation, the Common Core State Standards for Literacy: Science and Technical Subjects, and the ISTE National Educational Technology Standards
- 9.3 instructional strategies and resources for promoting students' development of conceptual understanding, inquiry skills, and scientific habits of mind
- 9.4 strategies and skills for planning and designing science instruction, including the use of techniques and approaches that meet the needs of diverse learners
- 9.5 instructional strategies and communication methods that encourage active inquiry, supportive interaction, and collaboration in the science classroom
- 9.6 strategies and resources for promoting students' reading, writing, and mathematics skills in science
- 9.7 strategies and skills for selecting, adapting, and using technological resources to enhance teaching and learning in science
- 9.8 procedures, resources, and guidelines for maintaining a safe science learning environment
- 9.9 strategies and skills for effectively assessing student understanding and mastery of essential science concepts and skills

Selected Bibliography of Standards and Sources Related to Science–Chemistry

State and National Standards and Curriculum Frameworks

1. Indiana Department of Education. (2010). *Indiana revised academic standards for science*. http://www.indianascience.org/files/standards_03_29_10.pdf
2. Council of Chief State School Officers (CCSSO)/National Governors Association (NGA). (2010). *Common core state standards for English language arts & literacy in history/social studies, science, and technical subjects*. http://www.corestandards.org/assets/CCSSI_ELA%20Standards.pdf
3. National Research Council. (1996). *National science education standards*. Washington, DC: The National Academies Press. <http://www.nap.edu/catalog/4962>
4. National Science Teachers Association. (2003). *Standards for science teacher preparation*. <http://www.ncate.org/ProgramStandards/NSTA/NSTStandards.doc>
5. American Association for the Advancement of Science. (1993). *Project 2061: Benchmarks for science literacy*. New York: Oxford University Press. <http://www.project2061.org/publications/bsl/default.htm>
6. International Society for Technology in Education (ISTE). (2008). *National educational technology standards for teachers*. http://www.iste.org/Libraries/PDFs/NETS_for_Teachers_2008_EN.sflb.ashx
7. National Research Council. (2010). *A framework for science education: Preliminary public draft*.

Sources on Science–Chemistry Content

8. American Association for the Advancement of Science and the National Science Teachers Association. *Atlas of science literacy*. Volume 1 (2001) and Volume 2 (2007). Washington, DC: American Association for the Advancement of Science.
9. Schwartz, C. V., Rieser, B., Davis, E., Kenyon, L., Archer, A., Fortus, D., et al. (2009). Developing a learning progression for scientific modeling: Making scientific modeling accessible and meaningful for learners. *Journal of Research in Science Teaching*, 46(6), 632–54.
10. Cooper, M. M., Grove, N., Underwood, S. M., & Klymkowski, M. W. (2010). Lost in Lewis structure: An investigation of student difficulties in developing representational competence. *Journal of Chemical Education*, 87(8), 869–74.

Selected Bibliography of Standards and Sources Related to Science—Chemistry

Sources on Student Learning and Pedagogical Methodology

11. Committee on Science Learning, Kindergarten Through Eighth Grade, National Research Council. (2007). *Taking science to school: Learning and teaching science in grades K–8*. (R. A. Duschl, H. A. Schweingruber, & A. W. Shouse, Eds.). Washington, DC: The National Academies Press.
12. Committee on High School Science Laboratories: Role and Vision, National Research Council. (2006). *America's lab report: Investigations in high school science*. (S. R. Singer, M. L. Hilton, & H. A. Schweingruber, Eds.). Washington, DC: The National Academies Press.
13. Costu, B., Ayas, A., & Niaz, M. (2010). Promoting conceptual change in first year students' understanding of evaporation. *Chemistry Education Research and Practice*, 11(1), 5–16.
14. van Driel, J. H., Verloop, N., & de Vos, W. (1998). Developing science teachers' pedagogical content knowledge. *Journal of Research in Science Teaching*, 35(6), 673–95.
15. Kaser, J. S., & Bourexis, P. S. (1999). *Enhancing program quality in science and mathematics*. Thousand Oaks, CA: Corwin Press, Inc.
16. Daehler, K., & Shinohara, M. (2001). A complete circuit is a complete circle: Exploring the potential of case materials and methods to develop teachers' content knowledge and pedagogical content knowledge of science. *Research in Science Education*, 31(2), 267–88.
17. Weiss, I. R., Knapp, M. S., Hollweg, K. S., & Burrell, G. (Eds.). (2001). *Investigating the influence of standards: A framework for research in mathematics, science, and technology education*. Washington, DC: The National Academies Press.
18. Valverde, G., & Schmidt, W. (1997). Refocusing U.S. math and science education. *Issues in Science and Technology*, Winter 1997–1998, 60–66.

Alignment of Educator Standards with State and National Standards

Indiana Educator Standards for Science—Chemistry	Indiana Revised Academic Standards for Science	Indiana Core Standards for Science	National Science Education Standards	NCATE/NSTA Standards for Science Teacher Preparation	Common Core State Standards for Literacy: Science and Technical Subjects	ISTE National Educational Technology Standards
<u>Standard 1: The Nature and Processes of Science</u> Chemistry teachers have a broad and comprehensive understanding of the nature of science and the processes of scientific inquiry.	Gr. 5–8 Process Standards, ICP Nature of Science Standard, Chemistry I Nature of Science Standard		Gr. 5–8, CS – A; Gr. 5–8, CS – E; Gr. 5–8, CS – G; Gr. 9–12, CS – A; Gr. 9–12, CS – E; Gr. 9–12, CS – G	Standard 2 – Nature of Science; Standard 3 – Inquiry; Standard 1 – B.4.33–34; Standard 1 – C.1.2–3, C.3.b.26, C.3.c.31; Standard 9 – Safety and Welfare	Reading: Gr. 6–8, 1–10; Gr. 9–10, 1–10; Gr. 11–12, 1–10	
<u>Standard 2: Central Concepts and Connections in Science</u> Chemistry teachers have a comprehensive understanding of the core ideas in other science disciplines and of the relationships between science, engineering, technology, and society.	Gr. 5–8, Process Standards, 5.1, 6.1, 7.1, 8.1, 5.2, 6.2, 7.2, 8.2, 5.3, 6.3, 7.3, 8.3, 5.4, 6.4, 7.4, 8.4, Chemistry I Nature of Science Standard, ICP Nature of Science Standard	5.1, 6.1, 7.1, 8.1, 5.2, 6.2, 7.2, 8.2, 5.3, 6.3, 7.3, 8.3, 5.4, 6.4, 7.4, 8.4,	Gr. 5–8, CS – C–G; Gr. 9–12, CS – E–G	Standard 4 – Issues; Standard 1 – B.4.29, 31; C.1.1–5; C.3.a.11–13; C.3.b.24, 25, 27; C.3.c.28–30		

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<u>Standard 3: Atomic Structure</u> Chemistry teachers have a broad and comprehensive understanding of the structure of atoms.	6.1, 8.1, C.2, ICP.4, ICP.5, ICP.7	6.1, 8.1, C.2, ICP.4, ICP.5, ICP.7	Gr. 9–12, CS – B	Standard 1 – C.3.a.1, .3; C.3.b.14		
<u>Standard 4: The Properties of Matter</u> Chemistry teachers have a broad and comprehensive understanding of the states of matter and their characteristic properties.	5.1, 6.1, 8.1, 8.4, C.1, C.3, C.5, C.6, C.7, C.8, ICP.3, ICP.5	5.1, 6.1, 8.1, 8.4, C.1, C.3, C.5, C.7, C.8, ICP.3	Gr. 5–8, CS – B; Gr. 9–12, CS – B	Standard 1 – C.3.a.1, .3, .7, .8; C.3.b.14–18, .20		
<u>Standard 5: Chemical Bonding</u> Chemistry teachers have a broad and comprehensive understanding of the principles of chemical bonding and the characteristics of intermolecular forces.	8.1, 8.4, C.3, C.6, ICP.5, ICP.6	8.1, 8.4, C.3, C.6, ICP.5	Gr. 9–12, CS – B	Standard 1 – C.3.a.2; C.3.b.14, .17, .21		

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<u>Standard 6: Chemical Reactions</u> Chemistry teachers have a broad and comprehensive understanding of common inorganic chemical reaction types and the principles of chemical reactivity.	C.1, C.4, C.5, C.7, C.8, ICP.5, ICP.6	8.1, C.1, C.4, C.5, C.7, C.8	Gr. 5–8, CS – B; Gr. 9–12, CS – B	Standard 1 – C.3.a.4 –.6, .8; C.3.b.21		
<u>Standard 7: Thermochemistry</u> Chemistry teachers have a broad and comprehensive understanding of the laws of thermodynamics and how they apply to chemical systems.	6.1, 6.4, 7.1, 7.4, C.7, ICP.1, ICP.3, ICP.4, ICP.5, ICP.6	6.1, 6.4, 7.1, 7.4, C.7, ICP.1, ICP.3, ICP.4, ICP.5, ICP.6	Gr. 5–8, CS – B; Gr. 9–12, CS – B	Standard 1 – C.3.a.4, C.3.b.16, C.3.b.23		
<u>Standard 8: Organic Chemistry and Biochemistry</u> Chemistry teachers have a broad and comprehensive understanding of organic chemistry and biochemistry.	6.3, C.3, C.4, C.9	6.3, C.3, C.4, C.9	Gr. 9–12, CS – B	Standard 1 – C.3.a.9, .10; C.3.b.22		

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Indiana Educator Standards for Science—Chemistry	Indiana Revised Academic Standards for Science	Indiana Core Standards for Science	National Science Education Standards	NCATE/NSTA Standards for Science Teacher Preparation	Common Core State Standards for Literacy: Science and Technical Subjects	ISTE National Educational Technology Standards
<u>Standard 9: Science Instruction and Assessment</u> Chemistry teachers have a broad and comprehensive understanding of content-specific instruction and assessment in science.			Teaching Standards A – E, Assessment Standards A – E	Standard 5 – General Skills of Teaching, Standard 6 – Curriculum, Standard 8 – Assessment, Standard 9 – Safety and Welfare	Reading: Gr. 6–8, 1–10; Gr. 9–10, 1–10; Gr. 11–12, 1–10 Writing: Gr. 6–8, 1–10; Gr. 9–10, 1–10; Gr. 11–12, 1–10	1a–1d, 2a–2d, 3a–3d, 4a–4b