Chemistry, Quarter 1, Unit 1.1

Kinetic Molecular Theory/Physical and Chemical Changes

Overview

Number of instructional days: 10 (1 day = 53 minutes)

Content to be learned

- Use appropriate data related to chemical and physical properties to distinguish one substance from another.
- Use appropriate data related to chemical and physical properties to identify an unknown substance.
- Explain the states of matter in terms of the particulate nature of matter.

Processes to be used

- Compare and contrast physical and chemical properties of matter.
- Make observations to classify changes of matter as physical or chemical.
- Model the gas, liquid, and solid states in terms of particles and their interactions.
- Define and give examples of plasma.

Essential questions

- What are the organizations and relative energies of particles in the four states of matter?
- How does a scientist classify changes of matter?
- How does a chemist use different physical and chemical properties to identify an unknown substance?

Written Curriculum

Grade Span Expectations

PS1 - All living and nonliving things are composed of matter having characteristic properties that distinguish one substance from another (independent of size or amount of substance).

PS1 (9-11) INQ –1

Use physical and chemical properties as determined through an investigation to identify a substance.

PS1 (9-11)–1 Students demonstrate an understanding of characteristic properties of matter by …

1a utilizing appropriate data (related to chemical and physical properties), to distinguish one substance from another or identify an unknown substance.

PS1 (Ext)–1 Students demonstrate an understanding of characteristic properties of matter by …

1aa explaining the states of a substance in terms of the particulate nature of matter ~~and the forces of interaction between particles~~.

Clarifying the Standards

Prior Learning

In grades K–2, students recorded and explained their observations as they grouped and sorted objects by physical properties. In grades 3–4, students learned how to sort objects using temperature and flexibility as they observed and described a change of state (e.g., freezing and thawing). In the fifth and sixth grades, students compared masses of objects of equal volume that were made of different substances. In eighth grade, they learned to measure mass and volume of both regular and irregular objects and to use those values along with the relationship $D = m/v$ to calculate density.

Current Learning

Since students have not had previous experiences with this content, instruction should begin at the developmental level. This content will not be addressed in future courses, therefore it must be taken to the level of drill and practice (mastery level).

Students examine physical and chemical properties of known substances and use those properties to help them identify an unknown substance. Within an investigation, students utilize appropriate data to distinguish changes of matter as physical or chemical; they also distinguish gas, liquid, and solid states in terms of particles and their interactions. Models are created and used to illustrate the three states of matter (solid, liquid, gas). Students also define and give examples of plasma.

Future Learning

Students will describe how pressure and temperature relate to the volume of a gas. Advanced students will quantitatively determine how the volume, pressure, temperature, and amount of a gas affect each other ($PV = nRT$).

Additional Research Findings

According to the *Atlas of Science Literacy* and *Making Sense of Secondary Science*, the concept of energy transformation among the different states of matter should have been taught prior to this unit (*Atlas*, p. 57; *Making Sense*, pp. 79–83).

Frequently, the concept that gases have mass and take up space is difficult for students to grasp; therefore it may be necessary to further explain the particle nature of gases. One suggested activity to help with this misconception is to mass an empty balloon, then have a student inflate the balloon, and mass it again. The small but measurable mass difference should clarify student understanding.

Research indicates that younger children tend to regard any rigid material as a solid, any powder as a liquid, and any nonrigid material—for example, a sponge or cloth—as intermediate between a solid and a liquid. Pupils explained that powders are liquids because they can be poured and that nonrigid materials are intermediate because they are soft, they crumble, or they can be torn. Thus, children decided the state of a material according to its appearance and behavior, with the result that they associated solidity with hardness, strength, and nonmalleability.

At age 11, pupils tend to regard powders as intermediate states rather than solids. Teachers might emphasize that powders are composed of small solids. However, researchers also caution that when students are subsequently learning the particulate theory of solids, they may wrongly infer that the theoretical particles are “powder grains.” Therefore, it is suggested that students first be comfortable with classifying materials according to the scientific view of the states of matter prior to learning particulate theory.

Children appear to identify a liquid as any material that is runny or can be poured. Consequently, their view of liquids includes powders. Further, in a child’s view, if the exemplary liquid is water, then all liquids may be regarded as water. Children may regard the liquid form of a material as having less weight than the same mass of its solid form.

Researchers have studied students’ conceptions of gases, and found that students do not initially appear to be aware that air and other gases possess material character. It is common for students to think that air and gas have contrasting affective connotations—for example: Air is good because it’s used for breathing and life, whereas gas is bad because it may be poisonous, dangerous, or inflammable.

When interviewed about what happens to a block of ice on a teaspoon, only 8 out of 43 students described the melting of ice in particle terms. Generally, pupils held the view that heat makes the particles move further apart. They appeared to use the underlined model that the volume of substances increases as its temperature rises, when unfortunately this model does not apply to melting ice.

Researchers found that pupils express the freezing process in terms of particles becoming more packed together. This idea may lead students to reason that water in its solid form (ice) doesn’t take up as much room as in its liquid or gaseous forms. Even though some pupils have been taught about latent heat and hydrogen bonding, none of them mentioned these concepts when explaining freezing.

When interviewed about what happens to water evaporating from a plate, only 8 out of 43 pupils mentioned particles are molecules. At least one was aware that the particles were “getting energy from somewhere and flying off.”

Pupils often regard atoms as small bits of solid or liquid that are static, nonuniform, and without cohesive force. Children appear to think that such bits vary in size and shape, having no space between them.

Researchers concluded that secondary school pupils understood most attributes of the particle model one at a time, but were unable to unify all particle behavior within a single concept.

Pupils aged 13 to 14 regarded the liquid state as halfway between solid and gas. As a result, pupils held ideas that greatly overestimated the spacing and speed of the particles of a liquid. The researchers suggest that, based on the pupils' misconceptions, a liquid would allow molecules to just move apart from each other. The liquid would also be compressible. Therefore, the pupils' model would not allow for explanation of evaporation.

Sixty percent of young adolescents indicated that gas is composed of particles; 46 percent said that there is empty space between particles; 50 percent said that intrinsic motion accounts for the distribution of particles in space.

Notes About Resources and Materials

Chemistry, Quarter 1, Unit 1.2

Atoms and Molecules

Overview

Number of instructional days: 10 (1 day = 53 minutes)

Content to be learned

- Explain how advances in technology have changed the understanding of atomic structure.
- Use data to explain how the understanding of atomic structure has changed.
- Compare the three subatomic particles of atoms (protons, electrons, neutrons).
- Compare the location within an atom, the relative mass, and the charge of the subatomic particles that make up an atom.

Processes to be used

- Conduct research about the structure of atoms.
- Compare and contrast the three subatomic particles of atoms in terms of location, mass, and charge.
- Use data such as diagrams, charts, and narratives.

Essential questions

- How have advances in technology changed our understanding of atomic structure?
- How are the three major subatomic particles similar and different?
- How is the current model of the atom different from previous models?
- How would you describe the current model of the atom in terms of the subatomic particles and their location within the atom?

Written Curriculum

Grade Span Expectations

PS1 - All living and nonliving things are composed of matter having characteristic properties that distinguish one substance from another (independent of size or amount of substance).

PS1 (9-11) MAS+ NOS –2

Scientific thought about atoms has changed over time. Using information (narratives or models of atoms) provided, cite evidence that has changed our understanding of the atom and the development of atomic theory.

PS1 (9-11)–2 Students demonstrate an understanding of characteristic properties of matter by …

2a using given data (diagrams, charts, narratives, etc.) and advances in technology to explain how the understanding of atomic structure has changed over time.

PS1 (9-11) MAS+ FAF – 4

Model and explain the structure of an atom or explain how an atom's electron configuration, particularly the outermost electron(s), determines how that atom can interact with other atoms.

PS1 (9-11)– 4 Students demonstrate an understanding of the structure of matter by …

4a comparing the three subatomic particles of atoms (protons, electrons, neutrons) and their location within an atom, their relative mass, and their charge.

Clarifying the Standards

Prior Learning

The concept of atoms and molecules was introduced in grades 5–6. In grade 6, students learned that, regardless of sample size, a substance can be identified by its properties. Students also learned to differentiate the characteristics of solids, liquids, and gases.

In grades 7–8, students created diagrams and/or models to represent the states of matter at the molecular level, and they identified an unknown substance given its characteristic properties.

Current Learning

Students cite evidence for the development of the historical models of the atom, starting with Dalton's atomic theory and continuing through the experiments of J.J. Thompson and Ernest Rutherford. The various modifications of the atomic model through the late 19th and 20th centuries are diagrammed. Students conduct investigations that simulate working with unknown structures.

Students compare the location of the three major subatomic particles of atoms (protons, electrons, and neutrons) and their location within an atom, their relative mass, and their charges.

Students have previously learned basic atomic structure (middle school–grade 9). This unit adds historical detail to the models.

Future Learning

In advanced chemistry classes, students will learn to write electron configurations to include *s, p, d*, and *f* orbitals. They will also relate to atomic interactions.

As part of the extension standards in biology, students will explain the energy transfer between cells in photosynthesis and cellular respiration, tracking ATP production and consumption (electron transfer chain).

Additional Research Findings

According to *Making Sense of Secondary Science*, students may mistakenly think that atoms are solid spheres. They also greatly exaggerate the distance among components of atoms. Physical and computer models should be used to help students accurately visualize atom structure. Students may also confuse the relative sizes of subatomic particles, especially the size of electrons, which are difficult to conceptualize (pp. 73–77).

Additionally, the *Atlas of Science Literacy* states that, to understand the content in this unit, students need to comprehend that the 100+ elements identified to date are the foundation for all matter and that these atoms are too small to be seen, even with a microscope. Finally, students should recognize that, while any given element's atoms are alike, they are different from atoms of other elements (p. 55).

Notes About Resources and Materials

Chemistry, Quarter 1, Unit 1.3

Nuclear Changes

Overview

Number of instructional days: 7 (1 day = 53 minutes)

Content to be learned

- Explain how the nuclear make-up of atoms governs alpha and beta emissions.
- Explain how alpha and beta emissions create changes in the nucleus of an atom that result in the formation of new elements and energy transformations.
- Explain the concept of half-life.
- Use the half-life principal to predict the approximate age of a material.
- Differentiate between fission and fusion in nuclear reactions.
- Differentiate between the relation of fission and fusion to element changes and energy formation.

Processes to be used

- Model and use symbolic representations to show changes within a system.
- Collect, analyze, and use data to predict the identity of the nuclear products.
- Model and make predictions based on data.
- Create and use simulations.

Essential questions

- What is the difference between alpha and beta emissions in terms of the energy and size of the particles and how does this determine the product of a nuclear reaction?
- How are new elements created in a nuclear reaction?
- How is half-life used to determine the approximate age of a material?
- How is fission different from fusion in terms of energy and products produced?

Written Curriculum

Grade Span Expectations

PS 2 - Energy is necessary for change to occur in matter. Energy can be stored, transferred, and transformed, but cannot be destroyed.

PS2 (9-11) INQ+SAE -6

Using information provided about chemical changes, draw conclusions about and explain the energy flow in a given chemical reaction (e.g., exothermic reactions, endothermic reactions).

PS2 (9-11) –6 Students demonstrate an understanding of physical, chemical, and nuclear changes by …

6c explaining and/or modeling how the nuclear make-up of atoms governs alpha and beta emissions creating changes in the nucleus of an atom results in the formation of new elements.

6d explaining the concept of half-life and using the half-life principal to predict the approximate age of a material

6e differentiating between fission and fusion in nuclear reactions and their relation to element changes and energy formation.

Clarifying the Standards

Prior Learning

Students in grades K–4 learned how light rays behave. In grades 5–6, students learned about the transfer heat energy. In grades 7–8, students learned the difference among conduction, convection, and radiation and how energy travels through different materials by each of these methods.

Current Learning

The concept of nuclear reactions is introduced for the first time at the high-school level. Students learn the structure of the nucleus and the nature of radioactive decay in terms of the particles emitted and the resulting changes in the nucleus. The concept of half-life and how it is used to determine the relative age of a substance is introduced. Students also learn to differentiate between fission and fusion in terms of the necessary conditions and products of the reactions; that all nuclear reactions involve changes in energy; and that nuclear radiation is a part of electromagnetic radiation. Through an investigation, students will demonstrate the concept of half-life.

Future Learning

Students will use the concept of half-life to determine the age of rock structures. They will demonstrate an understanding of the origin and evolution of galaxies and will explain the formation of the universe in terms of the Big Bang theory. Students will demonstrate an understanding of processes and change over time within the system of the universe and demonstrate an understanding of the life cycle of stars. In biology courses the concept of radioactive tracers is used as a tool to determine biochemical pathways, the age of fossils and artifacts.

Additional Research Findings

According to *Benchmarks for Science Literacy*:

> Understanding the general architecture of the atom and the roles played by the main constituents of the atom in determining the properties of materials now becomes relevant. Having learned earlier that all the atoms of an element are identical and are different from those of all other elements, students now come up against the idea that, on the contrary, atoms of the same element can differ in important ways.
>
> Students may at first take isotopes to be something in addition to atoms or as only the unusual, unstable nuclides. The most important features of isotopes are their nearly identical chemical behavior and different nuclear stabilities.
>
> The idea of half-life requires that students understand ratios and the multiplication of fractions, and be somewhat comfortable with probability. Games with manipulatives or computer simulations should help them in understanding the idea of how a constant proportional rate of decay is consistent with declining measures that only gradually approach zero. The mathematics of inferring backwards from measurements to age is not appropriate for most students (p. 79).

Notes About Resources and Materials

Chemistry, Quarter 1, Unit 1.4

Nuclear Applications

Overview

Number of instructional days: 10 (1 day = 53 minutes)

Content to be learned

- Describe various dating methods used to determine the age of different rock structures.
- Calculate the age of rocks from various regions using radioactive half-life.
- Given its constituent elements, isotopes, and rate of decay, provide evidence for geologic relationships between/among regions.
- Determine the relative age of rock structures by analyzing rock samples/rock data.

Processes to be used

- Model dating methods.
- Compare and contrast.
- Analyze data.

Essential questions

- How are dating methods used to determine the age of rock structures similar, and how are these dating methods different?
- How can constituent elements, isotopes, and rate of decay be used to calculate the age of a rock sample?
- How can geologic relationships among regions be determined?

Written Curriculum

Grade Span Expectations

ESS1 - The earth and earth materials as we know them today have developed over long periods of time, through continual change processes.

ESS1 (9-11) INQ+POC+ MAS—4

Relate how geologic time is determined using various dating methods (e.g. radioactive decay, rock sequences, fossil records).

ESS1 (9-11)—4 Students demonstrate an understanding of processes and change over time by …

4a describing various dating methods to determine the age of different rock structures.

4aa calculating the age of a rocks from various regions using radioactive half life (given its constituent elements, isotopes and rate of decay) and using those values to provide evidence for geologic relationships between/among the regions.

4bb analyzing samples of rock to determine the relative age of the rock structure.

Clarifying the Standards

Prior Learning

In grades K–4, students learned how physical erosion reshapes the land. In grades 7–8, students evaluated slow and fast processes to determine how the earth has changed over time, and in grade 9, students learned how heat effects the rock cycle and plate movement. Element cycling within the earth was also explored. Students in K–4 learned how light rays behave, and in grades 5–6, students learned about the transfer of heat energy. In grades 7–8, students learned the difference among conduction, convection, and radiation and how energy travels through different materials by each of these methods.

Current Learning

This unit requires students to apply their understanding of some key chemistry concepts that they learned previously. Instead of approaching this as an earth science unit in a chemistry class, it should be approached as a real-world application of chemistry principles. Students learn to describe various dating methods and use data to determine the relative and absolute age of rock samples and other materials, including the use of radioactive half-life to calculate the age of rocks and the analysis of the chemical composition of rocks to determine geologic relationships among different regions. Students should understand that rocks with similar chemical composition also have similar origins.

Future Learning

Students will engage in activities that help them understand how scientific theories about the structure of the universe have been advanced through the sophisticated use of technology.

Additional Research Findings

According to the *Atlas of Science Literacy*, prior to this unit, students must understand that thousands of layers of sedimentary rock have confirmed the long history of the changing surface of the earth and that the youngest layers are not necessarily found on top—due to folding, breaking, and uplift (p. 51).

Additionally, the *Science Curriculum Topic Study* states that crustal dynamics and geochemical processes provide a focus for understanding the solid earth (p. 68).

Making Sense of Secondary Science states that students may not fully understand the relative age of igneous, metamorphic, and sedimentary rocks due to misunderstanding of the method of rock formation. A brief review of rock types would eliminate this confusion (p. 113).

Notes About Resources and Materials