Chemistry, Quarter 3, Unit 3.1

Energy Transformations: Phases of Matter

Overview

Number of instructional days: 5 (1 day = 53 minutes)

Content to be learned

- Explain the states of a substance in terms of the particulate nature of matter.
- Explain the forces of interaction between particles.

Processes to be used

- Compare and contrast.
- Use and analyze models.
- Use measurement, evaluation, and calculation.

Essential questions

- How do inter-particle forces determine the behavior of a substance?
- How do you explain the states of matter in terms of the particles involved?
- What determines the amount of energy needed to change the state of a 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 (Ext)–1Students 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–4, students learned to observe and describe physical changes (e.g., freezing, thawing, tearing pieces of paper). In grades 5–6, students demonstrated an understanding of characteristic properties of matter by comparing the masses of equal volumes of different substances. In grades 7–8, students measured mass and volume of regular and irregular objects and used those values as well as the relationship $D = m/v$ to calculate density.

Current Learning

In quarter 1, students are introduced to the concept of matter and the particle characteristics of each phase.

Students explain the states of a substance in terms of the particulate nature of matter and the forces of interaction between the particles. They use the concept of physical equilibrium to explain change of state and its dependence on temperature and pressure. Energy flow within the system is explained along with the concepts of heat of fusion and heat of vaporization. To be successful, students need to understand electron configuration and chemical bonding, specifically, intermolecular forces as determined by electronegativity differences.

Students engage in an investigation that demonstrates heating and cooling curves in relation to phase and energy changes. They evaluate data in relation to phase diagrams and compare both melting and boiling points of various substances (heat of fusion and heat of vaporization). The learning in this unit will extend previous knowledge by linking subatomic interaction to macroscopic observations. Students have not previously related chemical bonding to the behavior of matter.

Future Learning

Students will determine the degree of change in the pressure of a given volume of gas when the temperature changes incrementally (doubles, triples, etc.). Advanced students will quantitatively determine how pressure, volume, temperature, and amount of gas affect each other ($PV = nRT$) in a system. In advanced physics courses, students will learn how temperature and pressure changes affect sound transmissions. Students will investigate the composition of stars as a function of the temperature and pressure of component gases.

Additional Research Findings

According to the *Atlas of Science Literacy,* vol.1, "an enormous variety of biological, chemical, and physical phenomena can be explained by changes in the arrangement and motion of atoms and molecules." (p. 59)

According to the *Atlas of Science Literacy*, vol. 2, students need to understand how the configuration of atoms in a molecule determines the molecule's properties. Shapes are particularly important in how large molecules interact with others. This foundational information is not mandated by the GSEs and may need to be taught in order for students to fully understand the content in this unit of study (p. 55).

A study of 15-year-olds by Engel, Clough, and Driver found that very few students understood heat transfer in terms of the behavior of particles. Less than 5 percent of the sample attempted to describe conduction in terms of particles and only a few of these used the accepted terms (*Making Sense of Secondary Science*, pp. 142).

Students need to understand that all matter, including the gas phase, has matter and takes up space. "Pupils may not regard 'gas' as having weight or mass" and "Cosgrove and Osborne found that many children of 8- to 17-year-olds regarded melting as similar to dissolving in that it is a gradual process and, in their view, almost unconnected with a particular temperature" (*Making Sense,* pp. 80, 81).

Erickson reports that distinguishing between the concepts of heat and temperature was one of the most difficult tasks for children (*Making Sense,* p. 139).

Students may find it difficult to transition from concrete, visual evidence to more abstract models of particle interactions.

According to *Benchmarks for Science Literacy,* "No matter how substances within a closed system interact with one another or how they combine or break apart, the total weight of the system remains the same. The idea of atoms explains the conservation of matter: If the number of atoms stays the same no matter how they are rearranged, then their total mass stays the same" (p. 79).

According to *Benchmarks for Science Literacy*, "Different energy levels are associated with different configurations of atoms and molecules. Some changes of configuration require an input of energy whereas others release energy." (p.86)

"When matter gets cold enough, atoms or molecules lock in place in a more or less orderly fashion as in solids. Increasing the temperature means increasing the average energy of motion of the atoms. So if the temperature is increased, atoms and molecules become more agitated and usually move slightly farther apart; that is, the material expands. At higher temperatures, the atoms and molecules are more agitated still and can slide past one another while remaining loosely bound, as in a liquid. At still higher temperatures, the agitation of the atoms and molecules overcomes the attractions between them and they can move around freely, interacting only when they happen to come very close-usually bouncing off one another, as in a gas." (*Science for All Americans* p.48)

Notes About Resources and Materials

Suggested websites

- National Science Foundation—Concord Consortium—Chemistry activities
  <http://www.concord.org/activities/subject/chemistry>

- National Science Foundation—Concord Consortium—Molecular Workbench
  <http://mw.concord.org/modeler/>

Chemistry, Quarter 3, Unit 3.2

Gas Law

Overview

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

Content to be learned

- Demonstrate understanding of characteristic properties of matter.
- Determine the degree of change in pressure of a given volume of gas when the temperature changes incrementally.
- Advanced students will quantitatively determine how volume, pressure, temperature, and amount of gas affect each other in a system.

Processes to be used

- Make observations, analyze, and calculate.
- Manipulate and rearrange gas law formulas.

Essential questions

- What is the relationship among temperature, pressure, and volume in an ideal gas?
- Given the quantity of a gas, its temperature, and its volume, how do you determine its pressure?

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 …

1b determining the degree of change in pressure of a given volume of gas when the temperature changes incrementally (doubles, triples, etc.).

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

1bb quantitatively determining how volume, pressure, temperature and amount of gas affect each other (PV=nRT) in a system.

Clarifying the Standards

Prior Learning

In grades K–4, students learned to observe and describe physical changes (e.g. freezing, thawing, tearing pieces of paper). In grades 5–6, students demonstrated an understanding of characteristic properties of matter by comparing the masses of equal volumes of different substances. In grades 7–8, students measured mass and volume of regular and irregular objects and used those values as well as the relationship $D = m/v$ to calculate density.

Current Learning

Students learn that ideal gases obey certain relationships. They learn the relationship between volume and pressure of a gas when the temperature is held constant (Boyle’s Law); the relationship between the temperature and volume of a gas when pressure is held constant (Charles’ Law); and the relationship between temperature and pressure of a gas if the volume is held constant (Gay-Lussac’s Law). Students also learn that these laws can be combined into one mathematical relationship (combined gas law). Advanced students describe the relationship between temperature, volume, pressure, and quantity of gas in the ideal gas law. Students need to be able to manipulate algebraic equations and to apply dimensional analysis to convert units.

Students qualitatively investigate the relationship between the pressure, temperature, and volume of gases in a laboratory setting. Lab experience includes the use of a piston/syringe-type apparatus to investigate pressure and volume at constant temperature. Students will use everyday items, such as a balloon and an ice bath/heat source, to investigate temperature and volume with constant pressure. Physical equilibrium and the pressure/volume relationship can be demonstrated using a vacuum pump. Students also practice gas law problems using the four formulas.

Quantitative skills, such as algebraic manipulation, are utilized for the first time with this content. The mathematical relationships of the gas laws are introduced. While students have described the states of matter, they will now understand that the behavior of matter in the gas phase can be quantified.

Some online resources that may be helpful are:

- National Science Foundation—Concord Consortium—Molecular Workbench

  <http://mw.concord.org/modeler/>

- National Science Foundation—Math and Science Partnership Network— Rhode Island Technology Enhanced Science Program (RITES)—Profile

  <http://rites.mspnet.org/index.cfm/profile>

- National Science Foundation—Concord Consortium—Rhode Island Technology Enhanced Science Program (RITES)—Materials: Materials, Investigations, and Probes

  <http://rites.concord.org/materials.html>

Future Learning

Advanced students will further apply gas laws to chemical equations and learn to predict the volume of gas produced in a chemical reaction given appropriate data (stoichiometry). In future elective courses such as environmental studies, aquaculture, and anatomy/physiology, students will examine phenomena involving gases such as global weather patterns, dissolved gases, and respiration.

Additional Research Findings

According to the *Atlas of Science Literacy*, vol. 1, in gases, the atoms or molecules have still more energy and are free of one another, except during occasional collisions (p. 59).

Science Matters states: At extreme high temperatures like those of the sun, a gas-like state of matter, plasma exists (fluorescent lights, plasma television). At very high temperatures, 100,000 Kelvin, electrons are completely stripped away. Plasmas have different physical properties such as conducting electricity. This foundational information is not mandated by the GSEs, but may need to be taught in order for students to fully understand the content in this unit of study (pp. 117–118).

The algebraic manipulations, dimensional analysis, and multiple pressure units will prove most challenging for students.

“Symbolic statements can be manipulated by rules of mathematical logic to produce other statements of the same relationship, which may show some interesting aspect more clearly” (*Atlas*, vol. 1, p. 27).

Researchers have found that students were less inclined to think in terms of pressure acting in all directions in air. Students tend to associate pressure and gases with *moving* air and assume that pressure acts only in moving gases and not static gases (*Making Sense of Secondary Science*, p. 152).

Particles crowded into a smaller space will increase pressure. Heating gases and causing the molecules to move faster and collide with more force also increases pressure (*Science Matters*, p. 117).

Due to the vastly different background knowledge and skills in algebra, teachers will need to teach and re-teach algebra skills in the context of the gas laws.

Chemistry, Quarter 3, Unit 3.3

Compounds and Formulas

Overview

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

Content to be learned

- Demonstrate understanding of how an element's electron configuration determines its oxidation state(s) and use this information to write chemical formulas.
- Demonstrate understanding of the structure of matter by writing formulae for compounds.
- Demonstrate understanding of the structure of matter by developing basic (excluding transition elements) models using electron structure.

Processes to be used

- Model chemical formulas and nomenclature.
- Use Lewis structures to determine valence electrons and bonding sites.
- Predict oxidation states.

Essential questions

- What process is used for naming compounds?
- What information is needed to write a correct chemical formula?
- Given the chemical formula of an ionic compound, how are the oxidation states of the component ions determined?

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+ 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 …

4b writing formulae for compounds and developing basic (excluding transition elements) models using electron structure.

Clarifying the Standards

Prior Learning

In grades 5 and 6, students distinguished among solutions, mixtures, and pure substances. In grades 7–8, students classified common elements using symbols and simple chemical formulas.

Current Learning

Students learn to write ionic formulas using predicted oxidation states. Common mono and polyatomic ions are introduced. Formulas are constructed using the laws of ions or balancing charges. Naming conventions (traditional and stock system) are introduced and applied, as are conventions of molecular nomenclature (traditional and stock system). Using formulas to determine percent composition is learned.

Advanced students are given percent or mass data to determine the empirical formula of compounds. Students will need to perform integer operations (least common multiple LCD) to balance the ionic charges. Students perform percent composition calculations. In addition, they recognize and recall the most common elements names/symbols. Students are engaged in activities involving correctly naming and writing formulas such as chemistry "bingo", puzzle cards, grids, and drill-and-practice. The laboratory experience may involve percent composition of a penny, the hydration of a tomato, or the composition of a hydrate.

Previously, students used symbols to represent chemical formulas. In this unit of study, they construct more varied and complex formulas. Students differentiate between ionic and covalent/molecular formulas. By the end of this unit, students should be able to write the formula and name any compound given its oxidation state information and corresponding elements.

Future Learning

Students will need this unit's information to be able to write, and correctly balance chemical equations. Advanced students will use this information to solve mass-mass stoichiometry problems. Students will use this information when enrolled in biology to study the biochemical reactions such as cellular respiration, photosynthesis, protein synthesis, and ecological nutrient cycling.

Additional Research Findings

According to the *Atlas of Science Literacy* vol. 1, in terms of chemical reactions, “A system usually has some properties that are different from those of its parts, but appear because of the interactions of those parts.” This foundational information is not mandated by the GSEs, but may need to be taught in order for students to fully understand the content in this unit of study (p. 55).

Learning and retaining the necessary steps to correctly name and write chemical formulas may be challenging for students. The concept of the polyatomic ion as a “charged molecule” could be a difficult. It is important for students to understand that covalent bonds are stronger than the electrostatic forces holding the ionic network together. Consequently, these polyatomic covalent bonds rarely break during chemical reactions.

According to *Benchmarks for Science Literacy*, students need to understand that “atoms often join with one another in various combinations in distinct molecules or in repeating three-dimensional crystal patterns. An enormous variety of biological, chemical, and physical phenomena can be explained by changes in the arrangement and motion of atoms and molecules.” Teachers may encounter difficulty in providing students with adequate visual and tactile representation of chemical formulas (p. 80).

Teachers should provide multiple sensory manipulatives such as puzzle cards to practice the steps needed to correctly name and write chemical formulas. Teachers could also use online tutorials to reinforce the process of chemical nomenclature and writing chemical formulas.

Chemistry, Quarter 3, Unit 3.4

Conservation of Energy

Overview

Number of instructional days: 5 (1 day = 53 minutes)

Content to be learned

- Describe or diagram the changes in energy that occur in different systems.
- Explain the Law of Conservation of Energy as it relates to the efficiency of a system.
- Advanced students will quantitatively determine the efficiency of a given system.

Processes to be used

- Measure and calculate the specific heat of a substance.
- Manipulate formulas.

Essential questions

- How is heat transferred within a material or from one material to another?
- What is the difference between the temperature of water in a glass and the amount of heat contained in the same glass?
- How can specific heat capacity be used to determine the identity of an unknown substance?
- What conditions are necessary for heat transfer to occur?

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) POC+SAE -5

Demonstrate how transformations of energy produce some energy in the form of heat and therefore the efficiency of the system is reduced (chemical, biological, and physical systems).

PS2 (9-11)-5 Students demonstrate an understanding of energy by…

5a describing or diagraming the changes in energy (transformation) that occur in different systems (eg. chemical = exo and endo thermic reactions, biological = food webs, physical = phase changes).

5b explaining the Law of Conservation of Energy as it relates to the efficiency (loss of heat) of a system.

PS2 (Ext)– 5 Students demonstrate an understanding of energy by…

5bb quantitatively determining the efficiency of a given system.

Clarifying the Standards

Prior Learning

In grades K–4, students described and showed that heat could be produced in many ways. In grades 5 and 6, students differentiated among the properties of various forms of energy. In grades 7 and 8, students constructed models to explain the transformation of energy from one form to another and explained that while energy may be stored, transferred, or transformed, the total amount of energy is conserved.

Current Learning

Students describe the changes in energy (transformation) that occur in different materials. They learn to calculate energy changes between materials. Students also learn to calculate the specific heat capacity of materials and use this property to identify an unknown substance. Advanced students identify sources of heat “loss” in the system and calculate the efficiency using percent error. Students need to perform algebraic manipulations and dimensional analysis. They are engaged in practice problems involving calculating heat transfer and specific heat capacity. In a laboratory setting, students measure temperature changes that occur when different materials are mixed and calculate the energy transfer that occurs. This information is used to calculate specific heat and to identify an unknown substance. Advanced students calculate the percent error and consequently determine the efficiency of the system.

Students previously learned that energy is transferred and transformed. In this unit, they calculate the quantities of energy transferred. For the first time, students learn that different materials have their own specific heat capacities due to unique atomic compositions.

Future Learning

Students will use this knowledge in future units to identify exothermic and endothermic chemical reactions. In more advanced chemistry courses, students will calculate entropy, enthalpy, and Gibbs free energy.

Additional Research Findings

According to the *Atlas of Science Literacy*, vol. 2, "As energy spreads out, whether by conduction, convection, or radiation, the total amount of energy stays the same. However, since it is spread out, less can be done with it. Thermal energy in a system is associated with the disordered motions of its atoms or molecules. Chemical energy is associated with the configuration of atoms and molecules that make up a substance. Some changes of configuration require net input of energy, whereas others cause a net release." This foundational information is not mandated by the GSEs, but may need to be taught in order for students to fully understand the content in this unit of study (p. 25).

Making Sense of Secondary Science states that students may find differentiating between heat and temperature difficult. "The words 'temperature' and 'heat' are often used interchangeably, but scientists think of the two terms in distinct ways. Heat refers to the total amount of atomic kinetic and potential energy of a material; temperature is a measure of the average kinetic energy of the particles" (p. 139). This unit requires algebraic manipulations. It also uses symbols to represent quantities that students may find confusing. One major challenge in teaching this content is the variance in students' math abilities.

One activity that may help students overcome challenges in this unit of study is to compare the heat content of the ocean to that of a pail of water. Although these two bodies may have different amounts of heat, their temperatures may be the same. The hands-on experience of measuring temperature changes based on the amount of material will help solidify the difference between heat and temperature.

According to the Benchmarks for Science Literacy, "Heat energy itself is a surprisingly difficult idea for students, who thoroughly confound it with the idea of temperature. A great deal of work is required for students to make the distinction successfully…" (p.81)

According to the Benchmarks for Science Literacy, "Transformations of energy usually produce some energy in the form of heat, which spreads around by radiation or conduction into cooler places. Although just as much total energy remains, its being spread out more evenly means less can be done with it." (p.86)