Middle School Topic Model Course II – Bundle 1
Properties of Matter

This is the first bundle of the Middle School Topics Model Course II. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 1 Question: This bundle is assembled to address the question "what causes changes in matter?"

Summary

The bundle organizes performance expectations with a focus on helping students begin to understand *properties of matter*. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

Each pure substance has characteristic physical and chemical properties that can be used to identify it (PS1.A as in MS-PS1-2 and MS-PS1-3). This idea connects to the concepts that substances can be classified as gases, liquids, or solids. In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide (PS1.A as in MS-PS1-4). Solids may be formed from molecules, or they may be extended structures with repeating subunits (PS1.A as in MS-PS1-1). Changes of state can occur with variations in temperature or pressure and can be described and predicted (PS1.A as in MS-PS1-4). Consequently, the state, the temperature, and the total number of atoms in the system all determine the total thermal energy of a system (PS3.A as in MS-PS1-4).

Substances are made from different types of atoms, which combine with one another in various ways (PS1.A as in MS-PS1-1). However, the total number of each type of atom is conserved, and thus the mass does not change (PS1.B as in MS-PS1-5). These ideas connect to the concept that when substances react chemically, 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 (PS1.B as in MS-PS1-2, MS-PS1-3, and MS-PS1-5). Some chemical reactions release energy, others store energy (PS1.B as in MS-PS1-6). These ideas about chemical reactions in the physical sciences connect closely to their application in the life sciences; within organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy (LS1.C as in MS-LS1-7). One example is cellular respiration, which involves chemical reactions with oxygen that release stored energy (PS3.D as in MS-LS1-7).

The engineering design ideas that sometimes, parts of different solutions may be incorporated into a new design based on the characteristics of the design that performed the best in each test (ETS1.B and ETS1.C as in MS-PS1-6 and MS-ETS1-3) could connect to many science ideas, such as how heat refers to the energy transferred due to the temperature difference between two objects (PS3.A as in MS-PS1-4), or how food moves through a series of chemical reactions in which it is broken down and rearranged to support growth (LS1.C as in MS-LS1-7). Connections could be made through engineering design tasks such as identifying the best characteristics of various designs for insulating a house or developing simulations of various feed rations for cattle.

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of developing models (MS-PS1-1, MS-PS1-4, MS-PS1-5, and MS-LS1-7), analyzing and interpreting data (MS-PS1-2 and MS-ETS1-3), designing solutions (MS-PS1-6), and obtaining, evaluating, and communicating information (MS-PS1-3). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Patterns (MS-PS1-2), Cause and

Effect (MS-PS1-4), Scale, Proportion, and Quantity (MS-PS1-1), Energy and Matter (MS-PS1-5, MS-PS1-6, and MS-LS1-7), and Structure and Function (MS-PS1-3). Many other crosscutting concept elements can be used in instruction. *All instruction should be three-dimensional.*	
Performance Expectations MS-PS1-1 and MS-LS1-7 are partially assessable.	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.] 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.] MS-PS1-3. **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-PS1-4. **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-PS1-5. **Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.** [Clarification Statement: Emphasis is on law of conservation of matter and on physical models or drawings, including digital forms, that represent atoms.] [Assessment Boundary: Assessment does not include the use of atomic masses, balancing symbolic equations, or intermolecular forces.] MS-PS1-6. **Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.*** [Clarification Statement: Emphasis is on the design, controlling the transfer of energy to the environment, and modification of a device using factors such as type and concentration of a substance. Examples of designs could involve chemical reactions such as dissolving ammonium chloride or calcium chloride.] [Assessment Boundary: Assessment is limited to the criteria of amount, time, and temperature of substance in testing the device.] MS-LS1-7. **Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism.** [Clarification Statement: Emphasis is on describing that molecules are broken apart and put back together and that in this process, energy is released.] [Assessment Boundary: Assessment does not include details of the chemical reactions for photosynthesis or respiration.] MS-ETS1-3. **Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.**

Example Phenomena	Before a big race, game, or meet, athletes often eat lots of pasta and starchy foods. Aerosol cans can explode if left in a hot car.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information. Students could *ask questions that arise from careful observation to clarify* [how] ***changes of state occur with variations in temperature or pressure***. MS-PS1-4 **Developing and Using Models** • Develop and/or use a model to describe phenomena. Students could *develop a model to describe* [that when combining two substances, the resulting] ***new substances*** [can] ***have different properties from those of the reactants***. MS-PS1-2 **Planning and Carrying Out Investigations** • Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation. Students could *evaluate and revise an experimental design* [intended to] *serve as the basis for evidence* [that] ***each pure substance has characteristic physical and chemical properties that can be used to identify it.*** MS-PS1-2 **Analyzing and Interpreting Data** • Analyze and interpret data to provide evidence for phenomena. Students could *analyze and interpret data to provide evidence* [that] ***the mass does not change*** [during chemical reactions]. MS-PS1-5 **Using Mathematical and Computational Thinking** • Use mathematical representations to describe and/or support scientific conclusions and design solutions. Students could *use mathematical representations to support conclusions* [that, after a chemical reaction, the] ***new substances*** [formed] ***have different properties from those of the reactants***. MS-PS1-2, MS-PS1-3, and MS-PS1-5 **Constructing Explanations and Designing Solutions** • Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. Students could *construct a scientific explanation based on valid and reliable evidence* [about how organisms get energy from food, including that] ***food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy***. MS-LS1-7

Additional Practices Building to the PEs (Continued)	**Engaging in Argument from Evidence** • Respectfully provide and receive critiques about one's explanations, procedures, models and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail. Students could *respectfully provide and receive critiques by citing relevant evidence and posing and responding to questions about models* [of how] ***chemical reactions of food supports growth***. MS-LS1-7 **Obtaining, Evaluating, and Communicating Information** • Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s). Students could *critically read scientific texts adapted for classroom use to obtain scientific information about the pattern* [that] ***solids may be formed from molecules, or they may be extended structures with repeating subunits***. MS-PS1-1
Additional Crosscutting Concepts Building to the PEs	**Patterns** • Patterns can be used to identify cause and effect relationships. Students could analyze data on *patterns* [of] ***chemical reactions*** [that] ***release energy*** [versus**]** ***others that store energy*** *to identify cause and effect relationships*. MS-PS1-6 **Scale, Proportion, and Quantity** • Phenomena that can be observed at one scale may not be observable at another scale. Students could support claims with evidence [that] ***the motion of atoms or molecules within a substance*** *may not be observable at* [the macroscopic] *scale*, [but that] ***thermal energy*** *is observable at* [the macroscopic] *scale*. MS-PS1-4 **Structure and Function** • Complex natural and designed structures/systems can be analyzed to determine how they function. Students could describe evidence that *complex designed systems can be analyzed to determine how they function*, [including that the] ***chemical reactions*** [used in design solutions that] ***release energy*** [can be analyzed to determine how they contribute to the function of the design system]. MS-PS1-6 and MS-ETS1-3
Additional Connections to Nature of Science	**Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • Theories are explanations for observable phenomena. Students could construct an argument that *theories are explanations*, [using as evidence the theory that] ***gases and liquids are made of molecules or inert atoms that are moving about relative to each other and that in a solid, atoms are closely spaced and may vibrate in position but do not change relative locations***. MS-PS1-4 **Science is a Way of Knowing** • Science knowledge is cumulative and many people, from many nations, have contributed to science knowledge. Students could obtain, evaluate, and communicate information about how *science knowledge is cumulative and many people have contributed to science knowledge*, [including knowledge about how] ***each pure substance has characteristic physical and chemical properties that can be used to identify it***. MS-PS1-2 and MS-PS1-3

MS-PS1-1 Matter and its Interactions

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 description of all individual atoms in a complex molecule or extended structure is not required.*]

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

Science and Engineering Practices

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.

Disciplinary Core Ideas

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.
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).

Crosscutting Concepts

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.

Observable features of the student performance by the end of the course:			
1	Components of the model		
	a	Students develop models of atomic composition of simple molecules and extended structures that vary in complexity. In the models, students identify the relevant components, including:	
		i.	Individual atoms.
		ii.	Molecules.
		iii.	Extended structures with repeating subunits.
		iv.	Substances (e.g., solids, liquids, and gases at the macro level).
2	Relationships		
	a	In the model, students describe* relationships between components, including:	
		i.	Individual atoms, from two to thousands, combine to form molecules, which can be made up of the same type or different types of atom.
		ii.	Some molecules can connect to each other.
		iii.	In some molecules, the same atoms of different elements repeat; in other molecules, the same atom of a single element repeats.
3	Connections		
	a	Students use models to describe* that:	
		i.	Pure substances are made up of a bulk quantity of individual atoms or molecules. Each pure substance is made up of one of the following:
			1. Individual atoms of the same type that are connected to form extended structures.
			2. Individual atoms of different types that repeat to form extended structures (e.g., sodium chloride).
			3. Individual atoms that are not attracted to each other (e.g., helium).
			4. Molecules of different types of atoms that are not attracted to each other (e.g., carbon dioxide).
			5. Molecules of different types of atoms that are attracted to each other to form extended structures (e.g., sugar, nylon).
			6. Molecules of the same type of atom that are not attracted to each other (e.g., oxygen).
		ii.	Students use the models to describe* how the behavior of bulk substances depends on their structures at atomic and molecular levels, which are too small to see.

MS-PS1-2 Matter and its Interactions

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 expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

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.

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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.

Disciplinary Core Ideas

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.

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.

Crosscutting Concepts

Patterns

- Macroscopic patterns are related to the nature of microscopic and atomic-level structure.

Observable features of the student performance by the end of the course:		
1	Organizing data	
	a	Students organize given data about the characteristic physical and chemical properties (e.g., density, melting point, boiling point, solubility, flammability, odor) of pure substances before and after they interact.
	b	Students organize the given data in a way that facilitates analysis and interpretation.
2	Identifying relationships	
	a	Students analyze the data to identify patterns (i.e., similarities and differences), including the changes in physical and chemical properties of each substance before and after the interaction (e.g., before the interaction, a substance burns, while after the interaction, the resulting substance does not burn).
3	Interpreting data	
	a	Students use the analyzed data to determine whether a chemical reaction has occurred.
	b	Students support their interpretation of the data by describing* that the change in properties of substances is related to the rearrangement of atoms in the reactants and products in a chemical reaction (e.g., when a reaction has occurred, atoms from the substances present before the interaction must have been rearranged into new configurations, resulting in the properties of new substances).

MS-PS1-3 Matter and its Interactions

Students who demonstrate understanding can:

MS-PS1-3. 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.*]

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

Science and Engineering Practices

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 6–8 builds on K–5 and progresses to evaluating the merit and validity of ideas and methods.

- 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 now supported by evidence.

Disciplinary Core Ideas

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.

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.

Crosscutting Concepts

Structure and Function

- Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.

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Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

- 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.

Influence of Science, Engineering and Technology on Society and the Natural World

- 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.

Observable features of the student performance by the end of the course:			
1	Obtaining information		
	a	Students obtain information from published, grade-level appropriate material from at least two sources (e.g., text, media, visual displays, data) about:	
		i.	Synthetic materials and the natural resources from which they are derived.
		ii.	Chemical processes used to create synthetic materials from natural resources (e.g., burning of limestone for the production of concrete).
		iii.	The societal need for the synthetic material (e.g., the need for concrete as a building material).
2	Evaluating information		
	a	Students determine and describe* whether the gathered information is relevant for determining:	
		i.	That synthetic materials, via chemical reactions, come from natural resources.
		ii.	The effects of the production and use of synthetic resources on society.
	b	Students determine the credibility, accuracy, and possible bias of each source of information, including the ideas included and methods described.	
	c	Students synthesize information that is presented in various modes (e.g., graphs, diagrams, photographs, text, mathematical, verbal) to describe*:	

		i.	How synthetic materials are formed, including the natural resources and chemical processes used.
		ii.	The properties of the synthetic material(s) that make it different from the natural resource(s) from which it was derived.
		iii.	How those physical and chemical properties contribute to the function of the synthetic material.
		iv.	How the synthetic material satisfies a societal need or desire through the properties of its structure and function.
		v.	The effects of making and using synthetic materials on natural resources and society.

MS-PS1-4 Matter and its Interactions

Students who demonstrate understanding can:

MS-PS1-4. 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 drawing and diagrams. Examples of particles could include molecules or inert atoms. Examples of pure substances could include water, carbon dioxide, and helium.]

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

Science and Engineering Practices

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.

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter

- 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, 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.
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.

PS3.A: Definitions of Energy

- 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. *(secondary)*
- 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. *(secondary)*

Crosscutting Concepts

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Observable features of the student performance by the end of the course:

1	Components of the model		
	a	To make sense of a given phenomenon, students develop a model in which they identify the relevant components, including:	
		i.	Particles, including their motion.
		ii.	The system within which the particles are contained.
		iii.	The average kinetic energy of particles in the system.
		iv.	Thermal energy of the system.

		v. Temperature of the system.
		vi. A pure substance in one of the states of matter (e.g., solid, liquid, gas at the macro scale).
2	Relationships	
	a	In the model, students describe* relationships between components, including:
		i. The relationships between:
		1. The motion of molecules in a system and the kinetic energy of the particles in the system.
		2. The average kinetic energy of the particles and the temperature of the system.
		3. The transfer of thermal energy from one system to another and:
		A. A change in kinetic energy of the particles in that new system, or
		B. A change in state of matter of the pure substance.
		4. The state of matter of the pure substance (gas, liquid, solid) and the particle motion (freely moving and not in contact with other particles, freely moving and in loose contact with other particles, vibrating in fixed positions relative to other particles).
3	Connections	
	a	Students use their model to provide a causal account of the relationship between the addition or removal of thermal energy from a substance and the change in the average kinetic energy of the particles in the substance.
	b	Students use their model to provide a causal account of the relationship between:
		i. The temperature of the system.
		ii. Motions of molecules in the gaseous phase.
		iii. The collisions of those molecules with other materials, which exerts a force called pressure.
	c	Students use their model to provide a causal account of what happens when thermal energy is transferred into a system, including that:
		i. An increase in kinetic energy of the particles can cause:
		1. An increase in the temperature of the system as the motion of the particles relative to each other increases, or
		2. A substance to change state from a solid to a liquid or from a liquid to a gas.
		ii. The motion of molecules in a gaseous state increases, causing the moving molecules in the gas to have greater kinetic energy, thereby colliding with molecules in surrounding materials with greater force (i.e., the pressure of the system increases).
	d	Students use their model to provide a causal account of what happens when thermal energy is transferred from a substance, including that:
		i. Decreased kinetic energy of the particles can cause:
		1. A decrease in the temperature of the system as the motion of the particles relative to each other decreases, or
		2. A substance to change state from a gas to a liquid or from a liquid to a solid.
		ii. The pressure that a gas exerts decreases because the kinetic energy of the gas molecules decreases, and the slower molecules exert less force in collisions with other molecules in surrounding materials.
	e	Students use their model to provide a causal account for the relationship between changes in pressure of a system and changes of the states of materials in the system.
		i. With a decrease in pressure, a smaller addition of thermal energy is required for particles of a liquid to change to gas because particles in the gaseous state are colliding with the surface of the liquid less frequently and exerting less force on the particles in the liquid, thereby allowing the particles in the liquid to break away and move into the gaseous state with the addition of less energy.
		ii. With an increase in pressure, a greater addition of thermal energy is required for particles of a liquid to change to gas because particles in the gaseous state are colliding with the surface of the liquid more frequently and exerting greater force on the particles in the liquid, thereby limiting the movement of particles from the liquid to gaseous state.

MS-PS1-5 Matter and its Interactions

Students who demonstrate understanding can:

MS-PS1-5. Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved. [Clarification Statement: Emphasis is on law of conservation of matter and on physical models or drawings, including digital forms, that represent atoms.] [*Assessment Boundary: Assessment does not include the use of atomic masses, balancing symbolic equations, or intermolecular forces.*]

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

Science and Engineering Practices

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 describe unobservable mechanisms.

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Connections to Nature of Science

Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

- Laws are regularities or mathematical descriptions of natural phenomena.

Disciplinary Core Ideas

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.
- The total number of each type of atom is conserved, and thus the mass does not change.

Crosscutting Concepts

Energy and Matter

- Matter is conserved because atoms are conserved in physical and chemical processes.

Observable features of the student performance by the end of the course:			
1	Components of the model		
	a	To make sense of a given phenomenon, students develop a model in which they identify the relevant components for a given chemical reaction, including:	
		i.	The types and number of molecules that make up the reactants.
		ii.	The types and number of molecules that make up the products.
2	Relationships		
	a	In the model, students describe* relationships between the components, including:	
		i.	Each molecule in each of the reactants is made up of the same type(s) and number of atoms.
		ii.	When a chemical reaction occurs, the atoms that make up the molecules of reactants rearrange and form new molecules (i.e., products).
		iii.	The number and types of atoms that make up the products are equal to the number and types of atoms that make up the reactants.
		iv.	Each type of atom has a specific mass, which is the same for all atoms of that type.
3	Connections		
	a	Students use the model to describe* that the atoms that make up the reactants rearrange and come together in different arrangements to form the products of a reaction.	
	b	Students use the model to provide a causal account that mass is conserved during chemical reactions because the number and types of atoms that are in the reactants equal the number and types of atoms that are in the products, and all atoms of the same type have the same mass regardless of the molecule in which they are found.	

MS-PS1-6 Matter and its Interactions

Students who demonstrate understanding can:

MS-PS1-6. Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.* [Clarification Statement: Emphasis is on the design, controlling the transfer of energy to the environment, and modification of a device using factors such as type and concentration of a substance. Examples of designs could involve chemical reactions such as dissolving ammonium chloride or calcium chloride.] [*Assessment Boundary: Assessment is limited to the criteria of amount, time, and temperature of substance in testing the device.*]

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

Science and Engineering Practices

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.

- Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.

Disciplinary Core Ideas

PS1.B: Chemical Reactions

- Some chemical reactions release energy, others store energy.

ETS1.B: Developing Possible Solutions

- A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. *(secondary)*

ETS1.C: Optimizing the Design Solution

- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process - that is, some of the characteristics may be incorporated into the new design. *(secondary)*
- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. *(secondary)*

Crosscutting Concepts

Energy and Matter

- The transfer of energy can be tracked as energy flows through a designed or natural system.

Observable features of the student performance by the end of the course:			
1	Using scientific knowledge to generate design solutions		
	a	Given a problem to solve that requires either heating or cooling, students design and construct a solution (i.e., a device). In their designs, students:	
		i.	Identify the components within the system related to the design solution, including:
			1. The components within the system to or from which energy will be transferred to solve the problem.
			2. The chemical reaction(s) and the substances that will be used to either release or absorb thermal energy via the device.
		ii.	Describe* how the transfer of thermal energy between the device and other components within the system will be tracked and used to solve the given problem.
2	Describing* criteria and constraints, including quantification when appropriate		
	a	Students describe* the given criteria, including:	
		i.	Features of the given problem that are to be solved by the device.
		ii.	The absorption or release of thermal energy by the device via a chemical reaction.
	b	Students describe* the given constraints, which may include:	
		i.	Amount and cost of materials.
		ii.	Safety.
		iii.	Amount of time during which the device must function.
3	Evaluating potential solutions		
	a	Students test the solution for its ability to solve the problem via the release or absorption of thermal energy to or from the system.	

	b	Students use the results of their tests to systematically determine how well the design solution meets the criteria and constraints, and which characteristics of the design solution performed the best.
4	Modifying the design solution	
	a	Students modify the design of the device based on the results of iterative testing, and improve the design relative to the criteria and constraints.

MS-LS1-7 From Molecules to Organisms: Structures and Processes

Students who demonstrate understanding can:

MS-LS1-7. Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism. [Clarification Statement: Emphasis is on describing that molecules are broken apart and put back together and that in this process, energy is released.] [*Assessment Boundary: Assessment does not include details of the chemical reactions for photosynthesis or respiration.*]

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

Science and Engineering Practices

Developing and Using Models
Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.

- Develop a model to describe unobservable mechanisms.

Disciplinary Core Ideas

LS1.C: Organization for Matter and Energy Flow in Organisms

- Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy.

PS3.D: Energy in Chemical Processes and Everyday Life

- Cellular respiration in plants and animals involve chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials.*(secondary)*

Crosscutting Concepts

Energy and Matter

- Matter is conserved because atoms are conserved in physical and chemical processes.

Observable features of the student performance by the end of the course:			
1	Components of the model		
	a	To make sense of a phenomenon, students develop a model in which they identify the relevant components for describing* how food molecules are rearranged as matter moves through an organism, including:	
		i.	Molecules of food, which are complex carbon-containing molecules.
		ii.	Oxygen.
		iii.	Energy that is released or absorbed during chemical reactions between food and oxygen.
		iv.	New types of molecules produced through chemical reactions involving food.
2	Relationships		
	a	In the model, students identify and describe* the relationships between components, including:	
		i.	During cellular respiration, molecules of food undergo chemical reactions with oxygen, releasing stored energy.
		ii.	The atoms in food are rearranged through chemical reactions to form new molecules.
3	Connections		
	a	Students use the model to describe*:	
		i.	The number of each type of atom being the same before and after chemical reactions, indicating that the matter ingested as food is conserved as it moves through an organism to support growth.
		ii.	That all matter (atoms) used by the organism for growth comes from the products of the chemical reactions involving the matter taken in by the organism.
		iii.	Food molecules taken in by the organism are broken down and can then be rearranged to become the molecules that comprise the organism (e.g., the proteins and other molecules in a hamburger can be broken down and used to make a variety of tissues in humans).
		iv.	As food molecules are rearranged, energy is released and can be used to support other processes within the organism.

MS-ETS1-3 Engineering Design

Students who demonstrate understanding can:

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

The performance expectation above was 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 experiences 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.	**ETS1.B: Developing Possible Solutions** • There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. • Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. **ETS1.C: Optimizing the Design Solution** • Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design.	

Observable features of the student performance by the end of the course:		
1	Organizing data	
	a	Students organize given data (e.g., via tables, charts, or graphs) from tests intended to determine the effectiveness of three or more alternative solutions to a problem.
2	Identifying relationships	
	a	Students use appropriate analysis techniques (e.g., qualitative or quantitative analysis; basic statistical techniques of data and error analysis) to analyze the data and identify relationships within the datasets, including relationships between the design solutions and the given criteria and constraints.
3	Interpreting data	
	a	Students use the analyzed data to identify evidence of similarities and differences in features of the solutions.
	b	Based on the analyzed data, students make a claim for which characteristics of each design best meet the given criteria and constraints.
	c	Students use the analyzed data to identify the best features in each design that can be compiled into a new (improved) redesigned solution.