## Substances

### 1 Mystery Mixture

**Students** begin their study of chemistry by observing a mystery mixture of two white, solid substances (nitric acid and sodium bicarbonate). After recording the physical characteristics of the dry mixture, they add water and record their observations of the results.

**Title:** Chemical Interactions, 2nd Edition

**FOSS:** Chemical Interactions, Second Edition

**Chemical Reactions:** Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS-PS1-1, MS-PS1-2, MS-PS1-3)

**Patterns** can be used to identify cause and effect relationships.

**MS-PS1-1.** Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

**PS1.A: Structure and Properties of Matter**
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (MS-PS1-1)

**PS1.B: Chemical Reactions**
- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS-PS1-2, MS-PS1-3, MS-PS1-5)

- Patterns can be used to identify cause and effect relationships.

**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.

**PS1.A: Structure and Properties of Matter**
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (MS-PS1-1)

**PS1.B: Chemical Reactions**
- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS-PS1-2, MS-PS1-3, MS-PS1-5)

- Patterns can be used to identify cause and effect relationships.

**MS-PS1-3.** Gather and make sense of information to describe how synthetic materials come from natural resources and impact society.

**PS1.A: Structure and Properties of Matter**
- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS-PS1-1)

**PS1.B: Chemical Reactions**
- Molecules are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS-PS1-1)

- Patterns can be used to identify cause and effect relationships.

### 2 Mixing Substances

**Students** observe a set of nine white solids, two of which are the substances in the mystery mixture. They develop a plan for testing pairs of substances to discover which two are in the mystery mixture. The testing that results from the mixing of seven different two-substance combinations is introduced as evidence of a chemical reaction.

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- Patterns can be used to identify cause and effect relationships.

### 3 Elements

**Students** learn that an element is a basic substance that cannot be broken into simpler substances by chemical interactions. They become familiar with the names and symbols of the 90 naturally occurring elements by studying the periodic table of the elements.

**MS-PS1-1.** Develop models to describe the atomic composition of simple molecules and extended structures.

**PS1.A: Structure and Properties of Matter**
- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS-PS1-1)

**MS-PS1-2.** Develop models to describe the atomic composition of simple molecules and extended structures.

**PS1.A: Structure and Properties of Matter**
- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS-PS1-1)

**PS1.B: Chemical Reactions**
- Molecules are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS-PS1-1)

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**MS-PS1-3.** Gather and make sense of information to describe how synthetic materials come from natural resources and impact society.

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**PS1.B: Chemical Reactions**
- Molecules are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS-PS1-1)

- Patterns can be used to identify cause and effect relationships.

**Caution and Effect**
- Causation and effect relationships may be used to predict phenomena in natural or designed systems.

**MS-PS1-4.** Develop models to describe the atomic composition of simple molecules and extended structures.

**PS1.A: Structure and Properties of Matter**
- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS-PS1-1)

**PS1.B: Chemical Reactions**
- Molecules are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS-PS1-1)

- Patterns can be used to identify cause and effect relationships.

**Caution and Effect**
- Causation and effect relationships may be used to predict phenomena in natural or designed systems.

**MS-PS1-5.** Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

**PS1.A: Structure and Properties of Matter**
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (MS-PS1-1)

**PS1.B: Chemical Reactions**
- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS-PS1-2, MS-PS1-3, MS-PS1-5)

- Patterns can be used to identify cause and effect relationships.

**Caution and Effect**
- Causation and effect relationships may be used to predict phenomena in natural or designed systems.

**MS-PS1-6.** Develop models to describe the atomic composition of simple molecules and extended structures.

**PS1.A: Structure and Properties of Matter**
- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS-PS1-1)

**PS1.B: Chemical Reactions**
- Molecules are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS-PS1-1)

- Patterns can be used to identify cause and effect relationships.

**Caution and Effect**
- Causation and effect relationships may be used to predict phenomena in natural or designed systems.

**MS-PS1-7.** Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

**PS1.A: Structure and Properties of Matter**
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (MS-PS1-1)

**PS1.B: Chemical Reactions**
- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS-PS1-2, MS-PS1-3, MS-PS1-5)

- Patterns can be used to identify cause and effect relationships.

**Caution and Effect**
- Causation and effect relationships may be used to predict phenomena in natural or designed systems.


**FOSS NGSS Correlation**

**Chemical Interactions, 2nd Edition**

**Version date:** 10/01/15

**Contact:** jpenchos@berkeley.edu

**NGSS Standards Addressed**

**Disciplinary Core Ideas (Framework)**

**Crosstiming Concepts**

| Inv. | Inv Title | Part | Part Summary | Sessions | Content | MS-PS1-3: Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred. | PS1.A: Structure and Properties of Matter | Systems and System Models | Cause and Effect
<table>
<thead>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Capture the Gas</td>
<td>3</td>
<td>Students learn that the gas produced in a reaction is carbon dioxide, one of the many gases in air. Students investigate air to confirm that it qualifies as matter—it has mass and occupies space.</td>
<td>3</td>
<td>Gas is matter—it has mass and occupies space.</td>
<td><em>•</em> Gas and liquids are made of molecules or inert atoms that are moving about relative to each other. (MS-PS1-4)</td>
<td><em>•</em> Gas and liquids are made of molecules or inert atoms that are moving about relative to each other. (MS-PS1-4) <em>•</em> 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) <em>•</em> The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. (MS-PS1-4)</td>
<td><em>•</em> Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. <em>•</em> Cause and effect relationships may be used to predict phenomena in natural or designed systems.</td>
<td></td>
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<tr>
<td>2</td>
<td>Air is Matter</td>
<td>2</td>
<td>Students refine their model of air (gas) as independent particles with significantly large distances between them. They use representations to show how the changes in particle density during compression and expansion.</td>
<td>3</td>
<td>Matter is made of particles. <em>•</em> Every substance is defined by a unique particle. <em>•</em> Gas is matter—it has mass and occupies space. <em>•</em> As compression when force is applied, gas expands when force is withdrawn.</td>
<td><em>•</em> Gases and liquids are made of widely spaced individual particles in constant motion. <em>•</em> There is nothing between gas particles except space.</td>
<td><em>•</em> Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. (MS-PS1-4) <em>•</em> 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) <em>•</em> The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. (MS-PS1-4)</td>
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<td>Students refine their model of air (gas) as independent particles with significantly large distances between them. They use representations to show how the changes in particle density during compression and expansion.</td>
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<tr>
<td>7</td>
<td>Kinetic Energy</td>
<td>1</td>
<td>After recording the pressure and composition of gas, students work with &quot;energy&quot; plastic bottles to find out what happens to air when it is heated and cooled. Students observe that air expands when heated and contracts when cooled. They use the kinetic particulate model to explain expansion and contraction.</td>
<td>2</td>
<td>Solids, liquids, and gases vary in how their particles are arranged in relationship to one another, but the particles are always in motion. <em>•</em> Kinetic energy is energy of motion. <em>•</em> The particles in substances gain kinetic energy as they warm, and lose kinetic energy as they cool.</td>
<td><em>•</em> Matter expands when the kinetic energy of its particles increases; matter contracts when the kinetic energy of its particles decreases.</td>
<td><em>•</em> The term &quot;heat&quot; as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of 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 to MS-PS1-4) <em>•</em> Temperature is not a direct measure of a system’s total thermal energy. The total thermal energy (sometimes termed 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 to MS-PS1-4)</td>
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**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.**

**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.**

**SP:** Science Practice

**EPS:** Engineering Practice

**S:** Science

**PS:** Practice Skills

**ED:** Engineering Design

**MS-PS1-2:** Matter is made of particles. Every substance is defined by a unique particle. Gas is matter—it has mass and occupies space. As compression when force is applied, gas expands when force is withdrawn. During compression and expansion, the number and character of particles in a sample of gas do not change; the space between the particles does change.

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**PS1.A:** Structure and Properties of Matter

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**MS-PS1-4:** The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.
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<th>Concept</th>
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<th>Disciplinary Core Ideas (Framework)</th>
<th>NGSS Standards Addressed</th>
<th>CROSSTALKING CONCEPTS</th>
<th>FOSS Title, Session, and Corresponding Content</th>
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</table>
| 4   | Liquid Expansion/Contraction | 3       | Students observe the brass sphere-and-ring demonstration. At room temperature, the sphere passes easily through the ring. When the sphere is cooled in ice water and then hot water, the sphere does not pass easily through the ring. Students observe that solids expand and contract. | **PS1.A: Structure and Properties of Matter**  
- Changes and liquids are made of molecules or atoms that are moving about relative to each other. (MS-PS1-4)  
- In a liquid, the molecules are constantly in contact with each other and the transfer of thermal energy from one object to another. (MS-PS1-4)  
- 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 to MS-PS1-4)  
**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 to MS-PS1-4)  
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**Cause and Effect**  
- Cause and effect relationships may be used to predict phenomena in natural or designed systems.  
- 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. | **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.  
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**FOSS Chemical Interactions, Second Edition**  
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Energy Transfer

1. Mixing Hot and Cold

Students call on their knowledge of mixing hot and cold liquids to predict the final temperature of a mixture of equal masses of hot and cold water. They conduct the activity and use their results to determine an algorithm for calculating final temperatures.

3. Particle Collisions

Students explore the concept of energy transfer as a consequence of collisions between particles. They engage in group discussions, listen to teacher lectures, watch interactive animations, and participate in a structured classroom reading. They are introduced to temperature as the average kinetic energy of particles in a substance, and they study how a thermometer works.

5. Heat

Students are introduced to the concept of heat as a unit of heat. They conduct a water-mixing investigation and use the results to calculate the number of calories transferred from hot water, and to cold water during the interaction. The numbers are equal, supporting the notion of conservation of energy.

Disciplinary Core Ideas (Framework)

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 to the transfer of 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.
- Temperature is not a measure of energy; the relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.
- Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.

PS3.B: Conservation of Energy and Energy Transfer

- When the kinetic energy of an object changes, there is inevitably some other change in energy at the same time.
- The energy of motion is transferred out of hotter regions or objects and into colder ones.

Crosscutting Concepts

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.

Energy and Matter
- Energy may take different forms (e.g., energy in fields, thermal energy, energy of motion).
- The transfer of energy can be tracked as energy flows through a designed or natural system.

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.

Pattern
- Patterns can be used to identify cause and effect relationships.

FOSS MS/NGSS Correlation

Chemical Interactions, 2nd Edition

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Contact: jpenchos@berkeley.edu

for the most updated version

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FOSS Chemical Interactions, 2nd Edition

**Title:** FOSS Chemical Interactions, Second Edition

**Part 2**

Problem:
- How to build a container preparation for the design challenge.
- Test their designs.
- Energy transfer to face an engineering challenge.

**Sessions**

**Part Summary**
- Engineers try to solve problems that meet a set of criteria and that work within the constraints of the problem.
- Materials with more widely spaced particles serve as better insulators.
- Insulating materials reduce energy transfer to conduct.
- The transfer of energy can be tracked as energy flows through a designed or natural system.
- Energy and Matter

**Content**
- The transfer of energy can be tracked as energy flows through a designed or natural system.
- Energy and Matter

**Notes**
- Energy is spontaneously transferred out of hotter regions or objects and into a colder sample and the environment. (MS-PS3-4)
- The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment. (MS-PS3-4)
- Energy is spontaneously transferred out of hotter regions or objects into the colder sample. (MS-PS3-3)
- Energy and Matter

**Standards Addressed**
- MS-PS3-3: Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.
- MS-ETS1-1: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ETS1-2: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- 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.
- MS-ETS1-4: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.
- PS1.A: Definitions of Energy
  - Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. (MS-PS3-3)(MS-PS3-4)
- PS1.B: Conservation of Energy and Energy Transfer
  - The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment. (MS-PS3-4)
  - Energy is spontaneously transferred out of hotter regions or objects and into the colder sample. (MS-PS3-3)
  - Energy and Matter

**Disciplinary Core Ideas**
- 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
  - Structure and Function
    - The transfer of energy can be tracked as energy flows through a designed or natural system.

**Crosscutting Concepts**
- 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
  - Structure and Function
    - The transfer of energy can be tracked as energy flows through a designed or natural system.

**Version date**
- For the most updated version

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7 Solutions

• Dissolving is an interaction between two substances in which one substance breaks apart and goes into another substance. A mixture is a combination of two or more substances.
• Dissolving occurs when one substance (solute) is reduced to particles and is distributed uniformly throughout the particles of a second substance (solvent).
• Dissolving involves both kinetic interactions (collisions) and attractive forces (bonds).

MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures.

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.

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.

PS1.A. Structure and Properties of Matter
• Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS-PS1-3)
• Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (MS-PS1-2)(MS-PS1-3)
• Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals). (MS-PS1-1)

PS1.A: Definitions of Energy
• Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. (MS-PS1-3),(MS-PS1-4)

Patterns
• Patterns can be used to identify cause and effect relationships.

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

7 Solutions

• Dissolving is an interaction between two substances in which one substance breaks apart and goes into another substance. A mixture is a combination of two or more substances.
• Dissolving occurs when one substance (solute) is reduced to particles and is distributed uniformly throughout the particles of a second substance (solvent).
• Dissolving involves both kinetic interactions (collisions) and attractive forces (bonds).

MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures.

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.

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.

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4 Phase Change

• Matter exists on Earth in three common states—solid, liquid, and gas.
• In solids, particles are held in place and move only by vibrating.
• In liquids, particles are held close but are able to move around and over one another.
• Change of state is the result of change of energy in the particles in a sample of matter.
• The temperatures at which phase changes occur are different for different substances.

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.

• Changes and laws 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)
• The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. (MS-PS1-4)

PS1.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 the second meaning; it refers to the energy transferred due to the temperature difference between two objects. (secondary to MS-PS1-4)
• Temperature is not a measure of energy; the relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. (secondary to MS-PS1-4)

Patterns
• Patterns can be used to identify cause and effect relationships.

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

Energy and Matter
• The transfer of energy can be tracked as energy flows through a designed or natural system.
### Part Summary

Students use candles to increase the energy transferred to wax and sugar. They observe that both wax and sugar change from solid to liquid when heated with a candle, and change back to solid when the flame is removed. Students use this experience to extend their understanding of melting and to reinforce the idea that different substances melt and freeze at different temperatures.

#### 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.

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- 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.

#### MS-PS1-4
- Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.

#### MS-PS1-4
- Plan an investigation to determine the relationships among the energy transformed, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.

#### MS-ETS1-1
- Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

#### MS-ETS1-2
- Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

#### 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 solutions to better meet the criteria for success.

#### MS-ETS1-4
- Develop a model to generate data for iterative design solutions (iterative), predicting and testing the impact of design changes on the system.

### Crosscutting Concepts

#### SP
- Patterns of energy can be used to identify cause and effect relationships.

#### MS-ETS1-2
- Cause and Effect
- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

#### MS-ETS1-3
- The transfer of energy can be tracked as energy flows through a designed or natural system.

### Disciplinary Core Ideas (Framework)

#### PS1.A: Structure and Properties of Matter
- Describe and quantify energy changes during transfers and transformation of matter.
- Describe and quantify energy changes during transfers and transformation of matter.

#### PS3.A: Definitions of Energy
- Energy can be classified as kinetic or势能.

#### MS-PS1-4
- Gases and liquids are made of molecules or inert atoms that are moving about freely in space.

#### MS-PS1-4
- Temperature is the best characteristic of each that can be combined into a new solution to better meet the criteria for success.

#### MS-PS1-4
- Develop a model to generate data for iterative design solutions (iterative), predicting and testing the impact of design changes on the system.

### Disciplinary Core Ideas

#### PS1.A: Structure and Properties of Matter
- Kinetic energy is the energy of the particles as measured by the temperature of the sample.

#### PS3.A: Definitions of Energy
- Energy can be classified as kinetic or potential.

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### Inv 9 Chemical Interactions, 2nd Edition

**Reaction**

<table>
<thead>
<tr>
<th>Inv</th>
<th>Title</th>
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<tr>
<td>1</td>
<td>Substance Models</td>
<td>Students review chemical formulas as symbolic representations for substances and learn that the fundamental building blocks of substances are atoms. Colored adhesive dots, introduced as representations of atoms, are used to construct two-dimensional representations of compounds—molecules and ionic compounds. Chemical bonds are introduced as the attractive forces holding particles together. Students make and analyze representations of particles of familiar substances.</td>
<td>3</td>
<td>All substances are made from some 100 different types of atoms (elements), which combine with one another in various ways. A compound is a substance composed of two or more different kinds of elements (kinds of atoms). Atoms combine to make particles of substances: molecules and ionic compounds. Molecules and ionic compounds are held together by attractive forces called bonds.</td>
<td>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.</td>
</tr>
<tr>
<td>2</td>
<td>Water Reaction</td>
<td>Students observe no change when atmospheric air is pumped through a sample of limewater. They blow added breath through limewater and observe a milky precipitate. Students use atom links to represent the reactant molecules and rearrange them to make product molecules. They write a balanced chemical equation for the reaction, using standard conventions.</td>
<td>3</td>
<td>All substances are made from some 100 different types of atoms (elements), which combine with one another in various ways. A chemical reaction is a process in which the atoms of substances (reactants) rearrange to form new substances (products). Atoms are neither created nor destroyed during chemical reactions, only rearranged.</td>
<td>MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures.</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
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<td></td>
<td>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.</td>
</tr>
<tr>
<td>4</td>
<td>Changing Phase</td>
<td>Students investigate all three ordinary states of matter, using a condensation apparatus. Hot water releases water vapor, which condenses on the icy tray, and then freezes to solid water. Students develop an explanation of the system, using their particle model.</td>
<td>3</td>
<td>The matter exists on Earth in three common states—solid, liquid, and gas. In gases, particles move independently through space. Change of state is the result of change of energy in the particles in a sample of matter. The processes of phase change are evaporation, condensation, melting, freezing, sublimation, and deposition.</td>
<td>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.</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MS-PS3-4. Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.</td>
</tr>
</tbody>
</table>

**Disciplinary Core Ideas (Framework)**

- **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.
- **MS-PS3-4.** Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.

**Crosscutting Concepts**

- **SP**
- **SP**
- **SP**

**FOSS MS/NGSS Correlation**

- **FOSS Chemical Interactions, Second Edition**
- **FOSS Chemical Interactions, Second Edition**

**Contact:** jpenchos@berkeley.edu

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Students are introduced to hydrochloric acid and think about what might happen if it were mixed with sodium bicarbonate. They observe a demonstration of the reaction and work with atom tiles to determine the products of the reaction. They conduct the reaction, bubbling the gas produced through lime water and evaporating the liquid, to confirm that the gas was carbon dioxide and that sodium chloride was left in the liquid.

Students work with baking soda and hydrochloric acid and think about what happens to the reactants. They observe a demonstration of the reaction, and students are introduced to the idea that some chemical reactions release energy, while others store energy. (MS-PS1-6)

## Limiting Factors

Students work with baking soda and two citric acid solutions, one twice as concentrated as the other. Using the syringe-and-bottle system, they observe the volumes of gas produced with equal volumes of the two solutions. They discover that the quantity of product is directly related to the reactant that is present in the least quantity, the limiting factor.

### Identify Key Ideas

Students look back on the entire Chemical Interactions Course and work individually and in groups to review the big concepts.

### Chemical Reactions

- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS-PS1-2, MS-PS1-3, MS-PS1-5)
- The total number of each type of atom is conserved, and thus the mass does not change. (MS-PS1-5)
- Some chemical reactions release energy, others store energy. (MS-PS1-6)

### Course and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems.
- Concepts can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.

### Crosscutting Concepts

- Scale, proportion, and quantity
- Systems and System Models
  - Systems and System Models: Scientific relationships can be represented through the use of algebraic expressions and equations.
  - Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.
  - Stability and Change: Explorations 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.