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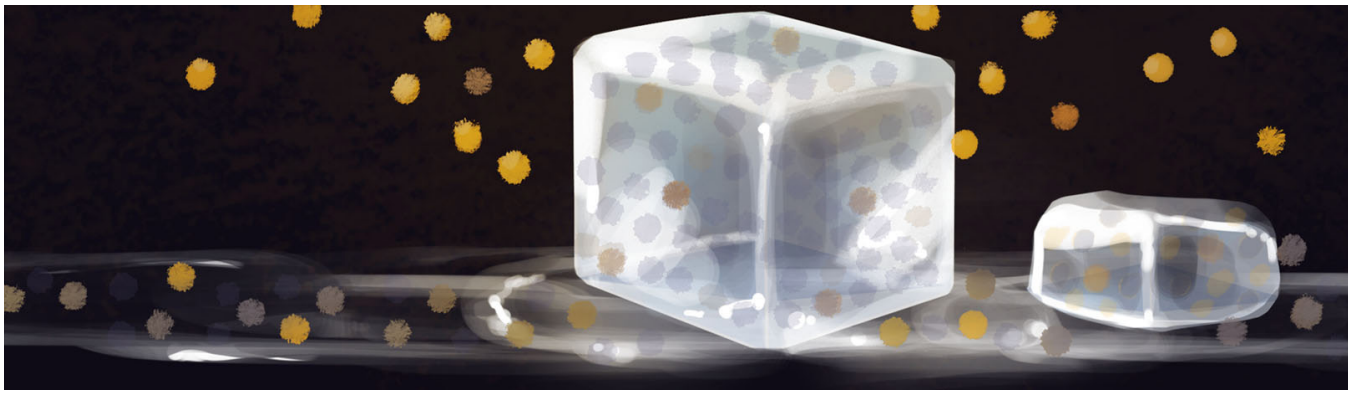

Phase Change:

Titan's Disappearing Lakes

Investigation Notebook
NYC Edition

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Developed by the Learning Design Group at the University of California, Berkeley's Lawrence Hall of Science.

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Safety Guidelines for Science Investigations

1. **Follow instructions.** Listen carefully to your teacher's instructions. Ask questions if you don't know what to do.

2. **Don't taste things.** No tasting anything or putting it near your mouth unless your teacher says it is safe to do so.

3. **Smell substances like a chemist.** When you smell a substance, don't put your nose near it. Instead, gently move the air from above the substance to your nose. This is how chemists smell substances.

4. **Protect your eyes.** Wear safety goggles if something wet could splash into your eyes, if powder or dust might get in your eyes, or if something sharp could fly into your eyes.

5. **Protect your hands.** Wear gloves if you are working with materials or chemicals that could irritate your skin.

6. **Keep your hands away from your face.** Do not touch your face, mouth, ears, eyes, or nose while working with chemicals, plants, or animals.

7. **Tell your teacher if you have allergies.** This will keep you safe and comfortable during science class.

8. **Be calm and careful.** Move carefully and slowly around the classroom. Save your outdoor behavior for recess.

9. **Report all spills, accidents, and injuries to your teacher.** Tell your teacher if something spills, if there is an accident, or if someone gets injured.

10. **Avoid anything that could cause a burn.** Allow your teacher to work with hot water or hot equipment.

11. **Wash your hands after class.** Make sure to wash your hands thoroughly with soap and water after handling plants, animals, or science materials.

Name: _____ Date: _____

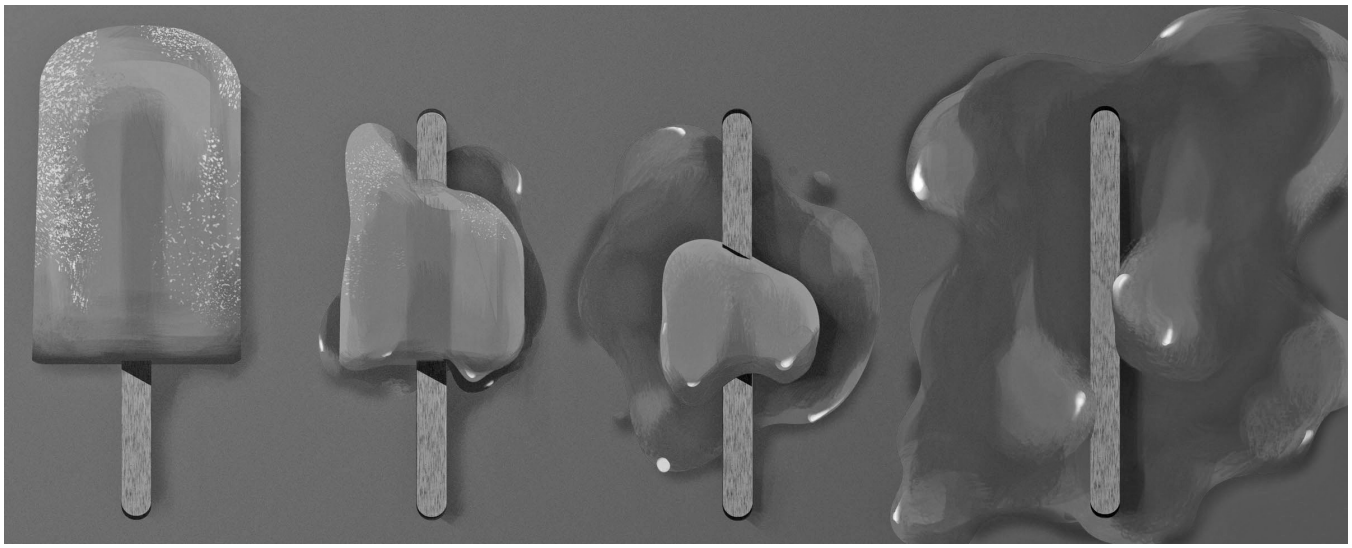
Phase Change: Titan's Disappearing Lakes
Unit Overview

In the *Phase Change* unit, you will investigate the mysterious disappearance of a lake on Titan, a large moon orbiting Saturn. Scientists believe the lake either evaporated or froze. To address this mystery, you will learn about the science behind phase change. You will begin your work at the macro scale, observing substances in different phases. You will then use a Simulation to explore different phases of a substance at the molecular scale. You will read an article on several surprising effects of water changing phase and communicate your understanding of the molecular scale through a dance and a visual model. You will learn about the roles of kinetic energy and molecular attraction in phase change by completing a hands-on activity, exploring in the Simulation, and watching a short video. Using the Simulation and a new article, you will uncover why Titan's lake disappeared much later than your current model of phase change would have predicted. You will then apply your understanding of phase change at the molecular scale to explain several office mysteries. Finally, you will work with your fellow student chemists to understand why a machine used to make fuel for Titan's lander mission is malfunctioning. You will evaluate evidence and determine the cause of the machine's malfunction as well as possible ways it can be fixed.

Name: _____ Date: _____

Chapter 1: Describing Phase Change at Two Scales
Chapter Overview

Today, you will begin your work as a student chemist, investigating the mysterious disappearance of a lake on Titan, a large moon orbiting Saturn. Scientists believe the lake either evaporated or froze. To address this mystery, you will learn about phase change. You will begin your work at the macro scale, observing substances in different phases. You will then use the *Phase Change* Simulation to explore different phases of a substance at the molecular level. You will learn about phase change at the molecular scale by reading an article on several surprising effects of water changing phase. Finally, you will communicate your understanding of the molecular scale description of phase change by choreographing a dance and constructing a model.



Name: _____ Date: _____

Lesson 1.2: Introducing Titan's Disappearing Lake

What explains a disappearing lake on a distant moon? Today, you will begin your work as student chemists who have been asked to investigate what caused the mysterious disappearance of a lake on Titan, a large moon orbiting Saturn. The lake is shown in a photograph taken in 2007 but not in a photo taken in the same spot in 2009. You are invited to join a team of chemists at the Universal Space Agency to determine what happened to the lake.

Unit Question

- How can the appearance of a substance change without it becoming a different substance?

Chapter 1 Question

- What happened to the liquid in Titan's lake?

Vocabulary

- phase

Name: _____ Date: _____

Warm-Up

There are three cups below. Each contains water.

What do you think is different about the water in each cup? Describe as many differences as you can in the space below.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Discussing Difference in Appearance

Discuss the phase change videos with your partner. Pick one of the videos and answer the questions about it below. Include terms from the word bank in your responses.

Word Bank

condensation	does not flow	evaporation	flows
freezing	gas	has its own shape	invisible
liquid	melting	phase change	solid
takes the shape of its container	visible		

1. How would you describe the appearance of the substance before the phase change?

_____

_____

_____

2. How would you describe the appearance of the substance after the phase change?

_____

_____

_____

3. Based on your description, choose which phase change you think occurred in your video. Circle the name of the video you discussed and the phase change you think occurred.

Video	Phase change that occurred
Condensation on a Cup	freezing (liquid to solid)
Evaporating Mud Puddle	melting (solid to liquid)
Melting Ice Pop Timelapse	evaporation (liquid to gas)
Ice Forming on Tree Branches	condensation (gas to liquid)

Name: _____ Date: _____

Reading "Titan Fact Sheet"

1. Read and annotate the article "Titan Fact Sheet" using the Active Reading strategies you have learned in previous units.
2. Review your annotations and answer the reflection question below.

Rate how successful you were at using Active Reading skills by responding to the following statement:

As I read, I paid attention to my own understanding and recorded my thoughts and questions.

- ☐ Never
- ☐ Almost never
- ☐ Sometimes
- ☐ Frequently/often
- ☐ All the time

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Homework: Reading "Air Pressure and Boyle's Law"

In this lesson, you began to think about different phases: solids, liquids, and gases. To learn more about gases, read and annotate the "Air Pressure and Boyle's Law" article. Then, answer the questions below.

1. What was Boyle's most famous discovery about gases?

_____

_____

_____

_____

2. How did Boyle change how scientists make discoveries?

_____

_____

_____

_____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Lesson 1.3: Investigating the Molecular Scale

What are molecules? What happens during a phase change? Yesterday, you watched a series of videos showing several phase changes. You discussed how the appearance of a substance changes during a phase change. Today, you will observe a phase change in the classroom and use a new tool called the *Phase Change* Simulation to determine what is happening at the molecular scale during a phase change.

Unit Question

- How can the appearance of a substance change without it becoming a different substance?

Chapter 1 Question

- What happened to the liquid in Titan's lake?

Key Concepts

- A solid holds its shape and does not take the shape of its container.
- A gas has no visible shape and fills its container.
- A liquid flows and can take the shape of its container.

Vocabulary

- molecule
- phase
- scale

Digital Tools

- *Phase Change* Simulation
- Scale Tool

Name: _____ Date: _____

Warm-Up

Answer the following questions about Titan and its disappearing methane lake. Refer to the "Titan Fact Sheet" from the last lesson if needed.

1. Write a question you have about Titan or about methane that could help you determine what happened to the lake.

_____

_____

_____

2. Liquid methane and liquid water are different, but they do have some things in common. What are some things that all liquids have in common?

_____

_____

_____

Name: _____ Date: _____

Considering Molecules and Phase Change

Safety Note: Using Hot Water

- Be careful around hot water and heating elements. Avoid splashing and protect your eyes as needed.

In the last lesson, we investigated the appearance of a substance when it changes phase. Today, we will complete an activity that will allow us to observe one or more phase changes. Read the instructions below. Then, complete this activity.

Setup Instructions

- Make sure the foam cup is filled with hot water. It should be one-quarter full.
- Take the plastic cup and turn it upside down. Place it on top of the foam cup.
- Observe any phase changes that occur, using the provided magnifying glasses as needed.
- Answer the questions below.

What did you observe happening in the cups?

_____

_____

_____

Did a phase change or phase changes occur? If so, which one or ones?

_____

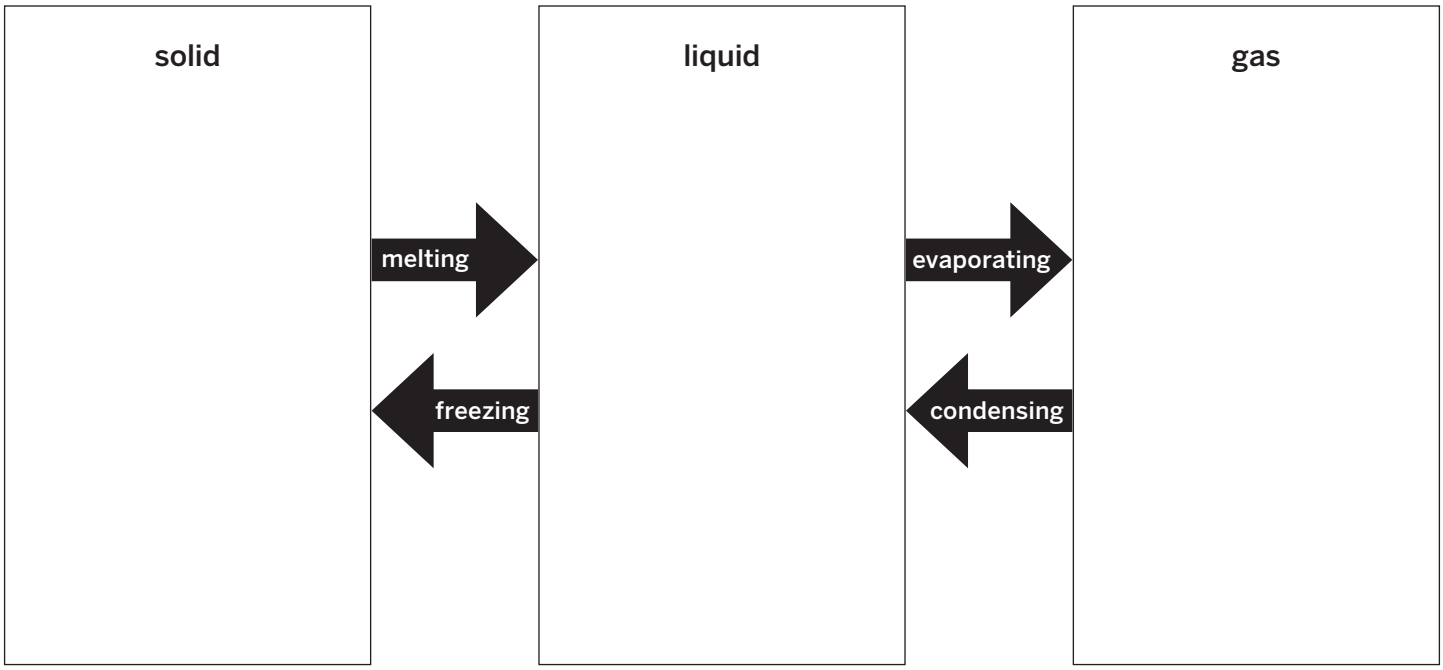
_____

_____

Name: _____ Date: _____

Modeling Molecules and Phases

1. Before completing this activity, think back on the phase change videos you watched in the last lesson and the hands-on activity you completed in this lesson. Also, consider observations you have made in relation to phase change in the past.
2. Then, use the boxes below to draw a model that shows what you think happens to water molecules at the molecular scale of each phase.
   - Use simple shapes, such as circles or squares, to represent the molecules.
   - **Note:** You will have the chance to revise your models in a later lesson.



Name: _____ Date: _____

Exploring the *Phase Change* Simulation

To: Student Chemists
From: Dr. Daniela Flores, Lead Chemist at the Universal Space Agency
Subject: *Phase Change* Simulation

UNIVERSAL SPACE AGENCY

You're off to a great start with your investigation of phase changes! Today, you will explore the *Phase Change* Simulation to further investigate Titan's methane-lake mystery at the molecular scale. As you read in the last lesson, Titan and Earth are similar in a few important ways. As molecules behave the same way everywhere in the universe, this Simulation will help you understand phase changes that occur on Titan. I look forward to your next update.

1. Launch the *Phase Change* Simulation.
2. As you explore the *Phase Change* Simulation, consider the following questions:
   - What can you do or change in the Sim?
   - What do you think you can learn from the Sim?

Name: _____ Date: _____

Investigating the Molecular Scale

Part 1

1. Launch the *Phase Change* Simulation and observe different phases in the Sim.
2. In the data table below, record your observations about the molecular scale of each phase.
3. Consider how the movement of molecules relates to the macro-scale appearance of each phase.

Phase	Macro-scale appearance	Molecular scale
Gas	Fills container and has no visible shape	
Liquid	Flows, stays at the bottom of the container, and takes shape of container	
Solid	Rigid and keeps its shape	

Name: _____ Date: _____

Investigating the Molecular Scale (continued)

Part 2

What happens to the molecules of a substance when it changes phase?

Mission: Use the Sim to find evidence related to the three claims found on the Universal Space Agency's forum.

1. In the *Phase Change* Simulation, cause a substance to change phase. Observe what happens to the molecules of that substance when it changes phase. (**Hint:** Track one or two molecules by pressing on them, then observe them.)
2. Think about the hands-on investigation as well as the observations you recorded in the data table on the previous page. Discuss which of the claims below is best supported by the evidence you have gathered in this lesson.

Which of the three claims do you think is best supported by evidence so far? (check one)

- ☐ **Claim 1 from I<3Space:** I think that molecules in a substance disappear or no longer exist when a substance changes phase. I think this because when a substance goes from liquid to gas, I can no longer see it.
- ☐ **Claim 2 from PLaNetLoVeR:** I think that molecules in a substance move differently when a substance changes phase. I think this because a liquid, gas, and solid do not move in the same way when you tilt the container they are in.
- ☐ **Claim 3 from scienceiscool:** I think that the molecules in a substance change into a new kind of molecule during a phase change. I think this because, when you tilt the container they are in, a liquid, gas, and solid do not move in the same way.

Name: _____ Date: _____

Homework: Reviewing Models

Review your molecular-scale models of different phases on page 13. Consider what you have learned in the Sim. Then, answer the question below.

What could you change or add to your models based on what you have learned about molecules and phases so far?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Lesson 1.4: *Weird Water Events*

You will discuss three claims by forum users about what happens to molecules during a phase change. You will then read an article set about weird water events, gathering evidence to support or refute the claims.

Unit Question

- How can the appearance of a substance change without it becoming a different substance?

Chapter 1 Question

- What happened to the liquid in Titan's lake?

Key Concepts

- A solid holds its shape and does not take the shape of its container.
- A gas has no visible shape and fills its container.
- A liquid flows and can take the shape of its container.

Vocabulary

- molecule
- phase
- refute
- scale

Digital Tools

- *Phase Change* Simulation

Name: _____ Date: _____

Warm-Up

Read the text below about Ellie, her friend, and a puddle. Think about what Ellie's evidence shows. Then, respond to the question.

> On the way to school, Ellie sat on a bench waiting for her friend. She noticed snow all around her. Later that day, Ellie and her friend walked home and passed the same bench. Ellie's friend said, "There is a puddle in front of the bench. It must have rained while we were in school, creating this puddle."
>
> Ellie disagreed. She had a different claim about how the puddle formed based on the evidence from her observations. Ellie's evidence was as follows:
>
> - The park was covered in snow that morning but not in the afternoon.
> - Ellie didn't need her jacket on the way home because it was so warm.
> - It was sunny all day.

Do you think the puddle was formed from rain? Why or why not?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Reading *Weird Water Events*

1. Select one of the four articles to read and annotate.
   - "Flash Floods in Slot Canyons"
   - "Glacier Caves of Iceland"
   - "Frozen Niagara Falls"
   - "Old Faithful Geyser"
2. Choose and mark annotations to discuss with your partner. Once you have discussed these annotations, mark them as discussed.
3. Now, choose and mark a question or connection, either one you already discussed or a different one you still want to discuss with the class.
4. Answer the reflection question below.

   Rate how successful you were at using Active Reading skills by responding to the following statement:

As I read, I paid attention to my own understanding and recorded my thoughts and questions.

- ☐ Never
- ☐ Almost never
- ☐ Sometimes
- ☐ Frequently/often
- ☐ All the time

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Homework: Tracking Molecule Movement

Launch the *Phase Change* Simulation.

1. Press a single molecule in the Sim, tracking its movement. Complete this step for a solid, liquid, and gas. (**Note:** Once you select a molecule to track, the molecule will be highlighted red or green, and dotted lines will appear that represent the molecule's path of motion.)

2. Sketch what you see for a molecule in each phase in the spaces below. Be sure that your drawings clearly illustrate the differences between phases.

3. Once you have completed the assignment in the Sim, answer the questions below.

solids	**liquids**	**gases**

Consider what you observed by tracking molecules in the Sim. Compared to molecules in other phases, what is different about the way molecules move in **solids**?

_____

_____

What is different about the way molecules move in **liquids**?

_____

_____

What is different about the way molecules move in **gases**?

_____

_____

Name: _____ Date: _____

Lesson 1.5: Investigating Evaporation and Freezing

Do molecules cease to exist, move differently, or become a new kind of molecule after a substance changes phase? You will work with a partner to gather evidence, determining what happens to molecules after a phase change.

Unit Question

- How can the appearance of a substance change without it becoming a different substance?

Chapter 1 Question

- What happened to the liquid in Titan's lake?

Key Concepts

- A solid holds its shape and does not take the shape of its container.
- A gas has no visible shape and fills its container.
- A liquid flows and can take the shape of its container.

Vocabulary

- freedom of movement
- molecule
- phase

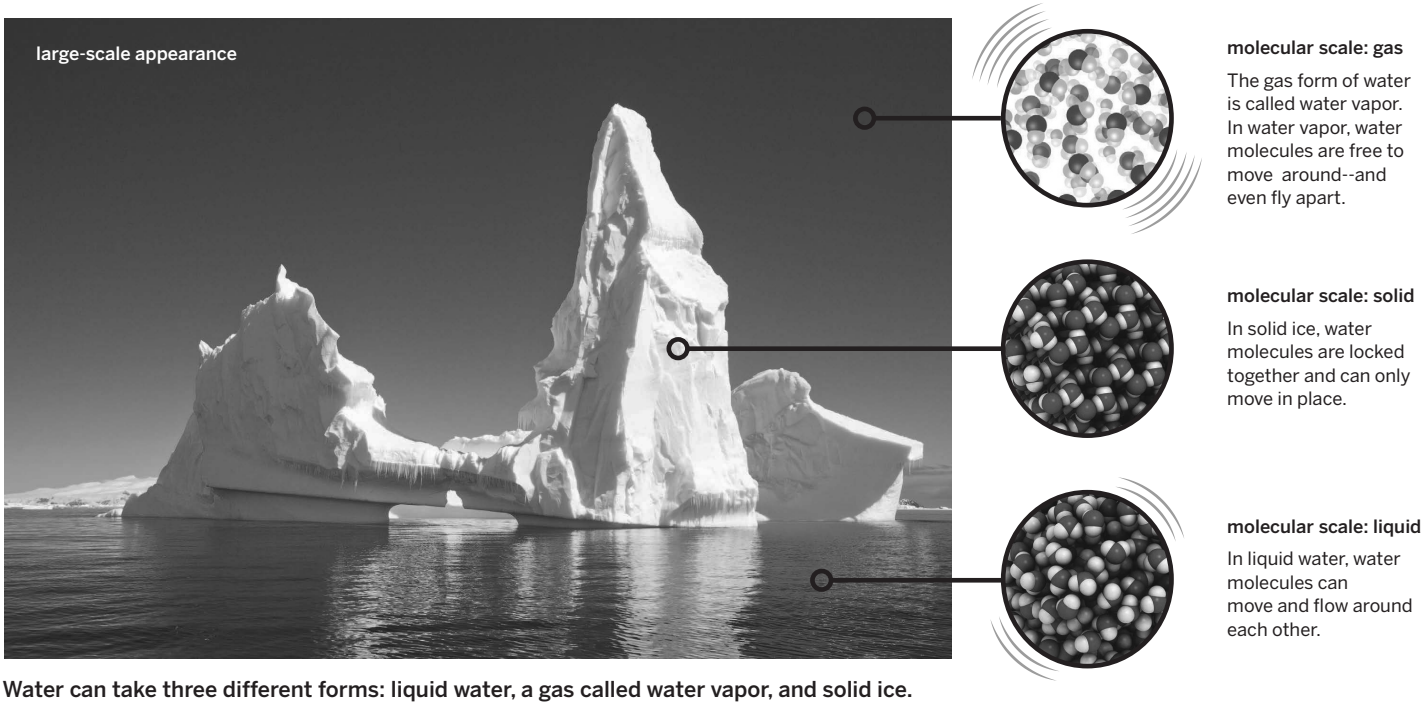
Digital Tools

- *Phase Change* Modeling Tool activity: Ice Pop

Name: _____ Date: _____

Warm-Up

In the *Weird Water Events* article set, the author uses the phrase *greater freedom of movement.* What do you think she means by this? Use clues from the diagram and the text below to determine what this phrase means. After you have written your response, share your ideas about freedom of movement with a partner.



Water can take three different forms: liquid water, a gas called water vapor, and solid ice.

You might think of water as a liquid, but water can actually exist in three different phases: liquid water, solid ice, and a gas called water vapor. No matter what phase water is in, the water is still made of the same molecules; they just move differently.

Describe what you think the phrase *greater freedom of movement* means.

_____

_____

_____

_____

Name: _____ Date: _____

Reading About Molecular Movement

Read and annotate the introduction to the article set *Weird Water Events* and review the diagram on the previous page.

Review your notes about the molecular scale from Lesson 1.3 on page 15. You may want to summarize these notes in the third column of the table below. After you have done this, edit or add to your notes, describing molecules' freedom of movement in each phase.

Phase	**Macro-scale appearance**	**Molecular scale (molecules' freedom of movement)**
Gas	Fills container and has no visible shape	
Liquid	Flows, stays at the bottom of the container, and takes shape of container	
Solid	Rigid and keeps its shape	

Name: _____ Date: _____

Reasoning About Freedom of Movement

What Happens to the Molecules of a Substance When It Changes Phase?

Consider previous activities you have completed in the Sim as well as textual evidence. Then, with your partner, discuss how this evidence either supports or refutes each claim.

Complete the tables on the next pages for **Claim 2** and **Claim 3**.

For help in completing the tables, refer to the examples provided for **Claim 1** below.

EXAMPLE

Claim 1: Molecules in a substance disappear or no longer exist when a substance changes phase.

Evidence	**This matters because . . .** (How does this evidence support or refute the claim?)	**Therefore, . . .** (claim)
Quotation from the article: "No matter what phase water is in, the water molecules stay the same; they just move differently."	If water molecules always stay the same, they cannot disappear when water changes phase.	Claim 1 is refuted.
Describe an important observation from the Sim: After removing the heat, the molecules' freedom of movement changed. The molecules went from moving around each other to moving in place.	In the Sim, the movement of the molecules changed, but the molecules did not disappear.	Claim 1 is refuted.

Name: _____ Date: _____

Reasoning About Freedom of Movement (continued)

Claim 2: Molecules in a substance move differently when a substance changes phase.

Evidence	**This matters because . . .** (How does this evidence support or refute the claim?)	**Therefore, . . .** (claim)
Quotation from the article: "No matter what phase water is in, the water molecules stay the same; they just move differently."	Explain why this evidence matters:	
Describe an important observation from the Sim:		

Name: _____ Date: _____

Reasoning About Freedom of Movement (continued)

Claim 3: Molecules in a substance change into a new kind of molecule during a phase change.

Evidence	**This matters because . . .** (How does this evidence support or refute the claim?)	**Therefore, . . .** (claim)
Quotation from the article: "No matter what phase water is in, the water molecules stay the same; they just move differently."	Explain why this evidence matters:	
Describe an important observation from the Sim:		

Name: _____ Date: _____

Reasoning About Freedom of Movement (continued)

Dr. Flores wants to know which of the forum claims is best supported by the evidence you have gathered from your previous Sim observations and the text. Select the claim you think is best supported from the options below.

- ☐ **Claim 1:** Molecules in a substance disappear or no longer exist when a substance changes phase.
- ☐ **Claim 2:** Molecules in a substance move differently when a substance changes phase.
- ☐ **Claim 3:** Molecules in a substance change into a new kind of molecule during a phase change.

Explain your choice below using evidence you have gathered thus far.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Modeling a Phase Change

1. Open the *Phase Change* Modeling Tool activity: Ice Pop. Listen to your teacher and follow the instructions below.
2. When your model is complete, press HAND IN. If you worked with a partner, write their name here:

_____

Goal: Show how an ice pop, and the molecules it is made of, are different before and after it melts.

Do:

- Press the pencil icon to edit the Substance Description for the ice pop before and after it has melted.
- Show how the molecules are moving.
- Select statements to describe the appearance of the substance.
- Select a phase.

Name: _____ Date: _____

Lesson 1.6: Modeling the Molecular Scale

Today, you will send your first models to Dr. Flores at the Universal Space Agency. To ensure you are ready, you will share what you have learned with your classmates. With a partner, you will create a dance that represents molecules' freedom of movement in each phase. You will then answer the Investigation Question and create a model for each claim about what happened to Titan's lake.

Unit Question

- How can the appearance of a substance change without it becoming a different substance?

Chapter 1 Question

- What happened to the liquid in Titan's lake?

Key Concepts

- A solid keeps its shape because its molecules only move in place, not around each other.
- A liquid can flow because its molecules move around, not away from each other.
- A gas does not have a visible shape because its molecules can move away from each other.
- A phase change is when the molecules that make up a substance experience a change to their freedom of movement. This phase change involves a macroscale change in appearance.
- A change that can be observed at the macroscale can be explained by a change at the molecular scale, which cannot be observed with the naked eye.

Vocabulary

- freedom of movement
- molecule
- phase

Digital Tools

- *Phase Change* Modeling Tool activities: Methane Lake Freezing, Methane Lake Evaporating

Name: _____ Date: _____

Warm-Up

In a few minutes, you will work with your partner to create three dances—one for each of the three phases. Each dance will represent the molecular freedom of movement of that particular phase.

If needed, turn back to page 21 in your notebook to refer to your homework from Lesson 1.4. Then, begin brainstorming ideas for movements that would show these phases.

Dance ideas for **solids**:

_____

_____

_____

Dance ideas for **liquids**:

_____

_____

_____

Dance ideas for **gases**:

_____

_____

_____

Name: _____ Date: _____

Creating a Freedom of Movement Dance

1. Work with your partner to come up with three dances or movements—one for each of the three phases.

2. Each dance will represent the molecular freedom of movement of each phase. Stay within your desk or assigned area as you choreograph your dance.

3. When instructed, team up with another pair.

4. Take turns presenting your dances. While Pair A presents, Pair B should guess which phase each dance represents. Then, switch roles, so Pair B presents while Pair A observes.

Name: _____ Date: _____

Write and Share: Explaining Everyday Phase Change

1. Select one of the four videos from the list below (if needed, navigate to the Digital Resources on your device and rewatch the video).
   - *Condensation on a Cup*
   - *Evaporating Mud Puddle*
   - *Melting Ice Pop Timelapse*
   - *Ice Forming on Tree Branches*

2. Respond to the prompt below, writing a sentence or two about the video you selected. Be sure your sentences include the terms: *molecule, phase change,* and *freedom of movement.*

3. Share your response with your group and listen to your group members' responses.

4. Revise your explanation if you gained a new understanding from your group discussion.

Think about the video you selected. As the phase change occurs in the video, what is happening at the molecular scale?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Modeling Evaporating and Freezing

Part 1

1. Open the *Phase Change* Modeling Tool activity: Methane Lake Freezing.
2. When your model is complete, press HAND IN. If you worked with a partner, write their name here:

_____

Goal: If the lake froze, show how the methane in the lake would be different in 2007 compared to 2009.

Do:

- Press the pencil icon and edit the Substance Description for the methane in 2007 (before freezing) and in 2009 (after freezing).
- Show how the molecules are moving.
- Select statements to describe the appearance of the methane.
- Select a phase.

Tips:

- The phases for the methane in 2007 and 2009 have already been selected for you.

Name: _____ Date: _____

Modeling Evaporating and Freezing (continued)

Part 2

1. Open the *Phase Change* Modeling Tool activity: Methane Lake Evaporating.
2. When your model is complete, press HAND IN. If you worked with a partner, write their name here:

_____

Goal: If the lake evaporated, show how the methane in the lake would be different in 2007 compared to 2009.

Do:

- Press the pencil icon and edit the Substance Description for the methane in 2007 (before evaporating) and in 2009 (after evaporating).
- Show how the molecules are moving.
- Select statements to describe the appearance of the methane.
- Select a phase.

Tips:

- The phases for the methane in 2007 and 2009 have already been selected for you.

Name: _____ Date: _____

Homework: Writing About the Titan Claims

In class, you created two models of the molecular scale: one showing evaporation and the other freezing. Now, you will write an explanation of your models. Open the Modeling Tool activities: Methane Lake Freezing and Methane Lake Evaporating to see your completed models, if needed. Then, use the word bank to complete your response.

Word Bank

freedom of movement	macro scale	molecular scale
solid	liquid	gas

What do the models you created using the Modeling Tool show? Use the space below to describe the models for each claim.

_____

_____

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Homework: Check Your Understanding

This is a chance to reflect on your learning so far. This is not a test. Be open and truthful when you respond.

Scientists investigate in order to figure things out. Are you getting closer to figuring out what happened to the lake on Titan?

1. I understand how the molecules in the lake were moving when it was a liquid. (check one)
   - ☐ yes
   - ☐ not yet

Explain your answer choice.

_____

_____

_____

2. I understand how changes at the molecular scale affected the lake's macro-scale appearance. (check one)
   - ☐ yes
   - ☐ not yet

Explain your answer choice.

_____

_____

_____

3. I understand how energy transfers affect the molecules in the lake. (check one)
   - ☐ yes
   - ☐ not yet

Explain your answer choice.

_____

_____

_____

Name: _____ Date: _____

Homework: Check Your Understanding (continued)

4. I understand how energy transfers affect the appearance of the lake. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

_____

5. I understand why energy transfers don't always affect the appearance of the lake. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

_____

6. What do you still wonder about phase change?

_____

_____

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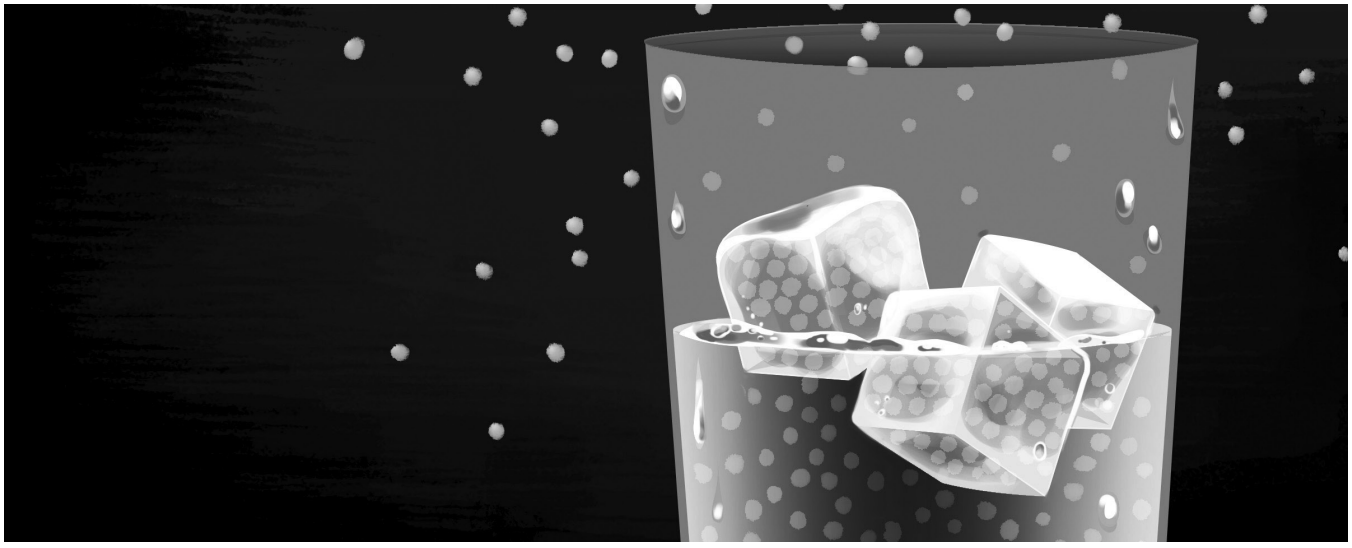
Name: _____ Date: _____

Chapter 2: Investigating Energy and Phase Change
Chapter Overview

In Chapter 2, you will explore what can cause changes in molecules' behavior. You will revisit the *Weird Water Events* article set and model featured phase changes in the Sim. You will then learn about the roles of kinetic energy and molecular attraction in phase change by completing a hands-on activity, exploring in the Sim, and watching a short video.



Name: _____ Date: _____

Lesson 2.1: Causing Freedom of Movement Changes

In this lesson, you will explore what can cause molecules' freedom of movement to change. You will return to the article you read about weird water events in Chapter 1 and use the Sim to try to recreate the phase change described. Then, you will discuss your observations with classmates who read the other articles in order to coordinate your evidence and determine what can cause molecules' freedom of movement to change.

Unit Question

- How can the appearance of a substance change without it becoming a different substance?

Chapter 2 Question

- What could cause liquid methane to change phase?

Vocabulary

- freedom of movement
- molecule
- phase

Digital Tools

- *Phase Change* Simulation
- *Phase Change* Modeling Tool activities: Flash Floods, Glacier Caves, Niagara Falls, Old Faithful

Name: _____ Date: _____

Warm-Up

1. Review your drawings from Lesson 1.3. These can be found on page 13 in your notebook.
2. Annotate your drawings, noting any changes you would like to make now that you know what happens at the molecular scale during phase changes.
3. Briefly answer the questions below. Then, time permitting, share your responses with your partner.

Have your ideas about what happens to molecules in the liquid, solid, and gas phase changed? If so, how? What evidence supports your ideas? If your ideas have not changed, what evidence have you found that supports your initial ideas?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Recreating *Weird Water Events* in the Sim

Part 1

1. Refer to the *Weird Water Events* article you read in Chapter 1.
2. Read the excerpt indicated below:
    - **"Flash Floods in Slot Canyons":** Read the second paragraph (starting with "Even in the desert").
    - **"Glacier Caves of Iceland":** Read from the second sentence of the third paragraph to the end of the article (starting with "In the ice walls of the cave").
    - **"Frozen Niagara Falls":** Read from the third sentence of the second paragraph to the end of the article (starting with "The cold weather causes").
    - **"Old Faithful Geyser":** Read from the second sentence of the second paragraph to the fourth sentence of the third paragraph (starting with "This hot rock heats up water" and ending with "so gas can expand to fill the space of its container").
3. As you read, annotate the passage, identifying the type of phase change described. Also, identify what caused the water molecules' freedom of movement to change. Highlight this information in the article.

Name: _____ Date: _____

Recreating *Weird Water Events* in the Sim (continued)

Part 2

- Launch the *Phase Change* Simulation and follow the steps below to recreate the phase change described in your *Weird Water Events* article.

1. Choose the substance (A, B, C, or D) that matches the starting phase of the water described in your text. Start with:
   - gas for "Flash Floods in Slot Canyons."
   - solid for "Glacier Caves of Iceland."
   - liquid for "Frozen Niagara Falls."
   - liquid for "Old Faithful Geyser."
2. Make the molecules' freedom of movement change for that substance. The change should match the phase change that occurred in your article.
3. When finished recreating the phase change in the Sim, follow the instructions for completing the table on the next page.

Table Instructions

- Referring to your text annotations and the observations you made in the Sim, complete the row for the article you read. Use the word bank below for reference.
- When directed to by your teacher, share the observations for your article with your group. As your team members present, complete the remaining table rows.

Word Bank

condensation	evaporation	freezing	melting
the water became hotter	the water became colder	transferred energy into the liquid	transferred energy out of the liquid

Name: _____ Date: _____

Recreating *Weird Water Events* in the Sim (continued)

	Type of phase change	What caused the water to change phase in the article?	How did you cause the phase change in the Sim?
Slot Canyons			
Glacier Caves			
Niagara Falls			
Old Faithful			

Name: _____ Date: _____

Modeling *Weird Water Events*

1. Open the *Phase Change* Modeling Tool activity for the article you read. Circle the name of your Modeling Tool activity:

   Flash Floods **Glacier Caves** **Niagara Falls** **Old Faithful**

2. When your model is complete, press HAND IN. If you worked with a partner, write their name here:

_____

Goal: Show what caused the phase change described in your article.

Do:

- Drag out two Substance Descriptions and describe the water.
- Move the Substance Descriptions up or down to show when the water had higher or lower energy.
- Drag out an arrow. Start the arrow at the Substance Description Before and move it to show energy transferring in or out.
- Label the arrow using a red hexagon.

Tips:

- The lines point to the energy level of the substance.
- The arrowhead can touch a line but doesn't need to.

Name: _____ Date: _____

Lesson 2.2: Understanding Energy Transfers

Today, you will begin to explore why transferring energy into or out of a substance changes its molecules' freedom of movement. You will explore energy's effect on freedom of movement by using a model that represents molecules as magnetic marbles. After collecting evidence by observing the marbles, you will use the Sim to collect more evidence. At the end of the lesson, you will watch a video and consider the difference between kinetic energy and freedom of movement.

Unit Question

- How can the appearance of a substance change without it becoming a different substance?

Chapter 2 Question

- What could cause liquid methane to change phase?

Key Concepts

- When energy is transferred to or from a substance, it can change the molecules' freedom of movement.

Vocabulary

- freedom of movement
- kinetic energy
- molecules
- phase
- temperature

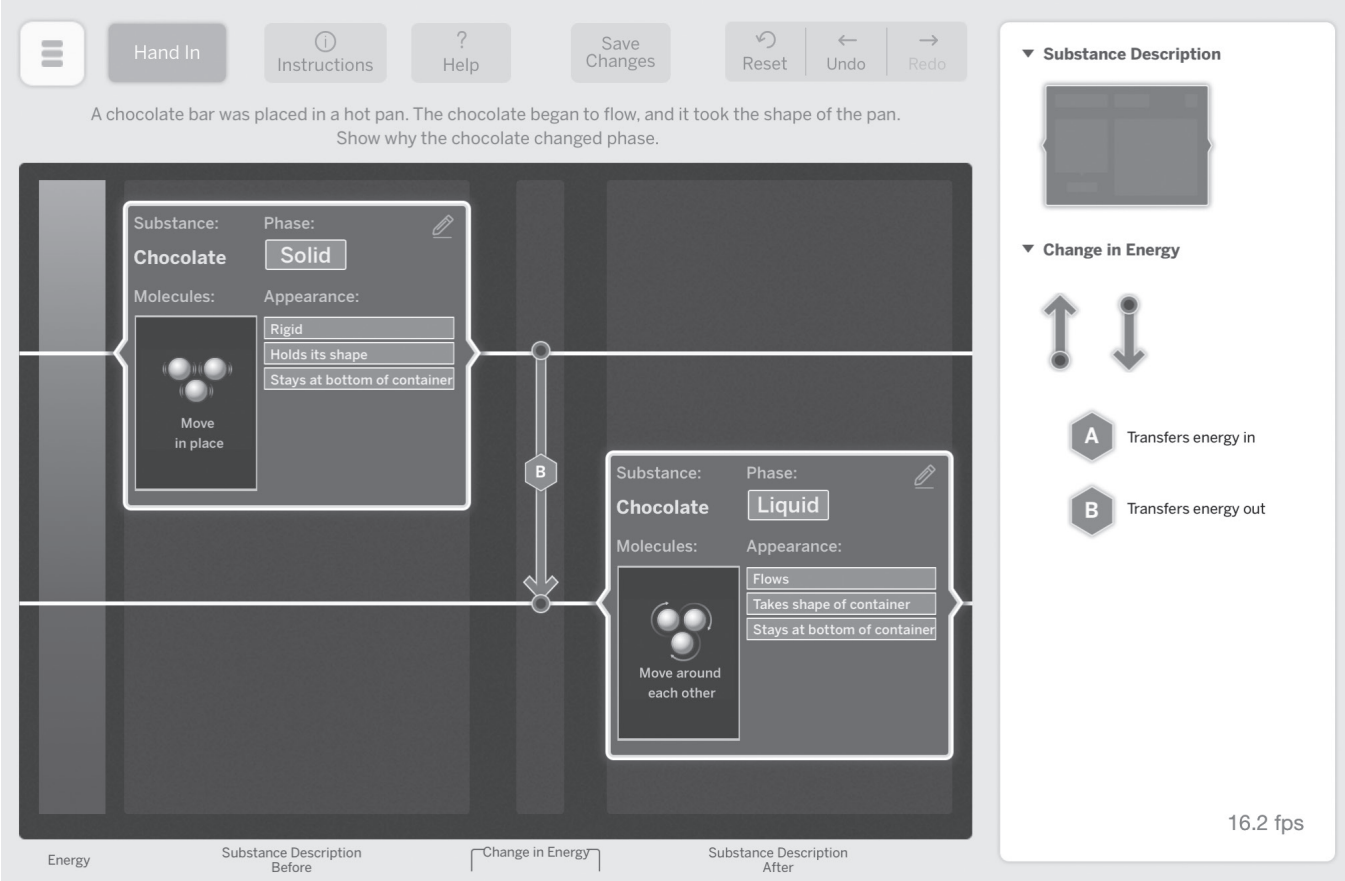
Digital Tools

- *Phase Change* Simulation
- *Phase Change* Modeling Tool activities: Water on Stove, Water in Freezer

Name: _____ Date: _____

Warm-Up

A student chemist created the following model to explain a phase change they observed at home: A chocolate bar was placed in a hot pan. The chocolate began to flow, and it took the shape of the pan.



Explain the changes you would make to the model in order to correctly show what changed the chocolate molecules' freedom of movement.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Experimenting with Magnetic Marbles

Safety Note: Using Magnets

- This activity uses low-strength magnets. Avoid putting these magnets near or in your mouth. If you or a classmate swallows a magnet, alert your teacher immediately.

In this activity, you will explore how adding energy affects molecules. The magnetic marbles represent molecules.

1. Place the container of marbles on the table. Observe the marbles. (Remember the marbles represent molecules.)

2. Add a small amount of energy to the marbles by shaking the closed container gently. Observe the marbles. Consider the effect adding energy to a substance has on the molecules.

3. Experiment by adding different amounts of energy to the container (or by letting the container rest). Observe what happens to the marbles.

4. Describe how transferring energy into the container affected the speed of the marbles.

_____

_____

_____

5. As the speed changed, what did you notice about the marbles' freedom of movement?

_____

_____

_____

6. Did your observations provide evidence to support any of the claims?

_____

_____

_____

Name: _____ Date: _____

Using the Sim to Observe Energy Transfer

Launch the Simulation. Consider the following question as you work: *Why can transferring energy into or out of a substance change molecules' freedom of movement?*

- You have caused phase changes in the Sim before. Before you start this new activity, think about how you created these phase changes in the past.
- Begin with substance A.
- Turn on the kinetic energy and press the play button to start the Sim.
- Transfer energy into the substance.
- Observe what happens to the molecules. Pay particular attention to the molecules' kinetic energy.
- Answer the first question.
- Once the highest energy possible has been reached, begin to transfer energy out of the substance. Pay particular attention to the molecules' kinetic energy.
- Answer the remaining questions.

Questions

1. Describe how transferring energy into the substance affected the speed of the molecules.

_____

_____

_____

2. As the speed changed, what did you notice about the molecules' freedom of movement?

_____

_____

_____

3. Did your observations provide evidence to support any of the claims?

_____

_____

_____

Name: _____ Date: _____

Explaining Zooming in on Phase Change

Today, we are considering three claims about why transferring energy into or out of a substance can change molecules' freedom of movement. The three claims are as follows:

- **Claim 1:** Transferring energy into or out of a substance changes its temperature, which changes the molecules' freedom of movement.
- **Claim 2:** Transferring energy into or out of a substance changes the molecules' kinetic energy, which changes their freedom of movement.
- **Claim 3:** Transferring energy into or out of a substance changes the molecules' speed, which changes their freedom of movement.

We are going to work together as a class to create a single claim. In preparation for this activity, answer the questions below and then write your own claim.

1. When you transfer energy into a substance, the temperature (check one)

   ☐ increases ☐ decreases ☐ stays the same

2. When you transfer energy into a substance, the molecules' kinetic energy (check one)

   ☐ increases ☐ decreases ☐ stays the same

3. When the above happens, the molecules are moving (check one)

   ☐ faster ☐ slower ☐ the same speed

Why do you think transferring energy into or out of a substance can change the molecules' freedom of movement? List your ideas here.

_____

_____

_____

Write a claim that responds to the question *Why can transferring energy into or out of a substance change molecules' freedom of movement?* Be sure to include the terms *kinetic energy, temperature,* and *speed* in your response.

_____

_____

_____

Name: _____ Date: _____

Homework: Modeling an Everyday Phase Change

Part 1: Modeling Water on the Stove

1. Open the *Phase Change* Modeling Tool activity: Water on Stove.
2. When your model is complete, press HAND IN. If you worked with a partner, write their name here:

_____

Goal: James put a pot of liquid water on the hot stove. When he came back the liquid was gone. Show why the water changed phase.

Do:

- Drag out two Substance Descriptions and describe water before and after.
- Move the Substance Descriptions up or down to show when the water had higher or lower energy.
- Drag out an arrow. Start the arrow at the Substance Description Before and move it to show energy transferring in or out.
- Label the arrow using a red hexagon.

Tips:

- The lines point to the kinetic energy of the substance.
- The arrowhead can touch a line but doesn't need to.

Name: _____ Date: _____

Homework: Modeling an Everyday Phase Change (continued)

Part 2: Modeling Water in the Freezer

1. Open the *Phase Change* Modeling Tool activity: Water in Freezer.
2. When your model is complete, press HAND IN. If you worked with a partner, write their name here:

_____

Goal: Hillary left a cup of water in the freezer. When she came back it was rigid and kept its shape. Show why the water changed phase.

Do:

- Drag out two Substance Descriptions and describe water before and after.
- Move the Substance Descriptions up or down to show when the water had higher or lower energy.
- Drag out an arrow. Start the arrow at the Substance Description Before and move it to show energy transferring in or out.
- Label the arrow using a red hexagon.

Tips:

- The lines point to the kinetic energy of the substance.
- The arrowhead can touch a line but doesn't need to.

Part 3

Explain how your models illustrate water in a freezer and on a stove. Be sure to include the terms *kinetic energy, temperature,* and *freedom of movement* in your response.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Homework: Reading "What Melts? What Burns?"

You have learned about how a transfer of energy can cause a phase change. Sometimes transferring energy to a substance causes it to burn, and sometimes it causes it to melt. Why is that? Read and annotate the "What Melts? What Burns?" article. Then, answer the questions below.

1. Is burning a phase change? Explain.

_____

_____

_____

_____

2. What determines whether a material melts or burns when heated?

_____

_____

_____

_____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Lesson 2.3: Evaluating Evidence and Claims

Today, you will receive new evidence about Titan. You will work with a partner to determine how the evidence can help you select or eliminate one of the claims about the lake on Titan. Prepare to send an important message to Dr. Flores explaining how you solved the mystery about what happened to the lake.

Unit Question

- How can the appearance of a substance change without it becoming a different substance?

Chapter 2 Question

- What could cause liquid methane to change phase?

Key Concepts

- When energy is transferred to or from a substance, it can change the molecules' freedom of movement.
- Temperature is a measure of the average kinetic energy of the molecules of a substance.
- Transferring energy to a substance increases the kinetic energy of that substance's molecules. Transferring energy from a substance decreases the kinetic energy of that substance's molecules.

Vocabulary

- freedom of movement
- kinetic energy
- molecule
- phase
- refute
- scale
- temperature

Digital Tools

- *Phase Change* Modeling Tool activities: Cause of Lake Freezing, Cause of Lake Evaporating

Name: _____ Date: _____

Warm-Up

Part 1

1. Open the *Phase Change* Modeling Tool activity: Cause of Lake Freezing.
2. When your model is complete, press HAND IN. If you worked with a partner, write their name here:

_____

Goal: Show what could cause liquid methane in the lake on Titan to freeze.

Do:

- Drag out two Substance Descriptions and describe the methane.
- Move the Substance Descriptions to show when the methane had higher or lower kinetic energy.
- Use an arrow to show how the kinetic energy changed.
- Label the arrow.

Tips:

- The lines point to the kinetic energy of the substance.
- Start the arrow at the 2007 Substance Description.
- The arrowhead can touch a line but doesn't need to.

Answer the question below, then turn to the next page.

If the Titan lake froze, how would the change in kinetic energy affect the speed of the molecules found in the lake? (check one)

- ☐ The kinetic energy would increase. The molecules would move faster.
- ☐ The kinetic energy would decrease. The molecules would move slower.
- ☐ There would be no change in kinetic energy. The molecules would move at the same speed.

Name: _____ Date: _____

Warm-Up (continued)

Part 2

1. Open the *Phase Change* Modeling Tool activity: Cause of Lake Evaporating.
2. When your model is complete, press HAND IN. If you worked with a partner, write their name here:

_____

Goal: Show what could cause liquid methane in the lake on Titan to evaporate.

Do:

- Drag out two Substance Descriptions and describe the methane.
- Move the Substance Descriptions to show when the methane had higher or lower kinetic energy.
- Use an arrow to show how the kinetic energy changed.
- Label the arrow.

Tips:

- The lines point to the level of kinetic energy of the substance.
- Start the arrow at the 2007 Substance Description.
- The arrowhead can touch a line but doesn't need to.

Answer the question below.

If the Titan lake evaporated, how would the change in kinetic energy affect the speed of the molecules found in the lake? (check one)

- ☐ The kinetic energy would increase. The molecules would move faster.
- ☐ The kinetic energy would decrease. The molecules would move slower.
- ☐ There would be no change in kinetic energy. The molecules would move at the same speed.

Name: _____ Date: _____

Interpreting Evidence About Phase Change

Titan Evidence Card Sort

1. Sit next to your partner. Place the Titan Evidence Sorting Background at the top of the desk between you.
2. Read the information on each evidence card.
3. Discuss each piece of evidence with your partner.
4. Place the evidence under the claim you think it supports.
5. Decide which claim you think is best supported and note your choice below.

Use these reasoning sentence starters to help you as you discuss the evidence:

- I think this card supports/refutes the claim _____ because . . .
- What do you think is important about this evidence card?
- How do you think this evidence connects to the claims? Does it support or refute one of the claims?
- I agree/disagree with your idea because . . .
- Can you use evidence to explain your thinking?

Based on the evidence, the strongest claim is: (check one)

- ☐ The lake on Titan evaporated.
- ☐ The lake on Titan froze.

I think the most convincing or strongest piece of evidence comes from: (check one)

- ☐ Evidence Card A
- ☐ Evidence Card B
- ☐ Evidence Card C
- ☐ Evidence Card D

Name: _____ Date: _____

Reasoning About Phase Change on Titan

1. Refer to the example in the first row of the Reasoning Tool (from Chapter 1).
2. Select the Titan Evidence Card you found most convincing.
3. If your evidence supports the claim that the lake evaporated, complete the first row after the example. If your evidence refutes the claim that the lake froze, complete the second row after the example.
4. Make sure to include the evidence card you selected in the left column of your Reasoning Tool.
5. If you have time, select an additional piece of evidence to analyze in the third row.

Evidence (Describe the most convincing evidence card.)	**This matters because . . .** (How does this evidence support or refute the claim?)	**Therefore, . . .** (claim)
Quotation from *Weird Water Events:* "No matter what phase water is in, the water molecules stay the same; they just move differently."	If water molecules always stay the same, they cannot disappear when water changes phase.	Therefore, the evidence refutes the claim that "molecules in a substance disappear or no longer exist when a substance changes phase."
		This evidence supports the claim that the lake evaporated.
		This evidence refutes the claim that the lake froze.

Name: _____ Date: _____

Writing a Scientific Argument

When you write your scientific argument to Dr. Flores:

- Remember to explain how your evidence supports or refutes a claim and why your evidence is significant.
- Review your Reasoning and Modeling Tools if needed.
- Use the sentence starters on page 57 and the word bank below to help you explain your thinking.

Word Bank

freedom of movement	evaporation	molecule	freezing
phase change	temperature	kinetic energy	energy

Dr. Flores would like an update on your research about what happened to the lake on Titan. Did the lake on Titan evaporate or freeze? After you clearly state your claim, explain how the evidence connects to the claim to support your argument. Remember to explain what happened at both the macro and molecular scale.

_____

_____

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_____

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_____

_____

_____

_____

Name: _____ Date: _____

Homework: Check Your Understanding

This is a chance to reflect on your learning so far. This is not a test. Be open and truthful when you respond.

Scientists investigate in order to figure things out. Are you getting closer to figuring out what happened to the lake on Titan?

1. I understand how the molecules in the lake were moving when it was a liquid. (check one)
   - ☐ yes
   - ☐ not yet

Explain your answer choice.

_____

_____

_____

2. I understand how changes at the molecular scale affected the lake's macro-scale appearance. (check one)
   - ☐ yes
   - ☐ not yet

Explain your answer choice.

_____

_____

_____

3. I understand how energy transfers affect the molecules in the lake. (check one)
   - ☐ yes
   - ☐ not yet

Explain your answer choice.

_____

_____

_____

Name: _____ Date: _____

Homework: Check Your Understanding (continued)

4. I understand how energy transfers affect the appearance of the lake. (check one)
   - ☐ yes
   - ☐ not yet

Explain your answer choice.

_____

_____

_____

5. I understand why energy transfers don't always affect the appearance of the lake. (check one)
   - ☐ yes
   - ☐ not yet

Explain your answer choice.

_____

_____

_____

6. What do you still wonder about phase change?

_____

_____

_____

_____

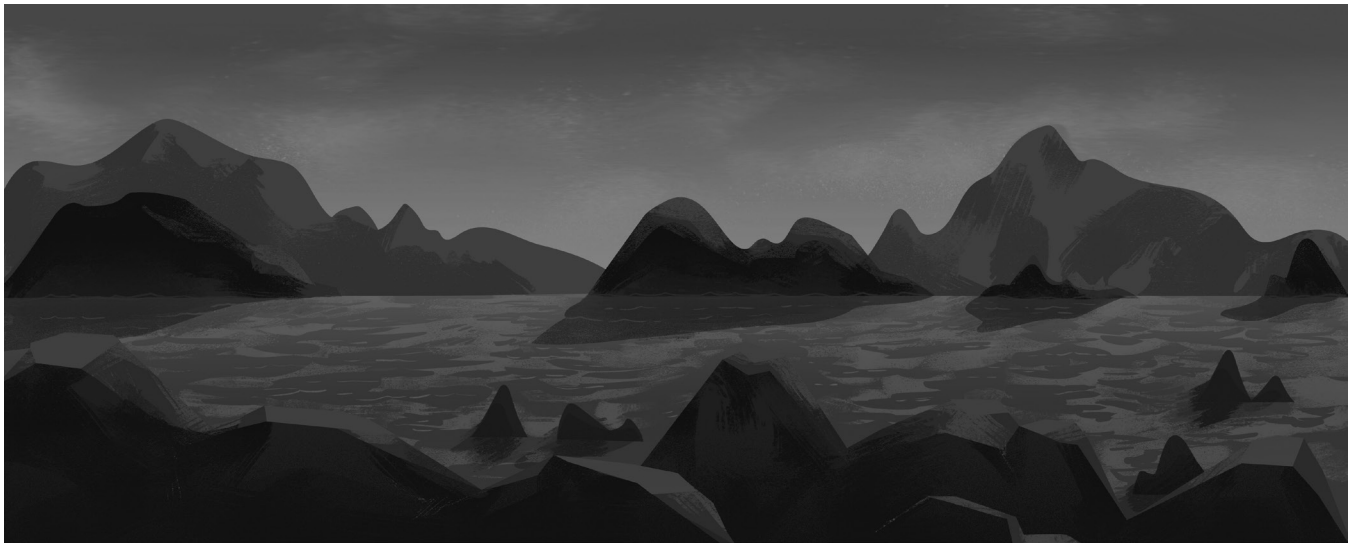
_____

_____

Name: _____ Date: _____

Chapter 3: Investigating Attraction and Phase Change

You have been called on to answer a puzzling question about the disappearance of Titan's lake. The lake seems to have evaporated surprisingly late in the summer season. Using the Sim and a new article, you will uncover why the lake disappeared much later than your current model of phase change would have predicted. You will conduct a hands-on investigation and model your findings to answer the Chapter 3 Question: *Why didn't the liquid methane change phase before 2007?* You will then apply your understanding of phase change at the molecular scale to explain several office mysteries.



Name: _____ Date: _____

Lesson 3.1: "Liquid Oxygen"

You have been called on to help answer a puzzling question about the evaporation of the lake on Titan. A space forum user has pointed out that summer on Titan started five years before the first image of the lake was taken. Why, then, didn't the lake evaporate sooner? Using the Sim and a science article, you will begin to investigate, attempting to answer the Chapter 3 Question: *Why didn't the liquid methane change phase before 2007?*

Unit Question

- How can the appearance of a substance change without it becoming a different substance?

Chapter 3 Question

- Why didn't the liquid methane change phase before 2007?

Vocabulary

- freedom of movement
- kinetic energy
- molecular attraction
- molecule
- phase
- temperature

Digital Tools

- *Phase Change* Simulation

Name: _____ Date: _____

Warm-Up

Dr. Flores received the below post on the space forum and needs your help responding. First, read the post and consider any initial ideas on how to respond. Then, complete the Sim activity below to gather evidence.

To: Student Chemists

From: 6a1i1e0

Subject: Question About Lake Evaporation

I read your findings about the lake but am confused about the argument that the lake evaporated between 2007 and 2009. The evidence shows that Titan first started getting hotter in 2002 when summer began, but the methane lake was still liquid five years later in 2007. If the temperature increased starting in 2002, then energy was being transferred into the lake. Why, then, hadn't it evaporated by 2007?

The forum user pointed out that energy began transferring into the lake as soon as summer started in 2002, yet the lake still had not evaporated five years later when the probe took the first picture. Your mission is to investigate how much energy a substance can gain or lose before it changes phase. Complete the steps below to test the possibility that energy was added without the lake changing phase.

1. Launch the Simulation.
2. Select substance B.
3. Transfer in as much energy as you can without causing a phase change.
4. Reset the Sim.
5. Transfer out as much energy as you can without causing a phase change.

Do all energy transfers lead to a phase change? How can you use the information from the Sim to respond to the forum user?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Reading "Liquid Oxygen"

1. Read and annotate the article "Liquid Oxygen."
2. Choose and mark annotations to discuss with your partner. Once you have discussed these annotations, mark them as discussed.
3. Now, choose and mark a question or connection, either one you already discussed or a different one you still want to discuss with the class.
4. Answer the reflection question below.

Rate how successful you were at using Active Reading skills by responding to the following statement:

As I read, I paid attention to my own understanding and recorded my thoughts and questions.

- ☐ Never
- ☐ Almost never
- ☐ Sometimes
- ☐ Frequently/often
- ☐ All the time

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Homework: Revisiting Your Initial Ideas

Think about what you learned from the reading and from the Sim. Then, record your initial response to the question below. Don't worry if you're not sure about your answer. You will have the chance to investigate further in the next lesson.

Why does an energy transfer not always result in phase change?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Lesson 3.2: Focusing on Molecular Attraction

To help answer questions about how much energy transfer is enough for a phase change, you will directly observe how a drop of water evaporates compared to a drop of isopropanol. You will then revisit the "Liquid Oxygen" article, using it to help you explain your findings. The Sim will further help you test your ideas, allowing you to fully explain your observations about water and isopropanol.

Unit Question

- How can the appearance of a substance change without it becoming a different substance?

Chapter 3 Question

- Why didn't the liquid methane change phase before 2007?

Vocabulary

- freedom of movement
- kinetic energy
- molecular attraction
- molecule
- phase
- temperature

Digital Tools

- *Phase Change* Simulation

Name: _____ Date: _____

Warm-Up

Today, you will observe drops of liquid water and compare them to drops of liquid isopropanol, noting whether either liquid evaporates. Given that the energy transferred in from the air will be the same for both liquids, make a prediction about whether both drops or only one drop will evaporate within five minutes.

Explain your prediction.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Investigating Molecular Attraction

Safety Note: Using Rubbing Alcohol

This lesson uses chemicals that may be harmful. The chemical isopropanol, also known as rubbing alcohol, is a flammable liquid and vapor. Avoid eye contact and do not inhale. If you suspect exposure, alert your teacher immediately.

Observing the Evaporation of Isopropanol Versus Water

In the last lesson, you began to investigate the question *Why does an energy transfer not always result in phase change?* You observed that a substance needs a certain amount of energy transferred in or out before a phase change will occur.

Today, you will observe two different liquids and note whether or not the same transfer of energy will cause them to evaporate. Note: The same amount of energy will be transferred into each liquid from the air.

Setup Instructions

1. On the left side of the paper towel, write "water." On the right side, write "isopropanol."
2. Place two drops of liquid water below the water label on the paper towel. Place two drops of isopropanol below the isopropanol label.
3. Draw a circle around each drop in order to indicate where the drop was before it began to evaporate.
4. While observing the drops of isopropanol and water, share your prediction and explanation from the Warm-Up with a partner.
5. After about five minutes, record your observations by completing the questions below.

Water

1. Did the liquid water evaporate after five minutes? (check one)

   ☐ yes ☐ no

2. Did this fit with your prediction? (check one)

   ☐ yes ☐ no

Isopropanol

1. Did the isopropanol evaporate after five minutes? (check one)

   ☐ yes ☐ no

2. Did this fit with your prediction? (check one)

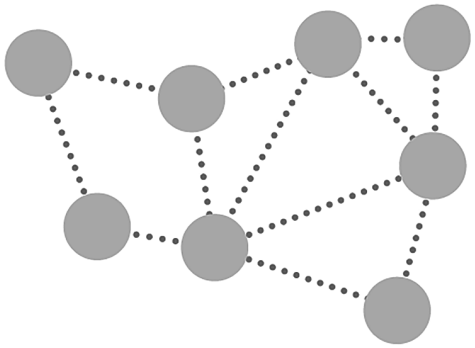
   ☐ yes ☐ no

Name: _____ Date: _____

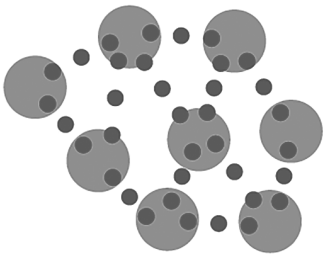
Second Read of "Liquid Oxygen"

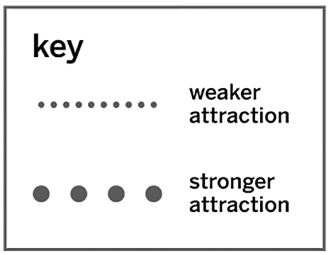
1. Reread paragraphs 2–3 of the "Liquid Oxygen" article. Also, review the Attraction diagram.
2. Then, highlight or add annotations to parts of the text that will help you answer the Investigation Question: *Why does an energy transfer not always result in phase change?*
3. Using your annotations, answer the question below.

Substance A



Substance B





Substance A is a gas and Substance B is a liquid. They are at the same temperature. Why is one a gas and one a liquid? Substance A has weaker attraction, and its molecules have enough energy to overcome the attraction between the molecules and fly apart. Substance B has a stronger attraction, and its molecules don't have enough energy to overcome the attraction between the molecules. Therefore, its molecules stay together.

Why does an energy transfer not always result in phase change?

_____

_____

_____

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Name: _____ Date: _____

Exploring Attraction in the Sim

Launch the Sim. Then, follow the instructions below to test the Investigation Question: *How does molecular attraction affect whether or not a phase change will occur?* As you complete the activity, answer the questions provided.

Part 1: Test 1

Complete the below steps for substances B and C. The first partner should test substance B and the second should test substance C. When you are finished, compare your results. Note: Substance B has a medium molecular attraction while substance C has a low molecular attraction.

1. Before starting, make a prediction: If substances B and C are both in the gas phase and are at the same energy level, which of the two substances will need to have more energy transferred out in order to change to the liquid phase? Substance B or substance C? Explain your answer.

_____

_____

_____

2. Transfer in energy to reach the highest amount of kinetic energy for both substance B and C.

3. Slowly transfer out energy from each substance. Note the temperature at which each substance changes phase.

   - Substance B changed to a liquid at _____ °C.
   - Substance C changed to a liquid at _____ °C.

4. Based on your observations above, which substance needed a greater decrease in kinetic energy in order to change phase?

   ☐ The substance with **low** attraction needed more energy transferred out in order to change phase.

   ☐ The substance with **medium** attraction needed more energy transferred out in order to change phase.

Name: _____ Date: _____

Exploring Attraction in the Sim (continued)

Part 2: Test 2

Complete the below steps for substances A and B. The first partner should test substance A and the second should test substance B. When you are finished, compare your results. Note: Substance A has a high molecular attraction while substance B has a medium molecular attraction.

1. Before starting, make a prediction: If substances A and B are both in the solid phase and are at the same energy level, which of the two substances will need to have more energy transferred in in order to change to the liquid phase? Substance A or substance B? Explain your answer.

_____

_____

_____

2. Transfer out energy to reach the lowest amount of kinetic energy for both substance A and B.

3. Slowly transfer in energy to each substance. Note the temperature at which each substance changes phase.

   - Substance A changed to a liquid at _____ °C.
   - Substance B changed to a liquid at _____ °C.

4. Based on your observations above, which substance needed a greater increase in kinetic energy in order to change phase?

   ☐ The substance with **medium** attraction needed more energy transferred in in order to change phase.

   ☐ The substance with **high** attraction needed more energy transferred in in order to change phase.

Name: _____ Date: _____

Exploring Attraction in the Sim (continued)

Part 3

Consider how attraction can affect a phase change. Then answer the questions below.

Two substances, both solids, start at the same temperature. You transfer the same amount of energy into both solids, but substance 1 becomes a liquid before substance 2. Based on this evidence, which substance has a stronger molecular attraction?

☐ substance 1 ☐ substance 2

Explain your answer.

_____

_____

_____

_____

Name: _____ Date: _____

Homework: Reflecting on Attraction

Reflect on what you have learned about attraction, energy transfer, and phase change.

Earlier in the lesson, you observed isopropanol and water drops on a paper towel. Even though the same amount of energy was transferred into both substances from the air, the isopropanol evaporated while the water did not. Why do you think the isopropanol changed phase, but the liquid water did not?

_____

_____

_____

_____

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Name: _____ Date: _____

Lesson 3.3: Modeling Attraction

In this lesson, you will collaborate with your fellow student chemists to identify how the evidence you have gathered helps answer the forum user's question *Why didn't the liquid methane change phase sooner?* Dr. Flores has asked for you to send your findings. Before you do so, you will first model your ideas. Then, you will send an explanation that Dr. Flores can share with the forum user.

Unit Question

- How can the appearance of a substance change without it becoming a different substance?

Chapter 3 Question

- Why didn't the liquid methane change phase before 2007?

Key Concepts

- Whether or not a phase change occurs is determined by the interaction between the kinetic energy of the molecules and the attraction pulling the molecules together.
- The molecular attraction of a substance never changes.

Vocabulary

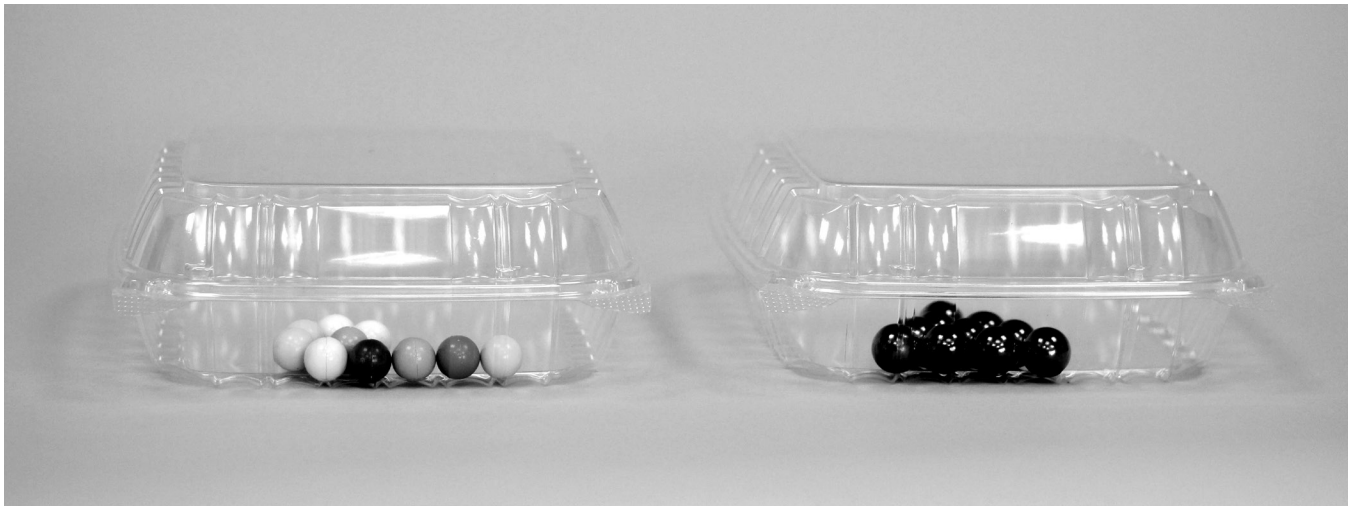
- freedom of movement
- kinetic energy
- molecular attraction
- molecule
- phase
- temperature

Digital Tools

- *Phase Change* Modeling Tool activity: Methane Lake 2002–2007

Name: _____ Date: _____

Warm-Up



In the image above, the container on the left is the same model that you used in an earlier lesson in which the magnetic marbles represented molecules. The container on the right also contains magnetic marbles, but these marbles are made from much stronger magnets. This new model represents molecules that have a very strong attraction. In a moment, you will see a video showing what happens when the kinetic energy of the marbles is increased by shaking each container.

1. Do you think it will be harder to get the strong magnets to "change phase"? Explain.

_____

_____

_____

_____

2. If you transfer energy into two solid substances, which do you think would melt first? (check one)

   ☐ a substance with stronger molecular attraction

   ☐ a substance with weaker molecular attraction

3. If you transfer energy out of two substances in the gas phase, which do you think would condense first? (check one)

   ☐ a substance with stronger molecular attraction

   ☐ a substance with weaker molecular attraction

Name: _____ Date: _____

Write and Share: Explaining Attraction

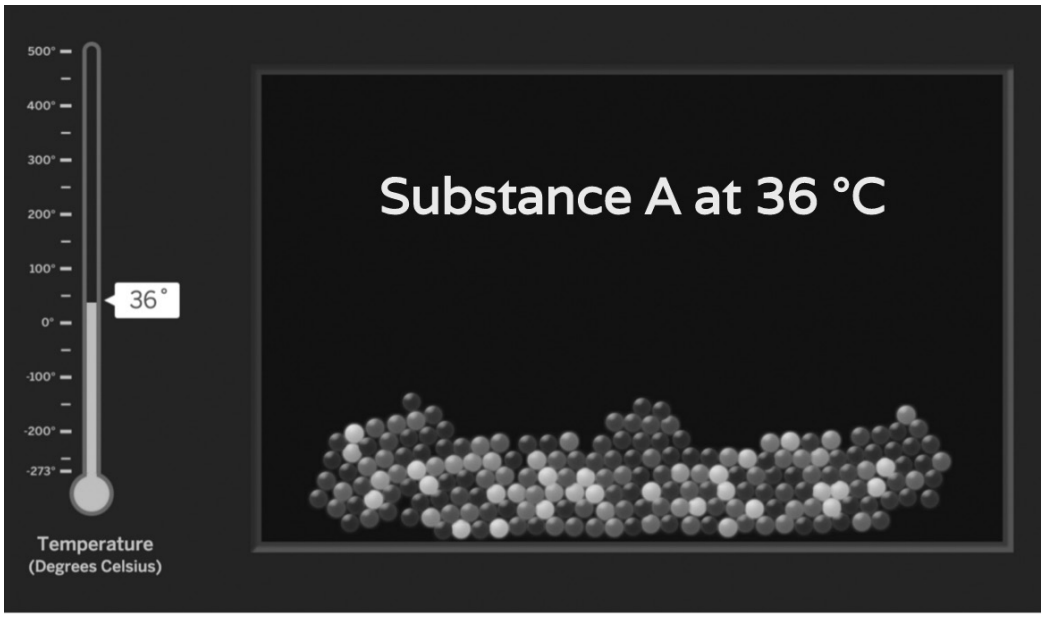
On the next few pages are three different pieces of evidence: evidence from the Sim, evidence from the *Magnetic Marbles Model* video, and evidence from the article "Liquid Oxygen." You will choose one piece of evidence and write about it, using the vocabulary terms provided. Then, you will share your writing with your group. After everyone in the group has shared, you'll use what you learned to write an explanation that answers the Chapter 3 Question: *Why didn't the liquid methane change phase before 2007?*

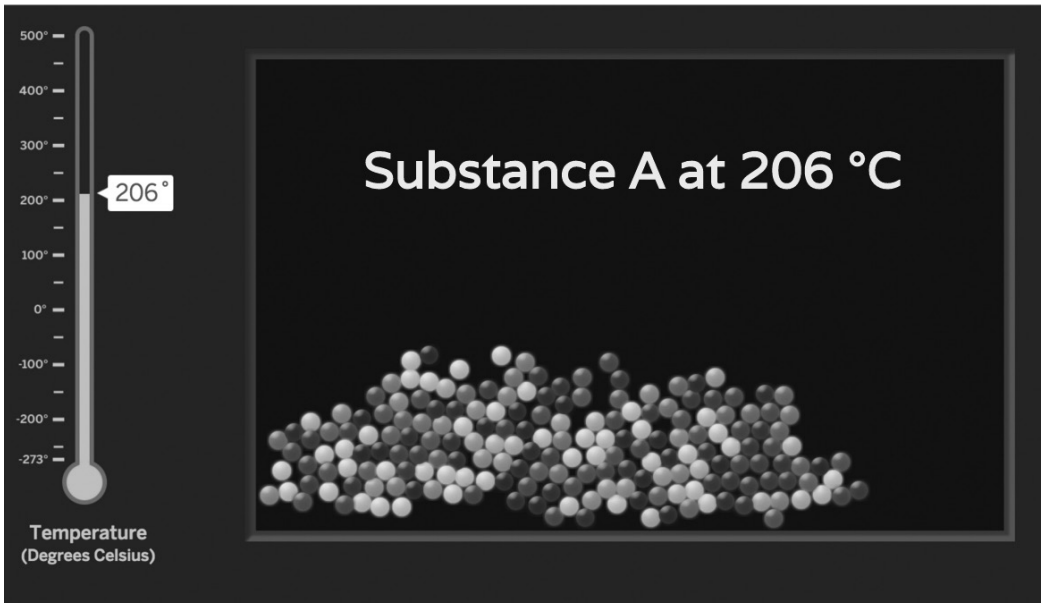
Name: _____ Date: _____

Write and Share: Explaining Attraction (continued)

Evidence from the Sim

The evidence from the Sim shows that enough energy was transferred into substance A to increase the kinetic energy of the molecules and raise the temperature to 200°C, but the freedom of movement and the phase did not change. Review the screenshots from the Sim. Then, use the terms *attraction, freedom of movement, kinetic energy,* and *overcome* to answer the questions on the next page.





Name: _____ Date: _____

Write and Share: Explaining Attraction (continued)

1. Describe what the Sim evidence shows you about attraction. Remember to use the terms *attraction, freedom of movement, kinetic energy,* and *overcome* in your response.

_____

_____

_____

2. Share your writing with your group and listen to what your group members wrote about their evidence.

3. How can this evidence help you answer the Chapter 3 Question: *Why didn't the liquid methane change phase before 2007?*

_____

_____

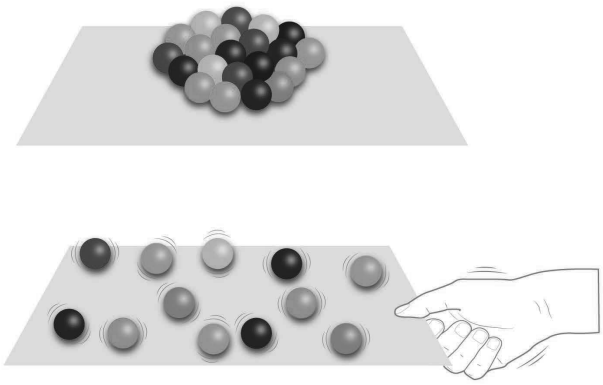
_____

Name: _____ Date: _____

Write and Share: Explaining Attraction (continued)

Evidence from the *Magnetic Marbles Model* Video

Look over the text below regarding the Magnetic Marbles Model you observed in the video. Consider what this model shows about attraction. Then, answer the questions.



Magnetic marbles

The magnetic marbles represent molecules, as well as the attraction that pulls molecules toward each other. Shaking the marbles represents transferring energy into a substance, which increases that substance's kinetic energy.

Initially, the magnetic marbles were in contact with each other. The container was then shaken, but the marbles still stayed together. After the container was shaken again, very hard, the magnetic attraction was eventually overcome, and the marbles separated.

1. Describe what the above evidence shows you about attraction. Remember to use the words *attraction, freedom of movement, kinetic energy,* and *overcome* in your response.

_____

_____

_____

2. Share your writing with your group and listen to what your group members wrote about their evidence.

3. How can this evidence help you answer the Chapter 3 Question *Why didn't the liquid methane change phase before 2007?*

_____

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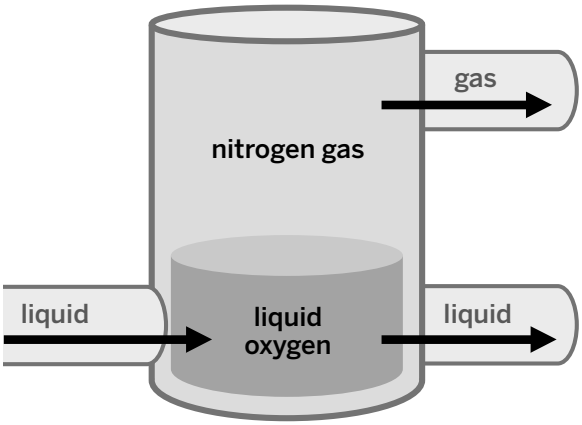
Name: _____ Date: _____

Write and Share: Explaining Attraction (continued)

Evidence from "Liquid Oxygen"

Review the text below from the "Liquid Oxygen" article. Consider what this text indicates about attraction. Then, answer the questions.

tank 3



The tank is warmed a little, allowing the nitrogen to evaporate and the liquid oxygen to stay behind.

Quotation from the article:

"The liquid mixture is then moved into a third tank that is heated up just a little so the nitrogen evaporates—the kinetic energy of the nitrogen becomes too strong for the attraction between molecules, and they escape into a gas. When the nitrogen evaporates, the liquid left behind is mostly oxygen."

1. Describe what the above evidence shows you about attraction. Remember to use the terms *attraction, freedom of movement, kinetic energy,* and *overcome* in your response.

_____

_____

_____

2. Share your writing with your group and listen to what your group members wrote about their evidence.

3. How can this evidence help you answer the Chapter 3 Question: *Why didn't the liquid methane change phase before 2007?*

_____

_____

_____

Name: _____ Date: _____

Modeling Attraction

1. Open the *Phase Change* Modeling Tool activity: Methane Lake 2002–2007.

2. When your model is complete, press HAND IN. If you worked with a partner, write their name here:

_____

Goal: Show why the liquid methane in the lake on Titan did not evaporate between 2002 and 2007.

Do:

- Drag out two Substance Descriptions and describe the methane.
- Move the Substance Descriptions to show methane's kinetic energy in 2002 compared to 2007.
- Use the arrows to compare the actual change of kinetic energy to the change needed for a phase change.
- Label the arrows.

Tips:

- Attach the tail end of the arrows to the Substance Description, Lake in 2002.
- The arrowheads can touch a line but don't need to.

Name: _____ Date: _____

Homework: Why Didn't the Liquid Methane Change Phase Before 2007?

Write a message to Dr. Flores explaining why the liquid methane did not change phase before 2007.

Remember, a strong explanation

- clearly states why or how something happened.
- might use terms such as *because, therefore, since,* and *this was caused by.*
- will state important causes and effects, providing evidence that supports ideas.

If helpful, use the terms from the word bank below. You might also consider reviewing your Modeling Tool or notes from the Write and Share routine earlier in this lesson.

Word Bank

attraction	adding energy	freedom of movement	gas
kinetic energy	liquid	molecules	phase change
removing energy	solid	speed	

Name: _____ Date: _____

Homework: Reading "Pressure and Temperature"

You have learned a lot about the role of temperature in phase change. To learn about pressure's role, read and annotate the "Pressure and Temperature" article. Then, answer the questions below.

1. Why is it easier for liquid water to evaporate on Mars than on Earth?

_____

_____

_____

_____

2. How can liquid reach higher temperatures in a pressure cooker than in an unsealed pot?

_____

_____

_____

_____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Lesson 3.5: Investigating Office Mysteries

Today, you will consider a new mystery. Unlike the lake on Titan, the mysteries in this lesson involve familiar materials and could easily happen at home or school. After receiving your group assignment, you will gather evidence in the Sim. You will then discuss your explanation with the rest of the group. The class will end with a whole-class discussion in which all groups share their mystery and explanation.

Unit Question

- How can the appearance of a substance change without it becoming a different substance?

Chapter 3 Question

- Why didn't the liquid methane change phase before 2007?

Key Concepts

- A solid keeps its shape because its molecules only move in place, not around each other.
- A liquid can flow because its molecules move around, not away from each other.
- A gas does not have a visible shape because its molecules can move away from each other.
- A phase change is when the molecules that make up a substance experience a change to their freedom of movement. This phase change involves a macroscale change in appearance.
- A change that can be observed at the macroscale can be explained by a change at the molecular scale, which cannot be observed with the naked eye.
- When energy is transferred to or from a substance, it can change the molecules' freedom of movement.
- Temperature is a measure of the average kinetic energy of the molecules of a substance.
- Transferring energy to a substance increases the kinetic energy of that substance's molecules. Transferring energy from a substance decreases the kinetic energy of that substance's molecules.
- Whether or not a phase change occurs is determined by the interaction between the kinetic energy of the molecules and the attraction pulling the molecules together.
- The molecular attraction of a substance never changes.
- A phase change occurs when the kinetic energy increases enough to overcome the attraction between molecules.
- A phase change occurs when the kinetic energy decreases enough so that the attraction between molecules pulls them together.
- Different substances can have either weaker or stronger molecular attraction.

Name: _____ Date: _____

Lesson 3.5: Investigating Office Mysteries (continued)

Vocabulary

- freedom of movement
- kinetic energy
- molecular attraction
- molecules
- phase
- temperature

Digital Tools

- *Phase Change* Simulation

Name: _____ Date: _____

Green Group: Warm-Up

Why are there drops of liquid on a soda can?

Read the description of the office mystery and write your prediction below.

> An office worker at the Universal Space Agency returned from lunch to find someone left him a gift—a cold can of soda to drink! But when the office worker picked up the can, he realized it was wet. The can was covered in a thin layer of liquid. Some of the liquid was slowly dripping onto his desk. What kind of liquid is on the officer worker's soda can, and how did the liquid get onto the surface of the can?

Using evidence from the articles you have read as well as the Sim and other activities you have completed in this lesson, write down your initial ideas about why this mystery occurred. Be ready to share your ideas.

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Name: _____ Date: _____

Green Group: Investigating Office Mysteries

The Soda Can Mystery

- Drops of liquid have appeared on a cold soda can. We know the can has no leaks in it. Another soda can, one that isn't cold, has no liquid on the outside. The lead chemist wants you to focus on the cold soda can. What is causing liquid to condense on the outside of the can? The lead chemist provides the following additional information:
- The air contains a lot of water vapor (water in gas form).
- The liquid on the can was tested and was determined to be water.

Launch the Sim. Then, gather evidence about the liquid on the can.

- Choose substance C (a gas), and then press the play icon to start the Sim. Notice how the molecules are moving.
- Try to make the substance condense into a liquid. Notice how the molecules are moving.
- Answer the questions and then write your message to the lead chemist.

1. The water molecules in the air (check one)
   - ☐ move in place.
   - ☐ move around but not away from each other.
   - ☐ can move away from each other.
2. The water molecules on the can (check one)
   - ☐ move in place.
   - ☐ move around but not away from each other.
   - ☐ can move away from each other.
3. The molecules of the can (check one)
   - ☐ move in place.
   - ☐ move around but not away from each other.
   - ☐ can move away from each other.

Name: _____ Date: _____

Green Group: Investigating Office Mysteries (continued)

The Universal Space Agency wants to know the results of your Sim investigation. Write your report to the lead chemist, explaining why drops of liquid water appeared on the outside of the cold, but not the warm, soda can. Use evidence from your investigation in your explanation.

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_____

Name: _____ Date: _____

Blue Group: Warm-Up

Why are there drops of liquid on a soda can?

Read the description of the office mystery and write your prediction below.

> An office worker at the Universal Space Agency returned from lunch to find someone left him a gift—a cold can of soda to drink! But when the office worker picked up the can, he realized it was wet. The can was covered in a thin layer of liquid. Some of the liquid was slowly dripping onto his desk. What kind of liquid is on the officer worker's soda can, and how did the liquid get onto the surface of the can?

Using evidence from the articles you have read as well as the Sim and other activities you have completed in this lesson, write down your initial ideas about why this mystery occurred. Be ready to share your ideas.

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Name: _____ Date: _____

Blue Group: Investigating the Office Mysteries

The Soda Can Mystery–Nitrogen

- The lead chemist wants you to determine why there is liquid water on the outside of the can but no liquid nitrogen. The lead chemist provides the following additional information:
- The air contains a lot of water vapor (gas), but air is made mostly of nitrogen gas.
- The liquid on the can was tested and was determined to be water.
- There was no evidence of liquid nitrogen on the can.
- The temperature of the can is colder than the temperature of the air.

Launch the Sim. Then, gather evidence to solve the nitrogen mystery.

1. Choose substance B (which has a medium attraction between its molecules), and then press the play icon to start the Sim.
2. First, make substance B a gas, increasing the temperature as much as possible.
3. Then, slowly cause substance B to condense.

   The substance changed into a liquid at _____ °C.

Now condense substance C (which has low attraction between its molecules).

4. Reset the Sim, and select substance C. Press the play icon to start the Sim.
5. First, make substance C a gas, increasing the temperature as much as possible.
6. Then, slowly cause substance C to condense.

   The substance changed into a liquid at _____ °C.

7. Think about what you observed in the Sim and the information the lead chemist sent you about the soda can. Which substance in the Sim best represents water (substance B or C)? Explain your answer in the space below.

_____

_____

_____

Name: _____ Date: _____

Blue Group: Investigating the Office Mysteries (continued)

8. Which substance in the Sim best represents nitrogen (substance B or C)? Explain your answer.

_____

_____

_____

The Universal Space Agency wants to know the results of your Sim investigation. Write your report to the lead chemist, explaining why there is liquid water on the outside of the can but no liquid nitrogen. Use evidence from your investigation in your explanation.

_____

_____

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_____

Name: _____ Date: _____

Purple Group: Warm-Up

Why can I smell a chocolate bar even though it is a solid?

Read the description of the office mystery and write your prediction below.

> On a warm afternoon, a Universal Space Agency office worker returned from lunch break and noticed the office smelled like chocolate. She didn't see anything in the air, but she noticed her coworker was opening the wrapper of a solid bar of chocolate. Why can the office worker smell the chocolate bar even though it is in solid form?

Using evidence from the articles you have read as well as the Sim and other activities you have completed in this lesson, write down your initial ideas about why this mystery occurred. Be ready to share your ideas.

_____

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Name: _____ Date: _____

Purple Group: Investigating the Office Mysteries

The Chocolate Bar Mystery

There is a chocolate smell wafting through the Universal Space Agency office. The staff could not see anything in the air, but they did find a recently opened solid bar of chocolate. The lead chemist provides the following additional information: In order to smell an object, molecules from that object need to reach the inside of your nose.

You have been researching phase changes and energy. Use what you have learned to help you solve this mystery by completing the following steps:

1. Share your ideas with your partner about what is causing the chocolate smell.
2. Discuss why you think the new information provided by the lead chemist might help you solve the office mystery. (**Hint:** Think about what you know about molecular movement, energy, attraction, and phase change.)
3. In order to smell a solid object, what would need to be true about the freedom of movement of that object's molecules? Write your thoughts below and then share with your partner.

_____

_____

_____

_____

_____

_____

The lead chemist wants you to determine what is happening to the freedom of movement of an object's molecules when you smell something. Is it possible to smell a chocolate bar when it is a solid? Launch the Sim and investigate.

- Use the Sim to determine if the molecules of a substance can be in two different phases at the same time.
- Go through each substance and see if you can get it to exist in two phases at once.
- Record as much evidence as you can in the table on the next page.

Name: _____ Date: _____

Purple Group: Investigating the Office Mysteries (continued)

Substance	Evidence	How did you find this evidence in the Sim?
A		
B		
C		

Name: _____ Date: _____

Purple Group: Investigating the Office Mysteries (continued)

The Universal Space Agency wants to know the results of your Sim investigation. Write your report to the lead chemist explaining why the staff can smell the chocolate bar. Use evidence from your investigation in your explanation.

Going further

You just learned that phase changes do not always happen in an expected way. If you were a professional scientist studying this situation, how would you go about investigating this phase change? What other questions would you ask? Write your response in the space below.

Name: _____ Date: _____

Sharing Office Mystery Evidence

Take turns discussing the mystery each group member investigated, allowing three minutes for each member. Be prepared to answer clarifying questions and support your ideas. Here are questions you should address when it is your turn:

- What was the mysterious phase change you investigated?
- How can you explain what happened?
- What evidence supports your explanation?

Name: _____ Date: _____

Homework: What Phase Change Can Tell Us About Titan

For homework you will watch *Lakes on Titan,* the second half of a documentary video from Chapter 1. Watch the video in the Digital Resources. Then, complete the reflection questions below.

Reflection Questions

1. What can experiments in a lab tell us about substances on Titan?

_____

_____

_____

_____

2. How does Dr. Hayes' and Dr. Malaska's research differ? Why are both research projects important?

_____

_____

_____

_____

Name: _____ Date: _____

Homework: Check Your Understanding

This is a chance to reflect on your learning so far. This is not a test. Be open and truthful when you respond.

Scientists investigate in order to figure things out. Are you getting closer to figuring out what happened to the lake on Titan?

1. I understand how the molecules in the lake were moving when it was a liquid. (check one)
   - ☐ yes
   - ☐ not yet

Explain your answer choice.

_____

_____

_____

2. I understand how changes at the molecular scale affected the lake's macro-scale appearance. (check one)
   - ☐ yes
   - ☐ not yet

Explain your answer choice.

_____

_____

_____

3. I understand how energy transfers affect the molecules in the lake. (check one)
   - ☐ yes
   - ☐ not yet

Explain your answer choice.

_____

_____

_____

Name: _____ Date: _____

Homework: Check Your Understanding (continued)

4. I understand how energy transfers affect the appearance of the lake. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

_____

5. I understand why energy transfers don't always affect the appearance of the lake. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

_____

6. What do you still wonder about phase change?

_____

_____

_____

_____

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Name: _____ Date: _____

Chapter 4: Science Seminar
Chapter Overview

The liquid oxygen machine used to fuel the Universal Space Agency's mission to Titan is malfunctioning. You will work with your fellow student chemists to evaluate evidence and determine the cause of this problem. You will then discuss the problem in the context of a Science Seminar, a student-led discussion. Finally, you will write your argument to the Universal Space Agency using evidence to support the claim you have selected.

Name: _____ Date: _____

Lesson 4.1: Introducing the Liquid Oxygen Problem

Today, you will consider a new problem: *Why is the liquid oxygen machine producing less liquid oxygen than normal?* This is an important question because without liquid oxygen, the Universal Space Agency cannot fuel its next mission to Titan. To begin your investigation, you will return to the diagram of the liquid oxygen machine from the "Liquid Oxygen" article. You will use your knowledge of molecular attraction to explain how the machine works.

Unit Question

- How can the appearance of a substance change without it becoming a different substance?

Chapter 4 Question

- Why is the liquid oxygen machine producing less liquid oxygen than normal?

Key Concepts

- A solid keeps its shape because its molecules only move in place, not around each other.
- A liquid can flow because its molecules move around, not away from each other.
- A gas does not have a visible shape because its molecules can move away from each other.
- A phase change is when the molecules that make up a substance experience a change to their freedom of movement. This phase change involves a macroscale change in appearance.
- A change that can be observed at the macroscale can be explained by a change at the molecular scale, which cannot be observed with the naked eye.
- When energy is transferred to or from a substance, it can change the molecules' freedom of movement.
- Temperature is a measure of the average kinetic energy of the molecules of a substance.
- Transferring energy to a substance increases the kinetic energy of that substance's molecules. Transferring energy from a substance decreases the kinetic energy of that substance's molecules.
- Whether or not a phase change occurs is determined by the interaction between the kinetic energy of the molecules and the attraction pulling the molecules together.
- The molecular attraction of a substance never changes.
- A phase change occurs when the kinetic energy increases enough to overcome the attraction between molecules.
- A phase change occurs when the kinetic energy decreases enough so that the attraction between molecules pulls them together.
- Different substances can have either weaker or stronger molecular attraction.

Name: _____ Date: _____

Lesson 4.1: Introducing the Liquid Oxygen Problem (continued)

Vocabulary

- freedom of movement
- kinetic energy
- molecular attraction
- molecule
- phase
- temperature

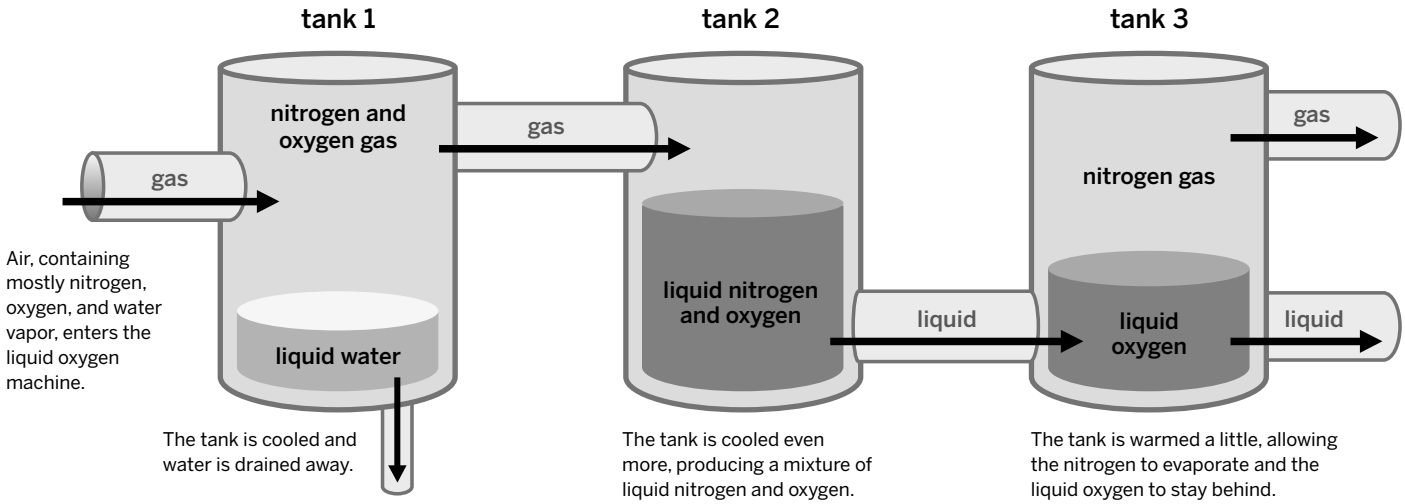
Digital Tools

- *Phase Change* Modeling Tool activities: Oxygen in Tank 1, Oxygen in Tank 2, Oxygen in Tank 3

Name: _____ Date: _____

Warm-Up

Liquid Oxygen Machine



In the "Liquid Oxygen" article, you read about how liquid oxygen is made and how it is needed to fuel rockets. The Universal Space Agency is planning to use liquid oxygen to fuel a rocket, carrying a new surface lander, to Titan. The launch window is short and needs to occur on a specific date or else the Universal Space Agency will need to wait for another year. But there is a problem. The liquid oxygen machine is producing less liquid oxygen than normal. You have been asked to determine what is causing this problem.

Write down any initial ideas you may have about why the liquid oxygen machine is not working.

_____

_____

_____

_____

_____

_____

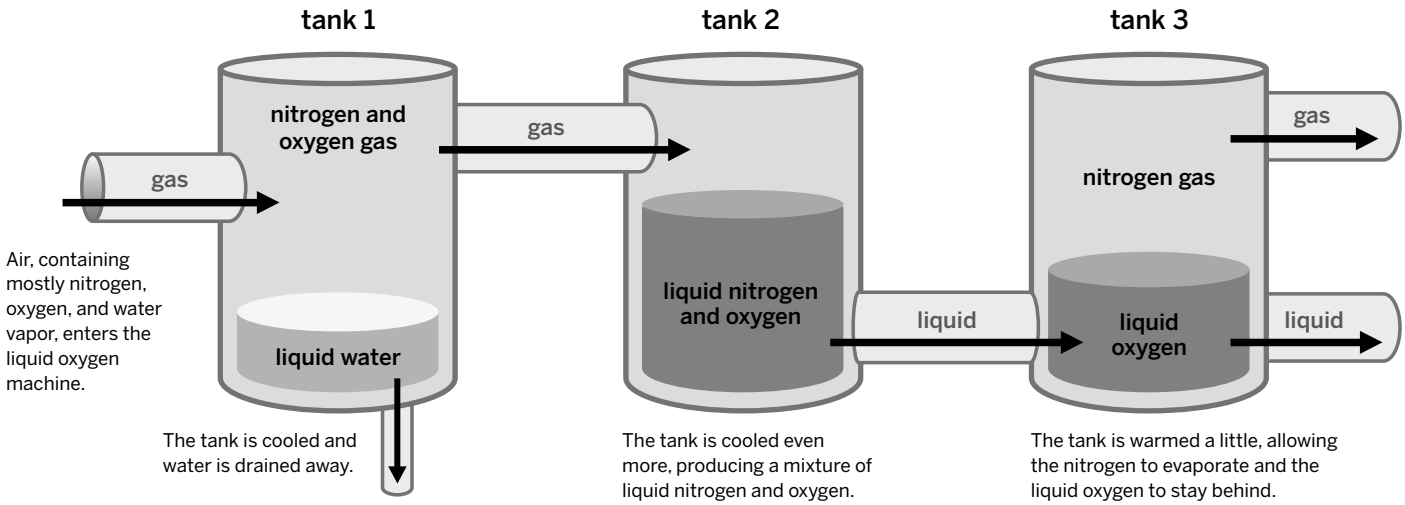
Name: _____ Date: _____

Annotating the Liquid Oxygen Machine

Before you can identify what is wrong with the liquid oxygen machine, you will need to understand how the machine is supposed to work. Read paragraph 7 of the "Liquid Oxygen" article in the section called "Using Attraction to Make Liquid Oxygen." Then, refer to the Liquid Oxygen Machine diagram included on the sheet in front of you. Write or draw annotations on the sheet, explaining how the liquid oxygen machine works. As you annotate, consider the following:

- Did kinetic energy increase or decrease in each tank? Why?
- What role did attraction play in whether or not a phase change occurred?
- What questions or ideas do you have about what might have gone wrong?

Liquid Oxygen Machine



Name: _____ Date: _____

Modeling Liquid Oxygen Tanks

Work with your group to use the Modeling Tool to show what happens in tanks 1, 2, and 3. If you have been assigned tank 2, turn to page 107. If you have been assigned tank 3, turn to page 108.

Tank 1

1. Open the *Phase Change* Modeling Tool activity: Oxygen in Tank 1.
2. When your model is complete, press HAND IN. If you worked with a partner, write their name here:

_____

Goal: Show what happens to oxygen gas in tank 1.

Do:

- Drag out two Substance Descriptions and describe the oxygen before and after.
- Move the Substance Descriptions up or down to compare the kinetic energy before and after the change.
- Use the arrows to compare the actual change of kinetic energy to the change needed for a phase change.
- Label the arrows.

Tips:

- Attach the tail end of the arrows to the Substance Description Before.
- The arrowheads can touch the line but don't need to.

Name: _____ Date: _____

Modeling Liquid Oxygen Tanks (continued)

Tank 2

1. Open the *Phase Change* Modeling Tool activity: Oxygen in Tank 2.
2. When your model is complete, press HAND IN. If you worked with a partner, write their name here:

_____

Goal: Show what happens to oxygen gas in tank 2.

Do:

- Drag out two Substance Descriptions and describe the oxygen before and after.
- Move the Substance Descriptions up or down to compare the kinetic energy before and after the change.
- Use the arrows to compare the actual change of kinetic energy to the change needed for a phase change.
- Label the arrows.

Tips:

- Attach the tail end of the arrows to the Substance Description Before.
- The arrowheads can touch a line but don't need to.

Name: _____ Date: _____

Modeling Liquid Oxygen Tanks (continued)

Tank 3

1. Open the *Phase Change* Modeling Tool activity: Oxygen in Tank 3.
2. When your model is complete, press HAND IN. If you worked with a partner, write their name here:

_____

Goal: Show what happens to oxygen in tank 3.

Do:

- Drag out two Substance Descriptions and describe the oxygen before and after.
- Move the Substance Descriptions up or down to compare the kinetic energy before and after the change.
- Use the arrows to compare the actual change of kinetic energy to the change needed for a phase change.
- Label the arrows.

Tips:

- Attach the tail end of the arrows to the Substance Description Before.
- The arrowheads can touch a line but don't need to.

Name: _____ Date: _____

Lesson 4.2: Analyzing Claims and Evidence

In order to fuel its upcoming mission to Titan, the Universal Space Agency urgently needs your help. Today, you will continue to investigate what is causing the liquid oxygen machine to produce less liquid oxygen than usual. You will use your understanding of phase change to determine how evidence supports or refutes three claims about why the machine is malfunctioning.

Unit Question

- How can the appearance of a substance change without it becoming a different substance?

Chapter 4 Question

- Why is the liquid oxygen machine producing less liquid oxygen than normal?

Key Concepts

- A solid keeps its shape because its molecules only move in place, not around each other.
- A liquid can flow because its molecules move around, not away from each other.
- A gas does not have a visible shape because its molecules can move away from each other.
- A phase change is when the molecules that make up a substance experience a change to their freedom of movement. This phase change involves a macroscale change in appearance.
- A change that can be observed at the macroscale can be explained by a change at the molecular scale, which cannot be observed with the naked eye.
- When energy is transferred to or from a substance, it can change the molecules' freedom of movement.
- Temperature is a measure of the average kinetic energy of the molecules of a substance.
- Transferring energy to a substance increases the kinetic energy of that substance's molecules. Transferring energy from a substance decreases the kinetic energy of that substance's molecules.
- Whether or not a phase change occurs is determined by the interaction between the kinetic energy of the molecules and the attraction pulling the molecules together.
- The molecular attraction of a substance never changes.
- A phase change occurs when the kinetic energy increases enough to overcome the attraction between molecules.
- A phase change occurs when the kinetic energy decreases enough so that the attraction between molecules pulls them together.
- Different substances can have either weaker or stronger molecular attraction.

Name: _____ Date: _____

Lesson 4.2: Analyzing Claims and Evidence (continued)

Vocabulary

- freedom of movement
- kinetic energy
- molecular attraction
- molecule
- phase
- temperature

Name: _____ Date: _____

Warm-Up

In Lesson 4.1, you learned that the machine used to fuel missions to Titan is not making enough liquid oxygen. We are waiting for a more detailed report from the Universal Space Agency. Before we receive the report, however—and now that you know how the liquid oxygen machine is supposed to work—what are some ideas you have about what could be causing it to malfunction?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Interpreting the Claims

1. Compare each claim on the Science Seminar Visual Claims sheet to your annotated Liquid Oxygen Machine Diagram sheet.

2. With your partner, discuss the following questions for each claim:
   - Why would this cause less liquid oxygen to be produced?
   - What could be going wrong in the tank to make this happen?

3. You may find it helpful to annotate your Science Seminar Visual Claims sheet. You may also add annotations to your Liquid Oxygen Machine Diagram sheet during your partner discussion.

Name: _____ Date: _____

Interpreting the Evidence

1. Discuss each piece of evidence. If needed, refer to the reference information below from the "Liquid Oxygen" article.

2. Consider the following questions as you discuss the Science Seminar Evidence Cards.
   - Is this a change from what normally happens with the liquid oxygen machine?
   - If there is a change, how would that affect whether or not the substances in the machine change phase?

3. Annotate your Liquid Oxygen Machine Diagram or Science Seminar Visual Claims sheet to indicate what the technicians observed about the malfunctioning liquid oxygen machine.

Review the following reference information from the "Liquid Oxygen" article:

- Water has a stronger attraction between molecules than oxygen or nitrogen.
- Oxygen has a stronger attraction than nitrogen.

Name: _____ Date: _____

Sorting the Evidence Cards

1. Using your annotated Liquid Oxygen Machine Diagram sheet, the Science Seminar Visual Claims sheet, and the reference information below, sort the Science Seminar Evidence Cards according to which claim they support or refute.
2. Discuss each piece of evidence and determine which of the claims, if any, the evidence card supports or refutes.
3. When you have finished sorting, follow the instructions from your teacher on how to attach (or make notes on the cards) for future use.

Review the following reference information from the "Liquid Oxygen" article:

- Water has a stronger attraction between molecules than oxygen or nitrogen.
- Oxygen has a stronger attraction than nitrogen.

Discuss the following questions with your group:

- Did any of the evidence refute any of the claims? If so, which ones?
- Based on the evidence, can we eliminate any of the claims?

Sentence Starters

I think this evidence supports this claim because . . .

I don't think this evidence supports this claim because . . .

I agree because . . .

I disagree because . . .

Name: _____ Date: _____

Homework: Reflecting on Claims and Evidence

The machine is making less liquid oxygen than normal. What is wrong?

Reflect on the claims and the evidence you examined today. At this point, which claim do you think is best supported by the evidence? (check one)

- ☐ **Claim 1:** There is frozen water in tank 2, which is blocking some of the oxygen from going into tank 3.
- ☐ **Claim 2:** Some of the liquid oxygen evaporated in tank 3.
- ☐ **Claim 3:** Some of the oxygen didn't condense in tank 2.

Explain your claim choice using the evidence you discussed today.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Lesson 4.3: Science Seminar

Why is the liquid oxygen machine producing less liquid oxygen than normal? In today's Science Seminar, you and your classmates will discuss the evidence, listen to each other's ideas, and try to arrive at the best explanation for why the liquid oxygen machine is malfunctioning. After hearing your classmates and participating in the discussion, you will prepare to write a convincing scientific argument in the next lesson.

Unit Question

- How can the appearance of a substance change without it becoming a different substance?

Chapter 4 Question

- Why is the liquid oxygen machine producing less liquid oxygen than normal?

Key Concepts

- A solid keeps its shape because its molecules only move in place, not around each other.
- A liquid can flow because its molecules move around, not away from each other.
- A gas does not have a visible shape because its molecules can move away from each other.
- A phase change is when the molecules that make up a substance experience a change to their freedom of movement. This phase change involves a macroscale change in appearance.
- A change that can be observed at the macroscale can be explained by a change at the molecular scale, which cannot be observed with the naked eye.
- When energy is transferred to or from a substance, it can change the molecules' freedom of movement.
- Temperature is a measure of the average kinetic energy of the molecules of a substance.
- Transferring energy to a substance increases the kinetic energy of that substance's molecules. Transferring energy from a substance decreases the kinetic energy of that substance's molecules.
- Whether or not a phase change occurs is determined by the interaction between the kinetic energy of the molecules and the attraction pulling the molecules together.
- The molecular attraction of a substance never changes.
- A phase change occurs when the kinetic energy increases enough to overcome the attraction between molecules.
- A phase change occurs when the kinetic energy decreases enough so that the attraction between molecules pulls them together.
- Different substances can have either weaker or stronger molecular attraction.

Name: _____ Date: _____

Lesson 4.3: Science Seminar (continued)

Vocabulary

- freedom of movement
- kinetic energy
- molecular attraction
- molecule
- phase
- temperature

Name: _____ Date: _____

Warm-Up

Today, you will be participating in a Science Seminar in which you will discuss claims and evidence to determine the best explanation for why the liquid oxygen machine is not producing enough oxygen. This discussion is very similar to the kind of discussion real scientists often have when faced with multiple claims.

Which of these expectations do you think is the most important to keep in mind for a successful Science Seminar? (check one)

- ☐ Students run the conversation.
- ☐ Students use evidence to support their ideas.
- ☐ Students explain their thinking.
- ☐ Students listen to one another.
- ☐ Students respond to one another.
- ☐ Students are open to changing their minds.

Name: _____ Date: _____

Preparing for the Science Seminar

Select the strongest claim and evidence you feel best supports it. Then, with your partner, discuss why you selected that claim.

Question: *Why is the liquid oxygen machine producing less liquid oxygen than normal?*

Which claim do you think is best supported by the evidence? (check one)

- ☐ **Claim 1:** There is frozen water in tank 2, which is blocking some of the oxygen from going into tank 3.
- ☐ **Claim 2:** Some of the liquid oxygen evaporated in tank 3.
- ☐ **Claim 3:** Some of the oxygen didn't condense in tank 2.

Reference information from the "Liquid Oxygen" article:

- Water has a stronger attraction between molecules than oxygen or nitrogen.
- Oxygen has a stronger attraction than nitrogen.

Referring to your Science Seminar Evidence Cards, record the evidence you feel best supports the claim you selected above. Then, explain how this evidence supports the claim.

Evidence	How does this evidence support (or refute) the claim?

Name: _____ Date: _____

Science Seminar Observations

Write a check mark in the right-hand column every time you hear one of your peers say or do something listed in the left-hand column. If you hear an interesting idea, write it in the last row of the table.

Observations during the seminar	**Check marks**
I heard a student use evidence to support a claim.	
I heard a student respectfully disagree with someone else's thinking.	
I heard a student explain how her evidence is connected to her claim.	
I heard a student evaluate the quality of evidence.	
I heard an idea that makes me better understand one of the claims. That idea is:	

Name: _____ Date: _____

Reflecting on the Science Seminar

When the Science Seminar is over, think about the claim you originally selected. After hearing your classmates' ideas, you may have changed your mind about which claim is best supported. Select the claim you now believe is the most convincing. This can be your original claim or a new one.

Which claim do you think is best supported by the evidence? (check one)

- ☐ Claim 1
- ☐ Claim 2
- ☐ Claim 3

Based on the Science Seminar discussion, record the evidence that you feel most strongly supports the claim you selected.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Lesson 4.4: Writing a Scientific Argument

After a thoughtful investigation and a rich discussion with other student chemists, you are prepared to write a scientific argument for Dr. Flores. You will select a claim and use the Reasoning Tool to develop ideas about how the evidence supports your claim. Then, you will use the Reasoning Tool to write your final argument about why the liquid oxygen machine is producing less liquid oxygen than normal.

Unit Question

- How can the appearance of a substance change without it becoming a different substance?

Chapter 4 Question

- Why is the liquid oxygen machine producing less liquid oxygen than normal?

Key Concepts

- A solid keeps its shape because its molecules only move in place, not around each other.
- A liquid can flow because its molecules move around, not away from each other.
- A gas does not have a visible shape because its molecules can move away from each other.
- A phase change is when the molecules that make up a substance experience a change to their freedom of movement. This phase change involves a macroscale change in appearance.
- A change that can be observed at the macroscale can be explained by a change at the molecular scale, which cannot be observed with the naked eye.
- When energy is transferred to or from a substance, it can change the molecules' freedom of movement.
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- The molecular attraction of a substance never changes.
- A phase change occurs when the kinetic energy increases enough to overcome the attraction between molecules.
- A phase change occurs when the kinetic energy decreases enough so that the attraction between molecules pulls them together.
- Different substances can have either weaker or stronger molecular attraction.

Name: _____ Date: _____

Lesson 4.4: Writing a Scientific Argument (continued)

Vocabulary

- claim
- evidence
- freedom of movement
- kinetic energy
- molecular attraction
- molecule
- phase
- reasoning
- refute
- temperature

Name: _____ Date: _____

Warm-Up

Scientists make a convincing argument by supporting their claim with evidence and clearly stating how the evidence connects to the claim.

Read the following question and argument.

Question: *Did the methane lake on Titan evaporate or freeze before the second photo was taken?*

Argument: The lake evaporated before the second photo was taken. Evidence Card C stated it had been summer for seven years when the second photo was taken. Evidence Card D stated that more energy is transferred to the lake in the summer than in other seasons.

Think about what is missing from the argument above. Then, select 1–2 statements from the list below that will make the argument more convincing.

- ☐ When used together, the evidence cards show that the amount of energy in the lake increased.
- ☐ The first and second photos of the methane lake were taken by the Cassini probe as it passed by in its orbit of Saturn.
- ☐ Once enough energy was transferred into the lake, kinetic energy could overcome the attraction of the methane molecules and cause the lake to evaporate.
- ☐ Titan is a moon that orbits Saturn. Besides Earth, it is one of the only other places in the solar system that has liquid seas and lakes.

Name: _____ Date: _____

Using the Reasoning Tool

1. In the right column of the table on the next page, record the claim you have selected.
2. After reviewing your Science Seminar Evidence Cards, select the evidence you feel best supports or refutes this claim. Record this evidence in the left column. Then, in the rows below, record up to three pieces of additional evidence you feel could further support or refute your claim.
3. In the middle column, explain how each piece of evidence either supports or refutes your claim.

Question: *Why is the liquid oxygen machine producing less liquid oxygen than normal?*

Claim 1: There is frozen water in tank 2, which is blocking some of the oxygen from going into tank 3.

Claim 2: Some of the liquid oxygen evaporated in tank 3.

Claim 3: Some of the oxygen didn't condense in tank 2.

Reference information from the "Liquid Oxygen" article:

- Water has a stronger attraction between molecules than oxygen or nitrogen.
- Oxygen has a stronger attraction than nitrogen.

Name: _____ Date: _____

Using the Reasoning Tool (continued)

Evidence	**This matters because . . .** (How does this evidence support or refute the claim?)	**Therefore, . . .** (claim)
		.

Name: _____ Date: _____

Preparing to Write

Before writing your final argument to the Universal Space Agency, answer the questions below. You may want to refer to your completed Reasoning Tool on page 126.

What is your most convincing piece of evidence?

_____

_____

Is there any evidence you will not be using? Explain below.

_____

_____

Are there two pieces of evidence that work together to make a stronger argument? If so, list them below.

_____

_____

_____

_____

Name: _____ Date: _____

Writing a Scientific Argument

When you write your scientific argument to Dr. Flores:

1. Remember to explain how your evidence supports or refutes the claim you selected and why your evidence is significant.
2. Review your Reasoning Tool and annotations on the Liquid Oxygen Machine Diagram on page 105.
3. Use the sentence starters below to help explain your thinking.

Question: *Why is the liquid oxygen machine producing less liquid oxygen than normal?*

Claim 1: There is frozen water in tank 2, which is blocking some of the oxygen from going into tank 3.

Claim 2: Some of the liquid oxygen evaporated in tank 3.

Claim 3: Some of the oxygen didn't condense in tank 2.

Reference information from the "Liquid Oxygen" article:

- Water has a stronger attraction between molecules than oxygen or nitrogen.
- Oxygen has a stronger attraction than nitrogen.

Scientific Argument Sentence Starters

Describing evidence	Explaining how the evidence supports the claim
The evidence that supports (or refutes) my claim is . . .	If_____, then . . .
My first piece of evidence is . . .	This is important because . . .
Another piece of evidence is . . .	Since, . . .
Scientists found . . .	Based on the evidence, I conclude that . . .
	This claim is stronger (or weaker) because . . .

Word Bank

energy	evaporation	freedom of movement	freezing
kinetic energy	molecule	phase change	temperature

Name: _____ Date: _____

Writing a Scientific Argument (continued)

Write a scientific argument that answers the question *Why is the liquid oxygen machine producing less liquid oxygen than normal?*

State your claim and use evidence to support it. For each piece of evidence you use, explain how the evidence supports your claim or refutes another claim. Remember to explain what happened at both the macro and molecular scale.

Name: _____ Date: _____

Writing a Scientific Argument (continued)

Name: _____ Date: _____

Homework: Revising an Argument

Revising an Argument

1. Reread the scientific argument you wrote during class.
2. If needed, finish writing your argument. Then, look for ways you could make your argument clearer or more convincing.
3. Read your argument aloud or have another person read it.
4. Consider the following questions as you review your argument:
   - Does your argument clearly explain what happened to the liquid oxygen machine?
   - Do you provide supporting evidence?
   - Do you thoroughly explain how the evidence supports your claim?
5. Rewrite any sections that could be clearer or more convincing.

Name: _____ Date: _____

Homework: Revising an Argument (continued)

Name: _____ Date: _____

Homework: Check Your Understanding

This is a chance to reflect on your learning so far. This is not a test. Be open and truthful when you respond.

1. I understand that scientists connect evidence to their claims to make stronger arguments. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

_____

_____

_____

2. What are the most important things you have learned in this unit about how the appearance of a substance can change without it becoming a different substance?

_____

_____

_____

_____

_____

3. What questions do you still have?

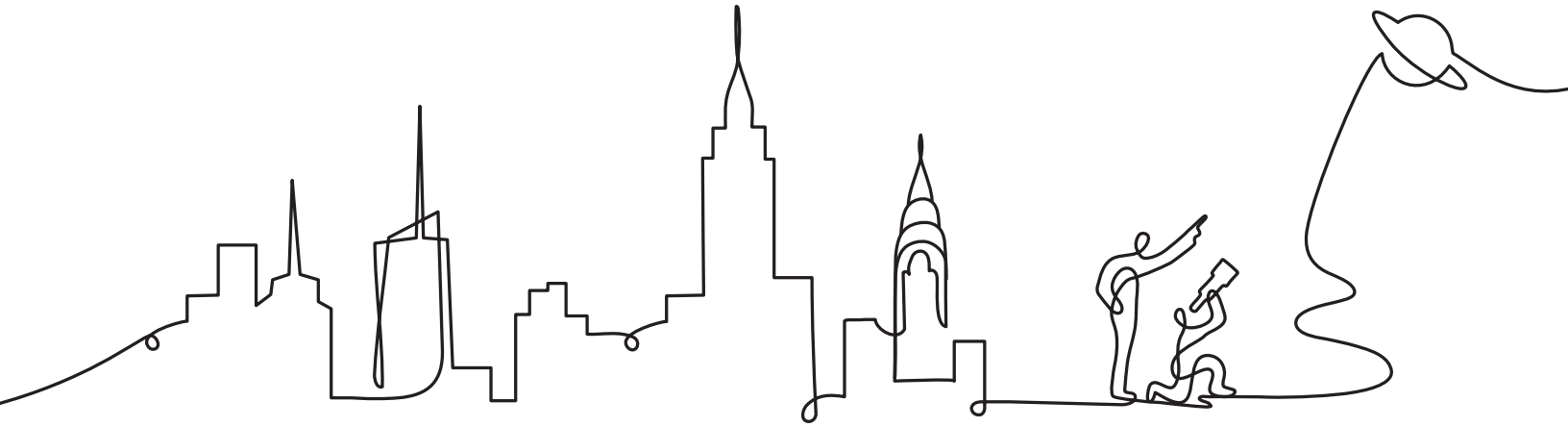
_____

_____

_____

_____

_____



New York City Companion Lesson

Name: _____ Date: _____

Reading "Icy Heat"

1. Read and annotate the "Icy Heat" article.
2. Choose and mark annotations to discuss with your partner. Once you have discussed these annotations, mark them as discussed.
3. Now, choose and mark a question or connection, either one you already discussed or a different one that you would like to discuss with the class.
4. Answer the reflection question below.

   Rate how successful you were at using Active Reading skills by responding to the following statement:

   As I read, I paid attention to my own understanding and recorded my thoughts and questions.

   - ☐ Never
   - ☐ Almost never
   - ☐ Sometimes
   - ☐ Frequently/often
   - ☐ All the time

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Second Read of "Icy Heat"

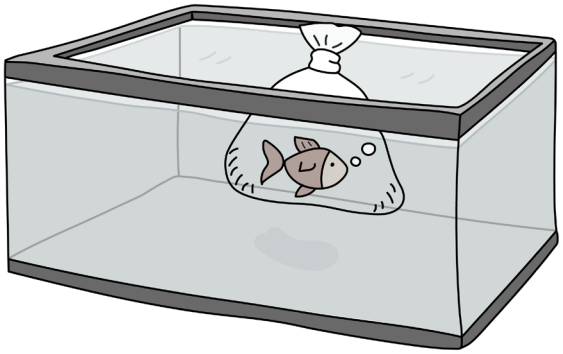
Part 1

Reread paragraph 5 of the article. As you read, highlight and annotate information that helps you understand the scientific meaning of the word *heat*. You will use that information to help you answer the question in Part 2.

Part 2

Read the following information. Use what you learned from "Icy Heat" to answer the questions.

Miguel bought a new fish for his fish tank. He brought the fish home in a plastic bag that was filled with water from the fish tank at the store. Before releasing the fish, he put the entire bag into his tank so the fish could get used to the temperature of the water in his tank at home.



Temperature of the water in his home tank: 21°C

Temperature of the water in the bag: 18°C

Miguel explains to his sister that heat is transferring from the water in the tank to the water in the bag. Miguel's sister doesn't believe him because the water in the tank doesn't feel hot.

How is it possible that heat is transferring from the water in the tank to the water in the bag, even though the water in the tank doesn't feel hot?

_____

_____

_____

_____

_____

_____

_____

Phase Change Glossary

freedom of movement: the way molecules in a substance move around relative to each other

libertad de movimiento: la forma en la que las moléculas de una sustancia circulan una en relación a la otra

heat: the thermal energy transferred from something at a higher temperature to something at a lower temperature

calor: la energía térmica transferida de algo con una temperatura más alta a algo con una temperatura más baja

kinetic energy: the energy that an object has because it is moving

energía cinética: la energía que tiene un objeto porque se está moviendo

molecular attraction: a pull between two molecules that is always the same for a substance

atracción molecular: un jalón entre dos moléculas que siempre es igual para una sustancia

molecule: a group of atoms joined together in a particular way

molécula: un grupo de átomos unidos de una manera particular

phase: a noticeably different form or state of the same substance

fase: una forma o estado visiblemente diferente de la misma sustancia

refute: to provide evidence that goes against a claim

refutar: proporcionar evidencia en contra de una afirmación

scale: the relative size of things

escala: el tamaño relativo de las cosas

temperature: a measure of how hot or cold something is

temperatura: una medida de qué tan caliente o frío está algo

thermal energy: the total kinetic energy of all the molecules that make up a sample

energía térmica: la energía cinética total de todas las moléculas que forman una muestra

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Phase Change:
Titan's Disappearing Lakes

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