Structure and Properties of Matter

Overview

Unit abstract

Upon completion of this unit of study, students will be able to apply an understanding that pure substances have characteristic physical and chemical properties and are made from a single type of atom or molecule. They will be able to provide molecular-level accounts to explain that chemical reactions involve regrouping of atoms to form new substances, and that atoms rearrange during chemical reactions. Students are expected to demonstrate proficiency in developing and using models and analyzing and interpreting data. Students use these science and engineering practices to demonstrate understanding of the disciplinary core ideas. The crosscutting concepts of scale, proportion, and quantity will support student understanding across the unit of study.

Essential questions

- How do atomic and molecular interactions explain the properties of matter that we see and feel?

- How can particles combine to produce a substance with different properties?

- What happens when new materials are formed? What stays the same and what changes?

Written Curriculum

Next Generation Science Standards[1]

MS. Structure and Properties of Matter
Students who demonstrate understanding can:

MS-PS1-1.   Develop models to describe the atomic composition of simple molecules and extended structures. [Clarification Statement: Emphasis is on developing models of molecules that vary in complexity. Examples of simple molecules could include ammonia and methanol. Examples of extended structures could include sodium chloride or diamonds. Examples of molecular-level models could include drawings, 3D ball and stick structures, or computer representations showing different molecules with different types of atoms.] [Assessment Boundary: Assessment does not include valence electrons and bonding energy, discussing the ionic nature of subunits of complex structures, or a complete depiction of all individual atoms in a complex molecule or extended structure.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to describe, test, and predict more abstract phenomena and design systems. ▪ Develop a model to predict and/or describe phenomena. (MS-PS1-1)	**PS1.A: Structure and Properties of Matter** ▪ Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS-PS1-1) ▪ Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals). (MS-PS1-1)	**Scale, Proportion, and Quantity** ▪ Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-PS1-1)

Connections to other DCIs in this grade-band: **MS.ESS2.A** (MS-PS1-2)
Articulation of DCIs across grade-bands: **5.PS1.A** (MS-PS1-1); **HS.PS1.A** (MS-PS1-1) **HS.ESS1.A** (MS-PS1-1)
Common Core State Standards Connections: *ELA/Literacy -* *RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-PS1-1)* *Mathematics -* *MP.2 Reason abstractly and quantitatively. (MS-PS1-1),(MS-PS1-2)* *MP.4 Model with mathematics. (MS-PS1-1)* *6.RP.A.3 Use ratio and rate reasoning to solve real-world and mathematical problems. (MS-PS1-1),(MS-PS1-2)* *8.EE.A.3 Use numbers expressed in the form of a single digit times an integer power of 10 to estimate very large or very small quantities, and to express how many times as much one is than the other. (MS-PS1-1)*

MS. Chemical Reactions

Students who demonstrate understanding can:

MS-PS1-2. **Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.** [Clarification Statement: Examples of reactions could include burning sugar or steel wool, fat reacting with sodium hydroxide, and mixing zinc with hydrogen chloride.] [Assessment Boundary: Assessment is limited to analysis of the following properties: density, melting point, boiling point, solubility, flammability, and odor.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Analyzing and Interpreting Data Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. - Analyze and interpret data to determine similarities and differences in findings. (MS-PS1-2) -------------------------------------- ***Connections to Nature of Science*** **Scientific Knowledge is Based on Empirical Evidence** - Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS1-2)	**PS1.A: Structure and Properties of Matter** - Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (MS-PS1-2) *(Note: This Disciplinary Core Idea is also addressed by MS-PS1-3.)* **PS1.B: Chemical Reactions** - Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS-PS1-2) *(Note: This Disciplinary Core Idea is also addressed by MS-PS1-3.)*	**Patterns** Macroscopic patterns are related to the nature of microscopic and atomic-level structure. (MS-PS1-2)

Connections to other DCIs in this grade-band: **MS.PS3.D** (MS-PS1-2); **MS.LS1.C** (MS-PS1-2); **MS.ESS2.A** (MS-PS1-2)

Articulation across grade-bands: **5.PS1.B** (MS-PS1-2); **HS.PS1.B** (MS-PS1-2)

Common Core State Standards connections: ELA/Literacy

RST.6-8.1	Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions *(MS-PS1-2)*
RST.6-8.7	Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-PS1-2)

Common Core State Standards connections: Mathematics

MP.2	Reason abstractly and quantitatively. (MS-PS1-2)
6.RP.A.3	Use ratio and rate reasoning to solve real-world and mathematical problems. *(MS-PS1-2)*
6.SP.B.4	Display numerical data in plots on a number line, including dot plots, histograms, and box plots. *(MS-PS1-2)*
6.SP.B.5	Summarize numerical data sets in relation to their context (MS-PS1-2)

Clarifying the standards

Prior learning

The following disciplinary core ideas are prior learning for the concepts in this unit of study. By the end of Grade 5, students know that:

- Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means.

- A model showing that gases are made from matter particles that are too small to see and are moving freely around in space can explain many observations, including the inflation and shape of a balloon and the effects of air on larger particles or objects.

- The amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish.

- Measurements of a variety of observable properties can be used to identify materials. (Boundary: At this grade level, mass and weight were not distinguished, and no attempt was made to define the unseen particles or explain the atomic-scale mechanism of evaporation and condensation.)

- When two or more different substances are mixed, a new substance with different properties may be formed.

- No matter what reaction or change in properties occurs, the total mass of the substances does not change. (Boundary: Mass and weight were distinguished at this grade level.)

Progression of current learning

Driving question 1
How can models be used to describe the atomic composition of simple molecules and extended structures?

Concepts	Practices
- Substances are made from different types of atoms. –Atoms are the basic units of matter - Substances combine with one another in various ways. –Molecules are two or more atoms joined together - Atoms form molecules that range in size from two to thousands of atoms. –Molecules can be simple or very complex - Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).	- Develop a model of a simple molecule. - Use the model of the simple molecule to describe its atomic composition. - Develop a model of an extended structure. - Use the model of the extended structure to describe its repeating subunits.

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- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).
  –Repeating subunits form patterns.
  –Diamonds and sodium chloride are composed of repeating subunits.

Driving question 2

How can data on the properties of substances before and after the substances interact be used to determine whether a chemical reaction has occurred?

Concepts	Practices
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. - Substances react chemically in characteristic ways. - In a chemical process, the atoms that make up the original substances are regrouped into different molecules; these new substances have different properties from those of the reactants. - The analysis of data on the properties of products and reactants can be used to determine whether a chemical process has occurred. - Density, melting point, boiling point, solubility, flammability, and odor are characteristic properties that can be used to identify a pure substance. - Macroscopic patterns are related to the nature of the atomic-level structure of a substance.	- Analyze and interpret data to determine similarities and differences from results of chemical reactions between substances before and after they undergo a chemical process. - Analyze and interpret data on the properties of substances before and after they undergo a chemical process. - Identify and describe possible correlation and causation relationships evidenced in chemical reactions. - Make logical and conceptual connections between evidence that chemical reactions have occurred and explanations of the properties of substances before and after they undergo a chemical process.

Integration of content, practices, and crosscutting concepts

Within this unit, students will use informational text and models (which can include student-generated drawings, 3-D ball-and-stick structures, or computer representations) to understand that matter is composed of atoms and molecules. These models should reflect that substances are made from different types of atoms. Student models can be manipulated to show that molecules can be disassembled into their various atoms and reassembled into new substances according to chemical reactions. This scientific knowledge can be used to explain the properties of substances. Students will examine and differentiate between physical and chemical properties of matter. They are limited to the analysis of the following characteristic properties: density, melting point, boiling point, solubility, flammability, and odor. This analysis of properties serves as evidence to support that chemical reactions of substances cause a rearrangement of atoms to form different molecules.

Students will also recognize that they are using models to observe phenomena too small to be seen. Students who demonstrate this understanding can develop or modify a model of simple molecules to describe the molecules' atomic composition. Examples of molecules that can be modeled include water, oxygen, carbon dioxide, ammonia, and methanol. Additionally, students will develop and modify a model that describes the atomic composition of an extended structure showing a pattern of repeating subunits. Examples may include sodium chloride and diamonds. Due to the repeating subunit patterns, models can include student-generated drawings, 3-D ball-and-stick structures, and computer representations.

Building upon these experiences, students will analyze and interpret data on the properties of substances in order to provide evidence that a chemical reaction has occurred. They will also analyze and interpret data to determine similarities and differences in findings. Students will recognize that macroscopic patterns are related to the nature of microscopic and atomic-level structure. They will use patterns to identify cause-and-effect relationships and graphs and charts to identify patterns in data.

Integration of mathematics and/or English Language Arts/literacy

Mathematics

- Integrate quantitative or technical information about the composition of simple molecules and extended structures that is expressed in words in a text with a version of that information expressed in a model.

- Reason quantitatively (with amounts, numbers, sizes) and abstractly (with variables).

- Develop a mathematical model to describe the atomic composition of simple molecules and extended structures.

- Use ratio and rate reasoning to describe the atomic composition of simple molecules and extended structures.

- Reason quantitatively with amounts, numbers, and sizes for properties like density, melting point, boiling point, solubility, flammability, and odor, and reason abstractly by assigning labels or symbols.

- Use ratio and rate reasoning to determine whether a chemical reaction has occurred.

- Display numerical data for properties such as density, melting point, solubility, flammability, and order in plots on a number line, including dot plots, histograms, and box plots.

- Summarize numerical data sets on the properties of substances before and after the substances interact to determine whether a chemical reaction has occurred. The summary of the numerical data sets must be in relation to their context.

English language arts/literacy

- Cite specific textual evidence to support analysis of science and technical texts on the characteristic properties of pure substances. Attend to precise details of explanations or descriptions about the properties of substances before and after they undergo a chemical process.

- Integrate qualitative information (flowcharts, diagrams, models, graphs, or tables) about the characteristic properties of substances before and after a chemical process has occurred with a version of that information expressed visually, *or* integrate technical information about the characteristic properties of substances before and after a chemical process has occurred with a version of that information expressed visually.

Future learning

Physical science

Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons surrounded by electrons.

The periodic table orders elements horizontally according to the number of protons in the atom's nucleus; it organizes elements with similar chemical properties vertically, in columns. The repeating patterns of this table reflect patterns of outer electron states.

The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.

A stable molecule has less energy than the same set of atoms separated; at least this much energy must be provided in order to take the molecule apart.

Earth and space science

The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years.

The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.

The Big Bang theory is supported by observations of distant galaxies receding from our own, by the measured composition of stars and nonstellar gases, and by the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe.

Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.

Chemical processes, their rates, and whether or not they store or release energy can be understood in terms of collisions of molecules and rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.

In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present.

The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.

Number of Instructional Days

Recommended number of instructional days: 18 (1 day = approximately 50 minutes)

Note—The recommended number of days is an estimate based on the information available at this time. Teachers are strongly encouraged to review the entire unit of study carefully and collaboratively to determine whether adjustments to this estimate need to be made.