

Lesson 5: Properties of Matter II (2 Days)

☐ Getting Started

In Lesson 4 you learned about particles of matter and their different states. In this lesson, you will look more closely at the states of matter by focusing on what causes the changes and why some matter is in one state while another may be in a different state. Specific changes you will examine include melting and boiling point as well as **density** — the measure of the mass per unit volume of matter — and **solubility** — the extent to which one substance is able to dissolve in another.

Other properties you will look at include volume, mass, and weight. **Volume** is the size of a three-dimensional space enclosed within or occupied by an object. **Mass** is a measure of the amount of matter an object contains. **Weight** is a measure of the heaviness of an object as a result of the influence of gravity. Although these properties do not explain the differences in matter, each one is evidence of the differences that exist among different elements.

Stuff You Need

- 250-ml beaker (kit)
- 3 irregularly shaped objects (such as small toys)
- calculator
- candle wax (kit)
- dynamometer (kit)
- heat source
- large cups (kit)
- large transparent container (such as a two-liter bottle with the top cut off)
- permanent marker
- ruler
- safety goggles (kit)
- saucepan
- scissors
- watch or timer
- wooden cube (kit)

Ideas to Think About

- What makes one piece of matter different from another?
- Why does matter "behave" the way it does in different circumstances?
- What patterns do you recognize with regards to the properties of matter?

Things to Know

- **density**: a measure of the mass per unit volume of matter
- **solubility**: the extent to which one substance is able to dissolve in another
- **volume**: the size of a three-dimensional space enclosed within or occupied by an object
- **mass**: a measure of the amount of matter an object contains
- **weight**: a measure of the heaviness of an object as a result of the influence of gravity



Draw My Science: Mass, Volume, and Density

www.beyondthepage.com/link/4647/

Watch this video about the basic properties of matter. Then answer the questions in the "Reading and Questions" section.

☐ Reading and Questions

Watch the video about the basic properties of matter (link provided) and then answer these questions.

1. What is the difference between mass and weight?

2. What is volume?

3. What is the formula for determining an object's density?

Activities

☐ Activity 1: Volume, Mass, and Weight

In today's lessons, you will be challenged to further develop your understanding of some of the properties of matter. In this activity, you will be finding the volume of both regular and irregular three-dimensional shapes. For regular shapes — cubes, rectangular prisms, spheres, and pyramids — you will use specific formulas to find volume. For irregular shapes, you will use a procedure called the displacement method to find volume. Remember that the formula for volume is a measure of the length x width x height of an object. This formula may vary some depending on the object, so be sure you consider the object before calculating its volume.

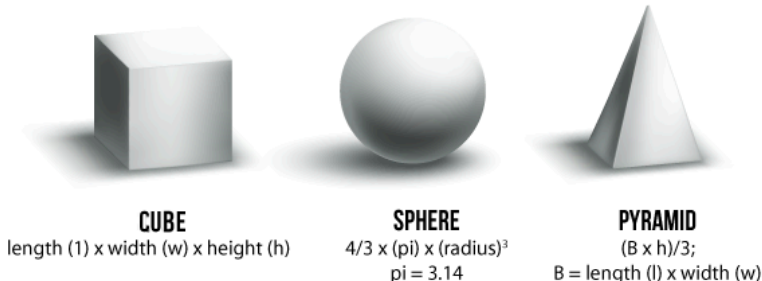
Volume of Regular Shapes

To find the formula for three-dimensional regular shapes, you will use the formulas listed on the "Three-Dimensional Shapes" graphic. Also note the following:

- Three-dimensional squares are called cubes, and rectangular objects are called rectangular prisms.
- Three-dimensional circular objects are spheres. Note that the measurement of pi (3.14) in the formula is a constant that represents a relationship between the distance around a circle (circumference) and the circle's diameter.
- Three-dimensional triangles are pyramids. In the formula, B is the base of the pyramid and is equal to the length x width of the bottom. The letter "h" represents the height of the pyramid.

Three-Dimensional Shapes

VOLUME OF THREE-DIMENSIONAL OBJECTS



Using the formulas provided, solve the problems on the "Volume of Regular Shapes" activity page.

Volume of Irregular Shapes

Not all objects have a regular shape; some have an irregular shape, and finding their volume can be challenging. One way to find the volume of an irregular shape is through the displacement method. This method involves putting an object in water and measuring how much the water level rises. In this part of the activity, you will use a very basic form of the displacement method.

First, gather your materials. You will need a transparent container (such as a 2-liter bottle with its top cut off), a marker, a ruler, an object that is a cube or rectangular prism (such as a small block of wood), a 250-ml beaker, and 3 irregularly shaped objects (such as small toys). You will record your measurements on the top section of the "Volume, Mass, and Weight" activity page.

Next, follow these steps:

1. Pour water into a transparent container. The container should be only $\frac{1}{2}$ to $\frac{2}{3}$ full. (You need enough water to be able to submerge your objects; if there is too much water, the water may overflow the container.)
2. Mark the water level in the container with a marker.
3. Use a ruler to find the length, width, and height of your cube (or rectangular prism). Record the object's volume in cubic centimeters.
4. Now place the cube in the container until it sinks or is completely submerged. If the object does not sink, use a pencil or other small object to push the object under the water completely. The object does not have to touch the bottom, but you will want to make sure that it is completely covered by water.
5. Use your marker to mark where the water line is now.
6. Keep the object in water as you carefully pour water from the container into your 250-ml beaker. Keep pouring out water until the water level is at the original (bottom) line.
7. Write down the amount of water in your beaker. This should be in milliliters.
8. Convert milliliters to cubic centimeters (cm^3). (Example: 200 milliliters = 200 cubic centimeters; 127 milliliters = 127 cubic centimeters)
9. This number should be close to the number you calculated in Step 3. It will not be exact but should be fairly close (within 5-10 milliliters).
10. Pour the water from the beaker back into your container.
11. Make sure the water is at the original line. If not, add water as needed.
12. Repeat the displacement method for each of your three irregularly shaped objects and record their volumes on the activity page.

In the next part of the activity, you will determine how much each of your 4 objects would weigh on Earth and on other locations in the solar system.

Mass is the amount of matter in an object, and weight is the measure of the heaviness of an object as a result of the influence of gravity. To help demonstrate this difference, you will find the weight of your four objects based on where the objects are located. First you will find each objects' weight on Earth and then determine what the objects would weigh on the Moon, Sun, Mars, and Jupiter.

Follow these steps and then record your data on bottom section of the "Volume, Mass, and Weight" activity page:

1. Using a dynamometer, measure the weight of your regular object and record its weight (in grams) in the Earth column of the table.
2. Repeat Step 1 for each of the three irregular objects.
3. Use the following information to calculate the weight of each object on other solar bodies (and record the weight for each object in the appropriate column):
 - Moon: weight is 16.7% of weight on Earth
 - Mars: weight is 37% of weight on Earth
 - Jupiter: weight is 236% of weight on Earth
 - Sun: weight is 2700% of weight on Earth

Day 2

☐ Activity 2: Independent Traits

For today's activity, you will be using information from Day 1 of this lesson to figure out density. You will also be using new materials to investigate melting point, boiling point, and solubility. Use the "Independent Traits" activity pages to record your data.

Density

For density, you will use the weight and volume information you collected yesterday. (Although mass and weight are not technically the same, you will use the weight measurements for objects on Earth that you found yesterday.)

Density is a measure of the relationship between the mass of an object and its volume. Density is a simple calculation:

$$\text{density} = \text{mass divided by volume (d = m/v)}$$

Since density involves both mass and volume, its unit of measure is a little complex: grams per cubic centimeter (g/cm^3). As you work on this activity, think about what patterns you see with regards to the increase or decrease of density.

Follow these steps:

1. Find the mass (weight) measurements of your cube and three irregular objects from the Earth column of the table on the "Volume, Mass, and Weight" page from Day 1. Copy this information onto the "Density" table of the "Independent Traits" activity page.
2. Copy the volume for each object onto the table. (For the cube, use the length x width x height calculation.)
3. Calculate density by dividing each object's mass by its volume. Record your answers.

CAUTION: The following procedure involves the use of heat. Use caution and be sure to observe the following rules:

- Wear safety goggles.
- If you have long hair or hair that goes to the collar of your shirt, you should tie it back in a ponytail.
- Do not stand over heat sources, regardless of how small.

Melting Point and Boiling Point

You will now compare melting points for water and for wax. Remember that the melting point is the temperature at which a substance changes from a solid to a liquid. You will also observe what occurs when water reaches its boiling point (the temperature at which a heated liquid turns to gas) and see whether the wax will reach its boiling point.

First, gather your materials: a saucepan, 2 cups of frozen water, 1 empty cup, candle wax, and a watch or timer. Next, follow these steps:

1. Fill a saucepan with water, place the pan on the stove, and turn the burner's heat to low or medium. You want the water to become warm, similar in temperature to a hot bath. Do NOT boil the water.
2. While waiting for the water to warm, remove one of the cups of ice from the freezer and place it and the block of wax next to each other. Do this away from the heat source on a table or countertop.
3. Observe what happens to the wax and the ice after 5 minutes and make note of it on the "Melting Point" table. Make another observation 5 minutes later.

4. After the 10 minutes, place the cup of frozen water aside and get the second cup out of the freezer.
5. Place this cup of frozen water in the warm water bath. Do not let the warm water directly touch the ice.
6. Place the wax in a similar cup and place that cup in the warm water bath as well. If the cup floats, weight the cup down.
7. Make an initial observation, make a second observation at 5 minutes, and then a third at 10 minutes. Record your observations on the table.
8. Remove the cups from the saucepan, put the pan of water back on the stove, and turn the burner temperature up so that the water begins to boil.
9. Once the water boils, remove the wax from the cup and place it directly into the boiling water.
10. Make an initial observation, a second at 5 minutes, and a third at 10 minutes. Be sure to note what is happening with both the wax and the boiling water. Record your observations on the table.
11. Do NOT try to remove the wax from the boiling water. Turn the heat off and carefully remove the pan from the heat source. Allow the water and pan to cool completely before you remove the wax.

Solubility

Remember that solubility is the extent to which one substance is able to dissolve in another. Dissolve means to become absorbed. Consider the data you've collected in this activity and then answer the questions in the "Solubility" section of the activity sheet.

☐ **Activity 3: Vocabulary Review**

Cut out the squares found on the two "Vocabulary Review" pages and match them as follows:

1. Match each term to its correct formula or picture.
2. Match each term to its correct definition.
3. Once you have confirmed that your choices are correct, gather the cards with the vocabulary words on them. Place on one side of the table the names of those properties that are independent of the amount of matter; place those that are dependent on the amount of matter on the other side of the table.
4. After you have checked those answers, gather the vocabulary cards and find the two that have direct relationships, meaning if one increases, the other increases (and if one decreases, the other decreases as well).

Wrapping Up

The goal of this lesson was to introduce ideas related to properties of matter. You have now covered most of the basic properties of matter and will use what you have learned in the final project for this unit.

Keep in mind that differences in density, boiling point, melting point, and solubility exist among all forms of matter. For example, wax is a solid at room temperature, yet water is not. Candle wax requires a higher temperature to turn from solid to liquid; at a similar temperature, water turns into a gas. The melting point of candle/pour wax is as follows:

- Nature Soy C-3 Containers & Tea lites: 125-130(degrees)F with a pouring temperature of 150-160(degrees)F (the pouring temperature is higher because the wax cools quickly as it's being poured and can transition from liquid to solid before pouring is complete)
- Nature Soy V-1 Votive & Tarts/Wax Melts & Floaters: 134-140(degrees)F with a pouring temperature of 160-170(degrees)F

As a challenge, investigate the following online:

- What is the combustion point of a candle wick? (The temperature at which the wick ignites is the combustion point.)
- Does candle wax boil?

VOLUME OF REGULAR SHAPES

FORMULAS FOR VOLUME:

- **CUBES:** LENGTH X WIDTH X HEIGHT
- **SPHERES:** $(4/3)(\pi)(\text{RADIUS})^3$ [$\pi \approx 3.14$]
- **PYRAMID:** $(B \times H)/3$ [THE BASE OF A PYRAMID (B) IS THE LENGTH X WIDTH OF THE BOTTOM. H IS THE HEIGHT OF THE PYRAMID.]

1) Four cubes of ice with an edge 4 cm each are left to melt in a spherical glass.

- What is the volume of one cube of ice?
- What is the volume of all four cubes?

The glass that the ice cubes are in is in the shape of a sphere. It has a radius of 6 cm.

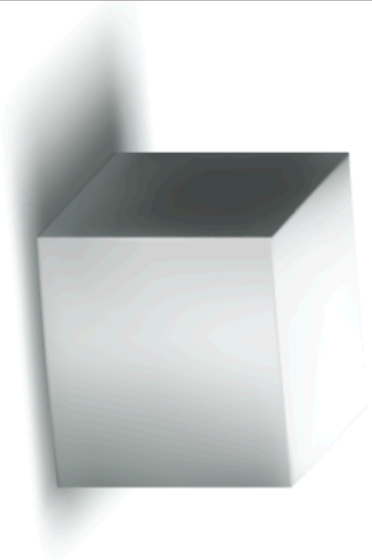
- What is the volume of the sphere?
- Challenging problem (Optional): What percentage of the sphere's volume is filled with water?



2) A cube with an edge of 20 cm is filled with water.

- What is the volume of the cube?
- What is the volume of a sphere with a radius of 20 cm?

Challenging problem (Optional): Would the water from the 20 cm cube fill this sphere?

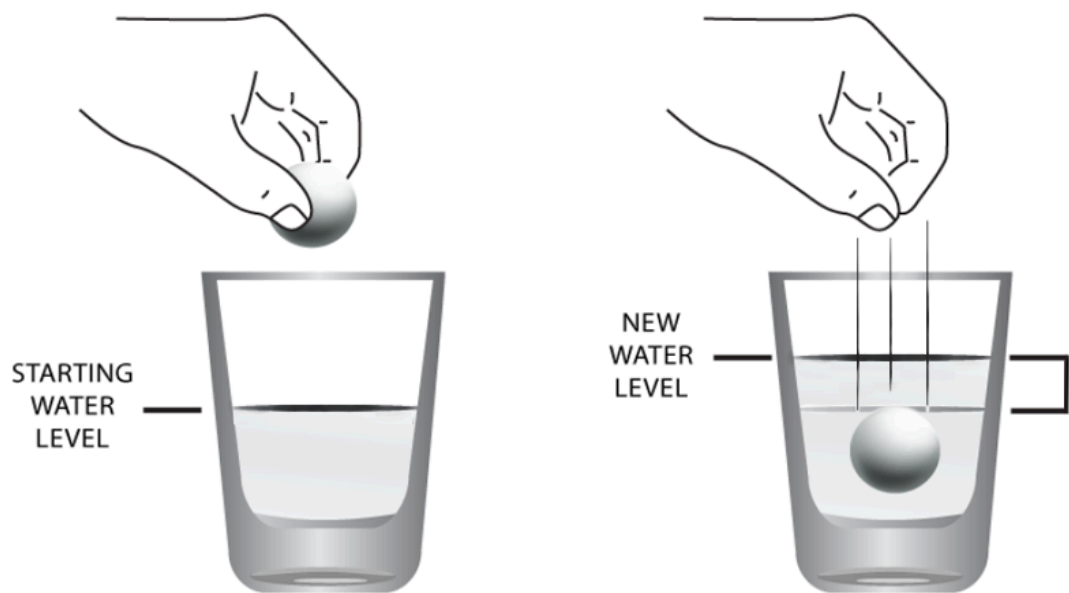


3) A pyramid has a length of 10 meters, a width of 6 meters and a height of 8 meters.

- What is the volume of the pyramid?



VOLUME, MASS AND WEIGHT



- Volume of cube using length x width x height: _____
- Volume of cube using the displacement method: _____
- Volume of Irregular Object 1: _____
- Volume of Irregular Object 2: _____
- Volume of Irregular Object 3: _____

Object	Earth	Moon	Mars	Jupiter	Sun
Example	1000	167	370	2360	27000
Regular Object 1					
Irregular Object 1					
Irregular Object 2					
Irregular Object 3					

Independent Traits

Density

Object	Mass (grams=g)	Volume (cubic centimeters = cm^3)	Density (m/v) g/cm^3
Example	100	200	
Regular Object (Cube)			
Irregular Object 1			
Irregular Object 2			
Irregular Object 3			

Melting Point and Boiling Point

Room Temperature

	5 Minutes	10 Minutes
Ice		
Wax		

Warm-Water Bath

	0 Minutes	5 Minutes	10 Minutes
Ice			
Wax			

Boiling Water

	0 Minutes	5 Minutes	10 Minutes
Wax			

Independent Traits

Solubility

Was there ever a point or a possibility during the activity where the water was absorbed and you could not tell a difference between the water that was previously frozen and the water that was being heated?

Do you think this was evidence of the solubility of water? Why or why not?

When did the wax melt? Did wax reach its boiling point?

Based on the definition of solubility, is wax soluble in water? (Hint: Was the wax absorbed by the water?)

VOCABULARY REVIEW

DENSITY

**MELTING
POINT**

**BOILING
POINT**

SOLUBILITY

VOLUME

MASS

a measure of the mass
per unit volume of
matter

the temperature at
which a substance
changes from a solid
to a liquid

the temperature at
which a heated liquid
turns to gas

the extent to which
one substance is able
to dissolve in another

the size of a three-
dimensional space
enclosed within or
occupied by an object

the property of an
object that is a measure
of the amount of matter
it contains

VOCABULARY REVIEW

$$D=m/v$$

length x width x height
 $\frac{4}{3} \times (\pi) \times (\text{radius})^3$
 $(B \times h)/3$



Lesson 5: Properties of Matter II (2 Days)

Getting Started

✿ Ideas to Think About

- What makes one piece of matter different from another?
- Why does matter "behave" the way it does in different circumstances?
- What patterns do you recognize with regards to the properties of matter?

📖 Things to Know

- **density:** a measure of the mass per unit volume of matter
- **solubility:** the extent to which one substance is able to dissolve in another
- **volume:** the size of a three-dimensional space enclosed within or occupied by an object
- **mass:** a measure of the amount of matter an object contains
- **weight:** a measure of the heaviness of an object as a result of the influence of gravity

⦿ Skills

- Compare the physical properties of pure substances that are independent of the amount of matter present including density, melting point, boiling point, and solubility to properties that are dependent on the amount of matter present to include volume, mass and weight. (S)

Introducing the Lesson

In this lesson your child will look at some more properties of matter. The lesson will be split into two days. The distinction between the two days involves how the properties are classified. Day 1 involves an introduction or review of ideas that will be important to understanding the activities in Day 2. Although Day 1 will seem a lot like a math lesson, the ability to understand volume, mass, and weight cuts across multiple areas of science.

On Day 1, your child will examine properties that are dependent on the amount of matter present. These properties include volume, mass and weight. On Day 2, he will look at properties that are independent of the amount of matter present. These properties include density, melting point, boiling point, and solubility.

If you have not done so already, have your child fill two plastic cups with water and place the cups in the freezer. He will need the cups of frozen water for a Day 2 activity.

Reading and Questions

1. What is the difference between mass and weight?

Mass measures how much matter is contained in an object. Weight measures the force of gravity on the mass of an object. An object's mass is the same everywhere; its weight would differ on the moon or on another planet.

2. What is volume?

The amount of space an object takes up or occupies.

3. What is the formula for determining an object's density?

mass divided by volume

Activities

Activity 1: Volume, Mass, and Weight

Use the following answer key to check your child's answers.

Volume of Regular Shapes Answer Key

1) Four cubes of ice with an edge 4 cm each are left to melt in a spherical glass.

• What is the volume of one cube of ice?

64 CUBIC CENTIMETERS

• What is the volume of all four cubes?

64 X 4 = 256 CUBIC CENTIMETERS

The glass that the ice cubes are in is in the shape of a sphere. It has a radius of 6 cm.

• What is the volume of the sphere?

VOLUME = $(4/3) \times (3.14) \times (6 \times 6 \times 6)$

= 904.32 CUBIC CENTIMETERS

• Challenging problem (Optional): What percentage of the sphere's volume is filled with water?

28.3 PERCENT = 28.3%



2) A cube with an edge of 20 cm is filled with water.

• What is the volume of the cube?

8000 CUBIC CENTIMETERS

• What is the volume of a sphere with a radius of 20 cm?

$(4/3) \times (3.14) \times (20 \times 20 \times 20) =$

33493.3 CUBIC CENTIMETERS

• Challenging problem (Optional): Would the water from the 20 cm cube fill this sphere?

NO; 33493.3 > 8000



3) A pyramid has a length of 10 meters, a width of 6 meters and a height of 8 meters.

• What is the volume of the pyramid?

$[(10 \times 6) \times 8] / 3 = 160$ CUBIC METERS



Volume, Mass, and Weight Answer Key

Object	Earth	Moon	Mars	Jupiter	Sun
Example	1000	167 (1000 x 0.167)	370 (1000 x 0.37)	2360 (1000 x 2.36)	27000 (1000 x 27)
Regular Object 1	100	16.7	37	236	2700
Irregular Object 1	75	12.6	27.8	177	2025
Irregular Object 2	50	8.4	18.5	118	1350
Irregular Object 3	25	4.2	9.25	57.25	672.5

This table will vary depending on what objects are used. What you should see with regards to a general trend is that the objects decrease in weight on the Moon and Mars with the Moon being heavier; objects should increase in weight on Jupiter and the Sun with the Sun being the heaviest. The table has been filled in to give an example.

Day 2**Activity 2: Independent Traits**

In this activity your child explored the concepts of density, melting point/boiling point, and solubility. This experiment requires parental supervision. NOTE: If you are having trouble removing the wax from the pan, try freezing the pan — the wax should then come off very easily.

Answer Key:

In both cases the ice will melt, and the rate of melting will vary based on the ambient temperature, with the warm water bath likely to speed up the rate that the ice melts. Since wax has a higher melting point than ice, the wax at room temperature should not change. It is possible that it may soften, but the general shape of the wax in the cup will not change. When the cup with wax is placed in the warm water, a change in shape is probable because the melting point of wax is between 125-140° Fahrenheit with pouring temperatures 10-30° Fahrenheit higher than the upper threshold depending on the wax. With regards to solubility, keep in mind that for an object or matter to be soluble it must be absorbed by the solvent, water in this case. Though wax may melt in warm water, it is not soluble because the water does not absorb it.

Q1: Yes. The water that was frozen was absorbed by the water that was being heated, so at some point you would not be able to tell the difference.

Q2: No. Based on the definition that solubility is the extent to which one substance is able to dissolve in another, one could argue that the water did not dissolve because it was the same substance. This is not solubility since only one substance was involved; it was a change in the state of matter (phase change).

Q3: The wax should have melted somewhere between 125° and 140° Fahrenheit (the time your child recorded will vary). Wax did not reach its boiling point because the melted wax did not change from a liquid to a gas.

Q4: No. Based on the definition of solubility, wax is not soluble in water.

Activity 3: Vocabulary ReviewAnswer Key

#1 and #2

- Density is a measure of the mass per unit volume of matter; its formula is $D = m/v$.
- Melting point is the temperature at which a substance changes from a solid to a liquid; its corresponding picture is ice melting.
- Boiling point is the temperature at which a heated liquid turns to gas; its corresponding picture is a pot of water boiling.
- Solubility is the extent to which one substance is able to dissolve in another; its corresponding picture is sugar being stirred into water.
- Volume is the size of a three-dimensional space enclosed within or occupied by an object; its formulas include length x width x height, $\frac{4}{3} \times (\pi) \times (\text{radius})^3$, and $(B \times h)/3$.
- Mass is the property of an object that is a measure of the amount of matter it contains; its corresponding picture is a balance.

#3: *Properties independent of the amount of matter* — melting point, boiling point, solubility

Properties dependent upon the amount of matter — volume, mass, density

#4: *Properties with direct relationships (if one increases, the other increases; if one decreases the other decreases)*

This one is challenging. The assumption is that you are working with the same element consistently. Also, the assumption is that temperature remains constant. If mass increases, volume increases, and if mass decreases, volume decreases.

Wrapping Up

Questions to Discuss

- Did the mass of objects change when they were taken from one solar body to the next? Why do you think the weight changed? (No, mass remains constant. The weight changed due to the force of gravity, which differs on various solar bodies.)
- What is the difference between weight and mass? (Weight is caused by gravity acting on matter; mass is the measure of the amount of matter in an object. Mass does not change, but weight does change based upon the force of gravity. More gravity means more weight; less gravity means less weight.)
- If you increase the mass of an object but keeps its volume the same, what do you think happens to the density of the object? (The density of the object increases.)
- If you increase the mass of an object but also increase its volume, what do you think happens to the density of the object? (The density of the object will remain constant.)
- If you keep the mass of an object the same but decrease its volume, what do you think happens to the density of the object? (The density of the object will increase.)
- As an object transitions from a solid to a liquid to a gas, what happens to the mass of the object? Volume? (Assuming that all the particles of the matter remain, the volume of the matter will increase, but its mass will remain constant.)
- Will the density of matter change if some of the matter is removed (think about pinching a piece off of a lump of clay)? (The density of the object will remain the same, but its volume and its weight will change.)
- Does a transition occur from one state to the next in water as ice melts and then boils? (Yes, as the temperature [amount of energy] in water increases, the water begins to transition from solid to liquid, and then from liquid to gas.)

Things to Review

- Some properties of matter depend on the amount of matter present (volume, mass, weight).
- Some properties of matter are independent of the amount of matter present (density, melting point, boiling point, solubility).
- The state of matter is influenced by the amount of energy present (as measured by temperature).