Richmond Public Schools
Department of Curriculum and Instruction
Curriculum Pacing And Resource Guide

Course Title/ Course #: EOC Chemistry/2802 or EOC Pre AP Chemistry/ 2804

Start day: 1

Meetings: 180 days

Course Description

This Chemistry course is designed to provide students with a detailed understanding of the interaction of matter and energy. This interaction is investigated through the use of laboratory techniques, manipulation of chemical quantities, and problem-solving applications. Scientific methodology is employed in experimental and analytical investigations, and concepts are illustrated with current practical applications that should include examples from environmental, nuclear, organic, and biochemistry content areas. Technology, including graphing calculators, computers, and probeware, are employed where feasible. Students will understand and use safety precautions with chemicals and equipment. The standards emphasize qualitative and quantitative study of substances and the changes that occur in them. In meeting the chemistry standards, students will be encouraged to share their ideas, use the language of chemistry, discuss problem-solving techniques, and communicate effectively. The Chemistry standards continue to focus on student growth in understanding the nature of science. This scientific view defines the idea that explanations of nature are developed and tested using observation, experimentation, models, evidence, and systematic processes. The nature of science includes the concepts that scientific explanations are based on logical thinking; are subject to rules of evidence; are consistent with observational, inferential, and experimental evidence; are open to rational critique; and are subject to refinement and change with the addition of new scientific evidence. The nature of science includes the concept that science can provide explanations about nature and can predict potential consequences of actions, but cannot be used to answer all questions.

Pacing Resources Assessments MP1

Time Frame	Standards of Learning	Units/ Topics/ Concepts	Resources	Assessments
2 weeks	CH.1a - CH.1j, CH. 4 a	**Scientific Inquiry:** Experimental Design Science Fair Topic CHEMath Dimensional	**VDOE Lesson Plans** Laboratory Safety and Skills (PDF) / (Word) Scientific Inquiry:	➢ Student will make connections between components of the nature of science and their investigations and the greater body of scientific knowledge and research by completing a science fair project.

		Analysis	Measurement/Data (PDF) / (Word) Moles Lab Activities (PDF) / (Word) **Review Power Point** Scientific Investigation Lab Equipment Lab Safety Writing the Lab Report Scientific Measurement Scientific Notation The SI System Metric Conversion Practice Significant Figures The Mole **Gizmos** Unit Conversions Unit Conversions 2 – Scientific Notations & Significant Figures Seed Germination Disease Spread Hershel Experiment Stoichiometry **Videos** Calculating reliability, accuracy and precision % Mass Molar Volume of Gases What is a Mole? **PhET Simulations:** Density Photoelectric Effect **Labs** Fizzing & Foaming – Using just a few simple household materials,	➢ Have students demonstrate safe laboratory practices, procedures, and techniques. ➢ Have students demonstrate the following basic lab techniques: filtering, using chromatography, and lighting a gas burner. ➢ Have students demonstrate an understanding of the Material Safety Data Sheet (MSDS) warning, including handling chemicals, lethal dose (LD), hazards, disposal, and chemical spill cleanup. ➢ Have students 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, evaporating dish, watch glass, wash bottle, and dropping pipette. ➢ Have students make the following measurements, using the specified equipment: - volume: graduated cylinder, volumetric flask, buret - mass: triple beam and electronic balances - temperature: thermometer and/or temperature probe - pressure: barometer and/or pressure probe. ➢ Have students 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.

			you can watch a glass of liquid turn into foam! A Simple Chemistry Experiment – Here is an easy yet interesting chemistry experiment that students can try in the classroom. Classic Chemistry Experiments – This printable PDF file has several classic chemistry experiments for students to try.	➢ Have students design and perform controlled experiments to test predictions, including the following key components: ○ hypotheses, independent and dependent variables, constants, controls, and repeated trials, ○ predicting outcome(s) when a variable is changed, ○ read measurements and record data, 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. ○ use common SI prefixes and their values (milli-, centi-, kilo-) in measurements and calculations. ○ processing of data in a report that documents background, objective(s), data collection, data analysis and conclusions. ➢ Have students 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 quantum models. ➢ Have students perform conversions between mass, volume, particles, and moles of a

				substance.
3 weeks	CH.5a-g	Phases of Matter & Kinetic Theory	**VDOE Lesson Plans** Vapor Pressure and Colligative Properties (PDF) / (Word) States of Matter (PDF) / (Word) Thermochemistry: Heat and Chemical Changes (PDF) / (Word) Heat Transfer and Heat Capacity (PDF) / (Word) Molar Heat of Fusion for Water (PDF) / (Word) The Colligative Properties of Solutions (PDF) / (Word) Charles' Law (PDF) / (Word) Partial Pressure (PDF) / (Word) **Review Power Point** Phases of Matter Phase Changes Measurement of Pressure and Temperature Gas Laws The Ideal Gas Law Kinetic Molecular Theory **Gizmos** Diffusion **Videos** Collecting & Identifying Gases Calculating Gas Volumes	➢ Have students explain the behavior of gases and the relationship between pressure and volume (Boyle's Law), and volume and temperature (Charles' Law). ➢ Have students solve problems and interpret graphs involving the gas laws. ➢ Have students identify how hydrogen bonding in water plays an important role in many physical, chemical, and biological phenomena. ➢ Have students interpret vapor pressure graphs. ➢ Have students graph and interpret a heating curve (temperature vs. time). ➢ Have students interpret a phase diagram of water. ➢ Have students calculate energy changes, using molar heat of fusion and molar heat of vaporization. ➢ Have students calculate energy changes, using specific heat capacity. ➢ Have students examine the polarity of various solutes and solvents in solution formation.

			Diffusion of Gases **POGIL Activities** Kinetic Molecular Theory Calorimetry Vapor Pressure Phase Changes Distillation **PhET Simulations:** States of Matter: Basics States of Matter Energy Forms & Changes Gas Properties Balloons & Buoyancy **Labs** Liquid Air Demonstration – See how gases can become liquids with this demonstration. Boyle's Law – This interactive page helps to demonstrate the famous Boyle's Law. The Cat's Meow – This simple and safe experiment shows how different molecules react at the surface of a liquid. Smell the Difference – This experiment shows how different molecules have different properties, even with their smells. Production of Oxygen – This experiment demonstrates to students how to generate oxygen and test its properties.	

3 weeks	CH.2a-c,i	Atomic Structure	**VDOE Lesson Plans** Radioactive Decay and Half-Life (PDF) / (Word) Isotopes (PDF) / (Word) Elements and Electron Configuration (PDF) / (Word) Atomic Structure: Elements (PDF) / (Word) Average Atomic Masses (PDF) / (Word) **Review Power Point:** Atomic Structure Atomic Structure II Nuclear Chemistry The Hydrogen Bomb The Dual Nature of the Electron Electrons in Atoms **Gizmos** Element Builder Bohr Model: Introduction Bohr Model of Hydrogen Electron Configuration **PhET Simulations:** Build an Atom Radioactive Dating Game Radio Waves & Electromagnetic Fields Alpha Decay Beta Decay	➢ Have students determine the atomic number, atomic mass, the number of protons, and the number of electrons of any atom of a particular element using a periodic table. ➢ Have students determine the number of neutrons in an isotope given its mass number. ➢ Have students perform calculations to determine the "weighted" average atomic mass. ➢ Have students perform calculations involving the half-life of a radioactive substance. ➢ Have students differentiate between alpha, beta, and gamma radiation with respect to penetrating power, shielding, and composition. ➢ Have students differentiate between the major atom components (proton, neutron and electron) in terms of location, size, and charge. ➢ Have students identify key contributions of principal scientists including: o atomos, initial idea of atom – **Democritus** o first atomic theory of matter, solid sphere model – **John Dalton** o discovery of the electron using the cathode ray tube experiment, plum pudding model – **J. J. Thomson** o discovery of the nucleus using the gold foil experiment, nuclear model – **Ernest Rutherford** o discovery of charge of electron using the oil drop experiment -**Robert Millikan** o energy levels, planetary model – **Niels Bohr** o quantum nature of energy – **Max Planck** o uncertainty principle, quantum mechanical model – **Werner Heisenberg**

			Nuclear Fission Balloons & Static Electricity Blackbody Spectrum Isotopes & Atomic Mass Models of the Hydrogen Atom Neon Lights & Other Discharge Lamps Rutherford Scattering **POGIL Activities** Atoms and Their Isotopes Analysis of Spectral Lines Lewis Dot Structures of Atoms and Ions Nuclear Fission and Fusion Nuclear Reaction Equations **Videos** What are Atoms? Atomic # & Atomic Mass Atomic Mass Calculating Relative Atomic Mass Drawing Electron Configuration Diagrams Energy Levels What is a weighted average? **Labs** Growing Crystals – Use this website to help demonstrate and experiment with growing different crystals using various elements. Experiments with Ammonia – This experiment educates students about ammonia and its properties. Enzyme Chemistry – Learn more about how the enzymes in food	○ wave theory, quantum mechanical model – **Louis de Broglie.** ➢ Have students differentiate between the historical and quantum models of the atom.

			create a chemical reaction that breaks down protein.	
1 week	CH.1a-j – CH.2a-c,i, CH.4 a, CH.5	**Review-Reteach-Benchmark Assessment**	❖ 30 Interactive Chemistry Quizzes ❖ SOL Pass ❖ 2015 Release Questions ❖ JLab Practice Problems ❖ VDOE SOL Practice Items	1st 9 Weeks Benchmark

Course Title/ Course #: EOC Chemistry/2802 or EOC Pre AP Chemistry/ 2804

Pacing Resources Assessments MP2				
Time Frame	**Standards of Learning**	**Units/ Topics/ Concepts**	**Resources**	**Assessments**
On-going	CH.1a - CH.1j	Scientific Inquiry: Experimental Design	Baking Soda Bubbles – An easy yet fun experiment using baking soda for students to see the properties of carbon dioxide. Experimenting with CO_2 – A simple and safe experiment for students to understand how CO2 works. Polymer Experiments – Find out what one AP chemistry class did with polymers here. Bubble Bomb – This fun and easy experiment shows how carbon dioxide works, and is great for all ages and grade levels.	➢ Have students conduct a lab that exemplifies the versatility and importance of organic compounds (e.g., aspirin, an ester, a polymer).
2 weeks	CH.2d-g	Periodic Trends	**VDOE Periodic Table** **VDOE Lesson Plans** Atomic Structure: Periodic Table (PDF) / (Word **Power Points** Periodic Tables Element Classes Periodic Trends **Periodic Table Activities** PT WKS Periodic Table Basics 1 (pdf) Periodic Table Basics 2(pdf)	➢ Have students distinguish between a group and a period. ➢ Have students identify key groups, periods, and regions of elements on the periodic table. ➢ Have students identify and explain trends in the periodic table as they relate to ionization energy, electronegativity, shielding effect, and relative sizes. ➢ Have students compare an element's reactivity to the reactivity of other elements in the table. ➢ Have students relate the position of an element on the periodic table to its electron configuration.

			Worksheet: Periodic Table Trends Worksheet: Periodic Table Trends Key Periodic Trends Graphing Periodic Trends **Review Power Point:** Periodic Trends **POGIL Activities** Periodicity of Elements **Videos** Periodic Table Periods & Groups Alkali Metals Alkine Earth Metals Halogens Noble Gases **Labs** Creepy Metals - To determine the tensile strength and creep in three common metals. A Copper Cycle – Using copper nitrate, learn about the many properties of the mineral copper. Can the Mettle of Metal be Improved? - To determine the effects of annealing, quenching, and tempering on metals, using bobbi pins, hair clip, single strand steel wire.	➢ Have students determine the number of valence electrons and possible oxidation numbers from an element's electron configuration. ➢ Have students write the electron configuration for the first 20 elements of the periodic table. ➢ Have students distinguish between physical and chemical properties of metals and nonmetals. ➢ Have students differentiate between pure substances and mixtures and between homogeneous and heterogeneous mixtures. ➢ Have students identify key contributions of principal scientists including: ○ periodic table arranged by atomic mass – **Dmitri Mendeleev** ○ periodic table arranged by atomic number – **Henry Moseley**
3 weeks	CH.3a,c-d & CH.6 a-b	Chemical Formulas & Bonding Types	**VDOE Lesson Plans** Properties of Compounds and Chemical Formulas (PDF) / (Word) Soap, Slime, and Creative	➢ Have students name binary covalent/molecular compounds. ➢ Have student name binary ionic compounds (using the Roman numeral system where

			Chromatography (PDF) / (Word) Mystery Anions (PDF) / (Word) Mystery Iron Ions (PDF) / (Word) Molecular Model Building (PDF) / (Word) Aspirin Analysis (PDF) / (Word) A Crystal Lab (PDF) / (Word) **Review Power Point:** Valence Electrons Ionic Bonding Ionic Compound Nomenclature Metallic Bonding Covalent Bonding (Molecules) Binary Molecular Nomenclature VSEPR and Molecular Geometry Intermolecular Forces of Attraction Polymers Nomenclature, Reactions, & Formulas Percent Composition, Empirical and Molecular Formulas Basic Biochemistry - Carbohydrate, Protein and Fat **Gizmos** Covalent Bonds Ionic Bonds **POGIL Activities** Chemical Formulas Organic Reactions Polymers **Videos**	appropriate). ➢ Have students predict, draw, and name molecular shapes (bent, linear, trigonal planar, tetrahedral, and trigonal pyramidal). ➢ Have students write the chemical formulas for certain common substances, such as ammonia, water, carbon monoxide, carbon dioxide, sulfur dioxide, and carbon tetrafluoride. ➢ Have students use polyatomic ions for naming and writing formulas of ionic compounds, including carbonate, sulfate, nitrate, hydroxide, phosphate, and ammonium. ➢ Have students draw Lewis dot diagrams to represent valence electrons in elements and draw Lewis dot structures to show covalent bonding. ➢ Have students use valence shell electron pair repulsion (VSEPR) model to draw and name molecular shapes (bent, linear, trigonal planar, tetrahedral, and trigonal pyramidal). ➢ Have students recognize polar molecules and non-polar molecules. ➢ Have students describe how saturation affects shape and reactivity of carbon compounds. ➢ Have students 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. ➢ Have students recognize that organic compounds play a role in natural and synthetic pharmaceuticals. ➢ Have students recognize that nucleic acids and proteins are important natural polymers.

			What are Ions? Ionic Bonds Formulas with Polyatomic Ions Halogens in Compounds Naming Ionic Compounds I Naming Ionic Compound II Polyatomic Ions VSEPR Theory VSEPR Theory II Organic Molecules **PhET Simulations:** • Atomic Interactions • Build a Molecule • Molecule Polarity • Molecules & Light • Molecule Shapes • Molecule Shapes: Basics	➢ Have students recognize that plastics formed from petrochemicals are organic compounds that consist of long chains of carbons.
2 weeks	CH.3b	Chemical Equations	**VDOE Lesson Plans** Matter and Energy: Equations and Formulas (PDF) / (Word) Predicting Products and Writing Equations (PDF) / (Word) **Review Power Points** Balancing Chemical Equations **Gizmos** Chemical Equations Balancing Chemical Equations **POGIL Activities** Balancing Chemical Reactions **Videos**	➢ Have students transform word equations into chemical equations and balance chemical equations. .

			Balancing Chemical Equations **PhET Simulations:** Balancing Chemical Equations	
2 weeks	CH.1, CH.2, CH.3, CH.5 & CH. 6	Review-Reteach-Benchmark Assessment	❖ 30 Interactive Chemistry quizzes ❖ SOL Pass ❖ 2015 Release Questions ❖ JLab Practice ❖ VDOE SOL Practice Items	2nd 9 Weeks Benchmark

Course Title/ Course #: EOC Chemistry/2802 or EOC Pre AP Chemistry/ 2804

Pacing Resources Assessments MP3				
Time Frame	**Standards of Learning**	**Units/ Topics/ Concepts**	**Resources**	**Assessments**
On-going	CH.1a - CH.1j	Scientific Inquiry: Experimental Design	Acid Rain – Measuring PH – This easy experiment teaches us how to measure PH levels and how acid rain can have an effect on it. Chemical Energy of Peanuts – Check out how the stored chemical energy found in peanuts can actually create sustainable energy. Crystals – This interesting experiment looks at what happens when certain gases and liquids cool down and lose water. Chemical Reaction Powered Car - This experiment can be used to create a moving car powered by a chemical reaction! Chemistry of Sweat - Use this experiment to see how sweat keeps your body cool. Virtual Chemistry Lab –	➢ Have students conduct a lab that exemplifies the rates of reactions and stoichiometric reactions.

			This interactive chemistry lab allows students to mix different chemicals to determine their reactions A Clock Reaction – This experiment shows different chemical reactions based on quantities of liquids and time spent mixed together.	
2 Weeks	CH.3e, f	Reaction Types & Rates	**VDOE Lesson Plans** The Rate of a Chemical Reaction (PDF) / (Word) Equilibrium and Le Chatelier's Principle (PDF) / (Word) **Review Power Points** Reaction Types Basic Thermochemistry Thermochemical Calculations Reaction Kinetics Equilibrium and Le Chatelier's Principle **Gizmos** Equilibrium & Concentration Equilibrium & Pressure	➢ Have students classify types of chemical reactions as synthesis, decomposition, single replacement, double replacement, neutralization, and/or combustion. ➢ Have students recognize equations for redox reactions and neutralization reactions ➢ Have students recognize that there is a natural tendency for systems to move in a direction of randomness (entropy). ➢ Have students distinguish between an endothermic and exothermic process. ➢ Have students interpret reaction rate diagrams. ➢ Have students identify and explain the effect the following factors have on the rate of a chemical reaction: catalyst, temperature, concentration, size of particles.

			Collision Theory **POGIL Activities** Classifying Types of Chemical Reactions Oxidation and Reduction Half-Reactions Net Ionic Reactions Collision Theory Dynamic Equilibrium Equilibrium and Le Chatelier's Principle **Videos** Types of Chemical Reactions What is Combustion? Redox Equations Collison Theory Part I Collison Theory Part II: Endothermic vs. Exothermic Rates of Reactions What are Reversible Reactions? LeChateller's Principle LeChatelier's Principle II What is Dynamic Equilibrium? **PhET Simulations:** The Greenhouse Effect Microwaves Reactions & Rates Reversible Reactions	➢ Have students distinguish between irreversible reactions and those at equilibrium. ➢ Have students 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.)
3 weeks	CH. 4 b	Stoichiometry Relationships	**VDOE Lesson Plans** Formulas and Percent	➢ Have students perform stoichiometric calculations

			Compositions of Ionic Compounds (PDF) / (Word) Molar Volume of a Gas (PDF) / (Word) Finding the Formula and Percent Composition (PDF) / (Word) **Review Power Point** Molar Relationships Stoichiometry **Gizmos** Limiting Reactants **Videos** % Yield Calculating Masses in Reactions Theoretical Yield **POGIL Activities** Limiting Reactants Percent Composition Molarity **PhET Simulations:** Reactants, Products & Leftovers Beer's Law Lab Molarity Concentration	involving the following relationships: ○ mole-mole; ○ mass-mass; ○ mole-mass; ○ mass-volume; ○ mole-volume; ○ volume-volume; ○ mole-particle; ○ mass-particle; and ○ volume-particle. ➢ Have students identify the limiting reactant (reagent) in a reaction. ➢ Have students calculate percent yield of a reaction. ➢ Have students perform calculations involving the molarity of a solution, including dilutions. ➢ Have students interpret solubility curves.

2 weeks	CH.4, c, d	Stoichiometry: Solutions, Acid/Base Theory	**VDOE Lesson Plans** Solution Concentrations (PDF) / (Word) Acids and Bases (PDF) / (Word) Acid-Base Theory (PDF) / (Word) **Power Points** Bulk Properties of Water Properties of Solutions Calculations of Solution Concentration Colloids and Suspensions Properties of Acids Bases pH Calculations **Gizmos** Colligative Properties Titration **POGIL Activities** Interpreting Solubility Curves Introduction to Acids and Bases Acid-Base Neutralization Reactions **PhET Simulation:** Salts & Solubility Sugar & Salt Solutions Acid-Base Solutions	➢ Have students differentiate between the defining characteristics of the Arrhenius theory of acids and bases and the Bronsted-Lowry theory of acids and bases. ➢ Have students identify common examples of acids and bases, including vinegar and ammonia. ➢ Have students compare and contrast the differences between strong, weak, and non-electrolytes. ➢ Have students relate the hydronium ion concentration to the pH scale. ➢ Have students perform titrations in a laboratory setting using indicators.

			pH Scale: Basics pH Scale **Labs** Antacid – An interesting experiment that takes a closer look at acids and bases. The SOLUTION to SOLUBILITY is the SOLVENT - To determine the solubility of three general types of common solvents: water, alcohol and xylene. Are We Saturated Yet? - To make and observe the properties of unsaturated, saturated, and supersaturated solutions, using photography fixer.	
2 weeks	CH1a-j – CH.5a-d	Review-Reteach-Benchmark Assessment	❖ 30 Interactive Chemistry quizzes ❖ SOL Pass ❖ 2015 Release Questions ❖ JLab Practice ❖ VDOE SOL Practice Items	3rd 9 Weeks Benchmark

Course Title/ Course #: EOC Chemistry/2802 or EOC Pre AP Chemistry/ 2804

Pacing Resources Assessments MP4				
Time Frame	**Standards of Learning**	**Units/ Topics/ Concepts**	**Resources**	**Assessments**
4 weeks	CH.1a-j – CH.6a-b	Review/ Reteach, Evaluation, Prepare for SOL Testing	Chemistry Summary Sheet SOL Review Website SOL Review Website Review Notes SOL Review Project "Mark Rosengarten's Amazing Chemistry PowerPoint Presentation" SOL Review Packet SOL Review Packet Key Chemistry Jeopardy-2004 Released SOL Test	Daily Assessments 30 Interactive Chemistry quizzes SOL Pass 2015 Release Questions JLab Practice VDOE SOL Practice Items
2 weeks	CH.1a-j – CH.6a-b	SOL Testing		
3 weeks	CH.1a-j – CH.6a-b	Enrichment: AP Chemistry Prep	**AP Chemistry Summer Assignments** ❖ **Science / AP Chem Summer Assignment** ❖ **AP Chemistry Summer Assignment - ScienceGeek.net** ❖ **AP CHEMISTRY SUMMER ASSIGNMENT - Schertz-Cibolo ...** ❖ **AP Chemistry Summer Assignment** **Chemistry Review Project** ❖ **Chemistry Review Poster Project Packet.doc** ❖ **Chemistry Review Poster Project Packet day 2.doc** ❖ **Chemistry Review Poster Project Packet day 3.doc** **Labs and Activities** ❖ **Kitchen Chemistry Labs** ❖ **Chemistry Review Game Project** ❖ **Forensic Science Activities** ❖ **Chemistry/ Biochemistry Labs** **POGIL Activities**	Have students complete a Science Fair Project ❖ Advance Biochemistry Science Fair Ideas Chemistry Game Board Project ❖ Scoring Guide Have students prepare an study booklet for next year's chemistry students.

			- Introduction to Voltaic Cells - Voltaic Cell Potentials **Field Trip: Applebee's Kitchen Tours** Applebee's Restaurant offers a **Mad Science** Kitchen Chemistry Field Trip. Cooking is all about chemistry! Amazing demonstrations will be performed. Students feel like chefs for a day as they step into our one of a kind kitchen to learn the basics of food safety and look at many of the substances contained in food products. Visit www.applemetrorestaurants.com	Have students create a viral video for a selected chemistry topic. IA Final Assessment Careers in Chemistry Project Careers in Chemistry Blog

Science Standards of Learning

Curriculum Framework 2010

Chemistry

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Commonwealth of Virginia

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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 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.

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.

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 (middle and high school); and Essential Knowledge, Skills, and Processes. The purpose of each column is explained below.

Understanding the Standard (K-5)
This section includes background information for the teacher. 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 instruction focusing on the standard.

Essential Understandings (middle and high school)
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 (K-12)
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.

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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.	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, 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, evaporating dish, watch glass, wash bottle, and dropping pipette. • make the following measurements, using the specified equipment: - volume: graduated cylinder, volumetric flask, buret - mass: triple beam and electronic balances - temperature: thermometer and/or temperature probe - pressure: barometer and/or pressure 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.

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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	• 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. • predict outcome(s) when a variable is changed. • read measurements and record data, 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. • use common SI prefixes and their values (milli-, centi-, kilo-) in measurements and calculations.

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.

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Essential Understandings	Essential Knowledge and Skills
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.	• demonstrate the use of scientific notation, using the correct number of significant digits with powers of ten notation for the decimal place. • 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 average atomic mass. • perform calculations according to significant digits rules. • 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. • use appropriate technology for data collection and analysis, including probeware interfaced to a graphing calculator and/or computer and computer simulations. • summarize knowledge gained through gathering and appropriate

Standard CH.1

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Essential Understandings	Essential Knowledge and Skills
	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 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.

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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 of its mass. Quarks are also located in the nucleus of the atom.	In order to meet this standard, it is expected that students will • determine the atomic number, atomic mass, the number of protons, and the number of electrons of any 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. • perform calculations involving the half-life of a radioactive substance. • 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 table. • identify and explain trends in the periodic table as they relate to ionization energy, electronegativity, shielding effect, and relative

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.

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Essential Understandings	Essential Knowledge and Skills
• The names of groups and periods on the periodic chart are alkali metals, alkaline earth metals, transition metals, halogens, and noble gases. • 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 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 electrons in a bond. Electronegativity increases from left to right within a period and decreases from top to bottom within a group.	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. • 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. • identify key contributions of principal scientists including: - *atomos*, initial idea of atom – Democritus - 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. Thomson - discovery of the nucleus using the gold foil experiment, nuclear model – Ernest Rutherford - discovery of charge of electron using the oil drop experiment –

Standard CH.2

<table>
<tr><td colspan="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
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e) periods;
f) trends including atomic radii, electronegativity, shielding effect, and ionization energy;
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h) chemical and physical properties; and
i) historical and quantum models.
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<tr><th>Essential Understandings</th><th>Essential Knowledge and Skills</th></tr>
<tr><td>• 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 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).
• Transition metals can have multiple oxidation states.
• Matter occurs as elements (pure), compounds (pure), and mixtures,</td><td>Robert Millikan
- energy levels, planetary model – Niels Bohr
- periodic table arranged by atomic mass – Dmitri 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.
• differentiate between the historical and quantum models of the atom.</td></tr>
</table>

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.

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Essential Understandings	Essential Knowledge and Skills
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 quantum mechanical 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.

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Essential Understandings	Essential Knowledge and Skills
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). • 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 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 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	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. • use polyatomic ions for naming and writing 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 structures to show covalent bonding. • use valence shell electron pair repulsion (VSEPR) model to draw and name molecular shapes (bent, linear, trigonal planar, tetrahedral, and trigonal pyramidal). • recognize polar molecules and non-polar molecules. • classify types of chemical reactions as synthesis, decomposition, single replacement, double replacement, neutralization, and/or

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.

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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 electrons are distributed unequally. • Major types of chemical reactions are - synthesis ($A+B \rightarrow AB$) - decomposition ($BC \rightarrow B+C$) - single replacement ($A+BC \rightarrow B+AC$) - double replacement ($AC+BD \rightarrow AD+BC$) - neutralization ($HX+MOH \rightarrow H_2O + MX$) - combustion ($C_xH_y + O_2 \rightarrow CO_2 + H_2O$). • 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 are exothermic reactions (heat producing) and endothermic reactions (heat absorbing). • Reactions occurring in both forward and reverse directions are reversible. Reversible reactions can reach a state of equilibrium, where the reaction rates of both the forward and reverse reactions are constant. Le Chatelier's Principle indicates the qualitative prediction of direction of change with temperature, pressure, and concentration.	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 the following factors 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.)

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. Back to CPR MP1 Back to CPR MP3

Essential Understandings	Essential Knowledge and Skills
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 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 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 the Arrhenius theory, acids are characterized by their sour taste, low pH, and the fact that they turn litmus paper red. According to the Arrhenius theory, bases are characterized by their bitter taste, slippery feel, high pH, and the fact that they turn litmus paper blue. According to the Bronsted-Lowry	In order to meet this standard, it is expected that students will • perform conversions between mass, volume, particles, and moles of a substance. • perform stoichiometric calculations involving the following relationships: - mole-mole; - mass-mass; - mole-mass; - mass-volume; - mole-volume; - volume-volume; - 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. • identify common examples of acids and bases, including vinegar and ammonia.

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.

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Essential Understandings	Essential Knowledge and Skills
theory, 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.	• 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.

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Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • Atoms and molecules are in constant motion. • 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 kinetic molecular theory 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 units include atm, kPa, and mm Hg. • An ideal gas does not exist, but this concept is used to model gas behavior. A real gas 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: $P_1V_1 = P_2V_2$). • At constant pressure, the volume of a fixed amount of gas is directly proportional to its absolute temperature (Charles' Law: $V_1/T_1 = V_2/T_2$).	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. • 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.

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Essential Understandings	Essential Knowledge and Skills
• 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 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 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 phase of matter is plasma. Plasma is formed 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 phase of matter at a given temperature as well as the temperature(s) at	

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.

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Essential Understandings	Essential Knowledge and Skills
which it changes 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. Back to CPR MP2 Back to CPR MP4	
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 lab that exemplifies the versatility and importance of organic compounds (e.g., aspirin, an ester, a polymer).