

Michigan Chemistry High School Content Expectations

Approved by the State Board of Education, October, 2006

Properties of matter

All objects and substances in the natural world are composed of matter. All matter has two fundamental properties: matter takes up space, and matter has inertia – it changes motion only when under the influence of a non-zero net force. Matter can be characterized in terms of its physical and chemical properties. These properties can be explained through the particulate model of matter, which describes the particles as atoms or molecules that are continuously in motion. The extent of the motion can be used to explain the physical properties associated with the common states of matter, solid, liquid and gas, as well as the changes of state. Whether or not a particular substance will exist as a solid, liquid or a gas will depend on the force due to particle motion in comparison to the force of attraction between particles. The attractive forces between particles are explained by the detailed structure of molecules and the atoms that compose them.

The structure of an atom in terms of its component protons, neutrons and electrons provides the basis for a systematic description of the building blocks of matter and their organization in the Periodic Table of the Elements. The Periodic Table demonstrates the relationship between the number of protons in an element, which is the defining characteristic of each element, and the chemical and physical properties of the elements. The Periodic Table also provides a structure for inquiry into the characteristics of the elements, since the electronic structure of atoms is reflected in the arrangement of elements in the Periodic Table. It is the electronic structure of atoms, especially the outermost electrons, that explains the chemical properties of elements and the breaking and making of bonds between atoms in a chemical reaction. An understanding of the bonding between elements leads to the concept of molecules as particles with specific combinations of atoms. When a substance consists of only one type of molecule it is referred to as a compound, with each compound having unique chemical and physical properties due to the detailed structure of its component molecules.

Changes in matter

As a general principle, a great deal of understanding chemistry is in differentiating what Nobelist Roald Hoffmann deftly labeled as “the same and not the same.” Chemistry is filled with comparisons that fall under this rubric. Isomerism, for instance, is built on this idea. Molecules have the same molecular formula, but have completely different properties (ethyl acetate and butyric acid). In photo- or thermal isomerization reactions, what constitutes the starting material and the product different on the basis of some observable property because here, too, the molecular formulas are the same. We create false dichotomies for the convenience of categorization (physical properties versus chemical properties, ionic versus covalent bonding), yet when you dissolve blue cobalt chloride in water, and the solution turns pink, it is hard to argue “dissolving is a simple act of physical change.”

Are polymorphous crystalline forms that different? There are real property differences that we would traditionally include as “chemical” changes (spectroscopic differences, for instance). Is dissolving sodium chloride in water and then evaporating the water to get it back that different? Not really. Ionic networks or lattices are complex structures with billions and billions of degenerate isomeric forms. Add a sample of radio-labeled sodium chloride to a differently-labeled sample; crystallization accomplishes a cross-over experiment no matter how you look at it.

Changes in matter then, are not simple binary classifications, but derived from defining what is changing and the criteria by which those changes are judged, particularly those properties that are used to make the decision about what sort of change has taken place. A useful concept that helps sort through these relationships is “material kind,” a term that we used when a substance is made up of a homogenous aggregate of atomic or molecular species (macroscopic “liquid water” is a “material kind,” and differentiates it from the matter – molecular water: “HOH” – that comprises it). Solid water and liquid water are different material kinds, while the matter that makes them up is the same.

Forms of energy

From the chemical perspective it is critical that the student understand the role of energy in the breaking and formation of chemical bonds, since bond breaking/making is the fundamental process in a chemical reaction. Potential energy is stored energy resulting from the attraction between two objects. Students commonly only understand gravitational potential energy. Just as the force of gravity results in potential energy changes as objects are moved relative to the earth, there are changes in potential energy when any particles held by a force (gravitational, electrical, magnetic, strong) are moved relative to each other. Chemical bonds are the result of a decrease in potential energy from the increased electrostatic attractions between atoms. Chemical bonds will not form unless there is a decrease in potential energy compared to the unbonded state. The strength of a chemical bond is directly proportional to the energy released when the bond forms from the separated gaseous atoms (ions). Breaking a chemical bond always requires energy to overcome the attractive forces holding the particle (ions, atoms, molecules) together. At grade 8 the student should be able to describe physical changes (changes of state, dissolving) in terms of rearranging the atoms, molecules or ions). At grade 12 the student should be able to describe chemical changes in terms of bond making and bond breaking to demonstrate a deeper understanding of the term “chemical potential energy”.

Energy transformations

The transfer of energy and the conservation of energy are of great explanatory and predictive value. Left on their own all systems will naturally move to a state of minimum energy and maximum randomness. Application of these two driving forces coupled with the conservation of matter and energy will allow students to explain and predict most chemical phenomena. Students will understand the tremendous energy released in nuclear reactions is a result of small amounts of matter being converted to energy.

STANDARD C1: INQUIRY, REFLECTION, AND SOCIAL IMPLICATIONS

Students will understand the nature of science and demonstrate an ability to practice scientific reasoning by applying it to the design, execution, and evaluation of scientific investigations. Students will demonstrate their understanding that scientific knowledge is gathered through various forms of direct and indirect observations and the testing of this information by methods including, but not limited to, experimentation. They will be able to distinguish between types of scientific knowledge (e.g., hypotheses, laws, theories) and become aware of areas of active research in contrast to conclusions that are part of established scientific consensus. They will use their scientific knowledge to assess the costs, risks, and benefits of technological systems as they make personal choices and participate in public policy decisions. These insights will help them analyze the role science plays in society, technology, and potential career opportunities.

Essential	Core and Recommended
<p>C1.1 Scientific Inquiry</p> <p>Science is a way of understanding nature. Scientific research may begin by generating new scientific questions that can be answered through replicable scientific investigations that are logically developed and conducted systematically. Scientific conclusions and explanations result from careful analysis of empirical evidence and the use of logical reasoning. Some questions in science are addressed through indirect rather than direct observation, evaluating the consistency of new evidence with results predicted by models of natural processes. Results from investigations are communicated in reports that are scrutinized through a peer review process.</p> <p>C1.1A Generate new questions that can be investigated in the laboratory or field.</p> <p>C1.1B Evaluate the uncertainties or validity of scientific conclusions using an understanding of sources of measurement error, the challenges of controlling variables, accuracy of data analysis, logic of argument, logic of experimental design, and/or the dependence on underlying assumptions.</p> <p>C1.1C Conduct scientific investigations using appropriate tools and techniques (e.g., selecting an instrument that measures the desired quantity—length, volume, weight, time interval, temperature—with the appropriate level of precision).</p> <p>C1.1D Identify patterns in data and relate them to theoretical models.</p> <p>C1.1E Describe a reason for a given conclusion using evidence from an investigation.</p>	<p>C1.1f Predict what would happen if the variables, methods, or timing of an investigation were changed.</p> <p>C1.1g Based on empirical evidence, explain and critique the reasoning used to draw a scientific conclusion or explanation.</p> <p>C1.1h Design and conduct a systematic scientific investigation that tests a hypothesis. Draw conclusions from data presented in charts or tables.</p> <p>C1.1i Distinguish between scientific explanations that are regarded as current scientific consensus and the emerging questions that active researchers investigate.</p>

C1.2 Scientific Reflection and Social Implications

The integrity of the scientific process depends on scientists and citizens understanding and respecting the “Nature of Science.” Openness to new ideas, skepticism, and honesty are attributes required for good scientific practice. Scientists must use logical reasoning during investigation design, analysis, conclusion, and communication. Science can produce critical insights on societal problems from a personal and local scale to a global scale. Science both aids in the development of technology and provides tools for assessing the costs, risks, and benefits of technological systems. Scientific conclusions and arguments play a role in personal choice and public policy decisions. New technology and scientific discoveries have had a major influence in shaping human history. Science and technology continue to offer diverse and significant career opportunities.

C1.2A Critique whether or not specific questions can be answered through scientific investigations.

C1.2B Identify and critique arguments about personal or societal issues based on scientific evidence.

C1.2C Develop an understanding of a scientific concept by accessing information from multiple sources. Evaluate the scientific accuracy and significance of the information.

C1.2D Evaluate scientific explanations in a peer review process or discussion format.

C1.2E Evaluate the future career and occupational prospects of science fields.

C1.2f Critique solutions to problems, given criteria and scientific constraints.

C1.2g Identify scientific tradeoffs in design decisions and choose among alternative solutions.

C1.2h Describe the distinctions between scientific theories, laws, hypotheses, and observations.

C1.2i Explain the progression of ideas and explanations that lead to science theories that are part of the current scientific consensus or core knowledge.

C1.2j Apply science principles or scientific data to anticipate effects of technological design decisions.

C1.2k Analyze how science and society interact from a historical, political, economic, or social perspective.

Standard C2: Forms of Energy

Students recognize the many forms of energy and understand that energy is central to predicting and explaining how and why chemical reactions occur. The chemical topics of bonding, gas behavior, kinetics, enthalpy, entropy, free energy, and nuclear stability are addressed in this standard.

Chemistry students relate temperature to the average kinetic energy of the molecules and use the kinetic molecular theory to describe and explain the behavior of gases and the rates of chemical reactions. They understand nuclear stability in terms of reaching a state of minimum potential energy.

Essential	Core
	<p>C2.1x Chemical Potential Energy Potential energy is stored whenever work must be done to change the distance between two objects. The attraction between the two objects may be gravitational, electrostatic, magnetic, or strong force. Chemical potential energy is the result of electrostatic attractions between atoms.</p> <p>C2.1a Explain the changes in potential energy (due to electrostatic interactions) as a chemical bond forms and use this to explain why bond breaking always requires energy.</p> <p>C2.1b Describe energy changes associated with chemical reactions in terms of bonds broken and formed (including intermolecular forces).</p> <p>C2.1c Compare qualitatively the energy changes associated with melting various types of solids in terms of the types of forces between the particles in the solid.</p>
<p>C2.2 Molecules in Motion Molecules that compose matter are in constant motion (translational, rotational, vibrational). Energy may be transferred from one object to another during collisions between molecules.</p> <p>C2.2A Describe conduction in terms of molecules bumping into each other to transfer energy. Explain why there is better conduction in solids and liquids than gases.</p> <p>C2.2B Describe the various states of matter in terms of the motion and arrangement of the molecules (atoms) making up the substance.</p>	<p>C2.2x Molecular Entropy As temperature increases, the average kinetic energy and the entropy of the molecules in a sample increases.</p> <p>C2.2c Explain changes in pressure, volume, and temperature for gases using the kinetic molecular model.</p> <p>C2.2d Explain convection and the difference in transfer of thermal energy for solids, liquids, and gases using evidence that molecules are in constant motion.</p> <p>C2.2e Compare the entropy of solids, liquids, and gases.</p> <p>C2.2f Compare the average kinetic energy of the molecules in a metal object and a wood object at room temperature.</p>
	<p>C2.3x Breaking Chemical Bonds For molecules to react, they must collide with enough energy (activation energy) to break old chemical bonds before their atoms can be rearranged to form new substances.</p> <p>C2.3a Explain how the rate of a given chemical reaction is dependent on the temperature and the activation energy.</p> <p>C2.3b Draw and analyze a diagram to show the activation energy for an exothermic reaction that is very slow at room temperature.</p>
	<p>C2.4x Electron Movement For each element, the arrangement of electrons surrounding the nucleus is unique. These electrons are found in different energy levels and can only move from a lower energy level</p>

	<p>(closer to nucleus) to a higher energy level (farther from nucleus) by absorbing energy in discrete packets. The energy content of the packets is directly proportional to the frequency of the radiation. These electron transitions will produce unique absorption spectra for each element. When the electron returns from an excited (high energy state) to a lower energy state, energy is emitted in only certain wavelengths of light, producing an emission spectra.</p> <p>C2.4a Describe energy changes in flame tests of common elements in terms of the (characteristic) electron transitions.</p> <p>C2.4b Contrast the mechanism of energy changes and the appearance of absorption and emission spectra.</p> <p>C2.4c Explain why an atom can absorb only certain wavelengths of light.</p> <p>C2.4d Compare various wavelengths of light (visible and nonvisible) in terms of frequency and relative energy.</p>
	<p>C2.5x Nuclear Stability</p> <p>Nuclear stability is related to a decrease in potential energy when the nucleus forms from protons and neutrons. If the neutron/proton ratio is unstable, the element will undergo radioactive decay. The rate of decay is characteristic of each isotope; the time for half the parent nuclei to decay is called the half-life. Comparison of the parent/daughter nuclei can be used to determine the age of a sample. Heavier elements are formed from the fusion of lighter elements in the stars.</p> <p>C2.5a Determine the age of materials using the ratio of stable and unstable isotopes of a particular type.</p> <p>C2.r5b Illustrate how elements can change in nuclear reactions using balanced equations. (<i>recommended</i>)</p> <p>C2.r5c Describe the potential energy changes as two protons approach each other. (<i>recommended</i>)</p> <p>C2.r5d Describe how and where all the elements on earth were formed. (<i>recommended</i>)</p>

Standard C3: Energy Transfer and Conservation

Students apply the First and Second Laws of Thermodynamics to explain and predict most chemical phenomena. Chemistry students use the term enthalpy to describe the transfer of energy between reactants and products in simple calorimetry experiments performed in class and will recognize Hess's Law as an application of the conservation of energy. Students understand the tremendous energy released in nuclear reactions is a result of small amounts of matter being converted to energy.

Essential	Core
	<p>C3.1x Hess's Law</p> <p>For chemical reactions where the state and amounts of reactants and products are known, the amount of energy transferred will be the same regardless of the chemical pathway. This relationship is called Hess's law.</p> <p>C3.1a Calculate the ΔH for a given reaction using Hess's Law.</p> <p>C3.1b Draw enthalpy diagrams for exothermic and endothermic reactions.</p> <p>C3.1c Calculate the ΔH for a chemical reaction using simple coffee cup calorimetry.</p> <p>C3.1d Calculate the amount of heat produced for a given mass of reactant from a balanced chemical equation.</p>
	<p>C3.2x Enthalpy</p> <p>Chemical reactions involve breaking bonds in reactants (endothermic) and forming new bonds in the products (exothermic). The enthalpy change for a chemical reaction will depend on the relative strengths of the bonds in the reactants and products.</p> <p>C3.2a Describe the energy changes in photosynthesis and in the combustion of sugar in terms of bond breaking and bond making.</p> <p>C3.2b Describe the relative strength of single, double, and triple covalent bonds between nitrogen atoms.</p>
<p>C3.3 Heating Impacts</p> <p>Heating increases the kinetic (translational, rotational, and vibrational) energy of the atoms composing elements and the molecules or ions composing compounds. As the kinetic (translational) energy of the atoms, molecules, or ions increases, the temperature of the matter increases. Heating a sample of a crystalline solid increases the kinetic (vibrational) energy of the atoms, molecules, or ions. When the kinetic (vibrational) energy becomes great enough, the crystalline structure breaks down, and the solid melts.</p> <p>C3.3A Describe how heat is conducted in a solid.</p> <p>C3.3B Describe melting on a molecular level.</p>	<p>C3.3x Bond Energy</p> <p>Chemical bonds possess potential (vibrational and rotational) energy.</p> <p>C3.3c Explain why it is necessary for a molecule to absorb energy in order to break a chemical bond.</p>
<p>C3.4 Endothermic and Exothermic Reactions</p> <p>Chemical interactions either release energy to the environment (exothermic) or absorb energy from the environment (endothermic).</p> <p>C3.4A Use the terms endothermic and exothermic correctly to describe chemical reactions in the laboratory.</p>	<p>C3.4x Enthalpy and Entropy</p> <p>All chemical reactions involve rearrangement of the atoms. In an exothermic reaction, the products have less energy than the reactants. There are two natural driving forces: (1) toward minimum energy (enthalpy) and (2) toward maximum disorder (entropy).</p>

<p>C3.4B Explain why chemical reactions will either release or absorb energy.</p>	<p>C3.4c Write chemical equations including the heat term as a part of equation or using ΔH notation.</p> <p>C3.4d Draw enthalpy diagrams for reactants and products in endothermic and exothermic reactions.</p> <p>C3.4e Predict if a chemical reaction is spontaneous given the enthalpy (ΔH) and entropy (ΔS) changes for the reaction using Gibb's Free Energy, $\Delta G = \Delta H - T\Delta S$ (Note: mathematical computation of ΔG is not required.)</p> <p>C3.4f Explain why some endothermic reactions are spontaneous at room temperature.</p> <p>C3.4g Explain why gases are less soluble in warm water than cold water.</p>
	<p>C3.5x Mass Defect</p> <p>Nuclear reactions involve energy changes many times the magnitude of chemical changes. In chemical reactions matter is conserved, but in nuclear reactions a small loss in mass (mass defect) will account for the tremendous release of energy. The energy released in nuclear reactions can be calculated from the mass defect using $E = mc^2$.</p> <p>C3.5a Explain why matter is not conserved in nuclear reactions.</p>

Standard C4: Properties of Matter

Compounds, elements, and mixtures are categories used to organize matter. Students organize materials into these categories based on their chemical and physical behavior. Students understand the structure of the atom to make predictions about the physical and chemical properties of various elements and the types of compounds those elements will form. An understanding of the organization the Periodic Table in terms of the outer electron configuration is one of the most important tools for the chemist and student to use in prediction and explanation of the structure and behavior of atoms.

Essential	Core
	<p>C4.1x Molecular and Empirical Formulae Compounds have a fixed percent elemental composition. For a compound, the empirical formula can be calculated from the percent composition or the mass of each element. To determine the molecular formula from the empirical formula, the molar mass of the substance must also be known.</p> <p>C4.1a Calculate the percent by weight of each element in a compound based on the compound formula.</p> <p>C4.1b Calculate the empirical formula of a compound based on the percent by weight of each element in the compound.</p> <p>C4.1c Use the empirical formula and molecular weight of a compound to determine the molecular formula.</p>
<p>C4.2 Nomenclature All compounds have unique names that are determined systematically.</p> <p>C4.2A Name simple binary compounds using their formulae.</p> <p>C4.2B Given the name, write the formula of simple binary compounds.</p>	<p>C4.2x Nomenclature All molecular and ionic compounds have unique names that are determined systematically.</p> <p>C4.2c Given a formula, name the compound.</p> <p>C4.2d Given the name, write the formula of ionic and molecular compounds.</p> <p>C4.2e Given the formula for a simple hydrocarbon, draw and name the isomers.</p>
<p>C4.3 Properties of Substances Differences in the physical and chemical properties of substances are explained by the arrangement of the atoms, ions, or molecules of the substances and by the strength of the forces of attraction between the atoms, ions, or molecules.</p> <p>C4.3A Recognize that substances that are solid at room temperature have stronger attractive forces than liquids at room temperature, which have stronger attractive forces than gases at room temperature.</p> <p>C4.3B Recognize that solids have a more ordered, regular arrangement of their particles than liquids and that liquids are more ordered than gases.</p>	<p>C4.3x Solids Solids can be classified as metallic, ionic, covalent, or network covalent. These different types of solids have different properties that depend on the particles and forces found in the solid.</p> <p>C4.3c Compare the relative strengths of forces between molecules based on the melting point and boiling point of the substances.</p> <p>C4.3d Compare the strength of the forces of attraction between molecules of different elements. (For example, at room temperature, chlorine is a gas and iodine is a solid.)</p> <p>C4.3e Predict whether the forces of attraction in a solid are primarily metallic, covalent, network covalent, or ionic based upon the elements' location on the periodic table.</p> <p>C4.3f Identify the elements necessary for hydrogen bonding (N, O, F).</p> <p>C4.3g Given the structural formula of a compound, indicate all the intermolecular forces present (dispersion, dipolar,</p>

	<p>hydrogen bonding).</p> <p>C4.3h Explain properties of various solids such as malleability, conductivity, and melting point in terms of the solid's structure and bonding.</p> <p>C4.3i Explain why ionic solids have higher melting points than covalent solids. (For example, NaF has a melting point of 995°C, while water has a melting point of 0° C.)</p>
	<p>C4.4x Molecular Polarity</p> <p>The forces between molecules depend on the net polarity of the molecule as determined by shape of the molecule and the polarity of the bonds.</p> <p>C4.4a Explain why at room temperature different compounds can exist in different phases.</p> <p>C4.4b Identify if a molecule is polar or nonpolar given a structural formula for the compound.</p>
	<p>C4.5x Ideal Gas Law</p> <p>The forces in gases are explained by the ideal gas law.</p> <p>C4.5a Provide macroscopic examples, atomic and molecular explanations, and mathematical representations (graphs and equations) for the pressure-volume relationship in gases.</p> <p>C4.5b Provide macroscopic examples, atomic and molecular explanations, and mathematical representations (graphs and equations) for the pressure-temperature relationship in gases.</p> <p>C4.5c Provide macroscopic examples, atomic and molecular explanations, and mathematical representations (graphs and equations) for the temperature-volume relationship in gases.</p>
	<p>C4.6x Moles</p> <p>The mole is the standard unit for counting atomic and molecular particles in terms of common mass units.</p> <p>C4.6a Calculate the number of moles of any compound or element given the mass of the substance.</p> <p>C4.6b Calculate the number of particles of any compound or element given the mass of the substance.</p>
	<p>C4.7x Solutions</p> <p>The physical properties of a solution are determined by the concentration of solute.</p> <p>C4.7a Investigate the difference in the boiling point or freezing point of pure water and a salt solution.</p> <p>C4.7b Compare the density of pure water to that of a sugar solution.</p>
<p>C4.8 Atomic Structure</p> <p>Electrons, protons, and neutrons are parts of the atom and have measurable properties, including mass and, in the case of protons and electrons, charge. The nuclei of atoms are composed of protons and neutrons. A kind of force that is only evident at nuclear distances holds the particles of the nucleus together against the electrical repulsion between the protons.</p>	<p>C4.8x Electron Configuration</p> <p>Electrons are arranged in main energy levels with sublevels that specify particular shapes and geometry. Orbitals represent a region of space in which an electron may be found with a high level of probability. Each defined orbital can hold two electrons, each with a specific spin orientation. The specific assignment of an electron to an orbital is determined by a set of 4 quantum numbers. Each element</p>

<p>C4.8A Identify the location, relative mass, and charge for electrons, protons, and neutrons.</p> <p>C4.8B Describe the atom as mostly empty space with an extremely small, dense nucleus consisting of the protons and neutrons and an electron cloud surrounding the nucleus.</p> <p>C4.8C Recognize that protons repel each other and that a strong force needs to be present to keep the nucleus intact.</p> <p>C4.8D Give the number of electrons and protons present if the fluoride ion has a -1 charge.</p>	<p>and, therefore, each position in the periodic table is defined by a unique set of quantum numbers.</p> <p>C4.8e Write the complete electron configuration of elements in the first four rows of the periodic table.</p> <p>C4.8f Write kernel structures for main group elements.</p> <p>C4.8g Predict oxidation states and bonding capacity for main group elements using their electron structure.</p> <p>C4.8h Describe the shape and orientation of <i>s</i> and <i>p</i> orbitals.</p> <p>C4.8i Describe the fact that the electron location cannot be exactly determined at any given time.</p>
<p>C4.9 Periodic Table</p> <p>In the periodic table, elements are arranged in order of increasing number of protons (called the atomic number). Vertical groups in the periodic table (families) have similar physical and chemical properties due to the same outer electron structures.</p> <p>C4.9A Identify elements with similar chemical and physical properties using the periodic table.</p>	<p>C4.9x Electron Energy Levels</p> <p>The rows in the periodic table represent the main electron energy levels of the atom. Within each main energy level are sublevels that represent an orbital shape and orientation.</p> <p>C4.9b Identify metals, non-metals, and metalloids using the periodic table.</p> <p>C4.9c Predict general trends in atomic radius, first ionization energy, and electronegativity of the elements using the periodic table.</p>
<p>C4.10 Neutral Atoms, Ions, and Isotopes</p> <p>A neutral atom of any element will contain the same number of protons and electrons. Ions are charged particles with an unequal number of protons and electrons. Isotopes are atoms of the same element with different numbers of neutrons and essentially the same chemical and physical properties.</p> <p>C4.10A List the number of protons, neutrons, and electrons for any given ion or isotope.</p> <p>C4.10B Recognize that an element always contains the same number of protons.</p>	<p>C4.10x Average Atomic Mass</p> <p>The atomic mass listed on the periodic table is an average mass for all the different isotopes that exist, taking into account the percent and mass of each different isotope.</p> <p>C4.10c Calculate the average atomic mass of an element given the percent abundance and mass of the individual isotopes.</p> <p>C4.10d Predict which isotope will have the greatest abundance given the possible isotopes for an element and the average atomic mass in the periodic table.</p> <p>C4.10e Write the symbol for an isotope, XZA, where Z is the atomic number, A is the mass number, and X is the symbol for the element.</p>

Standard C5: Changes in Matter

Students will analyze a chemical change phenomenon from the point of view of what is the same and what is not the same.

Essential	Core
	<p>C5.r1x Rates of Reactions (recommended) The rate of a chemical reaction will depend upon (1) concentration of reacting species, (2) temperature of reaction, (3) pressure if reactants are gases, and (4) nature of the reactants. A model of matter composed of tiny particles that are in constant motion is used to explain rates of chemical reactions. (recommended)</p> <p>C5.r1a Predict how the rate of a chemical reaction will be influenced by changes in concentration, and temperature, pressure. (recommended)</p> <p>C5.r1b Explain how the rate of a reaction will depend on concentration, temperature, pressure, and nature of reactant. (recommended)</p>
<p>C5.2 Chemical Changes Chemical changes can occur when two substances, elements, or compounds interact and produce one or more different substances whose physical and chemical properties are different from the interacting substances. When substances undergo chemical change, the number of atoms in the reactants is the same as the number of atoms in the products. This can be shown through simple balancing of chemical equations. Mass is conserved when substances undergo chemical change. The total mass of the interacting substances (reactants) is the same as the total mass of the substances produced (products).</p> <p>C5.2A Balance simple chemical equations applying the conservation of matter.</p> <p>C5.2B Distinguish between chemical and physical changes in terms of the properties of the reactants and products.</p> <p>C5.2C Draw pictures to distinguish the relationships between atoms in physical and chemical changes.</p>	<p>C5.2x Balancing Equations A balanced chemical equation will allow one to predict the amount of product formed.</p> <p>C5.2d Calculate the mass of a particular compound formed from the masses of starting materials.</p> <p>C5.2e Identify the limiting reagent when given the masses of more than one reactant.</p> <p>C5.2f Predict volumes of product gases using initial volumes of gases at the same temperature and pressure.</p> <p>C5.2g Calculate the number of atoms present in a given mass of element.</p>
	<p>C5.3x Equilibrium Most chemical reactions reach a state of dynamic equilibrium where the rates of the forward and reverse reactions are equal.</p> <p>C5.3a Describe equilibrium shifts in a chemical system caused by changing conditions (Le Chatelier's Principle).</p> <p>C5.3b Predict shifts in a chemical system caused by changing conditions (Le Chatelier's Principle).</p> <p>C5.3c Predict the extent reactants are converted to products using the value of the equilibrium constant.</p>
<p>C5.4 Phase Change/Diagrams Changes of state require a transfer of energy. Water has unusually high-energy changes associated with its changes of state.</p> <p>C5.4A Compare the energy required to raise the</p>	<p>C5.4x Changes of State All changes of state require energy. Changes in state that require energy involve breaking forces holding the particles together. The amount of energy will depend on the type of forces.</p>

<p>temperature of one gram of aluminum and one gram of water the same number of degrees.</p> <p>C5.4B Measure, plot, and interpret the graph of the temperature versus time of an ice-water mixture, under slow heating, through melting and boiling.</p>	<p>C5.4c Explain why both the melting point and boiling points for water are significantly higher than other small molecules of comparable mass (e.g., ammonia and methane).</p> <p>C5.4d Explain why freezing is an exothermic change of state.</p> <p>C5.4e Compare the melting point of covalent compounds based on the strength of IMFs (intermolecular forces).</p>
<p>C5.5 Chemical Bonds — Trends</p> <p>An atom's electron configuration, particularly of the outermost electrons, determines how the atom can interact with other atoms. The interactions between atoms that hold them together in molecules or between oppositely charged ions are called chemical bonds.</p> <p>C5.5A Predict if the bonding between two atoms of different elements will be primarily ionic or covalent.</p> <p>C5.4B Predict the formula for binary compounds of main group elements.</p>	<p>C5.5x Chemical Bonds</p> <p>Chemical bonds can be classified as ionic, covalent, and metallic. The properties of a compound depend on the types of bonds holding the atoms together.</p> <p>C5.5c Draw Lewis structures for simple compounds.</p> <p>C5.5d Compare the relative melting point, electrical and thermal conductivity and hardness for ionic, metallic, and covalent compounds.</p> <p>C5.5e Relate the melting point, hardness, and electrical and thermal conductivity of a substance to its structure.</p>
	<p>C5.6x Reduction/Oxidation Reactions</p> <p>Chemical reactions are classified according to the fundamental molecular or submolecular changes that occur. Reactions that involve electron transfer are known as oxidation/reduction (or "redox").</p> <p>C5.6a Balance half-reactions and describe them as oxidations or reductions.</p> <p>C5.6b Predict single replacement reactions.</p> <p>C5.6c Explain oxidation occurring when two different metals are in contact.</p> <p>C5.6d Calculate the voltage for spontaneous redox reactions from the standard reduction potentials.</p> <p>C5.6e Identify the reactions occurring at the anode and cathode in an electrochemical cell.</p>
<p>C5.7 Acids and Bases</p> <p>Acids and bases are important classes of chemicals that are recognized by easily observed properties in the laboratory. Acids and bases will neutralize each other. Acid formulas usually begin with hydrogen, and base formulas are a metal with a hydroxide ion. As the pH decreases, a solution becomes more acidic. A difference of one pH unit is a factor of 10 in hydrogen ion concentration.</p> <p>C5.7A Recognize formulas for common inorganic acids, carboxylic acids, and bases formed from families I and II.</p> <p>C5.7B Predict products of an acid-base neutralization.</p> <p>C5.7C Describe tests that can be used to distinguish an acid from a base.</p> <p>C5.7D Classify various solutions as acidic or basic, given their pH.</p> <p>C5.7E Explain why lakes with limestone or calcium carbonate experience less adverse effects from acid rain than lakes with granite beds.</p>	<p>C5.7x Brønsted-Lowry</p> <p>Chemical reactions are classified according to the fundamental molecular or submolecular changes that occur. Reactions that involve proton transfer are known as acid/base reactions.</p> <p>C5.7f Write balanced chemical equations for reactions between acids and bases and perform calculations with balanced equations.</p> <p>C5.7g Calculate the pH from the hydronium ion or hydroxide ion concentration.</p> <p>C5.7h Explain why sulfur oxides and nitrogen oxides contribute to acid rain.</p> <p>C5.r7i Identify the Brønsted-Lowry conjugate acid-base pairs in an equation. (<i>recommended</i>)</p>

<p>C5.8 Carbon Chemistry</p> <p>The chemistry of carbon is important. Carbon atoms can bond to one another in chains, rings, and branching networks to form a variety of structures, including synthetic polymers, oils, and the large molecules essential to life.</p> <p>C5.8A Draw structural formulas for up to ten carbon chains of simple hydrocarbons.</p> <p>C5.8B Draw isomers for simple hydrocarbons.</p> <p>C5.8C Recognize that proteins, starches, and other large biological molecules are polymers.</p>	
<p>32 essential performance expectations</p>	<p>80 core performance expectations + 6 recommended</p>