Regents Chemistry Syllabus

for

New York City

Revised 2001

This document has been keyed to the Key Understandings, Skills and Standards in

Core Curriculum: Physical Setting/Chemistry

THE STATE EDUCATION DEPARTMENT THE UNIVERSITY OF THE STATE OF NEW YORK
http://www.nysed.gov

This working draft includes the completed Units (I-IV), and the outline for the remainder of the course.

NOTE 1: All introductory passages in this document contain testable material.

NOTE 2: The 2002 Edition of the Physical Setting/Chemistry Reference Tables is available online at the url below.
http://www.emsc.nysed.gov/ciai/mst/sci.html

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This is the tentative outline for the remainder of the syllabus.

Each unit will be posted as soon as it has been completed.

Please note: The ordering of the Understandings and Skills is tentative, but the content they cover is testable.

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Diane Pillersdorf, Richmond Hill High School served as project director. She was assisted by Susan Brustein, Townsend Harris High School and Bea Werden, New Rochelle High School. Special thanks to Grace Zwillenberg , President of the Science Supervisors Association of New York City, for her support and guidance.

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This book was edited by Diane Pillersdorf and Susan Brustein with the assistance of Bea Werden and Ellen Mandel, Campus Magnet High School. Special recognition is given to Susan Brustein both for her technical expertise and for providing the Internet Resources.

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REFERENCES AND RESOURCES

CHEMISTRY CORE, WITH SKILLS AND REAL WORLD CONNECTIONS

This document has been developed to help teachers assist students to understand and apply scientific concepts, principles and theories pertaining to the physical setting and recognize the historical development of ideas in science.

Emphasis should be placed on science process skills that are based on a series of discoveries. Students learn most effectively when they have a central role in the discovery process. It should be the goal of the instructor to encourage science process skills that will provide students with the background and curiosity to investigate important issues in the world around them. Incorporating Standards 1, 2, 6, and 7 into the Chemistry Core Curriculum will insure that lessons provide a student-centered, problem-solving approach to chemistry. This document has been prepared with references to these standards to facilitate lesson planning. Teachers should look to infuse their lessons with these standards wherever possible. The Suggested Activities and Teacher Strategies are only guidelines provided to assist teachers in developing an instructional plan.

The "Major Understandings" were taken directly from the Physical Setting/Chemistry Core Curriculum. "Major Understandings" are not intended to be aims for individual lessons. They may be combined into one lesson or used as a basis for one or more lessons.

Students must achieve mastery of all "Major Understandings" and "Skills" listed in this document. The "Skills" section includes processes skills from Standard 4 (content) as well as process skills from Standards 1, 2, 6 and 7 (e.g.: mathematical analysis, scientific inquiry, engineering design, information systems, systems thinking, interconnectedness- common themes and interdisciplinary problem solving). Additional required information is found in the introduction to this document as well as the introduction to each unit. ALL "MAJOR UNDERSTANDINGS", "SKILLS" AND INTRODUCTIONS ARE TESTABLE ON THE NEW YORK STATE PHYSICAL SETTING/CHEMISTRY REGENTS ASSESSMENT.

Note 1: The use of e.g. denotes examples that may be used for in-depth study. The terms for example *and* such as *denote material that is testable. Items in parentheses denote further definition of the word(s) preceding the item and are testable.*

Note 2: The notation system used to indicate the Standards addressed in the "Skills" column is as follows:

[S4: 3.2ii] = Standard 4 Section 3.2ii
[S1: M.1.1] = Standard 1, Mathematical Analysis: 1.1

Note 3: "Required Lab" refers to those laboratory skills that will be testable on future Regents Examinations (Part D- Lab Assessment).

The Introduction from the New York State Physical Setting/Chemistry Core Curriculum is included in this document. Please read it carefully. It includes testable material. An appendix at the end of this book has been included which lists all of the process skills from Standards 1, 2, 4, 6 and 7. The Appendix listing reference materials and Internet resources may be useful.

Teachers should broaden or enrich their lessons to best suit the needs of their students. Each lesson should strive to incorporate a variety of teaching strategies that encourage scientific inquiry and address the various learning styles of students. Assessment should be ongoing and provide students with the feedback necessary to achieve mastery. Assessment options include: journal/log writing; oral presentation; research reports; projects; portfolios (labs reports); quizzes and unit exams.

SAFETY WARNING: Guidelines in the New York City Board of Education *Science Safety K-12 Manual* must be followed. Consult the relevant Material Safety Data Sheets (MSDSs) for ALL chemicals prior to conducting demonstrations or lab activities.

INTRODUCTION TO THE NEW YORK STATE PHYSICAL SETTING/ CHEMISTRY CORE DOCUMENT

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 under-standings 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 under-standing 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 student shave 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 inter-weave 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 Or 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 ($5.6 m^2$) which is equivalent to 1440 ft^2 ($134 m^2$) to accommodate a class of 24 safely in a combination laboratory/classroom.

or

- A minimum of 45 ft^2/pupil ($4.2 m^2$) which is equivalent to 1080 ft^2 ($101 m^2$) 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.

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UNIT I – The Physical Behavior of Matter

I THE PHYSICAL BEHAVIOR OF MATTER

Chemistry is the study of matter and energy. We explore matter through its properties and 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. All changes in matter are accompanied by changes in energy.

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

In the late 1700's solid evidence about the nature of matter, gained through quantitative scientific experiments, accumulated. Such evidence included the finding that during a chemical reaction matter is conserved. In the early 1800's a theory was proposed to explain these experimental facts. In this theory, atoms were hard, indivisible spheres 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 1800's in the kinetic molecular theory of matter, which was used to explain the properties of gases.

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	SUGGESTED ACTIVITIES and TEACHING STRATEGIES	REAL-WORLD CONNECTIONS
1. The three phases of matter (solid, liquids, and gases) have different properties. (3.1kk)	Use a simple particle model to differentiate among properties of a solid, a liquid, and a gas. [S4: 3.1xxii] Use knowledge of geometric arrangements to predict particle properties or behavior [S1:M1.	1. Compare the shape, volume, compressibility, and density, of solids, liquids and gases. 2. Create a graphic organizer to organize the properties of the phases of matter. 3. **Chemistry I: Teacher Resource Guide:** ▪ **" What is Matter?"** ▪ **"The Gas State: General Properties"** ▪ **"The Solid State"** **(Note: In future citations within this document, this resource has been identified as RG.)** 4. Students: slap a desk, move hand through water and air to determine in which phase they feel more resistance. Based on this experience have students make particle diagrams to represent the differences in the arrangement of particles in phases of matter. *Enrichment: The Plasma Phase of Matter; Properties of Liquids (e.g.: surface tension, viscosity, capillary action.)*	▪ Examples of commonly found solids, liquids, and gases. ▪ H_2O in our environment ▪ Solids ▪ Metallic ▪ Crystalline ▪ Amorphous (Quartz, glass, opal) ▪ Liquids ▪ Insects that walk on water ▪ Capillary tubes ▪ Viscosity ▪ Gases ▪ Helium balloons ▪ Components of air ▪ "Galileo Thermometer"

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	SUGGESTED ACTIVITIES and TEACHING STRATEGIES	REAL-WORLD CONNECTIONS
2. Matter is classified as a pure substance or as a mixture of substances. (3.1q)		1. Display and discuss samples of elements, compounds and mixtures. Show pure water, tea and muddy water to the class. Ask cooperative learning groups to determine how they might find out whether these samples were pure substances or mixtures. 2. Students should make and explain particle diagrams to show the differences in the composition of pure substances vs. mixtures.	
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) (continued on the next page)	Use particle models/diagrams to differentiate among elements, compounds, and mixtures [S4:3.1xxxvi] Recognize and convert various scales of measurement Length, mass [S1: M1.1; S6: 2.4, 3.2; S7:1.4]	1. Introduce the concept of physical properties by 2. Having students identify "secret objects" based on the oral description of classmates. Elicit - Physical (and chemical properties) can be used to identify matter. 3. Differentiating between metallic and non-metallic properties. 4. Brainstorming to create a list of physical and chemical properties. 5. Show examples of elements, compounds and mixtures. Have students describe several of these materials in terms of their physical properties. Elicit differences between mixtures and substances. 6. <u>Demonstration</u>: Combine iron and sulfur to form a mixture. Show that the elements each retain their original properties and can be separated by physical means. Then heat the mixture (to form the compound iron sulfide). Demonstrate that the properties of the heated material are no longer the same as those of the original constituents. A compound has been formed. 7. Place water and glycerin in two sealed tubes and have students determine if they are the same or different substances.	

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	SUGGESTED ACTIVITIES and TEACHING STRATEGIES	REAL WORLD CONNECTIONS
3. (continued) A pure substance (element or compound) has a constant composition and constant properties throughout a given sample, and from sample to sample. (3.1r)		3. Identify the need to use measurements; develop Metric system and International System (SI) units. See the Introduction to the NYS Physical Setting/Chemistry Core Introduce Reference Tables: ▪ Standard Temperature and Pressure ▪ Selected Units ▪ Selected Prefixes ▪ Important Formulas and Equations 4. RG: **"Density"** 5. Metric System Activities should enable students to: ▪ Use instruments and measure length (± .01cm), mass (± .01g) and volume (±.1ml); ▪ Apply the rules of Significant Figures when performing calculations and recognize uncertainty exists in all measurements; ▪ Calculate percent error as a part of labs; ▪ Use dimensional analysis for conversions between units. 6. Use Scientific Notation appropriately. 7. Videodisks and Transparencies are available	
4. A physical change results in the rearrangement of existing particles in a substance. (3.2a) A chemical change results in the formation of different substances with changed properties. (3.2a)	Use atomic and molecular models to explain common chemical reactions: distinguish between chemical and physical changes. [S4: 3.2i] [S1: S1.1, S2.1, 2.3, S3.1; S6:1, 5]	8. Compare and contrast physical and chemical properties and changes. 9. Introduce Scientific Method and apply to RG: **Chemical and Physical Changes** 10. Demonstration: Comparison of physical changes with chemical changes: ▪ tearing paper vs. burning paper ▪ breaking vs. burning wooden splints ▪ raw egg vs. cooked egg ▪ ice vs. liquid water vs. steam.	Physical changes: ▪ Vaporization (puddles) ▪ Melting of snow ▪ Forming potholes ▪ Creasing clothes ▪ Breaking a plate Chemical changes: ▪ Fires ▪ Dyeing clothing or hair ▪ Cooking ▪ Baking a cake ▪ Tarnishing of silver ▪ Corrosion ▪ Acid Rain's effect on buildings

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	SUGGESTED ACTIVITIES and TEACHING STRATEGIES	REAL-WORLD CONNECTIONS
8a. 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) 8b. The proportions of components in a mixture can be varied. Each component in a mixture retains its original properties. (3.1t)	[S1: S2.2: S2: 1, 2: S7: 1.1, 1.2, 1.3, 2]	1. Display samples of different kinds of mixtures including alloys, e.g: stainless steel, brass, bronze, silver jewelry. 2. Elicit mixtures may be homogeneous or heterogeneous. 3. Introduce solutions as a type of homogeneous mixture. 4. **RG: "Compounds and Mixtures"** 5. Make mayonnaise. 6. Compare and contrast (classify): aqueous mixtures of sucrose, starch, clay, sodium borate, oil and gelatin. 7. Examples – sand on a beach. 8. Create a concept map to compare and contrast elements, compounds and mixtures	• Separation by: filtration distillation, desalination, crystallization, extraction, and chromatography • Water quality testing • Hudson River: removal of PCBs • Alloys • Colloids • Emulsifiers (ice cream) • Sewage treatment
9. Differences in properties such as density, particle size, molecular polarity, boiling point, freezing point, and solubility permit physical separation of the components of the mixture. (3.1nn)	Describe the processes and uses of filtration, distillation, and chromatography in the separation of mixtures. [S4: 3.1xxiv]	1. Demonstrate several examples of separating mixtures e.g: iron filings, sand and salt; crystallization of copper sulfate; fractional distillation of water and ethanol mixture. 2. Discuss of water treatment plants. 3. **Lab. Activity**: Have students design and conduct an experiment in which they separating components of a mixture using chromatography, filtration, or distillation or a combination of several techniques. e.g.: salt and sand; polluted water; colors in black ink 4. **Revisit**: Polarity in the Bonding section	• Fractional distillation of petroleum • Centrifugation of blood to isolate plasma • Panning for gold (based on density)
10. A solution is a homogeneous mixture of a solute dissolved in a solvent. (3.1oo) (continued on the next page)	Interpret and construct solubility curves [S4: 3.1xxv] Use Reference Tables. [S1: M1.1, S3.1]	1. **RG: "Solutions: Qualitative Measurement of Solubility"** 2. Provide examples that will illustrate various types of solutions. Include various combinations of solutes and solvents in your examples.	• Soda • Dry cleaning

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	SUGGESTED ACTIVITIES and TEACHING STRATEGIES	REAL-WORLD CONNECTIONS
10. (continued) 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)	Use solubility curves to distinguish among saturated, supersaturated and unsaturated solutions [S4: 3.1xxxviii] Apply the adage "like dissolves like" to real-world situations. [S4: 3.1xxvi] Identify examples of physical equilibria as solution equilibrium and phase equilibrium, including the concept that a saturated solution is at equilibrium [S4: 3.4vii]	1. Compare quantity of solute dissolved in dilute vs. concentrated solutions 2. Use the Reference Tables – Solubility Curves to illustrate the differences among unsaturated, saturated, supersaturated solutions.(Sodium thiosulfate or sodium acetate can be used to prepare a supersaturated solution.). 3. **Lab activity**/Teacher Demonstration: Factors affecting the rate of dissolving of a solute. 4. **Lab activity**: Construct a solubility curve. **Revisit:** ▪ "like dissolves like" in Bonding. ▪ Saturated solution equilibrium in Kinetics ▪ Factors affecting rate of solution in Kinetics *Enrichment: Colloids, emulsions and suspensions*	
11. 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. (3.1qq)		1. Demonstrate freezing point depression by adding anti-freeze or salt to a test tube of water and comparing the temperature at which it solidifies with that of a test tube of pure water. 2. An application of freezing point depression can be observed in making ice cream. 3. Compare the boiling point of pure water as compared with salt water.	▪ Salting an icy sidewalk ▪ Ice cream making ▪ Antifreeze/engine coolant ▪ Airplane deicing ▪ Cooking pasta
12. Energy can exist in different forms, such as chemical, electrical, electromagnetic, heat, mechanical, and nuclear. **(4.1a)** (continued on the next page)	Distinguish between heat energy and temperature in terms of molecular motion and amount of matter [S4: 4.2i]	1. Show examples of energy conversions (e.g.: radiometer ; generator; motor; roller coaster.) 2. Have students write a description of each conversion.	▪ See next page.

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	SUGGESTED ACTIVITIES and TEACHING STRATEGIES	REAL-WORLD CONNECTIONS
12. (continued) Energy can exist in different forms, such as chemical, electrical, electromagnetic, heat, mechanical, and nuclear. **(4.1a)**		3. Temperature is a *measure* of the average kinetic energy of the particles, *not* a form of energy. Heat a rock or piece of metal and place it into a beaker of cool water whose temperature is known. Monitor changes in the temperature of the water. Guide students to conclude that heat is transferred. 4. Heat a rock or piece of metal and place it into a beaker of cool water whose temperature is known. Monitor changes in the temperature of the water. Guide students to conclude that heat is transferred spontaneously from a body of higher temperature. 5. *Enrichment:* $KE = 1/2mv^2$	<u>Energy Changes</u>: ▪ Chemical to Heat: burning fuel ▪ Electrical to Chemical: charging a battery ▪ Electrical to Light: operating a neon light ▪ Electrical to Mechanical: operating a motor ▪ Light to Chemical: photography ▪ Chemical to Electrical: batteries
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. **(4.2b)**	Convert temperatures from degrees Celsius (°C) to kelvins (K), and kelvins to Celsius degrees [S4: 3.4iii] [S1:M1.1]	1. Reference Table: Important Formulas and Equations - Temperature 2. **RG: "Measurement of Temperature"** 3. Example: Compare the amount of heat required to heat a glass of water with the amount of heat energy required to heat a bathtub full of water to the same temperature.	
14. Heat is transfer of energy (usually thermal energy) from a body of higher temperature to a body of lower temperature. (4.2a) Thermal energy is associated with the random motion of atoms and molecules. **(4.2a)**	Distinguish between heat energy and temperature in terms of molecular motion and amount of matter. [S4: 4.2i]	1. Reference Tables: 2. Physical Constants for Water 3. Important Formulas and Equations – Heat 4. **RG: "Measurement of Heat Energy (NB: Calculations MUST be in JOULES not calories).** 5. *Enrichment: The rate of expansion of substances vary according to their chemical properties.*	▪ Weather processes ▪ Greenhouse gases ▪ Thermostats

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	SUGGESTED ACTIVITIES and TEACHING STRATEGIES	REAL-WORLD CONNECTIONS
15. 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)	Identify examples of physical equilibria such as solution equilibrium and phase equilibrium, including the concept that a saturated solution is at equilibrium [S4: 3.4vii] Calculate the heat involved in a phase or temperature change for a given sample of matter [S4: 4.2iv] [S1: M1.1, M3.1] Explain phase change in terms of the changes in energy and intermolecular distances [S4: 4.2ii]	1. Develop heating and cooling curves 2. **Lab Activity/Teacher Demonstration**: Students should design (and conduct) an experiment in which a heating and/or cooling curve is produced. Use Lauric Acid or water. 3. **<u>Required Lab:</u> Students should design and conduct an experiment on Heat of Fusion and/or Vaporization.** 4. Transparencies and videodiscs are available **Revisit:** ▪ Phase Equilibria in Kinetics ▪ The Effect of Attractive Forces on Melting and Boiling Points	
16. Chemical and physical changes can be exothermic or endothermic. (4.1b)	Distinguish between endothermic and exothermic reactions, using energy terms in a reaction equation, ΔH, *[potential energy diagrams]* or experimental data [S4: 4.1i] [S1: S3.1, S3.3, M1.1, M3.1] […] *will be covered in Kinetics and Equilibrium*	1. Compare exothermic reactions (e.g. dissolve solid sodium hydroxide in water, heat a strip of magnesium ribbon) with endothermic reactions – (e.g. dissolve ammonium chloride in water or reaction of ammonium thiocyanate with barium hydroxide). 2. Introduce the Reference Table: Heats of Reactions 3. **<u>Required Lab</u>: Students should design and conduct an experiment on Heat of Solution.**	▪ Calorimetry ▪ Hot and cold packs
17. The structure and arrangement of particles and their interactions determine the physical state of a substance at a given temperature and pressure. (3.1jj)	Use a simple particle model to differentiate among properties of solids, liquids and gases. [S4: 3.1xxii] [S1: S3.1]	1. **RG: "Vapor Pressure of a Liquid"** 2. Have students interpret the Reference Table on Vapor Pressure of Four Liquids. 3. Demonstration that the boiling point of water changes with pressure. *Enrichment: The rate of expansion of substances vary according to their chemical properties.*	▪ Pressure Cookers ▪ Differences between cooking at high altitudes vs. at sea level ▪ Ice skating

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	SUGGESTED ACTIVITIES and TEACHING STRATEGIES	REAL-WORLD CONNECTIONS
18. Equal volumes of gases at the same temperature and pressure contain an equal number of particles. (3.4e)	Solve problems using combined gas law [S4: 3.4ii] ▪ Organize graph … ▪ Measure and record… [S1: M1.1, M2.1, M3.1, S2.1, S3.1; S6: 2.3]	1. Inquiry: Give students a balloon and a plastic soda bottle to explore the properties of gases. 2. Demonstrate the properties of gases: imploding soda can, expansion of a marshmallow, shaving cream or balloon in an evacuated Bell Jar. 3. Demonstrate Boyle's Law and Charles Law. ▪ Boyle's Law may be demonstrated using a sealed syringe with trapped air to which pressure is applied. ▪ You may demonstrate Charles Law with a balloon that is submerged in warm water and then into an ice bath. 4. Reference Table: Important Formulas and Equations – Combined Gas Law 5. **RG: "Boyle's Law –** The Relationship Between Pressure and the Volume of a Confined Gas" 6. **RG: "Charles' Law –** The Relationship Between Kelvin (Absolute) Temperature and Volume of a Confined Gas" 7. **RG: "Gay-Lussac and the Combined Gas Laws"** 8. *Enrichment: Avogadro's Number*	▪ Hot air Balloons ▪ Weather balloons ▪ Tire pressure: e.g.: blowouts ▪ The "Bends"

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	SUGGESTED ACTIVITIES and TEACHING STRATEGIES	REAL-WORLD CONNECTIONS
19. 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. **(3.4b)**	[S1: S1.1; S6: 2.2]	1. Demonstrate molecular motion using a Molecular Motion Demonstrator. 2. Possible analogy: billiard balls 3. RG: "Kinetic Molecular Theory of Gases" 4. Transparencies and videodiscs are available. 5. Demonstrate molecular motion using a Molecular Motion Demonstrator. 6. Possible analogy: billiard balls 7. **RG: "Kinetic Molecular Theory of Gases"** Transparencies and videodiscs are available.	▪ Odors are dispersed through the air (e.g.: perfume)
20. Kinetic molecular theory describes the relationships of pressure, volume, temperature, velocity, and frequency and force of collisions among gas molecules. **(3.4c)**	Explain the gas laws in terms of KMT [S4:3.4i]	1. Build on concepts developed during demonstrations and problem solving of the Gas Laws.	▪ Structure and composition of Earth's atmosphere (variations in pressure and temperature)
21. 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. **(3.4a)**	[S1: S1.1; S6 2.1]	1. Talk about approaching absolute zero for real vs. ideal gases. Have students brainstorm to determine what factors could account for the inability to cool a real gas to absolute zero. Extrapolate properties of real vs. ideal gases. 2. Transparencies and videodiscs are available	▪ Earth's primitive atmosphere

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UNIT II – Atomic Concepts

II ATOMIC CONCEPTS

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 – were 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

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	SUGGESTED ACTIVITIES and TEACHING STRATEGIES	REAL-WORLD CONNECTIONS
1. The modern model of the atom has evolved over a long period of time through the work of many scientists. (3.1a) (continued on the next page)	Relate experimental evidence to models of the atom [S4:h3.1ii] Use atomic models to describe the structure of an atom. [S1: S1.1, 1.2, S1.3, S2.1, 2.2, 2.3; S2: 1; S6: 2.1, 2.2, 2.4; S7: 2]	1. The "Black Box Experiment": Ask students to describe the contents of one or more sealed opaque containers holding "mystery " items (e.g.: buttons, paper clips, pebbles) to introduce Atomic Theory. 2. Develop atomic structure through student research culminating in written/oral reports on scientists with emphasis on their experiments and conclusions or 3. Organize small cooperative learning groups to read, summarize and present the information they learned reading about major discoveries Incorporate the work of the groups into a timeline of discoveries. **4. RG: Atomic Structure, Introduction – Historic Background** 5. A non-exhaustive list of important scientists and their contributions to Atomic Theory includes: • Democritus (460-370 B.C.) • Antoine Lavoisier (1743-1794) Atoms of an element are not changed by chemical reactions neither created nor destroyed (Conservation of Matter). • John Dalton (1766-1844) Worked: 1803-1807 • William Crookes (1832-1919) Worked: 1879 - Gas Discharge or Crookes' Tube • J.J. Thompson – Cathode Rays and electrons (1856-1940) Worked: 1897; "Plum-Pudding" Model of the Atom • Robert Millikan (1868-1953) Worked: 1909 Oil Drop Expt. • [Henry Becquerel (1853-1968) Worked: 1896 Radioactivity	

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	SUGGESTED ACTIVITIES and TEACHING STRATEGIES	REAL-WORLD CONNECTIONS
1. (continued) The modern model of the atom has evolved over a long period of time through the work of many scientists. (3.1a)		(continued) Important scientists and their contributions to Atomic Theory includes: • Marie Curie (1867-1934) Worked: late 1912- 1913 on radioactivity; discovered transuranium elements] • Ernest Rutherford (1871-1937): Worked: 1911 on Alpha Scattering experiment; the "Empty Space" Hypothesis • Henry Moseley (1887-1915): Worked: 1913 on the development of the concept of atomic numbers. • James Chadwick (1891-1974) Worked:1832 on Discovery of the neutron • Max Planck (1858-1947): Worked 1900- Quantum Theory - Energy is quantized. • Albert Einstein (1837-1955): Worked: 1905- Photoelectric Effect • Niels Bohr (1885-1962) Worked: 1913 -The Bohr Model *[...] will be covered in depth in Unit IV (Nuclear Chemistry)*	
2a. Each atom has a nucleus, with an overall positive charge, surrounded by one or more negatively charged electrons. (3.1b) 2b. Subatomic particles contained in the nucleus include pro ons and neutrons. (3.1c) 2c. The proton is positively charged, and the neutron has no charge. The electron is negatively charged. (3.1d) 2d. Protons and electrons have equal but opposite charges. The number of protons equals the number of electrons in an atom. . (3.1e) (continued on the next page	Use models to describe the structure of an atom [S4:3.1i] [S1: S1.1, S2.3, 2.4] Determine the number of protons or electrons in an atom or ion when given one of these values [S4: 3.1iii] [S1: M2.1, M.3.1]	1. Static electricity demonstrations • Pith balls • Electroscope • Rubber and Glass Rods • Balloons rubbed against hair • Use a charged comb to pick up bits of paper 2. Videodiscs on Rutherford 3. Introduce the Reference Table - Symbols used in Nuclear Chemistry 4. **RG: Rutherford Atom** 5. **RG: Nucleons – Parts of the Nucleus** 6. Discuss the differences between (neutral) atoms and ions. 7. Refer to Periodic Table of the Elements. 8. Provide activities to reinforce skills in determining the number of protons, neutrons and electrons.	

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	SUGGESTED ACTIVITIES and TEACHING STRATEGIES	REAL-WORLD CONNECTIONS
2e. 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)	Calculate the mass number of an atom, the number of neutrons or the number of protons, given the other two values [S4: 3.1iv] [S1: M.3.1]	9 Create a table to summarize the characteristics of the particles of an atom. 10 Student Activity: Create atomic models using such readily available materials as candies and toothpicks, clay, paper plates, or construction paper. Students should write descriptions of their models explaining how it relates to the structure of an atom. 11 **Revisit:** Reference Table - Symbols used in Nuclear Chemistry in Nuclear Chemistry	▪ Lasers
3a. 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) 3b. The protons in an atom (atomic number) identify the element. The sum of the protons and the neutrons in atom (mass number) defines an isotope. Common notations that represent isotopes include ^{14}C, $^{14}_{6}C$, carbon-14, C-14 (3.1g)	Interpret and write isotopic notation [S4: 3.1x]	1. **RG: Isotopes – Fractional Atomic Masses** 2. Provide reinforcement activities. **Revisit:** Isotopes in Nuclear Chemistry and the Periodic Table.	▪ Carbon dating ▪ Medical use of radioactive isotopes. ▪ Nuclear energy
4. The average atomic mass of an element is the weighted average of the masses of its naturally occurring isotopes. (3.1n)	Given an atomic mass, determine the most abundant isotope [S43.1xi] Calculate the atomic mass of an element, given the masses and the ratios of naturally occurring isotopes [S4:3.1xii] [S1: M3.1]	1. **RG: Isotopes – Fractional Atomic Masses** 2. **Lab Activity:** Determination of the average atomic mass of "Beanium": Use different types of beans to represent the isotopes of an element. Students should calculate the average atomic mass of their sample based on the average mass of each kind of bean and its relative percentage of the sample.	

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	SUGGESTED ACTIVITIES and TEACHING STRATEGIES	REAL-WORLD CONNECTIONS
5a. Each electron in an atom has its own distinct amount of energy. (3.1l) ——— 5b. When an electron in an atom gains a specific amount of energy, the electron moves to a higher energy state (excited state). (3.1j)	Distinguish between ground state and excited state electron configurations, e.g., 2-8-2 vs. 2-7-3 [S4: 3.1v] [S1: S1.1, 1.3: S3.1]	1. Discuss the contributions of Max Planck & Albert Einstein to Modern Atomic Theory. 2. **RG: The Bohr Model of the Atom** 3. Use the analogy of a Ladder. The rungs of ladder correspond to different energy levels. 4. Identify the electron configuration of an atom in the ground state. Discuss how the ground state configuration differs from the "excited state" configuration. 5. Have students determine the identify elements from their ground state configurations. *Enrichment:* ▪ *Demonstration – Photoelectric Effect (Zinc and ultraviolet light)* ▪ *Discuss isoelectronic configurations. Only one atom, but many ions will have the same electron configuration.*	▪ Colors in burning logs ▪ Cathode-ray tube – old TVs ▪ Neon lights ▪ Fireworks ▪ Forensic analysis ▪ Aurora Borealis, storms on sun and impact on modern telecommunications including radar, ▪ Photoelectric effect and Einstein
6. 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) (continued on the next page)	Identify an element by comparing its bright-line spectrum to given spectra [S43.1vi] [S1: S1.1, 1.3; S6: 2.1, 2.2]	1. Pass white light through a prism or diffraction grating to show a continuous spectrum. 2. Gas Discharge Tubes can be used to show bright line spectra when the light is observed through a spectroscope. The spectrum emitted by an element is specific to that element, a "fingerprint". 3. Flame tests can be helpful in identifying the presence of some elements. 4. Simulate an electron dropping back to its ground state by rolling a ball down steps. <u>Required Lab</u>: **: Flame Test –Spectroscopy: Students must be able to identify elements based on the results of flame tests. Students should be able to identify elements by comparing its emission spectrum to known spectra.**	▪ Discuss discovery of the element Helium. ▪ Spectral analysis of stars

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	SUGGESTED ACTIVITIES and TEACHING STRATEGIES	REAL-WORLD CONNECTIONS
7. 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)	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 [S4: 3.1vii] [S6: 2]	1. **RG: Valence Electrons and Dot Structures** *Enrichment: Modern Atomic Theory and Orbital Notation (e.g.: $1s^2 2s^2 2p^6$):*	
8. 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)	[S6: 2]	1. Standing waves can be simulated using a length of rope; an analogy can be made to the movement of ripples on a pond. 2. Student Activity to demonstrate region of maximum probability: Stretch a rubber band between both index fingers, and pluck one length of it. No matter where along the length the band is plucked, the area of greatest oscillation is always at the midpoint. 3. Quantized Whistle: Whistle from high to low in a single breath. Repeat while holding a long tube to your lips. Some frequencies cannot be whistled because their wavelengths are not a multiple of the length of the tube *Enrichment: Schroedinger, Heisenberg, Pauli, Hund, DeBroglie, et al; quantum numbers: n, l, m_l and m_s, the Aufbau Principle of electron –fill.*	

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UNIT III – Nuclear Chemistry

III NUCLEAR CHEMISTRY

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 nuclear changes that help run our modern world. 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.

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.

MAJOR UNDERSTANDINGS	SKILLS	SUGGESTED ACTIVITIES and TEACHING STRATEGIES	REAL-WORLD CONNECTIONS
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)	[S1:1.1, 1.3; S6: 2.1]	1. Discuss the contributions to our understanding of the nucleus of the many scientists and their discoveries e.g.: ▪ Wilhelm Roentgen (1845-1923) Worked: 1895 ▪ Henry Becquerel (1853-1968) Worked: 1896 Radioactivity ▪ Marie Curie (1867-1934) Worked: late 19thC – 1913 - radioactivity and discovery of transuranium elements ▪ Ernest Rutherford (1871-1937): Worked: 1911 on Alpha Scattering experiment; the "Empty Space" Hypothesis 2. Small group activity: Have students hold as many marbles as possible until marble begins to fall out. Draw analogy to stable vs. unstable nuclei. 3. Demonstration: Use a Geiger counter to show the presence of ionized gas particles that are caused by the emissions of unstable isotopes. *Enrichment: Zone of Stability: "Magic numbers" for neutrons*	

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	SUGGESTED ACTIVITIES and TEACHING STRATEGIES	REAL-WORLD CONNECTIONS
2. Energy released during nuclear reactions is much greater than the energy released during chemical reactions. (5.3c)	[S1:1.1]	1. ($E = mc^2$) A very small quantity of mass can be converted into an enormous amount of energy, and illustrate with "Real World Connections" *Enrichment: ($E = mc^2$)*	• Atomic bomb • Hydrogen bomb • Nuclear power plant • Solar energy
3. 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)	Determine decay mode and write nuclear equations showing alpha and beta decay [S4: 3.1ix] [S1:M1.1]	1. Videodiscs are available for this topic. 2. Discuss natural radioactivity. 3. Refer to the Periodic Table. 4. All nuclides with 84 or more protons are unstable and undergo radioactive decay 5. Introduce Reference Table – Selected Radioisotopes. 6. Elements of lower atomic number (<84) may also have unstable nuclides (e.g.: carbon-14). **Revisit:** Reference Table -Symbols used in Nuclear Chemistry (first introduced in the Unit II - Atomic Structure) *Enrichment:* ▪ *The "zone of stability" of nuclides* ▪ *The "Magic" number of neutrons – re: nuclear stability* ▪ *Very few unstable nuclides have even numbers of neutrons in their nucleus*	• Use of radium-based luminous paint, on watch and instrument dials 1920's • Smoke detectors (Ionization detectors contain radioactive source. e.g. americium-214) alpha decay • Carbon dating
4. 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)	Complete nuclear equations; predict missing particles from nuclear equations [S4: 4.4iii]	1. Provide ample examples and practice opportunities for writing, balancing and interpreting nuclear decay equations. Students should be able to predict missing particles from incomplete equations.	

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	SUGGESTED ACTIVITIES and TEACHING STRATEGIES	REAL-WORLD CONNECTIONS
5. 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)		1. Natural decay series: U-235, U-238 and Th-232 2. Refer to Reference Table-Selected Radioisotopes 3. Transparencies, charts & videos are available to illustrate nuclear fission and fusion reactions *Enrichment: K-capture (An electron from the K shell is absorbed into the nucleus) to form an element of lower atomic number.*	▪ Natural background radiation ▪ Nuclear fission and fusion reactions release energy ▪ Radioisotopes, tracers, transmutation ▪ Man-made elements.
6. Each radioactive isotope has a specific mode and rate of decay (half-life). (4.4a)	Calculate the initial amount, the fraction remaining, or the half-life of a radioactive isotope, given two of the three variables [S4:4.4I] [S1: M1.1, M2.1,M3.1; S6: 3.1, 3.2, 5]	1. Have students refer to the Reference Table – Selected Radioisotopes to compare modes of decay and differences in the half-lives of various nuclides. 2. **Lab Activity** on Half-Life: Simulate radioactive decay: ▪ Use a small bag (per group) of (mini) M&Ms to represent radioactive nuclides. Students should shake the M&Ms, and spill them out on a clean piece of paper. If the logo is not visible this indicates that nuclide has decayed. Count and record the number decayed nuclides in a data table, and remove transmuted particles. Repeat until none remain. (Alternative: use pennies - heads/tails. ▪ Measure the length of licorice sticks cut in successive halves to generate a half-life decay curve. 3. Reference Table - Important Formulas and Equations - Radioactive Decay 4. Emphasize that the rate of nuclear decay is NOT affected by any external conditions (e.g.: temperature, pressure, or the presence of chemical bonds) *Enrichment: Calculation of the half-life of an element:* $M_{final} = M_{initial} \times (Half\text{-}Life)^2$	▪ Man-made elements.

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	SUGGESTED ACTIVITIES and TEACHING STRATEGIES	REAL-WORLD CONNECTIONS
7a. Nuclear reaction includes natural and artificial transmission, fission, and fusion. **(4.4b)** 7b. 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)**	Compare and contrast fission and fusion reactions [S4: 4.4ii] [S7: 1.1, 1.2]	1. Provide ample examples and practice opportunities for identification of fission and fusion reactions. *Enrichment:* ▪ *Demonstrate a Chain Reaction* ▪ *(Dominoes set standing up in a row – push 1st one, the whole row falls)* ▪ *Binding energy* ▪ *Mass defect* ▪ $E=mc^2$	▪ Man-made elements ▪ The Sun/Stars ▪ Atomic ▪ Nuclear power plants ▪ Fission ▪ Fusion ▪ Nuclear submarines ▪ Cost-benefit analysis among various types of power production ▪ Bombs
8. There are benefits and risks associated with fission and fusion reactions. **(4.4f)**	[S1: S1.2; S2: 1,2; S7: 1.1, 1.2]	1. Student reports on the specific uses of radioactive isotopes; 2. Student Debate/Panel Discussion: ▪ Do the benefits outweigh the risks of using nuclear generated power ▪ Would you recommend placing that power plant in your neighborhood? ▪ Should foods be irradiated	▪ Nuclear Power Plants e.g.: Three Mile Island, Chernobyl, Indian Point
9a. 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)**	Identify specific uses of 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 [S4: 4.4iv] [S1: S1.2; S2: 1,2; S7: 1.1, 1.2, 1.3; 2]	1. See above.	

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	SUGGESTED ACTIVITIES and TEACHING STRATEGIES	REAL-WORLD CONNECTIONS
9b. 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)	See above.		▪ Nuclear waste ▪ Radioactive pollution ▪ Radium Dials on watches ▪ Radioactive tracers ▪ Radiation therapy ▪ Irradiated Food ▪ Storage problems associated with storing nuclear wastes.

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UNIT IV – Chemical Bonding

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	SUGGESTED ACTIVITIES and TEACHING STRATEGIES	REAL-WORLD CONNECTIONS
1. 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)	[S1: S2.3]	1. Use several examples of each kind of chemical bond, e.g.: salts, metals, organic compounds and water to demonstrate their varying physical properties. Ask students to group these materials based on similar properties. 2. Explain that chemical or physical properties are due to bonding type. 3. Compare the properties of elements in free vs. combined states (e.g.: Na metal, Cl_2 gas vs. NaCl). 4. Demonstrate the changes in properties of Fe and S in their free states compared with the properties of iron sulfide.	▪ Cleaning solutions ▪ Jewelry-both metallic and gemstones ▪ Adhesives ▪ Synthetic Fabrics ▪ Plastic ▪ Telephone Wires ▪ Table Salt ▪ Sand ▪ Helium Balloons
2a. Atoms attain a stable valence electron configuration by bonding with other atoms. Noble gases have stable valence electron configurations and tend not to bond. (5.2b) . *[When a bond is broken, energy is absorbed. When a bond is formed energy is released. (5.2l)]* *{...} will be covered later in this unit.* (continued on the next page)	Distinguish between valence and non-valence electrons given an electron configuration e.g.: 2-8-2 [S4: 3.1vii] Determine the noble gas configuration an atom will achieve when bonding [S4: 5.2iv] [S1:M1.1,S1.1; S6:5]	1. Discuss the stable electron configurations of the Noble Gases (stable octet). 2. Burn magnesium ribbon in air (warn student not to look directly at the light to show chemical change. Point out that energy is required to initiate the reaction and that in this instance energy was released (exothermic reaction). 3. Have students draw Bohr pictures of elements to show the valence shells (e.g.:: Mg and O and Ne) 4. Ask students how the noble gas configuration might be achieved when O and Mg combine to form MgO. Identify the bond between Mg and O as an ionic bond (transfer of electrons) . Identify the charged particles as ions 5. Predict change in radius of atoms based on tendency to gain or lose electrons. 6. Reinforce transfer of electrons to form ionic bonds with varying combination of elements, e.g.: Na and Cl, Na and O, Mg and Cl, Al and Cl, Na and N.	▪ Some substances (e.g.: Na, Li, etc.) are never found uncombined in nature. ▪ Metallurgy ▪ Static electricity ▪ Photosensitive glasses (AgCl is mixed with the glass)

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	SUGGESTED ACTIVITIES and TEACHING STRATEGIES	REAL-WORLD CONNECTIONS
2a. (continued) Atoms attain a stable valence electron configuration by bonding with other atoms. Noble gases have stable valence electron configurations and tend not to bond. (5.2b) 2b. 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		7. Use Bohr diagrams and electron configurations to enable students to predict which atoms are most likely to form positive or negative ions. Compare atomic to ionic radius and have students draw conclusions. 8. Demonstrate the attraction between oppositely charged particles e.g: charged balloons will stick to the wall; charged rubber comb will pick up small pieces of paper. Elicit that electrostatic forces hold the objects together. Relate this to the NaCl crystal. 9. Show examples of ionic crystal lattices. Use the model to explain properties of ionic substances which result from electrostatic attraction to all of the surrounding oppositely charged ions e.g.: electrical conductivity; brittleness, high melting point, cleavage, solubility in polar liquids. 10. Use a conductivity tester to demonstrate the ability of a solid salt, a salt solution and a molten salt to conduct a current. *Enrichment:* 1. *Introduce terms anion and cation.* 2. *Use orbital notation to explore bonding.*	
3a. Electron-dot diagrams (Lewis structures) can represent the valence electron arrangement in elements, compounds, and ions. (5.2d)	Demonstrate bonding concepts, using Lewis dot structures representing valence electrons: transferred (ionic bonding); *[shared (covalent bonding]:* in a stable octet. [S4:5.2i] [S1: S1.1; S6: 2.2] *[...]is covered later in this unit.*	1. Use Lewis Dot Diagrams to represent ionic compounds. 2. Have students draw Lewis structures of several elements and ionic compounds. Emphasize the differences between neutral and charged particles (ions). 3. **RG: Valence Electrons and Dot Structures** 4. **RG: Ionic Bonding**	▪ Labels on toothpaste, food, sunscreen, etc.

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	SUGGESTED ACTIVITIES and TEACHING STRATEGIES	REAL-WORLD CONNECTIONS
3b. *[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)** *[...] previously covered in the unit on the Physical Behavior of Matter (Unit 1)*		5. Formula writing and nomenclature for ionic compounds. including polyatomic ions. Introduce criss-cross method of determining the empirical formula for an ionic compound. 6. **RG: How Can One Predict the Formulas of Chemical Compounds.** 7. Introduce and use the Reference Table – Selected Polyatomic Ions. 8. **RG: Formula Writing Using Polyatomic Ions**	
4. Two major categories of compounds are ionic and molecular (covalent) compounds. **(5.2g)**		1. Use examples of molecular compounds (e.g.: CO_2, N_2, H_2O, and selected organic compounds to show common properties, i.e. solubility. conductivity, melting point (ability to sublime) Have students compare and contrast the properties of covalent and ionic substances. 2. Demonstrate the preparation of a molecular substance (e.g.: H_2, O_2 CO_2) 3. Help students understand that the different properties are due to different types of bonds. 4.	▪ Dry Ice ▪ Food ▪ Cellulose ▪ Nylon ▪ Petroleum ▪ Teflon ▪ Cosmetics

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	SUGGESTED ACTIVITIES and TEACHING STRATEGIES	REAL-WORLD CONNECTIONS
5. Chemical bonds are formed when valence electrons are; • transferred from one atom to another (ionic) • shared between atoms (covalent) • *[mobile within a metal (metallic)].* **(5.2a)** *[...] will be introduced later in this unit.*	Demonstrate bonding concepts, using Lewis dot structures representing valence electrons: • transferred (ionic bonding); • shared (covalent bonding); • in a stable octet [S4: 5.2i] [S6: 5]	1. Use Lewis or Bohr models to illustrate ways in which stable octets can be other than electron transfer. 2. Have students predict which atoms are most likely to form covalent bonds 3. **RG: Covalent Bonding**	
6. Electronegativity indicates how strongly an atom of an element attracts electrons in a chemical bond. .**(5.2j)** Electronegativity values are assigned according to arbitrary scales.**(5.2j)**	[S1:S1:M2.1 S6: 5]	1. Identify Electronegativity Values on the Reference Table – Properties of Selected Elements. 2. Compare electronegativity values between atoms in ionic bonds vs. atoms in covalent bonds. Determine likelihood of atoms to form ionic bonds based on Electronegativity values. 3. Have students correlate trends in electronegativity to the position of an element on the periodic table. 4. Using the Periodic Table have student note the relative locations of elements in ionically bonded substances compared with the relative positions of elements in covalently bonded substances. 5. Interpret differences between the electronegativity values to predict bond type. *Enrichment* ▪ *Relate the trends in Electronegativity with trends in Electron affinity; Ionization energy* ▪ *Introduce Coordinate Covalent Bonding e.g.: $H3O^{+}$, NH_4^{+}*	
7. The Electronegativity difference between two bonded atoms is used to assess the degree of polarity in the bond.**(5.2k)**	Distinguish between nonpolar covalent bonds (two of the same nonmetals) and polar covalent bonds [S4: 5.2v] [S6: 5]	1. **RG: Predicting Bond Type Using the Electronegativity Chart** (Note: Use Reference Table – Properties of Selected Elements for the Electronegativity Values)	

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	SUGGESTED ACTIVITIES and TEACHING STRATEGIES	REAL-WORLD CONNECTIONS
10. *[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)** *[...] previously covered in the unit on the Physical Behavior of Matter (Unit 1)*		1. Develop the IUPAC system for naming covalent compounds. ▪ Assign oxidation numbers. ▪ Discuss the multiple oxidation states that many non-metallic elements can exhibit. Show how Roman numerals are used to differentiate compounds containing the same elements, e.g.: NO NO_2, N_2O. N_2O_3, N_2O_5) . *Enrichment:* *Identify common names of covalent compounds*	
11. Chemical bonds are formed when valence electrons are;*[transferred from one atom to another (ionic), shared between atoms (covalent)]* [mobile within a metal (metallic)]. **(5.2a)** *[...]was covered earlier in this unit.*		1. Display samples of various metals and have students brainstorm to identify the properties of metals. 2. Have students propose a possible bonding structure to account for the distinct properties of metals. 3. Guide students to recognize that previously discussed bonding patterns cannot account for metallic properties. 4. Introduce metallic bonding (sea of mobile electrons). 5. Explain the properties metals exhibit in terms of metallic bonding.	▪ Electrical wires ▪ Pots and pans ▪ Jewelry ▪ Building materials

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	SUGGESTED ACTIVITIES and TEACHING STRATEGIES	REAL-WORLD CONNECTIONS
12. Compounds can be differentiated by their chemical and physical properties. (3.1dd)	Distinguish among ionic, molecular, and metallic substances, given their properties [S4: 3.1xix] Compare the physical properties of substances based on chemical bonds and intermolecular forces, e.g.: malleability, solubility, hardness, melting point and boiling point. [S4: 5.2ii]	1. Revisit: How can we differentiate substances based their chemical and physical properties. (This was first introduced in Unit I – The Physical Behavior of Matter.). 2. Use examples of familiar compounds to demonstrate chemical and physical properties e.g.: reactivity or physical state. Several pairs of compounds with similar properties can be used to show/elicit the properties which can be used to distinguish these substances. 3. Demonstration: Use a charged rod to show how water can be differentiated from cyclohexane. The charged rod will deflect a thin stream of water, but a thin stream of cyclohexane will not be affected. (Pour the liquid through a funnel with a narrow stem). 4. **RG: Types of Solids** 5. **Required Lab: Have students design and conduct an experiment in which they identify the type of bonding that exists in a substance. Students should base their bond type classifications on the characteristics they have tested such as melting point, solubility, and electrical conductivity.** 6. Use charts and models to demonstrate different arrangements of ions within ionic compounds or molecules within molecular compounds, or metal atoms within metallic bonds.	• Physiology of muscle and nervous impulse conduction

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	SUGGESTED ACTIVITIES and TEACHING STRATEGIES	REAL-WORLD CONNECTIONS
13a. 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. (5.2l) (continued on the next page)	[S6: 2.1, 5]	1. Balloons can be used to demonstrate the various shapes of molecules. Ask students to predict the what the molecules, e.g.: H_2 , HCl, $AlCl_3$, NH_3, H_2O, would probably look like prior to showing them the actual structure. (Two balloons tied together will simulate a linear molecule; three, a trigonal planar molecule, and four, a molecule which is tetrahedral. Round balloons of the same size can be used to simulate one particular element. Using different sized round balloons one can simulate bonds between different elements.) **Note**: The ability to identify the shapes of molecules is not a testable skill, but may aid students in visualizing distribution of charge.	• Helium balloons • Water
13b. *[Differences in the properties such as density, particle size, molecular polarity, boiling and freezing point and solubility permit physical separation of the components of the mixture. (3.1nn)]* ***[...] was covered in the unit on the Physical Behavior of Matter (Unit1).***	[S6: 2.1, 5]	2. Use Reference Table – Properties of Selected Elements: Electronegativity Values to predict which bonds will exhibit the polar vs. nonpolar characteristics. 3. Have students construct molecules: using the shape and polarity of bonds. Students should then identify the molecules as polar or non-polar.	• Dangers of nonpolar solvents as carcinogens or toxins

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	SUGGESTED ACTIVITIES and TEACHING STRATEGIES	REAL-WORLD CONNECTIONS
14a. Intermolecular forces created by the unequal distribution of charge results in varying degrees of attraction between molecules. Hydrogen bonding is an example of a strong intermolecular force.**(5.2m)** 14b. *[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)*[...] was covered in the unit the Physical Behavior of Matter (Unit 1).* 14c. The concepts of kinetic and potential energy can be used to explain physical processes that include: freezing (fusion), solidification (freezing), vaporization (evaporation and condensation) condensation, sublimation, and deposition. **(4.2c)**	Apply the adage "like dissolves like" to real world situations.[S4: 3.1xxvi] Explain vapor pressure, evaporation rate and phase changes in terms of intermolecular forces. [S4: 5.2iii]	1. Ask a student to pick up a tiny piece of paper with the tip of one finger. When the student is unsuccessful ask why? Elicit wetting the tip of the finger will allow the paper to be picked up. Ask why the water aids in picking up the paper 2. Students brainstorm a list of substances that are solid, liquid or gaseous at room temperature. Relate the phase that matter exists in to strength of the intermolecular attractions (Helium, Water or Ethanol, Wax). 3. Dissolve a styrofoam cup by placing in a beaker with a small amount of acetone. 4. Identify types of intermolecular attractions. 5. Discuss: boiling points of liquids increase as the mass of the molecule increases (exception: hydrogen bonded substances, e.g.: H_2O) 6. Refer to Reference Table – Vapor Pressure of Four Liquids - Ask students to account for the high boiling point of water compared with propanone (higher molecular mass). Introduce hydrogen bonding to explain this anomaly. 7. Revisit: 13b and 13c were introduced in Unit I - The Physical Behavior of Matter **(4.2c)**	

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:	SUGGESTED ACTIVITIES and TEACHING STRATEGIES	REAL-WORLD CONNECTIONS
15.When a bond is broken, energy is absorbed. When a bond is formed, energy is released. (5.2I)		1. Demonstrate chemical reactions breaking or forming bonds. Measure energy release or absorption by temperature or sensory observation. 2. Review the terms endothermic and exothermic. Have students use the Reference Table – Heats of Reaction to identify substances formed exothermically or endothermically. 3. Associate the heat of a reaction to the stability of the product. 4. Revisit heat of solution, heat of fusion to reteach the calculation of heat of a reaction (introduced originally in Unit I – The Physical Behavior of Matter.) 5. **Required Lab Activity: Determining the heat of a reaction,** e.g.: Burning a peanut: A peanut which has been pierced with a straightened paper clip is the placed into a clay base and ignited. The flame produced is used to heat a measured quantity of water at a known initial temperature. The heat of reaction for the burning of the peanut can then be determined	▪ Cellular respiration ▪ Burning of fossil fuels ▪ Caloric content of food ▪ Hand warmers

V PERIODICITY

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:
1. 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)	Describe the states of the elements at STP [S4: 3.1xviii]
2. Elements can be differentiated by chemical properties. Chemical properties describe how an element behaves during a chemical reaction. (3.1x)	
3. The placement or location of an element on the Periodic Table gives an indication of physical and chemical properties of the element. The elements on the periodic Table are arranged in order of increasing atomic number. (3.1y)	Explain the placement of an unknown element in the Periodic Table based on its properties [S4:3.1xvi]
4. 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. (3.1g)	Interpret and write isotopic notation [S4: 3.1x]
5. 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)	Classify elements as metals, nonmetals, metalloids, or noble gases by their properties [S4:3.1xiii]
6. 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)	Determine the group of an element, given the chemical formula of a compound, e.g., XCl or XCl_2 [S4: 3.1xv]
7. 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. (5.2f)	
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)	Compare and contract properties of elements within a group or a period for Groups 1,2,13-18 on the Periodic Table [S4: 3.1xiv]
9. The succession of elements across the same period demonstrates characteristics trends: differences in atomic radius, ionic radius, electronegativity, first ionization energy, metallic/nonmetallic properties.(3.1bb)	

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:
1. Types of chemical reactions include synthesis, decomposition, single replacement, double replacement (3.2b)	Identify types of chemical reactions [S4: 3.2ii]
2. 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)	
3. In all chemical reactions there is a conservation of mass, energy and charge (3.3a)	Interpret balanced chemical reactions in terms of conservation of matter and energy [S4: 3.3ii]
4. 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)	Balance equations, given the formulas for reactants and products]S4: 3.3i] Interpret balanced chemical equations in terms of conservation of matter and energy [S4: 3.3ii] Create and use models of particles to demonstrate balanced equations [S4 3.3iii] Calculate simple mole-mole stoichiometry problems, given a balanced equation. [S4: 3.3iv]
5. Types of chemical formulas include: empirical, molecular, and structural (3.1ee)	
6. 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)	Determine the molecular formula , given the empirical formula and the molecular mass.[S4: 3.3vii] Determine the empirical formula from a molecular formula [S4: 3.3v]
7. 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)	Calculate the formula mass and the gram-formula mass [S4: 3.3viii]
8. The percent composition by mass of each element in a compound can be calculated mathematically. (3.3f)	Determine the number of moles of a substance given its mass [S4: 3.3ix] Determine the mass of a given number of moles of a substance [S4: 3.3vi]
9. The concentration of a solution may be expressed: molarity (M), percent by volume, percent by mass, or parts per million (3.1pp)	Describe the preparation of a solution, given the molarity [S4: 3.1xxx] Interpret solution concentration data [S4: 3.1xxx] Calculate solution concentrations in molarity (M), percent mass, parts per million (ppm) [S4: 3.1xxix]

VII KINETICS AND EQUILIBRIUM

MAJOR UNDERSTANDINGS	SKILLS **The student should be able to:**
1.Collision Theory states that a reaction is most likely to occur if reactant particles collide with the proper energy and orientation **(3.4d)**	Use collision theory to explain how various factors, such as temperature, surface area, and concentration, influence the rate of reaction [S4:3.4vi]
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)**	
3. Some chemical and physical changes can reach equilibrium(3.4h)	Identify examples of physical equilibria as solution equilibrium and phase equilibrium, including the concept that a saturated solution is at equilibrium [S4:3.4vii]
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)**	Describe the concentration of particles and rates of opposing reactions in an equilibrium system [S4: 3.4iv]
5. Le Chatelier'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)**	Qualitatively describe the effect of stress on equilibrium, using LeChatelier's principle [S4:3.4v]
6. Energy released or absorbed by a chemical reaction can be represented by a potential energy diagram **(4.1c)**	Read and interpret potential energy diagrams: PE of reactants and products, activation energy (with or without a catalyst), heat of reaction [S4:4.1ii]
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 **(4.1d)**	

VIII ACIDS AND BASES

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:
1. 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 is depends on the concentration of ions **(3.1rr)**	
2. Behavior of many acids and bases can be explained by the Arrhenius theory Arrhenius acids and bases are electrolytes **(3.1rr)**	Given properties, identify substances as Arrhenius acids or bases [**S4:** 3.1xxxi]
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 $H_3O_{(aq)}$ the hydronium ion **(3.1vv)**	
4. Arrhenius Bases: yield $OH^-_{(aq)}$ (the hydroxyl ion) as the only negative ion in an aqueous solution. **(3.1ww)**	
5. The acidity or alkalinity of a solution can be measured by its pH value. The relative level of these solutions can be shown using indicators. (3.1ss)	Interpret changes in acid-base indicator color [**S4:** 3.1xxxiii]
6. On the pH scale, each decrease of one unit of pH represents a tenfold increase in hydronium ion concentration **(3.1tt)**	
7. In the process of neutralization, an Arrhenius Acid and an Arrhenius Base react to from a salt and water **(3.1xx)**	Write simple neutralization reactions when given the reactants [**S4:** 3.1xxiv]
8..Titration is a laboratory process in which a volume of a solution of known concentration is used to determine the concentration of another solution. **(3.1zz)**	Calculate the concentration or volume of a solution, using titration data [**S4:** 3.1xxxv]
9. There are alternative Acid/Base theories. One theory states that an acid is an H^+. and a base is an H^+ acceptor. **(3.1yy)**	

IX OXIDATION AND REDUCTION

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:
An oxidation-reduction (redox) reaction involves transfer of electrons. **(3.2d)**	Determine a missing reactant or product in a balanced equation [S4: 3.2iii]
Oxidation numbers (states) can be assigned to atoms and ions. Changes in oxidation numbers indicate that oxidation and reduction have occurred. (3.2g)	
Reduction is the gain of electrons. **(3.2e)**	
Oxidation is the loss of electrons. **(3.2g)**	
A half reaction can be written to represent reduction. **(3.2f)** A half reaction can be written to represent oxidation. **(3.2h)**	Write and balance half reactions for reduction and oxidation of free elements and their monatomic ions [S4: 3.2vi]
In a redox reaction the number of electrons lost is equal to the number of electrons gained. (3.3b)	Balance equations, number of electrons gained and lost, and charges in the reactants and products. [S4: 3.2v; 3.3i]
A voltaic cell spontaneously converts chemical energy to electrical energy. **(3.2k)**	Identify and label parts of a voltaic cell (cathode, anode, salt bridge) and direction of electron flow, given the reaction equation. [S4: 3.2vii] Use table of reduction potentials to determine whether a redox reaction is spontaneous [S4: 3.2x]
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)**	Compare and contrast voltaic and electrolytic cells [S4: 3.2ix]
An electrolytic cell requires electrical energy to produce chemical change. This process is known as electrolysis. **(3.2l)**	Identify and label the parts of an electrolytic cell (anode, cathode) and direction of electron flow, given the reaction equation [S4: 3.2viii]

MAJOR UNDERSTANDINGS	SKILLS The student should be able to:
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)**	
2a. 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)** 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. **(5.2c)**	Draw structural formulas for alkanes, alkenes, and alkynes containing a maximum of ten carbon atoms [**S4:** 3.1xxi]
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 **(3.1hh)**	Classify an organic compound based on its structural or condensed structural formula [**S4:** 3.1xvii]
Organic compounds can be named using the IUPAC system **(3.1ff)**	Draw a structural formula with the functional group(s) on a straight chain hydrocarbon backbone, when given the correct IUPAC name for the compound [**S4:** 3.1xx]
Isomers of organic compounds have the same molecular formula but different structures and properties.	
Types of organic reactions include: addition, substitution, polymerization, esterification, fermentation, oxidation, saponification and combustion. .	Identify types of organic reactions [**S4:** 3.2iv] Determine a missing reactant or product in a balanced equation [**S4:** 3.2iii]

APPENDIX I – SUGGESTED TIME LINE

Unit 1 – The Physical Behavior of .... 18 –22 days

Unit 2 – Atomic Concepts .... 13 –17 days

Unit 3 – Nuclear Chemistry .... 9 –12 days

Unit 4 – Chemical Bonding........ .... 18 -22 days

Unit 5 – Periodicity...9 –12 days

The suggested time line for the second semester is not available at this time.

APPENDIX II - INTERNET RESOURCES

Atomic Structure
It's Elemental - Element Math Game (calculate the number of proton, neutrons, electrons or nucleons) - http://education.jlab.org/elementmath/index.html
Merriam-Webster Dictionary and Thesaurus - http://www.m-w.com/home.htm
Simulations of Electron Motion Around the Nucleus - http://www.colorado.edu/physics/2000/periodic_table/index.html
Spectral lines - http://www.colorado.edu/physics/2000/quantumzone/index.html
The Bohr Model of the Atom - http://www.colorado.edu/physics/2000/quantumzone/bohr.html

Elements
The Elements Its Elemental - Element Concentration Game - http://education.jlab.org/elementconcentration/index.html
It's Elemental - Element Matching Game! - http://education.jlab.org/elementmatching/index.html
It's Elemental - Element Hangman! - http://education.jlab.org/elementhangman/index.html
It's Elemental - Element Flash Cards! - http://education.jlab.org/elementflashcards/index.html
Element Games - http://education.jlab.org/indexpages/elementgames.html
Element Bingo - http://education.jlab.org/beamsactivity/6thgrade/elementbingo/index.html
Element Word Search - http://education.jlab.org/beamsactivity/6thgrade/elementwordsearch/index.html

Electronegativity and Chemical Bonding
The Ionic Bond - http://dbhs.wvusd.k12.ca.us/Bonding/Ionic-Bond.html
Electronegativity and Bond Type - http://dbhs.wvusd.k12.ca.us/Bonding/Electroneg-Bond-Polarity.html
Which Elements form Ionic Bonds? - http://dbhs.wvusd.k12.ca.us/Bonding/Ionic-Bond-Which-Elements.html
Writing Lewis Structures: Obeying the Octet Rule - http://dbhs.wvusd.k12.ca.us/Bonding/Lewis-Structure-1.html
Prediction of Molecular Polarity for Simple Chemical Species http://dbhs.wvusd.k12.ca.us/Bonding/Molecular-Polarity.html
Formula Poker - http://www2.ncsu.edu/ncsu/pams/science_house/learn/CountertopChem/exp31.html

Lab Safety and MSDS Locators
***** Be sure to check the applicable MSDSs and the directions given in any online lab experiment before recommending it to students. Verify the safe manner of handling ALL chemicals before ALL demonstrations and lab exercises.**
The Laboratory Safety Institute: A National Center of Science Safety – www.labsafety.org
SIRI MSDS Index - http://hazard.com/msds2/
The MSDS HyperGlossary – Flammable Limits - http://www.ilpi.com/msds/ref/index.html
Where to find MSDS on the WEB - http://btc.montana.edu/nten/

Nuclear Chemistry
A Glossary of Nuclear Terms - http://www.nrc.gov/NRC/EDUCATE/GLOSSARY/
Alpha Decay- http://hyperphysics.phy-astr.gsu.edu/hbase/nuclear/radact.html#c2
The ABCs of Nuclear Science - http://www.lbl.gov/abc/
Beta Radioactivity - http://hyperphysics.phy-astr.gsu.edu/hbase/nuclear/beta.html#c2
Gamma Radioactivity- http://hyperphysics.phy-astr.gsu.edu/hbase/nuclear/radact2.html#c1
Radioactive Half-Life- http://hyperphysics.phy-astr.gsu.edu/hbase/nuclear/halfli.html
Nuclear Power - http://www.nelsonitp.com/physics/guide/pages/nuclear/rad2.html
Radioactive Decay of Candium - http://www2.ncsu.edu/ncsu/pams/science_house/learn/CountertopChem/exp32.html

The Periodic Table
Its Elemental - Interactive Periodic Table of Elements - http://education.jlab.org/itselemental/index.html
ChemicalElements.com (interactive Periodic Table of the Elements) - http://www.chemicalelements.com/
Periodic Table Games - http://chemistry2.csudh.edu/ptablegames/ptablegames.html
WebElements ScholarEdition - http://www.webelements.com/index.html
Periodic Table Challenge - http://www.ilpi.com/genchem/periodicquiz.html
Quiz Hub – the Periodic Table - http://quizhub.com/quiz/periodictable.cfm
Periodic Table Quiz - http://www.bpreid.com/applets/periodicNoWait.htm

Physical Behavior of Matter
Chromatography of Foods Lab Activity - http://www2.ncsu.edu/ncsu/pams/science_house/learn/CountertopChem/exp4.html
Physical & Chemical Changes Lab Activity -http://www2.ncsu.edu/ncsu/pams/science_house/learn/CountertopChem/exp5.html
The Law of Conservation of Matter Lab Activity - http://www2.ncsu.edu/ncsu/pams/science_house/learn/CountertopChem/exp3.html
Combustion - http://www2.ncsu.edu/ncsu/pams/science_house/learn/CountertopChem/exp2.html
Rate of Solution Lab Activity - http://www2.ncsu.edu/ncsu/pams/science_house/learn/CountertopChem/exp14.html
Density Lab Activity- http://library.thinkquest.org/2690/exper/exp25.htm

Research Resources
BioChem Links - http://biochemlinks.com/bclinks/bclinks.cfm
Chemdex - http://www.chemdex.org/
SciSeek(links to Web sites covering : agriculture, forestry, engineering, chemistry, physics and the environment.) http://www.sciseek.com/
The Internet Public Library - http://www.ipl.org/
Tutorial for the Critical Evaluation of Web Sites - http://www.ithaca.edu/library/Training/hott.html
U.S. Energy Information Administration - http://www.eia.doe.gov

Science Literacy
Academic Press Dictionary of Science and Technology http://www.harcourt.com/dictionary/
American Chemical Society (chemist connection, chemistry in the news, etc.- http://www.acs.org/
Bartleby.com - online reference library- http://www.bartleby.com/
ChemClub : World Chemistry Community - http://www.chemclub.com/
Kiwi Web (Chemistry and New Zealand) - http://www.chemistry.co.nz/
New York Times: Science - http://www.nytimes.com/pages/science/index.html
Reactive Reports (a Chemistry webzine) - http://www.acdlabs.com/webzine/awards.html
Science News Online http://www.sciencenews.org/
Scientific American – www.sciam.com
www.sTutorial for the Critical Evaluation of Web Sites - http://www.ithaca.edu/library/Training/hott.html

Teacher Resources
Home Experiments - http://scifun.chem.wisc.edu/HOMEEXPTS/HOMEEXPTS.html ***
New York Academy of Sciences – www.nyas.org
National Science Teachers Association – www.nsta.org
N^{10} - National Teachers Enhancement Network (online science education -- University of Montana) - http://btc.montana.edu/nten/
North Caroline State University Chemistry Outreach - http://www.ncsu.edu/chemistry/outreach/
Science Resources Directory (NYC Board of Education) - http://www.nycenet.edu/subjects/science.html
Science Teachers' Resource Center http: / / chem.lapeer.org
STANYS (Science Teachers of New York State) – http://sites.tier.net/stanys/
The Science House - Counter Top Chemistry – http://www2.ncsu.edu/ncsu/pams/science_house/learn/CountertopChem/index.html

APPENDIX III

Excerpts from:

Core Curriculum: Physical Setting/Chemistry

THE STATE EDUCATION DEPARTMENT THE UNIVERSITY OF THE STATE OF NEW YORK
http://www.nysed.gov

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Note: The pagination that appears on these excerpted pages is consistent with their location in the original document.

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

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

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

STANDARD 1—Analysis, Inquiry, and Design
Students will use mathematical analysis, scientific inquiry, and engineering design, as appropriate, to pose questions, seek answers, and develop solutions.

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

STANDARD 1
Analysis, Inquiry, and Design

MATHEMATICAL ANALYSIS:

continued

Key Idea 2:
Deductive and inductive reasoning are used to reach mathematical conclusions.

M2.1 Use deductive reasoning to construct and evaluate conjectures and arguments, recognizing that patterns and relationships in mathematics assist them in arriving at these conjectures and arguments.
- interpret a graph constructed from experimentally obtained data
  - ◆ identify relationships
    - § direct
    - § inverse
  - ◆ apply data showing trends to predict information

Key Idea 3:
Critical thinking skills are used in the solution of mathematical problems.

M3.1 Apply algebraic and geometric concepts and skills to the solution of problems.
- state assumptions which apply to the use of a particular mathematical equation and evaluate these assumptions to see if they have been met
- evaluate the appropriateness of an answer, based on given data

STANDARD 1
Analysis, Inquiry, and Design

SCIENTIFIC INQUIRY:

Key Idea 1:
The central purpose of scientific inquiry is to develop explanations of natural phenomena in a continuing, creative process.

S1.1 Elaborate on basic scientific and personal explanations of natural phenomena, and develop extended visual models and mathematical formulations to represent thinking.
- use theories and/or models to represent and explain observations
- use theories and/or principles to make predictions about natural phenomena
- develop models to explain observations

S1.2 Hone ideas through reasoning, library research, and discussion with others, including experts.
- locate data from published sources to support/defend/explain patterns observed in natural phenomena

S1.3 Work towards reconciling competing explanations, clarifying points of agreement and disagreement.
- evaluate the merits of various scientific theories and indicate why one theory was accepted over another

Key Idea 2:
Beyond the use of reasoning and consensus, scientific inquiry involves the testing of proposed explanations involving the use of conventional techniques and procedures and usually requiring considerable ingenuity.

S2.1 Devise ways of making observations to test proposed explanations.
- design and/or carry out experiments, using scientific methodology to test proposed calculations

S2.2 Refine research ideas through library investigations, including information retrieval and reviews of the literature, and through peer feedback obtained from review and discussion.
- use library investigations, retrieved information, and literature reviews to improve the experimental design of an experiment

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

continued

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 nutrons 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-C-OH with O above the second C)	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
	ix compare and contrast voltaic and electrolytic cells	3.2j
	x use a table of reduction potentials to determine whether a redox reaction is spontaneous	3.2k
	3.3 Apply the principle of conservation of mass to chemical reactions.	
	i balance equations, given the formulas for reactants and products	3.3c
	ii interpret balanced chemical equations in terms of conservation of matter and energy	3.3a, 3.3c

STANDARD 4
The Physical Setting

continued

iii	create and use models of particles to demonstrate balanced equations	3.3a, 3.3c
iv	calculate simple mole-mole stoichiometry problems, given a balanced equation	3.3c
v	determine the empirical formula from a molecular formula	3.3d
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 (°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 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: — 5.2a, 5.2d
  - § transferred (ionic bonding)
  - § shared (covalent bonding)
  - § in a stable octet

  Example:

atom	ion
K.	K^+
:C̈l:	$[:\ddot{C}l:]^-$

- 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

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