Teacher Guide: Phase Changes

Learning Objectives

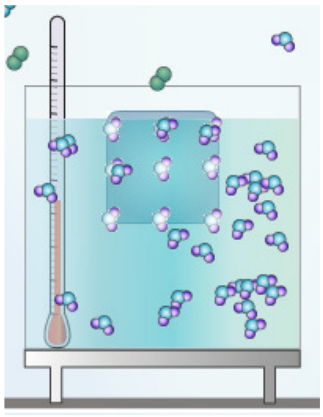
Students will…

- Describe and compare the molecular properties of solids, liquids, and gases.
- Observe how heating affects molecular motion.
- Create and explain a graph of temperature change during phase changes.
- Explain why temperature does not change much during a phase change.
- Determine the boiling, freezing, and melting points of water.
- Find how altitude affects the boiling, freezing, and melting points. (Extension)

Vocabulary

altitude, boil, boiling point, freeze, freezing point, gas, liquid, melt, melting point, phase, solid

Lesson Overview



The *Phase Changes* Gizmo™ illustrates how molecular motion is related to phase changes. As students add heat to the system, molecules move faster and phase changes occur—ice melts and water boils. When heat is taken away, condensation and freezing occur. Students can create a graph of temperature vs. time, and the altitude can be changed as well.

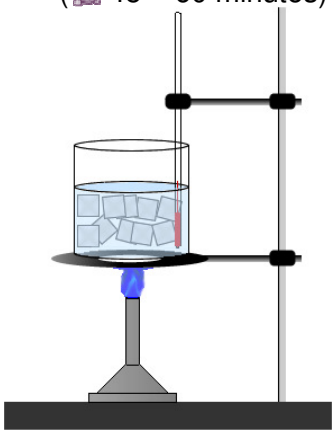
The Student Exploration sheet contains two activities and an extension:

- Activity A – Students determine the temperatures at which phase changes occur.
- Activity B – Students discover that adding heat energy causes molecules to move faster. The movement of molecules explains why ice melts and water boils.
- Extension – Students discover how altitude affects phase changes.

Suggested Lesson Sequence

1. **Pre-Gizmo activity: Phase change graph** (45 – 60 minutes)

   Before class, create an ice-water bath by placing a bag of ice and a small amount of water into a tub. The temperature should be close to 0 °C. Divide the class into lab groups, and ask students to put on goggles and aprons for safety.

   Have each group set up an apparatus to heat the ice water as shown. Stir the water constantly, and record the temperature every two minutes. Once the water is boiling, record 4 more temperature readings before turning off the burners. Graph the results, and discuss. Why does the temperature rise very slowly (or not at all) at first? Why does the temperature stop rising once the water starts to boil?

2. **Prior to using the Gizmo** (10 – 15 minutes)
   Before students are at the computers, pass out the Student Exploration sheets and ask students to complete the Prior Knowledge Questions. Discuss student answers as a class, but do not provide correct answers at this point. Afterwards, if possible, use a projector to introduce the Gizmo and demonstrate its basic operations. Demonstrate how to take a screenshot and paste the image into a blank document.

3. **Gizmo activities** (15 – 20 minutes per activity)
   Assign students to computers. Students can work individually or in small groups. Ask students to work through the activities in the Student Exploration using the Gizmo. Alternatively, you can use a projector and do the Exploration as a teacher-led activity.

4. **Discussion questions** (15 – 30 minutes)
   As students are working or just after they are done, discuss the following questions:
   - What are some of the differences between solids, liquids, and gases?
   - How does temperature relate to molecular motion?
   - What causes materials to change phase?
   - Why does the temperature stay constant during a phase change?
   - Why do water pipes burst in the winter?
   - Why does it take longer to cook pasta at high altitudes than at sea level?

5. **Follow-up activity: Boiling point** (30 – 45 minutes)
   In the last activity of the Student Exploration, students learn that altitude affects the boiling point of water. You can measure these effects with the help of a hot plate, a pressure cooker, and a vacuum chamber. To find a pressure cooker, you may have to solicit donations from parents. They can be purchased for as little as $20. Many schools have bell jars and vacuum pumps in their laboratories; they also are available in most science-supply catalogs.

   First, have students measure the boiling point of water in a beaker or pot that is heated by a hot plate. In most locations, the boiling point will be close to 100 °C. Then, measure the boiling point of water in a pressure cooker, where air pressure is much higher. Students will see that the boiling point is much higher under greater air pressure. Finally, put a beaker of water into a bell jar and use a vacuum pump to remove the air. When the pressure is low enough, the water will boil at room temperature!

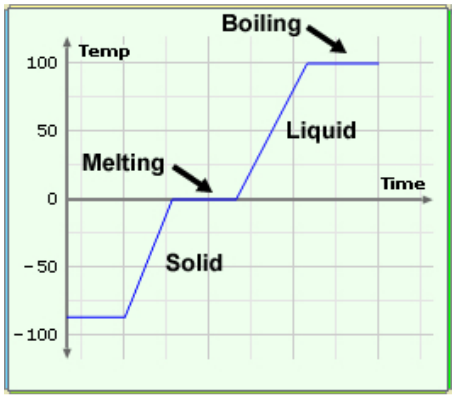
Scientific Background

Matter can exist in several phases, or states. The three states that exist naturally on Earth are solid, liquid, and gas. Plasma is a high-temperature phase that exists on stars. Several other phases have been discovered at temperatures near absolute zero.

Solids are characterized by atoms or molecules held in a rigid structure. Atoms in the structure may vibrate, but do not move freely. A solid has a definite shape and a definite volume. Liquids are characterized by molecules that are attracted to one another but can still move around so that they take the shape of their container. Liquids thus have a definite volume but an indefinite shape. Gases are characterized by rapidly moving molecules that move and collide freely. A

gas will expand to occupy all the space in its container. Gases also can be compressed to a very small volume. Thus gases do not have a definite shape or volume.

When a solid is heated, the atoms begin to vibrate more and more rapidly. Eventually the vibrations are strong enough to break the rigid bonds holding the atoms together, and the solid melts into a liquid. During the melting process, temperature does not increase because the added heat energy goes into melting the solid rather than heating the liquid.



In a liquid, the molecules move at a variety of speeds. The fastest-moving molecules can escape the surface of the liquid and become a gas. This process is called *evaporation*. As the liquid is heated, the average speed of the molecules increases until large bubbles of gas form within the liquid. This is *boiling*. The temperature remains constant during boiling because the fastest molecules are constantly leaving the liquid and escaping as gas.

Cooling produces the opposite phase changes. As a gas is cooled, the molecules slow down until their mutual attraction causes them to clump together and form droplets of liquid. This is *condensation*. When a liquid is cooled, the molecules move slowly enough that they can begin to form rigid chemical bonds in a crystalline lattice. This is *freezing*.

Health Connection: Keeping cool

If you look at a heating curve for water, the graph will show flat areas where the phase changes are occurring. This occurs because the heat energy is used to cause the phase change rather than raise the temperature of the water. Your body takes advantage of this fact to keep you cool on a hot day.

When you exercise on a hot day, glands in your skin produce sweat. Heat energy from your skin and the surrounding air causes the sweat to evaporate. This removes heat energy from your skin and cools your body down. Because you lose so much water when you sweat, it is essential to drink liquids while exercising. Sweat contains salt as well as water, so it is also important to replenish salt and other important minerals that are lost when you sweat.

Selected Web Resources

Pressure cookers: http://en.wikipedia.org/wiki/Pressure_cooking
Boiling water in a vacuum: http://www.exo.net/~pauld/Mars/4snowflakes/martianwater.html
Phases and phase changes: http://itl.chem.ufl.edu/2045_s00/lectures/lec_f.html
Phases animation: http://www.harcourtschool.com/activity/states_of_matter/
Physics of phase changes: http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/phase.html
Sweating: http://health.howstuffworks.com/sweat.htm

Related Gizmos:
Phases of Water: http://www.explorelearning.com/gizmo/id?661
Water Cycle: http://www.explorelearning.com/gizmo/id?435
Freezing Point of Salt Water: http://www.explorelearning.com/gizmo/id?426