Physical Setting/ Chemistry

Core Curriculum

THE UNIVERSITY OF THE STATE OF NEW YORK

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Physical Setting/
Chemistry
Core Curriculum

INTRODUCTION

The *Physical Setting/Chemistry Core Curriculum* has been written to assist teachers and supervisors as they prepare curriculum, instruction, and assessment for the chemistry content and process skills in the New York State *Learning Standards for Mathematics, Science, and Technology*. This core curriculum is an elaboration of the science content of that document and its key ideas and performance indicators. Key ideas are broad, unifying, general statements of what students need to know. The performance indicators for each key idea are statements of what students should be able to do to provide evidence that they understand the key idea.

The *Chemistry Core Curriculum* presents major understandings that give more specific detail to the concepts underlying the performance indicators in Standard 4. In addition, portions of Standards 1, 2, 6, and 7 have been elaborated to highlight skills necessary to allow students to evaluate proposed explanations of natural phenomena. The concepts and skills identified in the introductions and the major understandings of each key idea in the core curriculum will provide the material from which Regents examination items will be developed. Occasionally, examples are given in an effort to clarify information. These examples are not inclusive lists. Therefore, teachers should not feel limited by them.

This core is *not* a syllabus. This is a core for the preparation of high school curriculum, instruction, and assessment. The lack of detail in this core is not to be seen as a shortcoming. Rather, the focus on conceptual understanding in the core is consistent with the approaches recommended in the *National Science Education Standard* (National Research Council) and *Benchmarks for Science Literacy* (American Association for the Advancement of Science). The local courses designed using this core curriculum are expected to prepare students to explain both accurately and with appropriate depth concepts and models relating to chemistry. The core addresses only the content and skills to be assessed at the commencement level by the Physical Setting/Chemistry Regents examination. The core curriculum has been prepared with the assumption that the content, skills, and vocabulary as outlined in the *Learning Standards for Mathematics, Science, and Technology* at the elementary and intermediate levels have been taught previously. Work in grades 9-12 must build on the knowledge, understanding, and ability to do science that students have acquired in their earlier grades.

It is essential that instruction focus on the understanding of concepts, relationships, processes, mechanisms, models, and applications. Less important is the memorization of specialized terminology and technical details. In attaining scientific literacy, students will be able to demonstrate these understandings, generate explanations, exhibit creative problem solving and reasoning, and make informed decisions. Future assessments will test students' ability to explain, analyze, and interpret chemical processes and phenomena, and use models and scientific inquiry. The major understandings in this guide will also allow teachers more flexibility, making possible richer creativity in instruction and greater variation in assessment. The general nature of the major understandings in this core will encourage the teaching of science for understanding, rather than for memorization.

The order of presentation and numbering of all statements in this guide are not meant to indicate any recommended sequence of instruction. Ideas have not been prioritized, nor have they been organized to indicate teaching time allotments or test weighting. Many of the major understandings in this document are stated in a general rather than specific manner. It is expected that teachers will provide examples and applications in their teaching/learning strategies to bring about understanding of the major concepts involved. Teachers are encouraged to help students find and elaborate conceptual cross-linkages that interconnect many of the chemistry key ideas to each other, and to other mathematics, science, and technology learning standards.

Historical Content

The study of chemistry is rich in historical development. The learning standards encourage the inclusion not only of important concepts but also of the scientists who were responsible for discovering them. Robert Boyle, generally regarded as one of the fathers of modern chemistry, introduced systematic experimental methods into the study of chemistry. John Dalton laid down the tenets of the atomic theory at the beginning of the 19th century. By mid-century Mendeleev had completed most of his work organizing the Periodic

Table, and Amedeo Avogadro had provided keen insights into the relationships of gaseous molecules. Ernest Rutherford discovered the nucleus, and soon afterward Henry Moseley identified the atomic number as the identifying factor of the elements. Soon after, Albert Einstein proposed the insight into the interrelationship of matter and energy. Marie Curie worked with radioactive substances showing natural transmutations. Linus Pauling provided insights into the nature of the chemical bond in the 1930s, and introduced electronegativity values, an important tool in understanding bonding.

To successfully teach chemistry, teachers can interweave both the concepts and the scientists who were responsible for discovering them. Chemistry will be far more interesting when the human element can be incorporated into the lessons.

Scientific Thinking and a Scientific Method

Modern science began around the late 16th century with a new way of thinking about the world. Few scientists will disagree with Carl Sagan's assertion that "science is a way of thinking much more than it is a body of knowledge" (*Broca's Brain*, 1979). Thus science is a process of inquiry and investigation. It is a way of thinking and acting, not just a body of knowledge to be acquired by memorizing facts and principles. This way of thinking, the scientific method, is based on the idea that scientists begin their investigations with observations. From these observations they develop a hypothesis, which is extended in the form of a predication, and challenge the hypothesis through experimentation and thus further observations. Science has progressed in its understanding of nature through careful observation, a lively imagination, and increasing sophisticated instrumentation. Science is distinguished from other fields of study in that it provides guidelines or methods for conducting research, and the research findings must be reproducible by other scientists for those findings to be valid.

It is important to recognize that scientific practice is not always this systematic. Discoveries have been made that are serendipitous and others have not started with the observation of data. Einstein's theory of relativity started not with the observation of data but with a kind of intellectual puzzle.

Laboratory Requirements

Critical to understanding science concepts is the use of scientific inquiry to develop explanations of natural phenomena. Therefore, as a prerequisite for admission to the Physical Setting/Chemistry Regents Examination, students must have successfully completed 1200 minutes of laboratory experience with satisfactory reports on file. Because of the strong emphasis on student development of laboratory skills, a minimum of 280 minutes per week of class and laboratory time is recommended.

Prior to the written portion of the Regents examination, students will be required to complete a laboratory performance test during which concepts and skills from Standards 1, 2, 4, 6, and 7 will be assessed.

The Laboratory Setting

Laboratory safety dictates that a minimum amount of space be provided for each individual student. According to the National Science Teachers Association, recommended space considerations include:

- A minimum of 60 ft^2/pupil (5.6m^2) which is equivalent to 1440 ft^2 (134m^2) to accommodate a class of 24 safely in a combination laboratory/classroom.

Or,

- A minimum of 45 ft^2/pupil (4.2m^2) which is equivalent to 1080 ft^2 (101m^2) to accommodate a class of 24 safely in a stand-alone laboratory.

It is recommended that each school district comply with local, State, and federal codes and regulations regarding facilities and fire and safety issues.

Systems of Units

International System (SI) units are used in this core curriculum. SI units that are required for the chemistry core are listed in the Reference Tables. SI units are a logical extension of the metric system. The SI system begins with seven basic units, with all other units being derived from them (see Reference Tables). While some of the basic and derived units of the SI system are commonly used in chemistry (mole, kelvin, kilogram, meter, joule, volt), there are other units that are used in chemistry that are exceptions. Thus, in addition to the SI units, you will find liters used in volume measurements, atmospheres and torr used as pressure units, and Celsius as a temperature indicator.

Uncertainty of Measurements and Significant Figures

It is an important concept in chemistry that all measurements contain some uncertainty. Such data is reported in significant figures to inform the reader of the uncertainty of the measurement. When these values are used in calculations, it is vital that the answers to such calculations are not misleading, and hence, rules for addition, subtraction, multiplication, and division should be followed.

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

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

PROCESS SKILLS
BASED ON STANDARD 4

STANDARD 4—The Physical Setting
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.

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 4
The Physical Setting

Key Idea 3:
Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.

3.1 Explain the properties of materials in terms of the arrangement and properties of the atoms that compose them.

i	use models to describe the structure of an atom	3.1b, 3.1c
ii	relate experimental evidence (given in the introduction of Key Idea 3) to models of the atom	3.1a
iii	determine the number of protons or electrons in an atom or ion when given one of these values	3.1e
iv	calculate the mass of an atom, the number of neutrons or the number of protons, given the other two values	3.1f
v	distinguish between ground state and excited state electron configurations, e.g., 2-8-2 vs. 2-7-3	3.1j
vi	identify an element by comparing its bright-line spectrum to given spectra	3.1k
vii	distinguish between valence and non-valence electrons, given an electron configuration, e.g., 2-8-2	3.1l
viii	draw a Lewis electron-dot structure of an atom	3.1l
ix	determine decay mode and write nuclear equations showing alpha and beta decay	3.1p, 4.4b
x	interpret and write isotopic notation	3.1g
xi	given an atomic mass, determine the most abundant isotope	3.1n
xii	calculate the atomic mass of an element, given the masses and ratios of naturally occurring isotopes	3.1n
xiii	classify elements as metals, nonmetals, metalloids, or noble gases by their properties	3.1v, 3.1w, 3.1x, 3.1y
xiv	compare and contrast properties of elements within a group or a period for Groups 1, 2, 13-18 on the Periodic Table	3.1aa, 3.1bb
xv	determine the group of an element, given the chemical formula of a compound, e.g., XCl or XCl_2	3.1z
xvi	explain the placement of an unknown element on the Periodic Table based on its properties	3.1v, 3.1w, 3.1x, 3.1y
xvii	classify an organic compound based on its structural or condensed structural formula (i.e., CH_3COOH or  $-C-\overset{O}{C}-OH$)	3.1ff, 3.1gg, 3.1hh
xviii	describe the states of the elements at STP	3.1jj
xix	distinguish among ionic, molecular, and metallic substances, given their properties	3.1dd, 3.1w, 5.2g, 5.2h
xx	draw a structural formula with the functional group(s) on a straight chain hydrocarbon backbone, when given the IUPAC name for the compound	3.1ff, 3.1hh

STANDARD 4
The Physical Setting

continued

xxi	draw structural formulas for alkanes, alkenes, and alkynes containing a maximum of ten carbon atoms	3.1ff, 3.1gg
xxii	use a simple particle model to differentiate among properties of solids, liquids, and gases	3.1jj, 3.1kk
xxiii	compare the entropy of phases of matter	3.1mm
xxiv	describe the processes and uses of filtration, distillation, and chromatography in the separation of a mixture	3.1nn
xxv	interpret and construct solubility curves	3.1oo
xxvi	apply the adage “like dissolves like” to real-world situations	3.1oo
xxvii	interpret solution concentration data	3.1pp
xxviii	use solubility curves to distinguish among saturated, supersaturated, and unsaturated solutions	3.1oo
xxix	calculate solution concentration in molarity (M), percent mass, and parts per million (ppm)	3.1pp
xxx	describe the preparation of a solution, given the molarity	3.1pp
xxxi	given properties, identify substances as Arrhenius acids or Arrhenius bases	3.1uu
xxxii	identify solutions as acid, base, or neutral based upon the pH	3.1ss
xxxiii	interpret changes in acid-base indicator color	3.1ss
xxxiv	write simple neutralization reactions when given the reactants	3.1xx
xxxv	calculate the concentration or volume of a solution, using titration data	3.1zz
xxxvi	use particle models/diagrams to differentiate among elements, compounds, and mixtures	3.1r
3.2	Use atomic and molecular models to explain common chemical reactions.	
i	distinguish between chemical and physical changes	3.2a
ii	identify types of chemical reactions	3.2b, 3.2c
iii	determine a missing reactant or product in a balanced equation	3.2c, 3.2d
iv	identify organic reactions	3.2c
v	balance equations, given the formulas of reactants and products	3.2a, 3.3a, 3.3c
vi	write and balance half-reactions for oxidation and reduction of free elements and their monatomic ions	3.2f, 3.2h
vii	identify and label the parts of a voltaic cell (cathode, anode, salt bridge) and direction of electron flow, given the reaction equation	3.2k
viii	identify and label the parts of an electrolytic cell (cathode, anode) and direction of electron flow, given the reaction equation	3.2l
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x	use an activity series to determine whether a redox reaction is spontaneous	3.2k
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STANDARD 4
The Physical Setting

continued

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vi	determine the mass of a given number of moles of a substance	3.3f
vii	determine the molecular formula, given the empirical formula and the molecular mass	3.3d
viii	calculate the formula mass and gram-formula mass	3.3f
ix	determine the number of moles of a substance, given its mass	3.3f
3.4	Use kinetic molecular theory (KMT) to explain rates of reactions and the relationships among temperature, pressure, and volume of a substance.	
i	explain the gas laws in terms of KMT	3.4c
ii	solve problems, using the combined gas laws	3.4c
iii	convert temperatures in Celsius degrees ($^{\circ}$C) to kelvins (K), and kelvins to Celsius degrees	3.4e
iv	describe the concentration of particles and rates of opposing reactions in an equilibrium system	3.4i
v	qualitatively describe the effect of stress on equilibrium, using LeChatelier’s principle	3.4j
vi	use collision theory to explain how various factors, such as temperature, surface area, and concentration, influence the rate of reaction	3.4d
vii	identify examples of physical equilibria as solution equilibrium and phase equilibrium, including the concept that a saturated solution is at equilibrium	3.4h

Key Idea 4:
Energy exists in many forms, and when these forms change, energy is conserved.

4.1	Observe and describe transmission of various forms of energy.	
i	distinguish between endothermic and exothermic reactions, using energy terms in a reaction equation, ΔH, potential energy diagrams, or experimental data	4.1b
ii	read and interpret potential energy diagrams: PE reactants, PE products, activation energy (with or without a catalyst), heat of reaction	4.1c, 4.1d
4.2	Explain heat in terms of kinetic molecular theory.	
i	distinguish between heat energy and temperature in terms of molecular motion and amount of matter	4.2a, 4.2b
ii	explain phase change in terms of the changes in energy and intermolecular distances	4.2b
iii	qualitatively interpret heating and cooling curves in terms of changes in kinetic and potential energy, heat of vaporization, heat of fusion, and phase changes	4.2a, 4.2c
iv	calculate the heat involved in a phase or temperature change for a given sample of matter	4.2c

STANDARD 4 **The Physical Setting** **continued**	4.4 Explain the benefits and risks of radioactivity.	
	i calculate the initial amount, the fraction remaining, or the half-life of a radioactive isotope, given two of the three variables	4.4a
	ii compare and contrast fission and fusion reactions	4.4b, 4.4f, 5.3b
	iii complete nuclear equations; predict missing particles from nuclear equations	4.4c
	iv 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 once-living organisms, U-238 to Pb-206 ratio in dating geological formations, and Co-60 in treating cancer	4.4d
	Key Idea 5: Energy and matter interact through forces that result in changes in motion.	
	5.2 Students will explain chemical bonding in terms of the behavior of electrons.	
	i demonstrate bonding concepts, using Lewis dot structures representing valence electrons: § transferred (ionic bonding) § shared (covalent bonding) § in a stable octet Example: 	5.2a, 5.2d
	ii compare the physical properties of substances based on chemical bonds and intermolecular forces, e.g., conductivity, malleability, solubility, hardness, melting point, and boiling point	5.2n
	iii explain vapor pressure, evaporation rate, and phase changes in terms of intermolecular forces	5.2m
	iv determine the noble gas configuration an atom will achieve by bonding	5.2b
	v distinguish between nonpolar covalent bonds (two of the same nonmetals) and polar covalent bonds	5.2k

STANDARD 4: The Physical Setting

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.

Key Idea 3:

Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.

Chemistry is the study of matter—its properties and its changes. The idea that matter is made up of particles is over 2000 years old, but the idea of using properties of these particles to explain observable characteristics of matter has more recent origins. In ancient Greece, it was proposed that matter is composed of particles of four elements (earth, air, water, and fire) and that these particles are in continual motion. The idea that particles could explain properties of matter was not used for about 2000 years. In the late 1600s the properties of air were attributed to its particulate nature; however, these particles were not thought to be fundamental. Instead, it was thought that they could change into other particles with different properties.

In the late 1700s solid evidence about the nature of matter, gained through quantitative scientific experiments, accumulated. Such evidence included the finding that during a chemical reaction matter was conserved. In the early 1800s a theory was proposed to explain these experimental facts. In this theory, atoms were hard, indivisible spheres of different sizes and they combined in simple whole-number ratios to form compounds. The further treatment of particles of matter as hard spheres in continual motion resulted in the 1800s in the kinetic molecular theory of matter, which was used to explain the properties of gases.

In the late 1800s evidence was discovered that particles of matter could not be considered hard spheres; instead, particles were found to have an internal structure. The development of cathode ray tubes, and subsequent experiments with them in the 1860s, led to the proposal that small, negatively charged particles—electrons—are part of the internal structure of atoms. In the early 1900s, to explain the results of the "gold foil experiment," a small, dense nucleus was proposed to be at the center of the atom with electrons moving about in the empty space surrounding the nucleus. Around this time, energy was proposed to exist in small, indivisible packets called quanta. This theory was used to develop a model of the atom which had a central nucleus surrounded by shells of electrons. The model was successful in explaining the spectra of the hydrogen atom and was used to explain aspects of chemical bonding. Additional experiments with radioactivity provided evidence that atomic nuclei contained protons and neutrons.

Further investigation into the nature of the electron determined that it has wave-like properties. This feature was incorporated into the wave-mechanical model of the atom, our most sophisticated model, and is necessary to explain the spectra of multi-electron atoms.

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.*

PERFORMANCE INDICATOR 3.1 Explain the properties of materials in terms of the arrangement and properties of the atoms that compose them.

Major Understandings:

3.1a The modern model of the atom has evolved over a long period of time through the work of many scientists.

3.1b Each atom has a nucleus, with an overall positive charge, surrounded by negatively charged electrons.

3.1c Subatomic particles contained in the nucleus include protons and neutrons.

PERFORMANCE INDICATOR 3.1

continued

3.1d The proton is positively charged, and the neutron has no charge. The electron is negatively charged.

3.1e Protons and electrons have equal but opposite charges. The number of protons equals the number of electrons in an atom.

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 a neutron.

3.1g 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.

3.1h In the wave-mechanical model (electron cloud model) the electrons are in orbitals, which are defined as the regions of the most probable electron location (ground state).

3.1i Each electron in an atom has its own distinct amount of energy.

3.1j When an electron in an atom gains a specific amount of energy, the electron is at a higher energy state (excited state).

3.1k 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.

3.1l 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.

3.1m 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 The average atomic mass of an element is the weighted average of the masses of its naturally occurring isotopes.

3.1o Stability of an isotope is based on the ratio of neutrons and protons in its nucleus. Although most nuclei are stable, some are unstable and spontaneously decay, emitting radiation.

3.1p 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.

3.1q Matter is classified as a pure substance or as a mixture of substances.

3.1r A pure substance (element or compound) has a constant composition and constant properties throughout a given sample, and from sample to sample.

3.1s 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.

3.1t The proportions of components in a mixture can be varied. Each component in a mixture retains its original properties.

PERFORMANCE INDICATOR 3.1

continued

3.1u Elements are substances that are composed of atoms that have the same atomic number. Elements cannot be broken down by chemical change.

3.1v 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.

3.1w Elements can be differentiated by physical properties. Physical properties of substances, such as density, conductivity, malleability, solubility, and hardness, differ among elements.

3.1x Elements can also be differentiated by chemical properties. Chemical properties describe how an element behaves during a chemical reaction.

3.1y The placement or location of an element on the Periodic Table gives an indication of the physical and chemical properties of that element. The elements on the Periodic Table are arranged in order of increasing atomic number.

3.1z 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.

3.1aa The succession of elements within the same group demonstrates characteristic trends: differences in atomic radius, ionic radius, electronegativity, first ionization energy, metallic/nonmetallic properties.

3.1bb The succession of elements across the same period demonstrates characteristic trends: differences in atomic radius, ionic radius, electronegativity, first ionization energy, metallic/nonmetallic properties.

3.1cc 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.

3.1dd Compounds can be differentiated by their physical and chemical properties.

3.1ee Types of chemical formulas include empirical, molecular, and structural.

3.1ff 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.

3.1gg 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.

3.1hh Organic acids, alcohols, esters, aldehydes, ketones, ethers, halides, amines, amides, and amino acids are categories of organic compounds that differ in their structures. Functional groups impart distinctive physical and chemical properties to organic compounds.

3.1ii Isomers of organic compounds have the same molecular formula, but different structures and properties.

PERFORMANCE INDICATOR 3.1

continued

3.1jj The structure and arrangement of particles and their interactions determine the physical state of a substance at a given temperature and pressure.

3.1kk The three phases of matter (solids, liquids, and gases) have different properties.

3.1ll Entropy is a measure of the randomness or disorder of a system. A system with greater disorder has greater entropy.

3.1mm Systems in nature tend to undergo changes toward lower energy and higher entropy.

3.1nn Differences in properties such as density, particle size, molecular polarity, boiling and freezing points, and solubility permit physical separation of the components of the mixture.

3.1oo 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.

3.1pp The concentration of a solution may be expressed in molarity (M), percent by volume, percent by mass, or parts per million (ppm).

3.1qq 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.

3.1rr 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.

3.1ss The acidity or alkalinity of an aqueous solution can be measured by its pH value. The relative level of acidity or alkalinity of these solutions can be shown by using indicators.

3.1tt On the pH scale, each decrease of one unit of pH represents a tenfold increase in hydronium ion concentration.

3.1uu Behavior of many acids and bases can be explained by the Arrhenius theory. Arrhenius acids and bases are electrolytes.

3.1vv Arrhenius acids yield $H^+(aq)$, hydrogen ion as the only positive ion in an aqueous solution. The hydrogen ion may also be written as $H_3O^+(aq)$, hydronium ion.

3.1ww Arrhenius bases yield $OH^-(aq)$, hydroxide ion as the only negative ion in an aqueous solution.

3.1xx In the process of neutralization, an Arrhenius acid and an Arrhenius base react to form a salt and water.

3.1yy There are alternate acid-base theories. One theory states that an acid is an H^+ donor and a base is an H^+ acceptor.

3.1zz Titration is a laboratory process in which a volume of a solution of known concentration is used to determine the concentration of another solution.

PERFORMANCE INDICATOR 3.2

Use atomic and molecular models to explain common chemical reactions.

Major Understandings:

3.2a 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.

3.2b Types of chemical reactions include synthesis, decomposition, single replacement, and double replacement.

3.2c Types of organic reactions include addition, substitution, polymerization, esterification, fermentation, saponification, and combustion.

3.2d An oxidation-reduction (redox) reaction involves the transfer of electrons (e^-).

3.2e Reduction is the gain of electrons.

3.2f A half-reaction can be written to represent reduction.

3.2g Oxidation is the loss of electrons.

3.2h A half-reaction can be written to represent oxidation.

3.2i Oxidation numbers (states) can be assigned to atoms and ions. Changes in oxidation numbers indicate that oxidation and reduction have occurred.

3.2j An electrochemical cell can be either voltaic or electrolytic. In an electrochemical cell, oxidation occurs at the anode and reduction at the cathode.

3.2k A voltaic cell spontaneously converts chemical energy to electrical energy.

3.2l An electrolytic cell requires electrical energy to produce a chemical change. This process is known as electrolysis.

PERFORMANCE INDICATOR 3.3

Apply the principle of conservation of mass to chemical reactions.

Major Understandings:

3.3a In all chemical reactions there is a conservation of mass, energy, and charge.

3.3b In a redox reaction the number of electrons lost is equal to the number of electrons gained.

3.3c 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.

3.3d 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.

3.3e 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.

3.3f The percent composition by mass of each element in a compound can be calculated mathematically.

PERFORMANCE INDICATOR 3.4 Use kinetic molecular theory (KMT) to explain rates of reactions and the relationships among temperature, pressure, and volume of a substance.

Major Understandings:

3.4a The concept of an ideal gas is a model to explain the behavior of gases. A real gas is most like an ideal gas when the real gas is at low pressure and high temperature.

3.4b Kinetic molecular theory (KMT) for an ideal gas states that all gas particles:
- are in random, constant, straight-line motion.
- are separated by great distances relative to their size; the volume of the gas particles is considered negligible.
- have no attractive forces between them.
- have collisions that may result in a transfer of energy between gas particles, but the total energy of the system remains constant.

3.4c Kinetic molecular theory describes the relationships of pressure, volume, temperature, velocity, and frequency and force of collisions among gas molecules.

3.4d Collision theory states that a reaction is most likely to occur if reactant particles collide with the proper energy and orientation.

3.4e Equal volumes of gases at the same temperature and pressure contain an equal number of particles.

3.4f The rate of a chemical reaction depends on several factors: temperature, concentration, nature of the reactants, surface area, and the presence of a catalyst.

3.4g A catalyst provides an alternate reaction pathway, which has a lower activation energy than an uncatalyzed reaction.

3.4h Some chemical and physical changes can reach equilibrium.

3.4i 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.

3.4j LeChatelier's principle can be used to predict the effect of stress (change in pressure, volume, concentration, and temperature) on a system at equilibrium.

Key Idea 4:

Energy exists in many forms, and when these forms change energy is conserved.

Throughout history, humankind has tried to effectively use and convert various forms of energy. Energy is used to do work that makes life more productive and enjoyable. The Law of Conservation of Matter and Energy applies to phase changes, chemical changes, and nuclear changes that help run our modern world. With a complete understanding of these processes and their application to the modern world comes a responsibility to take care of waste, limit pollution, and decrease potential risks.

PERFORMANCE INDICATOR 4.1 Observe and describe transmission of various forms of energy.

Major Understandings:

4.1a Energy can exist in different forms, such as chemical, electrical, electromagnetic, thermal, mechanical, nuclear.

4.1b Chemical and physical changes can be exothermic or endothermic.

4.1c Energy released or absorbed during a chemical reaction can be represented by a potential energy diagram.

4.1d Energy released or absorbed during a chemical reaction (heat of reaction) is equal to the difference between the potential energy of the products and potential energy of the reactants.

PERFORMANCE INDICATOR 4.2 Explain heat in terms of kinetic molecular theory.

Major Understandings:

4.2a Heat is a transfer of energy (usually thermal energy) from a body of higher temperature to a body of lower temperature. Thermal energy is the energy associated with the random motion of atoms and molecules.

4.2b Temperature is a measurement of the average kinetic energy of the particles in a sample of material. Temperature is not a form of energy.

4.2c 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.

PERFORMANCE INDICATOR 4.4

Explain the benefits and risks of radioactivity.

Major Understandings:

4.4a Each radioactive isotope has a specific mode and rate of decay (half-life).

4.4b Nuclear reactions include natural and artificial transmutation, fission, and fusion.

4.4c Nuclear reactions can be represented by equations that include symbols which represent atomic nuclei (with mass number and atomic number), subatomic particles (with mass number and charge), and/or emissions such as gamma radiation.

4.4d Radioactive isotopes have many beneficial uses. Radioactive isotopes are used in medicine and industrial chemistry for radioactive dating, tracing chemical and biological processes, industrial measurement, nuclear power, and detection and treatment of diseases.

4.4e 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.

4.4f There are benefits and risks associated with fission and fusion reactions.

Key Idea 5:

Energy and matter interact through forces that result in changes in motion.

Atoms and molecules are in constant motion. Chemical bonding between atoms involves energy and the interaction of electrons with atomic nuclei. Intermolecular attractions, which may be temporary, occur when there is an asymmetric distribution of charge.

Within all chemical interactions, matter and energy are conserved according to the Law of Conservation of Matter and Energy. During a chemical change energy is absorbed or released as bonds are broken or formed. In maintaining conservation of matter and energy, nuclear changes convert matter into energy. The energy released during a nuclear change is much greater than the energy released during a chemical change.

The discovery of the energy stored in the nucleus of an atom, its uses, and its inherent benefits and risks is a continuing process that began with the serendipitous detection of the first radioactive isotope. Early researchers added to this knowledge and expanded our ability to utilize this newly discovered phenomenon. Using radioactivity, the inner structure of the atom was defined by other researchers. Scientists involved in the development of nuclear fission and the atomic bomb explored both peaceful and destructive uses of nuclear energy. Modern researchers continue to search for ways in which the power of the nucleus can be used for the betterment of the world.

PERFORMANCE INDICATOR 5.2

Explain chemical bonding in terms of the behavior of electrons.

Major Understandings:

5.2a Chemical bonds are formed when valence electrons are:
- transferred from one atom to another (ionic)
- shared between atoms (covalent)
- mobile within a metal (metallic)

5.2b Atoms attain a stable valence electron configuration by bonding with other atoms. Noble gases have stable valence configurations and tend not to bond.

5.2c 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.

5.2d Electron-dot diagrams (Lewis structures) can represent the valence electron arrangement in elements, compounds, and ions.

5.2e 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.

5.2f Some elements exist in two or more forms in the same phase. These forms differ in their molecular or crystal structure, and hence in their properties.

5.2g Two major categories of compounds are ionic and molecular (covalent) compounds.

5.2h 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.

5.2i When a bond is broken, energy is absorbed. When a bond is formed, energy is released.

5.2j Electronegativity indicates how strongly an atom of an element attracts electrons in a chemical bond. Electronegativity values are assigned according to arbitrary scales.

5.2k The electronegativity difference between two bonded atoms is used to assess the degree of polarity in the bond.

5.2l Molecular polarity can be determined by the shape of the molecule and distribution of charge. Symmetrical (nonpolar) molecules include CO_2, CH_4, and diatomic elements. Asymmetrical (polar) molecules include HCl, NH_3, and H_2O.

5.2m 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.

5.2n 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.

PERFORMANCE INDICATOR 5.3

Compare energy relationships within an atom's nucleus to those outside the nucleus.

Major Understandings:

5.3a 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 with high-energy particles.

5.3b Energy released in a nuclear reaction (fission or fusion) comes from the fractional amount of mass that is converted into energy. Nuclear changes convert matter into energy.

5.3c Energy released during nuclear reactions is much greater than the energy released during chemical reactions.

APPENDIX A
CHEMISTRY CORE TOPICS

This section contains ten topic areas in which the major understandings found in the core are sorted by content topic. These ten topic areas may be used for ease in curriculum writing; however, they do not connote a suggested scope and sequence.

I. Atomic Concepts

I.1 The modern model of the atom has evolved over a long period of time through the work of many scientists. (3.1a)

I.2 Each atom has a nucleus, with an overall positive charge, surrounded by one or more negatively charged electrons. (3.1b)

I.3 Subatomic particles contained in the nucleus include protons and neutrons. (3.1c)

I.4 The proton is positively charged, and the neutron has no charge. The electron is negatively charged. (3.1d)

I.5 Protons and electrons have equal but opposite charges. The number of protons equals the number of electrons in an atom. (3.1e)

I.6 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 a neutron. (3.1f)

I.7 In the wave-mechanical model (electron cloud model), the electrons are in orbitals, which are defined as the regions of the most probable electron location (ground state). (3.1h)

I.8 Each electron in an atom has its own distinct amount of energy. (3.1i)

I.9 When an electron in an atom gains a specific amount of energy, the electron is at a higher energy state (excited state). (3.1j)

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. (3.1k)

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. (3.1l)

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. (3.1m)

I.13 The average atomic mass of an element is the weighted average of the masses of its naturally occurring isotopes. (3.1n)

II. Periodic Table

II.1 The placement or location of elements 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. (3.1y)

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: $^{14}_{6}C$, ^{14}C, carbon-14, C-14. (3.1g)

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. (3.1v)

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. (3.1w)

II.5 Elements can be differentiated by chemical properties. Chemical properties describe how an element behaves during a chemical reaction. (3.1x)

II.6 Some elements exist in two or more forms in the same phase. These forms differ in their molecular or crystal structure, and hence in their properties. (5.2f)

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. (3.1z)

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. (3.1aa)

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. (3.1bb)

III. Moles/Stoichiometry

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. (3.1cc)

III.2 Types of chemical formulas include empirical, molecular, and structural. (3.1ee)

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. (3.3d)

III.4 In all chemical reactions there is a conservation of mass, energy, and charge. (3.3a)

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. (3.3c)

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. (3.3e)

III.7 The percent composition by mass of each element in a compound can be calculated mathematically. (3.3f)

III.8 Types of chemical reactions include synthesis, decomposition, single replacement, and double replacement. (3.2b)

IV. Chemical Bonding

IV.1 Compounds can be differentiated by their chemical and physical properties. (3.1dd)

IV.2 Two major categories of compounds are ionic and molecular (covalent) compounds. (5.2g)

IV.3 Chemical bonds are formed when valence electrons are (5.2a):

- transferred from one atom to another (ionic)
- shared between atoms (covalent)
- mobile within a metal (metallic)

IV.4 In a multiple covalent bond, more than one pair of electrons are shared between two atoms. (5.2e)

IV.5 Molecular polarity can be determined by the shape of the molecule and the distribution of charge. Symmetrical (nonpolar) molecules include CO_2, CH_4, and diatomic elements. Asymmetrical (polar) molecules include HCl, NH_3, and H_2O. (5.2l)

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. (5.2c)

IV.7 When a bond is broken, energy is absorbed. When a bond is formed, energy is released. (5.2i)

IV.8 Atoms attain a stable valence electron configuration by bonding with other atoms. Noble gases have stable valence configurations and tend not to bond. (5.2b)

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. (5.2n)

IV.10 Electron-dot diagrams (Lewis structures) can represent the valence electron arrangement in elements, compounds, and ions. (5.2d)

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. (5.2j)

IV.12 The electronegativity difference between two bonded atoms is used to assess the degree of polarity in the bond. (5.2k)

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. (5.2h)

V. Physical Behavior of Matter

V.1 Matter is classified as a pure substance or as a mixture of substances. (3.1q)

V.2 The three phases of matter (solids, liquids, and gases) have different properties. (3.1kk)

V.3 A pure substance (element or compound) has a constant composition and constant properties throughout a given sample, and from sample to sample. (3.1r)

V.4 Elements are substances that are composed of atoms that have the same atomic number. Elements cannot be broken down by chemical change. (3.1u)

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. (3.1s)

V.6 The proportions of components in a mixture can be varied. Each component in a mixture retains its original properties. (3.1t)

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. (3.1nn)

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. (3.1oo)

V.9 The concentration of a solution may be expressed as molarity (M), percent by volume, percent by mass, or parts per million (ppm). (3.1pp)

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 particles, the greater the effect. (3.1qq)

V.11 Energy can exist in different forms, such as chemical, electrical, electromagnetic, thermal, mechanical, and nuclear. (4.1a)

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 the energy associated with the random motion of atoms and molecules. (4.2a)

V.13 Temperature is a measurement of the average kinetic energy of the particles in a sample of material. Temperature is not a form of energy. (4.2b)

V.14 The concept of an ideal gas is a model to explain the behavior of gases. A real gas is most like an ideal gas when the real gas is at low pressure and high temperature. (3.4a)

V.15 Kinetic molecular theory (KMT) for an ideal gas states that all gas particles (3.4b):

1. are in random, constant, straight-line motion.
2. are separated by great distances relative to their size; the volume of the gas particles is considered negligible.
3. have no attractive forces between them.
4. have collisions that may result in the transfer of energy between gas particles, but the total energy of the system remains constant.

V.16 Collision theory states that a reaction is most likely to occur if reactant particles collide with the proper energy and orientation. (3.4d)

V.17 Kinetic molecular theory describes the relationships of pressure, volume, temperature, velocity, and frequency and force of collisions among gas molecules. (3.4c)

V.18 Equal volumes of different gases at the same temperature and pressure contain an equal number of particles. (3.4e)

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. (4.2c)

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. (3.2a)

V.21 Chemical and physical changes can be exothermic or endothermic. (4.1b)

V.22 The structure and arrangement of particles and their interactions determine the physical state of a substance at a given temperature and pressure. (3.1jj)

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. (5.2m)

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. (5.2n)

VI. Kinetics/Equilibrium

VI.1 Collision theory states that a reaction is most likely to occur if reactant particles collide with the proper energy and orientation. (3.4d)

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. (3.4f)

VI.3 Some chemical and physical changes can reach equilibrium. (3.4h)

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. (3.4i)

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. (3.4j)

VI.6 Energy released or absorbed by a chemical reaction can be represented by a potential energy diagram. (4.1c)

VI.7 Energy released or absorbed during 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. (4.1d)

VI.8 A catalyst provides an alternate reaction pathway, which has a lower activation energy than an uncatalyzed reaction. (3.4g)

VI.9 Entropy is a measure of the randomness or disorder of a system. A system with greater disorder has greater entropy. (3.1ll)

VI.10 Systems in nature tend to undergo changes toward lower energy and higher entropy. (3.1mm)

VII. Organic Chemistry

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. (3.1ff)

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. (3.1gg)

VII.3 Organic acids, alcohols, esters, aldehydes, ketones, ethers, halides, amines, amides, and amino acids are categories of organic molecules that differ in their structures. Functional groups impart distinctive physical and chemical properties to organic compounds. (3.1hh)

VII.4 Isomers of organic compounds have the same molecular formula but different structures and properties. (3.1ii)

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. (5.2e)

VII.6 Types of organic reactions include: addition, substitution, polymerization, esterification, fermentation, saponification, and combustion. (3.2c)

VIII. Oxidation-Reduction

VIII.1 An oxidation-reduction (redox) reaction involves the transfer of electrons (e^-). (3.2d)

VIII.2 Reduction is the gain of electrons. (3.2e)

VIII.3 A half-reaction can be written to represent reduction. (3.2f)

VIII.4 Oxidation is the loss of electrons. (3.2g)

VIII.5 A half-reaction can be written to represent oxidation. (3.2h)

VIII.6 In a redox reaction the number of electrons lost is equal to the number of electrons gained. (3.3b)

VIII.7 Oxidation numbers (states) can be assigned to atoms and ions. Changes in oxidation numbers indicate that oxidation and reduction have occurred. (3.2i)

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. (3.2j)

VIII.9 A voltaic cell spontaneously converts chemical energy to electrical energy. (3.2k)

VIII.10 An electrolytic cell requires electrical energy to produce chemical change. This process is known as electrolysis. (3.2l)

IX. Acids, Bases, and Salts

IX.1 Behavior of many acids and bases can be explained by the Arrhenius theory. Arrhenius acids and bases are electrolytes. (3.1uu)

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. (3.1rr)

IX.3 Arrhenius acids yield H^+ (aq), hydrogen ion as the only positive ion in an aqueous solution. The hydrogen ion may also be written as H_3O^+ (aq), hydronium ion. (3.1vv)

IX.4 Arrhenius bases yield OH^- (aq), hydroxide ion as the only negative ion in an aqueous solution. (3.1ww)

IX.5 In the process of neutralization, an Arrhenius acid and an Arrhenius base react to form a salt and water. (3.1xx)

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. (3.1zz)

IX.7 There are alternate acid-base theories. One theory states that an acid is an H^+ donor and a base is an H^+ acceptor. (3.1yy)

IX.8 The acidity or alkalinity of a solution can be measured by its pH value. The relative level of acidity or alkalinity of a solution can be shown by using indicators. (3.1ss)

IX.9 On the pH scale, each decrease of one unit of pH represents a tenfold increase in hydronium ion concentration. (3.1tt)

X. Nuclear Chemistry

X.1 Stability of isotopes is based on the ratio of neutrons and protons in its nucleus. Although most nuclei are stable, some are unstable and spontaneously decay, emitting radiation. (3.1o)

X.2 Each radioactive isotope has a specific mode and rate of decay (half-life). (4.4a)

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. (5.3a)

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, and ionizing power, and penetrating power. (3.1p)

X.5 Nuclear reactions include natural and artificial transmutation, fission, and fusion. (4.4b)

X.6 There are benefits and risks associated with fission and fusion reactions. (4.4f)

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. (4.4c).

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. (5.3b)

X.9 Energy released during nuclear reactions is much greater than the energy released during chemical reactions. (5.3c)

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. (4.4e)

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 disease. (4.4d)

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

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.		

IV. Chemical Bonding

KEY	LINK TO APPENDIX A	MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	REAL-WORLD CONNECTIONS
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

KEY	LINK TO APPENDIX A	MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	REAL-WORLD CONNECTIONS
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, △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)

VII. Organic Chemistry

KEY	LINK TO APPENDIX A	MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	REAL-WORLD CONNECTIONS
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.		

IX. Acids, Bases, and Salts

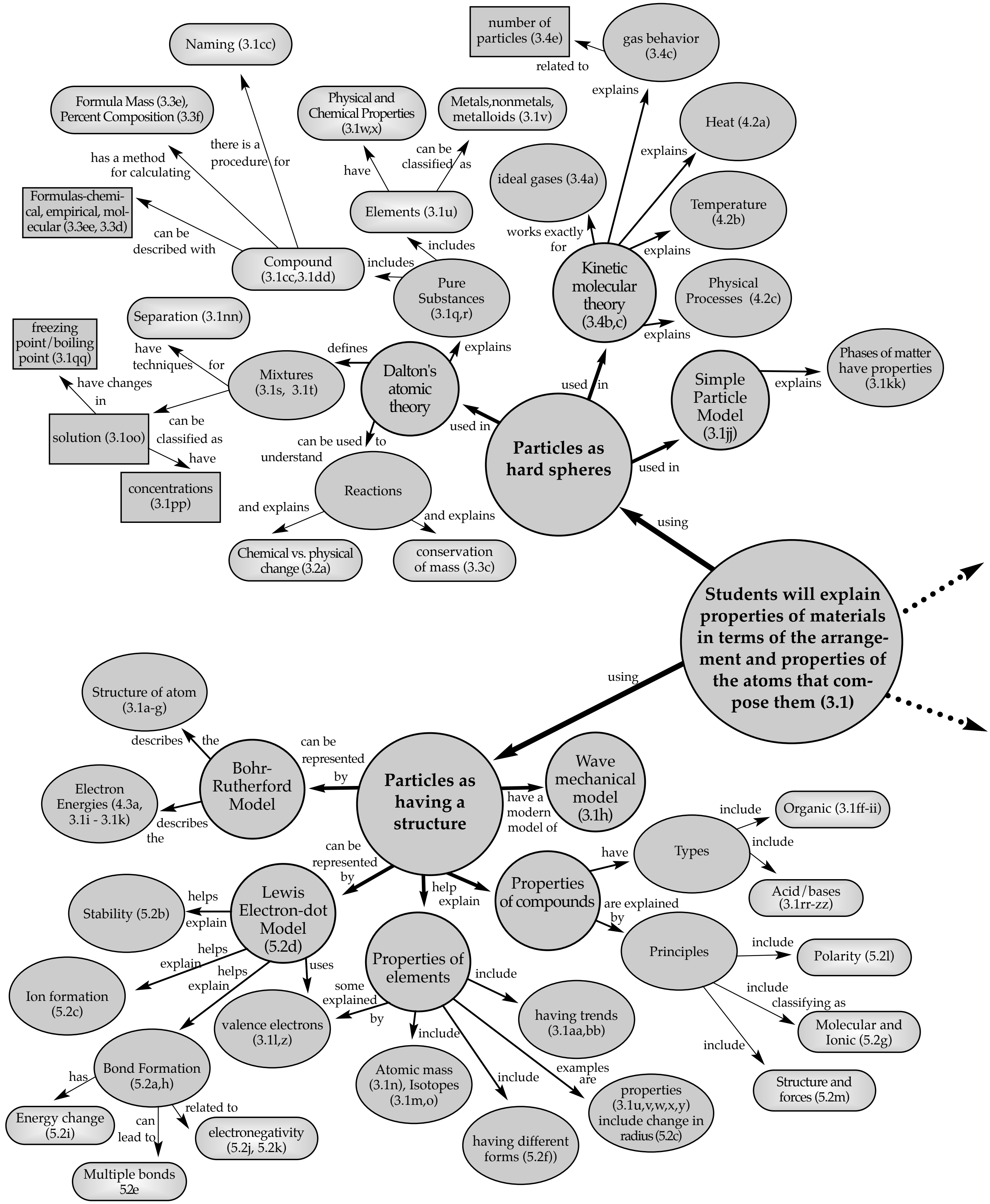
KEY	LINK TO APPENDIX A	MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	REAL-WORLD CONNECTIONS
3.1ss	IX.8	The acidity and alkalinity of an aqueous solution can be measured by its pH value. The relative level of acidity or alkalinity of a solution can be shown by using indicators.	interpret 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

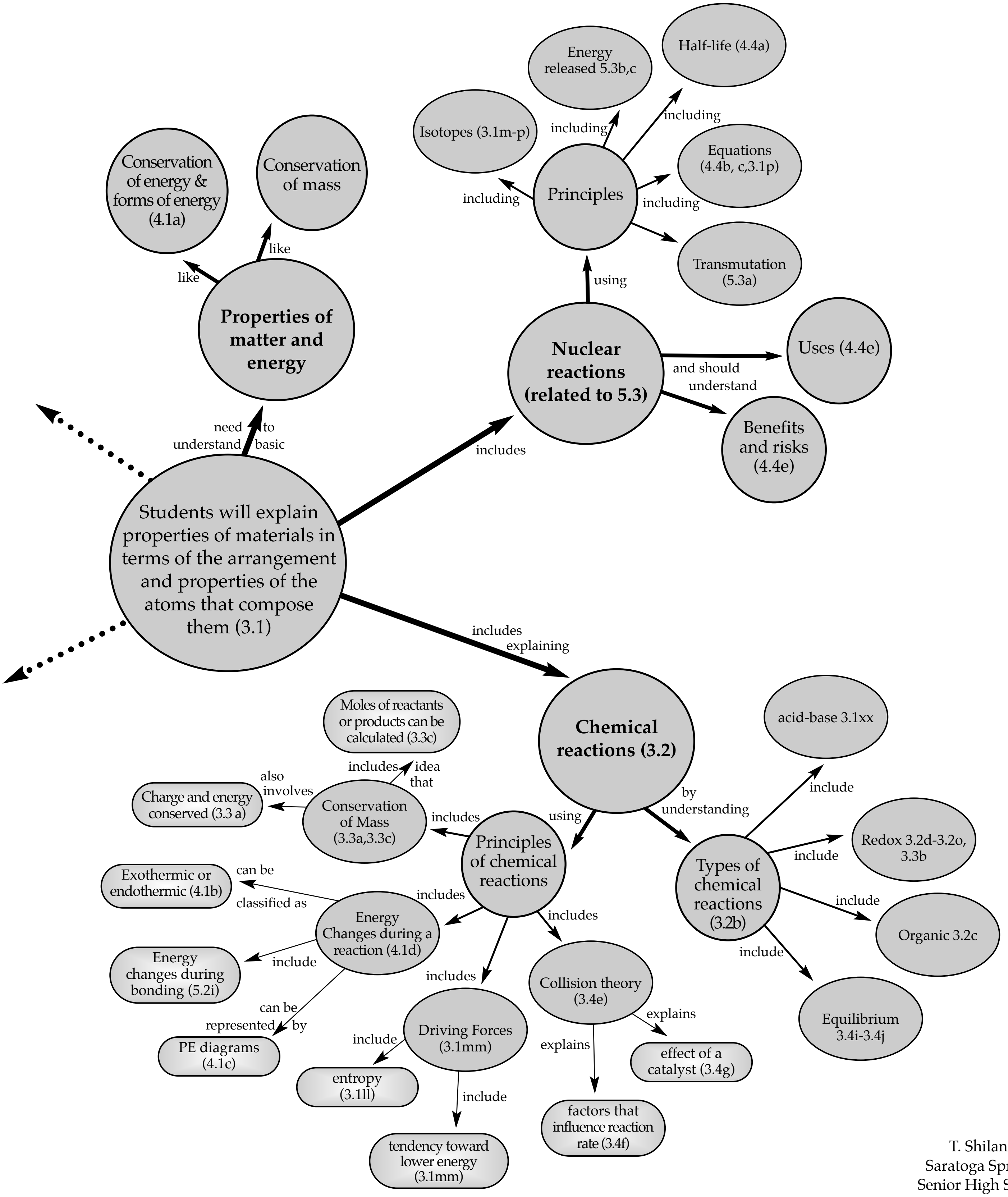
KEY	LINK TO APPENDIX A	MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	REAL-WORLD CONNECTIONS
3.1o	X.1	Stability of isotopes is based on the ratio of the neutrons and protons in its nucleus. Although most nuclei are stable, some are unstable and spontaneously decay emitting radiation.		
4.4a	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
Dalton's atomic theory
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)
explains
Pure Substances (3.1q,r)
includes
Compound (3.1cc,3.1dd)
can be described with
Formulas-chemical, empirical, molecular (3.3ee, 3.3d)
has a method for calculating
Formula Mass (3.3e), Percent Composition (3.3f)
there is a procedure for
Naming (3.1cc)
includes
Elements (3.1u)
have
Physical and Chemical Properties (3.1w,x)
can be classified as
Metals,nonmetals, metalloids (3.1v)
can be used to understand
Reactions
and explains
Chemical vs. physical change (3.2a)
and explains
conservation of mass (3.3c)
used in
Kinetic molecular theory (3.4b,c)
works exactly for
ideal gases (3.4a)
explains
gas behavior (3.4c)
related to
number of particles (3.4e)
explains
Heat (4.2a)
explains
Temperature (4.2b)
explains
Physical Processes (4.2c)
used in
Simple Particle Model (3.1jj)
explains
Phases of matter have properties (3.1kk)
using
Particles as having a structure
can be represented by
Bohr-Rutherford Model
describes the
Structure of atom (3.1a-g)
describes the
Electron Energies (4.3a, 3.1i - 3.1k)
have a modern model of
Wave mechanical model (3.1h)
can be represented by
Lewis Electron-dot Model (5.2d)
helps explain
Stability (5.2b)
helps explain
Ion formation (5.2c)
helps explain
Bond Formation (5.2a,h)
has
Energy change (5.2i)
can lead to
Multiple bonds 52e
related to
electronegativity (5.2j, 5.2k)
uses
valence electrons (3.1l,z)
help explain
Properties of elements
some explained by
include
Atomic mass (3.1n), Isotopes (3.1m,o)
include
having different forms (5.2f))
include
having trends (3.1aa,bb)
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)
include
Acid/bases (3.1rr-zz)
are explained by
Principles
include
Polarity (5.2l)
include classifying as
Molecular and Ionic (5.2g)
include
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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