Lab-Aids Correlations for
OHIO'S 2018 LEARNING STANDARDS:
CHEMISTRY

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This document is intended to show how our curriculum products align with the *Ohio Learning Standards for Chemistry*[1].

ABOUT OUR PROGRAMS
Lab-Aids Core Science Programs are developed to support current knowledge on the teaching and learning of science. All materials support an inquiry-driven pedagogy, with support for literacy skill development and with assessment programs that clearly show what students know and are able to do from using the programs. All programs have extensive support for technology in the school science classrooms and feature comprehensive teacher support. For more information, please visit www.labaids.com/NAC.

ABOUT *A Natural Approach to Chemistry*
A Natural Approach to Chemistry (NAC), written by Hsu, Chaniotakis, Carlisle, and Damelin, is published by, and available exclusively from, Lab-Aids, Ronkonkoma NY. This correlation is intended to show selected locations in NAC programs that support the Ohio Department of Education Learning Standards for Chemistry. It is not an exhaustive list; other locations may exist that are not listed here.

| A Natural Approach to Chemistry | | |
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| THEMES | | |
| • Energy is a unifying theme that explains why chemistry occurs<br>• The atomic model of matter is consistently woven through every chapter<br>• Understanding of 'why' chemistry occurs is emphasized<br>• Principles are illustrated with examples from the human body and the environment | | |
| ORGANIZATION OF CONTENT | | |
| Fundamentals | Chapters 1-4 | Present comprehensive overview of all main ideas in chemistry such as the atomic nature of matter, systems, temperature, and energy. *This is the "big picture" of chemistry.* |

[1] ttp://education.ohio.gov/getattachment/Topics/Learning-in-Ohio/Science/Ohios-Learnin[...]ndards-and-MC/SciFinalStandardsMC060719.pdf.aspx?lang=en-US

| A Natural Approach to Chemistry | | |
|---|---|---|
| Core Concepts | Chapters 5-14 | Present in-depth coverage of all major topic areas. They developed usable understanding of the big ideas laid out in the first four chapters. The treatment includes strong conceptual development as well as algebra-based quantitative problem solving.<br><br>All academic content and instruction standards for chemistry have been met by the end of Chapter 14. |
| Applications | Chapters 15 - 21 | Provide deeper exploration of significant areas of interest in chemistry.<br><br>Examples include rechargeable batteries, materials science, chemistry of the solar system, etc. |
| COMPLETE LEARNING SYSTEM | | |
| • Coordinated student textbook<br>• Integrated laboratory investigations manual containing 58 labs to choose from<br>• New laboratory control, data collection and probe system<br>• Evaluation elements throughout the curriculum (student book and lab investigation manual) through which student knowledge or skills are assessed or applied | | |

| Nature of Science<br>One goal of science education is to help students become scientifically literate citizens able to use science as a way of knowing about the natural and material world. All students should have sufficient understanding of scientific knowledge and scientific processes to enable them to distinguish what is science from what is not science and to make informed decisions about career choices, health maintenance, quality of life, community and other decisions that impact both themselves and others. | |
|---|---|
| **Categories** | **High School** |
| **Scientific Inquiry, Practice and Applications**<br>All students must use these scientific processes with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas. | • Identify questions and concepts that guide scientific investigations.<br>• Design and conduct scientific investigations using a variety of methods and tools to collect empirical evidence, observing appropriate safety techniques.<br>• Use technology and mathematics to improve investigations and communications.<br>• Formulate and revise explanations and models using logic and scientific evidence (critical thinking).<br>• Recognize and analyze explanations and models. |

<table>
<tr><td colspan="2">Nature of Science<br>One goal of science education is to help students become scientifically literate citizens able to use science as a way of knowing about the natural and material world. All students should have sufficient understanding of scientific knowledge and scientific processes to enable them to distinguish what is science from what is not science and to make informed decisions about career choices, health maintenance, quality of life, community and other decisions that impact both themselves and others.</td></tr>
<tr><th>Categories</th><th>High School</th></tr>
<tr><td></td><td><ul><li>Communicate and support scientific arguments.</li></ul></td></tr>
<tr><td>Science is a Way of Knowing<br>Science assumes the universe is a vast single system in which basic laws are consistent. Natural laws operate today as they did in the past and they will continue to do so in the future. Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise and extend this knowledge.</td><td><ul><li>Various science disciplines use diverse methods to obtain evidence and do not always use the same set of procedures to obtain and analyze data (i.e., there is no one scientific method).<ul><li>Make observations and look for patterns.</li><li>Determine relevant independent variables affecting observed patterns.</li><li>Manipulate an independent variable to affect a dependent variable.</li><li>Conduct an experiment with controlled variables based on a question or hypothesis.</li><li>Analyze data graphically and mathematically.</li></ul></li><li>Science disciplines share common rules of evidence used to evaluate explanations about natural phenomenon by using empirical standards, logical arguments and peer reviews.<ul><li>Empirical standards include objectivity, reproducibility, and honest and ethical reporting of findings.</li><li>Logical arguments should be evaluated with open-mindedness, objectivity and skepticism.</li></ul></li><li>Science arguments are strengthened by multiple lines of evidence supporting a single explanation.</li><li>The various scientific disciplines have practices, methods, and modes of thinking that are used in the process of developing new science knowledge and critiquing existing knowledge.</li></ul></td></tr>
<tr><td>Science is a Human Endeavor<br>Science has been, and continues to be, advanced by individuals of various races, genders, ethnicities, languages, abilities, family backgrounds and incomes.</td><td><ul><li>Science depends on curiosity, imagination, creativity and persistence.</li><li>Individuals from different social, cultural, and ethnic backgrounds work as scientists and engineers.</li><li>Science and engineering are influenced by technological advances and society; technological advances and society are influenced by science and engineering.</li><li>Science and technology might raise ethical, social and cultural issues for which science, by itself, does not provide answers and solutions.</li></ul></td></tr>
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| Nature of Science<br>One goal of science education is to help students become scientifically literate citizens able to use science as a way of knowing about the natural and material world. All students should have sufficient understanding of scientific knowledge and scientific processes to enable them to distinguish what is science from what is not science and to make informed decisions about career choices, health maintenance, quality of life, community and other decisions that impact both themselves and others. | |
|---|---|
| **Categories** | **High School** |
| **Scientific Knowledge is Open to Revision in Light of New Evidence**<br>Science is not static. Science is constantly changing as we acquire more knowledge. | • Science can advance through critical thinking about existing evidence.<br>• Science includes the process of comparing patterns of evidence with current theory.<br>• Some science knowledge pertains to probabilities or tendencies.<br>• Science should carefully consider and evaluate anomalies (persistent outliers) in data and evidence.<br>• Improvements in technology allow us to gather new scientific evidence. |

*Adapted from Appendix H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards

# Chemistry

## COURSE CONTENT

The following information may be taught in any order; there is no ODE-recommended sequence.

## C.PM: STRUCTURE AND PROPERTIES OF MATTER

| OHIO CHEMISTRY LEARNING STANDARDS | Content Elaboration | Lab-Aids *A Natural Approach to Chemistry*: Text Sections (X.X) and Laboratory Investigations (Inv X) | Selected Assessment Opportunities: Text (Ch X) and Laboratory Investigations (Inv X) |
|---|---|---|---|
| **C.PM.1: Atomic structure**<br>Physical Science included properties and locations of protons, neutrons and electrons, atomic number, mass number, cations and anions, isotopes and the strong nuclear force which holds the nucleus together. In this course, the historical development of the atomic model and the positions of electrons are explored in greater detail. In this course, electron configuration (extended and noble gas notation) and orbital diagrams can be shown for any element in the first three periods. Being aware of the quantum mechanical model as the currently accepted model for the atom is important for science literacy as it explains and predicts subatomic interactions, but details should be reserved for more advanced study. | | | |
| **Evolution of atomic models/theory** | Atomic models are constructed to explain experimental evidence and make predictions. The changes in the atomic model over time exemplify how scientific knowledge changes as new evidence emerges and how technological advancements like electricity extend the boundaries of scientific knowledge.<br>Although the quantum mechanical model of the atom explains the most experimental evidence, other models can still be helpful. Thinking of atoms as indivisible spheres is useful in explaining many physical properties of substances, such as the state (solid, liquid or gas) of a substance at room temperature. Bohr's planetary model is useful to explain and predict periodic trends in the properties of elements. | 2.1: Matter and the Elements<br>5.1: The Atom Has a Structure<br>5.2: The Quantum Atom<br><br>Inv 5A: Inside the Atom | Ch 2: p. 66-69 Qs 2, 5, 7<br>Ch 5: p. 162-165 Qs 1-15, 23-40, 64-70<br><br>Inv 5A: p. 47-48 Parts 2-4 |
| **Electrons** | Valence electrons are responsible for most of the chemical properties of elements.<br>Based on the quantum mechanical model, it is not possible to predict exactly where electrons are located but there is a region of space surrounding the nucleus in which there is a high probability of finding an electron (electron cloud or orbital). Data from atomic spectra (emission and absorption) gives evidence that electrons can only exist at certain discrete energy levels and not at energies between these levels. | 2.2: Molecules and Compounds<br>4.1 Understanding Chemical Change<br>6.1: The Periodic Table<br>6.2: Properties of Groups of Elements<br>6.3: Valence<br>7.2 Valence Electrons and Bonding Patterns | Ch 2: p. 66-69 Qs 15, 45<br>Ch 4: p. 128-131 Qs 7-9, 41, 42, 43, 45<br>Ch 6: p. 192-195 Qs 8-11, 25, 30-39, 45-52<br>Ch 7: p. 224-227 Qs 31, 32, 35, 36, 49-51, 53-62 |

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| | Atoms are usually in the ground state where the electrons occupy orbitals with the lowest available energy. | 7.3 Molecular Geometry and Lewis Dot Structures<br><br>Inv 5C: Spectroscopy<br>Inv 6A: Periodic Table Riddles<br>Inv 6B: Periodic Table Fill in the Blank | Inv 5C: p. 51-52 Parts 2-3<br>Inv 6A: p. 53-54 1-17<br>Inv 6B: p. 55-56 1, 2, 3, 5-8 |
| **Electron configurations** | Electron energy levels consist of sublevels (s, p, d and f), each with a characteristic number and shape of orbitals. Orbital diagrams and electron configuration can be constructed to show the location of the electrons in an atom using established rules.<br><br>However, the atom can become excited when the electrons absorb a photon with the precise amount of energy (indicated by the frequency of the photon) to move to an orbital with higher energy. Each element has a unique emission and absorption spectrum due to its unique electron configuration and specific electron energy jumps that are possible for that element. When an electron drops back down to the lower energy level, it emits a photon that has energy equal to the energy difference between the levels. The amount of energy is indicated by the frequency of the light that is given off and can be measured. | 5.3: Electron Configurations<br><br>Inv 5C: Spectroscopy<br>Inv 6C: Valence | Ch 5: p. 162-165 Qs 10-15, 41-51, 71-75<br><br>Inv 6C: p. 57-58 Parts 2-4 |
| **C.PM.2: Periodic Table**<br><br>In the Physical Science course, the concept that elements are placed in order of increasing atomic number in the periodic table such that elements with similar properties are placed in the same column is introduced. How the periodic table is divided into groups, families, periods, metals, nonmetals and metalloids is also included and will be revisited here. Additional ionization energies, electron affinities and periodic properties of the transition elements, and the lanthanide and actinide series are reserved for more advanced study. In this course, with more information about the electron configuration of elements, similarities in the configuration of the valence electrons for a particular group can be observed. | | | |
| **Properties** | The electron configuration of an atom can be determined from the position on the periodic table. The repeating pattern in the electron configuration for elements on the periodic table explains many of the trends in the properties observed. | 2.1: Matter and the Elements<br>4.1: Understanding Chemical Change | Ch 2: p. 66-69 Qs 8, 10, 38, 39<br>Ch 4: p. 128-131 Q 61<br>Ch 5: p. 162-165 Q 57 |

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| | | 5.2: The Quantum Atom<br>5.3: Electron Configurations<br>6.1: The Periodic Table<br>6.2: Properties of Groups of Elements<br>6.3: Valence<br><br>Inv 6A: Periodic Table Riddles<br>Inv 6B: Periodic Table Fill in the Blank<br>Inv 6C: Valence | Ch 6: p. 192-195 Qs 14, 21-27, 29, 35, 43<br><br>Inv 6A: p. 53-54 1-17<br>Inv 6B: p. 55-56 1-8<br>Inv 6C: p. 57-58 Parts 2-4 |
| **Trends** | Atomic theory is used to describe and explain trends in properties across periods or down columns including atomic radii, ionic radii, first ionization energies, electronegativities and whether the element is a solid or gas at room temperature. | 5.2: The Quantum Atom<br>6.1: The Periodic Table<br>6.2: Properties of Groups of Elements<br>6.3: Valence<br><br>Inv 6A: Periodic Table Riddles<br>Inv 6B: Periodic Table Fill in the Blank | Ch 5: p. 162-165 Q 57<br>Ch 6: p. 192-195 Qs 14, 21-27, 29, 35, 43<br><br>Inv 6A: p. 53-54 1-17<br>Inv 6B: p. 55-56 1-8 |
| **C.PM.3: Chemical bonding**<br><br>Content in the Physical Science course included recognizing that atoms with unpaired electrons tend to form ionic and covalent bonds with other atoms, forming molecules, ionic lattices or network covalent structures. In this course, electron configuration, electronegativity values and energy considerations will be applied to bonding and the properties of materials with different types of bonding. Detailed study of the structure of molecules responsible for life is reserved for more advanced courses . | | | |
| **Bonding** | Atoms of many elements are more stable when they are bonded to other atoms. In such cases, as atoms bond, energy is released to the surroundings, resulting in a system with lower energy. An atom's electron configuration, particularly the valence electrons, determines how an atom interacts with other atoms. Molecules, ionic lattices and network covalent structures have different, yet predictable, properties that depend on the identity of the elements and the types of bonds formed. | 4.1: Understanding Chemical Change<br>6.2: Properties of Groups of Elements<br>16.1: The Properties of Solids<br>16.2: The Microstructure of Solids | Ch 4: p. 128-131 Qs 5, 8, 10, 12, 13, 14, 39, 43-47<br>Ch 6: p. 192-195 Qs 36, 37, 39<br>Ch 16: p. 532-535 Qs 41, 45<br><br>Inv 2B: p. 11-14 Parts 2-5 |

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| | | Inv 2B: The Chemical Formula | |
| **Ionic** | Differences in electronegativity values can be used to predict where a bond fits on the continuum between ionic and covalent bonds. The polarity of a bond depends on the electronegativity difference and the distance between the atoms (bond length). | 7.1: What is a Chemical Bond<br>7.2: Valence Electrons and Bonding Patterns<br>8.1: Ionic Compounds<br><br>Inv 6C: Valence<br>Inv 7A: Lewis Structures<br>Inv 7B: The Geometry of Molecules | Ch 7: p. 224-227 Qs 1-5, 15-18, 21-29, 31,42-48, 50 |
| **Polar/Covalent** | Polar covalent bonds are introduced as an intermediary between ionic and pure covalent bonds. The concept of metallic bonding is also introduced to explain many of the properties of metals (e.g., conductivity). Since most compounds contain multiple bonds, a substance may contain more than one type of bond. Carbon atoms can bond together and with other atoms, especially hydrogen, oxygen, nitrogen and sulfur, to form chains, rings and branching networks that are present in a variety of important compounds, including synthetic polymers, fossil fuels and the large molecules essential to life. | 7.1: What is a Chemical Bond<br>7.2: Valence Electrons and Bonding Patterns<br>8.2: Molecular Compounds<br>17.1: Carbon Molecules<br>17.2: Functional Groups<br>18.1: Fats and Carbohydrates<br>18.3: Proteins<br><br>Inv 6C: Valence<br>Inv 7A: Lewis Structures<br>Inv 7B: The Geometry of Molecules<br>Inv 18C: Building an Amino Acid Chain | Ch 7: p. 224-227 Qs 1-5, 15-18, 21-29, 31,42-48, 50<br>Ch 17: p. 564-567 Qs 24, 30, 54<br>Ch 18: p. 600-603 Qs 22, 47, 54, 55, 90<br><br>Inv 6C: p. 57-58 Parts 2-4<br>Inv 7A: p. 59-60 Parts 1-3<br>Inv 7B: p. 61-62 Parts 1-4<br>Inv 18C: p. 145 Parts 1-2 |

**C.PM.4: Representing compounds**

Using the periodic table, formulas of ionic compounds containing specific elements can be predicted. This can include ionic compounds made up of elements from groups 1, 2, 17, hydrogen, oxygen and polyatomic ions (given the formula and charge of the polyatomic ion). Many different models can be used to represent compounds including chemical formulas, Lewis structures, and ball and stick models. These models can be used to visualize atoms and molecules and to predict the properties of substances. Lewis structures and molecular geometries will only be constructed for the following combination of elements: hydrogen, carbon, nitrogen, oxygen, phosphorus, sulfur and the halogens. Organic nomenclature is reserved for more advanced courses.

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| **Formula writing** | Using the periodic table, formulas of ionic compounds containing specific elements can be predicted. This can include ionic compounds made up of elements from groups 1, 2, 17, hydrogen, oxygen and polyatomic ions (given the formula and charge of the polyatomic ion). | 2.2: Molecules and Compounds<br>6.3: Valence<br>7.1: What is a Chemical Bond<br>10.1: Chemical Equations<br>10.2: Methods for Balancing Chemical Equations<br><br>Inv 2B: The Chemical Formula<br>Inv 8A: The Formula of a Hydrated Salt | Ch 2: p. 66-69 Qs 13, 42, 43, 44<br>Ch 6: p. 192-195 Qs 11, 39<br>Ch 7: p. 224-227 Qs 12-14, 17, 20, 24, 33-36, 39-42, 47, 48, 53-62, 64-66<br>Ch 10: p. 322-325 Qs 8, 10, 30, 31, 33, 34<br>Ch 18: p. 600-603 Qs 23, 27, 30, 35, 80, 91, 92<br><br>Inv 2B: p. 11-14 Parts 2-5<br>Inv 8A: p. 63-64 Part 2 |
| **Nomenclature** | Given the formula, a compound can be named using conventional systems that include Greek prefixes and Roman numerals where appropriate. Given the name of an ionic or covalent substance, formulas can be written. | 8.1: Ionic Compounds<br>8.2: Molecular Compounds<br><br>Inv 8B: Naming Chemical Compounds | Ch 8: p. 256-259 Qs 4, 10, 23-25, 27, 38, 48-51, 52-64, 69-77<br><br>Inv 8B: p. 65-66 Parts 2-4 |
| **Models and shapes (Lewis structures, ball and stick, molecular geometries)** | Each type of representation provides unique information about the compound. Different representations are better suited for particular substances. Lewis structures can be drawn to represent covalent compounds using a simple set of rules and can be combined with valence shell electron pair repulsion (VSEPR) theory to predict the three-dimensional electron pair and molecular geometry of compounds. | 7.3: Molecular Geometry and Lewis Dot Structures<br>18.3 Proteins<br>18.4: DNA and Molecular Reproduction<br><br>Inv 7A: Lewis Structures<br>Inv 7B: The Geometry of Molecules<br>Inv 18C: Building an Amino Acid Chain | Ch 7: p. 224-227 Qs 12-14, 17, 20, 24, 33-36, 39-42, 47, 48, 53-62, 64-66<br>Ch 18: p. 600-603 Qs 23, 27, 30, 35, 80, 91, 92<br><br>Inv 7A: p. 59-60 Parts 2-4<br>Inv 7B: p. 61-62 Parts 1-4<br>Inv 18C: p. 145 Part 1, Part 2 |
| **C.PM.5: Quantifying matter**<br><br>In earlier grades, properties of materials were quantified with measurements that were always associated with some error. In this course, scientific protocols for quantifying the properties of matter accurately and precisely are studied. | | | |

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| **Quantifying matter** | Using the International System of Units (SI), significant digits or figures, scientific notation, error analysis and dimensional analysis are vital to scientific communication.<br>There are three domains of magnitude in size and time: the macroscopic (human) domain, the cosmic domain and the submicroscopic (atomic and subatomic) domain. Measurements in the cosmic domain and submicroscopic domains require complex instruments and/or procedures.<br>Matter can be quantified in a way that macroscopic properties such as mass can reflect the number of particles present. Elemental samples are a mixture of several isotopes with different masses. The atomic mass of an element is calculated given the mass and relative abundance of each isotope of the element as it exists in nature. Because the mass of an atom is very small, the mole is used to translate between the atomic and macroscopic levels. A mole is equal to the number of atoms in exactly 12 grams of the isotope carbon-12. The mass of one mole of a substance is equal to its molar mass in grams. The molar mass for a substance can be used in conjunction with Avogadro's number and the density of a substance to convert between mass, moles, volume, and number of particles of a sample. | 1.1: What Chemistry is About<br>2.1: Matter and the Elements<br>2.2: Molecules and Compounds<br>2.3: Mixtures and Solutions<br>5.1: The Atom Has a Structure<br>8.4: Formula Masses<br>9.2: Concentration and Stability<br>11.1: Analyzing a Chemical Reaction<br>11.2: Percent Yield and Concentration<br>11.4: Solving Stoichiometric Problems<br>14.3: Stoichiometry and Gases<br><br>Inv 1B: Volume and Chemistry<br>Inv 1C: Mass and Chemistry<br>Inv 1D: Dimensional Analysis<br>Inv 2C: One in a Million<br>Inv 2D: Density Inv 5B: Spectrophotometry<br>Inv 5C: Spectroscopy<br>Inv 9A: Density and Concentration<br>Inv 9B: Solutions and Beer's Law<br>Inv 11A: Stoichiometry<br>Inv 11B: Stoichiometry: Quantitative Precipitate | Ch 1: p. 32-35 Qs 5, 7-15, 41-4760, 63, 66, 70-78<br>Ch 2: p. 66-69 Qs 6, 9, 16, 24, 27, 40, 41, 50, 52-80<br>Ch 5: p. 162-165 Qs 17, 18, 26, 27, 64-76<br>Ch 8: p. 256-259 Qs 65-77<br>Ch 9: p. 290-293 Qs 45, 50, 51, 55, 76-87<br>Ch 11: p. 360-365 Qs 1-6, 9-11, 15-21, 28-29, 38-69<br>Ch 14: p. 468-471 Qs 32, 73-81<br><br>Inv 1B: p. 3-4 Parts 1-3, Part 6<br>Inv 1C: p. 5-6 Parts 1-7<br>Inv 2C: p. 17-20 Parts 1-3, Parts 5-8<br>Inv 2C: p. 21-22 Parts 1-2<br>Inv 5B: p. 49-50 Parts 2-4<br>Inv 5C: p. 51-52 Parts 2-3<br>Inv 9A: p. 67-68 Parts 1-3<br>Inv 9B: p. 69-72 Parts 1-6<br>Inv 11A: p. 83-87 Part 1, Parts 3-8<br>Inv 11B: p. 88-90 Parts 1-6<br>Inv 14A: p. 117-120 Parts 1-3<br>Inv 14B: p. 121-122 Parts 1-5 |

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| | | Inv 14A: Determination of Butane's Molar Mass<br>Inv 14B: The Density of Air | |
| **C.PM.6: Intermolecular forces of attraction**<br>In middle school, solids, liquids, and gases were explored in relation to the spacing of the particles, motion of the particles and strength of attraction between the particles that make up the substance. The intermolecular forces of attraction between particles that determine whether a substance is a solid, liquid or gas at room temperature are addressed in greater detail in this course. | | | |
| **Types and strengths** | Intermolecular attractions are generally weak when compared to intramolecular bonds but span a wide range of strengths.<br>The composition of a substance and the shape and polarity of a molecule are particularly important in determining the type and strength of bonding and intermolecular interactions. Types of intermolecular attractions include London dispersion forces (present between all molecules), dipole-dipole forces (present between polar molecules) and hydrogen bonding (a special case of dipole-dipole where hydrogen is bonded to a highly electronegative atom such as fluorine, oxygen or nitrogen), each with its own characteristic relative strength. | 4.1: Understanding Chemical Changes<br>8.3: Intermolecular Forces | Ch 4: p. 128-131 Qs 1, 3, 5, 39<br>Ch 8: p. 256-259 Qs 15-19, 39-47, 63-64 |
| **Implications for properties of substances** | The configuration of atoms in a molecule determines the strength of the forces (bonds or intermolecular forces) between the particles and therefore the physical properties (e.g., melting point, boiling point, solubility, vapor pressure) of a material. Substances that have strong intermolecular forces or are made up of three-dimensional networks of ionic or covalent bonds, tend to be solids at room temperature and have high melting and boiling points. Nonpolar organic molecules are held together by weak London dispersion forces. In solid water, there is a network of hydrogen bonds between the particles that gives it an open structure. This is why water expands as it freezes and why solid water has a lower density than liquid water. This has important implications for life (e.g., ice floating on water acts as an | 16.1: The Properties of Solids<br>16.2: The Microstructure of Solids<br>17.1: Carbon Molecules<br>17.2: Functional Groups<br>18.4: DNA and Molecular Reproduction | Ch 16: p. 532-535 Qs 32-34, 41-48, 66, 67<br>Ch 17: p. 564-567 Qs 43-45<br>Ch 18: p. 600-603 Qs 28, 59, 102, 103, 105 |

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| | insulator in bodies of water to keep the temperature of the rest of the water above freezing). | | |
| **Melting and boiling point** | For a given substance, the average kinetic energy (temperature) needed for a change of state to occur depends upon the strength of the intermolecular forces between the particles. Therefore, the melting point and boiling point depend upon the amount of energy that is needed to overcome the attractions between the particles. Substances with longer chains provide more opportunities for these attractions and tend to have higher melting and boiling points. Increased branching of organic molecules results in lower melting and boiling points due to interference with the intermolecular attractions. Liquids boil when their vapor pressure is equal to atmospheric pressure. | 3.3: Phase Changes<br><br>Inv 3D: Heat of Fusion<br>Inv 4A: Phase Changes of Water | Ch 3: p. 98-101 Qs 16, 22-33, 48-50, 74-84<br><br>Inv 3D: p. 35-36 Parts 1-3<br>Inv 4A: p. 37-38 Parts 1-4 |
| **Solubility** | Substances will have a greater solubility when dissolving in a solvent with similar intermolecular forces. If the substances have different intermolecular forces, they are more likely to interact with themselves than the other substance and remain separated from each other. Water is a polar molecule and it is often used as a solvent since most ionic and polar covalent substances will dissolve in it. In order for an ionic substance to dissolve in water, the attractive forces between the ions must be overcome by the dipole-dipole interactions with the water. Dissolving of a solute in water is an example of a process that is difficult to classify as a chemical or physical change and it is not appropriate to have students classify it one way or another. | 9.1: Solutes, Solvents and Water | Ch 9: p. 290-293 Qs 5-7, 32-35, 37 |
| **Vapor pressure** | Evaporation occurs when the particles with enough kinetic energy to overcome the attractive forces separate from the rest of the sample to become a gas. The pressure of these particles is called vapor pressure. Vapor pressure increases with temperature. Particles with larger intermolecular forces have lower vapor pressures at a given temperature since the particles require more energy to overcome the attractive forces between | (3.3: Phase Changes) | (Ch 3: p. 98-101 Qs 16, 22-33, 48-50, 74-84) |

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| | them. Molecular substances often evaporate more due to the weak attractions between the particles and can often be detected by their odor. Ionic or network covalent substances have stronger forces and are not as likely to volatilize. These substances often have little, if any, odor. | | |

## C.IM: INTERACTIONS OF MATTER

| OHIO CHEMISTRY LEARNING STANDARDS | Content Elaboration | Lab-Aids *A Natural Approach to Chemistry*: Text Sections (X.X) and Laboratory Investigations (Inv X) | Selected Assessment Opportunities*:* Text (Ch X) and Laboratory Investigations (Inv X) |
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| **C.IM.1: Chemical reactions**<br><br>In the Physical Science course, coefficients were used to balance simple equations. Other representations, including Lewis structures and three-dimensional models, were also used and manipulated to demonstrate the conservation of matter in chemical reactions. In this course, more complex reactions will be studied, classified and represented with balanced chemical equations and three-dimensional models.<br>Classifying reactions into types can be a helpful organizational tool for recognizing patterns of what may happen when two substances are mixed. Teachers should be aware that the common reaction classifications that are often used in high school chemistry courses may lead to misconceptions because they are not based on the actual chemistry, but on surface features that can be similar from one system to another (e.g., exchanging partners), even though the underlying chemistry is not the same. However, these classifications may be useful in making predictions about what happens when two substances are mixed. | | | |
| **Types of reactions** | Some general types of chemical reactions are oxidation/reduction, synthesis, decomposition, single replacement, double replacement (including precipitation reactions and some acid-base neutralizations) and combustion reactions. Some reactions can fit into more than one category. For example, a single replacement reaction can also be classified as an oxidation/reduction reaction.<br>Identification of reactions involving oxidation and reduction as well as indicating what substance is being oxidized and what is being reduced are appropriate in this course. However, balancing complex oxidation/reduction reactions is reserved for more advanced study.<br>Organic molecules release energy when undergoing combustion reactions and are used to meet the energy needs of society (e.g., oil, gasoline, natural gas) and to provide the energy needs of biological | 2.1: Matter and the Elements<br>4.1: Understanding Chemical Change<br>4.2: Chemical Reactions<br>4.3: Chemical Reactions in the Lab<br>10.1: Chemical Equations<br>10.3: Types of Chemical Reactions<br>15.2: Oxidation-Reduction (Redox) Reactions<br>15.3: Balancing Redox Reactions | Ch 2: p. 66-69 Qs 5, 32, 33, 35-37<br>Ch 4: p. 128-131 Qs 4, 6, 16-27, 36, 38, 48-59, 65-72<br>Ch 10: p. 322-325 Qs 1-23, 29, 31, 39, 41-46, 64-71<br><br>Ch 15: p. 506-509 Qs 19, 20, 22-28, 37-44, 48, 49, 60, 61, 64, 70-74, 81, 83, 89-91<br>Ch 17: p. 564-567 Qs 20-31, 66-73, 76, 80, 81 |

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| | organisms (e.g., cellular respiration). When a reaction between two ionic compounds in aqueous solution results in the formation of a precipitate or molecular compound, the reaction often occurs because the new ionic or covalent bonds are stronger than the original ion-dipole interactions of the ions in solution. Laboratory experiences (3-D or virtual) with different types of chemical reactions should be provided. | 17.3: Organic Reactions<br>18.2 Photosynthesis and Respiration<br>19.1: The Chemistry of the Atmosphere<br><br>Inv 4B: Indicators of Chemical Reactions<br>Inv 4C: Chemical Changes<br>Inv 10A: Discovering the Solubility Rules<br>Inv 10B: Chemical Reactions<br>Inv 15C: Oxidation-Reduction Reactions | Ch 18: p. 600-603 Qs 9-18, 33, 60-79<br>Ch 19: p. 630-633 Qs 36-38, 44, 51, 53, 54, 72, 80, 81<br><br>Inv 4B: p. 39-41 Parts 2-13<br>Inv 4C: p. 43-46 Parts 2-10<br>Inv 10A: p. 75-76 Parts 1-4<br>Inv 10B: p. 77-80 Parts 1-7<br>Inv 15C: p. 127-128 Parts 1-4 |
| **Kinetics** | Reactions occur when reacting particles collide in an appropriate orientation and with sufficient energy. The rate of a chemical reaction is the change in the amount of the reactants or products in a specific period of time. Increasing the probability or effectiveness of the collisions between the particles increases the rate of the reaction. Therefore, changing the concentration of the reactants, changing the temperature or the pressure of gaseous reactants, or using a catalyst, can change the reaction rate. Likewise, the collision theory can be applied to dissolving solids in a liquid solvent and can be used to explain why reactions are more likely to occur between reactants in the aqueous or gaseous state than between solids. The rate at which a substance dissolves should not be confused with the amount of solute that can dissolve in a given amount of solvent (solubility). Mathematical treatment of reaction rates is reserved for more advanced study. Computer simulations can help visualize reactions from the perspective of the kinetic-molecular theory | 12.1: Reaction Rates<br>12.3: Chemical Pathways<br>12.4: Catalysts<br><br>Inv 12B: Reaction Rate and Concentration<br>Inv 18B: Catalysis and Enzymes | Ch 12: p. 404-407 Qs 1-4, 13-35, 48-62<br><br>Inv 12B: p. 95-98 Parts 2-6<br>Inv 18B: p. 143-144 Parts 1-3 |
| **Energy** | For chemical systems, potential energy is in the form of chemical energy and kinetic energy is in the form of thermal energy. The total amount of chemical energy and/or thermal energy in a system is impossible to measure. However, the energy change of a system can be calculated from measurements | 3.2 Heat and Thermal Energy<br>10.4: Chemical Reactions and Energy<br>18.2: Photosynthesis and Respiration | Ch 10: p. 322-325 Qs 1-23, 29, 31, 39, 41-46, 64-71<br>Ch 18: p. 600-603 Qs 9-18, 33, 60-79 |

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| **Energy** | (mass and change in temperature) from calorimetry experiments in the laboratory. Conservation of energy is an important component of calorimetry equations. Thermal energy is the energy of a system due to the movement of its particles. The thermal energy of an object depends upon the amount of matter present (mass), temperature and chemical composition.<br>Some materials require little energy to change their temperature and other materials require a great deal to change their temperature by the same amount. Specific heat is a measure of how much energy is needed to change the temperature of a specific mass of material a specific amount. Specific heat values can be used to calculate the thermal energy change, the temperature (initial, final or change in) or mass of a material in calorimetry. Water has a particularly high specific heat capacity, which is important in regulating Earth's temperature.<br>As studied in middle school, chemical energy is the potential energy associated with chemical systems. Chemical reactions involve valence electrons forming bonds to yield more stable products with lower energies. Energy is required to break interactions and bonds between the reactant atoms and energy is released when an interaction or bond is formed between the atoms in the products. Molecules with weak bonds (e.g., ATP) are less stable and tend to react to produce more stable products, releasing energy in the process. Generally, energy is transferred out of the system (exothermic) when the products have stronger bonds than the reactants and is transferred into the system (endothermic) when the reactants have stronger bonds than the products. Predictions of the energy requirements (endothermic or exothermic) of a reaction can be made given a table of bond energies. Graphic representations can be drawn and interpreted to represent the energy changes during a reaction. The role of energy in determining the spontaneity of chemical reactions is dealt with conceptually in this course. Entropy and its influence on the spontaneity of reactions are reserved for more advanced study. | Inv 3A Heat and Temperature<br>Inv 3B Specific Heat<br>Inv 3C Heat Flow and Thermal Equilibrium<br>Inv 10C: Calorimetry: Hess's Law<br>Inv 12A: Respiration and Temperature | Inv 3A: p. 23-26 Parts 1-8<br>Inv 3B: p. 27-30 Parts 1-6<br>Inv 3C: p. 31-33 Parts 1-4<br>Inv 10C: p. 81-82 Parts 1-4<br>Inv 12A: p. 91-94 Parts 5-7 |

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| **Equilibrium** | All reactions are reversible to a degree and many reactions do not proceed completely toward products but appear to stop progressing before the reactants are all used up. At this point, the amounts of the reactants and the products appear to be constant and the reaction can be said to have reached dynamic equilibrium. Dynamic equilibrium means the rate of the reverse reaction is equal to the rate of the forward reaction so there is no apparent change in the reaction.<br>If a chemical system at equilibrium is disturbed by a change in the conditions of the system (e.g., increase or decrease in the temperature, pressure on gaseous equilibrium systems, concentration of a reactant or product), then the equilibrium system will respond by shifting to a new equilibrium state, reducing the effect of the change (Le Chatelier's Principle). If products are removed as they are formed during a reaction, then the equilibrium position of the system is forced to shift to favor the products. In this way, an otherwise unfavorable reaction can be made to occur. Mathematical treatment of equilibrium reactions is reserved for advanced study. Computer simulations can help visualize the progression of a reaction to dynamic equilibrium and the continuation of both the forward and reverse reactions after equilibrium has been attained. | 12.2: Chemical Equilibrium<br><br>Inv 12C: Le Chatelier's Principle | Ch 12: p. 404-407 Qs 5-12, 36-47, 63-64<br><br>Inv 12C: p. 99-100 Parts 1-4 |
| **Acids/bases** | Properties of acids and bases and the ranges of the pH scale were introduced in Physical Science. In this course, the structural features of molecules are explored to further understand acids and bases. Acids often result when hydrogen is covalently bonded to an electronegative element and is easily dissociated from the rest of the molecule to bind with water to form a hydronium ion (H3O+). The acidity of an aqueous solution can be expressed as pH, where pH can be calculated from the concentration of the hydronium ion. Bases are likely to dissociate in water to form a hydroxide ion. Acids can react with bases to form a salt and water. Such neutralization reactions can be studied quantitatively by performing titration experiments. Detailed instruction about the equilibrium of acids and bases and the concept of | 13.1: The Chemical Nature of Acids and Bases<br>13.2: The pH Scale<br>13.3: Acid-Base Equilibria<br>13.4: Acid-Base Reactions<br><br>Inv 13A: The pH Scale<br>Inv 13B: Titration of Vinegar<br>Inv 13C: Commercial Antacids | Ch 13: p. 436-439 Qs 1-81<br><br>Inv 13A: p. 101-106 Parts 1-8<br>Inv 13B: p. 107-108 Parts 1-4<br>Inv 13C: p. 109-112 Parts 1-5 |

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| | Brønsted-Lowry and Lewis acids and bases is not the focus at this level. | | |
| **C.IM.2: Gas laws**<br><br>The kinetic-molecular theory can be used to explain the properties of gases (pressure, temperature and volume) through the motion and interactions of its particles. The focus in this course is solving problems using the gas laws and understanding their applications, rather than memorizing the specific names and formulas. Deviations from ideal gaseous behavior are reserved for more advanced study. Relationships between the volume, temperature and pressure can be explored in the laboratory or through computer simulations or virtual experiments. | | | |
| **Pressure, volume and temperature** | Problems can also be solved involving the changes in temperature, pressure, volume and amount of a gas. When two of these four are kept constant, the relationship between the other two can be quantified, described and explained using the kinetic-molecular theory. Real-world phenomena (e.g., why tire pressure increases in hot weather, why a hot air balloon rises) can be explained using this theory. When solving gas problems, the Kelvin temperature scale must be used since only in this scale is the temperature directly proportional to the average kinetic energy. The Kelvin temperature is based on a scale that has its minimum temperature at absolute zero, a temperature at which all motion theoretically stops. | 14.1: Pressure and Kinetic Theory<br>14.3: Stoichiometry and Gases<br><br>Inv 14A: Determination of Butane's Molar Mass | Ch 14: p. 468-471 Qs 2-4, 12-16, 17-31, 33-35, 73-80<br><br>Inv 14A: p. 117-120 Parts 2-3 |
| **Ideal gas law** | Since equal volumes of gases at the same temperature and pressure contain an equal number of particles (Avogadro's law), problems can be solved for an unchanging gaseous system using the ideal gas law ($PV = nRT$) where R is the ideal gas constant (e.g., represented in multiple formats, 8.31 joules/(mole·K). | 14.2: The Gas Laws<br><br>Inv 14A: Determination of Butane's Molar Mass | Ch 14: p. 468-471 Qs 5, 6, 17-31, 36-72<br><br>Inv 14A: p. 117-120 Parts 2-3 |
| **C.IM.3: Stoichiometry**<br><br>A stoichiometric calculation involves the conversion from the amount of one substance in a chemical reaction to the amount of another substance. The coefficients of the balanced equation indicate the ratios of the substances involved in the reaction in terms of both particles and moles. Molality and normality are concepts reserved for more advanced study. | | | |
| **Molecular calculations** | Once the number of moles of a substance is known, amounts can be changed to mass, volume of a gas, volume of solutions and/or number of particles. When performing a reaction in the lab, the experimental yield can be compared to the theoretical yield to calculate percent yield. | 10.1: Chemical Equations<br>10.2: Methods for Balancing Chemical Equations | Ch 10: p. 322-325 Qs 32, 36-38, 52-63<br>Ch 11: p. 360-365 Qs 1-3, 7-21, 38-45, 58-69 |

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| **Molecular calculations** | | 11.1: Analyzing a Chemical Reaction<br>11.2: Percent Yield and Concentration<br>11.4: Solving Stoichiometric Problems<br>14.3: Stoichiometry and Gases<br><br>Inv 11A: Stoichiometry<br>Inv 11B: Stoichiometry: Quantitative Precipitate<br>Inv 13D: Determining the Amount of Vitamin C<br>Inv 14A: Determination of Butane's Molar Mass | Ch 14: p. 468-471 Qs 32, 73-81<br><br>Inv 11A: p. 83-86 Parts 1-8<br>Inv 11B: p. 87-90 Parts 1-6<br>Inv 13D: p. 113-116 Parts 4-5<br><br>Inv 14A: p. 117-120 Parts 2-3 |
| **Solutions** | Molarity is a measure of the concentration of a solution that can be used in stoichiometric calculations. | 2.3: Mixtures and Solutions | Ch 2: p. 66-69 Qs 53-80 |
| **Limiting reagents** | The concept of limiting reagents is treated conceptually. Mathematical applications can be utilized, but it is important to address the symbolic representations as well. | 11.3: Limiting Reactants<br><br>Inv 11A: Stoichiometry<br>Inv 11B: Stoichiometry: Quantitative Precipitate | Ch 11: p. 360-365 Qs 7, 8, 30-37, 58-63<br><br>Inv 11A: p. 83-86 Parts 1-8<br>Inv 11B: p. 87-90 Parts 1-6 |