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ODYSSEY Molecular Explorer

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Correlation with the New York State

Learning Standards for Mathematics, Science, and Technology

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Standard 4—The Physical Setting:

Students will understand and apply scientific concepts, principles, and theories pertaining to the physical setting and living environment and recognize the historical development of ideas in science.

Key Idea 3:

Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.

Chemistry is the study of matter—its properties and its changes. The idea that matter is made up of particles is over 2000 years old, but the idea of using properties of these particles to explain observable characteristics of matter has more recent origins. In ancient Greece, it was proposed that matter is composed of particles of four elements (earth, air, water, and fire) and that these particles are in continual motion. The idea that particles could explain properties of matter was not used for about 2000 years. In the late 1600s the properties of air were attributed to its particulate nature; however, these particles were not thought to be fundamental. Instead, it was thought that they could change into other particles with different properties.

In the late 1700s solid evidence about the nature of matter, gained through quantitative scientific experiments, accumulated. Such evidence included the finding that during a chemical reaction matter was conserved. In the early 1800s a theory was proposed to explain these experimental facts. In this theory, atoms were hard, indivisible spheres of different sizes and they combined in simple whole-number ratios to form compounds. The further treatment of particles of matter as hard spheres in continual motion resulted in the 1800s in the kinetic molecular theory of matter, which was used to explain the properties of gases.

In the late 1800s evidence was discovered that particles of matter could not be considered hard spheres; instead, particles were found to have an internal structure. The development of cathode ray tubes, and subsequent experiments with them in the 1860s, led to the proposal that small, negatively charged particles—electrons—are part of the internal structure of atoms. In the early 1900s, to explain the results of the "gold foil experiment," a small, dense nucleus was proposed to be at the center of the atom with electrons moving about in the empty space surrounding the nucleus. Around this time, energy was proposed to exist in small, indivisible packets called quanta. This theory was used to develop a model of the atom which had a central nucleus surrounded by shells of electrons. The model was successful in explaining the spectra of the hydrogen atom and was used to explain aspects of chemical bonding. Additional experiments with radioactivity provided evidence that atomic nuclei contained protons and neutrons.

Further investigation into the nature of the electron determined that it has wave-like properties. This feature was incorporated into the wave-mechanical model of the atom, our most sophisticated model, and is necessary to explain the spectra of multi-electron atoms.

PERFORMANCE INDICATOR 3.1

Explain the properties of materials in terms of the arrangement and properties of the atoms that compose them.

Major Understandings:

3.1b Each atom has a nucleus, with an overall positive charge, surrounded by negatively charged electrons.

⟶ **LAB** *Atoms* "The Electron Cloud of an Argon Atom"

3.1d The proton is positively charged, and the neutron has no charge. The electron is negatively charged.

⟶ **LAB** *Atoms* "Nuclei and Electrons"

3.1e Protons and electrons have equal but opposite charges. The number of protons equals the number of electrons in an atom.

⟶ **LAB** *Atoms* "Nuclei and Electrons"

⟶ **LAB** *Atoms* "The Electron Cloud of an Argon Atom"

3.1f The mass of each proton and each neutron is approximately equal to one atomic mass unit. An electron is much less massive than a proton or a neutron.

⟶ **LAB** *Atoms* "Nuclei and Electrons"

3.1h In the wave-mechanical model (electron cloud model) the electrons are in orbitals, which are defined as the regions of the most probable electron location (ground state).

⟶ **LAB** *Atoms* "s- and p-Orbitals"

⟶ **LAB** *Atoms* "d-Orbitals"

3.1l The outermost electrons in an atom are called the valence electrons. In general, the number of valence electrons affects the chemical properties of an element.

⟶ **LAB** *Atoms* "The Electron Cloud of an Argon Atom"

3.1q Matter is classified as a pure substance or as a mixture of substances.

⟶ **MISCELLANEOUS** *Chemical Matter* "The Types of Mixtures"

3.1r A pure substance (element or compound) has a constant composition and constant properties throughout a given sample, and from sample to sample.

⟶ **MISCELLANEOUS** *Chemical Matter* "Examples of Chemical Elements"

⟶ **MISCELLANEOUS** *Chemical Matter* "The Types of Compounds"

3.1s Mixtures are composed of two or more different substances that can be separated by physical means. When different substances are mixed together, a homogeneous or heterogeneous mixture is formed.

⟶ **MISCELLANEOUS** *Chemical Matter* "The Types of Mixtures"

3.1t The proportions of components in a mixture can be varied. Each component in a mixture retains its original properties.

⟶ **MISCELLANEOUS** *Chemical Matter* "The Types of Mixtures"

⟶ **MISCELLANEOUS** *Solutions* "Miscible and Nonmiscible Liquids"

3.1u Elements are substances that are composed of atoms that have the same atomic number. Elements cannot be broken down by chemical change.

⟶ **Miscellaneous** *Chemical Matter* "Examples of Chemical Elements"

3.1w Elements can be differentiated by physical properties. Physical properties of substances, such as density, conductivity, malleability, solubility, and hardness, differ among elements.

⟶ **Lab** *Chemical Matter* "Chemical and Physical Properties"

3.1x Elements can also be differentiated by chemical properties. Chemical properties describe how an element behaves during a chemical reaction.

⟶ **Lab** *Chemical Matter* "Chemical and Physical Properties"

3.1cc A compound is a substance composed of two or more different elements that are chemically combined in a fixed proportion. A chemical compound can be broken down by chemical means. A chemical compound can be represented by a specific chemical formula and assigned a name based on the IUPAC system.

⟶ **Miscellaneous** *Chemical Matter* "The Types of Compounds"

3.1dd Compounds can be differentiated by their physical and chemical properties.

⟶ **Lab** *Chemical Matter* "Chemical and Physical Properties"

3.1ff Organic compounds contain carbon atoms, which bond to one another in chains, rings, and networks to form a variety of structures. Organic compounds can be named using the IUPAC system.

⟶ **Lab** *Organic Chem.* "Bonding Characteristics of Carbon"

⟶ **Lab** *Organic Chemistry* "Straight-Chain Alkanes"

⟶ **Lab** *Organic Chemistry* "Cyclic Hydrocarbons"

3.1gg Hydrocarbons are compounds that contain only carbon and hydrogen. Saturated hydrocarbons contain only single carbon-carbon bonds. Unsaturated hydrocarbons contain at least one multiple carbon-carbon bond.

⟶ **Lab** *Organic Chemistry* "Straight-Chain Alkanes"

⟶ **Lab** *Organic Chemistry* "Isomers of Alkenes and Alkynes"

3.1hh Organic acids, alcohols, esters, aldehydes, ketones, ethers, halides, amines, amides, and amino acids are categories of organic compounds that differ in their structures. Functional groups impart distinctive physical and chemical properties to organic compounds.

⟶ **Lab** *Organic Chemistry* "Functional Groups"

⟶ **Lab** *Organic Chemistry* "Comparing and Identifying Organic Compounds"

3.1ii Isomers of organic compounds have the same molecular formula, but different structures and properties.

⟶ **Lab** *Organic Chemistry* "Isomers of the Alkanes"

3.1jj The structure and arrangement of particles and their interactions determine the physical state of a substance at a given temperature and pressure.

⟶ **Lab** *Liquids & Solids* "The Melting Transition"

⟶ **Demonstration** *Chemical Matter* "Do physical changes affect the amount of matter?"

3.1kk The three phases of matter (solids, liquids, and gases) have different properties.

→ **Lab** *Chemical Matter* "Comparing the States of Matter"

→ **Lab** *Chemical Matter* "Side-by-Side Comparison of Solids, Liquids, and Gases"

3.1ll Entropy is a measure of the randomness or disorder of a system. A system with greater disorder has greater entropy.

→ **Lab** *Chemical Thermodynamics* "Entropy and the States of Matter"

3.1mm Systems in nature tend to undergo changes toward lower energy and higher entropy.

→ **Demonstration** *Chemical Thermodynamics* "Are gas expansions irreversible?"

→ **Demonstration** *Chem. Thermodyn.* "Do all spontaneous processes involve a visible increase of disorder?"

3.1oo A solution is a homogeneous mixture of a solute dissolved in a solvent. The solubility of a solute in a given amount of solvent is dependent on the temperature, the pressure, and the chemical natures of the solute and solvent.

→ **Demonstration** *Solutions* "How do salts dissolve in water?"

3.1pp The concentration of a solution may be expressed in molarity (M), percent by volume, percent by mass, or parts per million (ppm).

→ **Lab** *Solutions* "Concentration of a Dissolved Pesticide"

→ **Miscellaneous** *Solutions* "Molarity vs. Molality"

3.1yy There are alternate acid-base theories. One theory states that an acid is an H^+ donor and a base is an H^+ acceptor.

→ **Lab** *Acids & Bases* "Strong Acids"

→ **Lab** *Acids & Bases* "Structure and Acidity"

PERFORMANCE INDICATOR 3.2

Use atomic and molecular models to explain common chemical reactions.

Major Understandings:

3.2a A physical change results in the rearrangement of existing particles in a substance. A chemical change results in the formation of different substances with changed properties.

→ **Demonstration** *Kinetics* "What does a chemical reaction look like at the molecular level?"

PERFORMANCE INDICATOR 3.4

Use kinetic molecular theory (KMT) to explain rates of reactions and the relationships among temperature, pressure, and volume of a substance.

Major Understandings:

3.4a The concept of an ideal gas is a model to explain the behavior of gases. A real gas is most like an ideal gas when the real gas is at low pressure and high temperature.

⟶ **Miscellaneous** *Gases* "The Universality of the Ideal Gas Law"

3.4b Kinetic molecular theory (KMT) for an ideal gas states that all gas particles:

- are in random, constant, straight-line motion.
- are separated by great distances relative to their size; the volume of the gas particles is considered negligible.
- have no attractive forces between them.
- have collisions that may result in a transfer of energy between gas particles, but the total energy of the system remains constant.

⟶ **Lab** *Gases* "Mean Speed and Temperature"

3.4c Kinetic molecular theory describes the relationships of pressure, volume, temperature, velocity, and frequency and force of collisions among gas molecules.

⟶ **Lab** *Gases* "The Distribution of Kinetic Energies"

⟶ **Lab** *Gases* "Mean Speed and Temperature"

3.4d Collision theory states that a reaction is most likely to occur if reactant particles collide with the proper energy and orientation.

⟶ **Lab** *Kinetics* "Reactive Collisions Between Molecules"

3.4e Equal volumes of gases at the same temperature and pressure contain an equal number of particles.

⟶ **Demonstration** *Gases* "What is Avogadro's Law?"

3.4h Some chemical and physical changes can reach equilibrium.

⟶ **Lab** *Equilibria* "Equilibrium and Temperature"

3.4i At equilibrium the rate of the forward reaction equals the rate of the reverse reaction. The measurable quantities of reactants and products remain constant at equilibrium.

⟶ **Miscellaneous** *Equilibria* "The Dynamic Nature of Equilibria"

3.4j LeChatelier's principle can be used to predict the effect of stress (change in pressure, volume, concentration, and temperature) on a system at equilibrium.

⟶ **Lab** *Equilibria* "Equilibrium and Temperature"

⟶ **Lab** *Equilibria* "Equilibrium and Pressure"

Key Idea 4:

Energy exists in many forms, and when these forms change energy is conserved.

Throughout history, humankind has tried to effectively use and convert various forms of energy. Energy is used to do work that makes life more productive and enjoyable. The Law of Conservation of Matter and Energy applies to phase changes, chemical changes, and nuclear changes that help run our modern world. With a complete understanding of these processes and their application to the modern world comes a responsibility to take care of waste, limit pollution, and decrease potential risks.

PERFORMANCE INDICATOR 4.1

Observe and describe transmission of various forms of energy.

Major Understandings:

4.1a Energy can exist in different forms, such as chemical, electrical, electromagnetic, thermal, mechanical, nuclear.

⟶ **LAB** *Thermochemistry* "Thermal Energy"

4.1b Chemical and physical changes can be exothermic or endothermic.

⟶ **LAB** *Kinetics* "Examining a Reaction Mechanism"

4.1c Energy released or absorbed during a chemical reaction can be represented by a potential energy diagram.

⟶ **LAB** *Kinetics* "Examining a Reaction Mechanism"

4.1d Energy released or absorbed during a chemical reaction (heat of reaction) is equal to the difference between the potential energy of the products and potential energy of the reactants.

⟶ **LAB** *Kinetics* "Examining a Reaction Mechanism"

PERFORMANCE INDICATOR 4.2

Explain heat in terms of kinetic molecular theory.

Major Understandings:

4.2a Heat is a transfer of energy (usually thermal energy) from a body of higher temperature to a body of lower temperature. Thermal energy is the energy associated with the random motion of atoms and molecules.

⟶ **LAB** *Thermochemistry* "Thermal Energy"

⟶ **DEMONSTRATION** *Chem. Thermodyn.* "Do all spontaneous processes involve a visible increase of disorder?"

4.2b Temperature is a measurement of the average kinetic energy of the particles in a sample of material. Temperature is not a form of energy.

⟶ **LAB** *Gases* "Mean Speed and Temperature"

4.2c The concepts of kinetic and potential energy can be used to explain physical processes that include: fusion (melting), solidification (freezing), vaporization (boiling, evaporation), condensation, sublimation, and deposition.

⟶ **LAB** *Liquids & Solids* "The Melting Transition"

⟶ **DEMONSTRATION** *Chemical Matter* "Do physical changes affect the amount of matter?"

Key Idea 5:

Energy and matter interact through forces that result in changes in motion.

Atoms and molecules are in constant motion. Chemical bonding between atoms involves energy and the interaction of electrons with atomic nuclei. Intermolecular attractions, which may be temporary, occur when there is an asymmetric distribution of charge.

Within all chemical interactions, matter and energy are conserved according to the Law of Conservation of Matter and Energy. During a chemical change energy is absorbed or released as bonds are broken or formed. In maintaining conservation of matter and energy, nuclear changes convert matter into energy. The energy released during a nuclear change is much greater than the energy released during a chemical change.

The discovery of the energy stored in the nucleus of an atom, its uses, and its inherent benefits and risks is a continuing process that began with the serendipitous detection of the first radioactive isotope. Early researchers added to this knowledge and expanded our ability to utilize this newly discovered phenomenon. Using radioactivity, the inner structure of the atom was defined by other researchers. Scientists involved in the development of nuclear fission and the atomic bomb explored both peaceful and destructive uses of nuclear energy. Modern researchers continue to search for ways in which the power of the nucleus can be used for the betterment of the world.

PERFORMANCE INDICATOR 5.2

Explain chemical bonding in terms of the behavior of electrons.

Major Understandings:

5.2a Chemical bonds are formed when valence electrons are:

- transferred from one atom to another (ionic)
- shared between atoms (covalent)
- mobile within a metal (metallic)

⟶ **Lab** *Chemical Bonding* "Exploring Ionic Interactions"

⟶ **Lab** *Chemical Bonding* "Electron Sharing in Molecules"

⟶ **Lab** *Chemical Bonding* "Energetics of Covalent Bonding"

5.2e In a multiple covalent bond, more than one pair of electrons are shared between two atoms. Unsaturated organic compounds contain at least one double or triple bond.

⟶ **Lab** *Organic Chemistry* "Isomers of Alkenes and Alkynes"

⟶ **Miscellaneous** *Organic Chemistry* "*cis-trans* Isomers"

5.2f Some elements exist in two or more forms in the same phase. These forms differ in their molecular or crystal structure, and hence in their properties.

⟶ **Demonstration** *Main Groups & Transition Metals* "How different are the allotropes of carbon?"

5.2g Two major categories of compounds are ionic and molecular (covalent) compounds.

⟶ **Miscellaneous** *Chemical Matter* "The Types of Compounds"

⟶ **Lab** *Liquids & Solids* "Bonding in Crystalline Solids"

5.2h Metals tend to react with nonmetals to form ionic compounds. Nonmetals tend to react with other nonmetals to form molecular (covalent) compounds. Ionic compounds containing polyatomic ions have both ionic and covalent bonding.

⟶ **Lab** *Chemical Bonding* "Polyatomic Ions"

5.2i When a bond is broken, energy is absorbed. When a bond is formed, energy is released.

⟶ **Lab** *Chemical Bonding* "Energetics of Covalent Bonding"

5.2j Electronegativity indicates how strongly an atom of an element attracts electrons in a chemical bond. Electronegativity values are assigned according to arbitrary scales.

⟶ **Lab** *Chemical Bonding* "Polar Bonds and Molecules"

5.2k The electronegativity difference between two bonded atoms is used to assess the degree of polarity in the bond.

⟶ **Lab** *Chemical Bonding* "Classifying by Bond Polarity"

5.2l Molecular polarity can be determined by the shape of the molecule and distribution of charge. Symmetrical (nonpolar) molecules include CO_2, CH_4, and diatomic elements. Asymmetrical (polar) molecules include HCl, NH_3, and H_2O.

⟶ **Lab** *Chemical Bonding* "Comparing Conceivable Shapes for a Molecule"

⟶ **Miscellaneous** *Chemical Bonding* "Dipole Moments"

5.2m Intermolecular forces created by the unequal distribution of charge result in varying degrees of attraction between molecules. Hydrogen bonding is an example of a strong intermolecular force.

⟶ **Lab** *Liquids & Solids* "Structure and Dynamics of Liquid Water"

⟶ **Miscellaneous** *Liquids & Solids* "Elements with HydrogenBonding"

5.2n Physical properties of substances can be explained in terms of chemical bonds and intermolecular forces. These properties include conductivity, malleability, solubility, hardness, melting point, and boiling point.

⟶ **Lab** *Liquids & Solids* "Intermolecular Forces"