



Name: _____

Date: _____

Student Exploration: Colligative Properties

Vocabulary: boiling point, colligative property, concentration, dissociate, freezing point, manometer, osmosis, osmotic pressure, solute, solution, solvent, vapor pressure

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

1. When the forecast calls for freezing rain, salt is often spread on the roads. Why is this done?

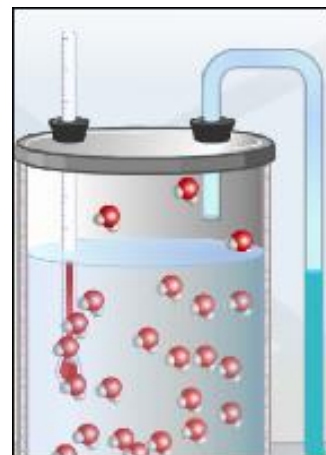
2. Antifreeze is added to car radiators to prevent the water in the radiators from both freezing and boiling. How do you think antifreeze affects the temperatures at which water freezes (the **freezing point**) and boils (the **boiling point**)?

Gizmo Warm-up

Adding salt or other substances to water can affect the temperature at which it freezes or boils. These effects and others, known as **colligative properties**, are explored in the *Colligative Properties* Gizmo.

Check that **No solute** is selected and the **Air temp.** is 25 °C.


1. Describe the motion of the water molecules in the beaker.



2. Change the **Air temp.** to -10 °C. What do you see as the water freezes? _____

3. Now change the **Air temp.** to 110 °C. What do you see as the water boils? _____



Activity A: Vapor pressure and boiling point	<u>Get the Gizmo ready:</u> <ul style="list-style-type: none"> • Check that No solute is selected. • Set the Air temp. to 25 °C. 	
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Introduction: At the surface of a body of water, water molecules are constantly moving from the liquid phase to the gas phase, and vice versa. The molecules that evaporate collide against the walls of the beaker, creating **vapor pressure**.

Vapor pressure can be measured by a **manometer**, a liquid-filled tube that is connected to the top of the beaker. Increasing the vapor pressure pushes the water in the tube, causing the water in the right arm of the tube to rise to a higher level than the water in the left arm of the tube.

Question: How does salt affect the properties of water?

1. **Observe:** Gradually increase the **Air temp.** to 95 °C. As you do this, observe the water in the manometer. What do you notice, and what does this indicate about the vapor pressure?

2. **Record:** Click the **Record** button below the table to see the vapor pressure in kilopascals (kPa). Use the Gizmo to find the vapor pressure at 5 °C, 50 °C, and 95 °C.

5°C: _____ 50 °C: _____ 95 °C: _____

3. **Analyze:** How does the temperature of the liquid relate to the vapor pressure? _____

4. **Measure:** To measure the boiling point, increase the **Air temp.** to 110 °C. When you see bubbles, click **Record**. The water temperature at this time is equal to the boiling point.

A. What is the boiling point of pure water? _____

B. What is the current vapor pressure? _____

C. Atmospheric pressure at sea level is equal to 101.32 kilopascals (kPa). Why do you think water boils when the vapor pressure is equal to atmospheric pressure?

(Activity A continued on next page)



Activity A (continued from previous page)

5. Compare: Click **Clear**. Set the **Air temp.** to 25 °C, and click **Record**. Compare the vapor pressure with **No solute** to the vapor pressure with **Sodium chloride** selected.

A. How does the presence of sodium chloride affect the vapor pressure of water?

B. Based on this effect, how do you expect the presence of sodium chloride to affect the boiling point of water? _____

6. Predict: How do you expect the addition of sodium chloride (table salt) to affect the freezing point of water? _____

7. Gather data: Use the Gizmo to find the vapor pressure at 25 °C, the boiling point, and the freezing point of pure water and the sodium chloride **solution**. To find the freezing point, lower the **Air temp.** to -10 °C, wait for the molecules to start freezing, and click **Record**. The water temperature at this time is equal to the freezing point. Complete the table below.

Solution	Vapor pressure at 25 °C	Boiling point	Freezing point
Pure water			
Water + sodium chloride			

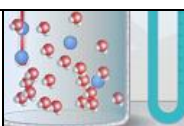
8. Analyze: How does adding sodium chloride affect the boiling and freezing points of water?

9. Apply: Based on what you have learned, why do people spread salt on the roads in winter?

10. Explore: Select the STUDY CONCENTRATION tab. On your own, explore how the **concentration** of sodium chloride affects the colligative properties of water.

Describe your results: _____



Activity B: Dissociation	<u>Get the Gizmo ready:</u> <ul style="list-style-type: none"> • Select the STUDY SOLUTE tab. • Set the Air temp to 25 °C. 	
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Introduction: When an ionic compound such as sodium chloride (NaCl) dissolves in water, it **dissociates**, or breaks up, into individual Na^+ and Cl^- ions. Different ionic compounds may dissociate into different numbers of ions, depending on their composition. Covalent compounds such as sucrose do not dissociate.

Question: How does the dissociation of a solute affect the colligative properties of a solution?

1. Observe: When the **Show molecular view** is on, you can see how many particles of **solute** are dissolved in the **solvent** (water). Solute particles are colored yellow, dark blue, green, and red. In the molecular view, you see the result of dissolving one molecule of solute into the solvent.

List the number of each kind of particle below.

No solute: _____ Sucrose: _____ Sodium chloride: _____

Calcium chloride: _____ Potassium chloride: _____

2. Predict: Colligative properties are determined solely by the number of solute particles in the solution. Based on this fact, which solute do you expect to have the greatest effect on the properties of water? The least effect?

3. Gather data: For each solute, measure the vapor pressure at a temperature of 25 °C. Then measure the boiling point and freezing point of each solution.

Solute	Number of particles	Vapor pressure at 25 °C	Boiling point	Freezing point
None				
Sucrose				
Sodium chloride				
Calcium chloride				
Potassium chloride				

(Activity B continued on next page)



Activity B (continued from previous page)

4. Analyze: How did the number of solute particles affect the colligative properties of water?

5. Find a pattern: The chemical formulas of the three ionic solutes are NaCl (sodium chloride), CaCl₂ (calcium chloride), and KCl (potassium chloride).

A. How does the chemical formula relate to the number of particles that result from the dissociation of a molecule? _____

B. Aluminum chloride has the formula AlCl₃. How many particles would a molecule of aluminum chloride dissociate into? _____

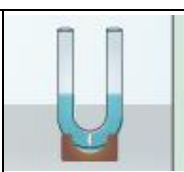
C. Based on the data you have collected so far, predict the boiling point and freezing point of a 1.0-mol/kg solution of aluminum chloride: _____

6. Check: Select the STUDY CONCENTRATION tab. You can model a 1.0-mol/kg solution of aluminum chloride by using a 2.0-mol/kg solution of sodium chloride. Use the Gizmo to find the boiling point and freezing point of a 1.0-mol/kg aluminum chloride solution.

Solute	Number of particles	Vapor pressure at 25 °C	Boiling point	Freezing point
Aluminum chloride				

7. Think and discuss: Colligative properties depend only on the number of particles, not the identity of the solute. What evidence could you use to demonstrate this point?



<p>Extension:</p> <p>Osmotic pressure</p>	<p><u>Get the Gizmo ready:</u></p> <ul style="list-style-type: none"> • Select the STUDY SOLUTE tab. • Set the Air temp. to 25 °C. 	
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Introduction: **Osmosis** is the flow of water across a semipermeable membrane from a region of lower solute concentration to a region of higher solute concentration. The membrane allows water, but not solute, to go through. Like boiling and freezing, osmosis is a colligative property.

Question: How do different solutes affect osmosis?

1. **Measure:** Adding pressure to a solution can prevent water from entering the solution via osmosis. The **osmotic pressure** of the solution is equal to the pressure required to stop osmosis. A higher osmotic pressure indicates a more highly saturated solution.

Select **Sucrose** and click **Record**. What is the osmotic pressure of sucrose? _____

2. **Predict:** Based on the osmotic pressure of sucrose, predict what the osmotic pressures will be for the other solutes:

Sodium chloride: _____ Calcium chloride: _____ Potassium chloride: _____

3. **Gather data:** Use the Gizmo to measure the osmotic pressure of each solute. (Note: The **Air temp.** must be set to 25 °C to collect data on osmotic pressure.) Write the results below.

Sodium chloride: _____ Calcium chloride: _____ Potassium chloride: _____

4. **Analyze:** How close were your predictions? _____

5. **Apply:** Eating a diet rich in sodium can increase the risk of high blood pressure. Why would excessive amounts of sodium in the blood lead to higher blood pressure?

6. **Summarize:** What do all the colligative properties you have studied have in common?

