APPENDIX B
PHYSICAL SETTING/CHEMISTRY CONTENT CONNECTIONS TABLE

STANDARD 4: The Physical Setting

The Content Connections Table has been designed to assist teachers in curriculum writing and lesson planning. Some of the listed major understandings have a related skill and / or real-world connection to a specific content focus area. The scope of the content connections and skills is not meant to be limited; i.e., a skill may be connected to more than one major understanding.

Additionally, real-world connections have been identified only to assist teachers in planning and are not meant to link these connections to any assessment.

Students will understand and apply scientific concepts, principles, and theories pertaining to the physical setting and living environment and recognize the historical development of ideas in science.

I. Atomic Concepts

KEY	LINK TO APPENDIX A	MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	REAL-WORLD CONNECTIONS
3.1a	I.1	3.1a The modern model of the atom has evolved over a long period of time through the work of many scientists.	relate experimental evidence (given in the introduction of Key Idea 3) to models of the atom (3.1ii)	
3.1b	I.2	3.1b Each atom has a nucleus, with an overall positive charge, surrounded by negatively charged electrons.	use models to describe the structure of an atom (3.1i)	
3.1c	I.3	3.1c Subatomic particles contained in the nucleus include protons and neutrons.		
3.1d	I.4	3.1d The proton is positively charged, and the neutron has no charge. The electron is negatively charged.		
3.1e	I.5	3.1e Protons and electrons have equal but opposite charges. The number of protons is equal to the number of electrons in an atom.	determine the number of protons or electrons in an atom or ion when given one of these values (3.1iii)	
3.1f	I.6	3.1f The mass of each proton and each neutron is approximately equal to one atomic mass unit. An electron is much less massive than a proton or neutron.	calculate the mass of an atom, the number of neutrons or the number of protons, given the other two values (3.1iv)	◆ lasers

I. Atomic Concepts

KEY	LINK TO APPENDIX A	MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	REAL-WORLD CONNECTIONS
3.1h	I.7	In the wave-mechanical model (electron cloud), the electrons are in orbitals, which are defined as regions of most probable electron location (ground state).		
3.1i	I.8	Each electron in an atom has its own distinct amount of energy.		
3.1j	I.9	When an electron in an atom gains a specific amount of energy, the electron is at a higher energy state (excited state).	distinguish between ground state and excited state electron configurations, e.g., 2-8-2 vs. 2-7-3 (3.1v)	
3.1k	I.10	When an electron returns from a higher energy state to a lower energy state, a specific amount of energy is emitted. This emitted energy can be used to identify an element.	identify an element by comparing its bright-line spectrum to given spectra (3.1vi)	◆ flame tests ◆ neon lights ◆ fireworks ◆ forensic analysis ◆ spectral analysis of stars
3.1l	I.11	The outermost electrons in an atom are called the valence electrons. In general, the number of valence electrons affects the chemical properties of an element.	draw a Lewis electron-dot structure of an atom (3.1viii) distinguish between valence and non-valence electrons, given an electron configuration, e.g., 2-8-2 (3.1vii)	
3.1m	I.12	Atoms of an element that contain the same number of protons but a different number of neutrons are called isotopes of that element.		
3.1n	I.13	The average atomic mass of an element is the weighted average of the masses of its naturally occurring isotopes.	given an atomic mass, determine the most abundant isotope (3.1xi) calculate the atomic mass of an element, given the masses and ratios of naturally occurring isotopes (3.1xii)	

II. Periodic Table

KEY	LINK TO APPENDIX A	MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	REAL-WORLD CONNECTIONS
3.1y	II.1	The placement or location of an element on the Periodic Table gives an indication of physical and chemical properties of that element. The elements on the Periodic Table are arranged in order of increasing atomic number.	explain the placement of an unknown element in the Periodic Table based on its properties (3.1xvi)	◆ similar properties and uses for elements in the same family ◆ characteristics of a class of elements are similar
3.1g	II.2	The number of protons in an atom (atomic number) identifies the element. The sum of the protons and neutrons in an atom (mass number) identifies an isotope. Common notations that represent isotopes include: ^{14}C, $^{14}_{6}C$, carbon-14, C-14.	interpret and write isotopic notation (3.1x)	
3.1v	II.3	Elements can be classified by their properties, and located on the Periodic Table, as metals, nonmetals, metalloids (B, Si, Ge, As, Sb, Te) , and noble gases.	classify elements as metals, nonmetals, metalloids, or noble gases by their properties (3.1xiii)	◆ similar properties and uses for elements in the same family
3.1w	II.4	Elements can be differentiated by their physical properties. Physical properties of substances, such as density, conductivity, malleability, solubility, and hardness, differ among elements.	describe the states of the elements at STP (3.1xviii)	◆ uses of different elements, e.g., use of semiconductors in solid state electronics and computer technology ◆ alloys as superconductors
3.1x	II.5	Elements can be differentiated by chemical properties. Chemical properties describe how an element behaves during a chemical reaction.		◆ metallurgy ◆ recovery of metals
5.2f	II.6	Some elements exist as two or more forms in the same phase. These forms differ in their molecular or crystal structure, and hence in their properties.		◆ different properties for each allotrope: ∞ oxygen gas vs. ozone ∞ coal vs. graphite vs. diamond vs. buckminsterfullerene

II. Periodic Table

KEY	LINK TO APPENDIX A	MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	REAL-WORLD CONNECTIONS
3.1z	II.7	For Groups 1, 2, and 13-18 on the Periodic Table, elements within the same group have the same number of valence electrons (helium is an exception) and therefore similar chemical properties.	determine the group of an element, given the chemical formula of a compound, e.g., XCl or XCl_2 (3.1xv)	
3.1aa	II.8	The succession of elements within the same group demonstrates characteristic trends: differences in atomic radius, ionic radius, electronegativity, first ionization energy, metallic/nonmetallic properties.	compare and contrast properties of elements within a group or a period for Groups 1, 2, 13-18 on the Periodic Table (3.1xiv)	
3.1bb	II.9	The succession of elements across the same period demonstrates characteristic trends: differences in atomic radius, ionic radius, electronegativity, first ionization energy, metallic/nonmetallic properties.		

III. Moles/Stoichiometry

KEY	LINK TO APPENDIX A	MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	REAL-WORLD CONNECTIONS
3.1cc	III.1	A compound is a substance composed of two or more different elements that are chemically combined in a fixed proportion. A chemical compound can be broken down by chemical means. A chemical compound can be represented by a specific chemical formula and assigned a name based on the IUPAC system.		◆ reading food and beverage labels (consumer Chemistry)
3.1ee	III.2	Types of chemical formulas include: empirical, molecular, and structural.		

III. Moles/Stoichiometry

KEY	LINK TO APPENDIX A	MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	REAL-WORLD CONNECTIONS
3.3d	III.3	The empirical formula of a compound is the simplest whole-number ratio of atoms of the elements in a compound. It may be different from the molecular formula, which is the actual ratio of atoms in a molecule of that compound.	determine the molecular formula, given the empirical formula and molecular mass (3.3vii) determine the empirical formula from a molecular formula (3.3v)	
3.3a	III.4	In all chemical reactions there is a conservation of mass, energy, and charge.	interpret balanced chemical equations in terms of conservation of matter and energy (3.3ii)	
3.3c	III.5	A balanced chemical equation represents conservation of atoms. The coefficients in a balanced chemical equation can be used to determine mole ratios in the reaction.	balance equations, given the formulas for reactants and products (3.3i) interpret balanced chemical equations in terms of conservation of matter and energy (3.3ii) create and use models of particles to demonstrate balanced equations (3.3iii) calculate simple mole-mole stoichiometry problems, given a balanced equation (3.3iv)	
3.3e	III.6	The formula mass of a substance is the sum of the atomic masses of its atoms. The molar mass (gram-formula mass) of a substance equals one mole of that substance.	calculate the formula mass and the gram-formula mass (3.3viii)	
3.3f	III.7	The percent composition by mass of each element in a compound can be calculated mathematically.	determine the number of moles of a substance, given its mass (3.3ix) determine the mass of a given number of moles of a substance (3.3vi)	

III. Moles/Stoichiometry

KEY	LINK TO APPENDIX A	MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	REAL-WORLD CONNECTIONS
3.2b	III.8	Types of chemical reactions include synthesis, decomposition, single replacement, and double replacement.	identify types of chemical reactions (3.2ii)	◆ recovery of metals from ores ◆ electroplating ◆ corrosion ◆ precipitation reactions ◆ dangers of mixing household chemicals together, e.g., bleach and ammonia ◆ electrolysis of active metal compounds ◆ explosives (inflation of air bags)

IV. Chemical Bonding

KEY	LINK TO APPENDIX A	MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	REAL-WORLD CONNECTIONS
3.1dd	IV.1	Compounds can be differentiated by their chemical and physical properties.	distinguish among ionic, molecular, and metallic substances, given their properties (3.1xix)	
5.2g	IV.2	Two major categories of compounds are ionic and molecular (covalent) compounds.		
5.2a	IV.3	Chemical bonds are formed when valence electrons are: transferred from one atom to another (ionic); shared between atoms (covalent); mobile within a metal (metallic).	demonstrate bonding concepts using Lewis dot structures representing valence electrons: transferred (ionic bonding); shared (covalent bonding); in a stable octet (5.2i)	◆ photosynthesis ◆ DNA bonding
5.2e	IV.4	In a multiple covalent bond, more than one pair of electrons are shared between two atoms. Unsaturated organic compounds contain at least one double or triple bond.		
5.2l	IV.5	Molecular polarity can be determined by the shape and distribution of the charge. Symmetrical (nonpolar) molecules include CO_2, CH_4, and diatomic elements. Asymmetrical (polar) molecules include HCl, NH_3, H_2O.		

IV. Chemical Bonding				
KEY	**LINK TO APPENDIX A**	**MAJOR UNDERSTANDINGS**	**SKILLS The student should be able to:**	**REAL-WORLD CONNECTIONS**
5.2c	IV.6	When an atom gains one or more electrons, it becomes a negative ion and its radius increases. When an atom loses one or more electrons, it becomes a positive ion and its radius decreases.		◆ saturated vs. unsaturated compounds—health connections
5.2i	IV.7	When a bond is broken, energy is absorbed. When a bond is formed, energy is released.		
5.2b	IV.8	Atoms attain a stable valence electron configuration by bonding with other atoms. Noble gases have stable valence electron configurations and tend not to bond.	determine the noble gas configuration an atom will achieve when bonding (5.2iv)	
5.2n	IV.9	Physical properties of substances can be explained in terms of chemical bonds and intermolecular forces. These properties include conductivity, malleability, solubility, hardness, melting point, and boiling point.		
5.2d	IV.10	Electron-dot diagrams (Lewis structures) can represent the valence electron arrangement in elements, compounds, and ions.	demonstrate bonding concepts, using Lewis dot structures representing valence electrons: transferred (ionic bonding); shared (covalent bonding); in a stable octet (5.2i)	◆ free radicals
5.2j	IV.11	Electronegativity indicates how strongly an atom of an element attracts electrons in a chemical bond. Electronegativity values are assigned according to arbitrary scales.		

KEY	LINK TO APPENDIX A	MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	REAL-WORLD CONNECTIONS
IV. Chemical Bonding				
5.2k	IV.12	The electronegativity difference between two bonded atoms is used to assess the degree of polarity in the bond.	distinguish between nonpolar covalent bonds (two of the same nonmetals) and polar covalent bonds (5.2v)	
5.2h	IV.13	Metals tend to react with nonmetals to form ionic compounds. Nonmetals tend to react with other nonmetals to form molecular (covalent) compounds. Ionic compounds containing polyatomic ions have both ionic and covalent bonding.		
V. Physical Behavior of Matter				
3.1q	V.1	Matter is classified as a pure substance or as a mixture of substances.		
3.1kk	V.2	The three phases of matter (solids, liquids, and gases) have different properties.	use a simple particle model to differentiate among properties of a solid, a liquid, and a gas (3.1xxii)	◆ common everyday examples of solids, liquids, and gases ◆ nature of H_2O in our environment ◆ solids ∞ metallic ∞ crystalline ∞ amorphous (quartz glass, opals) ∞ solid state ◆ liquids ∞ surface tension ∞ capillary ∞ viscosity ◆ gases ∞ real and ideal gases
3.1r	V.3	A pure substance (element or compound) has a constant composition and constant properties throughout a given sample, and from sample to sample.	use particle models/diagrams to differentiate among elements, compounds, and mixtures (3.1xxxvi)	

V. Physical Behavior of Matter

KEY	LINK TO APPENDIX A	MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	REAL-WORLD CONNECTIONS
3.1u	V.4	Elements are substances that are composed of atoms that have the same atomic number. Elements cannot be broken down by chemical change.		
3.1s	V.5	Mixtures are composed of two or more different substances that can be separated by physical means. When different substances are mixed together, a homogeneous or heterogeneous mixture is formed.		◆ alloys ◆ separation by filtration, distillation, desalination, crystallization, extraction, chromatography ◆ water quality testing ◆ colloids ◆ emulsifiers (making ice cream) ◆ sewage treatment
3.1t	V.6	The proportions of components in a mixture can be varied. Each component in a mixture retains its original properties.		
3.1nn	V.7	Differences in properties such as density, particle size, molecular polarity, boiling point and freezing point, and solubility permit physical separation of the components of the mixture.	describe the process and use of filtration, distillation, and chromatography in the separation of a mixture (3.1xxiv)	
3.1oo	V.8	A solution is a homogeneous mixture of a solute dissolved in a solvent. The solubility of a solute in a given amount of solvent is dependent on the temperature, the pressure, and the chemical natures of the solute and solvent.	interpret and construct solubility curves (3.1xxv) use solubility curves to distinguish among saturated, supersaturated and unsaturated solutions (3.1xxviii) apply the adage "like dissolves like" to real-world situations (3.1xxvi)	◆ degrees of saturation of solutions ◆ dry cleaning

V. Physical Behavior of Matter

KEY	LINK TO APPENDIX A	MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	REAL-WORLD CONNECTIONS
3.1pp	V.9	The concentration of a solution may be expressed as: molarity (M), percent by volume, percent by mass, or parts per million (ppm).	describe the preparation of a solution, given the molarity (3.1xxx) interpret solution concentration data (3.1xxx) calculate solution concentrations in molarity (M), percent mass, and parts per million (ppm) (3.1xxix)	
3.1qq	V.10	The addition of a nonvolatile solute to a solvent causes the boiling point of the solvent to increase and the freezing point of the solvent to decrease. The greater the concentration of solute particles the greater the effect.		◆ salting an icy sidewalk ◆ ice cream making ◆ antifreeze/engine coolant ◆ airplane deicing ◆ cooking pasta
4.1a	V.11	Energy can exist in different forms, such as chemical, electrical, electromagnetic, thermal, mechanical, and nuclear.		
4.2a	V.12	Heat is a transfer of energy (usually thermal energy) from a body of higher temperature to a body of lower temperature. Thermal energy is associated with the random motion of atoms and molecules.	distinguish between heat energy and temperature in terms of molecular motion and amount of matter (4.2i) qualitatively interpret heating and cooling curves in terms of changes in kinetic and potential energy, heat of vaporization, heat of fusion, and phase changes (4.2iii)	
4.2b	V.13	Temperature is a measure of the average kinetic energy of the particles in a sample of matter. Temperature is not a form of energy.	distinguish between heat energy and temperature in terms of molecular motion and amount of matter (4.2i) explain phase changes in terms of the changes in energy and intermolecular distance (4.2ii)	
3.4a	V.14	The concept of an ideal gas is a model to explain behavior of gases. A real gas is most like an ideal gas when the real gas is at low pressure and high temperature.		◆ Earth's primitive atmosphere ◆ use of models to explain something that cannot be seen

V. Physical Behavior of Matter				
KEY	**LINK TO APPENDIX A**	**MAJOR UNDERSTANDINGS**	**SKILLS** **The student should be able to:**	**REAL-WORLD CONNECTIONS**
3.4b	V.15	Kinetic molecular theory (KMT) for an ideal gas states all gas particles: ◆ are in random, constant, straight-line motion ◆ are separated by great distances relative to their size; the volume of gas particles is considered negligible ◆ have no attractive forces between them ◆ have collisions that may result in a transfer of energy between particles, but the total energy of the system remains constant.		
3.4d	V.16	Collision theory states that a reaction is most likely to occur if reactant particles collide with the proper energy and orientation.		
3.4c	V.17	Kinetic molecular theory describes the relationships of pressure, volume, temperature, velocity, and frequency and force of collisions among gas molecules.	explain the gas laws in terms of KMT (3.4i) solve problems, using the combined gas law (3.4ii)	◆ structure and composition of Earth's atmosphere (variations in pressure and temperature)
3.4e	V.18	Equal volumes of gases at the same temperature and pressure contain an equal number of particles.	convert temperatures in Celsius degrees (^{o}C) to kelvins (K), and kelvins to Celsius degrees (3.4iii)	
4.2c	V.19	The concepts of kinetic and potential energy can be used to explain physical processes that include: fusion (melting); solidification (freezing); vaporization (boiling, evaporation), condensation, sublimation, and deposition.	qualitatively interpret heating and cooling curves in terms of changes in kinetic and potential energy, heat of vaporization, heat of fusion, and phase changes (4.2iii) calculate the heat involved in a phase or temperature change for a given sample of matter (4.2iv) explain phase change in terms of the changes in energy and intermolecular distances (4.2ii)	◆ weather processes ◆ greenhouse gases

V. Physical Behavior of Matter

KEY	LINK TO APPENDIX A	MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	REAL-WORLD CONNECTIONS
3.2a	V.20	A physical change results in the rearrangement of existing particles in a substance. A chemical change results in the formation of different substances with changed properties.		
4.1b	V.21	Chemical and physical changes can be exothermic or endothermic.	distinguish between endothermic and exothermic reactions, using energy terms in a reaction equation, $\triangle H$, potential energy diagrams or experimental data (4.1i)	◆ calorimetry
3.1jj	V.22	The structure and arrangement of particles and their interactions determine the physical state of a substance at a given temperature and pressure.	use a simple particle model to differentiate among properties of solids, liquids, and gases (3.1xxii)	
5.2m	V.23	Intermolecular forces created by the unequal distribution of charge result in varying degrees of attraction between molecules. Hydrogen bonding is an example of a strong intermolecular force.	explain vapor pressure, evaporation rate, and phase changes in terms of intermolecular forces (5.2iii)	◆ refrigeration ◆ meniscus (concave/-convex) ◆ capillary action ◆ surface tension
5.2n	V.24	Physical properties of substances can be explained in terms of chemical bonds and intermolecular forces. These properties include conductivity, malleability, solubility, hardness, melting point, and boiling point.	compare the physical properties of substances based upon chemical bonds and intermolecular forces (5.2ii)	

VI Kinetics/Equilibrium

KEY	LINK TO APPENDIX A	MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	REAL-WORLD CONNECTIONS
3.4d	VI.1	Collision theory states that a reaction is most likely to occur if reactant particles collide with the proper energy and orientation.	use collision theory to explain how various factors, such as temperature, surface area, and concentration, influence the rate of reaction (3.4vi)	◆ synthesis of compounds
3.4f	VI.2	The rate of a chemical reaction depends on several factors: temperature, concentration, nature of reactants, surface area, and the presence of a catalyst.		◆ catalysts and inhibitors
3.4h	VI.3	Some chemical and physical changes can reach equilibrium.	identify examples of physical equilibria as solution equilibrium and phase equilibrium, including the concept that a saturated solution is at equilibrium (3.4 vii)	◆ balloons
3.4i	VI.4	At equilibrium the rate of the forward reaction equals the rate of the reverse reaction. The measurable quantities of reactants and products remain constant at equilibrium.	describe the concentration of particles and rates of opposing reactions in an equilibrium system (3.4iv)	
3.4j	VI.5	LeChatelier's principle can be used to predict the effect of stress (change in pressure, volume, concentration, and temperature) on a system at equilibrium.	qualitatively describe the effect of stress on equilibrium, using LeChatelier's principle (3.4v)	◆ Haber process
4.1c	VI.6	Energy released or absorbed by a chemical reaction can be represented by a potential energy diagram.	read and interpret potential energy diagrams: PE of reactants and products, activation energy (with or without a catalyst), heat of reaction (4.1ii)	
4.1d	VI.7	Energy released or absorbed by a chemical reaction (heat of reaction) is equal to the difference between the potential energy of the products and the potential energy of the reactants.		◆ burning fossil fuels ◆ photosynthesis ◆ production of photochemical smog

VI Kinetics/Equilibrium

KEY	LINK TO APPENDIX A	MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	REAL-WORLD CONNECTIONS
3.4g	VI.8	A catalyst provides an alternate reaction pathway which has a lower activation energy than an uncatalyzed reaction.		◆ enzymes in the human body
3.1ll	VI.9	Entropy is a measure of the randomness or disorder of a system. A system with greater disorder has greater entropy.	compare the entropy of phases of matter (3.1xxiii)	◆ relationship to phase change
3.1mm	VI.10	Systems in nature tend to undergo changes toward lower energy and higher entropy.		◆ chaos theory—randomness vs. order

VII. Organic Chemistry

KEY	LINK TO APPENDIX A	MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	REAL-WORLD CONNECTIONS
3.1ff	VII.1	Organic compounds contain carbon atoms which bond to one another in chains, rings, and networks to form a variety of structures. Organic compounds can be named using the IUPAC system.	classify an organic compound based on its structural or condensed structural formula (3.1xvii)	◆ biochemical molecules-formation of carbohydrates, proteins, starches, fats, nucleic acids ◆ synthetic polymers-polyethylene (plastic bags, toys), polystyrene (cups, insulation), polypropylene (carpets, bottles) polytetrafluoroethylene (nonstick surfaces—Teflon™), polyacrilonitrile (yarns, fabrics, wigs) ◆ disposal problems of synthetic polymers
3.1gg	VII.2	Hydrocarbons are compounds that contain only carbon and hydrogen. Saturated hydrocarbons contain only single carbon-carbon bonds. Unsaturated hydrocarbons contain at least one multiple carbon-carbon bond.	draw structural formulas for alkanes, alkenes, and alkynes containing a maximum of ten carbon atoms (3.1xxi)	
3.1hh	VII.3	Organic acids, alcohols, esters, aldehydes, ketones, ethers, halides, amines, amides, and amino acids are types of organic compounds that differ in their structures. Functional groups impart distinctive physical and chemical properties to organic compounds.	classify an organic compound based on its structural or condensed structural formula (3.1xvii) draw a structural formula with the functional group(s) on a straight chain hydrocarbon backbone, when given the correct IUPAC name for the compound (3.1xx)	◆ making perfume ◆ wine production ◆ nuclear magnetic resonance spectroscopy (NMR), (MRI) ◆ dyes ◆ cosmetics ◆ odors (esters)

KEY	LINK TO APPENDIX A	MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	REAL-WORLD CONNECTIONS
VII. Organic Chemistry				
3.1ii	VII.4	Isomers of organic compounds have the same molecular formula, but different structures and properties.		◆ types, varieties, uses of organic compounds ◆ organic isomers
5.2e	VII.5	In a multiple covalent bond, more than one pair of electrons are shared between two atoms. Unsaturated organic compounds contain at least one double or triple bond.		◆ saturated vs. unsaturated compounds—health connections
3.2c	VII.6	Types of organic reactions include: addition, substitution, polymerization, esterification, fermentation, saponification, and combustion.	identify types of organic reactions (3.2iv) determine a missing reactant or product in a balanced equation (3.2iii)	◆ saponification—making soap ◆ polymerization– formation of starches ◆ fermentation—alcohol production ◆ combustion of fossil fuels ◆ cellular respiration
VIII. Oxidation-Reduction				
3.2d	VIII.1	An oxidation-reduction (redox) reaction involves transfer of electrons (e^-).	determine a missing reactant or product in a balanced equation 3.2iii)	◆ electrochemical cells ◆ corrosion ◆ electrolysis ◆ photography ◆ rusting
3.2e	VIII.2	Reduction is the gain of electrons.		◆ smelting ◆ leaching (refining of gold) ◆ thermite reactions (reduction of metal oxides, e.g., aluminum)
3.2f	VIII.3	A half-reaction can be written to represent reduction.	write and balance half-reactions for oxidation and reduction of free elements and their monatomic ions (3.2vi)	
3.2g	VIII.4	Oxidation is the loss of electrons.		◆ recovery of active nonmetals (I_2)

VIII. Oxidation-Reduction

KEY	LINK TO APPENDIX A	MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	REAL-WORLD CONNECTIONS
3.2h	VIII.5	A half-reaction can be written to represent oxidation.		
3.3b	VIII.6	In a redox reaction the number of electrons lost is equal to the number of electrons gained.		
3.2i	VIII.7	Oxidation numbers (states) can be assigned to atoms and ions. Changes in oxidation numbers indicate that oxidation and reduction have occurred.		
3.2j	VIII.8	An electrochemical cell can be either voltaic or electrolytic. In an electrochemical cell, oxidation occurs at the anode and reduction at the cathode.	compare and contrast voltaic and electrolytic cells (3.2ix)	◆ patina (copper—Statue of Liberty)
3.2k	VIII.9	A voltaic cell spontaneously converts chemical energy to electrical energy.	identify and label the parts of a voltaic cell (cathode, anode, salt bridge) and direction of electron flow, given the reaction equation (3.2vii) use an activity series to determine whether a redox reaction is spontaneous (3.2x)	
3.2l	VIII.10	An electrolytic cell requires electrical energy to produce chemical change. This process is known as electrolysis.	identify and label the parts of an electrolytic cell (anode, cathode) and direction of electron flow, given the reaction equation (3.2viii)	◆ metallurgy of iron and steel ◆ electroplating

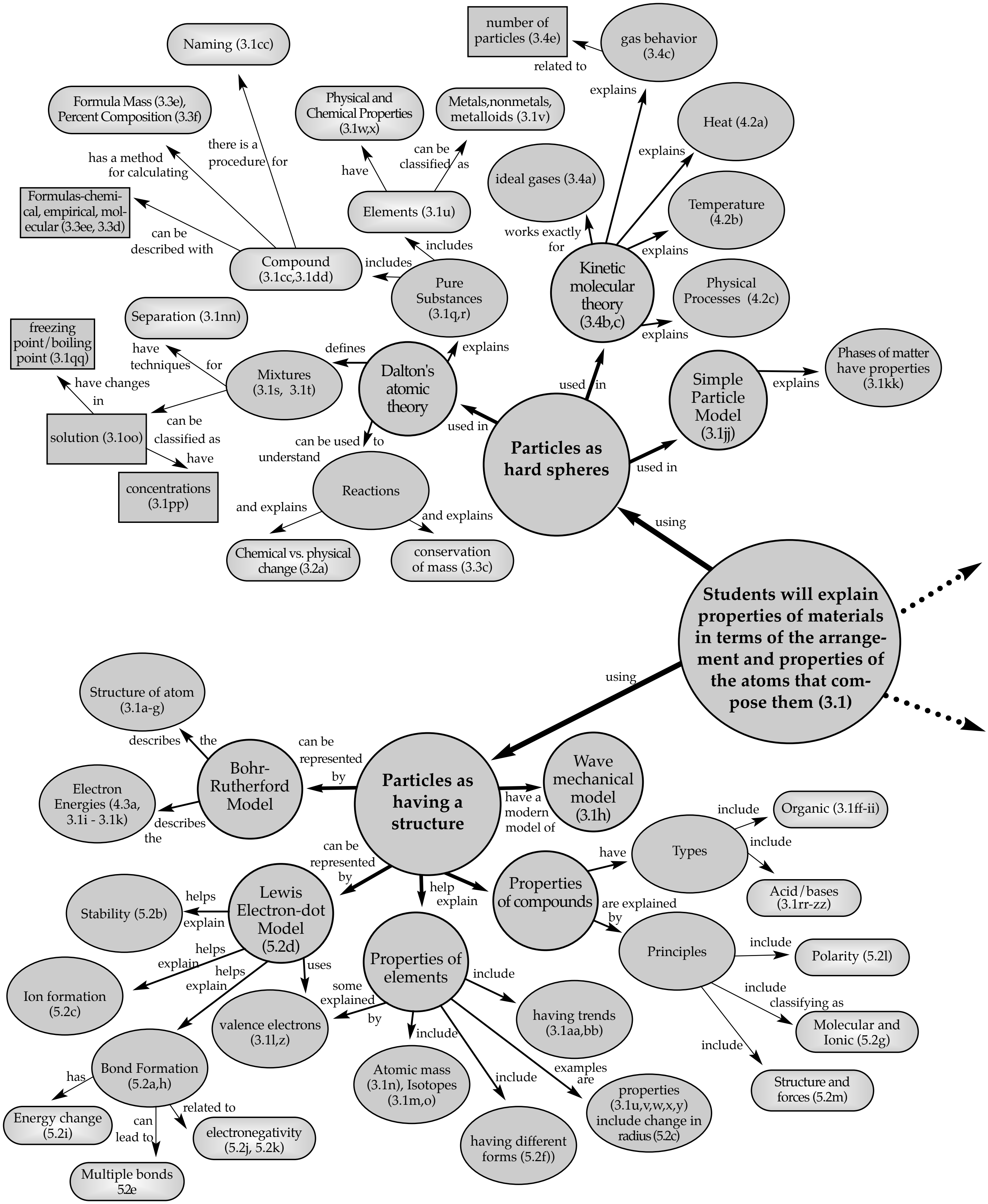
IX. Acids, Bases, and Salts

KEY	LINK TO APPENDIX A	MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	REAL-WORLD CONNECTIONS
3.1uu	IX.1	Behavior of many acids and bases can be explained by the Arrhenius theory. Arrhenius acids and bases are electrolytes.	given properties, identify substances as Arrhenius acids or Arrhenius bases (3.1xxxi)	
3.1rr	IX.2	An electrolyte is a substance which, when dissolved in water, forms a solution capable of conducting an electric current. The ability of a solution to conduct an electric current depends on the concentration of ions.		
3.1vv	IX.3	Arrhenius acids yield H^+ (aq), hydrogen ion as the only positive ion in aqueous solution. The hydrogen ion may also be written as $H_3O+_{(aq)}$, hydronium ion.		
3.1ww	IX.4	Arrhenius bases yield OH^- (aq), hydroxide ion as the only negative ion in an aqueous solution.		◆ cleaning agents
3.1xx	IX.5	In the process of neutralization, an Arrhenius acid and an Arrhenius base react to form salt and water.	write simple neutralization reactions when given the reactants (3.1xxxiv)	
3.1zz	IX.6	Titration is a laboratory process in which a volume of solution of known concentration is used to determine the concentration of another solution.	calculate the concentration or volume of a solution, using titration data (3.1xxxv)	
3.1yy	IX.7	There are alternate acid-base theories. One such theory states that an acid is an H^+ donor and a base is an H^+ acceptor.		

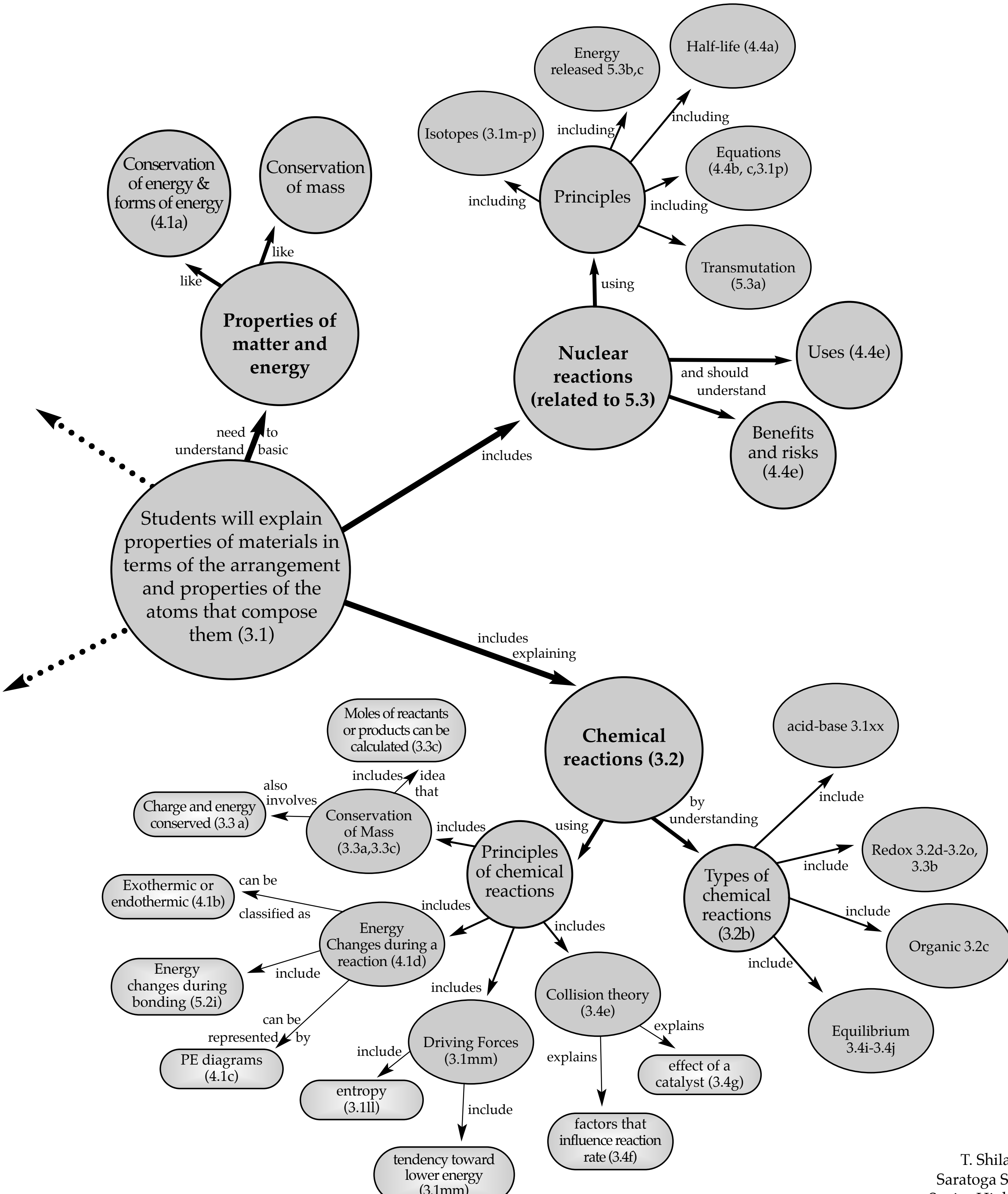
KEY	LINK TO APPENDIX A	MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	REAL-WORLD CONNECTIONS
IX. Acids, Bases, and Salts				
3.1ss	IX.8	The acidity and alkalinity of an aqueous solution can be measured by its pH value. The relative level of acidity or alkalinity of a solution can be shown by using indicators.	interpret changes in acid-base indicator color (3.1xxxiii) identify solutions as acid, base, or neutral based upon the pH (3.1xxxii)	◆ acid rain ◆ household chemicals ◆ buffers ◆ swimming pool chemistry ◆ blood acidosis/alkalosis
3.1tt	IX.9	On the pH scale, each decrease of one unit of pH represents a tenfold increase in hydronium ion concentration.		
X. Nuclear Chemistry				
3.1o	X.1	Stability of isotopes is based on the ratio of the neutrons and protons in its nucleus. Although most nuclei are stable, some are unstable and spontaneously decay emitting radiation.		
4.4a	X.2	Each radioactive isotope has a specific mode and rate of decay (half-life).	calculate the initial amount, the fraction remaining, or the half-life of a radioactive isotope, given two of the three variables (4.4i)	◆ radioactive dating
5.3a	X.3	A change in the nucleus of an atom that converts it from one element to another is called transmutation. This can occur naturally or can be induced by the bombardment of the nucleus by high-energy particles.		◆ nuclear fission and fusion reactions that release energy ◆ radioisotopes, tracers, transmutation ◆ man-made elements
3.1p	X.4	Spontaneous decay can involve the release of alpha particles, beta particles, positrons, and/or gamma radiation from the nucleus of an unstable isotope. These emissions differ in mass, charge, ionizing power, and penetrating power.	determine decay mode and write nuclear equations showing alpha and beta decay (3.1ix)	

X. Nuclear Chemistry

KEY	LINK TO APPENDIX A	MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	REAL-WORLD CONNECTIONS
4.4b	X.5	Nuclear reactions include natural and artificial transmutation, fission, and fusion.	compare and contrast fission and fusion reactions (4.4ii)	
4.4f	X.6	There are benefits and risks associated with fission and fusion reactions.		
4.4c	X.7	Nuclear reactions can be represented by equations that include symbols which represent atomic nuclei (with the mass number and atomic number), subatomic particles (with mass number and charge), and/or emissions such as gamma radiation.	complete nuclear equations; predict missing particles from nuclear equations (4.4iii)	
5.3b	X.8	Energy released in a nuclear reaction (fission or fusion) comes from the fractional amount of mass converted into energy. Nuclear changes convert matter into energy.		◆ production of nuclear power ∞ fission ∞ fusion (breeder reactors) ◆ cost-benefit analysis among various types of power production
5.3c	X.9	Energy released during nuclear reactions is much greater than the energy released during chemical reactions.		
4.4e	X.10	There are inherent risks associated with radioactivity and the use of radioactive isotopes. Risks can include biological exposure, long-term storage and disposal, and nuclear accidents.		◆ nuclear waste ◆ radioactive pollution
4.4d	X.11	Radioactive isotopes have many beneficial uses. Radioactive isotopes are used in medicine and industrial chemistry, e.g., radioactive dating, tracing chemical and biological processes, industrial measurement, nuclear power, and detection and treatment of diseases.	identify specific uses of some common radioisotopes, such as: I-131 in diagnosing and treating thyroid disorders; C-14 to C-12 ratio in dating living organisms; U-238 to Pb-206 ratio in dating geological formations; Co-60 in treating cancer (4.4iv)	◆ use of radioactive tracers ◆ radiation therapy ◆ irradiated food


Students will explain properties of materials in terms of the arrangement and properties of the atoms that compose them (3.1)
using
Particles as hard spheres
used in
Kinetic molecular theory (3.4b,c)
explains
gas behavior (3.4c)
related to
number of particles (3.4e)
Heat (4.2a)
Temperature (4.2b)
Physical Processes (4.2c)
works exactly for
ideal gases (3.4a)
Simple Particle Model (3.1jj)
Phases of matter have properties (3.1kk)
Dalton's atomic theory
Pure Substances (3.1q,r)
includes
Elements (3.1u)
have
Physical and Chemical Properties (3.1w,x)
can be classified as
Metals,nonmetals, metalloids (3.1v)
Compound (3.1cc,3.1dd)
there is a procedure for
Naming (3.1cc)
has a method for calculating
Formula Mass (3.3e), Percent Composition (3.3f)
can be described with
Formulas-chemical, empirical, molecular (3.3ee, 3.3d)
defines
Mixtures (3.1s, 3.1t)
have techniques for
Separation (3.1nn)
can be classified as
solution (3.1oo)
have changes in
freezing point/boiling point (3.1qq)
have
concentrations (3.1pp)
can be used to understand
Reactions
and explains
Chemical vs. physical change (3.2a)
conservation of mass (3.3c)
Particles as having a structure
can be represented by
Bohr-Rutherford Model
describes the
Structure of atom (3.1a-g)
Electron Energies (4.3a, 3.1i - 3.1k)
have a modern model of
Wave mechanical model (3.1h)
Lewis Electron-dot Model (5.2d)
helps explain
Stability (5.2b)
Ion formation (5.2c)
uses
valence electrons (3.1l,z)
Bond Formation (5.2a,h)
has
Energy change (5.2i)
can lead to
Multiple bonds 52e
related to
electronegativity (5.2j, 5.2k)
help explain
Properties of elements
some explained by
include
having trends (3.1aa,bb)
Atomic mass (3.1n), Isotopes (3.1m,o)
having different forms (5.2f))
examples are
properties (3.1u,v,w,x,y) include change in radius (5.2c)
Properties of compounds
have
Types
include
Organic (3.1ff-ii)
Acid/bases (3.1rr-zz)
are explained by
Principles
Polarity (5.2l)
include classifying as
Molecular and Ionic (5.2g)
Structure and forces (5.2m)

__Note:__ This is an example of how the chemistry core might be presented during the year. It is __not__ a suggested format from the New York State Education Department.



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PROCESS SKILLS
BASED ON STANDARDS 1, 2, 6, AND 7

Science process skills should be based on a series of discoveries. Students learn most effectively when they have a central role in the discovery process. To that end, Standards 1, 2, 6, and 7 incorporate in the Chemistry Core Curriculum *a student-centered, problem-solving approach to chemistry. This list is not intended to be an all-inclusive list of the content or skills that teachers are expected to incorporate into their curriculum. It should be a goal of the instructor to encourage science process skills that will provide students with background and curiosity to investigate important issues in the world around them.*

Note: The use of e.g. *denotes examples which may be used for in-depth study. The terms* for example *and* such as *denote material which is testable. Items in parentheses denote further definition of the word(s) preceding the item and are testable.*

STANDARD 1—Analysis, Inquiry, and Design

Students will use mathematical analysis, scientific inquiry, and engineering design, as appropriate, to pose questions, seek answers, and develop solutions.

STANDARD 1 Analysis, Inquiry, and Design **MATHEMATICAL ANALYSIS:**	*Key Idea 1:* Abstraction and symbolic representation are used to communicate mathematically. M1.1 Use algebraic and geometric representations to describe and compare data. • organize, graph, and analyze data gathered from laboratory activities or other sources ◆ identify independent and dependent variables ◆ create appropriate axes with labels and scale ◆ identify graph points clearly • measure and record experimental data and use data in calculations ◆ choose appropriate measurement scales and use units in recording ◆ show mathematical work, stating formula and steps for solution ◆ estimate answers ◆ use appropriate equations and significant digits ◆ show uncertainty in measurement by the use of significant figures ◆ identify relationships within variables from data tables ◆ calculate percent error • recognize and convert various scales of measurement ◆ temperature § Celsius (°C) § Kelvin (K) ◆ length § kilometers (km) § meters (m) § centimeters (cm) § millimeters (mm) ◆ mass § grams (g) § kilograms (kg) ◆ pressure § kilopascal (kPa) § atmosphere (atm) • use knowledge of geometric arrangements to predict particle properties or behavior

STANDARD 1 Analysis, Inquiry, and Design MATHEMATICAL ANALYSIS: continued	*Key Idea 2:* Deductive and inductive reasoning are used to reach mathematical conclusions. M2.1 Use deductive reasoning to construct and evaluate conjectures and arguments, recognizing that patterns and relationships in mathematics assist them in arriving at these conjectures and arguments. • interpret a graph constructed from experimentally obtained data ◆ identify relationships § direct § inverse ◆ apply data showing trends to predict information *Key Idea 3:* Critical thinking skills are used in the solution of mathematical problems. M3.1 Apply algebraic and geometric concepts and skills to the solution of problems. • state assumptions which apply to the use of a particular mathematical equation and evaluate these assumptions to see if they have been met • evaluate the appropriateness of an answer, based on given data

STANDARD 1 Analysis, Inquiry, and Design SCIENTIFIC INQUIRY:	*Key Idea 1:* The central purpose of scientific inquiry is to develop explanations of natural phenomena in a continuing, creative process. S1.1 Elaborate on basic scientific and personal explanations of natural phenomena, and develop extended visual models and mathematical formulations to represent thinking. • use theories and/or models to represent and explain observations • use theories and/or principles to make predictions about natural phenomena • develop models to explain observations S1.2 Hone ideas through reasoning, library research, and discussion with others, including experts. • locate data from published sources to support/defend/explain patterns observed in natural phenomena S1.3 Work towards reconciling competing explanations, clarifying points of agreement and disagreement. • evaluate the merits of various scientific theories and indicate why one theory was accepted over another *Key Idea 2:* Beyond the use of reasoning and consensus, scientific inquiry involves the testing of proposed explanations involving the use of conventional techniques and procedures and usually requiring considerable ingenuity. S2.1 Devise ways of making observations to test proposed explanations. • design and/or carry out experiments, using scientific methodology to test proposed calculations S2.2 Refine research ideas through library investigations, including information retrieval and reviews of the literature, and through peer feedback obtained from review and discussion. • use library investigations, retrieved information, and literature reviews to improve the experimental design of an experiment

STANDARD 1 Analysis, Inquiry, and Design SCIENTIFIC INQUIRY: continued	

STANDARD 1
Analysis, Inquiry, and Design

SCIENTIFIC INQUIRY:

continued

S2.3 Develop and present proposals including formal hypotheses to test explanations, i.e.; they predict what should be observed under specific conditions if their explanation is true.

- develop research proposals in the form of "if *X* is true and a particular test *Y* is done, then prediction *Z* will occur"

S2.4 Carry out a research plan for testing explanations, including selecting and developing techniques, acquiring and building apparatus, and recording observations as necessary.

- determine safety procedures to accompany a research plan

Key Idea 3:

The observations made while testing proposed explanations, when analyzed using conventional and invented methods, provide new insights into phenomena.

S3.1 Use various means of representing and organizing observations (e.g., diagrams, tables, charts, graphs, equations, and matrices) and insightfully interpret the organized data.

- organize observations in a data table, analyze the data for trends or patterns, and interpret the trends or patterns, using scientific concepts

S3.2 Apply statistical analysis techniques when appropriate to test if chance alone explains the result.

S3.3 Assess correspondence between the predicted result contained in the hypothesis and the actual result, and reach a conclusion as to whether or not the explanation on which the prediction is supported.

- evaluate experimental methodology for inherent sources of error and analyze the possible effect on the result
- compare the experimental result to the expected result; calculate the percent error as appropriate

S3.4 Using results of the test and through public discussion, revise the explanation and contemplate additional research.

S3.5 Develop a written report for public scrutiny that describes the proposed explanation, including a literature review, the research carried out, its results, and suggestions for further research.

STANDARD 1
Analysis, Inquiry, and Design:

ENGINEERING DESIGN

Key Idea 1:

Engineering design is an iterative process involving modeling and optimization (finding the best solution within given constraints); this process is used to develop technological solutions to problems within given constraints.

If students are asked to do a design project, then:

- Initiate and carry out a thorough investigation of an unfamiliar situation and identify needs and opportunities for technological invention or innovation.
- Identify, locate, and use a wide range of information resources, and document through notes and sketches how findings relate to the problem.
- Generate creative solutions, break ideas into significant functional elements, and explore possible refinements; predict possible outcomes, using mathematical and functional modeling techniques; choose the optimal solution to the problem, clearly documenting ideas against design criteria and constraints; and explain how human understandings, economics, ergonomics, and environmental considerations have influenced the solution.
- Develop work schedules and working plans which include optimal use and cost of materials, processes, time, and expertise; construct a model of the solution, incorporating developmental modifications while working to a high degree of quality (craftsmanship).

STANDARD 1 Analysis, Inquiry, and Design ENGINEERING DESIGN: continued	• Devise a test of the solution according to the design criteria and perform the test; record, portray, and logically evaluate performance test results through quantitative, graphic, and verbal means. Use a variety of creative verbal and graphic techniques effectively and persuasively to present conclusions, predict impact and new problems, and suggest and pursue modifications.

STANDARD 2—Information Systems
Students will access, generate, process, and transfer information using appropriate technologies.

STANDARD 2 INFORMATION SYSTEMS:	*Key Idea 1:* Information technology is used to retrieve, process, and communicate information as a tool to enhance learning. Examples include: • use the Internet as a source to retrieve information for classroom use, e.g., Periodic Table, acid rain *Key Idea 2:* Knowledge of the impacts and limitations of information systems is essential to its effectiveness and ethical use. Examples include: • critically assess the value of information with or without benefit of scientific backing and supporting data, and evaluate the effect such information could have on public judgment or opinion, e.g., environmental issues • discuss the use of the peer-review process in the scientific community and explain its value in maintaining the integrity of scientific publication, e.g., “cold fusion”

STANDARD 6—Interconnectedness: Common Themes
Students will understand the relationships and common themes that connect mathematics, science, and technology and apply the themes to these and other areas of learning.

STANDARD 6 Interconnectedness: Common Themes SYSTEMS THINKING:	*Key Idea 1:* Through systems thinking, people can recognize the commonalities that exist among all systems and how parts of a system interrelate and combine to perform specific functions. Examples include: • use the concept of systems and surroundings to describe heat flow in a chemical or physical change, e.g., dissolving process

STANDARD 6

Interconnectedness: Common Themes

MODELS:

Key Idea 2:

Models are simplified representations of objects, structures, or systems used in analysis, explanation, interpretation, or design.

2.1 Revise a model to create a more complete or improved representation of the system.
- show how models are revised in response to experimental evidence, e.g., atomic theory, Periodic Table

2.2 Collect information about the behavior of a system and use modeling tools to represent the operation of the system.
- show how information about a system is used to create a model, e.g., kinetic molecular theory (KMT)

2.3 Find and use mathematical models that behave in the same manner as the processes under investigation.
- show how mathematical models (equations) describe a process, e.g., combined gas law

2.4 Compare predictions to actual observations, using test models.
- compare experimental results to a predicted value, e.g., percent error

STANDARD 6

Interconnectedness: Common Themes

MAGNITUDE AND SCALE:

Key Idea 3:

The grouping of magnitudes of size, time, frequency, and pressures or other units of measurement into a series of relative order provides a useful way to deal with the immense range and the changes in scale that affect the behavior and design of systems.

3.1 Describe the effects of changes in scale on the functioning of physical, biological, or designed information systems.
- show how microscale processes can resemble or differ from real-world processes, e.g., microscale chemistry

3.2 Extend the use of powers of ten notation to understanding the exponential function and performing operations with exponential factors.
- use powers often to represent a large range of values for a physical quantity, e.g., pH scale

STANDARD 6

Interconnectedness: Common Themes

EQUILIBRIUM AND STABILITY:

Key Idea 4:

Equilibrium is a state of stability due either to a lack of change (static equilibrium) or a balance between opposing forces (dynamic equilibrium).

4.1 Describe specific instances of how disturbances might affect a system's equilibrium, from small disturbances that do not upset the equilibrium to larger disturbances (threshold level) that cause the system to become unstable.
- explain how a small change might not affect a system, e.g., activation energy

4.2 Cite specific examples of how dynamic equilibrium is achieved by equality of change in opposing directions.
- explain how a system returns to equilibrium in response to a stress, e.g., LeChatelier's principle

STANDARD 6 Interconnectedness: Common Themes PATTERNS OF CHANGE:	*Key Idea 5:* Identifying patterns of change is necessary for making predictions about future behavior and conditions. Examples include: • use graphs to make predictions, e.g., half-life, solubility • use graphs to identify patterns and interpret experimental data, e.g., heating and cooling curves

STANDARD 7—Interdisciplinary Problem Solving
Students will apply the knowledge and thinking skills of mathematics, science, and technology to address real-life problems and make informed decisions.

STANDARD 7 Interdisciplinary Problem Solving CONNECTIONS:	*Key Idea 1:* The knowledge and skills of mathematics, science, and technology are used together to make informed decisions and solve problems, especially those relating to issues of science/technology/society, consumer decision making, design, and inquiry into phenomena. 1.1 Analyze science/technology/society problems and issues on a community, national, or global scale and plan and carry out a remedial course of action. • carry out a remedial course of action by communicating the plan to others, e.g., writing and sending "a letter to the editor" 1.2 Analyze and quantify consumer product data, understand environmental and economic impacts, develop a method for judging the value and efficacy of competing products, and discuss cost-benefit and risk-benefit trade-offs made in arriving at the optimal choice. • compare and analyze specific consumer products, e.g., antacids, vitamin C 1.3 Design solutions to real-world problems on a community, national, or global scale, using a technological design process that integrates scientific investigation and rigorous mathematical analysis of the problem and of the solution. • design a potential solution to a regional problem, e.g., suggest a plan to adjust the acidity of a lake in the Adirondacks 1.4 Explain and evaluate phenomena mathematically and scientifically by formulating a testable hypothesis, demonstrating the logical connections between the scientific concepts guiding the hypothesis and the design of an experiment, applying and inquiring into the mathematical ideas relating to investigation of phenomena, and using (and if needed, designing) technological tools and procedures to assist in the investigation and in the communication of results. • design an experiment that requires the use of a mathematical concept to solve a scientific problem, e.g., an experiment to compare the density of different types of soda pop

STANDARD 7 **Interdisciplinary Problem Solving** **STRATEGIES:**	*Key Idea 2:* Solving interdisciplinary problems involves a variety of skills and strategies, including effective work habits; gathering and processing information; generating and analyzing ideas; realizing ideas; making connections among the common themes of mathematics, science, and technology; and presenting results. If students are asked to do a project, then the project would require students to: • work effectively • gather and process information • generate and analyze ideas • observe common themes • realize ideas • present results