Chemistry Pathway Endorsement Specs

Purpose

This document describes the specifications associated with the Chemistry Pathway Science Endorsements. There are three endorsements in the Biology Pathway: Science Core, Chemistry 1, and Chemistry 2.

The **Science Core Endorsement**, when attached to a current Education License, verifies that the individual has the skills and knowledge necessary to teach students three-dimensionally in a secondary science classroom and is required to teach Middle School Science Courses in Grades 6, 7, or 8. Additionally, this endorsement is required as a prerequisite to earn any high school Level-1 or Level-2 content specific science endorsement.

The **Chemistry 1 Endorsement**, when attached to a current Education License, verifies that the individual has the skills and knowledge necessary to teach students in a secondary physical chemistry science classroom and is required to teach High School (9-12) General Chemistry Courses. This endorsement is required as a prerequisite to earn the Chemistry 2 Endorsement.

The **Chemistry 2 Endorsement**, when attached to a current Education License, verifies that the individual has the skills and knowledge necessary to teach students in an advanced secondary physical chemistry classroom and is required to teach Advanced Chemistry (AP, CE, and IB) and high school chemistry elective courses. Those with this endorsement can also teach all the courses a Chemistry 1 endorsed educator can teach. NOTE: Advanced Chemistry (AP, CE, and IB) courses may also include additional requirements in order to be approved by the university or college board to teach.

Endorsement Requirement Areas

The Science Core endorsement is a prerequisite for the Chemistry 1 and Chemistry 2 Endorsements and has 7 requirement areas:

1. Earth Science Content Knowledge
2. Life Science Content Knowledge
3. Chemistry Content Knowledge
4. Physics Content Knowledge
5. Three-Dimensional Science & Engineering Pedagogical Knowledge
6. Science Education Teaching & Dispositions Knowledge
7. Science Classroom Lab Safety Knowledge

The Chemistry 1 Endorsement is a prerequisite for the Biology 2 Endorsement has 4 requirement areas:

8. Atoms, Bonds, & Reactions Content Knowledge
9. Equilibrium, Thermodynamics, & Electrochemistry Content Knowledge
10. Chemistry Laboratory Content Knowledge
11. Integration with Life & Earth Science Content Knowledge

The Chemistry 2 Endorsement has 2 requirement areas:

12. Advanced Quantitative Chemistry Lab Content Knowledge
13. Advanced Chemistry Content Knowledge

Endorsement Type

A professional endorsement will be awarded when all of the prerequisite and endorsement requirement areas have been met. An associate Science Core Endorsement will be awarded if the applicant has completed at least 3 of the 7 requirement areas. An associate Chemistry 1 Endorsement will be awarded if the applicant holds a Professional Science Core endorsement, has a college major or minor in Chemistry, **OR** has completed at least 5 of the 11 prerequisite and endorsement requirement areas. An associate Chemistry 2 Endorsement will be awarded if the applicant holds Professional Science Core and Chemistry 1 endorsements, has a college major in Chemistry, **OR** has completed at least 6 of the 13 requirement areas.

Requirement Area Options

The different options available to complete requirement areas 8-13 for the Chemistry 1 and Chemistry 2 Endorsements are described below. The options for requirement areas 1-7 associated with the Science Core Endorsement can be found in the Science Core Endorsement Specs. Quick links to the requirement area competencies are linked in parentheses.

Requirement Area 8: Atoms, Bonds, & Reactions Content Knowledge (C1.1)

Complete one of the following options to show evidence of competency in this Requirement Area

University Courses

- Any 3+ credit university course (passed with a grade of C or higher) in General Chemistry I
  - Lab course is not required but recommended
  - This course can be the same General Chemistry used to meet course requirements for the Science Core (6-8) Endorsement (if applicable).

College Major or Minor (Meets Requirement Areas 8-11 for the Chemistry 1 endorsement)

- College Major or Minor in Chemistry, Chemistry Education, Physical Science Education, or a Chemistry Variation (e.g., Biochemistry, Geochemistry, Physical Chemistry)
- Other College Majors or Minors may be approved for this endorsement with approval of USBE Science Specialist based on a transcript review

Content Knowledge Exam (Meets Requirement Areas 8-11 for the Chemistry 1 endorsement)

- **Praxis Exam**
  - Chemistry PRAXIS (5246) with score of 140 or higher
- **NES Test**
  - Chemistry NES Test (321) with score of 220 or higher
- Other equivalent state or national exams that meet competencies and approved by USBE

Requirement Area 9: Equilibrium, Thermodynamics, & Electrochemistry Content Knowledge (C1.1 and C1.2)

Complete one of the following options to show evidence of competency in this Requirement Area

University Courses

- Any 3+ credit university course (passed with a grade of C or higher) in General Chemistry II
  - Lab course is not required but recommended

- This course must indicate that it is a level-2 chemistry course and not simply a different level-1 chemistry course.

College Major or Minor (Meets Requirement Areas 8-11 for the Chemistry 1 endorsement)

- As described in Requirement Area 8 description

Content Knowledge Exam (Meets Requirement Areas 8-12 for the Chemistry 1 endorsement)

- As described in Requirement Area 8 description

Requirement Area 10: Chemistry Laboratory Content Knowledge (C1.4)

Complete one of the following options to show evidence of competency in this Requirement Area

University Courses

- Any 1+ credit university course (passed with a grade of C or higher) in a Chemistry Laboratory Experience
  - A course used for Requirements areas 8 and 9 that is worth 4+ credits will meet this requirement if the course included a laboratory component.

College Major or Minor (Meets Requirement Areas 8-11 for the Chemistry 1 endorsement)

- As described in Requirement Area 8 description

Content Knowledge Exam (Meets Requirement Areas 8-12 for the Chemistry 1 endorsement)

- As described in Requirement Area 8 description

Requirement Area 11: Integration with Life & Earth Science Content Knowledge (C1.3)

Complete one of the following options to show evidence of competency in this Requirement Area

University Courses

- Any 3+ credit university course (passed with a grade of C or higher) in Advanced/Applied Chemistry (e.g., Organic Chemistry, Biochemistry, Geochemistry, Physical Chemistry)
  - Lab course is not required but recommended

College Major or Minor (Meets Requirement Areas 8-11 for the Chemistry 1 endorsement)

- As described in Requirement Area 8 description

Content Knowledge Exam (Meets Requirement Areas 8-12 for the Chemistry 1 endorsement)

- As described in Requirement Area 8 description

Requirement Area 12: Advanced Quantitative Chemistry Lab Content Knowledge (C2.1)

Complete one of the following options to show evidence of competency in this Requirement Area

University Courses

- Any 3+ credit university course (passed with a grade of C or higher) in Analytical Chemistry with Lab
  - Lab course is Required to meet this requirement

College Major (Meets Requirement Areas 12-13 for the Chemistry 2 Endorsement)

- College Major in Chemistry, Chemistry Education, or a Chemistry Variation (e.g., Biochemistry, Geochemistry, Physical Chemistry)
- Other College Majors may be approved for this endorsement with approval of USBE Science Specialist based on a transcript review

Teaching Experience and Professional Learning (Meets Requirement Areas 12-13 for the Chemistry 2 Endorsement)

- Teach either AP Chemistry or IB Chemistry for 3 years.

- Attend the relevant Professional Learning for the course being taught.
    - AP Summer Institute for AP Chemistry.
    - Diploma Program Chemistry Workshop for IB Chemistry.
- Apply principles acquired in professional learning into teaching for 2 years.

Requirement Area 13: Advanced Chemistry Content Knowledge (C2.2)

Complete one of the following options to show evidence of competency in this Requirement Area

University Courses

- Complete **TWO** 3+ credit university courses (passed with a grade of C or higher) in any two of the following Advanced/Applied Chemistry in addition to the courses taken to meet Chemistry 1 Endorsement requirements (if applicable). *NOTE: Lab course is not required but recommended*
    - Biochemistry I and/or II
    - Geochemistry I and/or II
    - Organic Chemistry I and/or II
    - Physical Chemistry I and/or II
    - Other upper division (3000+) chemistry course

College Major (Meets Requirement Areas 12-13 for the Chemistry 2 Endorsement)

- As described in Requirement Area 12 description

Teaching Experience and Professional Learning (Meets Requirement Areas 12-13 for the Chemistry 2 Endorsement)

- As described in Requirement Area 12 description

Requirement Area Competencies

The Secondary Chemistry 1 competencies are organized into 1 section:

1. **Chemistry 1 Core Ideas** – The Utah Secondary Chemistry 1 qualifies teachers to teach the core High School (9-12) General Chemistry course focused specifically in the High School Chemistry (Physical Science) disciplinary core ideas:
   C1.1 Matter and Its Interactions
   C1.2 Energy
   C1.3 Integration with Life and Earth Science
   C1.4 Chemistry Laboratory Experience

The Secondary Chemistry 2 competencies are organized into 1 section:

1. **Chemistry 2 Core Ideas** – This endorsement is required to teach Advanced Chemistry (AP, CE, and IB) and high school chemistry elective courses. These competencies and requirements go above that of the core ideas found in the SEEd Chemistry Standards.
   C2.1 Advanced Quantitative Chemistry Lab
   C2.2 Advanced Chemistry Content Knowledge

Each of the requirement area competencies are described below. Quick links to each requirement area options are provided in the parentheses.

Requirement Area 8 - Atoms, Bonds, & Reactions Content Knowledge (Options)

Requirement Area C1.1: Matter and Its Interactions

Area C1.1.A: Structure and Properties of Matter

- C1.1.A.a Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.
- C1.1.A.b The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns.
- C1.1.A.c The repeating patterns of this table reflect patterns of outer electron states.
- C1.1.A.d The structure and interactions of matter at the bulk scale are determined by electrical forces within/between atoms
- C1.1.A.e Stable forms of matter are those in which the electric and magnetic field energy is minimized.
- C1.1.A.f A stable molecule has less energy, by an amount known as the binding energy, than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart

Area C1.1.B: Chemical Reactions

- C1.1.B.c The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.
- C1.1.B.d Chemical processes and properties of materials underlie many important biological and geophysical phenomena.

Area C1.1.C: Nuclear Processes

- C1.1.C.a The total number of neutrons plus protons does not change in any nuclear process.
- C1.1.C.b Spontaneous radioactive decays follow a characteristic exponential decay law.
- C1.1.C.c Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials from the isotope ratios present

Requirement Area 9 - Equilibrium, Thermodynamics, & Electrochemistry Content Knowledge (Options)

Requirement Area C1.1: Matter and Its Interactions

Area C1.1.B: Chemical Reactions

- C1.1.B.a Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in total binding energy (i.e., the sum of all bond energies in the set of molecules) that are matched by changes in kinetic energy.
- C1.1.B.b In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present.

Requirement Area C1.2: Energy

Area C1.2.A: Definitions of Energy

- C1.2.A.a Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system.
- C1.2.A.b At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
- C1.2.A.c Mechanical energy generally refers to some combination of motion and stored energy in an operating machine.
- C1.2.A.d Chemical energy generally is used to mean the energy that can be released or stored in chemical processes, and "electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. Historically, different units and names were used for the energy present in these different phenomena, and it took some time before the

relationships between them were recognized.
- C1.2.A.e These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as either motions of particles or energy stored in fields (which mediate interactions between particles).
- C1.2.A.f This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.

Area C1.2.B: Conservation of Energy and Energy Transfer
- C1.2.B.a Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems

Area C1.2.C: Electromagnetic Radiation
- C1.2.C.a Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. Quantum theory relates the two models. (Boundary: Quantum theory is not explained further at this grade level.)
- C1.2.C.b Atoms of each element emit and absorb characteristic frequencies of light, and nuclear transitions have distinctive gamma ray wavelengths. These characteristics allow identification of the presence of an element, even in microscopic quantities.

Requirement Area 10 - Chemistry Laboratory Content Knowledge (Options)

Requirement Area C1.4 Chemistry Laboratory Experience

Area C1.4.A: Laboratory Safety and Measurement Proficiency
- C1.4.A.a Demonstrate proficiency in maintaining a safe laboratory environment, including the correct use of Personal Protective Equipment (PPE), chemical storage, waste disposal, and emergency equipment.
- C1.4.A.b Perform precise quantitative measurements (e.g., using volumetric glassware, analytical balances) while attending to significant figures and units.

Area C1.4.B: Experimental Investigation of Matter, Atoms, and Reactions
- C1.4.B.a Design and perform experiments that demonstrate the relationship between atomic structure, periodic properties, and chemical reactivity.
- C1.4.B.b Collect and analyze qualitative and quantitative data to verify the conservation of atoms in chemical reactions.
- C1.4.B.c Utilize laboratory evidence to characterize chemical changes, distinguish between physical and chemical processes, and predict outcomes based on observed properties.

Area C1.4.D: Experimental Investigation of Equilibrium, Thermodynamics, and Electrochemistry
- C1.4.D.a Execute experiments to quantify energy changes (e.g., calorimetry, enthalpy of reaction) and describe them using energy diagrams.
- C1.4.D.b Collect and interpret data from reaction systems to demonstrate the factors that influence dynamic equilibrium and reaction rates.
- C1.4.D.c Perform laboratory procedures (e.g., titrations, electrochemical cell construction) to illustrate the principles of electrochemistry and energy transfer.

Requirement Area 11 - Integration with Life & Earth Science Content Knowledge (Options)

Requirement Area C1.3: Integration with Life and Earth Science

Area C1.3.A Competencies: Connections with Life Science

- C1.3.A.a Carbon-based chemistry. This includes the unique reactivity of groupings of atoms, interactions of nucleophiles and electrophiles, electron flow in organic reactions, and the 3-dimensional structure of carbon-based molecules.
- C1.3.A.b Biomolecules. This includes structure, properties, and reactivity of proteins, nucleic acids, lipids, and carbohydrates.
- C1.3.A.c Processing of carbon-based molecules by living organisms. This includes metabolism, toxicity, absorption, and excretion.

Area C1.3.B Competencies: Connections with Earth Science

- C1.3.B.a Processing of molecules by the environment and universe. This includes greenhouse gases, biogeochemical cycles, and energy flow.
- C1.3.B.b Human impact on the environment. This includes pollution (e.g., plastics, heavy metals, and other toxins), ocean acidification, environmental protection, green technologies, and societal energy resources.

Requirement Area 12 - Advanced Data Analysis Content Knowledge (Options)

Requirement Area C2.1: Advanced Quantitative Chemistry Lab

Area C2.1.A: Question, Methods, and Argumentation

- C2.1.A.a Identify a testable scientific question based on an observation, data, or a model
- C2.1.A.b Formulate a hypothesis or predict the results of an experiment.
- C2.1.A.c Identify experimental procedures that are aligned to a scientific question (which may include a sketch of a lab setup).
- C2.1.A.d Make observations or collect data from representations of laboratory setups or results, while attending to precision where appropriate.
- C2.1.A.e Identify or describe potential sources of experimental error.
- Explain how modifications to an experimental procedure will alter results.
- C2.1.A.f Make a scientific claim. and support it with evidence from experimental data.
- C2.1.A.g Support a claim with evidence from representations or models at the particulate level, such as the structure of atoms and/or molecules.
- C2.1.A.h Provide reasoning to justify a claim using chemical principles or laws, or using mathematical justification.
- C2.1.A.i Provide reasoning to justify a claim using connections between particulate and macroscopic scales or levels.
- C2.1.A.j Explain the connection between experimental results and chemical concepts, processes, or theories.
- C2.1.A.k Explain how potential sources of experimental error may affect the experimental results.

Area C2.1.B: Models, Data, Analysis, and Mathematical Routines

- C2.1.B.a Describe the components of and quantitative information from models and representations that illustrate particulate-level properties only.
- C2.1.B.b Describe the components of and quantitative information from models and representations that illustrate both particulate-level and macroscopic level properties.
- C2.1.B.c Represent chemical phenomena using appropriate graphing techniques, including

correct scale and units.
- C2.1.B.d Represent chemical substances or phenomena with appropriate diagrams or models (e.g., electron configuration).
- C2.1.B.e Represent visually the relationship between the structures and interactions across multiple levels or scales (e.g., particulate to macroscopic).
- C2.1.B.f Explain chemical properties or phenomena (e.g., of atoms or molecules) using given chemical theories, models, and representations.
- C2.1.B.g Explain whether a model is consistent with chemical theories.
- C2.1.B.h Explain the connection between particulate-level and macroscopic properties of a substance using models and representations.
- C2.1.B.i Explain the degree to which a model or representation describes the connection between particulate-level properties and macroscopic properties.
- C2.1.B.j Identify quantities needed to solve a problem from given information (e.g., text, mathematical expressions, graphs, or tables).
- C2.1.B.k Identify an appropriate theory, definition, or mathematical relationship to solve a problem.
- C2.1.B.l Explain the relationship between variables within an equation when one variable changes.
- C2.1.B.m Identify information presented graphically to solve a problem.
- C2.1.B.n Determine a balanced chemical equation for a given chemical phenomenon.
- C2.1.B.o Calculate, estimate, or predict an unknown quantity from known quantities by selecting and following a logical computational pathway and attending to precision (e.g., performing dimensional analysis and attending to significant figures).

Requirement Area 13 - Advanced Life Science Content Knowledge (Options)

Requirement Area C2.2: Advanced Chemistry Content Knowledge

Area C2.2.A: Atomic and Molecular Structure and Properties

- C2.2.A.a Quantitative relationship between the mass spectrum of an element and the masses of the element's isotopes.
- C2.2.A.b Quantitative relationship between the elemental composition by mass and the composition of substances in a mixture.
- C2.2.A.c Represent the electron configuration of an element or ions of an element using the Aufbau principle
- C2.2.A.d Represent the relationship between potential energy and distance between atoms, based on factors that influence the interaction strength.
- C2.2.A.e Represent a metallic solid and/or alloy using a model to show essential characteristics of the structure and interactions present in the substance.
- C2.2.A.f Represent a molecule with a Lewis diagram that accounts for resonance between equivalent structures or that uses formal charge to select between nonequivalent structures.
- C2.2.A.g Based on the relationship between Lewis diagrams, VSEPR theory, bond orders, and bond polarities: a) Explain structural properties of molecules. b) Explain electron properties of molecules.

Area C2.2.B: Intermolecular Forces and Properties

- C2.2.B.a Explain the relationship among the macroscopic properties of a substance, the particulate-level structure of the substance, and the interactions between these particles
- C2.2.B.b Explain the relationship between the macroscopic properties of a sample of gas or mixture of gases using the ideal gas law.

- C2.2.B.c Explain the relationship between the motion of particles and the macroscopic properties of gases with: a) The kinetic molecular theory (KMT). b) A particulate model. c) A graphical representation.
- C2.2.B.d Explain the relationship among non-ideal behaviors of gases, interparticle forces, and/or volumes.
- C2.2.B.e Calculate the number of solute particles, volume, or molarity of solutions.
- C2.2.B.f Explain the relationship between the solubility of ionic and molecular compounds in aqueous and nonaqueous solvents, and the intermolecular interactions between particles.
- C2.2.B.g Explain the relationship between the solubility of ionic and molecular compounds in aqueous and nonaqueous solvents, and the intermolecular interactions between particles.
- C2.2.B.h Explain the relationship between a region of the electromagnetic spectrum and the types of molecular or electronic transitions associated with that region.
- C2.2.B.i Explain the properties of an absorbed or emitted photon in relationship to an electronic transition in an atom or molecule.
- C2.2.B.j Explain the amount of light absorbed by a solution of molecules or ions in relationship to the concentration, path length, and molar absorptivity

Area C2.2.C: Chemical Reactions

- C2.2.C.a Explain the relationship between macroscopic characteristics and bond interactions for: a. Chemical processes. b. Physical processes.
- C2.2.C.b Explain changes in the amounts of reactants and products based on the balanced reaction equation for a chemical process.
- C2.2.C.c Identify the equivalence point in a titration based on the amounts of the titrant and analyte, assuming the titration reaction goes to completion.
- C2.2.C.d Identify a reaction as acid base, oxidation-reduction, or precipitation.
- C2.2.C.e Identify species as Brønsted Lowry acids, bases, and/or conjugate acid-base pairs, based on proton-transfer involving those species.
- C2.2.C.f Represent a balanced redox reaction equation using half-reactions.

Area C2.2.D: Kinetics

- C2.2.D.a Explain the relationship between the rate of a chemical reaction and experimental parameters.
- C2.2.D.b Identify the rate law expression of a chemical reaction using data that show how the concentrations of reaction species change over time.
- C2.2.D.c Explain the relationship between the rate of an elementary reaction and the frequency, energy, and orientation of molecular collisions.
- C2.2.D.d Represent the activation energy and overall energy change in an elementary reaction using a reaction energy profile.
- C2.2.D.e Identify the components of a reaction mechanism
- C2.2.D.f Identify the rate law for a reaction from a mechanism in which the first step is rate limiting.
- C2.2.D.g Identify the rate law for a reaction from a mechanism in which the first step is not rate limiting.
- C2.2.D.h Represent the activation energy and overall energy change in a multistep reaction with a reaction energy profile.
- C2.2.D.i Explain the relationship between the effect of a catalyst on a reaction and changes in the reaction mechanism.

Area C2.2.E: Thermodynamics

- C2.2.E.a Explain the relationship between experimental observations and energy changes

associated with a chemical or physical transformation.

- C2.2.E.b Represent a chemical or physical transformation with an energy diagram.
- C2.2.E.c Calculate the heat *q* absorbed or released by a system undergoing heating/ cooling based on the amount of the substance, the heat capacity, and the change in temperature.
- C2.2.E.d Explain changes in the heat *q* absorbed or released by a system undergoing a phase transition based on the amount of the substance in moles and the molar enthalpy of the phase transition.
- C2.2.E.e Calculate the heat *q* absorbed or released by a system undergoing a chemical reaction in relationship to the amount of the reacting substance in moles and the molar enthalpy of reaction.
- C2.2.E.f Calculate the enthalpy change of a reaction based on the average bond energies of bonds broken and formed in the reaction.
- C2.2.E.g Explain the relationship between the enthalpy of a chemical or physical process and the sum of the enthalpies of the individual steps.