

Atomic Structure: Mass Spectroscopy & Shell vs. Quantum Model	Learning objective 1.12 The student is able to explain why a given set of data suggests, or does not suggest, the need to refine the atomic model from a classical shell model with the quantum mechanical model. [See SP 6.3; Essential knowledge 1.C.2]	
	Learning objective 1.13 Given information about a particular model of the atom, the student is able to determine if the model is consistent with specified evidence. [See SP 5.3; Essential knowledge 1.D.1]	
	Learning objective 1.14 The student is able to use data from mass spectrometry to identify the elements and the masses of individual atoms of a specific element. [See SP 1.4, 1.5; Essential knowledge 1.D.2]	
	Learning objective 1.15 The student can justify the selection of a particular type of spectroscopy to measure properties associated with vibrational or electronic motions of molecules. [See SP 4.1, 6.4; Essential knowledge 1.D.3]	
LAB: Beers Law (Colorimetry)	Learning objective 1.16 The student can design and/or interpret the results of an experiment regarding the absorption of light to determine the concentration of an absorbing species in a solution. [See SP 4.2, 5.1; Essential knowledge 1.D.3]	
Law of Conservation of Matter	Learning objective 1.17 The student is able to express the law of conservation of mass quantitatively and qualitatively using symbolic representations and particulate drawings. [See SP 1.5; Essential knowledge 1.E.1]	
	Learning objective 1.18 The student is able to apply conservation of atoms to the rearrangement of atoms in various processes. [See SP 1.4; Essential knowledge 1.E.2]	
LAB: Gravimetric Analysis & Titration (Redox)	Learning objective 1.19 The student can design, and/or interpret data from, an experiment that uses gravimetric analysis to determine the concentration of an analyte in a solution. [See SP 4.2, 5.1, 6.4; Essential knowledge 1.E.2]	
	Learning objective 1.20 The student can design, and/or interpret data from, an experiment that uses titration to determine the concentration of an analyte in a solution. [See SP 4.2, 5.1, 6.4; Essential knowledge 1.E.2]	



Big Idea 2: Properties of Matter

Learning Objective Check List

Properties of Matter		
Bonding : Ionic, Covalent, Metallic	Learning objective 2.1 Students can predict properties of substances based on their chemical formulas, and provide explanations of their properties based on particle views. [See SP 6.4, 7.1; Essential knowledge components of 2.A–2.D]	
	Learning objective 2.2 The student is able to explain the relative strengths of acids and bases based on molecular structure, interparticle forces, and solution equilibrium. [See SP 7.2, connects to Big Idea 5, Big Idea 6; Essential knowledge components of 2.A–2.D]	
	Learning objective 2.17 The student can predict the type of bonding present between two atoms in a binary compound based on position in the periodic table and the electronegativity of the elements. [See SP 6.4; Essential knowledge components of 2.C]	
	Learning objective 2.18 The student is able to rank and justify the ranking of bond polarity on the basis of the locations of the bonded atoms in the periodic table. [See SP 6.1; Essential knowledge 2.C.1]	
	Learning objective 2.19 The student can create visual representations of ionic substances that connect the microscopic structure to macroscopic properties, and/or use representations to connect the microscopic structure to macroscopic properties (e.g., boiling point, solubility, hardness, brittleness, low volatility, lack of malleability, ductility, or conductivity). [See SP 1.1, 1.4, 7.1; Essential knowledge 2.C.2, connects to 2.D.1, 2.D.2]	
	Learning objective 2.20 The student is able to explain how a bonding model involving delocalized electrons is consistent with macroscopic properties of metals (e.g., conductivity, malleability, ductility, and low volatility) and the shell model of the atom. [See SP 6.2, 7.1; Essential knowledge 2.C.3, connects to 2.D.2]	
	Learning objective 2.26 Students can use the electron sea model of metallic bonding to predict or make claims about the macroscopic properties of metals or alloys. [See SP 6.4, 7.1; Essential knowledge 2.D.2]	
Molecular Structure	Learning objective 2.21 The student is able to use Lewis diagrams and VSEPR to predict the geometry of molecules, identify hybridization, and make predictions about polarity. [See SP 1.4; Essential knowledge 2.C.4]	
LAB: Bond Types	Learning objective 2.22 The student is able to design or evaluate a plan to collect and/or interpret data needed to deduce the type of bonding in a sample of a solid. [See SP 4.2, 6.4; Essential knowledge components of 2.D]	

Liquids and Solids	Learning objective 2.3 The student is able to use aspects of particulate models (i.e., particle spacing, motion, and forces of attraction) to reason about observed differences between solid and liquid phases and among solid and liquid materials. [See SP 6.4, 7.1; Essential knowledge 2.A.1]	
Gases and KMT	Learning objective 2.4 The student is able to use KMT and concepts of intermolecular forces to make predictions about the macroscopic properties of gases, including both ideal and nonideal behaviors. [See SP 1.4, 6.4; Essential knowledge 2.A.2]	
	Learning objective 2.5 The student is able to refine multiple representations of a sample of matter in the gas phase to accurately represent the effect of changes in macroscopic properties on the sample. [See SP 1.3, 6.4, 7.2; Essential knowledge 2.A.2]	
	Learning objective 2.6 The student can apply mathematical relationships or estimation to determine macroscopic variables for ideal gases. [See SP 2.2, 2.3; Essential knowledge 2.A.2]	
	Learning objective 2.12 The student can qualitatively analyze data regarding real gases to identify deviations from ideal behavior and relate these to molecular interactions. [See SP 5.1, 6.5; Essential knowledge 2.B.2, connects to 2.A.2]	
LAB: Chromatography	Learning objective 2.7 The student is able to explain how solutes can be separated by chromatography based on intermolecular interactions. [See SP 6.2; Essential knowledge 2.A.3]	
Solution Formation: Particle Interactions, Molarity, Solubility	Learning objective 2.8 The student can draw and/or interpret representations of solutions that show the interactions between the solute and solvent. [See SP 1.1, 1.2, 6.4; Essential knowledge 2.A.3]	
	Learning objective 2.9 The student is able to create or interpret representations that link the concept of molarity with particle views of solutions. [See SP 1.1, 1.4; Essential knowledge 2.A.3]	
	Learning objective 2.14 The student is able to apply Coulomb's law qualitatively (including using representations) to describe the interactions of ions, and the attractions between ions and solvents to explain the factors that contribute to the solubility of ionic compounds. [See SP 1.4, 6.4; Essential knowledge 2.B.2]	
	Learning objective 2.15 The student is able to explain observations regarding the solubility of ionic solids and molecules in water and other solvents on the basis of particle views that include intermolecular interactions and entropic effects. [See SP 1.4, 6.2; Essential knowledge 2.B.3, connects to 5.E.1]	
LAB: Separation Techniques	Learning objective 2.10 The student can design and/or interpret the results of a separation experiment (filtration, paper chromatography, column chromatography, or distillation) in terms of the relative strength of interactions among and between the components. [See SP 4.2, 5.1, 6.4; Essential knowledge 2.A.3]	



Big Idea 3: Chemical Reactions

Learning Objective Check List

Chemical Reactions		
Representing Chemical Reactions; Molecular, Ionic, Net Ionic Equations	Learning objective 3.1 Students can translate among macroscopic observations of change, chemical equations, and particle views. [See SP 1.5, 7.1; Essential knowledge components of 3.A–3.C]	
	Learning objective 3.2 The student can translate an observed chemical change into a balanced chemical equation and justify the choice of equation type (molecular, ionic, or net ionic) in terms of utility for the given circumstances. [See SP 1.5, 7.1; Essential knowledge 3.A.1]	
Stoichiometry and Limiting Reactants	Learning objective 3.3 The student is able to use stoichiometric calculations to predict the results of performing a reaction in the laboratory and/or to analyze deviations from the expected results. [See SP 2.2, 5.1; Essential knowledge 3.A.2]	
	Learning objective 3.4 The student is able to relate quantities (measured mass of substances, volumes of solutions, or volumes and pressures of gases) to identify stoichiometric relationships for a reaction, including situations involving limiting reactants and situations in which the reaction has not gone to completion. [See SP 2.2, 5.1, 6.4; Essential knowledge 3.A.2]	
LAB: Laws of Conservation of Matter and Definite Proportions	Learning objective 3.5 The student is able to design a plan in order to collect data on the synthesis or decomposition of a compound to confirm the conservation of matter and the law of definite proportions. [See SP 2.1, 4.2, 6.4; Essential knowledge 3.B.1]	
	Learning objective 3.6 The student is able to use data from synthesis or decomposition of a compound to confirm the conservation of matter and the law of definite proportions. [See SP 2.2, 6.1; Essential knowledge 3.B.1]	
Identifying Acid-Base and Redox Reactions	Learning objective 3.7 The student is able to identify compounds as Brønsted-Lowry acids, bases, and/or conjugate acid-base pairs, using proton-transfer reactions to justify the identification. [See SP 6.1; Essential knowledge 3.B.2]	
	Learning objective 3.8 The student is able to identify redox reactions and justify the identification in terms of electron transfer. [See SP 6.1; Essential knowledge 3.B.3]	
LAB: Redox Titration	Learning objective 3.9 The student is able to design and/or interpret the results of an experiment involving a redox titration. [See SP 4.2, 5.1; Essential knowledge 3.B.3]	

Physical vs. Chemical Changes	Learning objective 3.10 The student is able to evaluate the classification of a process as a physical change, chemical change, or ambiguous change based on both macroscopic observations and the distinction between rearrangement of covalent interactions and noncovalent interactions. [See SP 1.4, 6.1; Essential knowledge 3.C.1, connects to 5.D.2]	
Energy Changes in Reactions	Learning objective 3.11 The student is able to interpret observations regarding macroscopic energy changes associated with a reaction or process to generate a relevant symbolic and/or graphical representation of the energy changes. [See SP 1.5, 4.4; Essential knowledge 3.C.2]	
Electrochemistry: Galvanic and Electrolytic	Learning objective 3.12 The student can make qualitative or quantitative predictions about galvanic or electrolytic reactions based on half-cell reactions and potentials and/or Faraday's laws. [See SP 2.2, 2.3, 6.4; Essential knowledge 3.C.3]	
	Learning objective 3.13 The student can analyze data regarding galvanic or electrolytic cells to identify properties of the underlying redox reactions. [See SP 5.1; Essential knowledge 3.C.3]	



Big Idea 4: Kinetics

Learning Objective Check List

Kinetics		
Lab: Factors Affecting Rate	Learning objective 4.1 The student is able to design and/or interpret the results of an experiment regarding the factors (i.e., temperature, concentration, surface area) that may influence the rate of a reaction. [See SP 4.2, 5.1; Essential knowledge 4.A.1]	
Rate Laws	Learning objective 4.2 The student is able to analyze concentration vs. time data to determine the rate law for a zeroth-, first-, or second-order reaction. [See SP 5.1; Essential knowledge 4.A.2 , <i>connects to 4.A.3</i>]	
Half Life	Learning objective 4.3 The student is able to connect the half-life of a reaction to the rate constant of a first-order reaction and justify the use of this relation in terms of the reaction being a first-order reaction. [See SP 2.1, 2.2; Essential knowledge 4.A.3]	
Collision Theory	Learning objective 4.4 The student is able to connect the rate law for an elementary reaction to the frequency and success of molecular collisions, including connecting the frequency and success to the order and rate constant, respectively. [See SP 7.1; Essential knowledge 4.B.1 , <i>connects to 4.A.3, 4.B.2</i>]	
	Learning objective 4.5 The student is able to explain the difference between collisions that convert reactants to products and those that do not in terms of energy distributions and molecular orientation. [See SP 6.2; Essential knowledge 4.B.2]	
Energy Profile Graphs	Learning objective 4.6 The student is able to use representations of the energy profile for an elementary reaction (from the reactants, through the transition state, to the products) to make qualitative predictions regarding the relative temperature dependence of the reaction rate. [See SP 1.4, 6.4; Essential knowledge 4.B.3]	
	Learning objective 4.8 The student can translate among reaction energy profile representations, particulate representations, and symbolic representations (chemical equations) of a chemical reaction occurring in the presence and absence of a catalyst. [See SP 1.5; Essential knowledge 4.D.1]	
Mechanisms	Learning objective 4.7 The student is able to evaluate alternative explanations, as expressed by reaction mechanisms, to determine which are consistent with data regarding the overall rate of a reaction, and data that can be used to infer the presence of a reaction intermediate. [See SP 6.5; <i>connects to</i> Essential knowledge 4.C.1, 4.C.2, 4.C.3]	
Catalysts	Learning objective 4.9 The student is able to explain changes in reaction rates arising from the use of acid-base catalysts, surface catalysts, or enzyme catalysts, including selecting appropriate mechanisms with or without the catalyst present. [See SP 6.2, 7.2; Essential knowledge 4.D.2]	



Big Idea 5: Thermochemistry & Thermodynamics

Learning Objective Check List

Thermochemistry		
Graphical Representations	<p>Learning objective 5.1 The student is able to create or use graphical representations in order to connect the dependence of potential energy to the distance between atoms and factors, such as bond order (for covalent interactions) and polarity (for intermolecular interactions), which influence the interaction strength. [See SP 1.1, 1.4, 7.2, connects to Big Idea 2; Essential knowledge components of 5.A-5.E]</p>	
Temperature and Energy Transfers	<p>Learning objective 5.2 The student is able to relate temperature to the motions of particles, either via particulate representations, such as drawings of particles with arrows indicating velocities, and/or via representations of average kinetic energy and distribution of kinetic energies of the particles, such as plots of the Maxwell-Boltzmann distribution. [See SP 1.1, 1.4, 7.1; Essential knowledge 5.A.1]</p>	
	<p>Learning objective 5.3 The student can generate explanations or make predictions about the transfer of thermal energy between systems based on this transfer being due to a kinetic energy transfer between systems arising from molecular collisions. [See SP 7.1; Essential knowledge 5.A.2]</p>	
Conservation of Energy	<p>Learning objective 5.4 The student is able to use conservation of energy to relate the magnitudes of the energy changes occurring in two or more interacting systems, including identification of the systems, the type (heat versus work), or the direction of energy flow. [See SP 1.4, 2.2, connects to Essential knowledge 5.B.1, 5.B.2]</p>	
	<p>Learning objective 5.5 The student is able to use conservation of energy to relate the magnitudes of the energy changes when two nonreacting substances are mixed or brought into contact with one another. [See SP 2.2, connects to Essential knowledge 5.B.1, 5.B.2]</p>	
Calorimetry Calculations	<p>Learning objective 5.6 The student is able to use calculations or estimations to relate energy changes associated with heating/cooling a substance to the heat capacity, relate energy changes associated with a phase transition to the enthalpy of fusion/vaporization, relate energy changes associated with a chemical reaction to the enthalpy of the reaction, and relate energy changes to $P\Delta V$ work. [See SP 2.2, 2.3; Essential knowledge 5.B.3]</p>	
LAB: Calorimetry	<p>Learning objective 5.7 The student is able to design and/or interpret the results of an experiment in which calorimetry is used to determine the change in enthalpy of a chemical process (heating/cooling, phase transition, or chemical reaction) at constant pressure. [See SP 4.2, 5.1; Essential knowledge 5.B.4]</p>	
Enthalpy and Bond Energies	<p>Learning objective 5.8 The student is able to draw qualitative and quantitative connections between the reaction enthalpy and the energies involved in the breaking and formation of chemical bonds. [See SP 2.3, 7.1, 7.2; Essential knowledge 5.C.2]</p>	
Intramolecular and Intermolecular Forces	<p>Learning objective 5.9 The student is able to make claims and/or predictions regarding relative magnitudes of the forces acting within collections of interacting molecules based on the distribution of electrons within the molecules and the types of intermolecular forces through which the molecules interact. [See SP 6.4; Essential knowledge 5.D.1]</p>	
	<p>Learning objective 5.10 The student can support the claim about whether a process is a chemical or physical change (or may be classified as both) based on whether the process involves changes in intramolecular versus intermolecular interactions. [See SP 5.1; Essential knowledge 5.D.2]</p>	
	<p>Learning objective 5.11 The student is able to identify the noncovalent interactions within and between large molecules, and/or connect the shape and function of the large molecule to the presence and magnitude of these interactions. [See SP 7.2; Essential knowledge 5.D.3]</p>	

Thermodynamics		
ΔH° ; ΔS° ; ΔG° ; Coupled Reactions	Learning objective 5.12 The student is able to use representations and models to predict the sign and relative magnitude of the entropy change associated with chemical or physical processes. [See SP 1.4 ; Essential knowledge 5.E.1]	
	Learning objective 5.13 The student is able to predict whether or not a physical or chemical process is thermodynamically favored by determination of (either quantitatively or qualitatively) the signs of both ΔH° and ΔS° , and calculation or estimation of ΔG° when needed. [See SP 2.2, 2.3, 6.4 ; Essential knowledge 5.E.2, connects to 5.E.3]	
	Learning objective 5.14 The student is able to determine whether a chemical or physical process is thermodynamically favorable by calculating the change in standard Gibbs free energy. [See SP 2.2 ; Essential knowledge 5.E.3, connects to 5.E.2]	
	Learning objective 5.15 The student is able to explain how the application of external energy sources or the coupling of favorable with unfavorable reactions can be used to cause processes that are not thermodynamically favorable to become favorable. [See SP 6.2 ; Essential knowledge 5.E.4]	
Connections to Equilibrium and Kinetics	Learning objective 5.16 The student can use LeChatelier's principle to make qualitative predictions for systems in which coupled reactions that share a common intermediate drive formation of a product. [See SP 6.4 ; Essential knowledge 5.E.4, connects to 6.B.1]	
	Learning objective 5.17 The student can make quantitative predictions for systems involving coupled reactions that share a common intermediate, based on the equilibrium constant for the combined reaction. [See SP 6.4 ; Essential knowledge 5.E.4, connects to 6.A.2]	
	Learning objective 5.18 The student can explain why a thermodynamically favored chemical reaction may not produce large amounts of product (based on consideration of both initial conditions and kinetic effects), or why a thermodynamically unfavored chemical reaction can produce large amounts of product for certain sets of initial conditions. [See SP 1.3, 7.2 ; Essential knowledge 5.E.5, connects to 6.D.1]	