

Unit Summary		
<p><i>How can we trace synthetic materials back to natural ingredients?</i></p> <p>Students build understandings of what occurs at the atomic and molecular scale. Students apply their understanding that pure substances have characteristic properties and are made from a single type of atom or molecule. They also provide a molecular level accounts to explain states of matter and changes between states. The crosscutting concepts of <i>cause and effect</i>, <i>scale</i>, <i>proportion and quantity</i>, <i>structure and function</i>, <i>interdependence of science, engineering, and technology</i>, and <i>the influence of science, engineering and technology on society and the natural world</i> provide a framework for understanding the disciplinary core ideas. Students demonstrate grade appropriate proficiency in <i>developing and using models</i>, and <i>obtaining, evaluating, and communicating information</i>. Students are also expected to use the scientific and engineering practices to demonstrate understanding of the core ideas.</p>		
Student Learning Objectives		
<p>Gather and make sense of information to describe that synthetic materials come from natural resources and impact society. <i>[Clarification Statement: Emphasis is on natural resources that undergo a chemical process to form the synthetic material. Examples of new materials could include new medicine, foods, and alternative fuels.] [Assessment Boundary: Assessment is limited to qualitative information.]</i> (MS-PS1-3)</p>		
<p>Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed. <i>[Clarification Statement: Emphasis is on qualitative molecular-level models of solids, liquids, and gases to show that adding or removing thermal energy increases or decreases kinetic energy of the particles until a change of state occurs. Examples of models could include drawings and diagrams. Examples of particles could include molecules or inert atoms. Examples of pure substances could include water, carbon dioxide, and helium.]</i> (MS-PS1-4)</p>		
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Unit Sequence	
Part A: <i>How can you tell what the molecules are doing in a substance?</i>	
Concepts	Formative Assessment
<ul style="list-style-type: none"> Changes in particle motion, temperature, and state of a pure substance occur when thermal energy is added or removed. Qualitative molecular-level models of solids, liquids, and gases can be used to show that adding or removing thermal energy increases or decreases the kinetic energy of the particles until a change of state occurs. Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. In a liquid, the molecules are constantly in contact with others. In a gas, the molecules are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. The changes of state that occur with variations in temperature or pressure can be described and predicted using models of matter. The term heat as used in everyday language refers both to thermal energy and the transfer of that thermal energy from one object to another. Thermal energy is the motion of atoms or molecules within a substance. In science, heat is used to refer to the energy transferred due to the temperature difference between two objects. The temperature of a system is proportional to the average internal kinetic energy and potential energy per atom or molecule (whichever is the appropriate building block for the system's material). The details of the relationship between the average internal kinetic energy and the potential energy per atom or molecule depend on the type of atom or molecule and the interactions among the atoms in the material. Temperature is not a direct measure of a system's total thermal energy. The total thermal energy (sometimes called the total internal energy) of a system depends jointly on the temperature, the total number of atoms in 	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> Develop a model that predicts and describes changes in particle motion that could include molecules or inert atoms or pure substances. Use cause-and-effect relationships to predict changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed in natural or designed systems.

<p>the system, and the state of the material.</p> <ul style="list-style-type: none"> • Cause-and-effect relationships may be used to predict and describe changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed in natural systems. 	
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Unit Sequence	
Part B: How can we trace synthetic materials back to natural ingredients?	
Concepts	Formative Assessment
<ul style="list-style-type: none"> • Each pure substance has characteristic physical and chemical properties 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. • New substances that result from chemical processes have different properties from those of the reactants. • Natural resources can undergo a chemical process to form synthetic material. • Structures can be designed to serve particular functions by taking into account properties of different materials and how materials can be shaped and used. • Engineering advances have led to discoveries of important synthetic materials, and scientific discoveries have led to the development of entire industries and engineered systems using these materials. • Technology use varies from region to region and over time. • The uses of technologies (engineered/synthetic materials) and any limitations on their use are driven by individual or societal needs, desires, and values. • The uses of technologies (engineered/synthetic materials) and any limitations on their use are driven by the findings of scientific research and by differences in such factors as climate, natural resources, and economic conditions. 	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> • Obtain, evaluate, and communicate information to show that synthetic materials come from natural resources and affect society. • Gather, read, and synthesize information about how synthetic materials formed from natural resources affect society. • Assess the credibility, accuracy, and possible bias of each publication and methods used within the publication. • Describe how information about how synthetic materials formed from natural resources affect society is supported or not supported by evidence.

What It Looks Like in the Classroom

Students will locate information that describes changes in particle motion, changes in temperature, or changes in state as thermal energy is added to or removed from a pure substance. Students will then use models to predict and describe the changes in particle motion, temperature, and state of a pure substance. An example could include the change of state of water from its solid (ice) to liquid and vapor with the addition of thermal energy. Students will come to understand that this process is reversible through the removal of thermal energy, where the pure substance can return from a vapor to a liquid and back to a solid state.

Students who accurately demonstrate understanding will be able to develop qualitative molecular-level models of solids, liquids, and gases to show the cause-and-effect relationships of adding or removing thermal energy, which increases or decreases the kinetic energy of the particles until a change of state occurs. Models could include drawings and diagrams.

Students will also need to use mathematics to demonstrate their understanding of the particle motion that is taking place during these changes in state. They will use positive and negative numbers to represent the changes in particle motion and temperature as thermal energy is added or removed. They will then integrate an expression of that same quantitative information in a visual format.

It is important to note that students will need to be responsible for developing the models that they use. It is possible that the teacher could model the process with one type of model and provide opportunities for students to use different types of model to illustrate the same process. After students have a firm understanding of the motion of particles during a phase change, they will be able to move to the next section of this unit. In this portion of the unit of study, students will apply their understanding of particle and chemical change from Unit 1 to make sense of how natural resources react chemically to produce new substances. Students will explain that as a result of the rearrangement of atoms during a chemical process, the synthetic substance has different characteristic properties than the original pure substance. For example, pure substances like methane, carbon monoxide, and carbon dioxide can be combined chemically to form synthetic fuel. The synthetic fuel would have different characteristic properties than the original pure substances.

Within this unit, students will gather, read, and synthesize qualitative information from multiple sources about the use of natural resources to form synthetic materials and how these new materials affect society. Examples of new materials could include new medicine, foods, and alternative fuels. Some sources could include journals, articles, brochures, or digital media from government publications and/or private industries. Students will cite some of these sources to support the analysis of evidence that these synthetic materials were formed from natural resources and have an impact on society. They will pay special attention to the precise details of explanations or descriptions of how these new substances affect society. Students will also include relevant information from multiple print and digital sources about these impacts. While gathering this information, they will use search terms effectively, assess the credibility and accuracy of each source, and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Cite specific text to support the analysis of evidence that synthetic materials formed from natural resources affect society. Attend to the precise details of explanations or descriptions.
- Gather relevant information from multiple print and digital sources about the impact on society of synthetic materials that are formed from natural resources. Use search terms effectively, assess the credibility and accuracy of each source, and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.

Mathematics

- Integrate quantitative information about changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed that is expressed in words with a version of that information that is expressed visually.
- Understand that positive and negative numbers are used together to describe quantities having opposite directions or values. Use positive and negative numbers to represent changes in particle motion and temperature when thermal energy is added or removed, explaining the meaning of zero in each situation.

Modifications

(Note: Teachers identify the modifications that they will use in the unit. See NGSS Appendix D: [All Standards, All Students/Case Studies](#) for vignettes and explanations of the modifications.)

- Structure lessons around questions that are authentic, relate to students' interests, social/family background and knowledge of their community.
- Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling).
- Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies).
- Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).
- Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings.
- Use project-based science learning to connect science with observable phenomena.
- Structure the learning around explaining or solving a social or community-based issue.
- Provide ELL students with multiple literacy strategies.
- Collaborate with after-school programs or clubs to extend learning opportunities.
- Restructure lesson using UDL principals (http://www.cast.org/our-work/about-udl.html# VXmoXcfD_UA)

Research on Student Learning

Students may think everything that exists is matter, including heat, light, and electricity. Alternatively, they may believe that matter does not include liquids and gases or they are weightless materials. With specially designed instruction, some middle school students can learn the scientific notion of matter.

Students are deeply committed to a theory of continuous matter. Although some students may think that substances can be divided up into small particles, they do not recognize the particles as building blocks, but as formed as basically continuous substances under certain conditions.

Students at beginning of middle school may be at different points in their conceptualization of a "theory" of matter. Although some 5th graders may start seeing weight as a fundamental property of all matter, many students in 6th and 7th grade still appear to think of weight simply as "felt weight" -- something whose weight they can't feel is considered to have no weight at all. Accordingly, some students believe that if one keeps dividing a piece of Styrofoam, one would soon obtain a piece that weighed nothing.

Students of all ages show a wide range of beliefs about the nature and behavior of particles. They lack an appreciation of the very small size of particles; attribute macroscopic properties to particles; believe there must be something in the space between particles; have difficulty in appreciating the intrinsic motion of particles in solids, liquids and gases; and have problems in conceptualizing forces between particles. Despite these difficulties, there is some evidence that carefully designed instruction carried out over a long period of time may help middle-school students develop correct ideas about particles ([NSDL, 2015](#)).

Prior Learning

By the end of Grade 5, students understand 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 properties can be used to identify materials. (Boundary: At this grade level, mass and weight are not distinguished, and no attempt is 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 weight of the substances does not change. *[Note: Mass and weight are not distinguished by the end of 5th grade.]*

Future Learning

Chemistry

- Each atom has a charged substructure consisting of a nucleus made of protons and neutrons surrounded by electrons.
- The periodic table orders elements horizontally by the number of protons in nucleus of the element's atoms and arranges elements with similar chemical properties vertically in columns. The repeating patterns of this table reflect patterns of outer electron states.
- Electrical forces within and between atoms determine the structure and interactions of matter at the bulk scale.
- A stable molecule has less energy than the same set of atoms separated; at least this energy must be provided in order to take the molecule apart.
- Chemical processes, their rates, and whether or not they store or release energy can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with 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.

Physics

- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved even as, within the system, energy is continually transferred from one object to another and between its various possible forms.
- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position) of the particles.
- In some cases the relative position of energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.

Life science

- Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem.
- Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction).
- Humans depend on the living world for resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by

preserving landscapes of recreational or inspirational value.

- Resource availability has guided the development of human society.
- All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors.

Connections to Other Units

Grade 7 Unit 1: 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.
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).
- 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, and these new substances have different properties from those of the reactants.

Grade 7 Unit 3: 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.
- The total number of each type of atom is conserved, and thus the mass does not change.
- Some chemical reactions release energy, others store energy.

Sample of Open Education Resources

[Middle school Chemistry, Chapter 1: Solids, Liquids, and Gases](#) Students are introduced to the idea that matter is composed of atoms and molecules that are attracted to each other and in constant motion. Students explore the attractions and motion of atoms and molecules as they experiment with and observe the heating and cooling of a solid, liquid, and gas.

[Middle school Chemistry, Chapter 2: Changes of State](#) Students help design experiments to test whether the temperature of water affects the rate of evaporation and whether the temperature of water vapor affects the rate of condensation. Students also look in more detail at the water molecule to help explain the state changes of water.

[States of Matter:](#) Use interactive computer models to trace an atom's trajectory at a certain physical stage, and investigate how molecular behavior is responsible for the substance's state.

[Molecular View of a Gas:](#) Explore the structure of a gas at the molecular level. Molecules are always in motion. Molecules in a gas move quickly. All molecules are attracted to each other. Molecules can be weakly or strongly attracted to each other. The way that large molecules interact in physical, chemical and biological

applications is a direct consequence of the many tiny attractions of the smaller parts.

[Molecular View of a Liquid:](#) Explore the structure of a liquid at the molecular level. Molecules are always in motion. Molecules in a liquid move moderately. All molecules are attracted to each other. Molecules can be weakly or strongly attracted to each other. The way that large molecules interact in physical, chemical and biological applications is a direct consequence of the many tiny attractions of the smaller parts.

[Molecular View of a Solid:](#) Explore the structure of a solid at the molecular level. Molecules are always in motion, though molecules in a solid move slowly. All molecules are attracted to each other. Molecules can be weakly or strongly attracted to each other. The way that large molecules interact in physical, chemical and biological applications is a direct consequence of the many tiny attractions of the smaller parts.

Appendix A: NGSS and Foundations for the Unit

Gather and make sense of information to describe that synthetic materials come from natural resources and impact society. *[Clarification Statement: Emphasis is on natural resources that undergo a chemical process to form the synthetic material. Examples of new materials could include new medicine, foods, and alternative fuels.] [Assessment Boundary: Assessment is limited to qualitative information.]* (MS-PS1-3)

Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed. *[Clarification Statement: Emphasis is on qualitative molecular-level models of solids, liquids, and gases to show that adding or removing thermal energy increases or decreases kinetic energy of the particles until a change of state occurs. Examples of models could include drawings and diagrams. Examples of particles could include molecules or inert atoms. Examples of pure substances could include water, carbon dioxide, and helium.]* (MS-PS1-4)

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
<p>Obtaining, Evaluating, and Communicating Information</p> <ul style="list-style-type: none"> Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence. (MS-PS1-3) <p>Developing and Using Models</p> <ul style="list-style-type: none"> Develop a model to predict and/or describe phenomena. (MS-PS1-4) 	<p>PS1.A: Structure and Properties of Matter</p> <ul style="list-style-type: none"> Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (MS-PS1-3) Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. (MS-PS1-4) In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. (MS-PS1-4) <p>PS1.B: Chemical Reactions</p> <ul style="list-style-type: none"> 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),(MS-PS1-3) 	<p>Structure and Function</p> <ul style="list-style-type: none"> Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (MS-PS1-3) <p>Cause and Effect</p> <ul style="list-style-type: none"> Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS1-4) <p>-----</p> <p>Connections to Engineering, Technology, and Applications of Science</p> <p>Interdependence of Science, Engineering, and Technology</p> <ul style="list-style-type: none"> Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems. (MS-PS1-3)

	<p>PS3.A: Definitions of Energy</p> <ul style="list-style-type: none"> The term “heat” as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects. <i>(secondary to MS-PS1-4)</i> The temperature of a system is proportional to the average internal kinetic energy and potential energy per atom or molecule (whichever is the appropriate building block for the system’s material). The details of that relationship depend on the type of atom or molecule and the interactions among the atoms in the material. Temperature is not a direct measure of a system’s total thermal energy. The total thermal energy (sometimes called the total internal energy) of a system depends jointly on the temperature, the total number of atoms in the system, and the state of the material. <i>(secondary to MS-PS1-4)</i> 	<p>Influence of Science, Engineering and Technology on Society and the Natural World</p> <ul style="list-style-type: none"> The uses of technologies and any limitation on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time. (MS-PS1-3)
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English Language Arts	Mathematics
<p>Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. (MS-PS1-3) RST.6-8.1</p> <p>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). <i>(MS-PS1-4)</i> RST.6-8.7</p> <p>Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation. (MS-PS1-3) WHST.6-8.8</p>	<p>Understand that positive and negative numbers are used together to describe quantities having opposite directions or values (e.g., temperature above/below zero, elevation above/below sea level, credits/debits, positive/negative electric charge); use positive and negative numbers to represent quantities in real-world contexts, explaining the meaning of 0 in each situation. (MS-PS1-4) 6.NS.C.5</p>