Unit 2: Matter and Energy

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A characteristic property is a chemical or physical property that can be used to identify a substance. These properties of a substance are always the same no matter what the size of the sample is. Examples of characteristic properties include freezing/melting point, boiling/condensing point, density, magnetism, flammability and solubility. These types of characteristic properties are called intensive characteristics. Characteristic properties that do change with the size of the sample are called extensive characteristics. Examples of extensive characteristic properties are mass, volume, and weight.
Both of these men are skiing, but the man on the left is skiing on snow while the man on the right is skiing on sand. Snow and sand are both kinds of matter, but they have different properties. What are some ways snow and sand differ? One difference is the temperature at which they melt. Snow melts at 0°C, whereas sand melts at about 1600°C! The temperature at which something melts is its melting point. Melting point is just one of many physical properties of matter.

What Are Physical Properties?

Physical properties of matter are properties that can be measured or observed without matter changing to an entirely different substance. Physical properties are typically things you can detect with your senses. For example, they may be things that you can see, hear, smell, or feel.

Q: What differences between snow and sand can you detect with your senses?
A: You can see that snow and sand have a different color. You can also feel that snow is softer than sand. Both color and hardness are physical properties of matter.

Additional Physical Properties

In addition to these properties, other physical properties of matter include the state of matter. States of matter include liquid, solid, and gaseous states. For example at 20°C, coal exists as a solid and water exists as a liquid. Additional examples of physical properties include:

- odor
- boiling point
- ability to conduct heat
- ability to conduct electricity
- ability to dissolve in other substances

Some of these properties are illustrated in the Figures 2.1, 2.2, 2.3, and 2.4. The video at this URL below compares physical properties such as these for different classes of matter:
Q: The coolant that is added to a car radiator also has a lower freezing point than water. Why is this physical property useful?

A: When coolant is added to water in a car radiator, it lowers the freezing point of the water. This prevents the water in the radiator from freezing when the temperature drops below 0°C, which is the freezing point of pure water.
**Ability to Conduct Electricity**

Copper is a good conductor of electricity. That’s why electric wires are often made of copper. They are covered with a protective coating of plastic, which does not conduct electricity.

**FIGURE 2.4**

Q: Besides being able to conduct electricity, what other physical property of copper makes it well suited for electric wires?

A: Copper, like other metals, is ductile. This means that it can be rolled and stretched into long thin shapes such as wires.

Physical properties of matter can be divided into **extensive or intensive properties**. Intensive properties are properties of matter that do not depend on the amount of matter present. Examples include color, odor, luster, malleability, ductility, hardness, melting point, freezing point, boiling point and density. Extensive properties are properties of matter that do depend on the amount of matter present. Examples include mass, volume, weight and length.

**Summary**

- Physical properties of matter are properties that can be measured or observed without matter changing to an entirely different substance. Physical properties are typically things you can detect with your senses.
- Examples of physical properties of matter include melting point, color, hardness, state of matter, odor, and boiling point.

**Vocabulary**

- **physical property**: Property of matter that can be measured or observed without matter changing to an entirely different substance.
- **Intensive property**: Physical property of matter that does not depend on the amount of matter.
- **Extensive property**: Physical property of matter that does depend on the amount of matter.

**Practice**

Water is one of the most important substances on Earth, and it has some unique physical properties. Read in detail about any one of the physical properties of water at the URL below. Then make a poster or video demonstrating this property of water.

## Review

1. What is a physical property of matter?
2. List three examples of physical properties.
3. Compare and contrast two physical properties of apples and oranges.

## References

1. Swimming: Image copyright Brian Chase, 2012; Bottle: Image copyright Jason Stitt, 2012; composite created by CK-12 Foundation. Used under licenses from Shutterstock.com
2. Fir0002; modified by CK-12 Foundation. CC-BY-NC 3.0
3. Image copyright Rick Lord, 2012; modified by CK-12 Foundation. Used under license from Shutterstock.com
4. Image copyright pokchu, 2012; modified by CK-12 Foundation. Used under license from Shutterstock.com
Look at the two garden trowels pictured here. Both trowels were left outside for several weeks. One tool became rusty, but the other did not. The tool that rusted is made of iron, and the other tool is made of aluminum. The ability to rust is a chemical property of iron but not aluminum.

**What Are Chemical Properties?**

Chemical properties are properties that can be measured or observed only when matter undergoes a change to become an entirely different kind of matter. For example, the ability of iron to rust can only be observed when iron actually rusts. When it does, it combines with oxygen to become a different substance called iron oxide. Iron is very hard and silver in color, whereas iron oxide is flakey and reddish brown. Besides the ability to rust, other chemical properties include reactivity and flammability.

**Reactivity**

Reactivity is the ability of matter to combine chemically with other substances. Some kinds of matter are extremely reactive; others are extremely unreactive. For example, the metal magnesium is very reactive, even with water. When a pea-sized piece of magnesium is added to a small amount of water, it reacts explosively. You can observe this reaction in the video at the URL below. (Caution: Don’t try this at home!) In contrast, noble gases such as helium almost never react with any other substances.

http://www.youtube.com/watch?v=0QaaUw7B_js
Flammability

Flammability is the ability of matter to burn. When matter burns, it combines with oxygen and changes to different substances. Wood is an example of flammable matter. When wood burns, it changes to ashes, carbon dioxide, water vapor, and other gases. You can see ashes in the wood fire pictured in the Figure 3.1. The gases are invisible.

Q: How can you tell that wood ashes are a different substance than wood?
A: Ashes have different properties than wood. For example, ashes are gray and powdery, whereas wood is brown and hard.

Q: What are some other substances that have the property of flammability?
A: Substances called fuels have the property of flammability. They include fossil fuels such as coal, natural gas, and petroleum, as well as fuels made from petroleum, such as gasoline and kerosene. Substances made of wood, such as paper and cardboard, are also flammable.

Summary

- Chemical properties are properties that can be measured or observed only when matter undergoes a change to become an entirely different kind of matter. They include reactivity, flammability, and the ability to rust.
- Reactivity is the ability of matter to react chemically with other substances.
- Flammability is the ability of matter to burn.

Vocabulary

- chemical property: property of matter that can be measured or observed only when matter changes to an entirely different substance.
- flammability: Ability of matter to burn.
- reactivity: Ability of a substance to combine chemically with other substances.
**Practice**

The chart below shows the reactivity of several different metals. The metals range from very reactive to very unreactive. Study the chart and then answer the questions below.

<table>
<thead>
<tr>
<th>Metal</th>
<th>Reactivity</th>
<th>React with</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium</td>
<td>Very reactive</td>
<td>Water</td>
</tr>
<tr>
<td>Sodium</td>
<td>React with water</td>
<td></td>
</tr>
<tr>
<td>Lithium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnesium</td>
<td>React with acids</td>
<td></td>
</tr>
<tr>
<td>Aluminium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iron</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td></td>
<td>React with oxygen</td>
</tr>
<tr>
<td>Mercury</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silver</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gold</td>
<td>Very unreactive</td>
<td></td>
</tr>
</tbody>
</table>

1. What is the most reactive metal in the chart? What is the least reactive metal?
2. Complete this sentence: Only the most reactive metals in the chart react with ______________.
3. Is this statement true or false? Most metals in the chart react with oxygen.
4. Which of the following metals reacts with oxygen and acids but not with water?
   a. calcium
   b. magnesium
   c. copper

**Review**

1. What is a chemical property?
2. Define the chemical property called reactivity.
3. What is flammability? Identify examples of flammable matter.

**References**

1. Image copyright Virunja, 2012. Used under license from Shutterstock
The striking blue walls in this photo are actually the sheer ice walls of a massive glacier. The glacier in the picture is on the coast of Antarctica, and the bluish water in the foreground is the ocean off the Antarctic coast. The photo represents an important concept in physical science. Can you guess what it is?

Water, Water Everywhere

The photo above represents water in three common states of matter. **States of matter** are different phases in which any given type of matter can exist. There are actually four well-known states of matter: solid, liquid, gas, and plasma. Plasma isn’t represented in the iceberg photo, but the other three states of matter are. The iceberg itself consists of water in the solid state, and the ocean consists of water in the liquid state.

**Q:** Where is water in the gaseous state in the above photo?

**A:** You can’t see the gaseous water, but it’s there. It exists as water vapor in the air.

**Q:** Water is one of the few substances that commonly exist on Earth in more than one state. Many other substances typically exist only in the solid, liquid, or gaseous state. Can you think of examples of matter that usually exists in just one of these three states?

**A:** Just look around you and you will see many examples of matter that usually exists in the solid state. They include soil, rock, wood, metal, glass, and plastic. Examples of matter that usually exist in the liquid state include cooking oil, gasoline, and mercury, which is the only metal that commonly exists as a liquid. Examples of matter that usually exists in the gaseous state include oxygen and nitrogen, which are the chief gases in Earth’s atmosphere.
Phases Are Physical

A given kind of matter has the same chemical makeup and the same chemical properties regardless of its state. That’s because state of matter is a physical property. As a result, when matter changes state, it doesn’t become a different kind of substance. For example, water is still water whether it exists as ice, liquid water, or water vapor.

Properties of Solids, Liquids, and Gases

The most common states of matter on Earth are solids, liquids, and gases. How do these states of matter differ? Their properties are contrasted in the Figure 4.1. You can also watch videos about these three states of matter at the following URLs.

http://www.youtube.com/watch?v=s-KvoVzukHo
http://www.youtube.com/watch?v=NO9OGeHgtBY

Properties of Matter in Different States

Q: The Figure 4.2 shows that a liquid takes the shape of its container. How could you demonstrate this?
A: You could put the same volume of liquid in containers with different shapes. This is illustrated below with a beaker (left) and a graduated cylinder (right). The shape of the liquid in the beaker is short and wide like the beaker, while the shape of the liquid in the graduated cylinder is tall and narrow like that container, but each container holds the same volume of liquid.

Q: How could you show that a gas spreads out to take the volume as well as the shape of its container?
A: You could pump air into a bicycle tire. The tire would become firm all over as air molecules spread out to take the shape of the tire and also to occupy the entire volume of the tire.

Summary

• States of matter are different phases in which any given type of matter can exist. There are four well-known states of matter—solid, liquid, gas, and plasma—but only the first three states are common on Earth.
• State of matter is a physical property of matter. A given kind of matter has the same chemical makeup and the same chemical properties, regardless of state.
• Solids have a fixed volume and a fixed shape. Liquids have a fixed volume but take the shape of their container. Gases take both the volume and the shape of their container.

Vocabulary

• state of matter: Different phase (solid, liquid, gas, and plasma) in which matter can exist without the chemical makeup of matter changing.
Practice
Play the states of matter game at the following URL to reveal the hidden picture.

http://www.neok12.com/quiz/STSMAT01

Review
1. Define state of matter.
2. List four states of matter. Which states of matter are most common on Earth?
3. What type of property is state of matter? How could you demonstrate this?
4. Make a table comparing and contrasting solids, liquids, and gases.

References
1. CK-12 Foundation - Christopher Auyeung. . CC-BY-NC-SA 3.0
2. Image copyright william casey, 2012. . Used under license from Shutterstock.com
Both of these photos show the famous Golden Gate Bridge near San Francisco, California. The pictures were taken from about the same point of view on the same day, but they look very different. In the picture on the left, the deck of the bridge is almost completely hidden by a thick layer of fog. In the picture on the right the fog has disappeared, and the deck of the bridge—as well as the water below it—is clearly visible. Fog consists of tiny droplets of liquid water. The fog in the picture is like a cloud at ground level. Where did the fog come from, and where did it go?

**What Are Changes of State?**

The water droplets of fog form from water vapor in the air. Fog disappears when the water droplets change back to water vapor. These changes are examples of changes of state. A change of state occurs whenever matter changes from one state to another. Common states of matter on Earth are solid, liquid, and gas. Matter may change back and forth between any two of these states.

Changes of state are physical changes in matter. They are reversible changes that do not change matter’s chemical makeup or chemical properties. For example, when fog changes to water vapor, it is still water and can change back to liquid water again.

**Processes that Cause Changes of State**

Several processes are involved in common changes of state. They include melting, freezing, sublimation, deposition, condensation, and evaporation. The Figure 5.1 shows how matter changes in each of these processes.

**Q:** Which two processes result in matter changing to the solid state?

**A:** The processes are deposition, in which matter changes from a gas to a solid, and freezing, in which matter changes from a liquid to a solid.

**The Role of Energy in Changes of State**

Suppose that you leave some squares of chocolate candy in the hot sun. A couple of hours later, you notice that the chocolate has turned into a puddle like the one pictured in the Figure 5.2.

**Q:** What happened to the chocolate?
A: The chocolate melted. It changed from a solid to a liquid.

In order for solid chocolate to melt and change to a liquid, the particles of chocolate must gain energy. The chocolate pictured in the Figure 5.2 gained energy from sunlight. Energy is the ability to cause changes in matter, and it is always involved in changes of state. When matter changes from one state to another, it either absorbs energy—as when chocolate melts—or loses energy. For example, if you were to place the melted chocolate in a refrigerator, it would lose energy to the cold air inside the refrigerator. As a result, the liquid chocolate would change to a solid again.
Q: Why is energy always involved in changes of state?

A: The energy of particles of matter determines the matter’s state. Particles of a gas have more energy than particles of a liquid, and particles of a liquid have more energy than particles of a solid. Therefore, in order for matter to change from a solid to a liquid or from a liquid to a gas, particles of matter must absorb energy. In order for matter to change from a gas to a liquid or from a liquid to a solid, particles of matter must lose energy. You can learn more about the role of energy in changes of state at this URL: http://hogan.chem.lsu.edu/matter/chap26/animate3/an26_035.mov

Summary

- A change of state occurs whenever matter changes from one state to another. Changes of state are physical changes in matter. They are reversible changes that do not change matter’s chemical makeup or chemical properties.
- Processes involved in changes of state include melting, freezing, sublimation, deposition, condensation, and evaporation.
- Energy is always involved in changes of state. Particles of matter either absorb or lose energy when matter changes from one state to another.

Practice

Take the changing states quiz at the following URL. Be sure to check your answers.
http://www.bbc.co.uk/apps/ifl/schools/ks2bitesize/science/quizengine?quiz=changingstates&templateStyle=science

Review

1. Define change of state, and give an example.
2. Identify processes that change matter to a liquid state.
3. Why must energy be absorbed to change a liquid to a gas?
References

1. CK-12 Foundation - Christopher Auyeung. CC-BY-NC-SA 3.0
2. Image copyright Anteromite, 2012. Used under license from Shutterstock.com
3. . . CC BY-NC-SA
Want to buy a car – cheap? Notice that the ad did not say “in good condition” or even “needs a little work.” The car above is pretty beat up. The body is damaged, the windows are broken, and the interior is probably torn up. But this is still a car. It has all the components of a car, even though you would not want to buy it in the present condition. But change that condition and you have a (possibly) useable car.

**Physical Change**

As an ice cube melts, its shape changes as it acquires the ability to flow. However, its composition does not change. **Melting** is an example of a **physical change**. A physical change is a change to a sample of matter in which some properties of the material change, but the identity of the matter does not. Physical changes can further be classified as reversible or irreversible. The melted ice cube may be refrozen, so melting is a reversible physical change. Physical changes that involve a change of state are all reversible. Other changes of state include **vaporization** (liquid to gas), **freezing** (liquid to solid), and **condensation** (gas to liquid). Dissolving is also a reversible physical change. When salt is dissolved into water, the salt is said to have entered the aqueous state. The salt may be regained by boiling off the water, leaving the salt behind.

When a piece of wood is ground into sawdust, that change is irreversible since the sawdust could not be reconstituted into the same piece of wood that it was before. Cutting the grass or pulverizing a rock would be other irreversible physical changes. Fire wood also represents an irreversible physical change since the pieces cannot be put back together to form the tree.

**Summary**

- A physical change is a change to a sample of matter in which some properties of the material change, but the identity of the matter does not.
• In a reversible physical change, the original form of the matter can be restored.
• In an irreversible physical change, the original form cannot be restored.
• Melting ice and grinding wood into sawdust are examples of physical changes.

Practice

Use the link below to answer the following questions:
http://sites.jmu.edu/chemdemo/2012/07/27/metamorphic-magic-plastic/

1. Is punching a hole in the plastic a physical change?
2. Why is the heating and cooling of the plastic a physical change?

Review

1. Define physical change.
2. Why is melting an ice cube a reversible physical change?
3. Give an example of an irreversible physical change.

- **condensation**: When gas turns to a liquid.
- **freezing**: When a liquid turns to a solid.
- **melting**: When a solid turns to a liquid.
- **physical change**: A change to a sample of matter in which some properties of the material change, but the identity of the matter does not.
- **vaporization**: When liquid turns into gas.

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**References**

Do you like to cook?

Cooking is a valuable skill that everyone should have. Whether it is fixing a simple grilled cheese sandwich to preparing an elaborate meal, cooking demonstrates some basic ideas in chemistry. When you bake bread, you mix some flour, sugar, yeast, and water together. After baking, this mixture has been changed to form another substance (bread) that has different characteristics and qualities from the original materials. The process of baking has produced chemical changes in the ingredients that result in bread being made.

Chemical Change

Most of the elements we know about do not exist free in nature. Sodium cannot be found by itself (unless we prepare it in the laboratory) because it interacts easily with other materials. On the other hand, the element helium does not interact with other elements to any extent. So we can isolate helium from natural gas during the process of drilling for oil.

A chemical change produces a different materials than the ones we started with. One aspect of the science of chemistry is interest in the changes that matter undergoes. If all we had were the elements and they did nothing, life would be very boring (in fact, life would not exist since we need all those compounds to put our bodies together and sustain us). But the processes of change that take place when different chemicals are combined produce all the materials that we use daily.

One type of chemical change (already mentioned) is when two elements combine to form a compound. Another type involves the breakdown of a compound to produce the elements that make it up. If we pass an electric current through bauxite (aluminum oxide, the raw material for aluminum metal), we get metallic aluminum as a product.
However, the vast majority of chemical changes involve one compound being transformed into another compound. There are literally millions of possibilities when we take this approach to chemical change. New compounds can be made that produce better fabrics that are easier to clean and maintain, they can help preserve food so it doesn’t spoil as quickly, and we can make new medicines to treat diseases – all made possible by studying chemical change.

**Summary**

1. A chemical change produces a different materials than the ones we started with.

**Practice**

Use the link below to answer the following questions:

http://chemistry.about.com/od/lecturenotesl3/a/chemphyschanges.htm

1. Where do chemical changes take place?
2. What does a chemical change produce?
3. What are physical changes concerned with?

**Review**

1. What is a chemical change?
2. List three types of chemical changes.

**References**

The Law of conservation of Mass states, that in either physical or chemical changes that mass is exactly conserved, provided nothing is added or escapes.
These neat rows of cola bottles represent matter can in three different states—solid, liquid, and gas. The bottles and caps are solids, the cola is a liquid, and carbon dioxide dissolved in the cola is a gas. It gives cola its fizz. Solids, liquids, and gases such as these have different properties. Solids have a fixed shape and a fixed volume. Liquids also have a fixed volume but can change their shape. Gases have neither a fixed shape nor a fixed volume. What explains these differences in states of matter? The answer has to do with energy.

**Moving Matter**

Energy is the ability to cause changes in matter. For example, your body uses chemical energy when you lift your arm or take a step. In both cases, energy is used to move matter—you. Any matter that is moving has energy just because it’s moving. The energy of moving matter is called kinetic energy. Scientists think that the particles of all matter are in constant motion. In other words, the particles of matter have kinetic energy. The theory that all matter consists of constantly moving particles is called the kinetic theory of matter. You can learn more about the theory at this URL: [http://www.youtube.com/watch?v=Agk7_D4-deY](http://www.youtube.com/watch?v=Agk7_D4-deY).

**Kinetic Energy and States of Matter**

Differences in kinetic energy explain why matter exists in different states. Particles of matter are attracted to each other, so they tend to pull together. The particles can move apart only if they have enough kinetic energy to overcome this force of attraction. It’s like a tug of war between opposing sides, with the force of attraction between particles on one side and the kinetic energy of individual particles on the other side. The outcome of the “war” determines the state of matter.

- If particles do not have enough kinetic energy to overcome the force of attraction between them, matter exists as a solid. The particles are packed closely together and held rigidly in place. All they can do is vibrate. This explains why solids have a fixed volume and a fixed shape.
• If particles have enough kinetic energy to partly overcome the force of attraction between them, matter exists as a liquid. The particles can slide past one another but not pull apart completely. This explains why liquids can change shape but have a fixed volume.
• If particles have enough kinetic energy to completely overcome the force of attraction between them, matter exists as a gas. The particles can pull apart and spread out. This explains why gases have neither a fixed volume nor a fixed shape.

Look at the Figure 9.1. It sums up visually the relationship between kinetic energy and state of matter. You can see an animated diagram at this URL:


Q: How could you use a bottle of cola to demonstrate these relationships between kinetic energy and state of matter?
A: You could shake a bottle of cola and then open it. Shaking causes carbon dioxide to come out of the cola solution and change to a gas. The gas fizzes out of the bottle and spreads into the surrounding air, showing that its particles have enough kinetic energy to spread apart. Then you could tilt the open bottle and pour out a small amount of the cola on a table, where it will form a puddle. This shows that particles of the liquid have enough kinetic energy to slide over each other but not enough to pull apart completely. If you do nothing to the solid glass of the cola bottle, it will remain the same size and shape. Its particles do not have enough energy to move apart or even to slide over each other.

Summary

• According to the kinetic theory, particles of matter are in constant motion. The energy of motion is called kinetic energy.
• The kinetic energy of particles of matter determines the state of matter. Particles of solids have the least kinetic energy and particles of gases have the most.

Vocabulary

• kinetic theory of matter: Theory that all matter consists of constantly moving particles.
Practice

Watch the musical cartoon at this URL, and then answer the questions below.
http://www.youtube.com/watch?v=EH5v54dmb5U

1. What measure changes when molecules have more kinetic energy?
2. What does this measure represent?

Review

1. State the kinetic theory of matter.
2. Explain the relationship between kinetic energy and state of matter.

References

1. CK-12 Foundation - Zachary Wilson.  . CC-BY-NC-SA 3.0
• Define heat.
• Explain how thermal energy is transferred.

This chef is placing cookie dough in a hot oven. What will happen to the dough after he closes the oven door? Will the hot oven add “heat energy” to the dough? Not exactly. Contrary to popular belief, heat is not a form of energy.
**What Is Heat?**

**Heat** is the transfer of thermal energy between substances. Thermal energy is the kinetic energy of moving particles of matter, measured by their temperature. Thermal energy always moves from matter with greater thermal energy to matter with less thermal energy, so it moves from warmer to cooler substances. You can see this in the Figure 10.1. Faster-moving particles of the warmer substance bump into and transfer some of their energy to slower-moving particles of the cooler substance. Thermal energy is transferred in this way until both substances have the same thermal energy and temperature. For a visual introduction to these concepts, watch the animation “Temperature vs. Heat” at this URL:

http://www.sciencehelpdesk.com/unit/science2/3

![Figure 10.1](image)

Q: How is thermal energy transferred in an oven?

A: Thermal energy of the hot oven is transferred to the cooler food, raising its temperature.

**Cooling Down by Heating Up**

How do you cool down a glass of room-temperature cola? You probably add ice cubes to it, as in the Figure 10.2. You might think that the ice cools down the cola, but in fact, it works the other way around. The warm cola heats up the ice. Thermal energy from the warm cola is transferred to the much colder ice, causing it to melt. The cola loses thermal energy in the process, so its temperature falls.
Summary

- Heat is the transfer of thermal energy between substances. Thermal energy is the kinetic energy of moving particles of matter, measured by their temperature.
- Thermal energy always moves warmer to cooler substances until both substances have the same temperature.

Vocabulary

- **heat**: Transfer of thermal energy between objects that have different temperatures.

Practice

View the slides at the following URL, and then do the matching questions below. [http://www.slideshare.net/AlkorBilingual/u11-heat-temperature](http://www.slideshare.net/AlkorBilingual/u11-heat-temperature)

*Fill in the blank before each number with the letter of the term that is the best match. Note that there are more terms than needed.*

- 1. amount of heat in a system  
  - 2. increase in volume that occurs when a system gains thermal energy  
  - 3. state of matter that expands most when it is heated  
  - 4. unit used to measure heat  
  - 5. amount of thermal energy that is transferred from one system to another  
  - 6. instrument used to measure temperature

  a. contraction  
  b. heat  
  c. solid  
  d. expansion  
  e. temperature  
  f. heat meter  
  g. gas  
  h. joule  
  i. degree  
  j. thermometer

Review

1. Define heat.
2. Describe how thermal energy is transferred.
3. Hot cocoa is poured into a cold mug. Apply the concept of heat to explain what happens next.
References

1. CK-12 Foundation. CC-BY-NC-SA 3.0
2. Used under license from Shutterstock.com
• Define physical change, and give examples of physical change.
• Explain how physical changes can be reversed.

These stunning rock arches in Utah were carved by wind-blown sand. Repeated scouring by the sand wore away the rock, bit by tiny bit, like sandpaper on wood. The bits of rock worn away by the sand still contain the same minerals as they did when they were part of the large rock. They have not changed chemically in any way. Only the size and shape of the rock have changed, from a single large rock to millions of tiny bits of rock. Changes in size and shape are physical changes in matter.

What Is a Physical Change?

A physical change is a change in one or more physical properties of matter without any change in chemical properties. In other words, matter doesn’t change into a different substance in a physical change. Examples of physical change include changes in the size or shape of matter. Changes of state of matter—for example, from solid to liquid or from liquid to gas—are also physical changes. Some of the processes that cause physical changes include cutting, bending, dissolving, freezing, boiling, and melting. Four examples of physical change are pictured below. You can learn more about physical changes and why they occur by watching the video at this URL:

http://www.youtube.com/watch?v=RQTcSNVrNUk (13:35)
Q: In the Figure 11.1, what physical changes are occurring?

A: The paper is being cut into smaller pieces, which is changing its size and shape. The ice cubes are turning into a puddle of liquid water because they are melting. This is a change of state. The tablet is disappearing in the glass of water because it is dissolving into particles that are too small to see. The lighthouse is becoming coated with ice as ocean spray freezes on its surface. This is another change of state.

Reversing Physical Changes

When matter undergoes physical change, it doesn’t become a different substance. Therefore, physical changes are often easy to reverse. For example, when liquid water freezes to form ice, it can be changed back to liquid water by heating and melting the ice.

Q: Salt dissolving in water is a physical change. How could this change be reversed?

A: The salt water could be boiled until the water evaporates, leaving behind the salt. Water vapor from the boiling water could be captured and cooled. The water vapor would condense and change back to liquid water.

Summary

- A physical change in matter is a change in one or more of matter’s physical properties. In a physical change, matter may change its size, shape, or state, but its chemical properties do not change.
- Because the chemical properties of matter remain the same in a physical change, a physical change is often easy to reverse.
Vocabulary

- **Physical change**: Change in one or more of matter's physical properties.
- **Boiling point**: the temperature at which the vapor pressure is a liquid is equal to the external pressure (100 °C = 101.3 kPa = 1 atmosphere)
- **Evaporate**: the escape of molecules from the liquid into the gas phase.
• **Condense:** the process whereby a gas or vapor is changed into a liquid. Also any process by which a substance is made more dense.

• **Freeze:** the temperature at which a liquid changes into a solid; normally measured at 1 atmosphere pressure.
• **Melt:** the temperature at which a solid changes into a liquid. Same as the freezing point of the same substance.

• **Change of state of matter or phase change:** the ability of matter to change back and forth between between solid, liquid, or gas based on the amount of energy being added or taken away from the system.

**Practice**

Answer the questions below.

1. Describe an example of temperature causing a change in the size of matter.
2. How is temperature related to changes in the state of matter?

**Review**

1. Define physical change.
2. What are some examples of physical change?
3. The wood in the Figure 11.6 is being cut with a chainsaw. Is this a physical change? Why or why not?

**References**

2. . . CC BY-NC-SA
3. . . CC BY-NC-SA
4. . . CC BY-NC-SA
5. . . CC BY-NC-SA
6. Image copyright Voyagerix, 2012. . Used under license from shutterstock.com
What Is a Chemical Change?

A chemical change occurs whenever matter changes into an entirely different substance with different chemical properties. A chemical change is also called a chemical reaction. Many complex chemical changes occur to produce the explosions of fireworks. An example of a simpler chemical change is the burning of methane. Methane is the main component of natural gas, which is burned in many home furnaces. During burning, methane combines with
oxygen in the air to produce entirely different chemical substances, including the gases carbon dioxide and water vapor. You can watch some very colorful chemical changes occurring in the video at this URL:

http://www.youtube.com/watch?v=BqeWpywDuiY (2:54)

Identifying Chemical Changes

Most chemical changes are not as dramatic as exploding fireworks, so how can you tell whether a chemical change has occurred? There are usually clues. You just need to know what to look for. A chemical change has probably occurred if bubbles are released, there is a change of color, or an odor is produced. Other clues include the release of heat, light, or loud sounds. Examples of chemical changes that produce these clues are shown in the Figure 12.1.

**Q:** In addition to iron rusting, what is another example of matter changing color? Do you think this color change is a sign that a new chemical substance has been produced?

**A:** Another example of matter changing color is a penny changing from reddish brown to greenish brown as it becomes tarnished. The color change indicates that a new chemical substance has been produced. Copper on the surface of the penny has combined with oxygen in the air to produce a different substance called copper oxide.

**Q:** Besides food spoiling, what is another change that produces an odor? Is this a chemical change?

**A:** When wood burns, it produces a smoky odor. Burning is a chemical change.

**Q:** Which signs of chemical change do fireworks produce?

**A:** Fireworks produce heat, light, and loud sounds. These are all signs of chemical change. You can learn how fireworks produce these signs of chemical change at this URL: http://www.scifun.org/chemweek/fireworks/fireworks.htm.

Can Chemical Changes Be Reversed?

Because chemical changes produce new substances, they often cannot be undone. For example, you can’t change ashes from burning logs back into wood. Some chemical changes can be reversed, but only by other chemical
changes. For example, to undo tarnish on copper pennies, you can place them in vinegar. The acid in the vinegar combines with the copper oxide of the tarnish. This changes the copper oxide back to copper and oxygen, making the pennies reddish brown again. You can try this at home to see how well it works.

**Summary**

- A chemical change occurs whenever matter changes into an entirely different substance with different chemical properties. Burning is an example of a chemical change.
- Signs of chemical change include the release of bubbles, a change of color, production of an odor, release of heat and light, and production of loud sounds.
- Because chemical changes result in different substances, they often cannot be undone. Some chemical changes can be reversed, but only by other chemical changes.

**Vocabulary**

- **chemical change**: Change in matter that occurs when matter changes chemically into an entirely different substance with different chemical properties. The new substance cannot be changed back into the original substance in most cases.

**Practice**

Chemical changes always result in the. Physical changes do not. Do the interactive lab at the following URL to see if you can identify the chemical changes.


**Review**

1. What happens in any chemical change?
2. List three signs that a chemical change has occurred.
3. Give an example of a chemical change. Explain why you think it is a chemical change.
4. Why can chemical changes often not be reversed?

**References**

If you build a campfire like this one, you start with a big pile of logs. As the fire burns, the pile of logs slowly shrinks. By the end of the evening, all that’s left is a small pile of ashes. What happened to the matter that you started with? Was it destroyed by the fire?

Where’s the Matter?

It may seem as though burning destroys matter, but the same amount, or mass, of matter still exists after a campfire as before. Look at the sketch in Figure 13.1. It shows that when wood burns, it combines with oxygen and changes not only to ashes but also to carbon dioxide and water vapor. The gases float off into the air, leaving behind just the ashes. Suppose you had measured the mass of the wood before it burned and the mass of the ashes after it burned. Also suppose you had been able to measure the oxygen used by the fire and the gases produced by the fire. What would you find? The total mass of matter after the fire would be the same as the total mass of matter before the fire. To prove this you would have to find a way to contain the smoke given off by the fire as gas has mass.

Q: What can you infer from this example?
A: You can infer that burning does not destroy matter. It just changes matter into different substances.

Law of Conservation of Mass

This burning campfire example illustrates a very important law in science: the law of conservation of mass. This law states that matter cannot be created or destroyed. Even when matter goes through a physical or chemical change, the total mass of matter always remains the same.
The law of conservation of mass is an example of a Law of Nature. Laws of Nature are unchangeable events in our physical world. Others are the Law of Constant Proportions (compound synthesis and decomposition) and Law of Electrical Charges (opposites attract).

**Q:** How could you show that the mass of matter remains the same when matter changes state?

**A:** You could find the mass of a quantity of liquid water. Then you could freeze the water and find the mass of the ice. The mass before and after freezing would be the same, showing that mass is conserved when matter changes state.

**Summary**

- Burning and other changes in matter do not destroy matter. The mass of matter is always the same before and after the changes occur.
- The law of conservation of mass states that matter cannot be created or destroyed.

**Vocabulary**

- **law of conservation of mass:** Law stating that matter cannot be created or destroyed in chemical reactions.

**Practice**

At the following URL, apply the law of conservation of mass to a scene from a Harry Potter film. Then answer the questions below.

http://www.youtube.com/watch?v=3TsTOnNmkJ8 (2:05)

1. What is the mass of the professor in kilograms? What is the mass of the cat in kilograms? *(Hint: 1 pound = 0.45 kilograms)*
2. The scene must be magic because it defies the law of conservation of mass. Explain why.
Review

1. What is the law of conservation of mass?
2. Describe an example of the law of conservation of mass.

- law
- conservation of mass
- reactant
- product

References

1. CK-12 Foundation - Christopher Auyeung. . CC-BY-NC-SA 3.0