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**Student Exploration:** **Phase Changes**

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

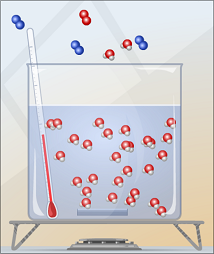
**Prior Knowledge Questions** (Do these BEFORE using the Gizmo.)

1. **A family from Minnesota turns off the heat and flies to Florida for a winter holiday. When they come home, all of their water pipes have burst. What do you think happened?**

The water in the pipes expanded when it froze and the pipe burst.

1. **Spaghetti takes about 9 minutes to cook at sea level, but about 14 minutes in the mountains. Why do you think this is so?**

Air pressure is lower; thus, the boiling point is lower. Also, it is generally more cold the higher the altitude. These factors will take the spaghetti longer to cook.

**Gizmo Warm-up**

In the *Phase Changes* Gizmo, select **Micro view** and set the **Ice volume** to 50 cm3. Notice the nitrogen (), oxygen (), and water () molecules.

Click **Play** (Play) and observe water molecules in the **solid** (ice), **liquid** (water), and **gas** (air) **phases**.

1. In which phase(s) are the molecules held rigidly together? Solid phase
2. In which phase(s) do the molecules move freely?

Gas and liquid

1. In which phase(s) are the molecules held in a defined shape? Solid
2. In which phase(s) do the molecules take the shape of their container? Gas and liquid

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| **Activity A:**  **Phase changes** | Get the Gizmo ready:   * Click **Reset** (Reset) and select **Macro view**. * Set the **Water temperature** to 10 °C. * Set the **Ice volume** to 0 cm3. | 557SE2 |

**Question: How is temperature related to phase changes?**

1. Predict: Based on your prior knowledge, predict the following:
   * 1. At what temperature will water change from a liquid to a solid (**freeze**)? 0
     2. At what temperature will water change from a solid to a liquid (**melt**)? 0
     3. At what temperature will water change from a liquid to a gas (**boil**)? 100
2. Investigate: Use the Gizmo to explore phase changes. Use the **Add/remove heat energy** slider to control the water temperature. Record your observations in your notes, then answer the questions below:
   * 1. At what temperature does water freeze? 0 This is the **freezing point**.
     2. At what temperature does ice melt? 0 This is the **melting point**.
     3. At what temperature does water boil? 100 This is the **boiling point**.
3. Observe: Set up the Gizmo to observe freezing. What do you notice about the temperature while the water is in the process of freezing? **Temperature would stay the same**
4. Explore: Use the Gizmo to investigate melting and boiling. Does the temperature change while either of these phase changes is occurring? **No, temperature stays the same**
5. Interpret: Select the GRAPH tab to see a graph of temperature vs. time. Click the “**–**” button until the whole graph is visible. What does the graph look like during a phase change?

The line is flat during a phase change.

1. Extend your thinking: Why do you think the temperature does not change much during a phase change? If possible, discuss your answer with your classmates and teacher.

While a phase is changing, it requires energy. The energy used in phase changes is from the heat.

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| **Activity B:**  **Temperature and molecular motion** | Get the Gizmo ready:   * Click **Reset**, and select the **Micro view**. * Set **Ice volume** to 0 cm3. * Set **Add/remove heat energy** to 0 J/s. |  |

**Question: Why do phase changes occur?**

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1. Compare: Set the **Water temperature** to 0 °C and click **Play**. Observe the water molecules. Click **Reset**, set the **Water temperature** to 100 °C, and click **Play** again.

What do you notice? **When the water temperature is at 100 degrees Celsius, the molecules are moving faster.**

1. Observe: Click **Reset**. The **mean molecular speed** of the water molecules is displayed below the container. Set the **Water temperature** to 0 °C and **Add/remove heat energy** to 400 J/s. Click **Play**.
   * 1. How does the mean speed of the water molecules change as they are heated?

The molecules move faster when the temperature is increased.

* + 1. Does the mean molecular speed change as much as the temperature as the water heats up? Explain.

**The mean molecular speed gets faster when the temperature of the water is being heated up. An example of this would be the mean molecular speed increasing by 1 meter per second for each temperature of degree change. Also, the mean molecular speed is faster at 100oC than at 0oC.**

1. Explain: How is temperature related to the motions of molecules? ­­**The higher the temperature is, the faster the molecules would move.**
2. Observe: Click **Reset**. Set the **Water temperature** to 20 °C and the **Ice volume** to 50 cm3. Set **Add/remove heat energy** to 0 J/s. Click **Play**. How do the molecules in the liquid interact with the molecules in the solid?

The liquid molecules would clash together with solid molecules, and that would break the bonds between the molecules in the solid, which will cause the ice to melt.

**(Activity B continued on next page)**

**Activity B (continued from previous page)**

1. Observe: Click **Reset**. Set the **Water temperature** to 100 °C and the **Ice volume** to 50 cm3. Click **Play**. How does this situation compare to the previous one?

**Liquid molecules move faster, and the ice would melt more quickly.**

1. Propose a theory: Based on what you have observed, explain why you think phase changes occur. If possible, discuss your theory with your classmates and teacher.

I believe that energy of molecular motion is what causes phase changes. When heat gets added to a liquid, the molecules get faster until they would break free of the liquid and becomes a gas. Same thing happens for a solid and gas. Energy levels vary and affect the current phase.

1. Apply: Use your theory to explain what happens at the molecular level in each of the following situations. Also, list the temperature at which each transition occurs.
   * 1. Ice is warmed to the melting point. The molecules in the solid vibrate with a lot of energy until they break free and become a liquid. Temperature: 0 Celsius
     2. Water is warmed to the boiling point. Water molecules move rapidly until they break free and become a gas. Temperature: 100 Celsius
     3. Water is cooled to the freezing point. Water molecules begin to move less, and they would stick together and become a solid. Temperature: 0 Celsius
2. Extend your thinking: Click **Reset**. Set the **Water temperature** to 0 °C, the **Ice volume** to   
   0 cm3, and **Add/remove heat energy** to -400 J/s. Click **Play** and wait until *all* of the water freezes.
   * 1. What volume of ice is created from 200 cm3 of water? **217.4 cc**
     2. Why do water pipes sometimes burst in the winter? **As water freezes, it expands. Then, the water pipe would burst.**

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| **Activity C:**  **Altitude and phase changes** | Get the Gizmo ready:   * Click **Reset**. * Set **Ice volume** to 0 cm3. * Set the **Altitude** to 5,000 meters (16,404 feet). | 557SE4 |

**Question: The altitude of a location is its vertical distance above sea level. How does altitude affect phase changes?**

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1. Form a hypothesis: As altitude increases, the air pressure decreases. How do you think the lower pressure will affect the following? (Circle your answers.)
   * 1. Freezing point: Increase Stay the same Decrease
     2. Melting point: Increase Stay the same Decrease
     3. Boiling point: Increase Stay the same Decrease
2. Experiment: Use the Gizmo to find the freezing, melting, and boiling points of water at 5,000 meters (16,404 feet). Write these values below.

Freezing point: 0 Melting point: 0 Boiling point: 0

1. Analyze: How did altitude affect the freezing, melting, and boiling points of water?

At each altitude, there are different points of pressure. At a higher altitude, the boiling point is lower.

1. Challenge: Try to explain these results based on the fact that air pressure decreases with altitude. If possible, discuss your ideas with your classmates and teacher.

As the air pressure decreases, you’re at a lower altitude because the pressure there is less harsh than that of the atmosphere.

1. Apply: Why does pasta take longer to cook in the mountains? Pasta takes longer to cook in the mountains since the boiling point is lower because of the high altitude.
2. Apply: A pressure cooker allows food to be cooked under high pressure. Why is this useful?

In some areas of the world, the pressure is low for families, thus the food might not cook as well. Having a pressure cooker would help the quality of the food.