Middle School Phenomenon Model Course 1 - Bundle 3
Chemical Reactions

This is the third bundle of the Middle School Phenomenon Model Course 1. 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 questions of "What are chemical reactions?"	
Summary The bundle organizes performance expectations around helping to expand students' understanding of matter and interactions of matter that can create new substances. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations. **Connections between bundle DCIs** The idea that in a chemical process, the atoms that make up the original substances are regrouped into different molecules (PS1.B as in MS-PS1-2, MS-PS1-3 and MS-PS1-5) connects to the concept that some chemical reactions release energy while others store energy (MS-PS1-6). These ideas about chemical processes also connect to the concept that the total number of each type of atom is conserved, and thus the mass does not change (MS-PS1-6). The concept that there are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem (ETS1.B as in MS-ETS1-3) could connect to multiple ideas such as that some chemical reactions release energy and others store energy (MS-PS1-6), substances react chemically in characteristic ways, and new substances have different properties from those of the reactants (PS1.A as in MS-PS1-2, MS-PS1-3, and MS-PS1-5). For example, students could be given the task of designing a device that operates as a result of a chemical reaction that releases energy, or a task of identifying what metal to use when building a bridge over a body of saltwater. In either task, students could first determine the criteria and constraints of the problem and then engage in the systematic process for evaluating solutions with respect to the criteria and constraints. **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 and using models (MS-PS1-5), analyzing and interpreting data (MS-PS1-2), constructing explanations and 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), Energy and Matter (MS-PS1-5 and MS-PS1-6), and Structure and Function (MS-PS1-3). Many other crosscutting concepts elements can be used in instruction. *All instruction should be three-dimensional.*	
Performance Expectations	MS-PS1-2. **Analyze and interpret data on the properties of substances before and after 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.*]

Performance Expectations (Continued)	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-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	When baking soda (a solid) and vinegar (a liquid) are combined, a gas is produced. Plastics (petroleum products) are found in thousands of everyday objects. When calcium chloride is dissolved in water, the temperature of the water decreases.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles. Students could *ask questions* [about the] **characteristic physical and chemical properties that can be used to identify pure substance**. MS-PS1-2 and MS-PS1-3 **Developing and Using Models** • Develop and/or use a model to predict and/or describe phenomena. Students could *develop a model to describe phenomena* [related to] **chemical reactions** [that] **release energy** [rather than] **store energy**. MS-PS1-6 **Planning and Carrying Out Investigations** • Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. Students could *plan an investigation collaboratively* [to determine if] **a chemical process** [occurred based on whether there is] **a new substance** [with] **different properties from those of the reactants** *and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim*. MS-PS1-2, MS-PS1-3, and MS-PS1-5

Additional Practices Building to the PEs (Continued)	**Analyzing and Interpreting Data** • Analyze and interpret data to provide evidence for phenomena. Students could *analyze and interpret data to provide evidence for phenomena* [related to the concept that in a chemical reaction]**, mass does not change**. MS-PS1-5 **Using Mathematics and Computational Thinking** • Use digital tools and/or mathematical concepts and arguments to test and compare proposed solutions to an engineering design problem. Students could *use digital tools to test and compare proposed solutions to an engineering design problem* [that requires use of a*]* **chemical reaction** [that] **stores energy**. MS-PS1-6 **Constructing Explanations and Designing Solutions** • Construct an explanation using models or representations. Students could *construct an explanation* [that in a chemical reaction,] **the total number of each type of atom is conserved, and thus the mass does not change**. MS-PS1-5 **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 critiques about models [that describe how, in a chemical reaction]**, the total number of each type of atom is conserved, and thus the mass does not change** by citing relevant evidence and posing questions that elicit pertinent elaboration and detail. MS-PS1-5 **Obtaining, Evaluating, and Communicating Information** • Communicate scientific and/or technical information (e.g. about a proposed object, tool, process, system) in writing and/or through oral presentations. Students could *communicate technical information in writing about a proposed object* [that] **releases** [**energy** [as a result of a chemical reaction]. MS-PS1-6
Additional Crosscutting Concepts Building to the PEs	**Systems and System Models** • Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. Students could use *models to represent systems and their interactions—such as* [the] *inputs, processes and outputs* [of a] **chemical** [reaction]*—and energy and matter flows within systems (e.g.,* **the atoms that make up the original substances are regrouped into different molecules** [and] **the release** [or storage of] **energy** [that results]**)**. MS-PS1-2, MS-PS1-3, MS-PS1-5, and MS-PS1-6

Additional Crosscutting Concepts Building to the PEs (Continued)	**Structure and Function** • Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts; therefore, complex natural and designed structures/systems can be analyzed to determine how they function. Students could describe how *microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the composition and relationships among its parts* [using the idea that] **in a chemical process, the atoms that make up the original substances are regrouped into different molecules** [as an example]. Students can further describe that [the resulting] **substances** *can be analyzed to determine how they function* [as] **these new substances have different properties from those of the reactants.** MS-PS1-2, MS-PS1-5 **Stability and Change** • Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale. Students could construct *explanations of* **substances that react chemically** *by examining the changes over time at different scales.* MS-PS1-2
Additional Connections to Nature of Science	**Scientific Knowledge is Open to Revision in Light of New Evidence** • Science knowledge is based upon logical and conceptual connections between evidence and explanations. Students could describe how [scientists used] *logical and conceptual connections between evidence and the explanation* **that in a chemical reaction, atoms that make up the original substances are regrouped into different molecules.** MS-PS1-2 **Science is a Way of Knowing** • Science is a way of knowing used by many people, not just scientists. Students can identify ways that *many people, not just scientists, use scientific knowledge* [about the] **characteristic physical and chemical properties of each pure substance**. MS-PS1-2

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-PS1-5 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-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.