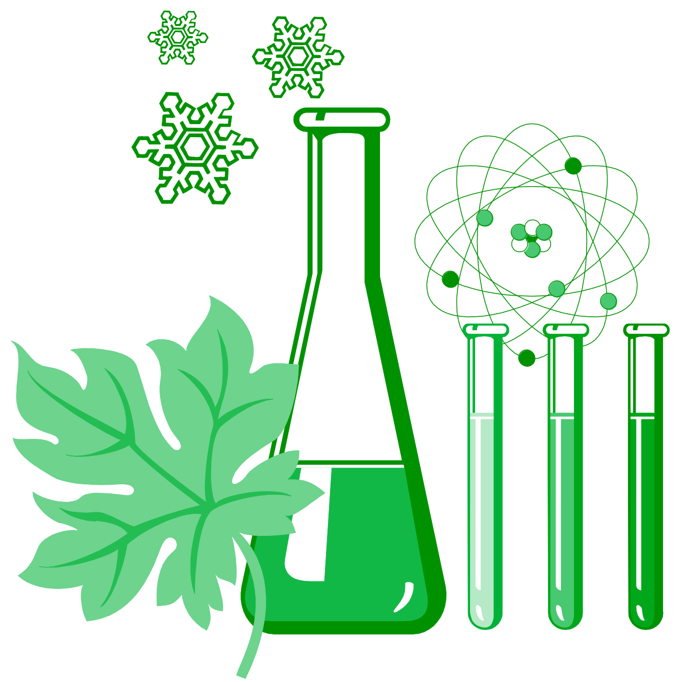

Science Standards of Learning Curriculum Framework

Chemistry

Final Review
November 18, 2010

Commonwealth of Virginia
Board of Education
Richmond, Virginia

Superintendent of Public Instruction
Patricia I. Wright, Ed.D.

Assistant Superintendent for Instruction
Linda M. Wallinger, Ph.D.

Office of Standards, Curriculum, and Instruction
Mark R. Allan, Ph.D., Director
Paula J. Klonowski, Science Coordinator
Barbara P. Young, Science Specialist

NOTICE
The Virginia Department of Education does not discriminate on the basis of race, sex, color, national origin, religion, age, political affiliation, veteran status, or against otherwise qualified persons with disabilities in its programs and activities.

The 2010 *Science Curriculum Framework* can be found in PDF and Microsoft Word file formats on the Virginia Department of Education's Web site at http://www.doe.virginia.gov.

Virginia *Science Standards of Learning* Curriculum Framework 2010
Introduction

The *Science Standards of Learning Curriculum Framework* amplifies the *Science Standards of Learning for Virginia Public Schools* and defines the content knowledge, skills, and understandings that are measured by the Standards of Learning tests. The *Science Curriculum Framework* provides additional guidance to school divisions and their teachers as they develop an instructional program appropriate for their students. It assists teachers as they plan their lessons by identifying essential understandings and defining the essential content knowledge, skills, and processes students need to master. This supplemental framework delineates in greater specificity the minimum content that all teachers should teach and all students should learn.

School divisions should use the *Science Curriculum Framework* as a resource for developing sound curricular and instructional programs. This framework should not limit the scope of instructional programs. Additional knowledge and skills that can enrich instruction and enhance students' understanding of the content identified in the Standards of Learning should be included as part of quality learning experiences.

The Board of Education recognizes that school divisions will adopt a K–12 instructional sequence that best serves their students. The design of the Standards of Learning assessment program, however, requires that all Virginia school divisions prepare students to demonstrate achievement of the standards for elementary and middle school by the time they complete the grade levels tested. The high school end-of-course Standards of Learning tests, for which students may earn verified units of credit, are administered in a locally determined sequence.

The Curriculum Framework serves as a guide for Standards of Learning assessment development. Assessment items may not and should not be a verbatim reflection of the information presented in the Curriculum Framework. Students are expected to continue to apply knowledge and skills from Standards of Learning presented in previous grades as they build scientific expertise.

Each topic in the *Science Standards of Learning* Curriculum Framework is developed around the Standards of Learning. The format of the Curriculum Framework facilitates teacher planning by identifying the key concepts, knowledge and skills that should be the focus of instruction for each standard. The Curriculum Framework is divided into two columns: Understanding the Standard (K-5); Essential Understandings (6 – Physics); and Essential Knowledge, Skills, and Processes. The purpose of each column is explained below.

Understanding the Standard
This section includes background information for the teacher (K-5). It contains content that may extend the teachers' knowledge of the standard beyond the current grade level. This section may also contain suggestions and resources that will help teachers plan lessons focusing on the standard.

Essential Understandings
This section delineates the key concepts, ideas and scientific relationships that all students should grasp to demonstrate an understanding of the Standards of Learning.

Essential Knowledge, Skills and Processes
Each standard is expanded in the Essential Knowledge, Skills, and Processes column. What each student should know and be able to do in each standard is outlined. This is not meant to be an exhaustive list nor a list that limits what is taught in the classroom. It is meant to be the key knowledge and skills that define the standard.

Standard CH.1

CH.1	The student will investigate and understand that experiments in which variables are measured, analyzed, and evaluated produce observations and verifiable data. Key concepts include a) designated laboratory techniques; b) safe use of chemicals and equipment; c) proper response to emergency situations; d) manipulation of multiple variables, using repeated trials; e) accurate recording, organization, and analysis of data through repeated trials; f) mathematical and procedural error analysis; g) mathematical manipulations including SI units, scientific notation, linear equations, graphing, ratio and proportion, significant digits, and dimensional analysis; h) use of appropriate technology including computers, graphing calculators, and probeware, for gathering data, communicating results, and using simulations to model concepts; i) construction and defense of a scientific viewpoint; and j) the use of current applications to reinforce chemistry concepts.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world. The nature of science includes the following concepts a) the natural world is understandable; b) science is based on evidence - both observational and experimental; c) science is a blend of logic and innovation; d) scientific ideas are durable yet subject to change as new data are collected; e) science is a complex social endeavor; and f) scientists try to remain objective and engage in peer review to help avoid bias. • Techniques for experimentation involve the identification and the proper use of chemicals, the description of equipment, and the recommended statewide framework for high school laboratory safety. • Measurements are useful in gathering data about chemicals and how they behave. • Repeated trials during experimentation ensure verifiable data.	~~Knowledge Skills~~ In order to meet this standard, it is expected that students will • make connections between components of the nature of science and their investigations and the greater body of scientific knowledge and research. • demonstrate safe laboratory practices, procedures, and techniques. • demonstrate the following basic lab techniques: filtering, ~~decanting~~, using chromatography, and lighting a gas burner. • understand Material Safety Data Sheet (MSDS) warnings, including handling chemicals, lethal dose (LD), hazards, disposal, and chemical spill cleanup. • identify the following basic lab equipment: beaker, Erlenmeyer flask, graduated cylinder, test tube, test tube rack, test tube holder, ring stand, wire gauze, clay triangle, crucible with lid, ~~evaporation~~ evaporating dish, watch glass, wash bottle, and dropping pipette. • make the following measurements, using the specified equipment: - volume: graduated cylinder, ~~pipette,~~ volumetric flask, buret - mass: ~~electronic or dial-a-gram~~ triple beam and electronic balances - temperature: thermometer and/or temperature probe

Standard CH.1

CH.1	The student will investigate and understand that experiments in which variables are measured, analyzed, and evaluated produce observations and verifiable data. Key concepts include a) designated laboratory techniques; b) safe use of chemicals and equipment; c) proper response to emergency situations; d) manipulation of multiple variables, using repeated trials; e) accurate recording, organization, and analysis of data through repeated trials; f) mathematical and procedural error analysis; g) mathematical manipulations including SI units, scientific notation, linear equations, graphing, ratio and proportion, significant digits, and dimensional analysis; h) use of appropriate technology including computers, graphing calculators, and probeware, for gathering data, communicating results, and using simulations to model concepts; i) construction and defense of a scientific viewpoint; and j) the use of current applications to reinforce chemistry concepts.

Essential Understandings	Essential Knowledge and Skills
• Data tables are used to record and organize measurements. • Mathematical procedures are used to validate data., including percent error to evaluate accuracy. • Measurements of quantity include length, volume, mass, temperature, time, and pressure to the correct number of significant digits. Measurements must be expressed in International System of Units (SI) units. • Scientific notation is used to write very small and very large numbers. • Algebraic equations represent relationships between dependent and independent variables. • Graphs are used to summarize the relationship between the independent and dependent variable. • Graphed data give a picture of a relationship. • Ratios and proportions are used in calculations. • Significant digits of a measurement are the number of known digits together with one estimated digit. • The last digit of any valid measurement must be estimated and is	- pressure: barometer and/or pressure probe. • identify, locate, and know how to use laboratory safety equipment, including aprons, goggles, gloves, fire extinguishers, fire blanket, safety shower, eye wash, broken glass container, and fume hood. • design and perform controlled experiments to test predictions, including the following key components: hypotheses, independent and dependent variables, constants, controls, and repeated trials. • ~~Identify variables.~~ • predict outcome(s) when a variable is changed. • read measurements and record data, ~~using~~ reporting the significant digits of the measuring equipment. • demonstrate precision (reproducibility) in measurement. • recognize accuracy in terms of closeness to the true value of a measurement. • determine the mean of a set of measurements. • use data collected to calculate percent error. • discover and eliminate procedural errors.

Standard CH.1

CH.1 The student will investigate and understand that experiments in which variables are measured, analyzed, and evaluated produce observations and verifiable data. Key concepts include

a) designated laboratory techniques;
b) safe use of chemicals and equipment;
c) proper response to emergency situations;
d) manipulation of multiple variables, using repeated trials;
e) accurate recording, organization, and analysis of data through repeated trials;
f) mathematical and procedural error analysis;
g) mathematical manipulations including SI units, scientific notation, linear equations, graphing, ratio and proportion, significant digits, and dimensional analysis;
h) use of appropriate technology including computers, graphing calculators, and probeware, for gathering data, communicating results, and using simulations to model concepts;
i) construction and defense of a scientific viewpoint; and
j) the use of current applications to reinforce chemistry concepts.

Essential Understandings

therefore uncertain.

- Dimensional analysis is a way of translating a measurement from one unit to another unit.
- Graphing calculators can be used to manage the mathematics of chemistry.
- Scientific questions drive new technologies that allow discovery of additional data and generate better questions. New tools and instruments provide an increased understanding of matter at the atomic, nano and molecular scale.
- Constant reevaluation in the light of new data is essential to keeping scientific knowledge current. In this fashion, all forms of scientific knowledge remain flexible and may be revised as new data and new ways of looking at existing data become available.

Essential Knowledge and Skills

- ~~know most frequently used~~ use common SI prefixes and their values (milli-, centi-, ~~deci-,~~ kilo-) in measurements and calculations.
- demonstrate the use of scientific notation, using the correct number of significant digits with powers of ten notation for the decimal place.
- ~~Correctly utilize the following when graphing~~ graph data utilizing the following:
  - independent variable (horizontal axis)
  - dependent variable (vertical axis)
  - scale and units of a graph
  - regression line (best fit curve).
- calculate mole ratios, percent composition, conversions, and ~~relative~~ average atomic mass.
- ~~Use the rules for performing operations~~ perform calculations ~~with~~ according to significant digits rules.
- ~~utilize~~ convert measurements using dimensional analysis.
- use graphing calculators to solve chemistry problems.
- read a measurement from a graduated scale, stating measured digits plus the estimated digit.

Standard CH.1

CH.1 The student will investigate and understand that experiments in which variables are measured, analyzed, and evaluated produce observations and verifiable data. Key concepts include

a) designated laboratory techniques;
b) safe use of chemicals and equipment;
c) proper response to emergency situations;
d) manipulation of multiple variables, using repeated trials;
e) accurate recording, organization, and analysis of data through repeated trials;
f) mathematical and procedural error analysis;
g) mathematical manipulations including SI units, scientific notation, linear equations, graphing, ratio and proportion, significant digits, and dimensional analysis;
h) use of appropriate technology including computers, graphing calculators, and probeware, for gathering data, communicating results, and using simulations to model concepts;
i) construction and defense of a scientific viewpoint; and
j) the use of current applications to reinforce chemistry concepts.

Essential Understandings	Essential Knowledge and Skills
	• use appropriate technology for data collection and analysis, including probeware interfaced to a graphing calculator and/or computer and computer simulations. • ~~use probeware to gather data.~~ • summarize knowledge gained through gathering and appropriate processing of data in a report that documents background, objective(s), data collection, data analysis and conclusions. • explain the emergence of modern theories based on historical development. For example, students should be able to explain the origin of the atomic theory beginning with the Greek atomists and continuing through the most modern ~~Q~~quantum models.

Standard CH.2

CH.2	The student will investigate and understand that the placement of elements on the periodic table is a function of their atomic structure. The periodic table is a tool used for the investigations of a) average atomic mass, mass number, and atomic number; b) isotopes, half lives, and radioactive decay; c) mass and charge characteristics of subatomic particles; d) families or groups; e) periods; f) trends including atomic radii, electronegativity, shielding effect, and ionization energy; g) electron configurations, valence electrons, and oxidation numbers; h) chemical and physical properties; and i) historical and quantum models.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • The periodic table is arranged in order of increasing atomic numbers. • The atomic number of an element is the same as the number of protons. In a neutral atom, the number of electrons is the same as the number of protons. All atoms of an element have the same number of protons. • The average atomic mass for each element is the weighted average of that element's naturally occurring isotopes. • The mass number of an element is the sum of the number of protons and neutrons. It is different for each element's isotopes. • An isotope is an atom that has the same number of protons as another atom of the same element but has a different number of neutrons. Some isotopes are radioactive; many are not. • Half-life is the length of time required for half of a given sample of a radioactive isotope to decay. • Electrons have little mass and a negative (–) charge. They are located in electron clouds or probability clouds outside the nucleus. • Protons have a positive (+) charge. Neutrons have no charge. Protons and neutrons are located in the nucleus of the atom and comprise most	~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will • ~~Using a periodic chart,~~ determine the atomic number, atomic mass, the number of protons, and the number of electrons~~, and the number of neutrons~~ of any ~~neutral~~ atom of a particular element using a periodic table. • determine the number of neutrons in an isotope given its mass number. • perform calculations to determine the "weighted" average atomic mass. • ~~determine~~ perform calculations involving the half-life of a radioactive substance. • ~~describe~~ differentiate between alpha, beta, and gamma radiation with respect to penetrating power, shielding, and composition. • differentiate between the major atom components (proton, neutron and electron) in terms of location, size, and charge. • distinguish between a group and a period. • identify key groups, periods, and regions of elements on the periodic

Standard CH.2

CH.2 The student will investigate and understand that the placement of elements on the periodic table is a function of their atomic structure. The periodic table is a tool used for the investigations of

a) average atomic mass, mass number, and atomic number;
b) isotopes, half lives, and radioactive decay;
c) mass and charge characteristics of subatomic particles;
d) families or groups;
e) periods;
f) trends including atomic radii, electronegativity, shielding effect, and ionization energy;
g) electron configurations, valence electrons, and oxidation numbers;
h) chemical and physical properties; and
i) historical and quantum models.

Essential Understandings

of its mass. Quarks are also located in the nucleus of the atom.

- The names of groups and periods on the periodic chart are alkali metals, alkaline earth metals, transition metals, halogens, and noble gases~~, and metalloids~~.
- Metalloids have properties of metals and nonmetals. They are located between metals and nonmetals on the periodic table. Some are used in semiconductors.
- Periods and groups are named by numbering columns and rows. Horizontal rows called periods have predictable properties based on an increasing number of electrons in the outer ~~orbitals~~ energy levels. Vertical columns called groups or families have similar properties because of their similar valence electron configurations.
- The Periodic Law states that when elements are arranged in order of increasing atomic numbers, their physical and chemical properties show a periodic pattern.
- Periodicity is regularly repeating patterns or trends in the chemical and physical properties of the elements arranged in the periodic table.
- Atomic radius is the measure of the distance between radii of two identical atoms of an element. Atomic radius decreases from left to right and increases from top to bottom within given groups.
- Electronegativity is the measure of the attraction of an atom for

Essential Knowledge and Skills

table.

- identify and explain trends in the periodic table as they relate to ionization energy, electronegativity, shielding effect, and relative sizes.
- compare an element's reactivity to the reactivity of other elements in the table.
- relate the position of an element on the periodic table to its electron configuration.
- ~~use an element's electron configuration to~~ determine the number of valence electrons and possible oxidation numbers from an element's electron configuration.
- write the electron configuration for the first 20 elements of the periodic table.
- distinguish between physical and chemical properties of metals and nonmetals.
- differentiate between pure substances and mixtures and between homogeneous and heterogeneous mixtures.
- ~~major insights regarding the atomic model of the atom and~~ identify key contributions of principal scientists ~~include~~ including:
  - ~~particles~~ *atomos*, initial idea of atom – Democritus

Standard CH.2

CH.2 The student will investigate and understand that the placement of elements on the periodic table is a function of their atomic structure. The periodic table is a tool used for the investigations of

a) average atomic mass, mass number, and atomic number;
b) isotopes, half lives, and radioactive decay;
c) mass and charge characteristics of subatomic particles;
d) families or groups;
e) periods;
f) trends including atomic radii, electronegativity, shielding effect, and ionization energy;
g) electron configurations, valence electrons, and oxidation numbers;
h) chemical and physical properties; and
i) historical and quantum models.

Essential Understandings

electrons in a ~~covalent~~ bond. Electronegativity increases from left to right within a period and decreases from top to bottom within a group.

- Shielding effect is constant within a given period and increases within given groups from top to bottom.
- Ionization energy is the energy required to remove the most loosely held electron from a neutral atom. Ionization energies generally increase from left to right and decrease from top to bottom of a given group.
- Electron configuration is the arrangement of electrons around the nucleus of an atom based on their energy level.
- Electrons are added one at a time to the lowest energy levels first (Aufbau Principle). Electrons occupy equal-energy orbitals so that a maximum number of unpaired electrons results (Hund's Rule).
- Energy levels are designated 1–7. Orbitals are designated s, p, d, and f according to their shapes ~~s, p, d, f orbitals~~ and relate to the regions of the Periodic Table. An orbital can hold a maximum of two electrons (Pauli Exclusion Principle).
- Atoms can gain, lose, or share electrons within the outer energy level.
- Loss of electrons from neutral atoms results in the formation of an ion with a positive charge (cation). Gain of electrons by a neutral atom results in the formation of an ion with a negative charge (anion).

Essential Knowledge and Skills

- first atomic theory of matter, solid sphere model – John Dalton
- discovery of the electron using the cathode ray tube experiment, plum pudding model – J. J. Thom~~p~~son
- discovery of the nucleus using the gold foil experiment, nuclear model – Ernest Rutherford
- discovery of charge of electron using the oil drop experiment – Robert Millikan
- energy levels, planetary model ~~of atom~~ – Niels Bohr
- periodic table arranged by atomic mass – D~~e~~mitri~~y~~ Mendeleev
- periodic table arranged by atomic number – Henry Moseley
- quantum nature of energy – Max Planck
- uncertainty principle, quantum mechanical model – Werner Heisenberg
- wave theory, quantum mechanical model – Louis de Broglie.
- ~~quantum numbers, quantum mechanical model – Erwin Schrödinger.~~

- differentiate between the historical and quantum models of the atom.

Standard CH.2

CH.2 The student will investigate and understand that the placement of elements on the periodic table is a function of their atomic structure. The periodic table is a tool used for the investigations of

a) average atomic mass, mass number, and atomic number;
b) isotopes, half lives, and radioactive decay;
c) mass and charge characteristics of subatomic particles;
d) families or groups;
e) periods;
f) trends including atomic radii, electronegativity, shielding effect, and ionization energy;
g) electron configurations, valence electrons, and oxidation numbers;
h) chemical and physical properties; and
i) historical and quantum models.

Essential Understandings	Essential Knowledge and Skills
• Transition metals can have multiple oxidation states. • Matter occurs as elements (pure), compounds (pure), and mixtures, which may be homogeneous (solutions) or heterogeneous. Some elements, such as oxygen, hydrogen, fluorine, chlorine, bromine, iodine, and nitrogen, naturally occur as diatomic molecules. • Matter is classified by its chemical and physical properties. • Physical properties refer to the condition or quality of a substance that can be observed or measured without changing the substance's composition. Important physical properties are density, conductivity, melting point, boiling point, malleability, and ductility. • Chemical properties refer to the ability of a substance to undergo chemical reaction and form a new substance. • Reactivity is the tendency of an element to enter into a chemical reaction. • Discoveries and insights related to the atom's structure have changed the model of the atom over time. Historical models have included solid sphere, plum pudding, nuclear, and planetary models. The modern atomic theory is called the ~~Q~~quantum ~~M~~mechanical ~~M~~model.	

Standard CH.3

CH.3 The student will investigate and understand how conservation of energy and matter is expressed in chemical formulas and balanced equations. Key concepts include

a) nomenclature;
b) balancing chemical equations;
c) writing chemical formulas;
d) bonding types;
e) reaction types; and
f) reaction rates, kinetics, and equilibrium.

Essential Understandings

The concepts developed in this standard include the following:

- Chemical formulas are used to represent compounds. Subscripts represent the relative number of each type of atom in a molecule or formula unit. The International Union of Pure and Applied Chemistry (IUPAC) system is used for naming compounds.
- When pairs of elements form two or more compounds, the masses of one element that combine with a fixed mass of the other element form simple, whole-number ratios (Law of Multiple Proportions).
- ~~Elements and compounds react in different ways.~~ Compounds have different properties than the elements from which they are composed.
- Conservation of matter is represented in balanced chemical equations. A coefficient is a quantity that precedes a reactant or product ~~symbol or~~ formula in a chemical equation and indicates the relative number of particles involved in the reaction.
- The empirical formula shows the simplest whole-number ratio in which the atoms of the elements are present in the compound. The molecular formula shows the actual number of atoms of each element in one molecule of the substance.
- Lewis dot diagrams are used to represent valence electrons in an element. Structural formulas ~~also~~ show the arrangements of atoms and bonds in a molecule and are represented by Lewis dot structures.
- Bonds form between atoms to achieve stability. Covalent bonds involve the sharing of electrons between atoms. Ionic bonds involve the transfer of electrons between ions. Elements with low ionization energy form

Essential Knowledge and Skills

~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will

- name binary covalent/molecular compounds.
- name binary ionic compounds (using the Roman numeral system where appropriate).
- predict, draw, and name molecular shapes (bent, linear, trigonal planar, tetrahedral, and trigonal pyramidal).
- transform word equations into chemical equations and balance chemical equations.
- write the chemical formulas for certain common substances, such as ammonia, water, carbon monoxide, carbon dioxide, sulfur dioxide, and carbon tetrafluoride.
- ~~recognize the formulas and names of certain polyatomic ions, such as carbonate, sulfate, nitrate, hydroxide, phosphate, and ammonium, and~~ use ~~these~~ polyatomic ions for naming and writing ~~the~~ formulas of ionic compounds, including carbonate, sulfate, nitrate, hydroxide, phosphate, and ammonium.
- draw Lewis dot diagrams to represent valence electrons in elements and draw Lewis dot ~~diagrams~~ structures to show covalent bonding.
- use valence shell electron pair repulsion (VSEPR) model to ~~predict,~~ draw and name molecular shapes (bent, linear, trigonal planar, tetrahedral, and trigonal pyramidal).
- recognize polar molecules and non-polar molecules.

Standard CH.3

CH.3	The student will investigate and understand how conservation of energy and matter is expressed in chemical formulas and balanced equations. Key concepts include a) nomenclature; b) balancing chemical equations; c) writing chemical formulas; d) bonding types; e) reaction types; and f) reaction rates, kinetics, and equilibrium.

Essential Understandings	Essential Knowledge and Skills
positive ions (cations) easily. Elements with high ionization energy form negative ions (anions) easily. Polar bonds form between elements with very different electronegativities. Non-polar bonds form between elements with similar electronegativities. • Polar molecules result when ~~a molecule behaves as if one end were positive and the other end negative~~ electrons are distributed unequally. • ~~Spontaneous reactions may be fast or slow. Randomness (entropy), heat content (enthalpy), and temperature affect spontaneity.~~ • Major types of chemical reactions are - synthesis (A+B →AB) - decomposition (BC →B+C) - single replacement (A+BC →B+AC) - double replacement (AC+BD →AD+BC) - neutralization (HX+MOH → H_2O + MX) - combustion (C_xH_y + O_2 → CO_2 + H_2O). • Kinetics is the study of reaction rates. Several factors affect reaction rates, including temperature, concentration, surface area, and the presence of a catalyst. • Reaction rates/kinetics are affected by activation energy, catalysis, and the degree of randomness (entropy). Catalysts decrease the amount of activation energy needed. • Chemical reactions ~~based on the net heat energy~~ are exothermic reactions (heat producing) and endothermic reactions (heat absorbing). • Reactions occurring in both forward and reverse directions are	• classify types of chemical reactions as synthesis, decomposition, single replacement, double replacement, neutralization, and/or combustion. • recognize that there is a natural tendency for systems to move in a direction of randomness (entropy). • recognize equations for redox reactions and neutralization reactions. • distinguish between an endothermic and exothermic process. • interpret reaction rate diagrams. • identify and explain the effect ~~of~~ the following factors ~~that affect the rate and time~~ have on the rate of a chemical reaction: ~~(~~catalyst, temperature, concentration, size of particles~~)~~. • distinguish between irreversible reactions and those at equilibrium. • predict the shift in equilibrium when a system is subjected to a stress (Le Chatelier's Principle) and identify the factors that can cause a shift in equilibrium (temperature, pressure, and concentration.) • ~~Identify common examples of reaction types.~~

Standard CH.3

CH.3	The student will investigate and understand how conservation of energy and matter is expressed in chemical formulas and balanced equations. Key concepts include a) nomenclature; b) balancing chemical equations; c) writing chemical formulas; d) bonding types; e) reaction types; and f) reaction rates, kinetics, and equilibrium.

Essential Understandings	Essential Knowledge and Skills
reversible. Reversible reactions can reach a state of *equilibrium*, where the reaction rates of both the forward and reverse reactions are constant. ~~can occur in two directions simultaneously.~~ Le Chatelier's Principle indicates the qualitative prediction of direction of change with temperature, pressure, and concentration.	

Standard CH.4

CH.4 The student will investigate and understand that chemical quantities are based on molar relationships. Key concepts include

a) Avogadro's principle and molar volume;
b) stoichiometric relationships;
c) solution concentrations; and
d) acid/base theory; strong electrolytes, weak electrolytes, and nonelectrolytes; dissociation and ionization; pH and pOH; and the titration process.

Essential Understandings

The concepts developed in this standard include the following:

- Atoms and molecules are too small to count by usual means. A *mole* is a way of counting any type of particle (atoms, molecules, and formula units).
- Avogadro's number = 6.02×10^{23} particles per mole.
- Molar mass of a substance is its average atomic mass in grams from the Periodic Table.
- Molar volume = ~~22.4 dm^3/mole and/or~~ 22.4 L/mole for any gas at standard temperature and pressure (STP).
- Stoichiometry involves quantitative relationships. Stoichiometric relationships are based on mole quantities in a balanced equation.
- Total grams of reactant(s) = total grams of product(s).
- Molarity = ~~moles/dm^3 or~~ moles of solute/L of solution.
- [ ] refers to molar concentration.
- When solutions are diluted, the moles of solute present initially remain.
- The saturation of a solution is dependent on the amount of solute present in the solution.
- Two important classes of compounds are acids and bases. Acids and bases are defined by several theories. According to ~~T~~the Arrhenius theory ~~of~~, acids are characterized by their sour taste, low pH, and the fact that they turn litmus paper red. According to ~~T~~the Arrhenius theory ~~of~~, bases are characterized by their bitter taste, slippery feel, high pH, and the fact that they turn litmus paper blue. According to ~~T~~the

Essential Knowledge and Skills

~~Knowledge~~ ~~Skills~~ In order to meet this standard, it is expected that students will

- perform conversions between mass, volume, particles, and moles of a substance.
- ~~Make~~ perform stoichiometric calculations involving the following relationships:
  - mole-mole;
  - mass-mass;
  - mole-mass;
  - mass-volume;
  - mole-volume; ~~and~~
  - volume-volume;
  - ~~particle-particle;~~
  - mole-particle;
  - mass-particle; and
  - volume-particle.
- identify the limiting reactant (reagent) in a reaction.
- calculate percent yield of a reaction.
- perform calculations involving the molarity of a solution, including dilutions.
- interpret solubility curves.
- differentiate between the defining characteristics of the Arrhenius theory of acids and bases and the Bronsted-Lowry theory of acids and bases.

Standard CH.4

CH.4 The student will investigate and understand that chemical quantities are based on molar relationships. Key concepts include

a) Avogadro's principle and molar volume;
b) stoichiometric relationships;
c) solution concentrations; and
d) acid/base theory; strong electrolytes, weak electrolytes, and nonelectrolytes; dissociation and ionization; pH and pOH; and the titration process.

Essential Understandings	Essential Knowledge and Skills
Bronsted-Lowry theory ~~of~~, acids are proton donors, whereas bases are proton acceptors. Acids and bases dissociate in varying degrees. • Strong electrolytes dissociate completely. Weak electrolytes dissociate partially. Non-electrolytes do not dissociate. • pH is a number scale ranging from 0 to 14 that represents the acidity of a solution. The pH number denotes hydrogen (hydronium) ion concentration. The pOH number denotes hydroxide ion concentration. The higher the hydronium $[H_3O^+]$ concentration, the lower the pH. • pH + pOH = 14 • Strong acid-strong base titration is the process that measures [H~~+~~$^+$] and $[OH^-]$. • Indicators show color changes at certain pH levels.	• identify common examples of acids and bases, including vinegar and ammonia. • compare and contrast the differences between strong, weak, and non-electrolytes. • relate the hydronium ion concentration to the pH scale. • perform titrations in a laboratory setting using indicators.

Standard CH.5

CH.5	The student will investigate and understand that the phases of matter are explained by kinetic theory and forces of attraction between particles. Key concepts include a) pressure, temperature, and volume; b) partial pressure and gas laws; c) vapor pressure; d) phase changes; e) molar heats of fusion and vaporization; f) specific heat capacity; and g) colligative properties.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • Atoms and molecules are in constant motion, and the amount of motion depends on the substance's state of matter. • The phase of a substance depends on temperature and pressure. • Temperature is a measurement of the average kinetic energy in a sample. There is a direct relationship between temperature and average kinetic energy. • The Kkinetic Mmolecular Ttheory is a model for predicting and explaining gas behavior. • Gases have mass and occupy space. Gas particles are in constant, rapid, random motion and exert pressure as they collide with the walls of their containers. Gas molecules with the lightest mass travel fastest. Relatively large distances separate gas particles from each other. • Equal volumes of gases at the same temperature and pressure contain an equal number of particles. Pressure Uunits include atm, KkPa, and mm of Hg. • An Iideal Ggas does not exist, but this concept is used to model gas behavior. A Rreal Ggas exists, has intermolecular forces and particle volume, and can change states. The Ideal Gas Law states that PV = nRT. • The pressure and volume of a sample of a gas at constant temperature are inversely proportional to each other (Boyle's Law: $P_1V_1 = P_2V_2$).	Knowledge Skills In order to meet this standard, it is expected that students will • explain the behavior of gases and the relationship between pressure and volume (Boyle's Law), and volume and temperature (Charles' Law). • solve problems and interpret graphs involving the gas laws. • identify how hydrogen bonding in water plays an important role in many physical, chemical, and biological phenomena. • interpret vapor pressure graphs. • graph and interpret a heating curve (temperature vs. time). • interpret a phase diagram of water. • calculate energy changes, using molar heat of fusion and molar heat of vaporization. • calculate energy changes, using specific heat capacity. • Perform calorimetry calculations. • examine the polarity of various solutes and solvents in solution formation.

Standard CH.5

CH.5	The student will investigate and understand that the phases of matter are explained by kinetic theory and forces of attraction between particles. Key concepts include a) pressure, temperature, and volume; b) partial pressure and gas laws; c) vapor pressure; d) phase changes; e) molar heats of fusion and vaporization; f) specific heat capacity; and g) colligative properties.

Essential Understandings	Essential Knowledge and Skills
• At constant pressure, the volume of a fixed amount of gas is directly proportional to its absolute temperature (Charles' Law: $V_1/T_1 = V_2/T_2$). • The Combined Gas Law ($P_1V_1/T_1 = P_2V_2/T_2$) relates pressure, volume, and temperature of a gas. • The sum of the partial pressures of all the components in a gas mixture is equal to the total pressure of a gas mixture (Dalton's law of partial pressures). • Forces of attraction (intermolecular forces) between molecules determine ~~the physical changes of state~~ their state of matter at a given temperature. Forces of attraction include hydrogen bonding, dipole-dipole attraction, and London dispersion (van der Waals) forces. • Vapor pressure is ~~a property of a substance determined by intermolecular forces~~ the pressure of the vapor found directly above a liquid in a closed container. When the vapor pressure equals the atmospheric pressure, a liquid boils. Volatile liquids have high vapor pressures, weak intermolecular forces, and low boiling points. Nonvolatile liquids have low vapor pressures, strong intermolecular forces and high boiling points. • Solid, liquid, and gas phases of a substance have different energy content. Pressure, temperature, and volume changes can cause a change in physical state. Specific amounts of energy are absorbed or released during phase changes. • A fourth ~~state~~ phase of matter is ~~the~~ plasma ~~phase~~. ~~A~~ Plasma is formed	

Standard CH.5

CH.5	The student will investigate and understand that the phases of matter are explained by kinetic theory and forces of attraction between particles. Key concepts include a) pressure, temperature, and volume; b) partial pressure and gas laws; c) vapor pressure; d) phase changes; e) molar heats of fusion and vaporization; f) specific heat capacity; and g) colligative properties.

Essential Understandings	Essential Knowledge and Skills
when a gas is heated to a temperature at which its electrons dissociate from the nuclei. • A heating curve graphically describes the relationship between temperature and energy (heat). It can be used to identify a substance's ~~state~~ phase of matter at a given temperature as well as the temperature(s) at which it changes ~~state~~ phase. It also shows the strength of the intermolecular forces present in a substance. • Molar heat of fusion is a property that describes the amount of energy needed to convert one mole of a substance between its solid and liquid states. Molar heat of vaporization is a property that describes the amount of energy needed to convert one mole of a substance between its liquid and gas states. Specific heat capacity is a property of a substance that tells the amount of energy needed to raise one gram of a substance by one degree Celsius. The values of these properties are related to the strength of their intermolecular forces. • Solutions can be a variety of solute/solvent combinations: gas/gas, gas/liquid, liquid/liquid, solid/liquid, gas/solid, liquid/solid, or solid/solid. • Polar substances dissolve ionic or polar substances; nonpolar substances dissolve nonpolar substances. The number of solute particles changes the freezing point and boiling point of a pure substance. • A liquid's boiling point and freezing point are affected by changes in atmospheric pressure. A liquid's boiling point and freezing point are affected by the presence of certain solutes.	

Standard CH.6

CH.6	The student will investigate and understand how basic chemical properties relate to organic chemistry and biochemistry. Key concepts include a) unique properties of carbon that allow multi-carbon compounds; and b) uses in pharmaceuticals and genetics, petrochemicals, plastics and food.

Essential Understandings	Essential Knowledge and Skills
It is expected that the content of this SOL is incorporated into the appropriate SOL as that content is being taught (i.e., bonding types, shapes, etc.) and not isolated as a discrete unit. The concepts developed in this standard include the following: • The bonding characteristics of carbon contribute to its stability and allow it to be the foundation of organic molecules. These characteristics result in the formation of a large variety of structures such as DNA, RNA and amino acids. • Carbon-based compounds include simple hydrocarbons, small carbon-containing molecules with functional groups, complex polymers, and biological molecules. • Petrochemicals contain hydrocarbons, including propane, butane, and octane. • There is a close relationship between the properties and structure of organic molecules. • Common pharmaceuticals that are organic compounds include aspirin, vitamins, and insulin. • Small molecules link to make large molecules, called polymers, that have combinations with repetitive subunits. Natural polymers include proteins and nucleic acids. Human-made (synthetic) polymers include polythene, nylon and Kevlar.	In order to meet this standard, it is expected that students will • describe how saturation affects shape and reactivity of carbon compounds. • draw Lewis dot structures, identify geometries, and describe polarities of the following molecules: CH_4, C_2H_6, C_2H_4, C_2H_2, CH_3CH_2OH, CH_2O, C_6H_6, CH_3COOH. • recognize that organic compounds play a role in natural and synthetic pharmaceuticals. • recognize that nucleic acids and proteins are important natural polymers. • recognize that plastics formed from petrochemicals are organic compounds that consist of long chains of carbons. • conduct a ~~synthesis~~ lab that exemplifies the versatility and importance of organic compounds (e.g., aspirin, an ester, a polymer).