AmplifyScience

Chemical Reactions:

Mysterious Substance in Westfield's Water

Investigation Notebook with Article Compilation

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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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Chemical Reactions:

Mysterious Substance in Westfield's Water

Investigation Notebook

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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: _____

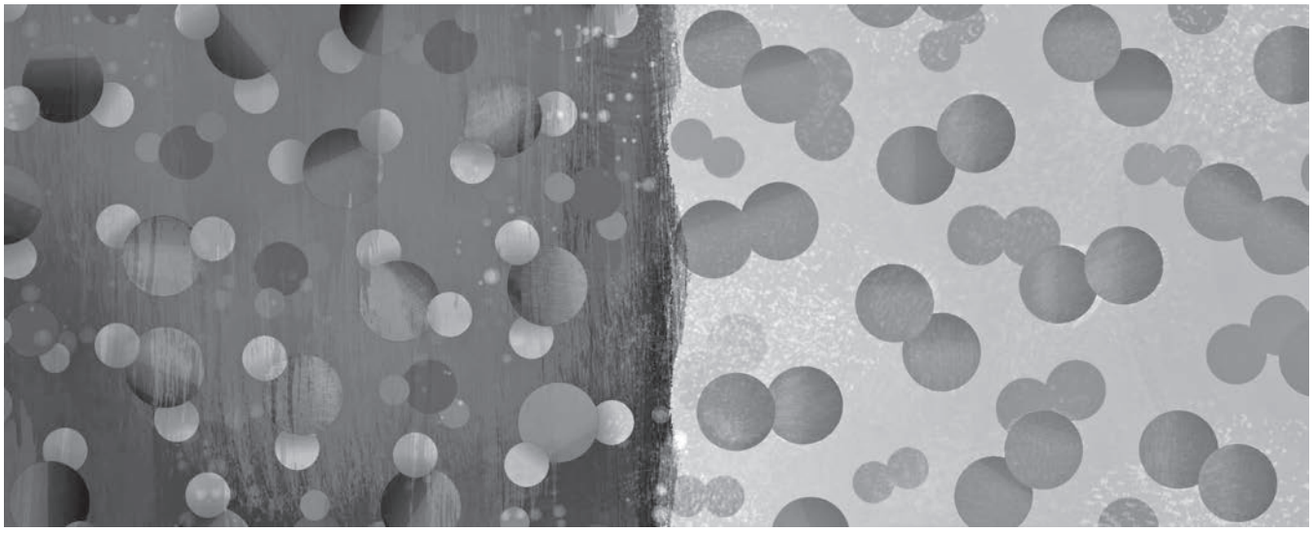
Chemical Reactions
Unit Overview

A strange reddish-brown substance is coming out of the water pipes in the town of Westfield. What is this substance, and where did it come from? As a student chemist you will help Dr. Samara Yung's chemistry lab to solve this mystery. Using a Simulation, science articles, videos, and models, you will investigate what the reddish-brown substance is and how it formed.

Name: _____ Date: _____

Chapter 1: Properties and Atoms
Chapter Overview

A mysterious reddish-brown substance has been discovered coming out of the water pipes in Westfield. As student chemists, it is up to you to identify this mysterious substance and determine if it is the same as or different from the other substances in the water system. To do this, you'll need to make detailed observations as you learn what makes substances the same or different.



Name: _____ Date: _____

Lesson 1.2: A Water Mystery in Westfield

A neighborhood in the town of Westfield is in a panic. Recently, a strange reddish-brown substance has been seen coming out of the residents' pipes whenever they turn on the water. The neighborhood association has recommended that they avoid using the water until the mysterious substance has been identified. Chemist Dr. Samara Yung has been called in to help the residents of Westfield determine what is going on. Is the water toxic? As a student chemist, you will be assisting Dr. Yung as she determines what the reddish-brown substance is and why it is coming out of Westfield's water pipes.

Unit Question

- How do new substances form?

Chapter 1 Question

- What is the reddish-brown substance in the water?

Vocabulary

- property
- substance

Name: _____ Date: _____

Warm-Up

Look at the two images of water below. One glass has clean water, and the other has dirty water. Think about how you use water every day. Then, answer the question below.

How would your life be different if you didn't have clean water at home?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Investigating a Mysterious Substance

To: Student Chemists
From: Dr. Samara Yung, Lead Chemist
Subject: Water Crisis in Westfield

Last week, I received a call from Alexa Anderson, a resident of Westfield. When she turned on her faucet for a glass of water, a strange reddish-brown substance came out. She called a few of her neighbors and found out that the reddish-brown substance was coming out of their water pipes, too.

My lab uses chemistry to identify unknown substances, so I went to Westfield to take some samples. I took a sample of the water coming out of the pipes and another sample from the well where the neighborhood's water comes from. I analyzed the samples and made an interesting discovery. The water coming out of the pipes contains the mysterious reddish-brown substance, but I didn't find any of the reddish-brown substance in the water sample that I took from the well. Instead, I found something else. It appears that some fertilizer from a nearby farm seeped into the well water.

We need to do more analysis in order to identify the reddish-brown substance, but my lab is unfortunately busy with other projects right now. Therefore, I need your help to get to the bottom of this mystery. The residents of Westfield need answers!

Chapter 1 Question: *What is the reddish-brown substance in the water?*

Claim 1: The reddish-brown substance is the same as the substance that makes up the pipes.

Claim 2: The reddish-brown substance is the same substance as the fertilizer.

Claim 3: The reddish-brown substance is not the same as either the fertilizer or the substance that makes up the pipes.

Name: _____ Date: _____

Observing Substances

Safety Note: Using Chemicals

The substances in this investigation should remain sealed in their containers. Do not taste or touch the substances in the investigation. The sodium nitrate and iron oxide granules present irritation risks. If sodium nitrate gets on your skin or clothes, rinse the substance off with water. If you get a substance in your eyes, rinse the affected area with water for 15 minutes. If iron oxide is inhaled, move to fresh air and seek medical help for any breathing difficulties.

Chemical Warning

The *Chemical Reactions* kit contains chemicals that may be harmful if misused. These chemicals are not to be used without adult supervision. Chemicals used in this activity are:

- iron oxide granules
- iron filings
- sodium nitrate

Look at the Safety Guidelines on page 1 before you begin your investigation.

Dr. Yung has provided you with samples of three substances she collected from Westfield. With your group, observe each of these samples and discuss what you observe. Then, record your observations below.

What did you observe about the sample of the pipe substance?

_____

_____

_____

_____

What did you observe about the sample of fertilizer?

_____

_____

_____

_____

Name: _____ Date: _____

Observing Substances (continued)

What did you observe about the sample of the reddish-brown substance?

_____

_____

_____

_____

Name: _____ Date: _____

Lesson 1.3: Analyzing Substances and Properties

You already know that a mysterious reddish-brown substance has been discovered coming out of the water pipes in Westfield. Now that you have observed the sample substances' properties, it's time to think about how your observations can help you identify this reddish-brown substance. Dr. Yung needs you to gather evidence that will help her determine what the reddish-brown substance is and whether or not it is the same as any of the other substances in Westfield's water pipes. Today, you will gain more practice in observing properties chemists use when identifying an unknown substance.

Unit Question

- How do new substances form?

Chapter 1 Question

- What is the reddish-brown substance in the water?

Vocabulary

- property
- substance

Digital Tools

- *Chemical Reactions* Sorting Tool activity: Evaluating Evidence

Name: _____ Date: _____

Warm-Up

David and Luisa are trying to determine if two samples are the same or different substances. First, they observed sample 1 and sample 2. Then, they wrote down their observations. Review their observations. Then, answer the questions below.

David's Observations

Sample 1	Sample 2
light color solid	light color solid

Luisa's Observations

Sample 1	Sample 2
white powder clear crystals	white powder cloudy crystals

Which student's observations would prove more useful to a chemist? (check one)

- ☐ David's observations
- ☐ Luisa's observations

Explain your answer.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Investigating Substances

Safety Note: Using Chemicals

Do not taste or touch the substances in the investigation. Mix substances only when you are told to do so by your teacher. The substances present skin irritation risks. Wash exposed areas when finished. If a substance gets on your skin or clothes, tell your teacher, and rinse the substance off with water. If you get a substance in your eyes, tell your teacher and rinse your eyes with water for 15 minutes. If a substance is inhaled, move to fresh air and seek medical help for any breathing difficulties.

Chemical Warning

The *Chemical Reactions* kit contains chemicals that may be harmful if misused. Read cautions on individual containers carefully. These chemicals are not to be used without adult supervision.

Look at the Safety Guidelines on page 1 before you begin your investigation.

Working with your group of four, observe each of the four samples. Discuss what you observe and then record the properties of each sample in the table. Then, use the completed table to answer the question on the next page.

Sample 1	Sample 2	Sample 3	Sample 4

Name: _____ Date: _____

Investigating Substances (continued)

Based on your observations, do you think any of the samples are the same type of substance? (check one)

- ☐ yes
- ☐ no

Explain your answer.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Evaluating Evidence

Three students at another school observed two of the same samples you did earlier in this lesson. With a partner, complete the following steps:

1. Launch the *Chemical Reactions* Sorting Tool activity: Evaluating Evidence and review the observations on each evidence card.
2. Use the Evidence Criterion to discuss which observations you think are the strongest.
3. Place each evidence card on the Evidence Gradient based on how strong you think it is.
4. When your Evidence Gradient is complete, press HAND IN. If you worked with a partner, write his or her name here: _____

Goal: Sort the cards using the Evidence Criterion: More detailed observations provide stronger evidence.

Do: Use the strongest piece of evidence to decide if these two samples are the same substance.

Based on the strongest pieces of evidence on your Evidence Gradient, which claim about the two samples do you think is best supported? (check one)

☐ Samples 1 and 2 are the **same** substance.

☐ Samples 1 and 2 are **different** substances.

Explain how the strongest pieces of evidence support your claim.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Homework: Comparing Different Substances at Home

Look at the substances listed below. Pick two different substances that you have at home and observe them. Then, list the substances you selected and record their properties in the table. After you have completed the table, answer the questions below.

- wood
- plastic
- rubber
- cotton
- wool
- water
- metal
- honey
- leather
- paper
- milk
- glass
- sugar
- clay
- soap

	Observations
Substance 1:	
Substance 2:	

What properties do both substances have in common?

_____

_____

_____

What properties make the two substances different?

_____

_____

_____

Name: _____ Date: _____

Lesson 1.4: "Atomic Zoom-In"

You've learned that observing properties is useful in telling different substances apart, but why do substances have different properties anyway? Today, you will begin to investigate this question by watching a video and reading an article about atoms, the tiny pieces of matter that make up everything.

Unit Question

- How do new substances form?

Chapter 1 Question

- What is the reddish-brown substance in the water?

Key Concepts

- Different substances have different properties.

Vocabulary

- atoms
- property
- scale
- substance

Digital Tools

- Scale Tool

Name: _____ Date: _____

Warm-Up

The image below shows water and oil, which are two different substances with different properties.

Water

Oil

List one property that water and oil do not share.

_____

Why do you think water and oil have different properties? List your ideas below.

_____

_____

_____

_____

Name: _____ Date: _____

Reading "Atomic Zoom-In"

1. Read and annotate the article "Atomic Zoom-In."
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: Rewatching *Everything Is Made of Atoms*

1. Rewatch the *Everything Is Made of Atoms* video in Digital Resources.
2. Open the Scale Tool and find an atom.
3. Answer the question below.

Why can't you see individual atoms without special tools?

_____

_____

_____

_____

Name: _____ Date: _____

Lesson 1.5: Investigating Atoms and Properties

Now that you know that atoms make up all matter in the universe, it's time to investigate how atoms are related to the properties of substances we can observe. Today, you will explore a digital simulation that models substances at a scale our eyes simply cannot see. You'll then revisit the "Atomic Zoom-In" article and use it to help you determine why different substances have different properties. As student chemists, you will need to use more than just your senses to understand how and why substances are different.

Unit Question

- How do new substances form?

Chapter 1 Question

- What is the reddish-brown substance in the water?

Key Concepts

- Different substances have different properties.

Vocabulary

- atoms
- model
- property
- scale
- substance

Digital Tools

- *Chemical Reactions* Simulation

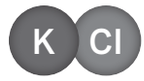
Name: _____ Date: _____

Warm-Up

Two of the samples you observed during a previous lesson are shown below with the group of atoms that repeat to make up each sample. Take a look at the samples and the groups of atoms using the atom key as a guide. Then, answer the questions below.

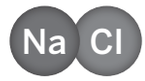
Sample 1

repeating group of atoms



Sample 2

repeating group of atoms



Atom Key

Based on this information, do you think samples 1 and 2 share all the same properties? (check one)

- ☐ yes
- ☐ no

Explain your answer.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Investigating Substances in the Sim

Part 1: Introducing the *Chemical Reactions* Simulation

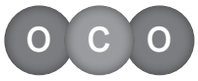
Launch the *Chemical Reactions* Simulation. As you explore the Sim, discuss the following questions with your partner:

- What do you notice about the different substances in Chemical Stockroom mode?
- How is observing substances in this mode different from observing substances in real life?
- What questions do you have about this mode?

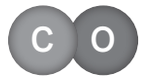
Part 2: Using the Chemical Stockroom to Compare Samples

With your partner, compare the atomic-scale models of the three samples shown below. Discuss how these models are similar and how they are different. Choose the claim about the samples you think fits best. Then, use the *Chemical Reactions* Simulation to gather evidence about these claims. When you are ready, answer the questions below.

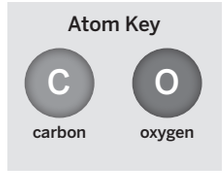
sample 1



sample 2



sample 3



Based on the atomic-scale models of the samples, which of the following claims do you think is best? (check one)

- ☐ **Claim 1:** All three samples have the same properties. Therefore, they are the same substance.
- ☐ **Claim 2:** Two samples have the same properties. Therefore, they are the same substance. However, one sample has a different set of properties. Therefore, this sample is a different substance.
- ☐ **Claim 3:** All three samples have different properties. Therefore, they are different substances.

Name: _____ Date: _____

Investigating Substances in the Sim (continued)

Find the substances represented by these models in the Chemical Stockroom mode of the Sim. Observe their properties. Then, answer the questions below.

Does the evidence from the Sim support the claim that you chose?

- ☐ yes
- ☐ no

What evidence did you find in the Sim to support your answer?

_____

_____

_____

_____

Based on my observations in the Sim, I think:

a. Sample 1 and sample 2 are (check one)

- ☐ the same substance with the **same** properties.
- ☐ different substances with **different** properties.

b. Sample 1 and sample 3 are (check one)

- ☐ the same substance with the **same** properties.
- ☐ different substances with **different** properties.

c. Sample 2 and sample 3 are (check one)

- ☐ the same substance with the **same** properties.
- ☐ different substances with **different** properties.

Name: _____ Date: _____

Second Read of "Atomic Zoom-In"

You are investigating the question: *Why do different substances have different properties?*

Reread the passage "How Atoms Make Your Orange Juice Smell Good and Your Socks Smell Bad" in the "Atomic Zoom-In" article. Also, review the diagrams associated with this text, gathering evidence about the Investigation Question. Then, use the evidence you gathered from the excerpt and diagrams to answer the question below.

How do the types and numbers of atoms that repeat to make up a substance affect its properties?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Homework: Modeling Samples in the Lab

In her lab, Dr. Yung has two samples that are both made up of hydrogen (H) and carbon (C) atoms. Some of the properties of each sample and a model of the repeating group of atoms that make up sample 1 are shown on the next page.

Use the Modeling Tool: Two Samples at the Atomic Scale student sheet on the next page to create a model that represents a repeating group of atoms that could make up sample 2. Follow the instructions below.

Goal: Create a model that represents a repeating group of atoms that could make up sample 2.

Do:

- For sample 2, draw a possible atomic-scale model.
- Optional: Color in the key and the atoms that make up samples 1 and 2 using the colors indicated on the atom key.

Tips:

- Refer to properties of each sample provided.
- There is more than one possible answer.

Name: _____ Date: _____

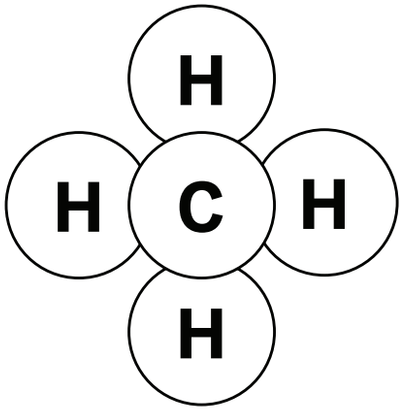
Modeling Tool: Two Samples at the Atomic Scale

Goal: Create a model that represents a repeating group of atoms that could make up sample 2.

Sample 1

Made of: hydrogen (H) and carbon (C)
Smell: odorless
Boils at: -164°C
Looks like: colorless gas

Repeating group of atoms:



Sample 2

Made of: hydrogen (H) and carbon (C)
Smell: similar to gasoline
Boils at: 36°C
Looks like: colorless liquid

Repeating group of atoms:

Key

Atom Name	Color in model
hydrogen	H white
carbon	C black

Name: _____ Date: _____

Lesson 1.6: Identifying the Reddish-Brown Substance

The people of Westfield are waiting anxiously for you to identify the mysterious reddish-brown substance in their water. Today, you will have a chance to review what you've learned during this chapter by discussing it with your fellow student chemists. You will then get some new information about the mysterious reddish-brown substance from Dr. Yung, which you will use to write an explanation to the people of Westfield. The identity of the reddish-brown substance in the water won't stay a mystery for much longer!

Unit Question

- How do new substances form?

Chapter 1 Question

- What is the reddish-brown substance in the water?

Key Concepts

- Different substances have different properties.
- Things that are too small (or too large) to see can be studied with models.
- Substances have different properties because they are made of different groups of atoms. These groups vary in the type or number of atoms that make up the group.
- Groups of atoms repeat to make up a substance.

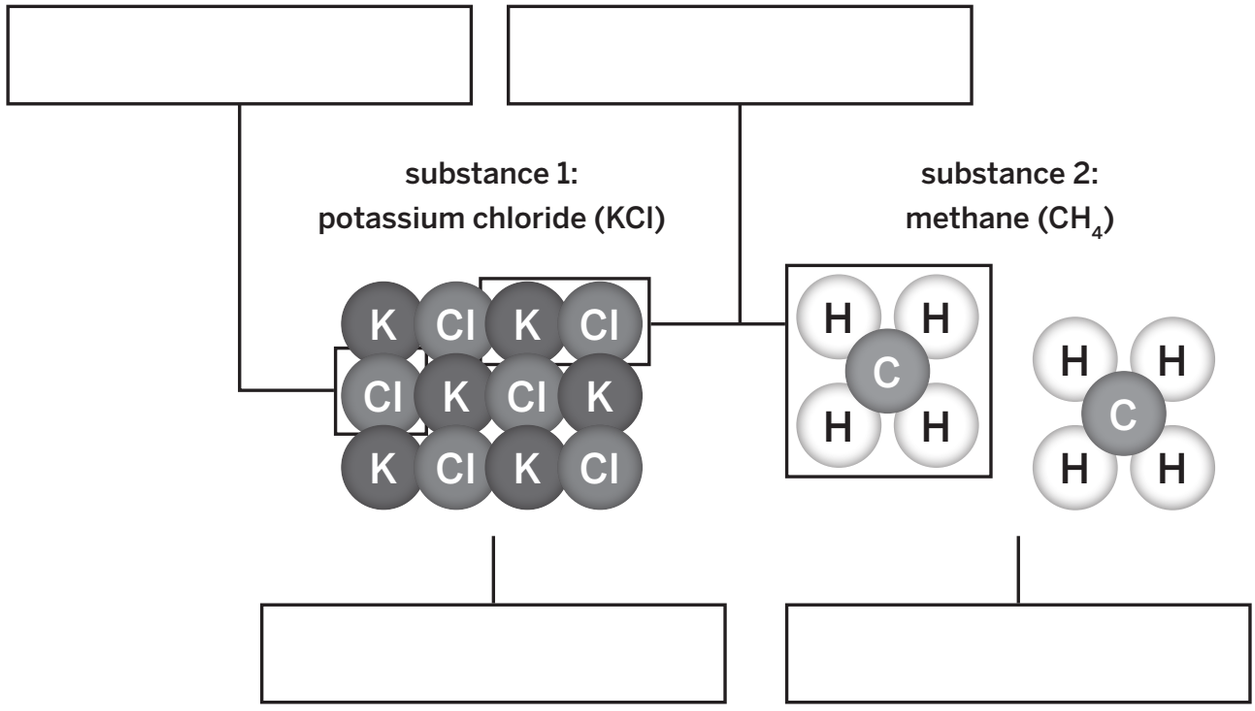
Vocabulary

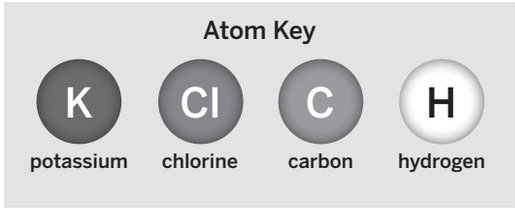
- atoms
- element
- model
- property
- scale
- substance

Name: _____ Date: _____

Warm-Up

Below are atomic-scale models of two different substances. Use the terms in the word bank to label these models. Use each of the terms only once.





Word Bank

atom	repeating atom group	extended structure	molecules

Name: _____ Date: _____

Word Relationships

With your partner, use the Word Relationships Cards to create sentences that answer the Investigation Question: *Why do different substances have different properties?*

- Use at least two words from the Word Relationships Cards in each sentence. Take turns as both the speaker and the listener.
- You and your partner may use the same word more than once. Try to use all the vocabulary words.
- There are many different sentences that could help to answer the Investigation Question. You and your partner will need to create multiple sentences in order to answer the question completely.

Word Bank

atoms	model	property	substance

Name: _____ Date: _____

Identifying the Reddish-Brown Substance

Part 1: Reviewing the Evidence

Go to pages 8–9 in your Investigation Notebook to review the properties of the pipes, the fertilizer, and the reddish-brown substance that you observed at the beginning of Chapter 1. With a partner discuss these observations and which claim is best supported by the evidence. Then, answer the question below.

Chapter 1 Question: *What is the reddish-brown substance in the water?*

Based on the evidence, which claim about the reddish-brown substance is best supported? (check one)

- ☐ **Claim 1:** The reddish-brown substance is the same as the substance that makes up the pipes.
- ☐ **Claim 2:** The reddish-brown substance is the same substance as the fertilizer.
- ☐ **Claim 3:** The reddish-brown substance is not the same as either the fertilizer or the substance that makes up the pipes.

Complete the following sentence based on the claim you chose:

The group of atoms that repeats to make up the reddish-brown substance . . . (check one)

- ☐ could be the same as the substance that makes up the pipes.
- ☐ could be the same as the fertilizer.
- ☐ could not be the same as either the fertilizer or the substance that makes up the pipes.

Name: _____ Date: _____

Identifying the Reddish-Brown Substance (continued)

Part 2: Examining Atomic-Scale Models

After analyzing the samples, Dr. Yung was able to model the atoms and groups of atoms that repeat to make up the pipe, the fertilizer, and the reddish-brown substance. Examine these models and use the discussion questions to discuss them with your partner. Then, choose the claim you think is best supported.

pipe

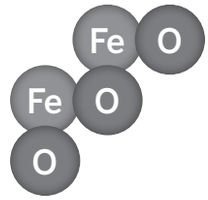
repeating atom: Fe

fertilizer

repeating group of atoms: $NaNO_3$

reddish-brown substance

repeating group of atoms: Fe_2O_3



Atom Key

Discussion Questions

- How are these models different from real life?
- What information do these models give you that you cannot get by just observing the substances?
- Do these models support the same claim as the observations you made?

Based on this evidence, which claim about the reddish-brown substance is best supported? (check one)

- ☐ **Claim 1:** The reddish-brown substance is the same as the substance that makes up the pipes.
- ☐ **Claim 2:** The reddish-brown substance is the same substance as the fertilizer.
- ☐ **Claim 3:** The reddish-brown substance is not the same as either the fertilizer or the substance that makes up the pipes.

Name: _____ Date: _____

Identifying the Reddish-Brown Substance (continued)

Part 3: Writing to the People of Westfield

Dr. Yung wants you to explain what the reddish-brown substance is to the people of Westfield. As you write your argument, remember to:

- state your claim about the identity of the reddish-brown substance.
- use evidence from both your observations and the atomic-scale models to support your claim.
- include the vocabulary words listed below in your argument.

Chapter 1 Question: *What is the reddish-brown substance in the water?*

Claim 1: The reddish-brown substance is the same as the substance that makes up the pipes.

Claim 2: The reddish-brown substance is the same substance as the fertilizer.

Claim 3: The reddish-brown substance is not the same as either the fertilizer or the substance that makes up the pipes.

Word Bank

atom	model	property	substance

Write an argument for the people of Westfield identifying the reddish-brown substance.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Homework: Revising an Explanation

Once you have finished writing your argument, go back and read it again. Try reading your argument out loud or asking another person to read it. Then, use the revision checklist below to see whether or not there are any changes you can make to improve the writing in your argument.

Revision Checklist

1. Did you clearly state a claim about the identity of the reddish-brown substance? (check one)

   ☐ yes ☐ no

2. Did you provide evidence from your observations that supports your claim? (check one)

   ☐ yes ☐ no

3. Did you provide evidence from the atomic-scale models that supports your claim? (check one)

   ☐ yes ☐ no

4. Did you thoroughly explain how these pieces of evidence support your claim? (check one)

   ☐ yes ☐ no

5. If you answered "no" to any of these questions, revise your writing to make it clearer and more convincing. If you need to, rewrite your argument below.

Write an argument for the people of Westfield identifying the reddish-brown substance.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

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 to the questions below.

Scientists investigate in order to figure things out. Am I getting closer to figuring out what made the water in Westfield turn reddish-brown?

1. I understand how to tell if the reddish-brown substance is the same as or different from the pipe and fertilizer. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

2. I understand how the reddish-brown substance formed. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

3. I understand why there might be something else in the water besides the reddish-brown substance. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

4. What do you still wonder about how substances form?

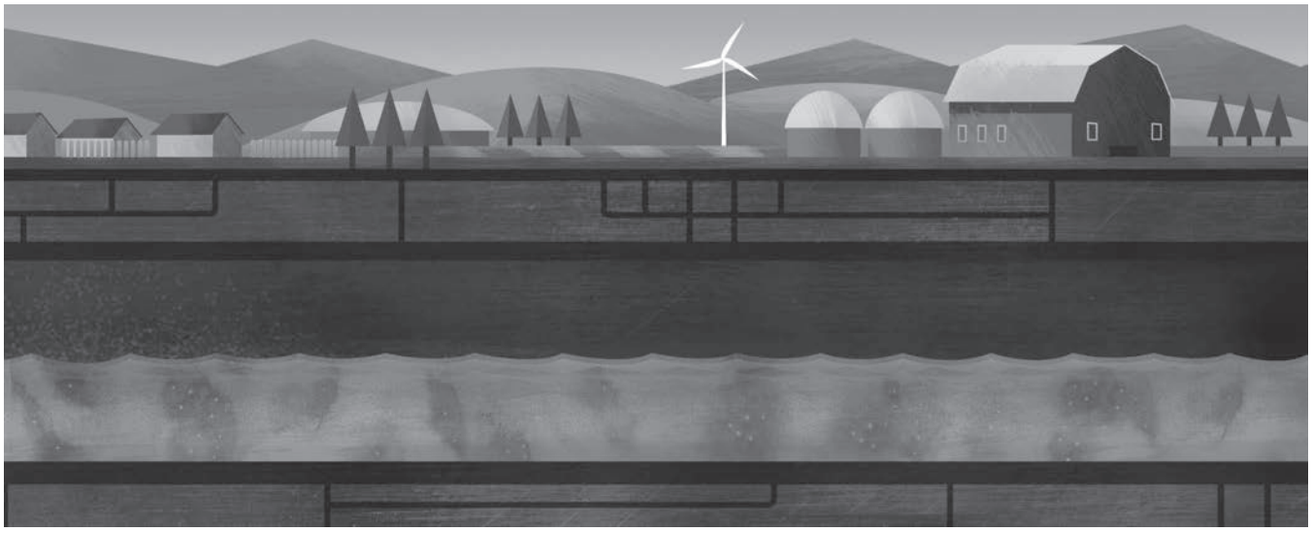
_____

_____

Name: _____ Date: _____

Chapter 2: Reactions
Chapter Overview

Now that you have identified the reddish-brown substance as rust, the people of Westfield want to know how rust formed in their water pipes. It is your job to explain how and why the rust ended up in Westfield's water. To do this, you'll need to figure out how substances form and whether one substance can change into another.



Name: _____ Date: _____

Lesson 2.1: Investigating Substance Changes

Now that you have identified the mysterious reddish-brown substance as rust, the people of Westfield need to know how the rust in their water formed. Could either the iron pipes or the fertilizer have changed into the rust found in Westfield's water? Today, you will begin to investigate this question by gathering evidence from a hands-on activity and Simulation, determining whether it is possible for substances to change into other substances.

Unit Question

- How do new substances form?

Chapter 2 Question

- How did the rust form?

Vocabulary

- atoms
- chemical reaction
- model
- product
- property
- reactant
- scale
- substance

Digital Tools

- *Chemical Reactions* Simulation

Name: _____ Date: _____

Warm-Up

Read the below message. Then, answer the questions that follow.

To: Student Chemists
From: Dr. Samara Yung, Lead Chemist
Subject: Water Crisis in Westfield

You did a nice job in identifying the mysterious substance as rust! The people of Westfield are very grateful for your explanation. However, they now want to know where the rust came from and how it got into their water.

Rust can form naturally over time when iron is exposed to water or air. I looked at another neighborhood that uses a similar well system to see if they have rust in their water, too. However, none of the neighbors reported a problem with rusty water. I also didn't find any fertilizer in the water sample I took from their well. It seems something unusual is causing the rust to form in Westfield's pipes.

I need you to keep investigating how the rust formed. Before you get started, here are three claims for you to consider:

- **Claim 1:** The iron pipes changed into rust.
- **Claim 2:** The fertilizer changed into rust.
- **Claim 3:** The iron pipes and the fertilizer changed into rust.

Good luck! The people of Westfield are waiting for an answer.

Which of Dr. Yung's claims seems the most likely to you right now? (check one)

- ☐ **Claim 1:** The iron pipes changed into rust.
- ☐ **Claim 2:** The fertilizer changed into rust.
- ☐ **Claim 3:** The iron pipes and the fertilizer changed into rust.

Name: _____ Date: _____

Investigating Substance Changes

Safety Note: Using Chemicals

Do not taste or touch the substances in the investigation. Remember to mix substances only when your teacher prompts you to do so. Use safety goggles as directed by your teacher. If the substances get on your skin or clothes, rinse the substance off with water for several minutes. If you get a substance in your eyes, rinse your eyes with water for 15 minutes.

Chemical Warning

The *Chemical Reactions* kit contains chemicals that may be harmful if misused. Read cautions on individual containers carefully. These chemicals are not to be used without adult supervision. Chemicals used in this activity are:

- Calcium chloride ($CaCl_2$)
- Sodium carbonate (Na_2CO_3)

Look at the Safety Guidelines on page 1 before you begin your investigation.

Investigation Question: *Can substances change into different substances?* (check one)

☐ yes

☐ no

Name: _____ Date: _____

Investigating Substance Changes (continued)

Complete this hands-on activity as you begin to investigate the question: *Can substances change into different substances?*

Preparation

1. Put on your safety goggles.
2. Familiarize yourself with the materials on your tray.

Initial Observations

3. Do not mix any liquids yet. Never taste or smell anything.
4. Record the properties of each substance in the data table below. **Reminder:** Properties are things such as color, texture, and phase at room temperature.

Combining Substances

5. Slowly pour the entire contents of each cup into the cup labeled "product."
6. Do not stir the product. It's important that you not move the cup.
7. Observe what happens in the product cup for at least one minute.
8. Record the properties of the substance or substances inside the product cup.

Before combining		**After combining**
Substance 1: calcium chloride ($CaCl_2$), dissolved in water	Substance 2: sodium carbonate (Na_2CO_3), dissolved in water	Product

What happened when you combined the two substances together in the cup? (check one)

- ☐ The substances changed into different substances.
- ☐ The substances did not change into different substances.
- ☐ I am not sure if the substances changed into different substances.

Name: _____ Date: _____

Mixing Substances in the Sim

Part 1: Exploring Laboratory A Mode

Launch the *Chemical Reactions* Sim. As you explore Laboratory A mode, discuss the following questions with your partner:

- What can you do with different substances in Laboratory A mode?
- What details can you observe about the substances in Laboratory A mode?
- When you review the test results at the end, what other features do you notice?
- What questions do you have about Laboratory A mode?

Part 2: Mixing Substances in the Sim

With a partner, gather evidence by observing what happens when you mix two substances together in the Sim. The two substances are the same two substances you mixed together in the investigation earlier in this lesson. Look for additional evidence that will help you to answer the Investigation Question: *Can substances change into different substances?*

1. In Laboratory A mode, press the Add Substance button and choose calcium chloride ($CaCl_2$).
2. Press the Add Substance button and choose sodium carbonate (Na_2CO_3).
3. Press TEST and observe what happens.
4. Press RESULTS and examine the results.
5. Press REVIEW and compare the substances at the Test Start and Test End.
6. Turn on View Atomic Scale and View Properties toggles.
7. Use evidence from the final review screen to help you answer the questions below.

What happened when you combined the two substances together in the cup? (check one)

- ☐ The substances changed into different substances.
- ☐ The substances did not change into different substances.
- ☐ I am not sure if the substances changed into different substances.

Name: _____ Date: _____

Mixing Substances in the Sim (continued)

Explain your answer using evidence from the Sim.

_____

_____

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Reflecting on the Investigation Question

Based on the evidence you collected in the hands-on activity and the Sim, answer the Investigation Question. Then, answer the discussion questions by sharing your supporting evidence with your partner.

Can substances change into different substances? (check one)

- ☐ yes
- ☐ no

Discussion Questions

- What evidence did you gather from the hands-on investigation that supports your claim?
- What evidence did you gather from the Sim investigation that supports your claim?

Name: _____ Date: _____

Homework: Reading "Synthetic Materials: Making Substances in the Lab"

To learn how scientists apply their knowledge of substances at the atomic scale to create synthetic materials, read and annotate the "Synthetic Materials: Making Substances in the Lab" article. Then, answer the questions below.

How are synthetic substances made?

_____

_____

_____

At the atomic level, are synthetic medicines different from natural medicines? Explain your answer.

_____

_____

_____

Why is it useful to be able to produce synthetic medicines?

_____

_____

_____

_____

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 2.2: Explaining Chemical Reactions

You've discovered that substances can change into different substances during chemical reactions, but what actually happens during a chemical reaction? How do substances change into different substances? What do the starting substances (reactants) have to do with the ending substances (products)? In order to understand how the rust formed in their water, the people of Westfield need you to help them answer these questions. In this lesson, you will get one step closer to answering these questions by observing chemical reactions in the Sim and using tokens to investigate chemical reactions.

Unit Question

- How do new substances form?

Chapter 2 Question

- How did the rust form?

Key Concepts

- During a chemical reaction, one or more starting substances (reactants) change into one or more different substances (products).

Vocabulary

- atoms
- chemical reaction
- model
- product
- property
- reactant
- rearrange
- scale
- substance

Digital Tools

- *Chemical Reactions* Simulation
- Optional: *Chemical Reactions* Sorting Tool activity: Digital Token Model

Name: _____ Date: _____

Warm-Up

In the last lesson, Dr. Yung presented three claims about how the rust in Westfield's water might have formed:

Claim 1: The iron pipes changed into rust.

Claim 2: The fertilizer changed into rust.

Claim 3: The iron pipes and the fertilizer changed into rust.

You have already observed that when two substances are mixed together, a chemical reaction can change them into different substances. Now, use the Sim to test whether or not a chemical reaction can happen with only one substance.

1. Launch the Sim and open Laboratory A mode.
2. Press the Add Substance button and select water (H_2O). Do not add a second substance.
3. Press TEST and observe what happens.
4. After testing, use evidence from the final review screen to help you answer the question below.

Can a chemical reaction happen with only one substance? (check one)

☐ yes

☐ no

Name: _____ Date: _____

Finding Chemical Reactions

With a partner, complete the Sim mission below to help answer the Investigation Question: *How do substances change into different substances during chemical reactions?* As you work, remember to use the key concept: *During a chemical reaction, one or more starting substances (reactants) change into one or more different substances (products).*

Mission: Find two substances that react when mixed together and two substances that do not react when mixed together.

1. Launch the Sim and open Laboratory A mode.
2. Press the Add Substance button and select two substances of your choice.
3. Press TEST, then press RESULTS, then press REVIEW.
4. With your partner, discuss whether or not a chemical reaction occurred.
5. Carefully rewatch the atomic-scale animation.
    - If a chemical reaction occurred, answer question 1 below. If a chemical reaction did not occur, answer question 2 below.
6. Repeat the above steps with different substances until you have found two substances that react and two that do not react.
7. When you have finished your tests, answer question 3 below.

Question 1: When a chemical reaction occurs, what happens to the atoms of the two substances?

_____

_____

_____

Question 2: When a chemical reaction does not occur, what happens to the atoms of the two substances?

_____

_____

_____

Question 3: Did any of the atoms ever change type? (check one)

☐ yes

☐ no

Name: _____ Date: _____

Explaining Chemical Reactions

You are about to receive a Chemical Reaction Card as well as tokens that represent the different atoms in the reaction.

1. Examine the chemical reaction on your card to see which reactants and products are involved.
2. On your card, use the tokens to build the reactants.
3. Then, show your partner how the reactants become the products in your chemical reaction.
4. Answer the Investigation Question by using the tokens and the vocabulary words shown below to explain to your partner what is happening in your chemical reaction.

Investigation Question: *How do substances change into different substances during chemical reactions?*

Word Bank

atom	chemical reaction	model	product
property	reactant	substance	

Name: _____ Date: _____

Homework: Finding Single-Substance Reactions in the Sim

Mission: Find a chemical reaction that happens with only one substance.

1. Launch the Sim and open Laboratory A mode.
2. Press the Add Substance button and select one substance (other than water). Do not add a second substance.
3. Observe the Sim test to determine whether or not a chemical reaction occurred.
4. If a chemical reaction did occur, answer the question below.
5. If a chemical reaction did not occur, repeat with a different substance until you have observed a chemical reaction.

When a chemical reaction occurs with only one substance, what happens to the atoms of that substance?

_____

_____

_____

Name: _____ Date: _____

Lesson 2.3: Explaining How the Rust Formed

The people of Westfield know there is rust in their water, but they still don't know how it formed. In this lesson, you will answer this question for them, using what you have learned about chemical reactions to evaluate the three claims presented by Dr. Yung. Once you have chosen a claim, you will create a visual model of how the rust formed. This model will help you write to the people of Westfield, explaining how the rust in their water formed.

Unit Question

- How do new substances form?

Chapter 2 Question

- How did the rust form?

Key Concepts

- During a chemical reaction, one or more starting substances (reactants) change into one or more different substances (products).
- During a chemical reaction, atoms do not change from one type to another.
- During a chemical reaction, atoms rearrange to form different groups of atoms.

Vocabulary

- atoms
- chemical reaction
- model
- product
- property
- reactant
- rearrange
- scale
- substance

Digital Tools

- Optional: *Chemical Reactions* Sorting Tool activity: Digital Token Model

Name: _____ Date: _____

Warm-Up

It is almost time to explain to the people of Westfield how the rust in their water formed. What have you learned so far about how new substances form? List your ideas below.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Testing the Claims

With a partner, use the tokens to test each of Dr. Yung's three claims. Discuss whether the atoms of the substance or substances in each claim could possibly rearrange to form rust. Then, record which of the claims you think is possible.

iron pipes

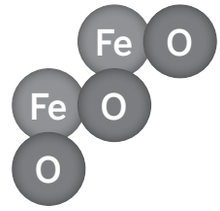
repeating atom: Fe

fertilizer

repeating group of atoms: $NaNO_3$

rust

repeating group of atoms: Fe_2O_3



Atom Key

Claim 1: The iron pipes changed into rust. (check one)

- ☐ A chemical reaction of the iron pipes **could** form rust
- ☐ A chemical reaction of the iron pipes **could not** form rust.

Claim 2: The fertilizer changed into rust. (check one)

- ☐ A chemical reaction of the fertilizer **could** form rust.
- ☐ A chemical reaction of the fertilizer **could not** form rust.

Claim 3: The iron pipes and the fertilizer changed into rust. (check one)

- ☐ A chemical reaction of the iron pipes and fertilizer **could** form rust.
- ☐ A chemical reaction of the iron pipes and fertilizer **could not** form rust.

Name: _____ Date: _____

Modeling How the Rust Formed

Use the directions below and complete the Modeling Tool activity: How the Rust Formed on the next page to help you explain to the people of Westfield how the rust in their water formed.

Goal: Show how the iron pipes and fertilizer changed into rust.

Do:

- In the Before space, draw the iron pipes and fertilizer before they changed into rust.
- In the After space, draw the rust.
- In the During the change space, draw or describe how the iron pipes and fertilizer changed into rust.
- Label your model or create a key.

Tips:

- Use the Substance Reference Guide if you need to.
- You can draw more than one repeating group of atoms for a substance if needed.

Substance Reference Guide

iron pipes

properties
- gray
- solid at room temperature

repeating atom: Fe

fertilizer

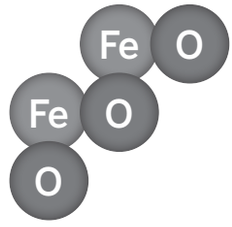
properties
- white
- solid at room temperature

repeating group of atoms: $NaNO_3$

rust

properties
- reddish-brown
- solid at room temperature

repeating group of atoms: Fe_2O_3

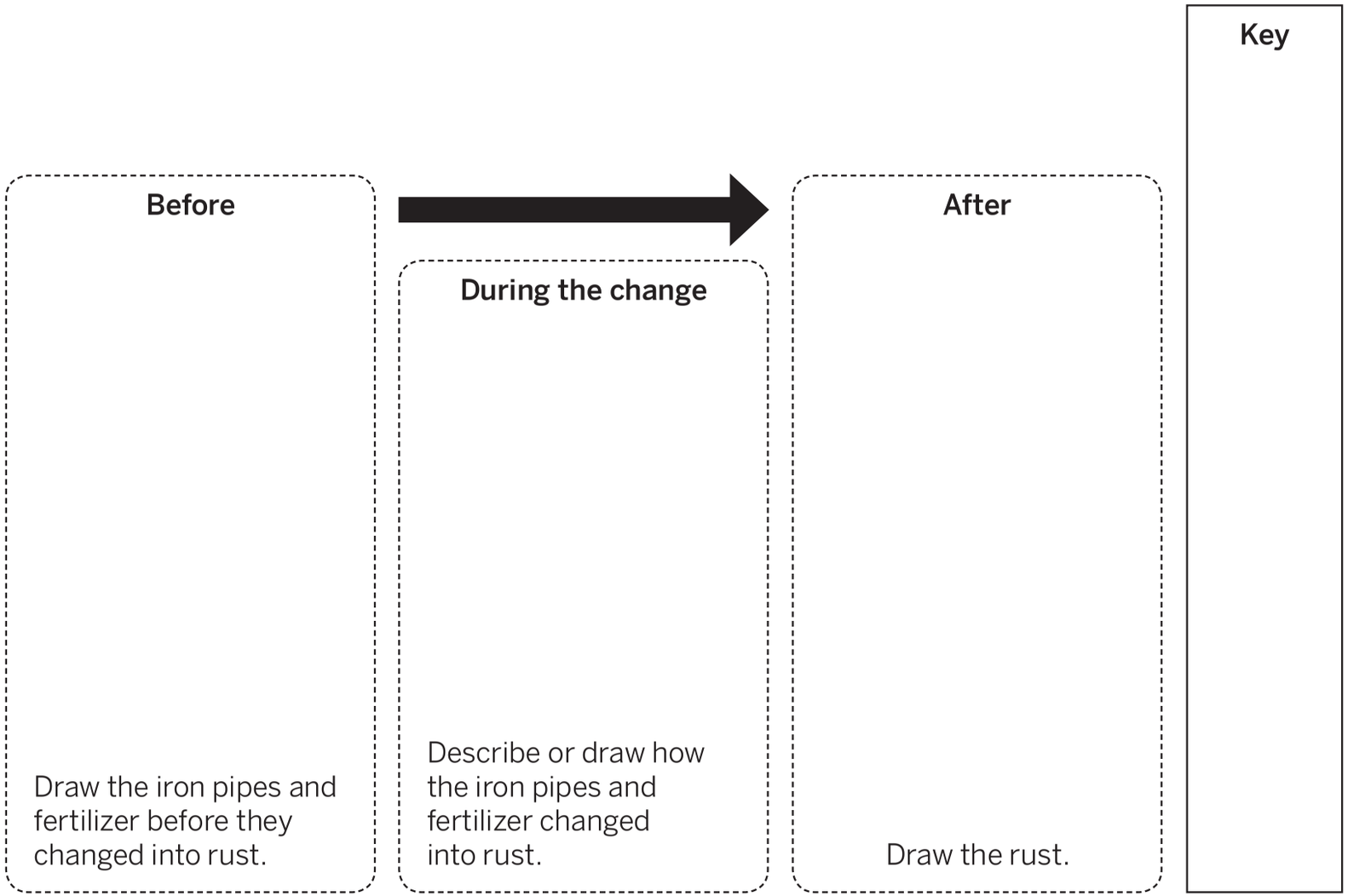


Atom Key

Name: _____ Date: _____

Modeling Tool: How the Rust Formed

Goal: Make a model that explains how the iron pipes and fertilizer changed into rust.



Name: _____ Date: _____

Writing to Westfield

Use the model you created to help you write an argument for the people of Westfield in which you support a claim about how the rust in their water formed. As you write your argument, remember to:

- State your claim about how the rust formed.
- Use evidence from the token activity to support your claim.
- Include vocabulary terms from the word bank below in your argument.

Chapter 2 Question: *How did the rust form?*

Claim 1: The iron pipes changed into rust.

Claim 2: The fertilizer changed into rust.

Claim 3: The iron pipes and the fertilizer changed into rust.

Word Bank

atoms	chemical reactions	model	product
reactant	rearrange	substance	

Explain to the people of Westfield how the rust in their water formed.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Homework: Revising an Argument

Once you have finished writing your argument, go back and read it again. Try reading your argument out loud or asking another person to read it. Then, use the revision checklist below to see whether or not there are any changes you can make to improve the writing in your argument.

Revision Checklist

1. Did you clearly state a claim about how the rust formed? (check one)

   ☐ yes ☐ no

2. Did you provide evidence from the token activity that supports your claim? (check one)

   ☐ yes ☐ no

3. Did you thoroughly explain how the evidence supports your claim? (check one)

   ☐ yes ☐ no

If you answered *no* to any of these questions, revise your writing to make it clearer and more convincing. If you need to, rewrite your argument.

Explain to the people of Westfield how the rust in their water formed.

_____

_____

_____

_____

_____

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_____

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_____

_____

Name: _____ Date: _____

Homework: Reading "Meet a Scientist Who Preserves Artwork"

You have used your knowledge of chemical reactions to figure out what is going on with Westfield's water. To learn about a scientist who uses chemical reactions in her work, read and annotate the "Meet a Scientist Who Preserves Artwork" article. Then, answer the question below.

What is one interesting thing you learned from this article?

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

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 2.5: Reflecting on Chemical Reactions

One of Dr. Yung's students, Lee, has been doing some experiments in the lab. He ended up with some surprising results; however, Lee isn't quite sure what happened. Lee is asking for help from student chemists. With your knowledge of substances, atoms, and chemical reactions, he thinks you will be able to help him explain what is going on. Are you up for the challenge?

Unit Question

- How do new substances form?

Chapter 2 Question

- How did the rust form?

Key Concepts

- Different substances have different properties.
- Things that are too small (or too large) to see can be studied with models.
- Substances have different properties because they are made of different groups of atoms. These groups vary in the type or number of atoms that make up the group.
- Groups of atoms repeat to make up a substance.
- During a chemical reaction, one or more starting substances (reactants) change into one or more different substances (products).
- During a chemical reaction, atoms do not change from one type to another.
- During a chemical reaction, atoms rearrange to form different groups of atoms.

Vocabulary

- atoms
- chemical reaction
- model
- product
- property
- reactant
- rearrange
- scale
- substance

Digital Tools

- *Chemical Reactions* Simulation

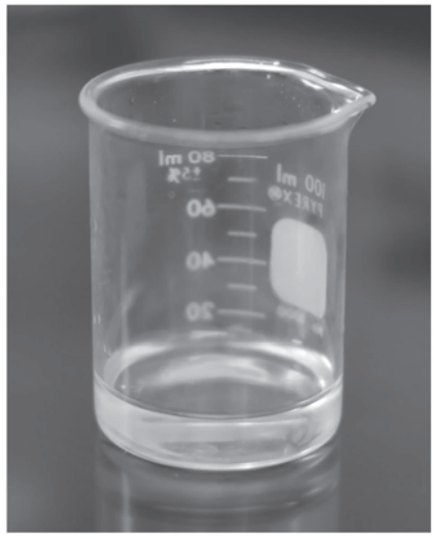
Name: _____ Date: _____

Green Group: Warm-Up

Lee, a student working with Dr. Yung, has been conducting some experiments. He combined sodium and hydrogen chloride and ended up with some interesting results. He would like to explain the experiment to his classmates, but he does not understand what happened. Can you help Lee?

In a few minutes, you will see a video of what happened when Lee combined two substances. Images of the starting substances are shown below. Before you watch the video, examine these images and write detailed observations about the properties of each substance. **Remember:** A property is something that can be observed about a substance, such as color, smell, or boiling point.

sodium



hydrogen chloride

Observe the image of sodium. List the properties you see.

_____

_____

_____

Observe the image of hydrogen chloride. List the properties you see.

_____

_____

_____

Name: _____ Date: _____

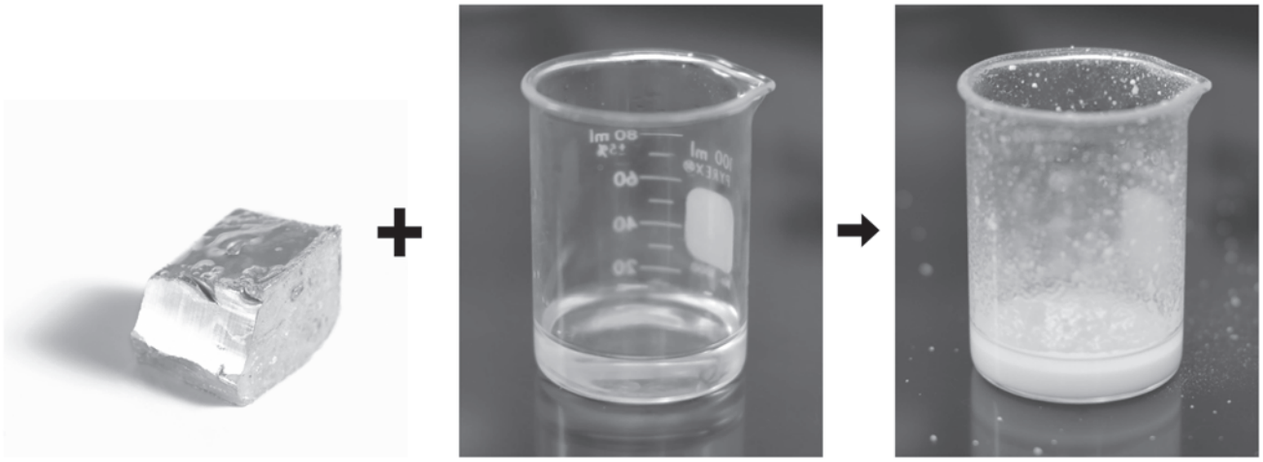
Green Group: Analyzing the Results of the Experiment

Part 1: Making Detailed Observations

Below are images of sodium and hydrogen chloride before they were mixed together. There is also an image of the results, which was taken after sodium and hydrogen chloride were mixed together.

1. With a partner, compare the properties of sodium and hydrogen chloride you observed during the Warm-Up.
2. Work together to observe the results image. Record the properties you see.
3. Then, answer the questions below.

Remember: Different substances have different properties.



sodium hydrogen chloride results

List the properties you see for sodium:	List the properties you see for hydrogen chloride:	List the properties you see for the results:

Name: _____ Date: _____

Green Group: Analyzing the Results of the Experiment (continued)

Based on these properties, how many different substances were involved in the video? (check one)

- ☐ one substance
- ☐ two substances
- ☐ three substances
- ☐ more than three substances

Use the properties you observed to explain your answer.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Green Group: Analyzing the Results of the Experiment (continued)

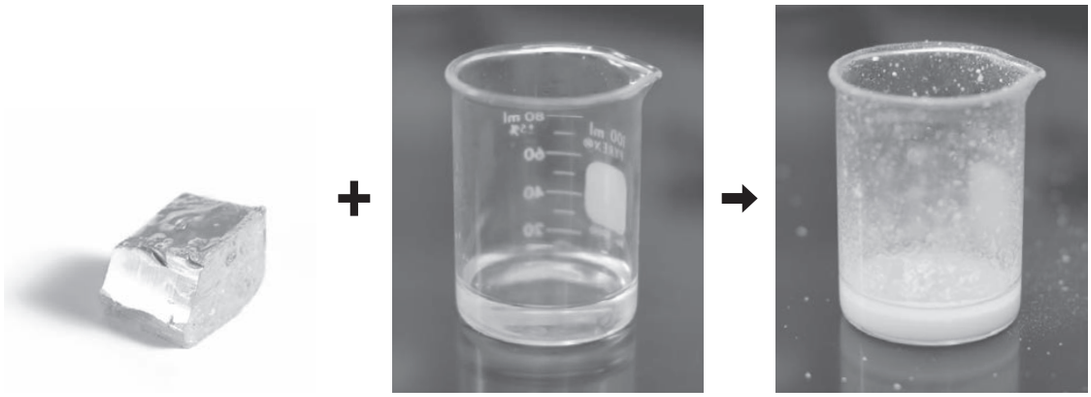
Part 2: Thinking About the Experiment at the Atomic Scale

Although you couldn't see them, all the substances in the video (the sodium, hydrogen chloride, and the results) are made up of atoms. Models of repeating atoms or repeating groups of atoms that make up the sodium, the hydrogen chloride, and the results are shown below.

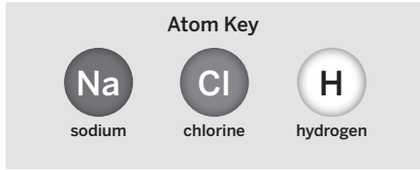
1. With a partner, examine the atomic-scale models shown below.
2. Then, answer the questions.

Remember:

- Substances have different properties because they are made of different groups of atoms. These groups vary in the type or number of atoms that make up the group.
- Groups of atoms repeat to make up a substance.



sodium hydrogen chloride results



Based on the groups of atoms shown above, how many different substances were involved in the video? (check one)

- ☐ one substance
- ☐ two substances
- ☐ three substances
- ☐ more than three substances

Name: _____ Date: _____

Green Group: Analyzing the Results of the Experiment (continued)

Explain your answer.

_____

_____

_____

What do the atomic-scale models show you that your observations of properties cannot?

_____

_____

_____

Name: _____ Date: _____

Green Group: Analyzing the Results of the Experiment (continued)

Part 3: Investigating the Experiment in the Sim

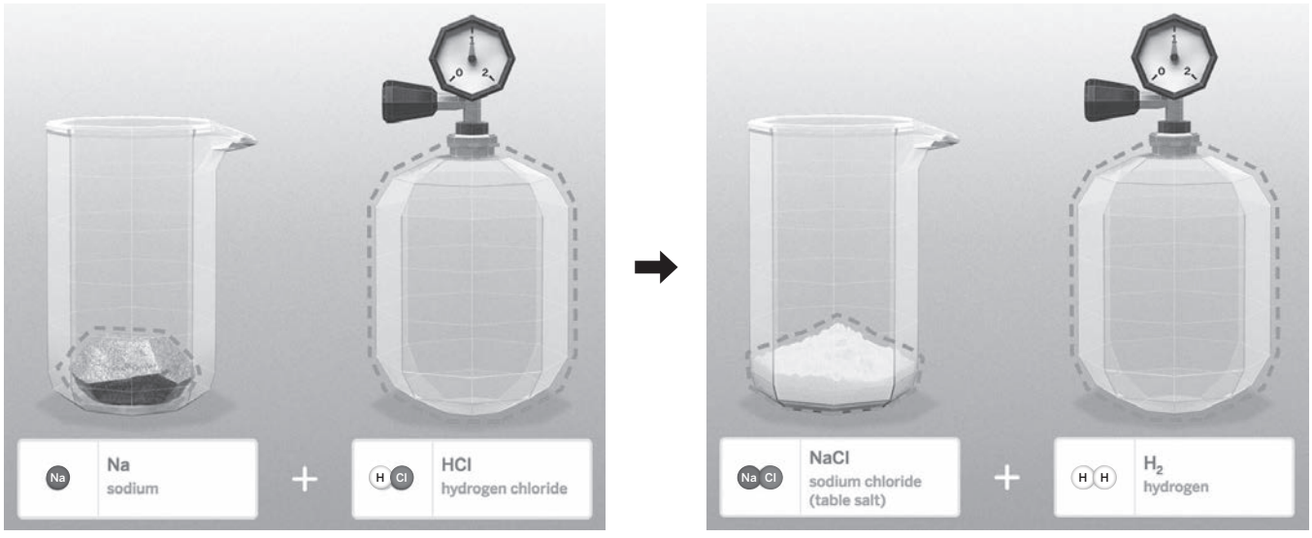
Based on your observations of properties and the atomic-scale models, you may have noticed that when Lee combined the sodium and hydrogen chloride, these two substances, called the reactants, changed into two different substances: the products. How is that possible?

You may realize that what happened in the video is called a chemical reaction. You will now use the Sim to further explore this chemical reaction.

1. Launch the Sim and open Laboratory A mode.
2. Press the Add Substance button and select sodium (Na) and hydrogen chloride (HCl). Then, press TEST.
3. Watch the atomic-scale animation, replaying if necessary. Press RESULTS. Then, press REVIEW.
4. Discuss the question below with a partner.

Remember:

- During a chemical reaction, atoms do not change from one type to another.
- During a chemical reaction, atoms rearrange to form different groups of atoms.



Note: You may notice that hydrogen chloride appears as a gas in the Sim and as a liquid in the video. This is because the hydrogen chloride in the video was dissolved in water. The chemist did this to make it easier to mix the substances together. The water will not affect the reaction.

Discuss the following with your partner: How did sodium and hydrogen chloride change into two different substances?

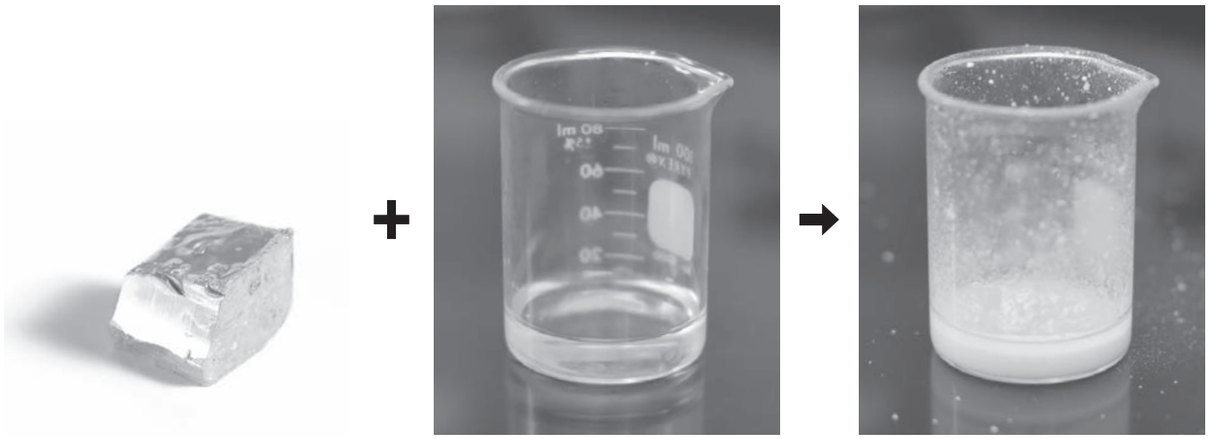
Name: _____ Date: _____

Green Group: Analyzing the Results of the Experiment (continued)

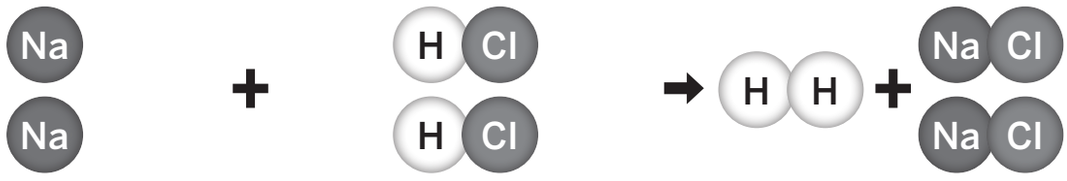
Part 4: Using Tokens to Explain the Experiment

You now know that the *Sodium and Hydrogen Chloride* video showed a chemical reaction. Two substances, sodium and hydrogen chloride, changed into two different substances, hydrogen and sodium chloride. You observed this reaction in the video and in the Sim. Now it is time to explain this reaction to Lee, so he can tell his classmates what happened.

1. Using the tokens provided by your teacher, build the reactants from this experiment.
2. Then, use the same tokens used for the reactants to build the products.
3. As you build the products, discuss the following question with a partner: *How did sodium and hydrogen chloride change into different substances?*
4. Use the following vocabulary words in your discussion: *atom, chemical reaction, products, reactants,* and *rearrange.*



sodium (reactant) **hydrogen chloride (reactant)** **results (products)**



Atom Key

Na sodium — Cl chlorine — H hydrogen

Note: You may notice that more than one atom of sodium and more than one group of hydrogen chloride is needed for this reaction.

Name: _____ Date: _____

Green Group: Analyzing the Results of the Experiment (continued)

How did sodium and hydrogen chloride change into two different substances? (Be sure to use key concepts and provide examples from the Sim or the token activity in your explanation.)

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

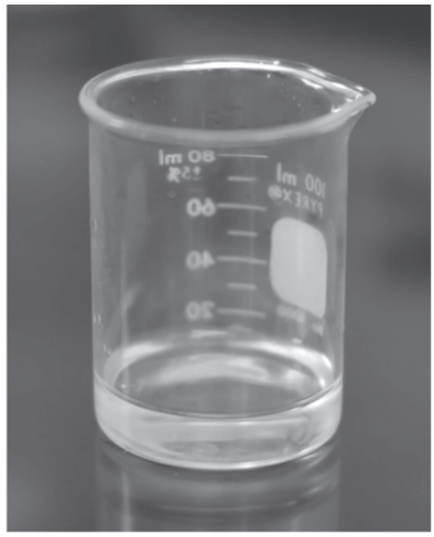
Name: _____ Date: _____

Purple Group: Warm-Up

Lee, a student working with Dr. Yung, has been conducting some experiments. He combined sodium and hydrogen chloride and ended up with some interesting results. He would like to explain the experiment to his classmates, but he does not understand what happened. Can you help Lee?

In a few minutes, you will see a video of what happened when Lee combined two substances. Images of the starting substances are shown below. Before you watch the video, examine these images and write detailed observations about the properties of each substance. **Remember:** A property is something that can be observed about a substance, such as color, smell, or boiling point.

sodium



hydrogen chloride

Observe the image of sodium. List the properties you see.

_____

_____

_____

Observe the image of hydrogen chloride. List the properties you see.

_____

_____

_____

Name: _____ Date: _____

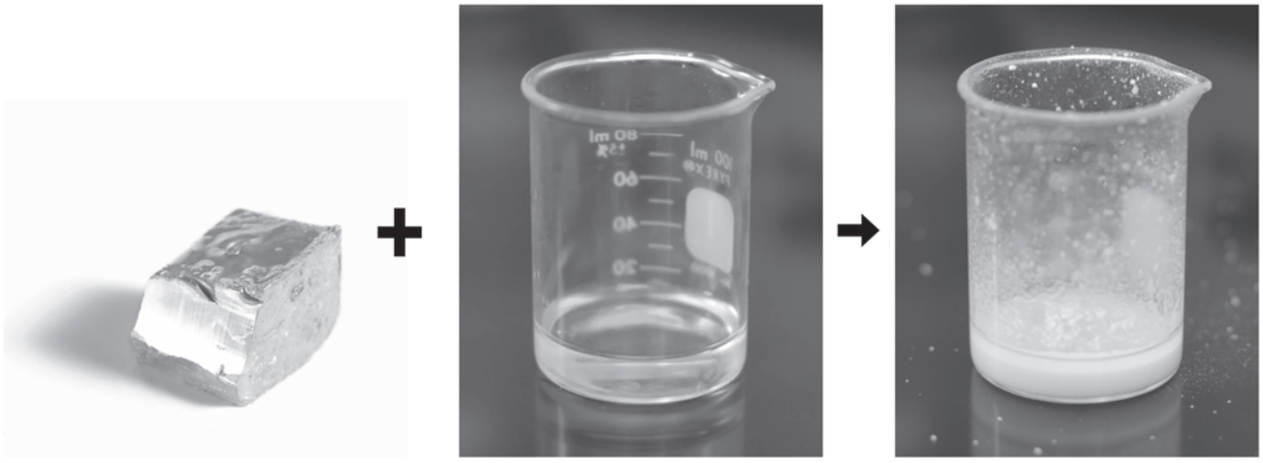
Purple Group: Analyzing the Results of the Experiment

Part 1: Making Detailed Observations

Below are images of sodium and hydrogen chloride before they were mixed together. There is also an image of the results, which was taken after sodium and hydrogen chloride were mixed together.

1. With a partner, compare the properties of sodium and hydrogen chloride you observed during the Warm-Up.
2. Work together to observe the results image. Record the properties you see.
3. Then, answer the questions below.

Remember: During a chemical reaction, one or more starting substances (reactants) change into one or more different substances (products).



sodium hydrogen chloride results

List the properties you see for sodium:	List the properties you see for hydrogen chloride:	List the properties you see for the results:

Name: _____ Date: _____

Purple Group: Analyzing the Results of the Experiment (continued)

Do you think a chemical reaction occurred? Use your observations to explain your answer.

_____

_____

_____

_____

_____

_____

Part 2: Thinking About the Experiment at the Atomic Scale

In order to know what really happened during Lee's experiment, we need to look at the atomic scale. Models of repeating atoms or repeating groups of atoms that make up the sodium, the hydrogen chloride, and the results are shown on the next page.

1. With a partner, examine the atomic-scale models shown on the next page.
2. Then, answer the questions.

Remember: During a chemical reaction, one or more starting substances (reactants) change into one or more different substances (products).

Name: _____ Date: _____

Purple Group: Analyzing the Results of the Experiment (continued)

sodium

hydrogen chloride

results

Atom Key

sodium chlorine hydrogen

Do you think a chemical reaction occurred? Use the atomic-scale models to explain your answer.

_____

_____

_____

_____

What do the atomic-scale models show you that your observations of properties cannot?

_____

_____

_____

_____

Name: _____ Date: _____

Purple Group: Analyzing the Results of the Experiment (continued)

Part 3: Investigating the Experiment in the Sim

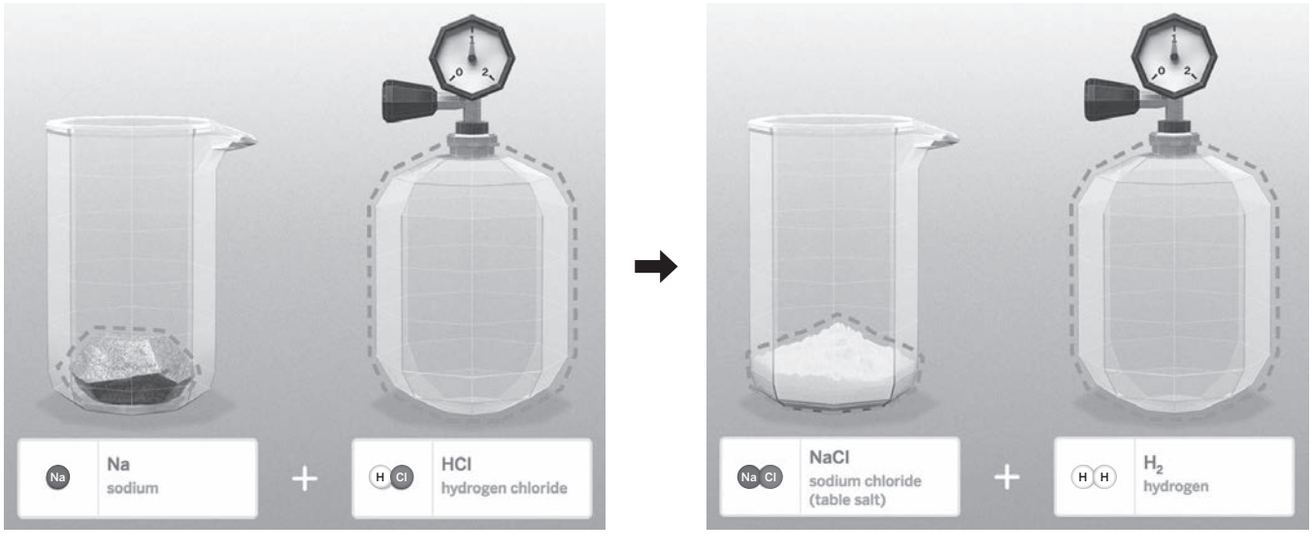
Based on your observations of properties and the atomic-scale models, you may have noticed that when Lee combined the sodium and hydrogen chloride, these two substances, called the reactants, changed into two different substances: the products. How is that possible?

You may realize that what happened in the video is called a chemical reaction. You will now use the Sim to further explore this chemical reaction.

1. Launch the Sim and open Laboratory A mode.
2. Press the Add Substance button and select sodium (Na) and hydrogen chloride (HCl). Then, press TEST.
3. Watch the atomic-scale animation, replaying if necessary. Press RESULTS. Then, press REVIEW.
4. Discuss the question below with a partner.

Remember:

- During a chemical reaction, atoms do not change from one type to another.
- During a chemical reaction, atoms rearrange to form different groups of atoms.



Note: You may notice that hydrogen chloride appears as a gas in the Sim and as a liquid in the video. This is because the hydrogen chloride in the video was dissolved in water. The chemist did this to make it easier to mix the substances together. The water will not affect the reaction.

Discuss the following with your partner: How did sodium and hydrogen chloride change into two different substances?

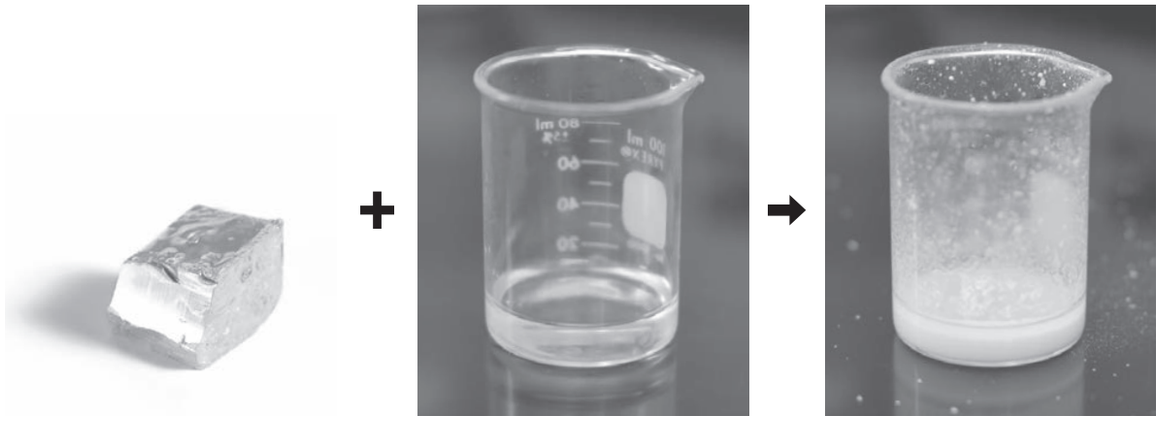
Name: _____ Date: _____

Purple Group: Analyzing the Results of the Experiment (continued)

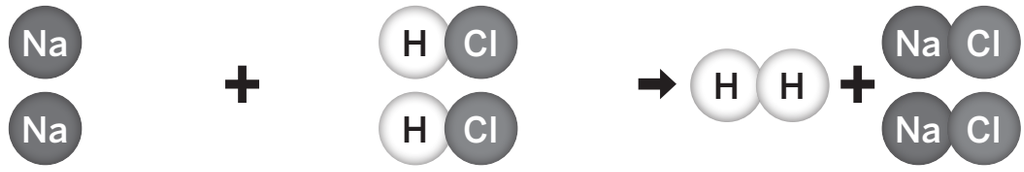
Part 4: Using Tokens to Explain the Experiment

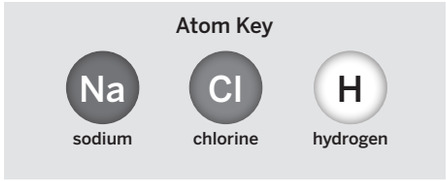
You now know that the *Sodium and Hydrogen Chloride* video showed a chemical reaction. Two substances, sodium and hydrogen chloride, changed into two different substances, hydrogen and sodium chloride. You observed this reaction in the video and in the Sim. Now it is time to explain this reaction to Lee, so he can tell his classmates what happened.

1. Using the tokens provided by your teacher, build the reactants from this experiment.
2. Then, use the same tokens used for the reactants to build the products.
3. As you build the products, discuss the following question with a partner: *How did sodium and hydrogen chloride change into different substances?*
4. Use the following vocabulary words in your discussion: *atom, chemical reaction, products, reactants,* and *rearrange.*



sodium (reactant) hydrogen chloride (reactant) results (products)





Note: You may notice that more than one atom of sodium and more than one group of hydrogen chloride is needed for this reaction.

Name: _____ Date: _____

Purple Group: Analyzing the Results of the Experiment (continued)

How did sodium and hydrogen chloride change into two different substances? (Be sure to use key concepts and provide examples from the Sim or the token activity in your explanation.)

Name: _____ Date: _____

Blue Group: Warm-Up

Lee and some other students working with Dr. Yung were conducting an experiment and ended up with some confusing results. In the experiment, each student combined sodium and hydrogen chloride, but, as shown in the table below, each student ended up with different results. Lee is trying to determine what happened.

In a few minutes, you will see a video of what happened when Lee combined two substances. Before you watch the video, see if you can predict why each student ended up with different results.

Student's name	**Starting substance**	**Ending substance**
Lee	sodium and hydrogen chloride	hydrogen and sodium chloride
Vera	sodium and hydrogen chloride	hydrogen, sodium chloride, and sodium
Domingo	sodium and hydrogen chloride	hydrogen, sodium chloride, and hydrogen chloride

Why do you think Vera and Domingo ended up with three substances after the chemical reaction while Lee only ended up with two?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Blue Group: Analyzing the Results of the Experiment

Part 1: Exploring in Laboratory B Mode

Launch the Sim. Open Laboratory B mode and explore with your partner. Share what you both notice.

As you explore Laboratory B mode, discuss the following question with your partner: *What can you do in this mode of the Sim that you could not do before?*

Name: _____ Date: _____

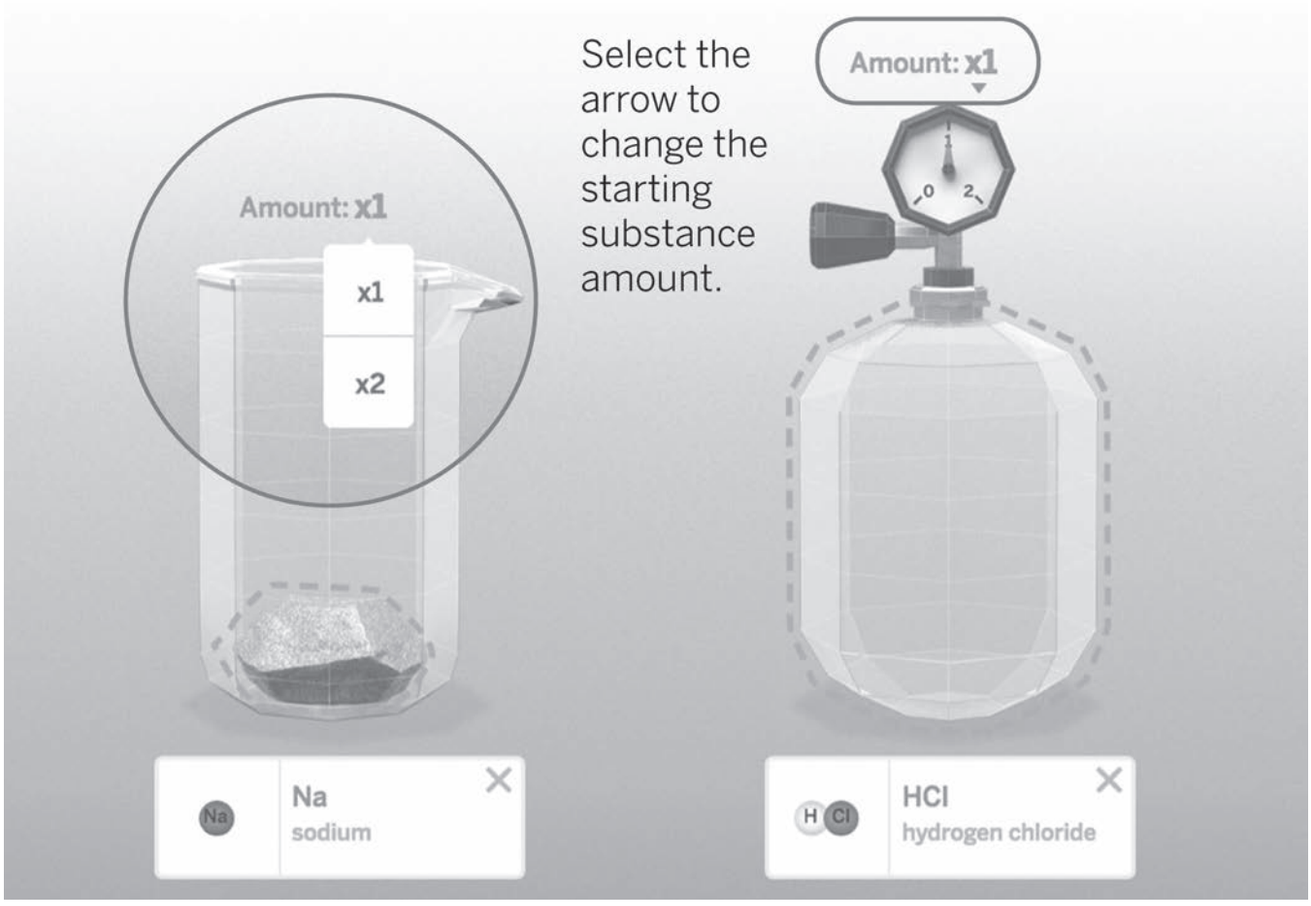
Blue Group: Analyzing the Results of the Experiment (continued)

Part 2: Investigating the Experiment in the Sim

You may have already noticed that in Laboratory B mode you can change the amount of the starting substances. You can add twice (x2) the amount of one or both of the starting substances. Now, you will use this mode of the Sim to see if you can re-create Lee, Vera, and Domingo's results from the Warm-Up.

Mission: Re-create Lee, Vera, and Domingo's results.

1. Launch the Sim and open Laboratory B mode.
2. Work with a partner to re-create Lee, Vera, and Domingo's results. Use the data table on the next page as a reference.
3. Record how you accomplished each mission on the next page.



Note: You may notice that hydrogen chloride appears as a gas in the Sim and as a liquid in the video. This is because the hydrogen chloride in the video was dissolved in water. The chemist did this to make it easier to mix the substances together. The water will not affect the reaction.

Name: _____ Date: _____

Blue Group: Analyzing the Results of the Experiment (continued)

Student's name	Starting substance	Ending substance
Lee	sodium and hydrogen chloride	hydrogen and sodium chloride
Vera	sodium and hydrogen chloride	hydrogen, sodium chloride, and sodium
Domingo	sodium and hydrogen chloride	hydrogen, sodium chloride, and hydrogen chloride

Explain how you re-created Lee's results.

_____

_____

_____

_____

Explain how you re-created Vera's results.

_____

_____

_____

_____

Explain how you re-created Domingo's results.

_____

_____

_____

_____

Name: _____ Date: _____

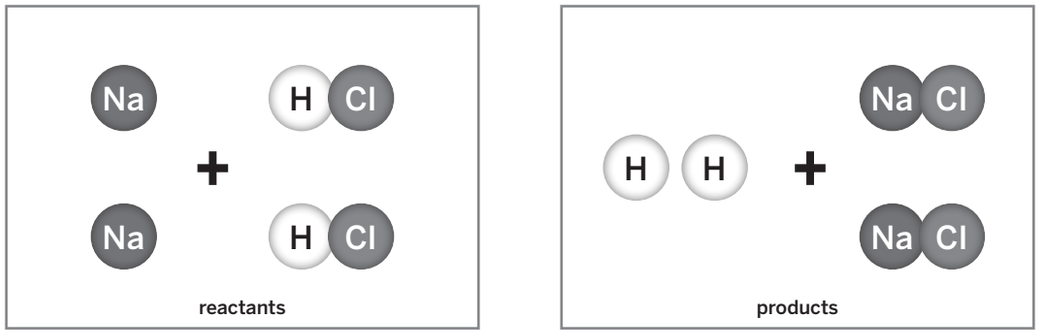
Blue Group: Analyzing the Results of the Experiment (continued)

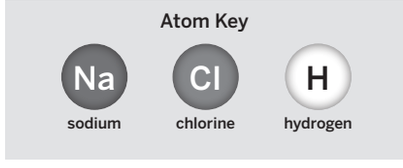
Part 3: Explaining the Experiment

Below you will see an atomic-scale model of the reaction from Lee's experiment. You will now use tokens to model how Vera and Domingo ended up with different results. Use your explanations from the Sim on page 76, if needed.

1. Using the tokens provided by your teacher, model the chemical reaction that produced Lee's results.
2. Then, use the tokens to model the chemical reaction that produced Vera's results.
3. Finally, use the tokens to model the chemical reaction that produced Domingo's results.
4. Discuss the similarities and differences between these three chemical reactions.
5. In the space below, write an explanation that explains why Lee, Vera, and Domingo each ended up with different results.

Lee's Experiment





Note: You may notice that more than one atom of sodium and more than one group of hydrogen chloride is needed for this reaction.

Explain why Lee, Vera, and Domingo all ended up with different results.

_____

_____

_____

Name: _____ Date: _____

Homework: Reading "Endothermic and Exothermic Reactions"

How do instant cold packs get cold? Why are fires hot? To find out, read and annotate the "Endothermic and Exothermic Reactions" article. Then, answer the questions below.

What is the difference between an *endothermic* and an *exothermic* reaction?

_____

_____

_____

_____

How does an instant cold pack get cold so quickly?

_____

_____

_____

_____

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: 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 to the questions below.

Scientists investigate in order to figure things out. Am I getting closer to figuring out what made the water in Westfield turn reddish-brown?

1. I understand how to tell if the reddish-brown substance is the same as or different from the pipe and fertilizer. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

2. I understand how the reddish-brown substance formed. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

3. I understand why there might be something else in the water besides the reddish-brown substance. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

4. What do you still wonder about how substances form?

_____

_____

Name: _____ Date: _____

Chapter 3: Accounting for Atoms
Chapter Overview

If the rust in Westfield's water formed during a chemical reaction between the iron pipes and the fertilizer, then could this chemical reaction have produced other substances as well? Before you can provide the people of Westfield with a complete answer, you'll need to determine what can happen to the atoms of substances during a chemical reaction.

Name: _____ Date: _____

Lesson 3.1: "What Happens When Fuels Burn?"

You have now solved two mysteries for the people of Westfield. You identified the reddish-brown substance in their water as rust, and you also explained that it formed from a chemical reaction between the iron pipes and the fertilizer. Now that the people of Westfield know that a chemical reaction produced the rust in their water, they are worried this reaction could have produced other substances. Today, you will begin your final investigation for the people of Westfield by watching a video and reading an article about what happens to atoms during a familiar type of chemical reaction: burning.

Unit Question

- How do new substances form?

Chapter 3 Question

- What was produced during the reaction between the iron pipes and the fertilizer?

Vocabulary

- atoms
- chemical reaction
- model
- product
- property
- reactant
- rearrange
- scale
- substance

Name: _____ Date: _____

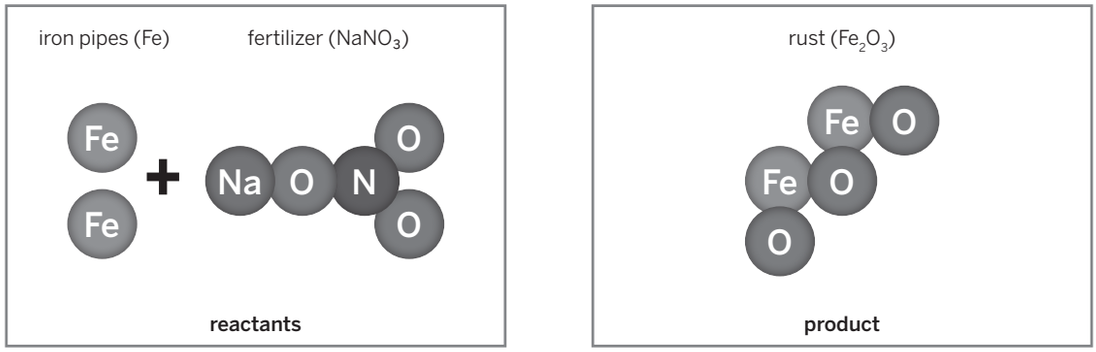
Warm-Up

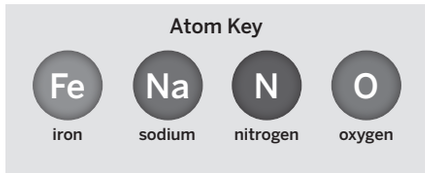
Read the message below and look at the diagram. Then, answer the question below.

To: Student Chemists
From: Dr. Samara Yung, Lead Chemist
Subject: One More Question

Thanks for your explanations. The people of Westfield now understand how the rust in their water could have formed from a chemical reaction between the iron pipes and the fertilizer. However, before the townspeople can consider this mystery solved, they need to be certain that the chemical reaction between the iron pipes and the fertilizer didn't produce any other substances, in addition to the rust, which could be dangerous to drink. You've done a good job so far, so I'm assigning this final investigation to you.

Review the atomic-scale model below, which is similar to the model you created in Chapter 2. This model shows the chemical reaction that formed the rust. If there are any other substances in the water, you should be able to find some clues here.





Did all the atoms that made up both reactants (the iron pipe and the fertilizer) rearrange to form the product (rust)? (check one)

☐ yes ☐ no

Name: _____ Date: _____

Reading "What Happens When Fuels Burn?"

1. Read and annotate the article "What Happens When Fuels Burn?"
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. (check one)

- ☐ 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: _____

Lesson 3.2: Burning at the Atomic Scale

What happens to atoms during a chemical reaction? Today, you will continue to investigate this question by looking more closely at what happens to the atoms of a substance when the substance burns. By using the Sim to observe substances burning at the atomic scale, and by revisiting the "What Happens When Fuels Burn?" article, you will begin to determine what can and cannot happen to atoms during a chemical reaction.

Unit Question

- How do new substances form?

Chapter 3 Question

- What was produced during the reaction between the iron pipes and the fertilizer?

Vocabulary

- atoms
- chemical reaction
- model
- product
- property
- reactant
- rearrange
- scale
- substance

Digital Tools

- *Chemical Reactions* Simulation

Name: _____ Date: _____

Warm-Up

Examine the image your teacher is projecting. Think about the *Burning Paper* video you watched during the last lesson. Then, answer the questions below.

What do you think happens to the atoms of a substance when it burns? (check one)

- ☐ **Claim 1:** All of the atoms are destroyed.
- ☐ **Claim 2:** All of the atoms rearrange to form a different substance or different substances.
- ☐ **Claim 3:** Some of the atoms are destroyed, and some of the atoms rearrange to form a different substance or different substances.

Explain why you chose your answer.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Burning Fuel in the Sim

Remember that when we burn something, we are causing a chemical reaction to occur by mixing a substance with oxygen at a high temperature. With a partner, use the Sim to gather evidence about what happens to the atoms of a substance when it burns. This evidence will help you select one of the three claims listed below.

What happens to the atoms of a substance when it burns?

Claim 1: All of the atoms are destroyed.

Claim 2: All of the atoms rearrange to form a different substance or different substances.

Claim 3: Some of the atoms are destroyed, and some of the atoms rearrange to form a different substance or different substances.

1. Launch the Sim and open Laboratory A mode.
2. Press the Add Substance button and select hydrogen (H_2) and oxygen (O_2). Then, press TEST.
3. Watch the atomic-scale animation. Press RESULTS. Then, press REVIEW and discuss the final results with your partner.
4. Press RESET and repeat steps 2 and 3 for methane (CH_4) and oxygen (O_2).
5. When you are finished, answer the questions below.

Did you observe any evidence that atoms are destroyed as a substance burns? (check one)

☐ yes ☐ no

Explain your answer using observations from the Sim.

_____

_____

_____

Did you observe any evidence that atoms rearrange as a substance burns? (check one)

☐ yes ☐ no

Explain your answer using observations from the Sim.

_____

_____

_____

Name: _____ Date: _____

Second Read of the Fuel Article

One partner will read about ethanol (in the section labeled "Carbon-Containing Fuels"), and one partner will read about hydrogen fuel. If you have been assigned to read about hydrogen fuel, turn to the next page.

Reading About Carbon-Containing Fuels

Reread the "Carbon-Containing Fuels" section of "What Happens When Fuels Burn?" Review both the text and diagrams, collecting evidence about the three claims below. After you have reread the section, answer the question below the article. Then, use the partner discussion questions to share what you read with your partner.

What happens to the atoms of a substance when it burns?

Claim 1: All of the atoms are destroyed.

Claim 2: All of the atoms rearrange to form a different substance or different substances.

Claim 3: Some of the atoms are destroyed, and some of the atoms rearrange to form a different substance or different substances.

What happens to the atoms that make up ethanol as it burns?

_____

_____

_____

_____

Partner Discussion Questions

What type of fuel did you read about?

What happens to the atoms of the fuel as it burns?

What are some similarities between burning ethanol and burning hydrogen fuel?

What are some differences between burning ethanol and burning hydrogen fuel?

Name: _____ Date: _____

Second Read of the Fuel Article (continued)

Reading About Hydrogen Fuel

Reread the "Hydrogen Fuel" section of "What Happens When Fuels Burn?" Review both the text and diagrams, collecting evidence about the three claims below. After you have reread the section, answer the question below the article. Then, use the partner discussion questions to share what you read with your partner.

What happens to the atoms of a substance when it burns?

Claim 1: All of the atoms are destroyed.

Claim 2: All of the atoms rearrange to form a different substance or different substances.

Claim 3: Some of the atoms are destroyed, and some of the atoms rearrange to form a different substance or different substances.

What happens to the atoms that make up hydrogen fuel as it burns?

_____

_____

_____

_____

Partner Discussion Questions

What type of fuel did you read about?

What happens to the atoms of the fuel as it burns?

What are some similarities between burning ethanol and burning hydrogen fuel?

What are some differences between burning ethanol and burning hydrogen fuel?

Name: _____ Date: _____

Sharing Evidence and Discussing Claims

With a partner, share the evidence you gathered from the Sim and the article about what happens to the atoms of a substance when it burns. Discuss which of the three claims you think is best supported by this evidence. Then, answer the question below.

Discuss the following with a partner: What evidence did you gather from the Sim and the article about what happens to the atoms of a substance when it burns?

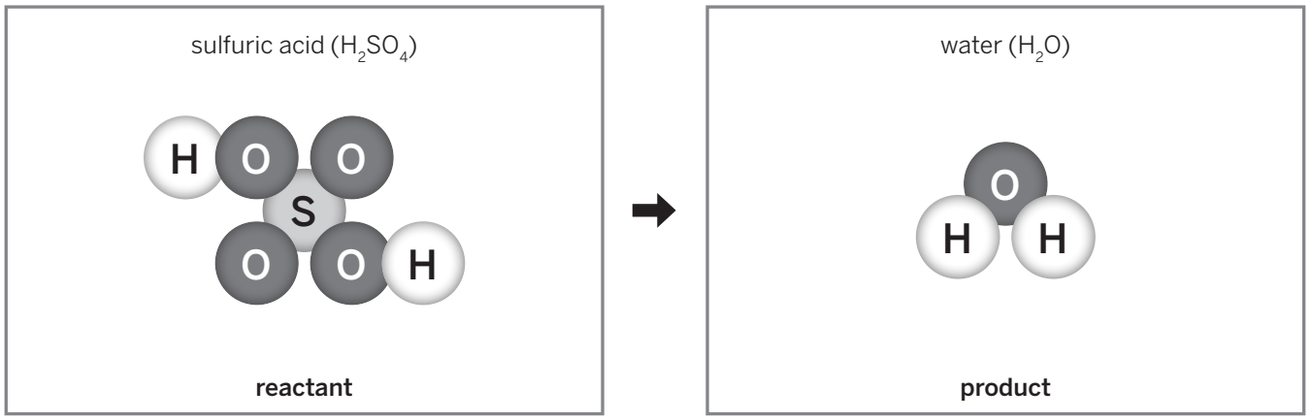
What happens to the atoms of a substance when it burns? (check one)

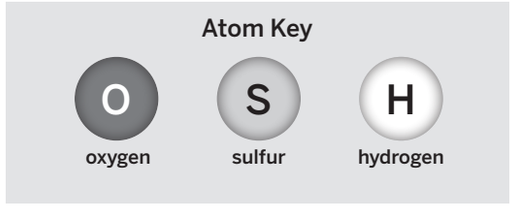
- ☐ **Claim 1:** All of the atoms are destroyed.
- ☐ **Claim 2:** All of the atoms rearrange to form a different substance or different substances.
- ☐ **Claim 3:** Some of the atoms are destroyed, and some of the atoms rearrange to form a different substance or different substances.

Name: _____ Date: _____

Homework: Critiquing a Model

Desiré was investigating a chemical reaction. When she heated it up, she found that sulfuric acid (H_2SO_4) changed into water (H_2O). She made the following atomic-scale model to show what she thinks happened.





Do you think this is a complete model of what happened during the chemical reaction? (check one)

☐ yes ☐ no

Explain your answer. Describe why the model is either complete or incomplete.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Lesson 3.3: Investigating How Products Form

From your investigations into burning substances, you have learned that atoms are not destroyed during a chemical reaction. But, can a chemical reaction create atoms? Today, you will examine a case in which one type of atom seems to have changed into a different type of atom. You will determine if such a chemical reaction is possible. By using tokens and talking to your fellow student chemists, you will investigate what actually happened during this chemical reaction.

Unit Question

- How do new substances form?

Chapter 3 Question

- What was produced during the reaction between the iron pipes and the fertilizer?

Key Concepts

- During a chemical reaction, all of the atoms that make up the reactants rearrange to form the products.

Vocabulary

- atoms
- chemical reaction
- model
- product
- property
- reactant
- rearrange
- scale
- substance

Name: _____ Date: _____

Warm-Up

Jessie is a student chemist who assists Dr. Yung in her lab. While she was working, Jessie added some chlorine gas to a container she thought was empty. After Jessie added the chlorine gas, however, a solid, yellow substance formed in the container. Jessie tested the substance and identified it as sulfur. When Dr. Yung asked Jessie to explain what had happened in the container, she claimed that a chemical reaction had changed the chlorine into sulfur.

Jessie's Claim: A chemical reaction changed the chlorine into sulfur.

Do you think that the container was actually empty before Jessie added the chlorine? (check one)

☐ yes ☐ no

Do you think that Jessie's claim is correct? (check one)

☐ yes ☐ no

Explain why you think Jessie's claim is either correct or incorrect.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Investigating Jessie's Claim

Part 1: Investigating the Claim

Dr. Yung told Jessie that she needed evidence to support her claim. When Jessie examined the contents of the container more closely, she realized that sulfur was not the only substance in the container. A colorless gas was also inside the container. Jessie moved this gas into a different container and tested it. She identified it as hydrogen chloride.

Procedure

1. With a partner, use tokens to build the two products Jessie discovered in the container.
2. Use the tokens from the two products to determine whether or not the container was actually empty before Jessie added the chlorine.
3. Discuss the following questions with your partner:
    - Was the container empty before Jessie added the chlorine? How can you tell?
    - Could the chlorine have changed into sulfur? Why or why not?
    - Could the chlorine have changed into hydrogen chloride? Why or why not?

Part 2: Identifying the Other Reactant

If the container was not empty when Jessie added the chlorine gas, then what could have been inside it? On the next page is an image showing the reaction inside the container. There is also a table that lists some of the substances that Dr. Yung keeps in her lab. The group of atoms that repeat to form each substance, as well as some of the properties of each substance, are included in the table.

Procedure

1. Use the tokens and the information in the table on the next page to determine what the other reactant inside the container could have been.
2. Once you have identified the other reactant, answer the questions below.

The other reactant inside the container was: (check one)

- ☐ iron sulfide (FeS)
- ☐ sodium sulfide (Na_2S)
- ☐ hydrogen (H_2)
- ☐ hydrogen sulfide (H_2S)
- ☐ sulfuric acid (H_2SO_4)
- ☐ sulfur dioxide (SO_2)

Name: _____ Date: _____

Investigating Jessie's Claim (continued)

Explain your answer.

_____

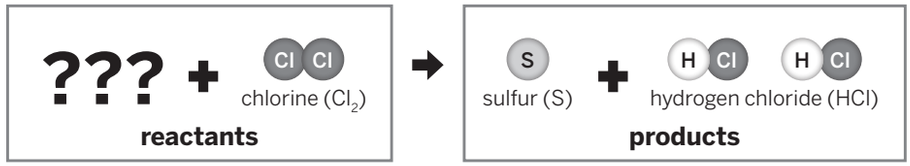
_____

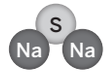
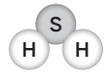
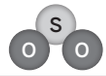
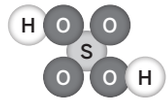
_____

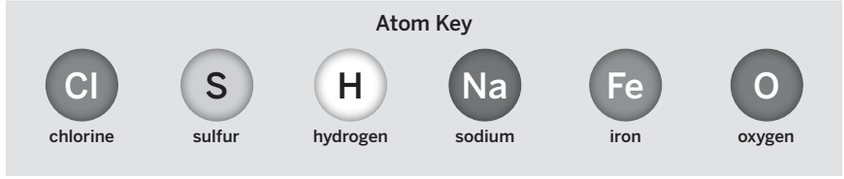
_____

_____

_____



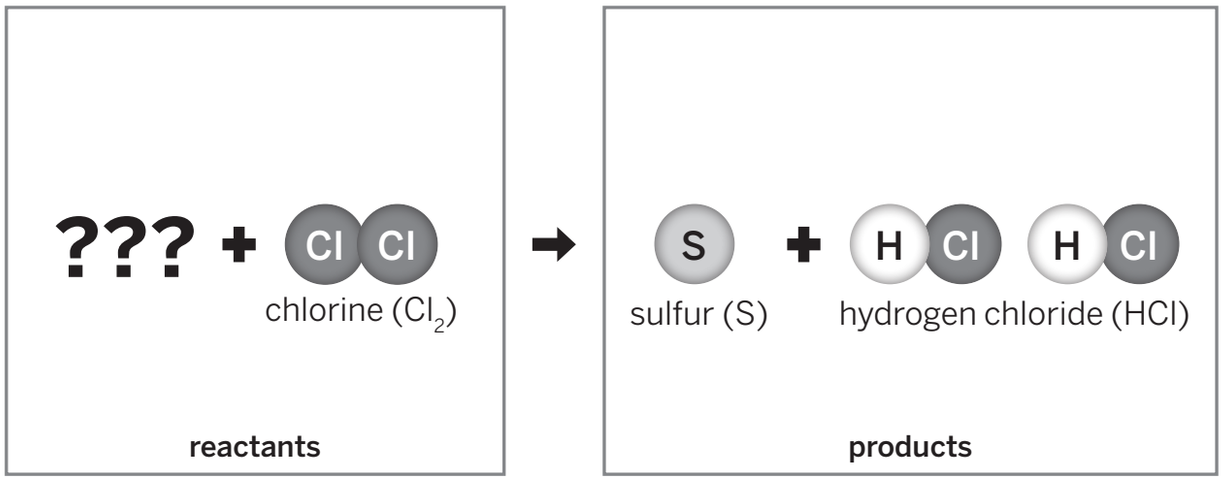
Substance	Group of repeating atoms	Properties
iron sulfide (FeS)		black solid, odorless
hydrogen (H_2)		colorless gas, odorless
sodium sulfide (Na_2S)		yellow solid, smells strongly like rotten eggs
hydrogen sulfide (H_2S)		colorless gas, smells strongly like rotten eggs
sulfur dioxide (SO_2)		colorless gas, smells strongly like a burnt match
sulfuric acid (H_2SO_4)		colorless liquid, odorless

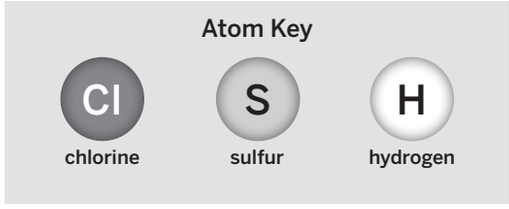


Name: _____ Date: _____

Word Relationships

With your partner, use the Word Relationships Cards to create sentences that answer the question: *What happened during the chemical reaction that caused the sulfur and hydrogen chloride to form?*





- Use at least two words from the Word Relationships Cards in each sentence. Take turns as both the speaker and the listener.
- You and your partner may use the same word more than once. You do not need to use all the vocabulary words.
- There are many different ways to answer this question. You and your partner will need to create multiple sentences in order to answer the question completely.

Word Bank

atoms	chemical reaction	model
product	property	reactant
rearrange	substance	

Name: _____ Date: _____

Homework: Reading "What Happens to Your Food?"

How does what you eat become part of your body? To find out, read and annotate the "What Happens to Your Food?" article. Then, answer the questions below.

After your body breaks food down, what are three things that can happen to the atoms from your food?

_____

_____

_____

_____

Would you be able to get energy from food if there weren't chemical reactions in your body?

_____

_____

_____

_____

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 3.4: What's in Westfield's Water?

It's finally time to determine what was produced during the reaction between the iron pipes and the fertilizer in Westfield. You already know that rust was produced, but was there anything else in Westfield's water? Using new evidence from Dr. Yung and the ideas you have learned by investigating what happens to atoms during a chemical reaction, you will be able to solve this mystery and explain to the people of Westfield what happened to their water.

Unit Question

- How do new substances form?

Chapter 3 Question

- What was produced during the reaction between the iron pipes and the fertilizer?

Key Concepts

- During a chemical reaction, all of the atoms that make up the reactants rearrange to form the products.
- During a chemical reaction, atoms cannot be created or destroyed.

Vocabulary

- atoms
- chemical reaction
- model
- product
- property
- reactant
- rearrange
- scale
- substance

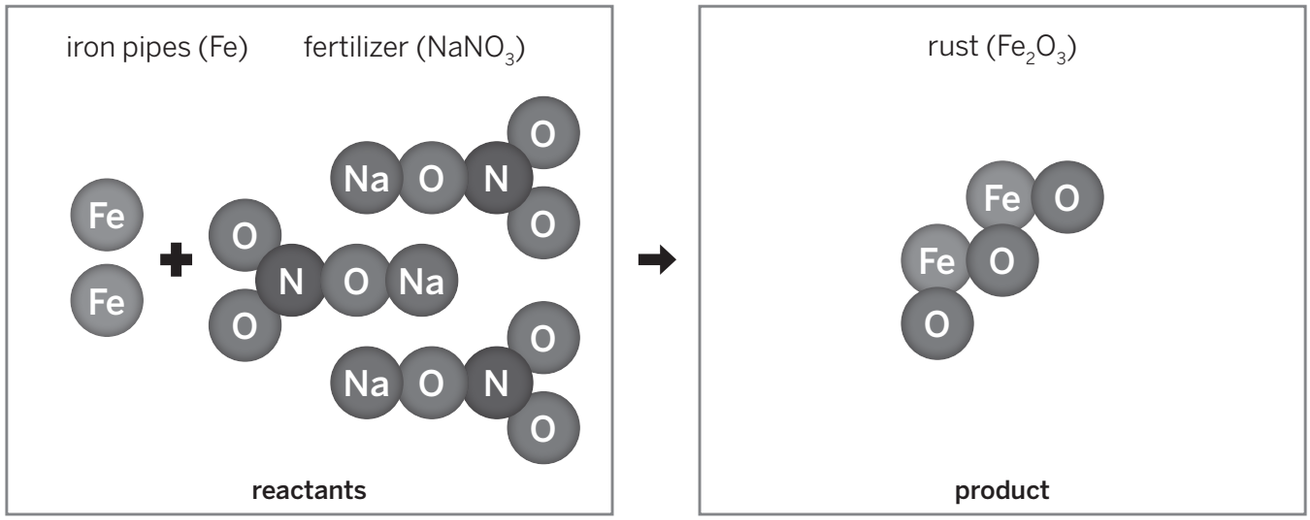
Digital Tools

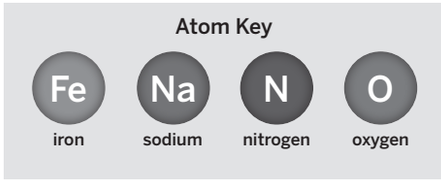
- Optional: *Chemical Reactions* Sorting Tool activity: Digital Token Model

Name: _____ Date: _____

Warm-Up

The people of Westfield are still waiting on an answer to their question: *What was produced during the reaction between the iron pipes and the fertilizer?* To help answer this question, Dr. Yung has provided you with the atomic-scale model below. Examine this model and use it to answer the questions below.





What was produced during the reaction between the iron pipes and the fertilizer? (check one)

- ☐ **Claim 1**: During the chemical reaction, only the rust was produced.
- ☐ **Claim 2:** During the chemical reaction, the rust and another substance were produced.

Explain your answer.

_____

_____

_____

_____

_____

Name: _____ Date: _____

Identifying the Other Product

After running some more tests, Dr. Yung discovered another substance in Westfield's water. Dr. Yung is not sure of the substance's identity but has narrowed it down to two possibilities. Both of the two substances have similar properties. With a partner, use the atomic-scale models provided by Dr. Yung to determine the identity of this substance. Be sure to refer back to the diagram projected by your teacher to help you determine the identity of this substance. Then, discuss the questions below.

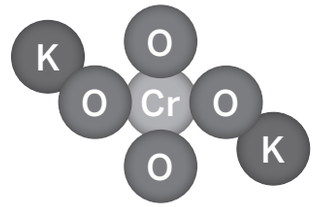
sodium nitrite

repeating group of atoms: $NaNO_2$

properties
- yellow
- solid at room temperature
- odorless

potassium chromate

repeating group of atoms: K_2CrO_4



properties
- yellow
- solid at room temperature
- odorless

Atom Key

Based on these atomic-scale models, what other substance could be in the water besides rust? (check one)

- ☐ sodium nitrite ($NaNO_2$)
- ☐ potassium chromate (K_2CrO_4)
- ☐ both sodium nitrite ($NaNO_2$) and potassium chromate (K_2CrO_4)

Discussion Questions

- Which answer did you select and why?
- What information can you get from an atomic-scale model that you couldn't get just by observing the properties of a substance?
- How are the atoms shown in the atomic-scale models above different from actual atoms?

Name: _____ Date: _____

Modeling the Products of the Reaction

Complete the Modeling Tool activity: Products of the Reaction on the next page to help you explain to the people of Westfield what is in their water.

Goal: Create a model that shows what was produced during the chemical reaction between the iron pipes and the fertilizer.

Do:

- In the After space, draw an atomic-scale model of what was produced during the chemical reaction between the iron pipes and the fertilizer.
- Color the atoms using the key found on your teacher's screen.
- In the During the change space, describe or draw how the product or products were formed.

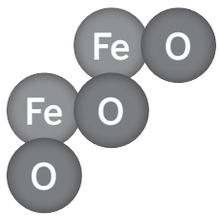
Tips:

- An atomic-scale model of the iron pipes and fertilizer is already shown.
- Use the Substance Reference Guide if you need to.
- You can draw more than one repeating group of atoms for a substance if needed.

Substance Reference Guide

rust

repeating group of atoms (Fe_2O_3)

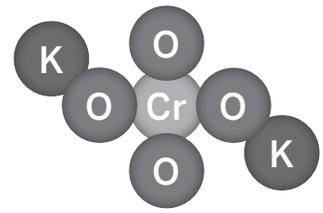


sodium nitrite

repeating group of atoms ($NaNO_2$)

potassium chromate

repeating group of atoms (K_2CrO_4)



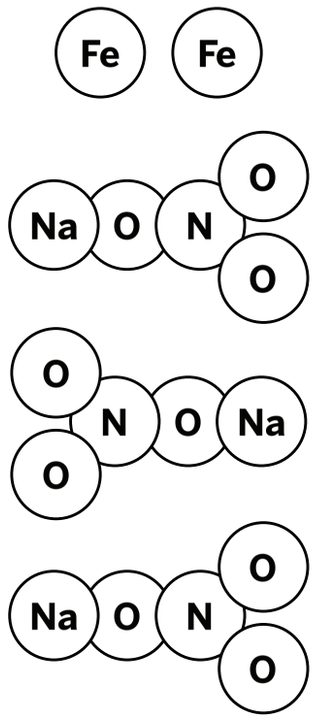
Atom Key

Name: _____ Date: _____

Modeling Tool: Products of the Reaction

Goal: Create a model that shows what was produced during the chemical reaction between the iron pipes and the fertilizer.

Before



During the change

Describe or draw how the product or products were formed.

After

Draw an atomic-scale model of everything that was produced during the chemical reaction between the iron pipes and the fertilizer.

Key

Name: _____ Date: _____

Writing to Westfield

Use the model you created to help you write an argument for the people of Westfield explaining what is in their water. As you write your argument, remember to

- state your claim and identify the substances in the water.
- use evidence from the model you created to support your claim.
- include vocabulary terms from the word bank below in your argument.

Chapter 3 Question: *What was produced during the reaction between the iron pipes and the fertilizer?*

Claim 1: During the chemical reaction, only the rust was produced.

Claim 2: During the chemical reaction, the rust and another substance were produced.

Word Bank

atoms	chemical reaction	model	product
reactant	rearrange	substance	

Explain to the people of Westfield what is in their water.

Name: _____ Date: _____

Homework: Revising a Report

Once you have finished writing your report, go back and read it again. Try reading your report out loud or asking another person to read it. Then, use the revision checklist below to see whether or not there are any changes you can make to improve the writing in your report.

Revision Checklist

1. Did you clearly state a claim and identify the substances that are in the water? (check one)

   ☐ yes ☐ no

2. Do you provide evidence from your Modeling Tool sheet that supports your claim? (check one)

   ☐ yes ☐ no

3. Do you thoroughly explain how the evidence supports your claim? (check one)

   ☐ yes ☐ no

If you answered no to any of these questions, revise your writing to make it clearer and more convincing. If you need to, rewrite your argument.

Explain to the people of Westfield what is in their water.

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 to the questions below.

Scientists investigate in order to figure things out. Am I getting closer to figuring out what made the water in Westfield turn reddish-brown?

1. I understand how to tell if the reddish-brown substance is the same as or different from the pipe and fertilizer. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

2. I understand how the reddish-brown substance formed. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

3. I understand why there might be something else in the water besides the reddish-brown substance. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

4. What do you still wonder about how substances form?

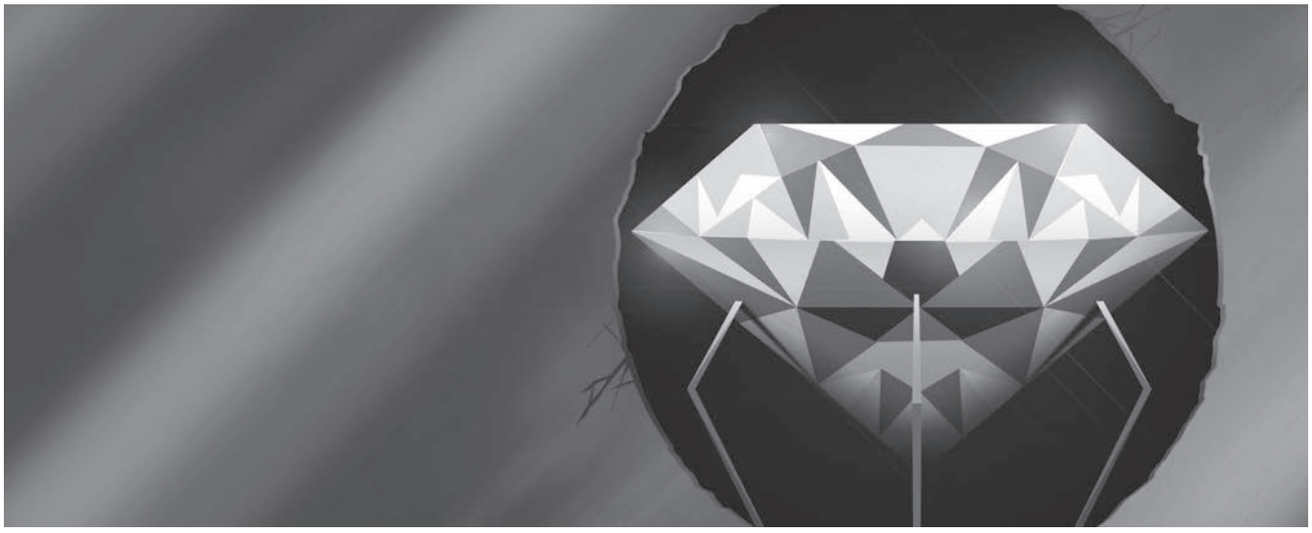
_____

_____

Name: _____ Date: _____

Chapter 4: Science Seminar
Chapter Overview

A diamond has been stolen from the Westfield Museum. At the scene of the crime, police discovered an unknown substance, which they believe the criminal used during the robbery. Now, Dr. Yung needs your knowledge of chemical reactions to help the police identify this unknown substance. They need your help in determining who might have used this substance to steal the diamond!



Name: _____ Date: _____

Lesson 4.1: Chemistry at the Crime Scene

Now that you've finished your investigation of Westfield's water supply, Dr. Yung has a new case for you. There has been a robbery at the Westfield Museum. A thief used an unknown substance to steal a rare and expensive diamond. Your assignment is to use your knowledge of chemical reactions to identify the unknown substance and advise the police on who might have used that substance to steal the diamond.

Unit Question

- How do new substances form?

Chapter 4 Question

- Who might have used the unknown substance to steal the diamond?

Key Concepts

- Different substances have different properties.
- Things that are too small (or too large) to see can be studied with models.
- Substances have different properties because they are made of different groups of atoms. These groups vary in the type or number of atoms that make up the group.
- Groups of atoms repeat to make up a substance.
- During a chemical reaction, one or more starting substances (reactants) change into one or more different substances (products).
- During a chemical reaction, atoms do not change from one type to another.
- During a chemical reaction, atoms rearrange to form different groups of atoms.
- During a chemical reaction, all of the atoms that make up the reactants rearrange to form the products.
- During a chemical reaction, atoms cannot be created or destroyed.

Vocabulary

- atoms
- chemical reaction
- claim
- evidence
- model
- product
- property
- reactant
- rearrange
- scale
- substance

Name: _____ Date: _____

Warm-Up

Respond to the question below.

What information might help a chemist identify an unknown substance?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Identifying an Unknown Substance

To: Student Chemists
From: Dr. Samara Yung, Lead Chemist
Subject: Someone Stole the Lavoisier Diamond!

There's been a robbery at the Westfield Museum! This morning, the museum staff discovered the rare and expensive Lavoisier Diamond was missing. When police arrived, they found a hole had been made in the glass display case where the diamond was stored. Next to the display case, they found a plastic container that was half full with an unknown substance. Police think that the thief may have used some of the substance to make a hole in the glass and may have accidentally left the rest of the substance behind.

The chief of police has asked me to help them identify this unknown substance and determine who could have used it to steal the Lavoisier Diamond. As you have recent experience in working with the community of Westfield, I am turning the case over to you. I hope you remember what you have learned so far about the chemical reactions. I think you will need to use your knowledge to help the police crack this case!

Name: _____ Date: _____

Identifying an Unknown Substance (continued)

Evaluating Observations of the Unknown Substance

There were four police officers at the crime scene. The officers wrote down their observations of the unknown substance that was used to make a hole in the glass.

1. With a partner, read the observations written down on the Unknown Substance Evidence Cards given to you by your teacher. Annotate the cards with any questions or ideas you have.
2. Discuss the cards with your partner and evaluate each observation using the Evidence Criterion included below.
3. Once you have evaluated each observation, place the cards on the Evidence Gradient sheet with the strongest pieces of evidence near the top and the less strong pieces of evidence near the bottom.
4. When you are finished, answer the questions below.

Evidence Criterion: More detailed observations provide stronger evidence.

Which officer provided the strongest evidence? (check one)

- ☐ Officer Hodges
- ☐ Officer Lee
- ☐ Officer Diaz
- ☐ Officer Williams

Explain why you think this officer's observations provided the strongest evidence.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Identifying an Unknown Substance (continued)

Identifying the Unknown Substance

The police have made a short list of substances they think could have been used to make a hole in the glass. All of these substances are corrosive, which means they can cause damage when they come in contact with substances such as glass. With a partner, examine the table below. Then, use the strongest evidence from the officers' observations to help you determine which substance was used to make a hole in the glass.

Substance name	Properties
hydrobromic acid	• faint yellow color • strong, irritating odor • liquid at room temperature
hydrofluoric acid	• colorless • strong, irritating odor • liquid at room temperature
iodine monochloride	• dark red color • strong, irritating odor • liquid at room temperature
perchloric acid	• colorless • odorless • liquid at room temperature

Name: _____ Date: _____

Identifying an Unknown Substance (continued)

Which of these substances do you think is the unknown substance the criminal used to make a hole in the glass? (check one)

- ☐ hydrobromic acid
- ☐ hydrofluoric acid
- ☐ iodine monochloride
- ☐ perchloric acid

Explain your answer.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Discussing New Evidence

After you identified the unknown substance as hydrofluoric acid, the police contacted a local chemical supply company to see whether or not anyone had purchased hydrofluoric acid recently. When the company told the police that they do not sell hydrofluoric acid, the police asked whether or not anyone had purchased substances that might have been used to make hydrofluoric acid. In response, the company released information about three suspicious orders.

1. With a partner, examine the information about the three orders shown in the table below.
2. Work together to discuss the information in the table using the discussion questions.
3. When you are ready, individually answer the question at the bottom of the page.

Name	Job	Substances ordered
Pat	sculptor	• sulfuric acid • calcium fluoride
Alex	gardener	• sulfuric acid • magnesium chloride
Tracy	chemist	• purified water • fluorine

Discussion Questions

- At this point, can you tell whether or not any of these suspects could have made hydrofluoric acid using the substances they ordered? Why or why not?
- To help you determine whether or not any of these suspects could have made the hydrofluoric acid, what other information do you need to know about hydrofluoric acid?
- What other information would you need to know about the substances listed in the table?

Explain why knowing additional information about the hydrofluoric acid and other substances might be helpful in solving this crime.

_____

_____

_____

_____

Name: _____ Date: _____

Discussing New Evidence (continued)

Science Seminar Question: *Which suspect is most likely to have made the hydrofluoric acid?*

Claim 1: Pat is most likely to have made the hydrofluoric acid by using sulfuric acid and calcium fluoride.

Claim 2: Alex is most likely to have made the hydrofluoric acid by using sulfuric acid and magnesium chloride.

Claim 3: Tracy is most likely to have made the hydrofluoric acid by using purified water and fluorine.

Based on what you know so far, which suspect do you think is most likely to have made the hydrofluoric acid? (check one)

- ☐ Pat
- ☐ Alex
- ☐ Tracy
- ☐ not sure

Name: _____ Date: _____

Lesson 4.2: Analyzing Claims and Evidence

In the case of the missing diamond, police have identified three suspects who ordered suspicious substances from a chemical supply company. Before the police bring in anyone for questioning, however, they need to know whether or not any of these suspects could have made hydrofluoric acid using the substances they ordered. In this lesson, you will use new evidence to assist with this police investigation, determining which reactants could have produced hydrofluoric acid during a chemical reaction.

Unit Question

- How do new substances form?

Chapter 4 Question

- Who might have used the unknown substance to steal the diamond?

Key Concepts

- Different substances have different properties.
- Things that are too small (or too large) to see can be studied with models.
- Substances have different properties because they are made of different groups of atoms. These groups vary in the type or number of atoms that make up the group.
- Groups of atoms repeat to make up a substance.
- During a chemical reaction, one or more starting substances (reactants) change into one or more different substances (products).
- During a chemical reaction, atoms do not change from one type to another.
- During a chemical reaction, atoms rearrange to form different groups of atoms.
- During a chemical reaction, all of the atoms that make up the reactants rearrange to form the products.
- During a chemical reaction, atoms cannot be created or destroyed.

Vocabulary

- atoms
- chemical reaction
- claim
- evidence
- model
- product
- property
- reactant
- rearrange
- scale
- substance

Name: _____ Date: _____

Warm-Up

To: Student Chemists
From: Dr. Samara Yung, Lead Chemist
Subject: Hydrofluoric Acid

You did a great job at using properties to identify the substance found at the crime scene as hydrofluoric acid. We're lucky that at least one of the police officers provided detailed observations!

Here is some additional information about hydrofluoric acid at the atomic scale. This may help you as you continue to investigate this case.

hydrofluoric acid

repeating group of atoms: HF

Atom Key

How might this information about hydrofluoric acid at the atomic scale help you with your investigation?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Modeling Possible Reactions

The police want your help to decide if they should continue investigating the three suspects. Complete the Modeling Tool activity: Making Hydrofluoric Acid on page 118 to show the police whether or not each of the suspects could have produced hydrofluoric acid with the substances they ordered from the chemical supply company.

Goal: Create atomic-scale models that show whether or not each of the suspects could have produced hydrofluoric acid.

Do:

- In the Before space, color in the atoms of each substance using the key at the bottom of the Substance Reference Guide on your teacher's screen.
- Use the atoms to determine whether or not each suspect's substances could have produced hydrofluoric acid.
- If you think a suspect could produce hydrofluoric acid, draw an atomic-scale model of hydrofluoric acid in the After space. If there are enough atoms, draw more than one repeating group. Also, draw any other atoms that were involved in this chemical reaction and color them in.
- If you think a suspect could not produce hydrofluoric acid, write an explanation of why this is the case in the After space.

Tips:

- In the Before space, you have been provided with atomic-scale models of each suspect's substances. These atomic-scale models are also provided in the Substance Reference Guide.

Name: _____ Date: _____

Modeling Possible Reactions (continued)

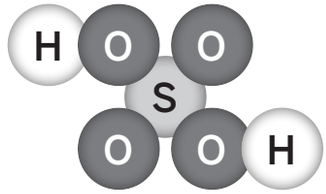
Substance Reference Guide

hydrofluoric acid

repeating group of atoms:
HF

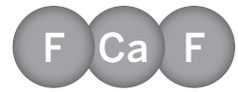
sulfuric acid

repeating group of atoms:
H_2SO_4



calcium fluoride

repeating group of atoms:
CaF_2

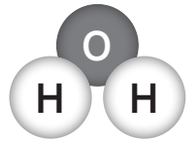


magnesium chloride

repeating group of atoms:
$MgCl_2$

purified water

repeating group of atoms:
H_2O



fluoride

repeating group of atoms:
F_2

Atom Key

After you have completed your models, answer the following question:

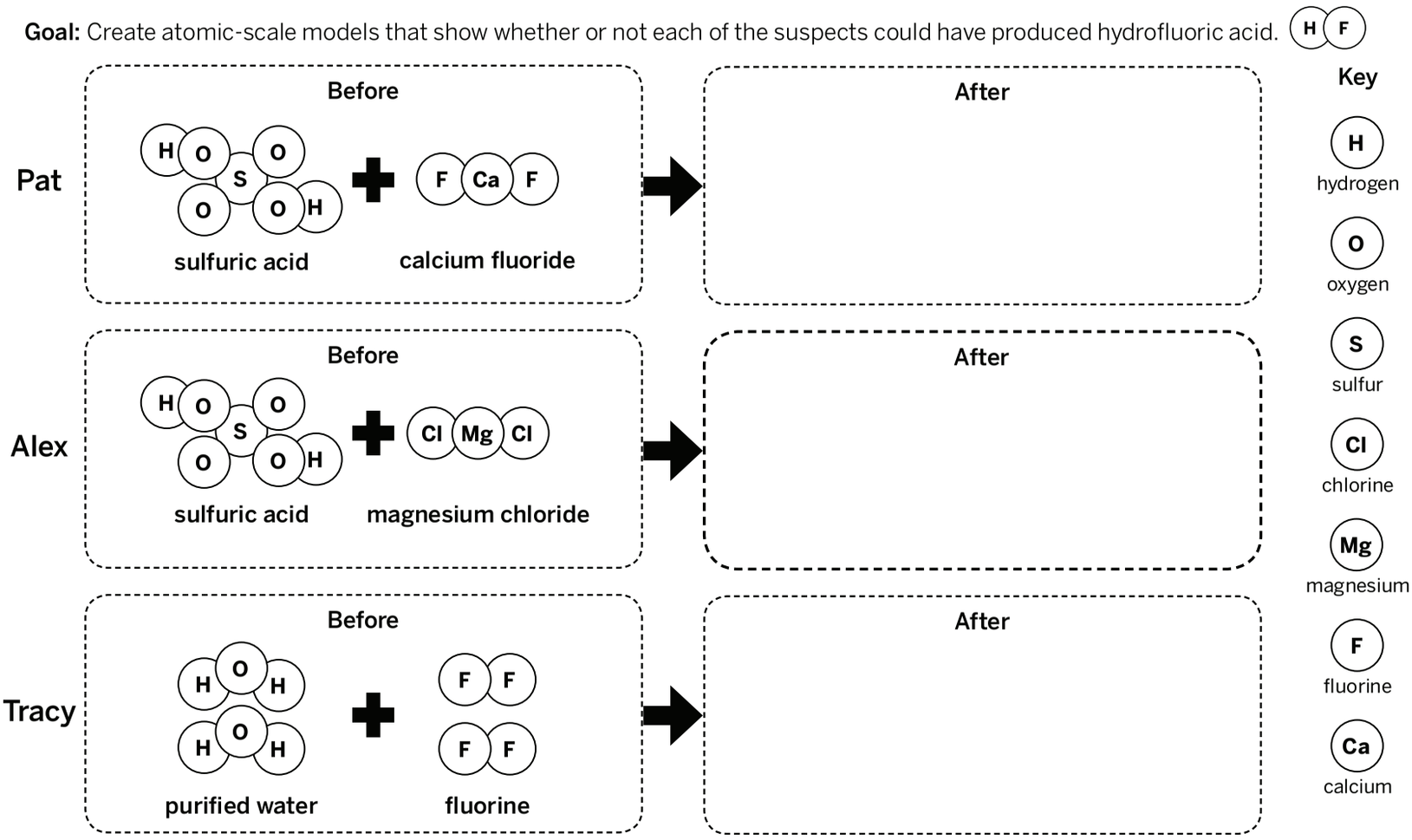
Based on your models, which of the suspects could have produced the hydrofluoric acid? (check one)

- ☐ Pat
- ☐ Alex
- ☐ Tracy
- ☐ none of the suspects

Name: _____ Date: _____

Modeling Tool: Making Hydrofluoric Acid

Goal: Create atomic-scale models that show whether or not each of the suspects could have produced hydrofluoric acid.



Name: _____ Date: _____

Analyzing New Evidence

Based on your models, the police obtained search warrants for Pat and Tracy's houses. They were able to find new evidence about the substances in each of their houses.

1. Examine the Suspect Evidence Cards, annotating with any questions or ideas you have. If useful, you may also color in the atoms on the cards using the atom key on your teacher's screen.
2. Review the model you completed in the last activity on page 118. Consider how the information in the Suspect Evidence Cards might relate to your completed model. You may revise your model if needed.
3. As you sort the cards using the Evidence Sorting Grid on the next page, discuss your choices with your partner. If you think a card belongs in more than one category, place it on the line between those two categories. If you are not sure which category a card belongs in, set that card to the side.

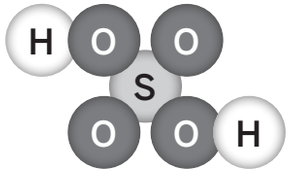
Substance Reference Guide

hydrofluoric acid

repeating group of atoms: HF

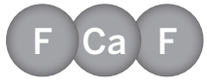
sulfuric acid

repeating group of atoms: H_2SO_4



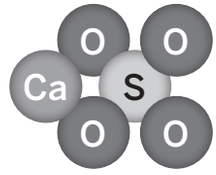
calcium fluoride

repeating group of atoms: CaF_2



calcium sulfate

repeating group of atoms: $CaSO_4$

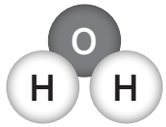


magnesium chloride

repeating group of atoms: $MgCl_2$

purified water

repeating group of atoms: H_2O

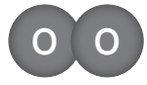


fluorine

repeating group of atoms: F_2

oxygen

repeating group of atoms: O_2



Atom Key

Name: _____ Date: _____

Evidence Sorting Grid

Evidence Pat made the hydrofluoric acid:	Evidence Tracy made the hydrofluoric acid:
Evidence Pat did **not** make the hydrofluoric acid:	Evidence Tracy did **not** make the hydrofluoric acid:

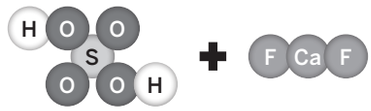
Name: _____ Date: _____

Identifying the Primary Suspect

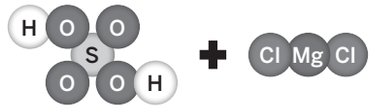
Based on how you sorted the Suspect Evidence Cards with your partner, answer the questions below. Remember that you will have a chance to change your mind in the next lesson.

Question: Which suspect is most likely to have made the hydrofluoric acid? 

Claim 1: Pat is most likely to have made the hydrofluoric acid by using sulfuric acid and calcium fluoride.



Claim 2: Alex is most likely to have made the hydrofluoric acid by using sulfuric acid and magnesium chloride.



Claim 3: Tracy is most likely to have made the hydrofluoric acid by using purified water and fluorine.

Atom Key

Name: _____ Date: _____

Identifying the Primary Suspect (continued)

Based on what you know so far, which suspect do you think is most likely to have made the hydrofluoric acid? (check one)

- ☐ Pat
- ☐ Alex
- ☐ Tracy
- ☐ not sure

Explain your answer using at least one piece of evidence from your Suspect Evidence Cards.

_____

_____

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Lesson 4.3: Engaging in a Science Seminar

The police are almost ready to bring in one of the suspects for questioning in the case of the missing diamond, but who should be the primary suspect? During today's Science Seminar, you and your fellow student chemists will have an opportunity to discuss the claims and evidence in this case. By the end of this lesson, you will be ready to write a scientific argument to the police explaining which suspect you think is most likely to have produced the hydrofluoric acid.

Unit Question

- How do new substances form?

Chapter 4 Question

- Who might have used the unknown substance to steal the diamond?

Key Concepts

- Different substances have different properties.
- Things that are too small (or too large) to see can be studied with models.
- Substances have different properties because they are made of different groups of atoms. These groups vary in the type or number of atoms that make up the group.
- Groups of atoms repeat to make up a substance.
- During a chemical reaction, one or more starting substances (reactants) change into one or more different substances (products).
- During a chemical reaction, atoms do not change from one type to another.
- During a chemical reaction, atoms rearrange to form different groups of atoms.
- During a chemical reaction, all of the atoms that make up the reactants rearrange to form the products.
- During a chemical reaction, atoms cannot be created or destroyed.

Vocabulary

- atoms
- chemical reaction
- claim
- evidence
- model
- product
- property
- reactant
- rearrange
- reasoning
- scale
- scientific argument
- substance

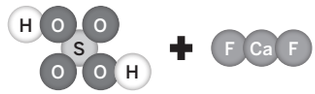
Name: _____ Date: _____

Warm-Up

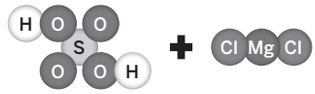
Review your annotated Suspect Evidence Cards from the last lesson.

Question: Which suspect is most likely to have made the hydrofluoric acid?

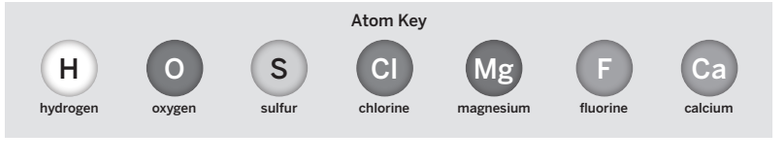
Claim 1: Pat is most likely to have made the hydrofluoric acid by using sulfuric acid and calcium fluoride.



Claim 2: Alex is most likely to have made the hydrofluoric acid by using sulfuric acid and magnesium chloride.



Claim 3: Tracy is most likely to have made the hydrofluoric acid by using purified water and fluorine.



Draw a star on the evidence card or cards that best support your claim. Why did you choose this evidence?

_____

_____

_____

_____

_____

Which claim do you think is the most convincing? (check one)

- ☐ **Claim 1:** Pat is most likely to have made the hydrofluoric acid by using sulfuric acid and calcium fluoride.
- ☐ **Claim 2:** Alex is most likely to have made the hydrofluoric acid by using sulfuric acid and magnesium chloride.
- ☐ **Claim 3:** Tracy is most likely to have made the hydrofluoric acid by using purified water and fluorine.

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: _____

Homework: Writing a Scientific Argument

Prepare to write by answering the questions below. After you have answered the questions, write a scientific argument that answers the Science Seminar Question.

Question: Which suspect is most likely to have made the hydrofluoric acid? 

Claim 1: Pat is most likely to have made the hydrofluoric acid by using sulfuric acid and calcium fluoride. 

Claim 2: Alex is most likely to have made the hydrofluoric acid by using sulfuric acid and magnesium chloride. 

Claim 3: Tracy is most likely to have made the hydrofluoric acid by using purified water and fluorine. 

Atom Key

H	O	S	Cl	Mg	F	Ca
hydrogen	oxygen	sulfur	chlorine	magnesium	fluorine	calcium

Which claim are you going to make in your argument?

Claim 1: Pat is most likely to have made the hydrofluoric acid by using sulfuric acid and calcium fluoride.

Claim 2: Alex is most likely to have made the hydrofluoric acid by using sulfuric acid and magnesium chloride.

Claim 3: Tracy is most likely to have made the hydrofluoric acid by using purified water and fluorine.

None of the above. I will write my own claim: _____

_____

Name: _____ Date: _____

Homework: Writing a Scientific Argument (continued)

Review the Suspect Evidence Cards and the models you created to show whether or not each suspect could have made hydrofluoric acid. Consider how the information presented in the evidence cards might relate to your models. Then, select the pieces of evidence you are going to use in your argument from the list below.

- ☐ **Evidence Card A:** When the police searched Pat's house, they found some calcium sulfate ($CaSO_4$).
- ☐ **Evidence Card B:** The police did **not** find hydrofluoric acid (HF), sulfuric acid (H_2SO_4), or calcium fluoride (CaF_2) in Pat's house.
- ☐ **Evidence Card C:** When the police searched Tracy's house, they found some purified water (H_2O).
- ☐ **Evidence Card D:** The police did **not** find hydrofluoric acid (HF), fluorine (F_2), or any other unusual substances in Tracy's house.
- ☐ **Evidence Card E:** According to Dr. Yung, calcium sulfate ($CaSO_4$) is a substance commonly used in sculpting.
- ☐ **Evidence Card F:** According to Dr. Yung, oxygen (O_2) is a colorless, odorless gas that is commonly found in air.
- ☐ **Evidence Card G:** The chemical supply company confirmed the delivery of sulfuric acid (H_2SO_4) and calcium fluoride (CaF_2) to Pat's house.
- ☐ **Evidence Card H:** The chemical supply company confirmed the delivery of purified water (H_2O) and fluorine (F_2) to Tracy's house.

Name: _____ Date: _____

Homework: Writing a Scientific Argument (continued)

Write a scientific argument that addresses the question: *Which suspect is most likely to have made the hydrofluoric acid?* First, state your claim. Then, use evidence to support your claim. For each piece of evidence you use, explain how the evidence supports your claim. As you write, refer back to your completed Modeling Tool on page 118 and Suspect Evidence Cards.

Name: _____ Date: _____

Homework: Writing a Scientific Argument (continued)

Name: _____ Date: _____

Homework: Check Your Understanding

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

1. I understand that more detailed observations provide stronger evidence. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

_____

_____

_____

_____

2. What are the most important things you have learned in this unit about how new substances form?

_____

_____

_____

_____

_____

_____

3. What questions do you still have?

_____

_____

_____

_____

_____

_____

Chemical Reactions Glossary

atoms: the tiny pieces that all matter—all the stuff in the world—is made of

átomos: los pedacitos diminutos de los cuales toda la materia del mundo está hecha

boiling point: the temperature at which a substance changes from the liquid phase to the gas phase

punto de ebullición: la temperatura a la cual una sustancia cambia de la fase líquida a la fase gaseosa

chemical formula: letters and numbers showing the types and number of atoms that repeat to make up a substance

fórmula química: letras y números que muestran los tipos y la cantidad de átomos que se repiten para formar una sustancia

chemical reaction: a process in which atoms rearrange to form new substances

reacción química: un proceso en el que los átomos se reorganizan para formar nuevas sustancias

corrosive: able to cause damage

corrosivo: capaz de causar daño

extended structure: a structure formed by repeating groups of atoms that link together in a large network

estructura extendida: una estructura formada por grupos repetidos de átomos que se enlazan entre sí en una gran red

fertilizer: a substance that is added to soil to help plants grow

fertilizante: una sustancia que se agrega a la tierra para ayudar a que crezcan las plantas

melting point: the temperature at which a substance changes from the solid phase to the liquid phase

punto de fusión: la temperatura a la cual una sustancia cambia de la fase sólida a la fase líquida

model: an object, diagram, or computer program that helps us understand something by making it simpler or easier to see

modelo: un objeto, diagrama o programa de computadora que nos ayuda a entender algo haciéndolo más simple o fácil de ver

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

molécula: un grupo de átomos unidos de una manera particular

Chemical Reactions Glossary (continued)

product: an ending substance that is made during a chemical reaction
producto: una sustancia final que se crea durante una reacción química

property: something that can be observed about a substance, such as color, smell, or boiling point
propiedad: algo que se puede observar acerca de una sustancia, como el color, olor o punto de ebullición

reactant: a starting substance that is part of a chemical reaction
reactivo: una sustancia inicial que es parte de una reacción química

rearrange: to change the order or position of something
reorganizar: cambiar el orden o posición de algo

scale: the relative size of things
escala: el tamaño relativo de las cosas

substance: something that is made of all the same atoms or groups of atoms
sustancia: algo que está completamente hecho de los mismos átomos o grupos de átomos

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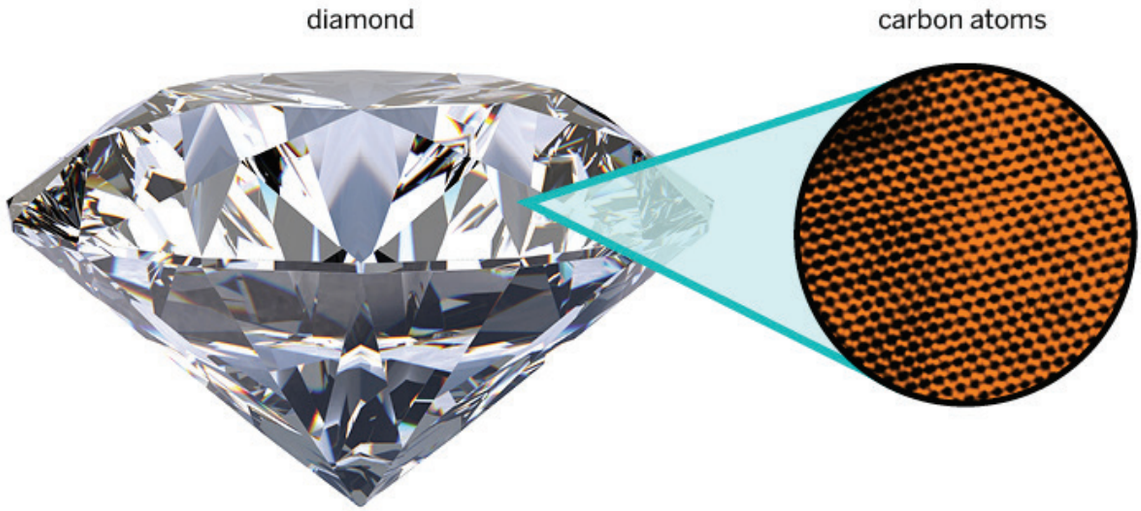
Chemical Reactions:

Mysterious Substance in Westfield's Water

Article Compilation

Table of Contents: Articles



Diamonds are made of just one kind of atoms, called carbon atoms.

Atomic Zoom-In

Comparing Substances at a Very Small Scale

Imagine you're eating breakfast. The wooden table you're sitting at is hard, your orange juice smells sweet, and the sugar in your sugar bowl is white. The day has just begun, but you've already come into contact with many substances, each of which has its own set of properties. What is it that gives these substances their different properties? To understand where these differences come from, scientists observe substances at a very small scale—much smaller than we can observe in our daily lives. Let's zoom in and see what we find. What is matter actually made of?

In the 1800's, John Dalton was the first to propose the idea that all matter is made of tiny pieces called atoms. Today we call this "the atomic theory." Since it is a theory it may sound like scientists are not sure about it, but a scientific theory is an idea that has a lot of evidence that many scientists have gathered over a long time. Even today scientists continue to gather evidence that all matter is made of atoms!

Atoms are too small for us to see, but scientists currently know of 118 different types of atoms in the universe, including oxygen, carbon, silver, and gold. Every substance is made of a unique combination of atoms. Substances can be made of just one type of atom or a specific group of atoms that repeats over and over. Chemists represent these groups of atoms using chemical formulas: letters and numbers showing the types and numbers of atoms that repeat to make up a substance. Substances have different properties because they are made of different types and numbers of atoms that repeat.

How Atoms Make Your Orange Juice Smell Good and Your Socks Smell Bad

Have you ever noticed how good orange juice smells when you pour yourself a glass? You may be surprised to learn that for many brands of orange juice, the aroma is added. Orange

juice is often kept in big tanks for a time before it is packaged and shipped. The juice needs to be processed in order to keep it from spoiling. This processing can cause the pleasant orange scent and flavor to fade. To address this problem, chemists add a substance that makes the packaged juice smell and taste like fresh-squeezed oranges. That substance is called ethyl butyrate (EH-thul BYOO-tuh-rate).

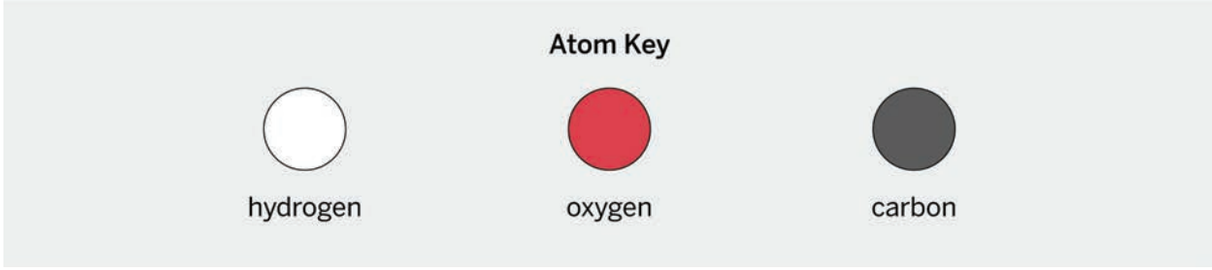
Ethyl butyrate is a naturally occurring substance found in many fruits. If you examined a sample of ethyl butyrate, you might observe that it is a clear liquid with a strong smell of pineapple or orange. It has a chemical formula of $C_6H_{12}O_2$, which means it is always made of groups of 6 carbon atoms, 12 hydrogen atoms, and 2 oxygen atoms. This group of different atoms forms a pattern—it repeats over and over again to make up the substance. The more times the pattern repeats, the more ethyl butyrate you have.

Even very small differences at the atomic scale can have important effects on the properties of a substance. One substance that is similar to ethyl butyrate at the atomic scale is called Isovaleric (EYE-so-vuh-LAIR-ick) acid. If you were to observe the properties of Isovaleric acid, you would see that it is also a colorless liquid, but you would never get it confused with ethyl butyrate. Why? Instead of the pleasant smell of citrus, you would smell something similar to sweaty gym socks. Gross!

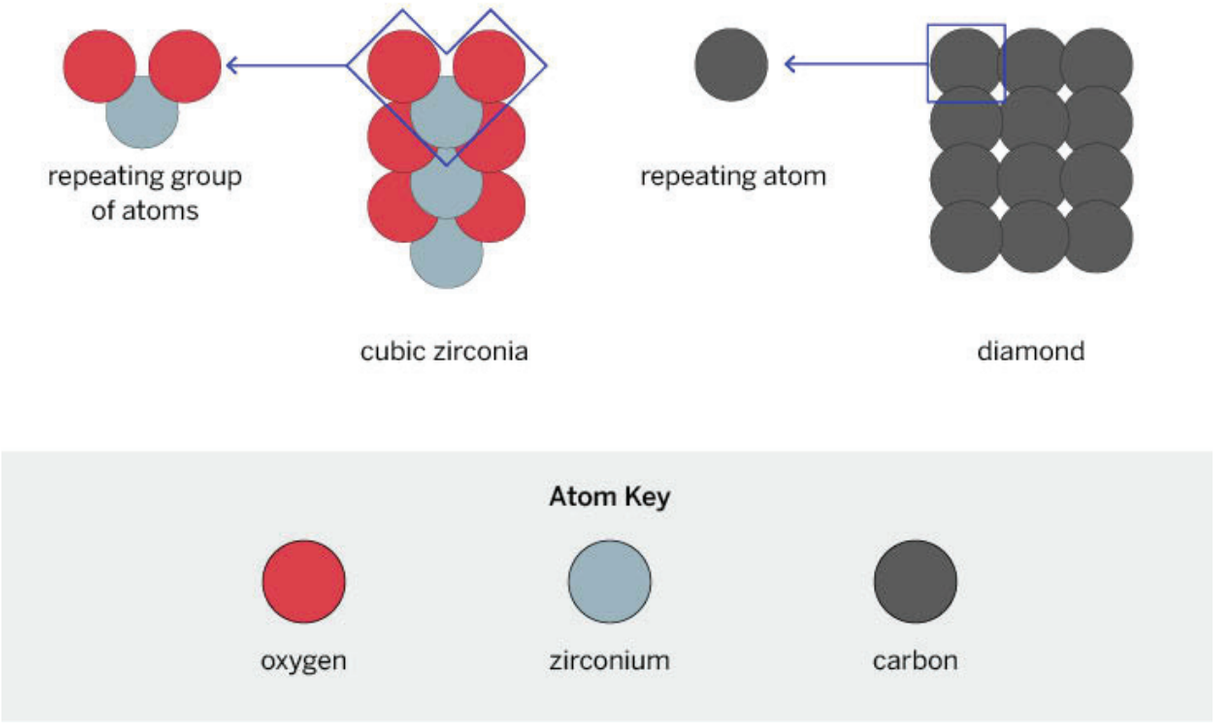
Why do these two substances have different properties? Looking more closely at the atoms in Isovaleric acid, you can see that it is made of groups of 5 carbon atoms, 10 hydrogen atoms, and 2 oxygen atoms, so its chemical formula is $C_5H_{10}O_2$. Ethyl butyrate and Isovaleric acid have different properties because the atoms that make up each substance are grouped differently. Isovaleric acid has one fewer carbon atom and 2 fewer hydrogen atoms. These atoms are also arranged in a different

ethyl butyrate

isovaleric acid



Ethyl butyrate (left) and Isovaleric acid (right) are both made up of repeating groups of carbon, hydrogen, and oxygen atoms. However, one smells like citrus and the other smells like sweaty gym socks!



Diamonds are made of carbon atoms stuck together in a repeating pattern, while cubic zirconia is made of zirconium and oxygen atoms stuck together in a repeating pattern.

pattern. At the atomic scale, these seem like small differences, but even small differences are enough to give the two substances very different properties.

Are These Diamonds Real? Chemistry in Jewel Trading

Diamonds come from deep inside Earth and are often polished and used in jewelry. Because they are very popular, they are also very expensive! Due to the high price of diamonds, jewelry makers sometimes use substances that share some of the same properties as diamonds, but cost less. One of these substances is a human-made material called cubic zirconia. At first glance, cubic zirconia and diamond look very much alike: both are clear, shiny, and solid at room temperature. However, diamonds and cubic zirconia do not share all of the same properties. For one thing, diamonds are the hardest naturally occurring substance that we know of, so they are very hard to scratch. In fact, diamonds are often used in saws to cut very hard things, like stone. Cubic zirconia is not as hard as diamond—it can be scratched easily, and isn't nearly hard enough to cut through stone. Diamond and cubic zirconia are also different in other ways, such as melting point.

Diamond and cubic zirconia have different properties because they are made of different atoms. Diamond is made of carbon atoms packed together tightly, and its chemical formula is a single letter, C, which stands for carbon. Diamond is always made of carbon atoms stuck together in a repeating pattern. Cubic zirconia is made of groups of one zirconium atom and two oxygen atoms. Its chemical formula is ZrO_2. This atom group repeats to make up a cubic zirconia gemstone. If a gemstone is made of atoms other than carbon, chemists can tell that it isn't a real diamond.

Fresh orange juice smells good because it contains a certain molecule.

Substances are made of atoms or groups of atoms that repeat. The number and type of atoms that repeat are different for different substances. Diamonds are made of just carbon atoms repeating. Cubic zirconia is a different substance because it has a different group of atoms that repeat.

All substances are made of groups of repeating atoms, but these groups can take different forms. In some cases, like ethyl butyrate from orange juice and Isovaleric acid from sweaty socks, these repeating atom groups form separate units called molecules. Individual molecules are not connected to the molecules next to them. Many of the substances that you encounter every day, such as air and water, are made of individual molecules. In other cases, like cubic zirconia and diamond, these repeating atom groups link together to form large networks known as extended structures. In extended structures, the atom groups repeat over and over again with all of the atoms connected to their neighbors. Besides diamond and cubic zirconia, there are many other substances made of atoms that form extended structures, such as graphite, metal, and even salt crystals. However, whether they form individual molecules or extended structures, atoms are the basic ingredients that make up every substance and determine its specific properties. Differences at the atomic scale are what make substances look, smell, and feel the way they do.

Substances found in Earth's rain forests have treated many medical conditions for thousands of years. Today, scientists try to make versions of those substances in the lab.

Synthetic Materials: Making Substances in the Lab

For billions of years, every substance on Earth was produced in nature, through natural processes, and without input from people. However, within the last few centuries, people have begun experimenting with making substances we can't find in nature. Substances that are produced by humans instead of being found in nature are called synthetic. Scientists make synthetic substances by arranging atoms and molecules in the lab. They use what they know about different types of atoms and molecules to arrange them and make the kinds of substances they want. One type of synthetic material that you probably use every day is plastic. Scientists developed plastics in the early 1900s. Plastic is made from petroleum, a natural resource that is also used to make gasoline and other products. By combining different atoms and molecules, scientists are able to make lots of different kinds of plastic for lots of different purposes, from bottles to boats. Plastic is very useful, but also causes problems. For example, a large amount of plastic ends up in the ocean and harms ocean animals.

In some cases, synthetic substances are copies of substances found in nature. If the synthetic substances are copies of natural substances, scientists can analyze the natural substances and arrange the same types of atoms in the

Many common medicines used today are synthetic versions of substances found naturally in Earth's rain forests.

same way. For example, many plants found in the rain forests of Asia, Africa, and South America have properties that can be used for healing all kinds of health problems, from small cuts to serious diseases. These plants have been used for healing by people who live in and near the rain forests for thousands of years, and in recent years, scientists have begun to understand the substances inside them that make them good for healing. In some cases, scientists have been able to make synthetic versions of those substances, producing them in large amounts without needing to travel to the rain forests.

Synthetic medicines aren't any different at the atomic level from the natural medicines found in the rain forest. After all, molecules are just molecules—whether they're made in nature or in a lab, the same types of atoms arranged in the same ways always form the same molecules that behave in the same ways.

The rain forest is a rich source of medicines for humans to use, but it may not be for much longer. Earth's rain forests are being burned and cut down to make room for farms and other uses. In fact, about 325 square kilometers (125 square miles) are cut down every day. At this rate, our rain forests may be gone soon.

Lora Angelova is a chemist who works with artwork at the Tate Museum in London.

Meet a Scientist Who Preserves Artwork

Over time, artwork can begin to fade, crack, and fall apart in all kinds of other ways. That's where Lora Angelova comes in. Angelova is a chemist who researches the science of art conservation at the Tate Museum in London, England. Art conservation means protecting and caring for works of art so that they will last a long time.

How can a chemist protect art? Like everything else in the universe, artwork is made of atoms. Those atoms combine in different ways to form different materials—paper, canvas, or wood for painting on, ingredients for paint, materials that can be turned into sculptures, and more. As a chemist, Angelova's job is to figure out what all these different works of art are made of and how to take care of them so they're available for many generations to enjoy.

As a chemist at the Tate, Angelova helps take care of all kinds of artwork. "If someone is trying to clean an artwork and they're not sure what it's made of, they might ask me to help do a material analysis on the object," she says. "Once we know what it's made of, we know how it might break down over time and how to store it."

Whenever possible, Angelova analyzes artwork using techniques that don't harm the work at all—for example, she considers whether a painting is made with oil paint or acrylic paint, and she has instruments that can tell her what kinds of pigments (the substances that give paints and inks their colors) were used in mixing the paint. That information can provide hints and sometimes tell her what she needs to know.

However, in some cases, Angelova needs to take a tiny sample of the artwork to test and find out what the artwork is made of. These samples are so tiny that in most cases, they are only visible under a microscope! By running these samples through certain machines, she can gather information about the materials.

Once she's identified the materials that make up an artwork, Angelova considers how those materials are likely to degrade, or fall apart, over time—like why some paintings get tiny cracks in them, or how the ingredients in paint separate over time and cause damage to paintings. She can come up with a plan to store the artwork properly, to protect it from pollution and other things that are bad for it, and to clean it when it gets dirty. Her goal is to keep the artwork from degrading for as long as possible. "There's a lot of chemistry involved in finding out why degradation happens, how it happens, and how we can slow it down," she says.

Angelova also works on a project with many other scientists to find out how nanotechnology, or technology that works on the scale of atoms and molecules, might be used in art conservation work for the future. While other scientists work on ways to make canvases stronger at the molecular level and creating protective layers that can keep art from degrading as quickly, Angelova is working on ways to clean artwork using extremely gentle soaps that are safe for sensitive materials.

Angelova didn't know about art conservation when she was young, but the combination of art and science is a natural fit for her. "I always really liked art, and was a science nerd as a kid. I was either in the science lab or the art room," she says. In college, she intended to study biology and printmaking (a type of art that involves printing with paint or ink), but fell in love with chemistry instead and decided to take as many art classes as she could without officially being an art major. It wasn't until after she graduated that she discovered that she could combine her loves of science and art through conservation science: "I came across some articles from the National Gallery of Art in Washington, DC, interviewing their scientists. I had no idea that was something people did," she says. She earned a Ph.D. in chemistry at Georgetown University while working with a scientist at the National Gallery to learn about art conservation.

Angelova likes working at the Tate and considering how to make sure art is available for the public, both now and in the future—and working at the museum hasn't made her any less excited about the works of art she's conserving. "This is my first time working in a museum, and I absolutely love being here, working with modern and contemporary art," she says, "There are so many interesting and complex questions about how to display art. And on my breaks, I can pop around the corner and look at some art."

Burning is one example of an exothermic reaction.

Endothermic and Exothermic Reactions

When you light something on fire, you're starting a chemical reaction. The same is true when a plant takes in sunlight and turns it into food the plant can use to grow. However, these two chemical reactions have very different relationships with energy. Where energy is concerned, there are two kinds of reactions: those that release energy and those that take in energy from their environments.

An exothermic reaction is a reaction that releases stored energy. The stored energy in the reactants has been released from storage and converted from potential energy into kinetic energy. Kinetic energy always means more motion, so this change from potential energy to kinetic energy means the atoms in the products move faster than the atoms in the reactants. One example of an exothermic reaction is burning: when a fuel like wood or gasoline reacts with oxygen, stored energy is released. This released energy is what causes fire to be hot and bright.

An endothermic reaction is a reaction that takes in energy from its surroundings and stores the energy away—that is, the products have more stored energy than the reactants. Endothermic reactions absorb energy, so one way of identifying them is by measuring temperature. If the products of a reaction are at a lower temperature than the reactants were, congratulations: you probably have an endothermic reaction. You might even use an

Photosynthesis is an endothermic reaction.

endothermic reaction when you get a bump or a bruise and want to keep it cool. The instant cold packs you can place on minor injuries to help reduce swelling use endothermic reactions to get cold quickly.

Photosynthesis is another example of an endothermic reaction—when carbon dioxide and water are combined in a plant's cells with energy from the sun, they react to form glucose and oxygen molecules. These glucose and oxygen molecules have more stored energy than the carbon dioxide and water. The plant can use that energy later, or the stored energy can be passed up the food chain when the plant is eaten by an animal.

When you burn wood in a fireplace, the wood is the fuel that keeps the fire going. Cars are powered by fire inside their engines; gasoline is the fuel that keeps those fires burning.

What Happens When Fuels Burn?

Most people burn fuels every single day. Fuels are substances that release energy when they burn. They are very important to us because we use the energy from burning fuels to do many things, such as run cars and buses, heat homes, and cook food. For example, gasoline is the fuel used in most car engines. When it burns, the energy it releases makes the car move. To prepare for a long trip, you fill your gas tank with gasoline—but after you drive for a while, the tank is empty and you need to fill it up again. What happened to the gasoline? Where did it go?

When we burn something—whether it is a log, a match, or the gasoline in our gas tank—what we are actually doing is causing a chemical reaction. Burning gasoline may not seem like the kinds of chemical reactions that you have seen before. After all, chemical reactions cause substances to change into other substances as the atoms of the reactants rearrange to form the products. When gasoline burns, it doesn't seem to change into a different substance. Instead, it seems to disappear, leaving you with an empty tank. If burning gasoline actually causes a chemical reaction to happen, then why doesn't your tank fill up with a different substance? Can a chemical reaction cause something to change into nothing?

Antoine Lavoisier was a French scientist who did many experiments to find out whether matter could disappear or be added during a chemical reaction.

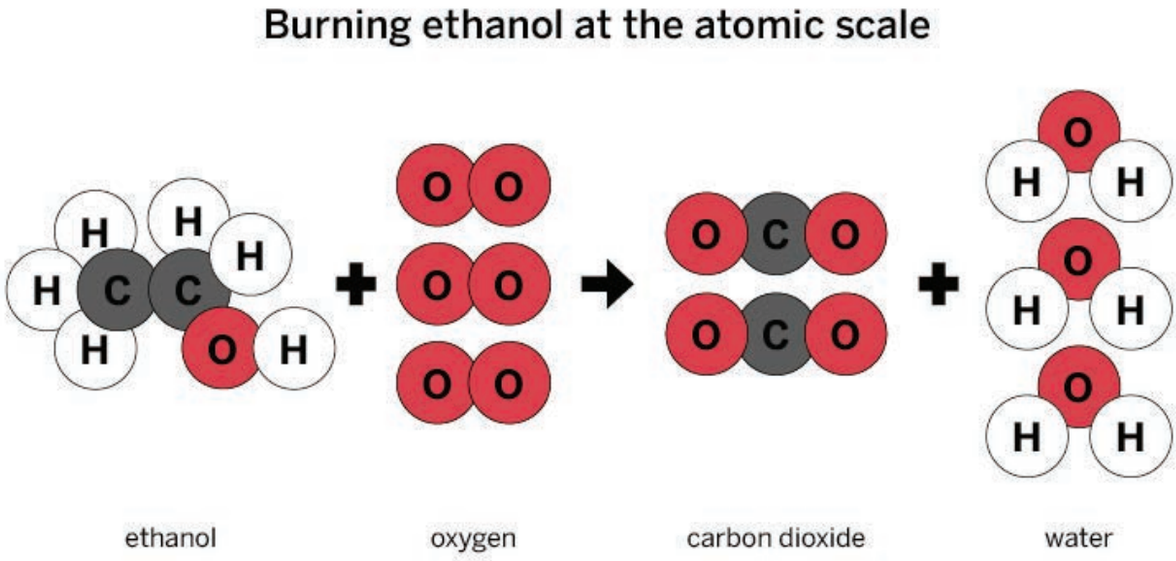
Scientists began to wonder about this question back in the 1700s. Around this time, a French scientist named Antoine Lavoisier (an-TWAN la-VWA-see-ay) began studying what happened to the masses of substances before and after a chemical reaction. Mass is a measure of how much matter makes up an object. First, Lavoisier measured the mass of two reactants before mixing them to cause a chemical reaction. After the reaction had happened, he measured the mass of the products. Every time, Lavoisier found that the reactants and the products had the same mass! Through these experiments, Lavoisier helped come up with the idea we now call the Law of Conservation of Matter: matter cannot be created or destroyed during chemical reactions. This is because the atoms that make up all matter cannot be created or destroyed during chemical reactions. This law tells us that all of the atoms that go into a chemical reaction must come out in the form of one substance or another. Chemical reactions cause atoms to rearrange into new and different groups, but the atoms themselves never stop existing, and new atoms never appear out of nowhere.

So what does the Law of Conservation of Matter have to do with burning gasoline? It means that even though your gas tank is empty, the atoms that formed the gasoline must still exist somewhere in some form. The only reason that these atoms seem to disappear is because the substances that form when gasoline burns are invisible gases. You can't see them, but they are there, and sometimes that isn't a good thing.

Carbon-Containing fuels

Gasoline is just one of many fuels that contain carbon. One of the most common fuels in use today is ethanol, a substance made up of groups of two carbon atoms, six hydrogen atoms, and one oxygen atom. Ethanol is made from corn and used as a substitute for gasoline. Like gasoline, ethanol is a colorless liquid at room temperature. When you burn anything, including ethanol, you are mixing it with oxygen. However, just having oxygen around isn't enough to make something burn; this reaction only happens at a high temperature. Burning reactions release energy in the forms of heat and light, but these chemical reactions result in more than just energy. See the diagram below to learn more.

The chemical reaction that happens when ethanol and oxygen mix produces two substances: carbon dioxide and water in the gas phase. Since both of these are invisible, colorless gases, it seems like nothing is left of the liquid that was in your gas tank. However, the atoms of the reactants haven't disappeared at all—they've only rearranged to form the products. The carbon dioxide and water produced by this chemical reaction enter the atmosphere whenever we burn ethanol or other carbon-containing fuels. In the recent past, humans have increased the amount of carbon dioxide in Earth's atmosphere by burning such fuels, resulting in widespread changes to Earth's climate. In response to these effects, scientists are working to find fuels that can release energy without producing carbon dioxide.



When ethanol burns, it mixes with oxygen, and the atoms of these reactants rearrange to form two products: carbon dioxide and water in the gas phase.

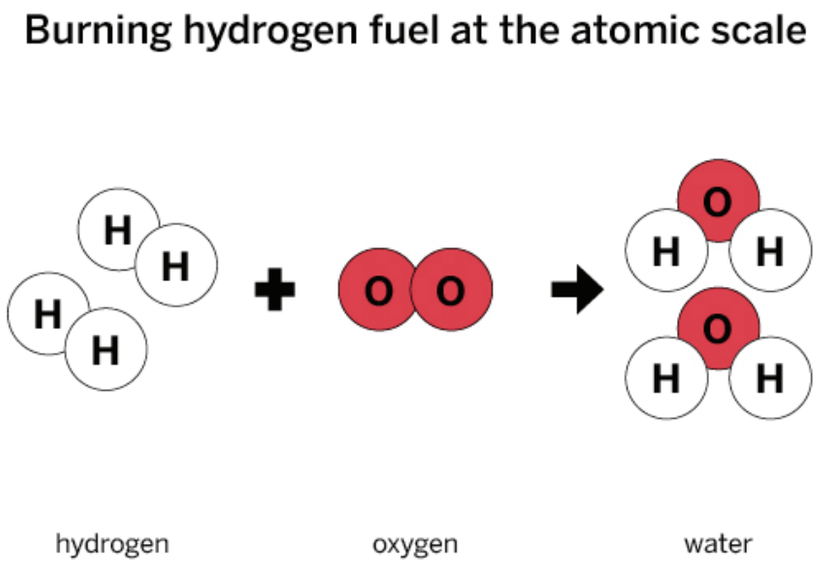
Hydrogen Fuel

Like gasoline, hydrogen is a fuel that can be burned to power cars and buses. However, unlike gasoline, hydrogen does not contain carbon. It is a substance made up of hydrogen atoms. When you burn anything, including hydrogen fuel, you are mixing it with oxygen. Still, having oxygen around won't cause something to burn on its own; this reaction only happens at a high temperature. Fires are hot and bright because burning reactions release energy, but energy is not the only result of these chemical reactions. See the diagram below to learn more.

The chemical reaction that happens when hydrogen and oxygen mix produces only one substance: water in the gas phase. Since this is an invisible, colorless gas, you can't see it, which makes it seem like nothing is left behind by burning hydrogen fuel. However, the atoms of the reactants haven't disappeared at all—they've only rearranged to form the product.

The water produced by this chemical reaction enters the atmosphere whenever we burn hydrogen. Still, compared to the carbon dioxide that is produced when we burn gasoline, ethanol, and other carbon-containing fuels, the water produced by burning hydrogen has a less harmful effect on Earth's climate.

If we can power our cars with hydrogen without producing carbon dioxide, then why don't more vehicles use hydrogen fuel? Unfortunately, the technology needed to use hydrogen as a fuel is expensive, and storing hydrogen fuel can be difficult. Also, the most common way of getting pure hydrogen is by separating it from substances that contain carbon—so although burning hydrogen fuel does less harm to Earth's climate than burning carbon-containing fuels, the production of hydrogen fuel is still a problem for scientists trying to reduce climate change.



When hydrogen burns, it mixes with oxygen, and the atoms of these reactants rearrange to form the product: water in the gas phase.

When you eat, some of the atoms in your food are rearranged through chemical reactions and become part of your body. Without food, our bodies wouldn't be able to grow.

What Happens to Your Food?

Your body needs food to make it grow. Food gives your body the energy it needs to run properly. Food also provides the matter your body needs to add more cells and get bigger. How does that actually work—how does what you eat become part of your body? Without chemical reactions, your body wouldn't be able to use food at all.

Atoms can't be created or destroyed, only moved around and combined into different types of molecules and complex structures. This is as true in your body as it is anywhere else in the universe. The atoms in the food you eat either stay in your body and are rearranged into new substances there or pass through your body and become your waste.

The food you eat doesn't stay in the delicious form you recognize for long: as soon as it goes into your mouth, your body starts breaking it down. The molecules from the food are rearranged into simpler molecules and extended structures that your body can use to meet its needs. These rearranged molecules can be used by the body to release energy or to support growth.

The molecules your body can use fall into a few different categories, like starches, amino acids, and fats. Starches are molecules your body breaks down and uses to release energy. Releasing energy happens during a chemical reaction called cellular respiration, which is similar to burning. During cellular respiration,

Through chemical reactions in the body, food allows us to grow from babies into children, then teenagers, then adults.

the atoms from the molecules your body has broken down are combined with oxygen and rearranged to form carbon dioxide and water. Amino acids are molecules that make up larger molecules called proteins, which form muscle tissue and perform many other functions in the body. Amino acids become proteins through a chemical reaction. Fat molecules in your food remain fat in the body, which is used to protect your organs and keep you warm. Fat can also be used to release energy through a chemical reaction.

Without chemical reactions, food wouldn't be very helpful to your body. You wouldn't be able to get energy from it, and you certainly wouldn't be able to grow and mature from a baby into a child, a teenager, and then an adult. So next time you notice a growth spurt, thank the chemical reactions that take place in your body!

Chemical Reactions:
Mysterious Substance
in Westfield's Water

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