SUCCESS
ACADEMY
EDUCATION
INSTITUTE

Physical Science:

Unit 2

Solids and Liquids and Gases, Oh My!: Lessons

Lesson 1: Ice Cream, Anyone?

Lesson Objective: Phase changes can occur as a result of changes in the temperature of a substance. To make ice cream, the ingredients need to be cold enough to freeze.

Materials Needed

- For the teacher: extra ice, plastic tablecloths (1 per lab table)
- For each group: paper towels, sponge, measuring cups and spoons
- For each scholar: ¼ cup half-and-half (cream), ¼ cup milk, â…” tbsp sugar (2 sugar packets), ¼ tsp vanilla, 1 tsp of chocolate syrup (optional), quart-sized resealable plastic bag, gallon-sized resealable plastic bag, plastic cup, spoon, straw

Prep

- Materials Prep:
    - Review **5-Minute Ice Cream Recipe** by **Food.com**.
    - Purchase enough bags of ice to accommodate all groups in each class.
    - Cover each table with a plastic tablecloth (optional).
    - Between classes, restock materials as needed.

- Intellectual Prep:
    - Watch **Making Ice Cream with Salt: The Effect of Salt on the Freezing and Boiling Points of Water Video** by MITTechTV (5 minutes, 15 seconds).
    - Read **Freezing Science: The Role of Salt in Making Ice Cream** by The Kitchn.

What are scholars doing in this lesson?

- Scholars are introduced to the unit's Essential Question and are challenged to make their own ice cream with provided materials.

Do Now

- Follow the **Do Now plan**.

Launch

- Let's have an ice cream party to celebrate the start of a new unit! However, there isn't any space left in the teacher workroom freezer, so we need to make our own ice cream.
- Tell scholars that you purchased the following ingredients: cream, milk, sugar, vanilla, and ice. There is enough for each scholar to make one individual serving: ¼ cup cream, ¼ cup milk, â…" tbsp sugar (2 sugar packets), and ¼ tsp vanilla!
    - Say: Your challenge is to use the provided materials to make ice cream!

Experiment

- Scholars develop procedures and attempt to make ice cream. (They will inevitably fail because unbeknownst to them, they are missing one key ingredient: salt.)
- Scholars clean up and reflect on the outcome of the experiment in their Lab Notebooks.
- Scholars brainstorm questions they will need to answer before attempting to make ice cream again.
- As scholars are working, circulate and ensure they create a thorough list of questions.

[**Engagement Tip:** Allow scholars to pour the contents of their failed experiment into a cup and enjoy a "milkshake" as they reflect on their work.]

Discourse Debrief experiment:

- Ask: How did you attempt to create ice cream from the provided materials? Did it work?
- Ask: What **phase changes** occurred as you were working? Why?
    - Define **temperature** and **kinetic energy**.
- Ask: What questions must we answer before we can try again?

Introduce the Essential Question:

- Ask: How can we make ice cream without putting the ingredients into the freezer?
    - Explain to scholars that throughout the unit, we will work to answer their questions and at the end, they will attempt the challenge again!

Accountability (Lab Notebook)

- Score scholar reflections from the experiment in their Lab Notebooks.

Scoring

- Score scholars on a 1–4 scale (below expectations through exceeding expectations) based on classwork. Do not penalize scholars for initial misconceptions about content but rate them on effort and writing. Watch for misconceptions around heat energy, such as “not enough cold energy got into the ice cream ingredients.”
    - Look for the following when scoring scholar responses:
        - A clear claim that identifies the outcome of their experiment
        - Specific evidence from their experiment that supports their claim
        - Justification/reasoning for why the evidence provided explains or supports their claim
        - High effort shown in writing with complete sentences and proper grammar/punctuation seen throughout the response

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Lesson 2: Molecular Dances (Two Days)

Lesson Objective: Molecular motion is always present in solids, liquids, and gases. Heating and cooling change the speed and position of the molecules that make up a substance. Temperature is a measure of the average kinetic energy of particles, and temperature is not a form of energy. Scholars must be able to make connections between phase changes, energy, and intermolecular distance. Increased energy causes the molecules in a substance to spread, whereas lowered energy causes them to condense. When particles spread or condense, a phase change can occur. Substances have different properties after a phase change. Materials Needed

- For the teacher: 1–2 tape measures
- For each scholar: clipboard

Prep

- Materials Prep:
    - Secure a large open space to use for class. If one is not available, move tables to the perimeter to create a large space in the classroom.

- Intellectual Prep:
    - Watch **Temperature Video** by Teacher's Pet (2 minutes, 56 seconds).

What are scholars doing in this lesson?

- Scholars use a model of molecular dances to better understand the motion and changes of molecules in different states of matter. On day two, they are challenged to expand this model to explain the molecule changes that occur during phase changes.

Day One

Do Now

- Follow the **Do Now plan**.

Launch

- We know we must lower the temperature of the ice cream ingredients to solidify them. What does that really mean, though? What is "temperature" a measure of?
- Today, we will create a full-class model to learn more about temperature, states of matter, and molecular movement.

Activity Adapted from Terry Bollinger's 2013 essay on molecules, "A Dance of Molecules"

- Read the following scenarios aloud, and have the whole class model the parts.
- In the middle of each model, pause the group and have two scholars step out from the center to measure the space occupied by the class. Measurements should note the length and width of the group at its widest points, first across the room in one direction, and then the other. Alternatively, you could measure the perimeter/circumference with a cloth measuring tape or long string.
- Pause in between sections as needed to allow scholars to return to their clipboards and take notes on their observations.
    - The Random Texting Dance
        - Imagine a crowd of people in some city plaza who are walking rapidly and constantly texting or tweeting. (Any resemblance of this to real life is purely coincidental.) They are all so engaged in what they are typing that for the most part, they are blissfully unaware of each other's existence, except when they sometimes bump harmlessly into each other.
        - Let's call this situation the random texting dance because all that motion makes it a bit like a dance, but one with no particular pattern to it.
    - The Random Square Dance
        - Now let's look at a second version of the same crowd, one that I'll call the random square dance. In this old-fashioned crowd, no one is texting. In

fact, by the rules of this crowd, no one is even allowed to move forward unless they can find and grasp the hand of another dancer, even if only for a few moments. Once they find such a helping hand, both of the dancers can move and change positions within the crowd. That part is like a real square dance, but unlike a real square dance, there's no pattern in the overall motion of the crowd.

    - In some ways, the random texting dance and the random square dance are not all that different. In both cases, individual dancers can move about pretty much randomly through the crowd. A video of their motions likely would show rather similar results, with perhaps more turns and pivots in the random square dance.
    - However, if you look more closely at the two cases, you find out something a bit surprising: The random texting dance behaves a lot like a gas, whereas the random square dance looks a lot more like a liquid. To see this difference, you only need to look at what happens when the two dances encounter a big empty space.
        - In the random texting dance, no one is connected to anyone else. That means that every time one of the dancers encounters the edge of an empty space, she or he will just drift off randomly into it. That's a pretty close equivalent to a gas expanding out into an open container.
        - In the random square dancing, something starkly different happens. These dancers can only move forward when there are hands for them to grasp, and there are no hands in the big empty space!
        - The lack of a path forward quickly results in a well-defined boundary at which the dancers can travel no further. Dancers at this boundary are even pulled a bit more tightly toward the crowd, since they have hands pulling them inward, but no hands pulling them out. That's a different situation from the interior where hands pull equally in all directions. The pull at the boundary also tends to smooth out any bumps, since any person sticking far out will be pulled only back toward the crowd, without any canceling pulls from any other direction.
        - Put that all together and you have pretty much exactly what happens at the surface of a true liquid: The molecules are required to "lock hands" with other molecules to move forward, so they end up forming a flat, dense, and elastic (bumps and dimples get flattened out) boundary. If you recognize that bonds are bonds no matter what the scale is, the physics of the random square dance crowd really is no different from that of the molecules in a liquid. The presence of such a boundary is the literal definition of the difference between a gas and a liquid and is why the random texting crowd qualifies not as a liquid but as a gas.

- Scholars sit with their lab group and brainstorm ideas to add a representation of the molecules in a solid to the model.
    - Select a method or two for the class to model together. Pause the group and have two scholars step out from the center to take measurements of the space occupied by the class.

[**Tip:** Guard against the misconception that molecular movement stops in a solid.]

- As scholars are working, monitor behavior and provide scholars with opportunities to take notes.

Discourse Debrief activity:

- Ask: How is molecular movement different in each state of matter?
    - Relate this to kinetic energy. Press scholars to draw connections between kinetic energy and the three states of matter they know.
- Display the data on the space taken up by the group while modeling.
    - Ask: What trend do you notice in the data?
        - Define **intermolecular distance**.
    - Ask: Which states of matter have a **definite** volume? An **indefinite** volume? How do you know on a molecular level?
    - Ask the scholars who measured the group what they noticed about the shape of the class during this exercise.
        - Explain that whereas **solids** have a definite shape, **liquids** and **gases** have an indefinite shape. (They learned this in elementary school, but may not remember.)

Make broader connections:

- Ask: Can you notice evidence of these molecular properties in these materials every day? For example, why might it be harder to trap a gas than a liquid?

Make connections to the Essential Question:

- Ask: How does knowledge of molecular movement help us answer the Essential Question?

Accountability (Lab Notebook)

- Grade scholars' models of solids in their Lab Notebooks.

Scoring Award points as follows:

- Award scholars two points for a clear, neat, and complete model.
    - Note: Use the answers to plan your Launch for day two of the lesson.

Day Two

Do Now

- Follow the **Do Now plan**.

Launch

- Ask: How do molecules behave differently in solids, liquids, and gases? Ask scholars to use the dancing scenarios in their responses. Remind them that they were acting as molecules.
- Ask: What happens when substances change their state of matter?
    - Define **phase change** and have scholars brainstorm different types of phase changes they remember from elementary school.
        - Note: Scholars may know more phase changes than focused on during this unit. They should focus on the main phase changes of melting, freezing, and evaporation for today's activity.
- Explain: Today, we will continue our discussion about the investigation and determine what makes phase changes occur.

Activity

- Scholars work with their lab group and brainstorm ideas to add representations of phase changes to the model from day one.
    - Halfway through the activity time, select a method or two for the class to model together. Pause the group and have two scholars step out from the center to take measurements of the space occupied by the class.
- As scholars are working, monitor behavior and press scholars to connect the difference between molecular behavior between states of matter to predict their behavior between phase changes.

Discourse Debrief activity:

- Have scholars share their new models for the different phase changes.
- Think of a real-life example of a phase change. Ask: Where do molecules get the energy for their movement?
    - Ask: How are temperature and molecular movement related?
    - In elementary school, you learned that heating is a transfer of energy from a body of higher temperature to a body of lower temperature. Using your new knowledge from this lesson, why does thermal energy always naturally move in that direction?
        - Show **Heat, Temperature, and Thermal Energy Video** by Likeable Science on YouTube (first 2 minutes, 50 seconds).
        - Wait for scholars to mention the idea of temperature or energy. Define **thermal energy**.
- Ask: To make a liquid into a solid, what do you do?
    - Encourage scholars to use evidence from the investigation and the video. Scholars should recognize that a temperature decrease turns a liquid into a solid.
    - Ask scholars about how temperature changes are related to other phase changes.

- Scholars revise their models from day one in their Lab Notebooks. Ensure they are revising on both a macroscopic and molecular scale.

Make connections to the Essential Question:

- Ask: How does what we learned today help us understand why our ice cream wouldn't freeze on the first day of the unit?

Accountability (Exit Ticket) Todd wants to know what happens to water molecules as they undergo phase changes.

1. Complete the table below to help Todd accurately compare water in each state of matter. [4]

Name	Ice	Water	Water Vapor
State of Matter	Solid	Liquid	Gas
Temperature	0 °C or lower	Above 0 °C but below 100 °C	100 °C or higher
Molecular Motion Rank from 1-3. 1 = slowest 3 = fastest	1	2	3
Average Kinetic Energy Rank from 1-3. 1 = lowest 3 = highest	1	2	3
Volume (Definite or indefinite?)	Definite	Definite	Indefinite
Shape (Definite or indefinite?)	Definite	Indefinite	Indefinite

2. In the space below, create a visual model to represent the relative intermolecular distance of the molecules in each state of matter. Add labels and a key (if helpful) to ensure your model is easy to understand. [2]

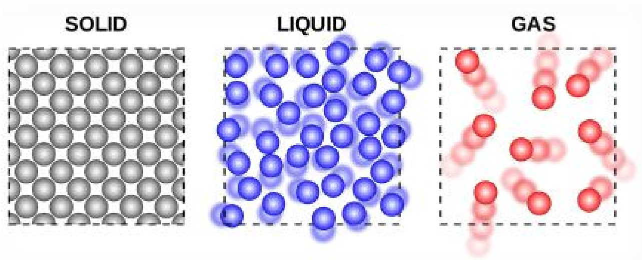
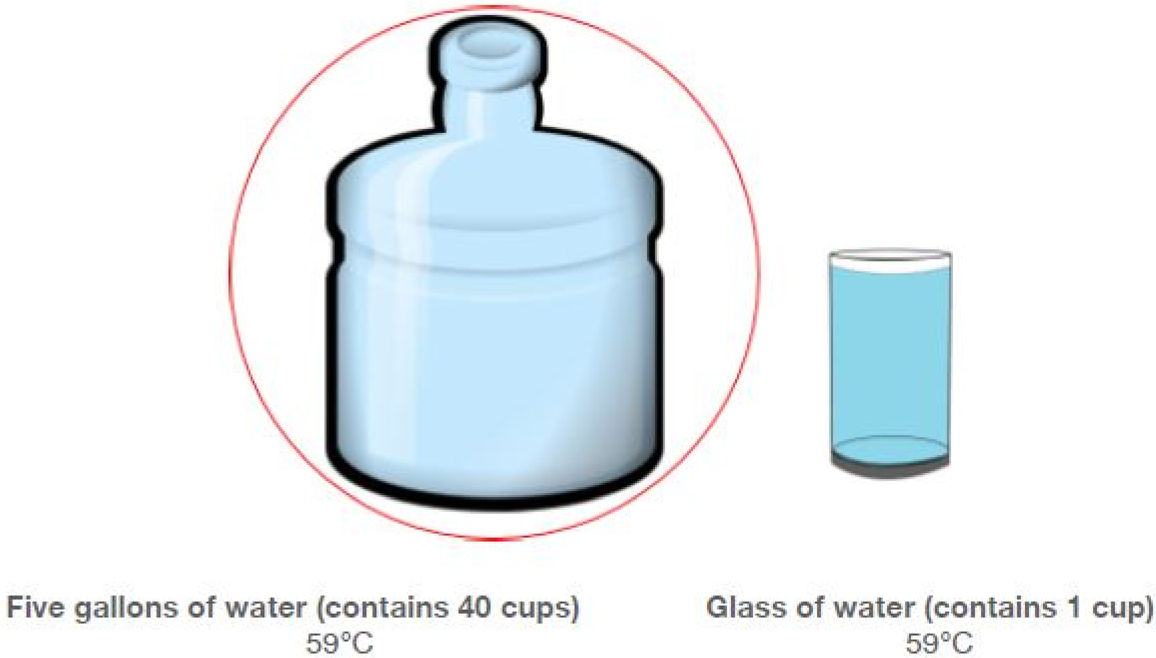


Image Credit: **ertunc** , Public domain, via Wikiversity

Todd also wonders about the difference between *temperature* and *thermal energy.*

3. Which would have more thermal energy: five gallons of water at 59°C or one cup of water at 59°C? Circle your answer below. [1]



Scoring Award points as follows:

1. Award one point for each row that is filled in correctly.
2. Award two points for three labeled drawings that clearly show understanding of the relative spacing of molecules in a solid, liquid, and gas.

    - Award partial credit of one point if labels are missing, but drawing is clear
    - Award partial credit of one point if there is one error

3. Award one point for circling the five-gallon jug.

Lesson 3: Achieving Balance

Lesson Objective: Substances at different temperatures often come into contact, which results in thermal energy flowing from the warmer substance to the cooler one in an attempt to reach thermal equilibrium. Endothermic processes are accompanied by or require the absorption of heat (heating), while exothermic processes are accompanied by the release of heat (cooling). Materials Needed

- For each group: hot plate, large beaker of room temperature water, 1 cup of refrigerated water, 1 cup of ice, 2 smaller beakers, 2 styrofoam cups, 2 graduated cylinders, 2 thermometers
- For each scholar: goggles

Prep

- Materials Prep:
  - Freeze enough ice cubes for all groups in each class or purchase bags of ice.
- Intellectual Prep:
  - Read **Chemistry LibreTexts 11.4: Phase Changes (CC BY-NC-SA 4.0)**.

What are scholars doing in this lesson?

- Scholars design their own experiment to determine what happens when objects of different temperatures come together.

Do Now

- Follow the **Do Now plan**.

Launch

- We now know that molecules behave differently in different states of matter. We also know that they move at different speeds based on the temperature of a substance.
  - Ask: What happens when you put objects or substances that don’t have matching temperatures side by side? This will help us determine what happened to the molecules when the ice cream ingredients came into contact with the ice (and why they ended up as a liquid instead of a solid).

Experiment

- Scholars design their own experiments to determine the effects of combining substances of different temperatures and/or states using the provided materials.
- Sample procedure:
  - Heat 50 mL of water in a beaker on a hot plate for 3 minutes.
  - While the water is heating up, pour 50 mL of room temperature water into a second beaker.
  - Take the starting temperature of each beaker of water. Then combine the two into one cup.
  - Record the temperature of the combined cup every 30 seconds for 2 minutes.
- Scholars graph their data using an appropriate graph (most likely a double line graph).
  - Ask scholars how they decided what type of graph to use.
- As scholars are working, circulate and press them to draw meaning from their data and connect it back to the ice cream experiment.

Discourse Debrief experiment:

- Display scholar work.
    - Ask the class to evaluate the graph. Is it clear? Is it accurate? Complete?
        - Ensure exemplar graphs have a title, appropriately labeled axes, correct units, and a logical scale.
            - Model for scholars how to determine and create a logical scale. Explain how you determine appropriate intervals, keep consistent intervals, and graph data with values both above and below zero.
- Scholars share conclusions.
    - Ask: What happens on a molecular level when substances of two different temperatures are combined? Why?
        - Press scholars to explain this in terms of the transfer of thermal energy, intermolecular distance, and molecular movement. If helpful, use the space in the Lab Notebooks to model their explanations.
        - Define **endothermic** and **exothermic**. Provide a few scenarios from the prep material.
            - Ask scholars to explain in their own words what the difference is between endothermic and exothermic reactions on a macroscopic and molecular level.
        - Define <u>thermal equilibrium</u>. Explain that thermal equilibrium is the condition under which two substances in physical contact with each other exchange no heat energy. Two substances in thermal equilibrium are said to be at the same temperature.

Make connections to the Essential Question:

- Ask: What likely happened on the first day of our unit when the ice cream ingredients came into contact with the ice?
- Ask: How could you lower the temperature of the ingredients enough to make them freeze?

Accountability (Exit Ticket) After attending his cousin's birthday party in his backyard, Michael forgot his balloon outside when he went to bed. Overnight, the temperature dropped significantly. When Michael saw the same balloon the next morning, it looked different.

1. Explain what caused this change. Assume no air escaped from the balloon. [3]

The decrease in temperature outside made the air surrounding the balloon colder. Because the balloon was warmer than the air, some of the thermal energy from the balloon transferred into the air. This caused the balloon to cool, making the molecules condense, and lowering and deflating the balloon.

2. What does this model tell you about the relationship between temperature and volume? [1]
    1. Volume and temperature increase together
    2. As temperature increases, volume decreases
    3. As temperature decreases, volume increases
    4. Volume and temperature do not have a relationship

Scoring Award points as follows:

1. Award one point for each of the following:

    - An appropriate claim (must reference temperature and their effect on molecular movementâ€" saying "time went by" is not an acceptable response)
    - At least one piece of evidence to support the claim (from background knowledge and/or the provided pictures)
    - An explanation of the science that supports the evidence (should reflect full conceptual understanding of relevant concepts from the lesson)

2. Award one point for selecting answer A.

Lesson 4: Total Meltdown

Lesson Objective: Various substances undergo phase changes at different temperatures. Scholars understand that the ice cream ingredients didn't freeze on the first day of the unit because they didn't cool enough to reach their freezing points! They will not know that the boiling or freezing point of a substance can actually change based on environmental conditions. They can better differentiate between evaporation and boiling. Materials Needed

- For each group: 20 mL candle wax pellets, 2 glass test tubes, 2 thermometers, water, 2 ring stands, 2 test tube clamps, 2 thermometer clamps, 2 hot plates, 2 beakers, 20 mL dark chocolate
- For each scholar: apron, goggles

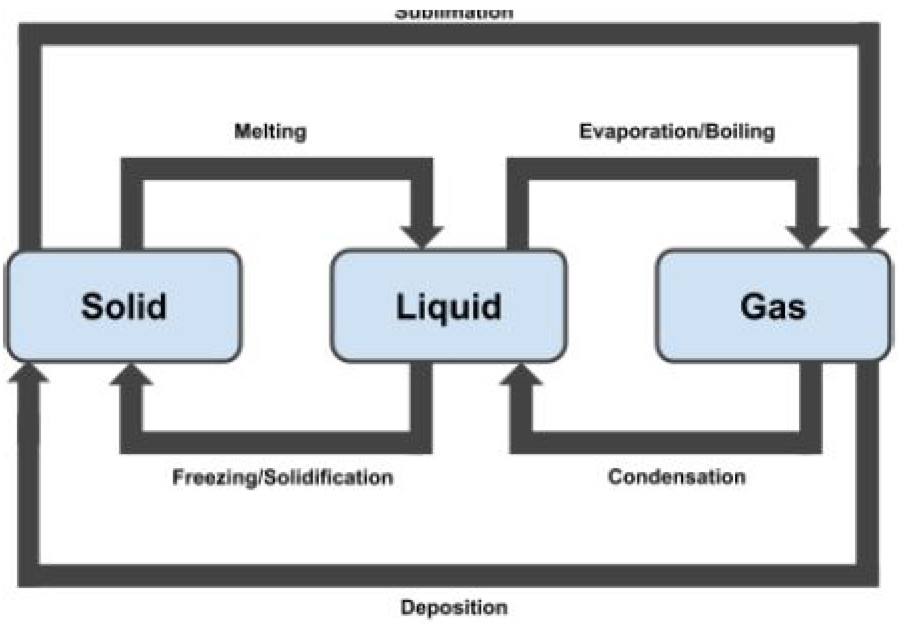
Prep

- Materials Prep:

    - Check the allergy list to ensure that no scholars have an allergy to chocolate.

- Intellectual Prep:

    - Read **Chemistry LibreTexts 7.3: Phase Changes** (**CC BY-NC-SA 4.0**).
    - Review definitions of terms introduced in the lesson.
    - Review the phase change diagram below that you will use during discourse.



What are scholars doing in this lesson?

- Scholars design and conduct an experiment to better understand melting to make connections to freezing and the unit's Essential Question.

Do Now

- Follow the **Do Now plan**.

Launch

- Ask: What happens to a candle when you light it? Why?
    - Define **melting point** and **melting**.
        - A melting point is the boundary between a substance being a solid and a liquid, so a substance's melting point is usually also its **freezing point**, or the temperature at which **freezing** occurs.
        - Today, we're going to see if we can find this temperature for two different substances. On the first day of the unit, our ice cream ingredient did not freeze, but our ice melted. By studying melting, maybe we can learn something that will help us next time we try to create ice cream!

Experiment

- Scholars design and record a procedure for heating wax and chocolate and create a table for collecting data during their experiment. Sample procedure:
    - Fill a beaker â…" of the way with water.
    - Place this beaker on a hot plate and heat it at medium heat.

    - Place the test tube containing candle wax in the water. Make sure that the test tube is NOT resting on the bottom of the beaker. Use a clamp to prop up the test tube in the water.
    - Take the temperature of the wax every 30 seconds by dipping the thermometer into the wax. Record the results.
    - Once the substance in the test tube has completely liquified, remove the test tube from the hot water by carefully raising the clamps on the ring stand.
    - Turn off the hot plate and leave the beaker of water to cool.
    - Repeat the steps above with a new hot plate and beaker (to avoid invalid data) to find the melting point of the chocolate.

- As scholars are working, circulate and press them to explain the significance of their observations.

Discourse Debrief experiment:

- Ask: What are your initial observations based on your experiment?

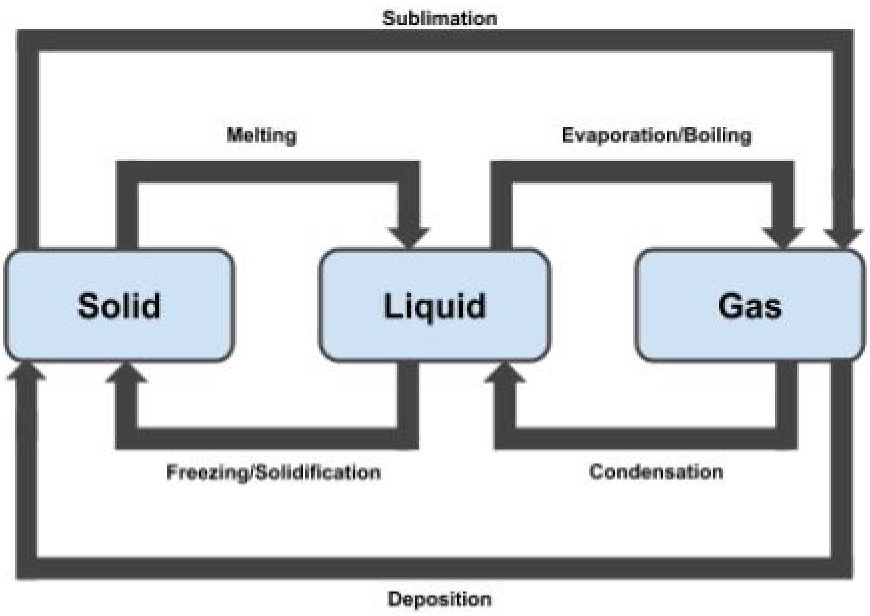
Make connections to the Essential Question:

- Ask: How could we apply our understanding from this experiment and discussion to our ice cream challenge?

    - Push scholars to identify that the substances must not have reached the freezing or melting point, so a phase change did not occur. Scholars should leave the discussion knowing that the freezing point of the ice cream mixture must be higher than what they have tried so far.

Make broader connections:

- Review all of the words that describe the different kinds of phase change using the diagram below.



- Have scholars give examples of familiar phase changes.
- Briefly explain the difference between **evaporation** and **boiling** because these are commonly confused terms for scholars. Define **boiling point**.
- Provide examples that scholars are familiar with to expose them to deposition (like frost forming on a cold window) and sublimation (which visibly occurs when you handle dry ice).

Accountability (Exit Ticket) Two substances are cooled in separate beakers. After 10 minutes of cooling, both substances have a temperature of 5°C. At this temperature, one substance is a liquid and the other is a solid. Use the information provided to answer the questions that follow:

1. Which statement is true? [1]

1. Both substances must have a melting point below 5°C.
2. One substance must have a freezing point below 5°C.
3. Both substances must have a freezing point above 5°C.
4. One substance must have a boiling point of exactly 5°C.

1. I
2. II
3. III
4. IV
5. I and IV

2. Which statement best describes why freezing point and melting point are usually the same for a substance? [1]

1. A phase change between liquid and solid occurs at this point.
2. A phase change between gas and solid occurs at this point.
3. Freezing and melting cannot be told apart.

4. All substances melt and freeze at the same temperature.

Scoring Award points as follows:

1. Award one point for answer B.
2. Award one point for answer A.

Lesson 5: Graphing Phase Changes

Lesson Objective: The temperature of a substance remains the same as it undergoes a phase change due to kinetic energy staying the same (only potential energy is changing). Heating and cooling curves show the slopes and plateaus that occur as the temperature of a substance changes over time, with a positive slope indicative of heating and a negative slope indicative of cooling. A plateau on a heating curve occurs because the energy being taken in is used to overcome intermolecular forces. A plateau on a cooling curve occurs because while potential energy is released as molecules condense, kinetic energy does not begin to change again until the phase change is complete. Materials Needed

- For each scholar: ruler

Prep

- Intellectual Prep:
    - Watch **Heat in Changes of State Video** by Teacher's Pet (first 2 minutes, 2 seconds).
    - Watch **2.5 Heating/Cooling Curves (Potential and Kinetic Energy Changes) Video** by Ms. Long (8 minutes, 27 seconds).

What are scholars doing in this lesson?

- Scholars use their data from the previous lesson to create their own heating curves.

Do Now

- Follow the **Do Now plan**.

Launch

- Show this following heating curve:

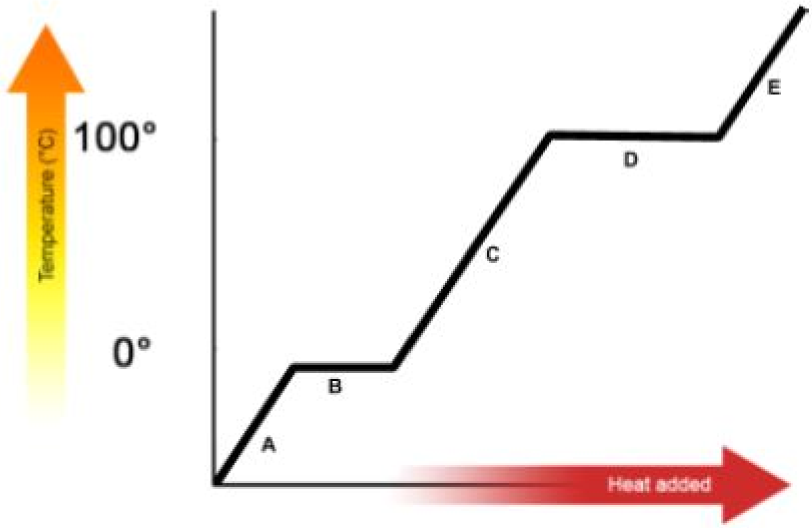


Image Credit: Adapted from [Community College Consortium for Bioscience Credentials](), [CC BY 3.0](), via Wikimedia Commons

- Ask: What is shown in this graph?
- Describe the shape of this graph.
- During our first attempt at making ice cream, we experienced some undesirable phase changes. Is there a way to prevent ice from melting? What actually causes a phase change, at the molecular level?
- Today we will graph our data from yesterday's experiment to see if it illuminates anything new that will help us in our challenge!

Activity

- Scholars create heating curves using the data from Lesson 4.
- Scholars analyze their data and record findings in their Lab Notebooks.
- As scholars are working, circulate and coach those struggling with graph creation. Diagnose the root cause and provide transferrable feedback, and then check back 7–10 minutes later to assess progress. For example, some students may not use a sensible scale while others may not graph the appropriate variables on the axes.

[**Tip:** Scholars may be familiar with drawing a line of best fit on a graph. Explain to scholars why they should avoid this when creating heating/cooling curves.]

Discourse Debrief activity:

- Share scholar work samples. Ask:
    - Is the shape of your graph what you expected? Explain.
    - What do the parts of the graph with a positive **slope** signify? A negative slope?
    - What do the **plateaus** in the graph signify?

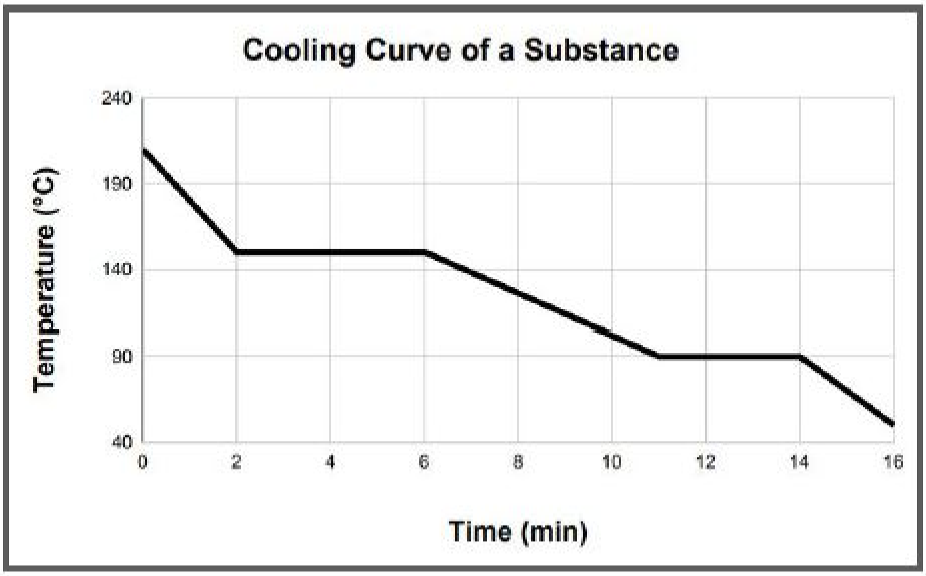
- Explain that separating (or **condensing**) molecules actually overcomes **intermolecular forces** between molecules. Separating molecules from one another is work that requires energy. Conversely, condensing molecules releases energy. Both cause a temporary interruption in the heating or cooling pattern, which creates the plateaus on the graph. During those time periods, the **potential energy** changes, whereas the kinetic energy (and therefore the temperature of the substance) remains the same.

    - Compare intermolecular forces and intramolecular forces to help scholars understand the difference. Discuss **molecular (covalent)** and **ionic bonds** (review terms from Unit 1) and explain that in a phase change, these are not changing, but rather the forces between molecules are.

Make connections to the Essential Question:

- Show the **Reading Heating and Cooling Curves Video** by SMSphysSCIENCE (4 minutes, 59 seconds).
- Connect this back to the ice cream experiment. Ask:
    - On day one of the unit, which substance(s) underwent a phase change when you combined all of the ingredients? What happened to the overall temperature of the mixture? What were the molecules doing during these phase changes? Were they moving closer to or further from each other?
    - How can you apply your knowledge from today's lesson to your next attempt to make ice cream?
        - If scholars struggle to answer, explain that they may need to reframe their thinking. They have been thinking about how to help the ice stay solid longer so it can freeze the other ingredients, but maybe there's another way to draw thermal energy from the ingredientsâ€" using a phase change.

Accountability (Exit Ticket) The image below shows the cooling curve for a substance.



1. Describe what is happening to the substance between the 2- and 6-minute marks. Explain how you know with evidence from the graph. [2]

Between the 2- and 6-minute marks, the substance is undergoing a phase change from a gas to a liquid. This is shown by the plateau on the graph. During the phase change, kinetic energy and temperature are stable.

2. What is the state of the substance at 70°C?

1. Solid
2. Liquid
3. Gas
4. It is impossible to tell

3. Which statements about what happens to energy levels during phase changes are true? [1]

1. Average kinetic energy and potential energy decrease
2. Average potential energy changes, while average kinetic energy stays the same
3. Average kinetic and potential energy increase

1. I
2. II
3. III
4. I and II

Scoring Award points as follows:

1. Award one point for each of the following:
    - Identifying the phase change between the 2- and 6-minute marks
    - Identifying relevant evidence from the graph (the plateau)
2. Award one point for answer A.
3. Award one point for answer B.

Lesson 6: A Pinch of Salt

Lesson Objective: The addition of another substance can elevate (increase) or depress (decrease) the boiling point of a substance. Materials Needed

- For each group: beaker, thermometer, water, ring stand, thermometer clamp, hot plate, salt (each group needs at least 45 mL), sugar (each group needs at least 45 mL), colored pencils
- For each scholar: apron, goggles

Prep

- Intellectual Prep:
    - Read **Boiling, Freezing, and Pressure** by Science Toy.

What are scholars doing in this lesson?

- Scholars conduct an experiment to determine the boiling point of water with the addition of other substances in order to make connections to the unit's Essential Question.

Do Now

- Follow the **Do Now plan**.

Launch

- Show **How To Cook Pasta Video** by Start Cooking. (You can stop the video around 40 seconds, after scholars have observed the salting.)
    - Why do you need boiling water?
    - Why do you think people salt the water?
- Explain that today's investigation is all about the boiling point of water! Ask:
    - Is it possible that salt or other substances could somehow affect the boiling point of water? Does salting your pasta water really make it boil faster, as many people claim? Is there any way that learning about pasta can help us make ice cream? Today, we'll find out!

Experiment

- Scholars develop procedures to find the boiling point of plain water, sugar water, or salt water.
    - Allow time for the class to discuss and agree on controlled variables.

[**Tip:** To avoid running out of time, assign each group *one* of the three types of water. Allow the class to share data.]

- Sample procedure:
    - Scholars pour 150 mL of water into a glass beaker and place it on the hot plate.
    - Scholars turn the hot plate on and dial it to a predetermined level (assign this based on your hot plates).
    - Scholars record the temperature of the water every minute and find its boiling point.
    - Once the water is fully boiling, scholars turn off the hot plate and let the materials cool down.
    - Scholars repeat this activity using water containing 45 mL of dissolved salt and then water containing 45 mL of dissolved sugar.
- After getting their results, scholars graph their data in their Lab Notebooks using a triple line graph.

[**Tip:** Allow scholars to use colored pencils to highlight the three lines on their graph.]

- Circulate and check in with scholars whom you coached during the last lesson. Assess their progress and provide updated feedback.

Discourse Debrief experiment:

- Scholars share data. Discuss:
    - What is happening to the molecules when water boils?
    - Did each substance boil at the same time? Ask:
        - Which substance do you think requires the most energy to go from room temperature to boiling? What's your evidence?
        - Explain that substances have different boiling points, just like they have different melting and freezing points! This is due to the molecular makeup of each unique substance.
    - Scholars should take note of how sugar and salt each affected the boiling point.
    - Ask: How do you think salt would impact freezing point?

[**Tip:** Scholars may be surprised to learn that the salt water actually takes *longer* to boil than the plain water. It is a common myth that it makes the water boil faster. So why do so many people believe it? This is a good topic to explore further if time allows. Note: While salt raises the boiling point of water, salt does not interact with all substances in the same way that it interacts with water.]

Make connections to the Essential Question:

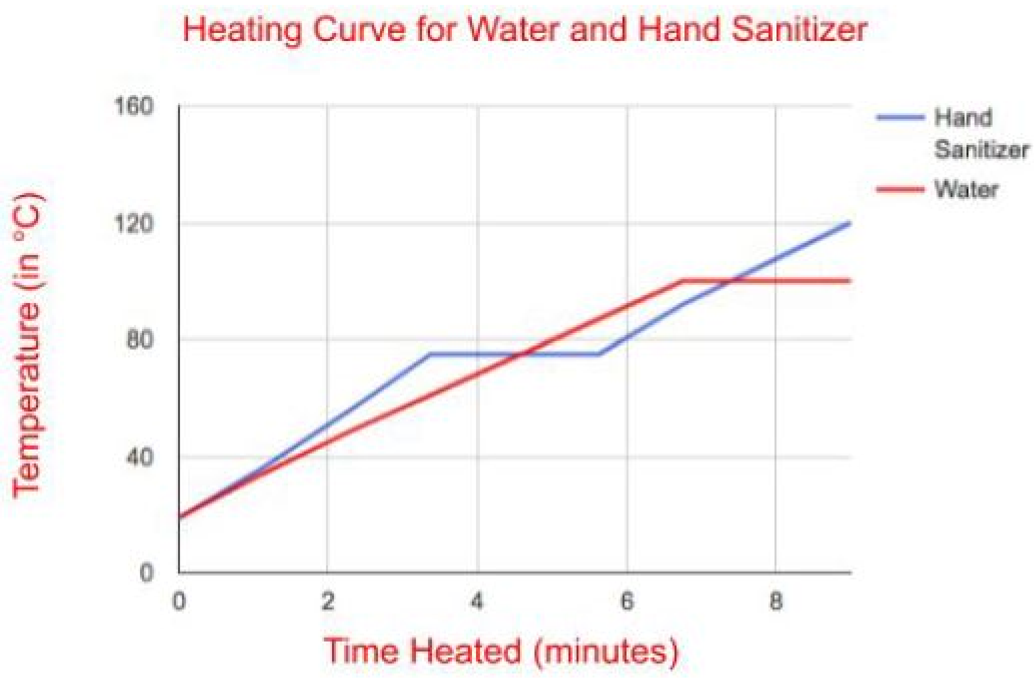
- Ask: We want to make our ice cream freeze, not boil! Is there any way to apply the findings from today's investigation to our ice cream challenge?

Accountability (Exit Ticket) Shayne conducted an experiment to determine whether hand sanitizer or water had a lower boiling point. He collected the data in the table below.

Time on hotplate	**0 min**	**1 min**	**2 min**	**3 min**	**4 min**	**5 min**	**6 min**	**7 min**	**8 min**
Temperatureof hand sanitizer	19°C	36°C	55°C	75°C	75°C	75°C	92°C	106°C	120°C
Temperatureof water	19°C	34°C	48°C	61°C	74°C	87°C	100°C	100°C	100°C

1. Create a double line graph to display Shayne's data. Ensure you include the following:
    - **Axes:** x- and y-axis labels, units, and a logical scale [2]
    - **Data:** all provided data graphed accurately [1]

Exemplar:



Scoring Award points as follows:

1. Award one point for each of the following:

   - Accurate x- and y-axis labels with correct units (must have both axes labeled correctly for credit)
   - A logical scale so that the data fits within the provided space and is clearly visible (Do not award points if there are more than three unused grid lines on both axes)
   - Correctly plotted data (assume an acceptable range of ± 20 seconds and ± 3°C for all points, and award partial credit if there is one error)

Lesson 7: An Icy Experiment

Lesson Objective: The addition of another substance can elevate (increase) or depress (decrease) the melting or freezing point of a substance. Salt depresses the freezing point of water. Materials Needed

- For each group: 3 identical cups or beakers, 3 identical ice cubes, ¼ tsp measuring spoon, salt, sugar, tape, and a marker

Prep

- Materials Prep:
  - Freeze enough ice cubes for all groups in each class.

What are scholars doing in this lesson?

- Scholars conduct an experiment to determine how other substances affect the melting of ice.

Do Now

- Follow the **Do Now plan**.

Launch

- Ask: Can you think of something that gets very, very cold and still remains a liquid or gas?
    - Some examples include dry ice and liquid nitrogen, which are gases that can cause frostbite in humans.
    - Why do you think that happens?
- Based on yesterday's lab results, how do you think salt and sugar might affect ice? Why?
    - Today, we will have the opportunity to test this out! Maybe we can get some information that will help us create our ice cream!

Experiment

- Scholars complete an experiment to see how adding salt or sugar affects the rate at which ice melts by following the procedure below:
    - Label three containers as "salt," "sugar," and "control."
    - Place one ice cube into each container.
    - Measure ¼ tsp salt onto the ice cube in the container labeled "salt."
    - Measure ¼ tsp sugar onto the ice cube in the container labeled "sugar."
    - Leave the ice cube in the container labeled "control" as is.
    - Observe each ice cube over 20 minutes, stopping every 5 minutes to record notes.
- Scholars then complete analysis question in their Lab Notebooks:
    - Which was the first cube to melt completely? Which was the last to melt? Why do you think that is?

[**Classroom Management Tip:** As scholars are waiting for the ice to melt, give them something else to work on (such as a related article to read, an online simulation to complete, or Exit Ticket feedback to review).]

- As scholars are working, circulate and press them to apply their findings to the ice cream challenge. Take note of scholars who are applying this data and selecting best evidence exceptionally and highlight their work during the discourse.

Discourse Debrief experiment:

- Discuss the results of the experiment. Compile class data. Ask:
    - What trends do you notice in the data?
        - In this activity, you tried adding salt and sugar to ice to see whether the substance would help melt the ice. In other words, you wanted to test whether these substances could demonstrate **freezing point depression**, or the lowering of the ice's freezing point so that it melted into a liquid at a lower temperature than normal.
            - Define **elevation** as well, and familiarize scholars with terms such as freezing point elevation, boiling point depression, etc.

Make broader connections:

- Ask: What does this data make you think about the melting points of different substances?
    - Show **How Does Salt Melt Ice? Video** by Reactions (first 1 minute, 15 seconds).
    - Note: Salt does not necessarily have the same effect for all substances' freezing or boiling points.

Make connections to the Essential Question:

- Ask: How can we apply this information to our ice cream challenge?

Accountability (Exit Ticket) During the winter, Khari takes a walk on a beach with his family. He is surprised to see that the ocean water isn't frozen. He takes the temperature of the water, and discovers that it is −2°C! He knows that the freezing point of water is 0°C, so he doesn't understand how it is possible that the ocean water is both −2°C and still a liquid.

He asks his siblings what they think, and they reply with the following ideas:

- Asani: Well, maybe the ocean just can't freeze. It's so big that not all the water is the same temperature. If some of it is not as cold, it cannot freeze!
- Tabia: I know that the ocean water contains a lot of salt; the salt must make it harder for ice to form and stay together!

1. Which of the two statements above is most accurate? Explain and justify your response. [3]

Tabia's statement is most accurate. Khari doesn't know it, but what he is observing in the water is called freezing point depression. The salt in the ocean is mixing with the water and causing the freezing point to lower, so even though the water is colder than 0°C, it is able to remain a liquid.

Scoring Award points as follows:

1. Award one point for each of the following:
    - Identifying Tabia's statement as most accurate

- Providing at least one piece of compelling evidence to support the claim (must be scientifically accurate and directly related to classwork)
- Justification/reasoning that connects the evidence to the claim (likely defining “freezing point depression” or explaining the behavior of the salt and water on a molecular level)
- Note: If scholars do not select Tabia’s claim as most accurate but present sound evidence and reasoning for another choice, award points for evidence and reasoning as appropriate.

Lesson 8: Why Do Boiling, Melting, and Freezing Points Vary?

Lesson Objective: Intermolecular forces and atmospheric pressure affect the temperature at which a phase change occurs. The boiling point of a liquid depends on the intermolecular forces present between the molecules in the liquid, because you must disrupt those forces to change it from a liquid to a gas. Lowering atmospheric pressure will lower the boiling point of a liquid. This is due to the fact that the vapor pressure of water depends upon temperature. Materials Needed

- For the teacher: mason jar (with screw on ring lid), laminated index card, screen covering (for top of mason jar), bucket, water
- For each group: 2 pennies, 2 eyedroppers, water, acetone, paper towels

Prep

- Intellectual Prep:
    - Watch the **Liquids: Crash Course Chemistry #26 Video** (11 minutes, 3 seconds) to learn about intermolecular forces.
    - Watch the **Boiling, Atmospheric Pressure, and Vapor Pressure Video** by Wayne Breslyn (6 minutes, 4 seconds).
    - Review and practice the surface tension demonstration by watching the **7 Science Tricks with Surface Tension Video** by Physics Girl (1:13–1:54).
- Materials Prep:
    - Fill a mason jar ¾ way with water.
    - Place the screen on top of the mason jar and screw on the ring lid.
    - Place a laminated index card on top of the screen and press down.
    - Place the mason jar with the index card over a bucket.
    - Practice turning the mason jar upside down until the laminated index card sticks to the top and remove your hand from the index card.
    - With the mason jar still upside down, hold the mason jar still with one hand and remove the index card completely.

What are scholars doing in this lesson?

- Scholars conduct an experiment to investigate how understanding surface tension connects to the effect of intermolecular forces and atmospheric pressure on phase changes.

Do Now

- Follow the **Do Now plan**.

Launch

- Show the surface tension demonstration. Ask:
    - Why do you think the water stays in the jar when it is inverted?
        - Do not provide an answer to this question yet.

Experiment

- Scholars use droppers to see how many drops of two different substances (water and acetone) can fit on the head of a penny. They follow the procedure below:
    - Set a penny on the table, heads up.
    - Fill an eyedropper with water.
    - While counting, slowly drop the water onto the penny, one drop at a time, until the water spills over the edge of the penny.
    - Repeat with acetone on the second penny.
    - Wipe down the pennies to remove any extra liquid.
- Circulate and press scholars to explain the phenomena they observe.

Discourse Debrief experiment:

- Have scholars share the results of their experiment.
- Ask: Why do you think more drops of water fit on the penny than acetone?
    - Define **surface tension**.
        - Revisit the “Random Texting Dance” and “Random Square Dance” from Lesson 2. Press scholars to make connections between the idea of surface tension and the descriptions in the model.
- Explain:
    - From earlier units, we know that smaller particles in a molecule are held together by attractive forces. These forces are called intermolecular forces, as you learned in an earlier lesson.
    - All substances experience intermolecular forces, which can attract or repel molecules. Because of the particles within each compound, some experience stronger intermolecular forces than others. For example, the attractive intermolecular forces between water molecules are stronger than those in the acetone molecules.
    - While intermolecular forces often attract molecules to one another, kinetic energy tends to make them move around and separate. These are in tension with one another and determine whether something is a solid, a liquid, or a gas! If the average

kinetic energy is greater than the attractive forces, a substance will be a gas. If the kinetic energy is less than the attractive forces, it will be a liquid or solid.

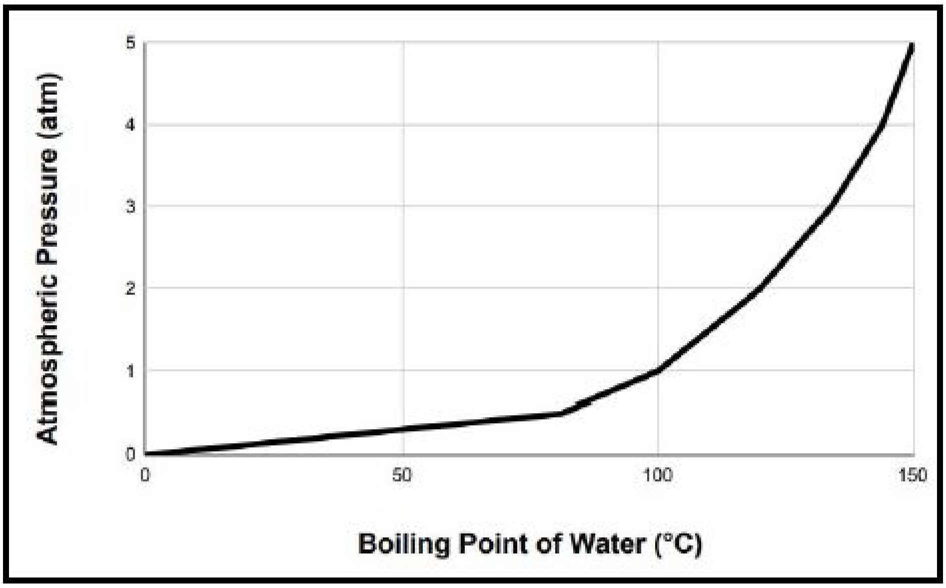
- Develop and record a hypothesis about the relationship between a substance's intermolecular forces and boiling point.

    - Display the boiling points for water and acetone (water boils at 100°C, and acetone at 56°C). Ask: Given what you have learned, why do you think different substances change phases at unique temperatures?

        - Show the **Boiling, Atmospheric Pressure, and Vapor Pressure Video** by Wayne Breslyn (6 minutes, 4 seconds).
        - Stop the video after each section to discuss, answer questions, and summarize key takeaways. Define **atmospheric pressure** and vapor pressure when they come up. Scholars should take note of new understandings in their Lab Notebooks.

[**Tip:** Understanding atmospheric pressure and vapor pressure as well as their effects on matter will likely be tricky for scholars. They also may find it difficult to believe that atmospheric pressure exists because they don't "feel it." Consider revisiting these concepts on another day to give scholars more practice and familiarity with them.]

- Highlight that due to pressure, the boiling point of a liquid can actually change. Scholars may find this very surprising, as they likely remember learning certain "boiling points" in elementary school (i.e., they learned that water boils at 100°C or 212°F). Explain that when we speak about the "boiling point" of a substance, we are commonly actually referring to its **normal boiling point** (a measure of the boiling point when there is "1 atmosphere" of pressure, which is roughly equivalent to sea level).
- Display the following graph, which shows how the boiling point of water changes when atmospheric pressure changes, to support understanding.



Make connections to the Essential Question:

- Ask: How can you apply what you have learned today to the ice cream challenge?

Make broader connections:

- Revisit the demonstration from the beginning of class. Ask scholars to explain the science behind what they saw in the demonstration.

Accountability (Exit Ticket)

1. Tyla begins heating 200 mL samples of two different substances at the same time. She notices that they begin to boil at different times. If she heats them both under identical conditions, why might one substance boil before the other? Use your knowledge of intermolecular forces and energy in your response. [4]

The two substances are different and thus have different intermolecular forces. Substances with stronger attractive intermolecular forces have molecules that are harder to separate. Because of this, more energy is required to physically spread the molecules apart.

Tyla lives in Denver, Colorado, while her friend Esther lives in Philadelphia, Pennsylvania. They each heated 200 mL of Substance A in their respective cities, and noticed a 5 degree difference in the substance’s boiling point. The table shows some facts for each city on the day they heated Substance A.

Location	OutsideTemperature (â„‰	Elevation(ft. above sea level)	Weather	Time
Philadelphia, PA	56	39	Windy	12 PM
Denver, CO	50	5300	Calm	10:15 AM

2. Which is the best explanation for the difference in boiling points? [1]

1. Two identical substances never have the same boiling point.
2. The atmospheric pressure is most likely different in each city due to their respective elevations, which could affect the boiling point of the substance.
3. Since it was colder in Philadelphia, it would have taken Substance A longer to boil.
4. Since it was colder in Denver, it would have taken Substance A longer to boil.

Scoring Award points as follows:

1. Award one point for each of the following:
    - An accurate claim
    - Identifying that unique substances have varying intermolecular forces (or comparing the relative strength of the substances’ intermolecular forces)
    - Identifying that the molecules in one substance may be harder to separate (or providing alternative background information that is accurate and relevant)
    - Explaining that overcoming stronger intermolecular forces requires more energy
2. Award one point for selecting answer B.

Lesson 9: Ice Cream Party, Take Two (Two Days)

Lesson Objective: Multiple factors influence the state of a substance. A mixture of ice and salt has a lower temperature than their ice by itself, allowing the liquid ice cream ingredients to freeze when they are exposed to the cold brine! Materials Needed

- For the teacher: extra ice, plastic tablecloths (1 per lab table), extra sugar, large supply of salt
- For each group: paper towels, sponge, measuring cups and spoons
- For each scholar: ¼ cup half-and-half (cream), ¼ cup milk, â…” tbsp sugar (2 sugar packets), ¼ tsp vanilla, 1 tsp chocolate syrup (optional), quart-sized resealable plastic bag, gallon-sized resealable plastic bag, plastic cup, spoon, straw

[**Tip:** Scholars who cannot eat ice cream can use a partially frozen or unfrozen freeze pop in place of the milk/cream/sugar mixture.]

Prep

- Materials Prep:
    - Review the **5-Minute Ice Cream Recipe** by Food.com.
    - Purchase enough bags of ice to accommodate all groups in each class.
    - Cover each table with a plastic tablecloth (optional).
    - Between classes, restock materials as needed.

What are scholars doing in this lesson?

- Scholars demonstrate their understanding of phase changes by developing an accurate procedure for making ice cream. If they have applied these ideas correctly, they will succeed in making ice cream during day two!

Day One

Do Now

- Follow the **Do Now plan**.

Launch

- The final challenge is here! You will have another chance to create your own ice cream!
- Develop a new plan for making ice cream that incorporates everything you have learned in this unit. You can also use other materials in the lab upon request (although you can't add them to the part you'll be eating)!

[**Tip:** Show scholars some of the additional materials that are available, including salt and sugar.]

Activity

- Scholars draft a new plan to make ice cream.
- As scholars are working, circulate and ensure they develop procedures that apply their knowledge from the unit. Coach scholars as needed and press those who are struggling to apply their understanding by using scaffolded questioning.

[**Engagement Tip:** If many groups are having a hard time, stop the class and allow a group that has a strong plan to share their ideas and reasoning with their peers.]

Discourse Debrief activity:

- Show a sample procedure. Ask:
    - Do you think this procedure will be successful? What evidence from the unit supports your claim?
- Compare your new procedure to the one from the beginning of the unit.
    - Explain the changes to your procedure.

Accountability (Lab Notebook)

- Scholars trade, review, and evaluate a peer's work from another group for clarity and incorporation of best evidence.

Scoring Award points as follows:

1. Award one point for each of the following.

- Plan is clear, with each step well-defined
- Plan shows evidence of understanding and correct application of concepts from class

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Day Two

Do Now

- Follow the **Do Now plan**.

Launch

- Today is the big day! You will use your new plan to create ice cream!
    - Ask scholars if they are confident that their procedures will be successful.

Experiment

- Scholars make any final updates to their procedures and then execute them to create ice cream!
- As scholars are working, circulate and press them to explain the science behind their work. Record qualitative data regarding scholar mastery of unit goals.

[**Materials Management Tip:** Leave ample time for cleanup after this investigation!]

Discourse Debrief experiment:

- Ask: Was your procedure successful? Why or why not?

Make connections to the Essential Question:

- Ask: How can we make ice cream without putting the ingredients into the freezer?

Accountability (Exit Ticket)

1. Evaluate the success of your plan. If your plan was successful, provide a detailed explanation of the reasons why it worked. If your plan was unsuccessful, provide a detailed explanation of why you think it failed and explain at least one way you would change it if you could redo this challenge. Use the space for any necessary illustrations. [3]

Today was successful due to the effective revisions my group made to the original procedure. On the first day of the unit, our ingredients melted. This time, the ice was kept on the outside of the bag and combined with salt to depress (lower) its melting point. This enabled the ice to draw more energy from the ingredients in the inner resealable plastic bag, lowering their temperature and ultimately causing them to freeze.

Scoring Award points as follows:

1. Award one point for each of the following:

- An accurate evaluation of the performance of their plan
- Evidence that reflects a high-level understanding of unit content
- Either reasoning to support the evidence or one proposed change to improve the procedure

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Unit Vocabulary

Vocabulary List

- **temperature**
- **solid**
- **liquid**
- **gas**
- **thermal energy**

- **kinetic energy**
- **definite**
- **indefinite**
- **phase change**
- **intermolecular distance**
- **endothermic**
- **exothermic**
- **melting**
- **melting point**
- **freezing**
- **freezing point**
- **boiling point**
- **boiling**
- **evaporation**
- **plateau**
- **slope**
- **intermolecular forces**
- **molecular (covalent) bonds**
- **ionic bonds**
- **condense**
- **potential energy**
- **freezing point elevation or depression**
- **elevate/elevation**
- **depress/depression**
- **surface tension**
- **atmospheric pressure**