CUNY TASC Science Curriculum
Matter, Energy, & Interactions

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&

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CUNY TASC Science Curriculum
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Lesson #1: An Introduction to Studying Science
- Our Focus: Matter, Energy, and Interactions

Lesson #2: What Is Matter?
- Stuff with mass & volume!

Lesson #3: Scale & Atomic Theory
- Everything in the world is made up of atoms.

Lesson #4: Physical Properties & Physical Change
- Properties help us identify substances.

Lesson #5: An Important Physical Change: Change of State
- Solid, liquid, gas, and plasma are different states of matter.
- Heat makes particles move faster and is responsible for change of state.

Lesson #6: An Important Physical Property: Electric Charge
- Like charges repel each other and opposite charge attract.

Lesson #7: The Atom
- The structure of an atom.
- Elements & the periodic table.

Lesson #8: How Atoms Bond to Form Molecules
- How do atoms stick together to make everything in the world?

Lesson #9: Chemical Reactions
- A chemical reaction happens when bonds form or break.

Lesson #10: Conservation of Mass & the Water Cycle
- The water molecule in your glass might have been produced by the Hindenburg explosion!

Why teach physical science?

“Most systems or processes depend at some level on physical and chemical subprocesses that occur within it, whether the system in question is a star, Earth’s atmosphere, a river, a bicycle, the human brain, or a living cell… To understand the physical and chemical basis of a system, one must ultimately consider the structure of matter at the atomic and subatomic scales to discover how it influences the system’s larger scale structures, properties, and functions. Similarly, understanding a process at any scale requires awareness of the interactions occurring—in terms of the forces between objects, the related energy transfers, and their consequences. In this way, the physical sciences—physics and chemistry—underlie all natural and human created phenomena... An overarching goal for learning in the physical sciences, therefore, is to help students see that there are mechanisms of cause and effect in all systems and processes that can be understood through a common set of physical and chemical principles.” p. 103

“Physical science core ideas answer two fundamental questions—“*What is everything made of?*” and “*Why do things happen?*”—that are not unlike questions that students themselves might ask. These core ideas can be applied to explain and predict a wide variety of phenomena that occur in people’s everyday lives, such as the evaporation of a puddle of water, the transmission of sound, the digital storage and transmission of information, the tarnishing of metals, and photosynthesis. And because such explanations and predictions rely on a basic understanding of matter and energy, students’ abilities to conceive of the interactions of matter and energy are central to their science education.” p. 104

“Understanding chemical reactions and the properties of elements is essential not only to the physical sciences but also is foundational knowledge for the life sciences and the earth and space sciences.” p. 110

from *A Framework For K-12 Science Education, Disciplinary Core Ideas - Physical Sciences*
http://www.nap.edu/read/13165

Lesson #1: An Introduction to Studying Science

Note to the Teacher:

My experience studying science in school was that thousands of seemingly unrelated topics were taught to me, one after the other, with very little discussion of how they were connected or how they formed a coherent explanation of how the world works. One of my goals in this curriculum is to focus on a central theme of **matter** and how it **interacts** with other matter and with **energy** to explain what happens around us every day.

This curriculum (10 lessons) focuses on **matter**. Understanding matter is the basis for all sciences, and if students don't have this background, they are limited if what they can understand in biology, earth sciences, and space sciences. These 10 lessons offer a strong foundation for all other science learning. For example, a thorough understanding of photosynthesis is dependent on students understanding atoms, molecules, elements, chemical formulas, and chemical reactions. All of this is covered in this lesson set.

This first lesson focuses on interaction, which is the most accessible concept for students out of matter, energy, and interactions. They see that they can predict the outcome of many interactions in the world because of their past observations. I hope that this serves two goals.

The first goal is that students see that they can (and should) apply their own observations to what we discuss in class. It's also meant to connect the often abstract study of science with concrete, recognizable phenomena relevant to students' lives. All of science is built on observing things happening in the world, and asking questions about how or why those things happened the way that they did. The Richard Feynman reading, "The Making of a Scientist," addresses this in a charming way.

The second, less direct goal is that students to begin the study of science with confidence that they already understand a few things. Science strikes me as a field that presents itself as all-knowing, dropping a 40-pound textbook in your lap and expecting you to just memorize what the geniuses have figured out. This has made a lot of us feel pretty dumb in the past. In this curriculum, I want the students' first activity in science to be something that they could do with some confidence.

Connected to this, I hope that this curriculum offers a more humane view of the field—that science is just the (often flawed and limited) current understanding of how things work in our world. It's unfinished, it's often wrong, and it's ongoing. At some point, it's worth mentioning a few things that have been revised, like the belief that the Earth was the center of the universe or that smoking was good for your health. The revision to these beliefs is not to imply that "we've got it all figured out now," but rather ask the question, "What will we revise and understand better 100 years from now?"
- Rebecca Leece

Objectives

- Students will understand that "matter, energy, and interactions" is the main theme in this class.
- Students will understand what an interaction is.
- Students will understand that they can connect their observations to scientific discussions in class.
- Students will understand that making observations and asking questions is key to the practice of science.

Materials

- Handout, What would happen if…?
- Reading, "The Making of a Scientist"
- Handout, Notes on Today's Lesson
- Homework Assignment

Lesson Steps

Review the fields of science, and the methodology of this curriculum.

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1. Introduce this unit on science by asking students what the different fields of science are. Start them off with one as an example and elicit the rest of them.
   a. Chemistry
   b. Biology
   c. Earth Science
   d. Astronomy
   e. Physics

   The TASC expects students to know all five of these fields, but it's impossible to cover all of these fields in one class. Instead, this class will focus on core ideas that are essential and common to all five fields.

Introduce our central idea: Matter, Energy, and Interactions.

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2. What are the core ideas? MATTER, ENERGY, and how they INTERACT in any combination. It's fine if this seems confusing right now because we will return to this central idea every lesson. Let's start with INTERACTIONS. What is an interaction? Elicit a few ideas and write a definition on the board.

   Interaction = two or more things come together and have an effect on each other

   Offer a few examples, such as:
   - Two people fall in love
   - Lightning strikes a tree

- Two cars crash
- You take a pill and your headache goes away.

3. Ask students to work with a partner and think of three examples of interactions and write them down. Give them 2-3 minutes to do this and then ask several groups to share. Makes a list on the board as students share their ideas.

4. Check off a few of the interactions that you will discuss in the coming science lessons, such as lightning hitting a tree.

Introduce observations and questioning as central practices of science.

5. Introduce the idea that science is based on OBSERVATIONS and QUESTIONS. Write these two terms on the board. Explain that everything we know about science comes from scientists making observations of the world and asking questions based on those observations. Say that everyone in the room has already made many observations, and that we will use those observations in our discussions of science.

6. For example, what would happen if you dropped a spoonful of sugar into water? Ask the students what happens. Point out that they already know what happens, but the next step is to ask questions about this. The first question is "Why does the sugar dissolve in water? Why doesn't it fall to the bottom like pieces of metal would?" Ask a few more questions, like "Can I mix an infinite amount of sugar into the water? Why not? Why does it dissolve at the beginning but not at the end? Why can't you see the sugar after it dissolves? Can you get the sugar back out? Would sugar dissolve in any liquid or only water?"

7. Distribute the handout. Ask students to work with a partner to use their previous experience to make notes on what would happen in each interaction. In the third column, students should write two questions about the interaction. Do one more example to get them started.

8. Stop students when the first few groups finish or when you think they've got the idea. Have two pairs of students to come together to compare answers. Address the whole class with any outstanding questions.

In-class reading.

9. (This can also be done as homework.) Distribute the reading "The Making of a Scientist." Ask students to select a passage (or section) that stands out to them for any reason. They might select a passage they agree or disagree with, or a passage that they like or dislike. They should make a few notes in the margin about why they chose that passage. A passage might be one sentence, a few sentences, or a paragraph or two.

(Feynman's father was a postal clerk. How does this change your reading of the passage?)

10. When most of the class is finished, have students share their passage with a partner. After a few minutes of discussion, come together as a whole class and hear a few examples. If it doesn't come out naturally in the discussion, ask why Feynman was making a distinction because knowing the name of something versus observing/noticing things.

Review the structure of the class: Quiz, Lesson, Summary.

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11. Congratulate the students on their good work on the first day of science, and tell them when their next science lesson will be. Review how you will be teaching science:

- **a.** At the beginning of each lesson, there will be a cumulative quiz on the previous lesson. This is to help students review and reinforce the ideas. Explain that students who take tests or quizzes more frequently tend to remember the material better and also do better on future tests.
- **b.** After the quiz, there will be a new lesson. Students will need to take notes during the lessons. Group and pair work is central to all lessons.
- **c.** At the end of every lesson, you or the students will summarize the main ideas of the lesson.

Summarize today's lesson.

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12. The first summary isn't going to be a formal summary—it's going to be notes. Ask students to work in pairs to make notes on what you talked about and did during today's lesson. Their list of notes doesn't have to be in complete sentences. It can include definitions of words, a note about an activity of question that was discussed, or anything else. It doesn't have to be in order. The idea is just to get down the most important ideas and concepts that were discussed in class today.

13. Collect ideas and record them on the board after they have had enough time to work on this.

14. Distribute your own version of notes. A model is provided in this lesson set, "Notes on Today's Lesson." Point out how similar they are (even if they aren't that similar).

Homework

Distribute the homework assignment. Students should write a letter to you about their past experiences learning science. Ask students if their past experiences learning about science are mostly good, bad, or neutral. And ask them to think of at least one specific teacher or situation that they remember and describe it to you in the letter.

Offer an example of your own to model how to do this. (For example, the only thing I remember from my physics class in high school was being out in the hallways throwing balls around. I had no idea why we were doing that. A few years later, I enrolled in a physics class in college and I had a very hard time in that class. I had never heard of the words or concepts they were talking about, even though I supposedly had taken physics in high school.)

Encourage students to be honest in their letters.

Vocabulary from this Lesson

- Interactions
- Observations
- Summarize

Lesson #1: What would happen if … ?

Imagine the following interactions. What happens? Make some notes in the second column. Then ask questions about each interaction, such as "Why does the gasoline catch on fire but the water doesn't? Can we explain the difference?"

Interaction	What would happen?	Questions
You drop a lit match into a gas tank full of gasoline.		
You drop a lit match into a glass of water.		
You stir one spoonful of sugar into a glass of water.		
You put small pieces of iron into a glass of water and leave them there for one month.		
You leave a bowl of ice cream in the sun.		

You pour oil into water.		
You pour blue ink into water.		

Lesson #1: Reading

As you read this article, choose a passage that stands out to you. Underline it. Why does it stand out to you? Write a few notes in the margin about why you choose it.

The Making of a Scientist
by Richard Feynman

We used to go to the Catskill Mountains, a place where people from New York City would go in the summer. The fathers would all return to New York to work during the week and come back only for the weekend. On weekends, my father would take me for walks in the woods and he'd tell me about interesting things that were going on in the woods. When the other mothers saw this, they thought it was wonderful and that the other fathers should take their sons for walks. They tried to work on them but they didn't get anywhere at first. They wanted my father to take all the kids, but he didn't want to because he had a special relationship with me. So it ended up that the other fathers had to take their children for walks the next weekend.

The next Monday, when the fathers were all back at work, we kids were playing in a field. One kid says to me, "See that bird? What kind of bird is that?"

I said, "I haven't the slightest idea what kind of a bird it is."

He says, "It's a brown-throated thrush. Your father doesn't teach you anything!"

But it was the opposite. He had already taught me: "See that bird?" he says. "It's a Spencer's warbler." (I knew he didn't know the real name.) "Well, in Italian, it's a *Chutto Lapittida*. In Portuguese it's a *Bom da Peida*. In Chinese, it's a *Chung-long-tah*, and in Japanese, it's a *Katano Tekeda.* You can know the name of the bird in all the languages of the world, but when you're finished, you'll know absolutely nothing whatever about the bird. You'll only know about humans in different places, and what they call the bird. So let's look at the bird and see what it's *doing*—that's what counts." (I learned very early the difference between knowing the name of something and knowing something.)

He said, "For example, look: the bird pecks at its feathers all the time. See it walking around, pecking at its feathers?"

"Yeah."

He says, "Why do you think birds peck at their feathers?"

I said, "Well, maybe they mess up their feathers when they fly, so they're pecking them in order to straighten them out."

"All right," he says. "If that were the case, then they would peck a lot just after they've been flying. Then, after they've been on the ground a while, they wouldn't peck so much anymore—you know what I mean?"

"Yeah."

He says, "Let's look and see if they peck more just after they land."

It wasn't hard to tell: there was not much difference between the birds that had been walking around a bit and those that had just landed. So I said, "I give up. Why does a bird peck at its feathers?"

"Because there are lice bothering it," he says. "The lice eat flakes of protein that come off its feathers."

He continued, "Each louse has some waxy stuff on its legs, and little mites eat that. The mites don't digest it perfectly, so they emit from their rear ends a sugar-like material, in which bacteria grow."

Finally he says, "So you see, everywhere there's a source of food, there's *some* form of life that finds it."

Now, I knew that it may not have been exactly a louse, that it might not be exactly true that the louse's legs have mites. That story was probably incorrect in detail, but what he was telling me was right in principle.

Not having experience with many fathers, I didn't realize how remarkable he was. How did he learn the deep principles of science and the love of it, what's behind it, and why it's worth doing? I never really asked him, because I just assumed that those were things that fathers knew.

My father taught me to notice things. One day, I was playing with an "express wagon," a little wagon with a railing around it. It had a ball in it, and when I pulled the wagon, I noticed something about the way the ball moved. I went to my father and said, "Say, Pop, I noticed something. When I pull the wagon, the ball rolls to the back of the wagon. And when I'm pulling it along and I suddenly stop, the ball rolls to the front of the wagon. Why is that?"

"That, nobody knows," he said. "The general principle is that things which are moving tend to keep on moving, and things which are standing still tend to stand still, unless you push them hard. This tendency is called 'inertia,' but nobody knows why it's true." Now, that's a deep understanding. He didn't just give me the name.

He went on to say, "If you look from the side, you'll see that it's the back of the wagon that you're pulling against the ball, and the ball stands still. As a matter of fact, from the friction it starts to move forward a little bit in relation to the ground. It doesn't move back."

I ran back to the little wagon and set the ball up again and pulled the wagon. Looking sideways, I saw that indeed he was right. Relative to the sidewalk, it moved forward a little bit.

That's the way I was educated by my father, with those kinds of examples and discussions: no pressure—just lovely, interesting discussions. It has motivated me for the rest of my life, and makes me interested in *all* the sciences. (It just happens I do physics better.) I've been caught, so to speak—like someone who was given something wonderful when he was a child, and he's always looking for it again. I'm always looking, like a child, for the wonders I know I'm going to find—maybe not every time, but every once in a while.

Originally published in *Cricket* Magazine, October 1995 (Vol. 23, #2).

Lesson #1: Notes on Today's Lesson

- Different branches of science:
    - Biology
    - Chemistry
    - Physics
    - Earth science
    - Astronomy

- We don't have time to learn each field, so we'll focus on ideas that are common to all of them by studying "Matter, energy, and interactions."

- Interaction = two or more things come together and have an effect on each other. We used our past experiences to say what the result of certain interactions would be. We also asked questions about these interactions.

- Observations and questions are central to how science is done.

- Read "The Making of a Scientist," which gave an example of people making observations and asking questions.

- Structure of science lessons:
    1. Quiz
    2. New lesson (take notes)
    3. Summarize

Lesson #1: Homework

Dear Students,

Welcome to our science unit! I'm excited to work with you in this section—we are going to work hard to learn a lot, but we also will do a lot of fun activities in class together.

I know that not everyone has had good experiences learning science. It's helpful for me to understand how you feel about learning science as we start this part of the class. To help me, please write me a letter about your past experiences. You can be honest—if your experiences were good, bad, or forgettable, you can tell me.

I'd like you to include a paragraph on each of these topics:

1. How do you feel about learning science? (Excited, bored, scared, intimidated?) Why?

2. Describe one teacher, class, or learning experience you've had related to science. Pick your most memorable memory—good or bad!

3. Finally, what are your plans for after you pass the TASC? Are you interested in attending college, and if so, what would you like to study? What kinds of jobs appeal to you?

I look forward to reading your letters!

Warmly,
Your Science Teacher

Lesson #2: What is Matter?

Note to the Teacher:

The first half of this curriculum is devoted to matter. It covers what matter is (and isn't), what some of the properties of matter are, how you can change the phase of matter, and finally ends with atomic theory: that all of matter is made up of atoms. Once they have this, you can discuss how the structure of atoms determines if atoms will participate in chemical reactions and join together to form molecules, which in turn form proteins and other macromolecules, which in turn form plants and animals. Without chemical reactions, our whole world would just be a soup of lonely atoms.

In this lesson, we focus on what matter is. Matter has a formal science definition of anything that has mass and takes up space (or has volume). This lesson covers matter, mass, and volume in some depth. You might also add that all of matter is made up of particles, but we'll also get that in future lessons.

If you have a scale in class, it's worth having students measure the mass of some objects. You can bring objects in or just have them measure things in the classroom: keys, phones, pens, chalk, books. This lesson does not go into how to measure volume, but it would fit well with this lesson if you are interested in adding it.

A big challenge of this lesson is that gas is matter, too. Most students don't recognize gas as matter. The final section is devoted to undoing this misconception, but in my experience this is something that needs to be reviewed many times over the course of the semester before students are convinced that gas has mass and volume and, thus, is matter.

Objectives

- Students understand what is and is not matter.
- Students understand mass, volume, and how they are different.
- Students understand that gas is matter too.

Materials

- Quiz, copies for all students
- Sorting cards, one pack for each *pair* of students
- Handout: Sentence Starters
- Handout: Is it matter?
- 2 balloons of the same size
- Tape
- Yardstick or ruler
- Reading: "Matter has mass and volume."

Lesson Steps

Give the quiz.

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1. Give the quiz! Ask students to work on it by themselves, without consulting notes, for a few minutes. Remind them that this is excellent practice, asking their brains to try to remember what you talked about last time. After a few minutes, tell them that they can use their notes or talk with a partner. Review the answers briefly.

2. Review the goals of the quizzes:

    a. Every time you try to access a memory, your brain gets the signal that this is an important piece of information and it builds that memory stronger. Quizzing yourself is a great way to reinforce memories, which is why flashcards work.

    b. It gives everyone a chance to remember what you did last time and ask questions about it.

    c. Because all the science lessons are connected, it sets the stage for the next lesson.

Introduce matter.

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3. Write "Matter, Energy, and Interactions" on the board. Ask students which word you focused on last time. (Interactions) Today, we will focus on MATTER.

4. Introduce two definitions of **matter**.

a. The first definition is STUFF. Matter is stuff in the world. Include some examples like water, people, clothes, iPhones, grass, food, air.

b. The second definition is the formal science definition. Matter is anything (or stuff) that has mass and takes up space.

Review mass.

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5. In order to understand this, we need to understand what mass and volume is. Define **mass**.

a. Mass is a measurement of how much something weighs. We use a scale to measure mass. We can measure mass in pounds or kilograms. (Example: He weighs 160 pounds.) I make a list of words on the board to associate with mass:
   i. Weight
   ii. Heaviness
   iii. Use a scale to measure it
   iv. Pounds, ounces, grams

b. Ask students to vote on which of the above four words seems like the best, most memorable definition for them. (This is not about getting a consensus but about having students evaluate information and make a decision about what will help them remember the concept the best.)

(Note to teacher: there is a difference between mass and weight that is difficult and time-consuming to teach. Weight is the measure of the pull of gravity on an object and is computed by multiplying mass times the force of gravity. Mass is the amount of matter. This distinction is complicated by the fact that in science labs all over the country, this distinction is ignored when mass is measured on a scale—that is, mass is measured as weight. I have found the distinction between mass and weight unnecessary for HSE students. The formal definition of weight vs. mass won't come up until Physics 101, but mass OFTEN comes up, so it is important that students can recognize mass as a measurement taken on a scale.)

c. Distribute one pack of sorting cards to each pair of students. Ask them to sort the cards based on how much mass they think each image has. Draw a continuum on the board and label it:

less mass ⟷ more mass

Working with a partner, students should place their cards in order from less to more mass.

d. Review as a class. Ask, Does anything have the exact same mass?

Review volume.

6. Define **volume**.

a. Volume is a measurement of how much space something takes up. We can't use a scale to measure this. We need to use a tape measure. For example, you might have two different sized plates, one small and one large. These plates have different volumes. They take up different amounts of space. Here's two ways to define volume. Ask students which one they like better:
   i. Size
   ii. How big or small it is
   iii. How much space something takes up

b. Ask students to make a second continuum, on a second piece of paper. This time, label it like this:

   less volume ⟷ more volume

   Students should use the same sorting cards, but now re-sort them based on volume. This should give a different result. Ask them to record the order on a piece of paper.

c. Review as a class. A few questions to ask: What changed position when you organized by volume? Why? Does the empty or full Coke can have more volume?

7. Ask students, "What is the difference between mass and volume?" Talk about how they will remember the difference. Explain that thinking about HOW to remember something really does help you remember it. For example, say that you think of mass as how HEAVY something is, and you think of volume as how much SPACE it takes up. You might draw a weight on the board, label it "100 pounds" and write Mass above it. For volume, you might draw a bus and a small car or bicycle, or a small and large suitcase.

8. **Note:** A number of teachers have asked us about the right answer to this activity. The main thing to emphasize is that mass = weight. When students put these in order by mass, they are thinking about how much they weigh. The most important take away is that students realize that mass=weight and volume=size. We measure weight with a scale and size with a tape measure. The exact weight and size of each object isn't as important.

However, if your students want to answer it definitively, you might give them the following weights for each object and let them decide the correct order. They would still have consider grams vs ounces vs pounds, and they would have to consider place value for smaller items. You might tell them that 1 oz. = 28 g. and 1lb. = 16 oz., then let them figure out what the order should be based on these values below.

Ceramic pan - 6 lbs.
Cup of honey - 12 oz.
Cup of water - 8.3 oz.
Empty Coke can - 16.5 g
Foil pan - 23 g
Full Coke - 366 g
Golf ball - 1.62 oz.
Ping pong ball - 2.7 g
Plastic cooler - 9 lbs.
Popped kernel - .09 g
Styrofoam cooler - 5.6 oz.
Unpopped kernel - .1 g

9. Distribute the sentence starters and give students a choice to work on it with a partner or alone.

Is it matter?

10. Let's come back to matter! If you erased the definition of matter, ask students, "What is matter again?" Ask students how they would decide if something is matter or not. (Get to the answer that they would need to test if it had mass and volume. If it has both mass and volume, it is matter.)

11. Distribute "Is it matter?" Students should work in groups of 2 or 3. Encourage them to make notes on the final question about how they decided. Review as a class.

Gas is matter too.

12. It's worth spending some time talking about gas. Many students don't recognize gas as a form of matter. Discuss how you might test is a gas has mass or volume. If time allows, ask students to brainstorm ways to measure the mass and volume of a gas.

13. One way to test if air has volume is to blow air into a balloon. Does that air take up space inside the balloon? Yes.

14. In order to test if the air has mass, you might compare the weight of the filled balloon with the weight of an empty balloon. If you have a sensitive scale in the classroom, you can weigh the empty balloon and then weigh the full balloon (although it's hard to keep the balloon from rolling off of the scale). You could also bring a basketball and an air pump to class to compare the weight in grams of an empty basketball and a full basketball. An empty basketball may weigh about 576 grams and a full basketball should weigh about 5 more grams. These demonstrations show that air has weight.

If you don't have a scale, you can attach the full balloon to one end of a meter stick and an empty balloon to the other end. Ask students what would happen if you balance the stick on your finger (your finger is in the center of the meter stick) if the balloons weigh the same. Ask them what would happen if you balance it on your finger and they don't weigh the same. Do it to show that the filled balloon weighs more than the empty balloon. You can pass it around the class and have people try to balance it, so that they can see that the side with the full balloon always tips down.

A word of warning: Try this at home first to see if you can come up with conclusive results. Unforeseen variables in how much tape is used or where the balloon is attached to the yardstick can throw this off. You may also want to use larger balloons that can hold more air, in order to have obvious results.

Summary

15. Do the summary as a group. Write the following on the board and ask the students to tell you what you learned about each concept in today's class.

a. Matter
b. Mass
c. Volume
d. Gas

Another option is to give students three more sample summaries to choose from, if they need more support writing their own summaries. Samples are included with the handouts at the end of the lesson.

16. (Make sure you have a coherent definition for matter, mass, and volume. For gas, you should note that not everyone was sure that gas was a form of matter, so you decided to test to see if air met the definition of having both mass and volume. You used a balloon to see that air took up space, and then you compared the weight of a full and empty balloon to see that it has mass, so air has both mass and volume and therefore must be matter.)

17. Remind them that they will have a quiz on these topics at the beginning of the next class.

Homework

Distribute the reading, "Matter has mass and volume." Ask students to read it and summarize the main ideas in one paragraph for homework.

Vocabulary

- Matter
- Mass
- Volume

Quiz #1: Interactions

1. What's an interaction?

2. Give two examples of interactions.

3. Fill in the blank:

   The theme of our science study is Matter, ______________, & Interactions.

Lesson #2: Matter Sorting Cards

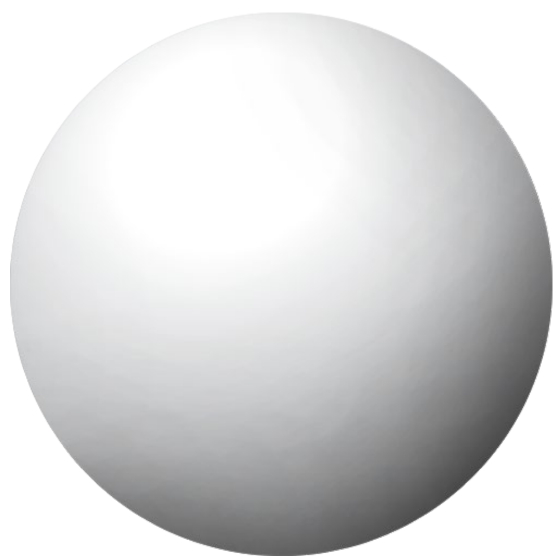
Styrofoam Cooler

24 inches wide
12 inches tall
12 inches deep

Plastic Cooler

24 inches wide
12 inches tall
12 inches deep

Golf ball



Ping pong ball

Ceramic pan

12 inches long
6 inches wide
3 inches deep

Foil pan

12 inches long
6 inches wide
2 inches deep

Empty Coke can

Full Coke can

popped popcorn kernel

unpopped popcorn kernel

1 cup of honey

1 cup of water

Lesson #2: Sentence Starters

Complete each sentence, or answer the question.

1. Mass is…

2. Volume is…

3. How are mass and volume different?

4. An example of something that has a lot of mass is…

5. An example of something that has a lot of volume is…

6. An example of something that has a lot of mass but not a lot of volume is…

7. An example of something that has a lot of volume but not a lot of mass is…

Lesson #2: Is it matter?

This list includes things that are matter and things that are not matter. Discuss with a partner which things are matter. Mark each thing that is matter.

rocks	salt	dissolved sugar
baby powder	Mars	helium
milk	steam	human being
air	rotten apples	light
love	heat	opinions
dust	water	sound
music	bacteria	The Sun
atoms	oxygen	cells

Explain your thinking. How did you decide if something is matter or not?

Adapted from Uncovering Student Ideas in Science, Volume 1*, by Page Keeley, Francis Eberle, and Lynn Farrin, NSTA Press.*

Lesson #2: Summary

Pick the best summary of today's class. Why is it the best? What's wrong with the other two? How can you improve the best one?

#1

Today we learned about matter, which is anything that has mass and volume. We sorted different objects by mass and then by volume. Then, we completed sentences about mass and volume. Next, we tried to decide whether different things like water, sound and air were matter. Then, we did a demonstration with a balloon and a yardstick.

#2

The topic of today's lesson is matter, which is stuff. Next week we will have a quiz on it. First, we learned about the definition of mass and volume. Then, we arranged some things according to size. The plastic cooler was the biggest and the popcorn kernel was smallest. The plastic cooler was heavier than the styrofoam cooler. My partner and I disagreed about whether a full and an empty Coke can have the same volume. I didn't think air was matter, but my teacher said it was.

#3

Everything in the world is made of matter (unless it's form of energy). One definition of matter is STUFF in the world. A formal definition is anything that has mass (weight) and volume. Mass is a measurement of how much something weighs. We use a scale to measure weight. I like the word "heaviness" to remember what mass is. Volume is a measurement of how much space something takes up. I remember volume by thinking of the word "size". A bowling ball is an example of something with a lot of mass, but not a lot of volume. A cloud has a lot of volume, but not much mass. Light and sound don't have mass or volume, so they aren't matter. It might seem like air isn't matter either, but we showed that a balloon filled with air is heavier than an empty balloon, so air must be matter.

Lesson #3: Scale & the Atomic Theory

Note to the Teacher:

The last lesson introduced matter, mass, and volume. This lesson picks up on volume and introduces the huge scope of size of matter. In looking at matter, we could be talking about the size of an atom, a cell, a human, an ocean, the atmosphere, the Earth, or the solar system. I added this lesson after noticing that some students didn't distinguish between the size of an atom and a cell. Both are microscopic, so it makes sense to just categorize them together. But the size difference is enormous—in fact, there are about the same number of atoms in one cell as there are cells in the human body!

But the concept of this lesson is more important than just heading off a misunderstanding between atom/cell. The Next Generation Science Standards list "scale, proportion, and quantity" as one of their crosscutting concepts, and I think that's right. Students (and all of us!) have a hard time visualizing and comprehending the very tiny or the very vast—it's just too abstract. I hope that this lesson, while basic, sets up a framework for students that you can refer back to through the rest of the lessons.

In the first part of this lesson, students sort things in order of size. If it's possible, post this on the wall of your classroom after this lesson so that you can refer to it and continue to add to it. If students struggle with sorting the objects on the macro/micro continuum, have them first make a pile of "smallish" things and "big" things. Then they can work with only one of those piles and put things into order as well as they can. They don't have to do this activity perfectly—it's not a test.

In the second part of this lesson, students are again working with scale, but this time within one system. For example, you can start with the ocean, and then look at what makes up the ocean: fish, water, salt, shells, sand, seaweed. And then you can look at what makes up a fish: head, tail, bones, muscles. And eventually, you get down to atoms. This is the heart of the first part of this curriculum: the atomic theory, which states, "Everything is made up of atoms."

The atomic theory is the foundation for biology, chemistry, physics, earth science, and astronomy. Without a clear understanding of this idea, students can't come to learn photosynthesis, genes and inheritance, climate, or pollution in an in-depth way.

The final message of this lesson is that the structure and behavior of these atoms (on the micro level) explains a lot of the visible (macro) phenomena in the world. This lesson introduces this idea but doesn't go into it in depth. We will come back to this idea in future lessons.

Objectives

- Students consider how huge the difference in size of matter is, and that there is a huge range of sizes even within matter that is considered microscopic.
- Students think about breaking matter down into its "ingredients."
- Students learn that everything in the world is ultimately made up of tiny particles called atoms.

Materials

- Quiz
- Sorting card sets (one set for every two students) (Print and cut these up ahead of time and mix them up so that they are out of order.)
- Handout: Scale
- Handout: What's it made up of?
- Handout: Paraphrasing the Atomic Theory
- Handout: Summary
- Reading: "Matter is made of atoms."
- Optional: Internet access & screen to show a YouTube movie

Lesson Steps

Give the quiz.

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1. This quiz is meant to ask students to recall information from the previous lesson on matter, mass, and volume. Ask students to work on it for a few minutes alone, without consulting their notes. Walk around the classroom to get a sense of who understands and remembers.

2. After most of them have written down what they can, have them discuss it with a partner and consult notes.

3. Review the quiz as a class. Pay special attention to the differentiation between mass and volume. Ask them what helps them understand each concept the most.

Introduce the idea of scale of matter.

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4. Draw the macro/micro continuum on the board as it is in the handout. Define macro and micro. Say, Today we'll talk more about matter—the huge range of size of matter, from a planet to a virus.

5. Distribute packs of sorting cards, one pack per pair of students. Ask them to sort them according to SIZE on the continuum. (Does size refer to mass or to volume?) Make sure that this is a partner activity and not done alone—the point is the conversation between

students. If they aren't sure what an object is, they can leave it out. Remind them that it's okay to be wrong.

6. Once half of the groups have finished, have two groups compare their answers. Did they come up with the same order?

7. Take notes on the micro/macro continuum as students dictate an order for the items to you.

8. If time and technology allow, show the 9-minute film on scale called "Powers of Ten," free on Youtube here: https://www.youtube.com/watch?v=0fKBhvDjuy0. After watching, ask students what things we might add into our continuum (cell, DNA, atom, possibly). Add only those things students suggest.

Look at the scale within one "system." (If a cookie is your system, you could break it down into smaller and smaller parts, i.e.: Cookie→ butter→ fats→ atoms)

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9. Say you just ate the most glorious, delicious cookie you've ever had. You want to know why it was so delicious. What would you find out about? Elicit questions from the students. A few examples:

    a. What ingredients?
    b. How it was made—temperature, mixing technique, equipment, etc.?

    How the cookies were made is important, but right now we're especially interested in the ingredients. Knowing what ingredients are in something can tell you a lot about it. The ingredients can tell you how healthy or unhealthy it is, how sweet or bitter or salty it might taste, what color it might be, etc. This is the same in science. Knowing what substance/matter/objects are made up of will tell us a lot about the properties of that substance.

10. Distribute the handout "What's it made up of?" Students should work with a partner to make a list of "ingredients" of each of these things from the sorting activity.
    a. Ocean
    b. New York City
    c. Human

11. What if you continued to break the ingredients down into smaller and smaller pieces? What would you end up with? The ultimate ingredient is the atom. **Atoms make up**

all of matter. This is a core idea for all sciences. It's okay if students don't know what an atom is. We will learn all about atoms in the next few lessons.

12. Elicit from the students the "ingredients" of one of the things listed on the handout. Ask which things are alive. Circle the things that are alive. Ask if anyone know what living things are made up of. (Cells.) Show this in your board illustration. And then point out that all things, cells included, are made up of atoms.

Ocean → water, salt, fish, seaweed, shells, sand, crabs, sharks

cells cells cells cells

atoms atoms atoms atoms atoms atoms atoms atoms

13. Ask the group how many cells they think are in the human body. Write down their guesses. (A human has 37 trillion cells = 37,000,000,000,000 cells.) Talk about how it's really hard to think about that number—it's just so large. Return to the concept that one cell is made up of atoms. Ask students how many atoms they think make up a cell—just a guess. (The answer is almost the same as the number of cells in a person. One cell = 100 trillion atoms = 100,000,000,000,000 atoms.) In this unit on Matter, we'll be talking a lot about atoms.

14. Add CELL and ATOM to the sorted objects that you worked with in the first activity.

15. Distribute the handout *Paraphrase the Atomic Theory*. Students can work with a partner or alone.

The structure and behavior of atoms explain why many things happen around us.

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16. Connect to Lesson #1 on interactions.

a. You stir one spoonful of sugar into a glass of water. (Here, the sugar dissolves into the water. This is an example of a mixture. We'd be able to separate these two by boiling the water out.)

b. You put a piece of iron into a glass of water and leave it there for one month. (Here, the iron reacts chemically with the water molecules to for a new substance: rust.)

In our first lesson, we asked why these lead to such radically different outcomes. We can find the answer in the difference in atoms in iron and sugar. Iron is made up on only one type of large atom. Sugar is made up of three different smaller atoms. The difference in structure and behavior of these atoms explains the very different results of mixing them with water. When we learn more about atoms, we'll be able to explain this difference.

Summarize

17. Give students the Summary handout and have them select the best summary. Ask them to make a few notes about what's wrong with the other summaries. After a few minutes, they should discuss their decision with a partner.

Homework

Students should read and summarize the reading "Matter is made of atoms."

Vocabulary

- Macro
- Micro
- Atom
- Atomic theory
- Particle

Quiz #2: What is matter?

1. What is the scientific definition of matter?

2. True or false? Air is not matter. Explain why it's true or false.

Does it go better with mass or with volume? Check one.

	mass	volume
3. How much space something takes up		
4. Kilograms or pounds		
5. Heaviness		
6. Size		
7. Weigh it on a scale		

Lesson #3: Scale

MACRO

micro

Lesson #3: Sorting Cards

Solar system

Sun

The planet Earth

Ocean

City

Whale

Human

Lung

iPhone

Cookie

Mosquito

Bacteria

Lesson #3: What's it made up of?

What are they made up of? Make a list. Follow the example.

	What's it made up of?
Cookie	Sugar, butter, flour, eggs, chocolate, Salt, baking soda, vanilla
Ocean	
New York City	
Human	

Lesson #3: Paraphrasing the Atomic Theory

Imagine that you are sitting in a lecture in college, and the professor says the following quote. Your friend turns to you and says, "I didn't understand that. What's he mean?" What's this quote saying? Help your friend out by trying to explain what this means.

If, in some catastrophe, all of scientific knowledge was destroyed, and only one sentence was saved, what statement would contain the most information in the fewest words? I believe it is the atomic theory that *all things are made of atoms—little particles that move around in perpetual motion.* In that one sentence, there is an enormous amount of information about the world.

Adapted from Richard Feynman, *Six Easy Pieces*, page 4.

Feynman is saying that…

Lesson #3: Summary

Pick the best summary of today's class. Why is it the best? What's wrong with the other two? How can you improve the best one?

#1

Today in class we arranged some things according to size. The solar system was the biggest and the smallest was an atom. Atoms and cells are about the same size: very small. Richard Feynman was a scientist who thinks that the atomic theory is the most important piece of knowledge to pass down to the next generation.

#2

Today we talked about big matter and small matter. We arranged things on a scale from micro (small) to macro (big). (We weren't talking about mass or heaviness—we were talking about volume or size.) We learned that all of matter is made up of atoms. Atoms are tiny particles. Apparently knowing about these atoms will explain why things happen in the world.

#3

Atoms are like ingredients for everything in the world. Anything that is matter is made up of cells, which are made up of atoms. This is called the atomic theory. First, we demonstrated this by organizing some objects from small to big. Next we talked about the different ingredients in a cookie and how they are made up of atoms. Finally we paraphrased a quote by a scientist, which was about atoms as particles.

Lesson #4: Physical Properties & Physical Change

Note to the Teacher:

The content takeaway of this lesson is that physical properties are descriptive of a substance. They include color, odor, flexibility, solubility, density, mass, volume, shape, texture, brittleness, transparency… the list goes on. I initially taught this lesson by having students make a list of physical properties of different substances. It was pretty boring, and I don't think it got the point across that properties are the main way we are able to identify substances in nature, since nature doesn't label things URANIUM or LEAD or GOLD.

In this version of the lesson, I tried to correct this by asking students to identify things based only on their properties, which mimics what scientists have to do. This activity also asks students to draw on their past observations, which is something we started to do in the first lesson. I also wanted to teach students that properties are not only something that you observe with your eyes or nose, but that you might perform some sort of test for solubility, density, brittleness, etc.

The second activity asks students to figure out a way to solve a mystery. They are presented with three unlabeled bottles of white fluid, and told that one is soap (or shampoo), one is hair conditioner, and one is lotion. With a partner, they have to come up with a way to solve this problem. First, they just make observations of the substance, like odor or thickness/thinness. Drawing on their experience with these three substances and those substances' properties, they need to come up with tests to perform on the substance to gather more information. One test they should also think of is foaming/sudsing capacity. They can mix a little of each substance with water on their hands to see if it foams up. Another test they might think to do is to see if the substance absorbs into their skin well—if it does, it's probably the lotion.

One problem with many science experiments is that students are not asked to plan out their own exploration or inquiry. They are given instructions and they just follow the instructions to the prescribed end. Every student in the class follows the same path and gets the same result. This shuts students out of how science is actually done. I hope that students find this activity more engaging and memorable for having planned out their own scientific tests and explorations. If you are also teaching ELA, you might have them write up their process as an essay.

Physical and chemical properties are often taught together. I decided to divide them since a chemical property is about how a substance reacts to form new substances, and we have not laid the groundwork yet for students to understand this. Lesson #9 in this set, about chemical bonding, will cover the concept of chemical properties.

Objectives

- Students will be able to define and offer examples of physical properties.
- Students plan out their own investigation of physical properties to solve a problem.
- Students will understand what a physical change is.

Materials

- Quiz
- Handout, "What is it?"
- Handout packet, "Use physical properties to solve a mystery!"
- Handout: Physical Changes
- Three identical bottles (ideally, squirt bottles), labeled 1-3. Fill each bottle with either soap (or shampoo), hair conditioner, or lotion.
- Small plastic cups, 3 per pair of students.
- A Sharpie marker
- Plenty of paper towels.
- Access to a sink.
- Optional: a piece of foil, a piece of string, and scissors.
- Two readings: "Matter has observable properties." and "Properties are used to identify substances."

Lesson Steps

Give the quiz.

Introduce physical properties.

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1. Ask students to imagine that a team of scientists just discovered a cave on Long Island, and inside that cave are some rocks that are unlike any other rocks in the world. For example, there is a smooth, purple, iridescent rock that smells like gasoline. What is the first thing that the scientists will do? They will make a list of the physical properties of each of these rocks. Make a list on the board of physical properties of the rock—smooth, purple, iridescent, smells like gasoline. Scientists can then compare the list of properties to properties of known substances. Physical properties are characteristics of a substance, and include mass, volume, color, shape, odor, texture, and many other things.

2. Distribute the handout "What is it?" Student should work in pairs to identify what each thing is based on the known properties. Do one as an example before they start working. When half of the students are done, go over it together. (Answers: 1) glass, 2) oil, 3) aluminum foil, 4) styrofoam, 5) chalk, 6) clay, 7) pencil eraser, 8) charcoal)

<u>What am I? Parlor Game</u>
(an alternate activity to use instead of mystery substances handout)

1) What kinds of questions can we ask if we want to get at the physical properties of a substance? Brainstorm and put on easel paper. Some examples after students have had time to generate ideas:
    - What is the density?
    - How brittle is it? How strong is it?
    - What color is it?
    - Is it opaque or clear?
    - How well does it reflect light?
    - How well does it conduct electricity?
    - Is it malleable? Does it stretch?
    - Does it have high or low viscosity? Does it flow at room temperature?
    - Is it normally solid at room temperature?
    - Does it dissolve in water?
    - Etc.

2) Everyone has a post-it with the name of some kind of matter stuck on their forehead in a way that everyone can read the name except them.

3) You can only ask or provide information about the physical or chemical properties of the substance on your forehead.

4) Don't guess the substance until you have asked as many questions as possible.

5) Model with a mystery substance on your own forehead (*honey*). Ask questions about physical properties.

honey	
Example of questions allowed: *What color is it?* *Can I break it with my hands?*	Example of questions not allowed: *Where can I find it?*
Example of clues allowed: *It's sticky.* *It has a high viscosity.*	Example of clues not allowed: *You put it in your tea.* *Bees make it.*

6) Groups of 3. Five minutes per person. First round, person with post-it asks questions about physical properties.

7) Everyone starts at the same time. Set timer for 2 minutes. After two minutes, call switch. 2 minutes. Call switch. 2 minutes.

- If people need more time, do another round. Second round, other members of the group can give clues about physical properties the mystery substance has.

These are the items to be written on post-its: *glass, oil, aluminum foil, styrofoam, chalk, clay, pencil eraser, charcoal, bread, milk, peanut butter, lotion, wood, steel, shampoo, sugar, gold, plastic, bar of soap, diamond, rock, molasses, sand, cloud, water, glue, butter, rubber, graphite, ceramic, hair conditioner, salt*

3. Next, point out that sometimes you can describe a property just by observing it. An example of this is color—you just look at it to find out what color it is. But some other properties need to be tested. For example, if you want to find out if something floats, the best way to test this is by throwing it into water. If you want to find out how heavy something it, you can try to pick it up.

Ask students to make a list of tests mentioned in the handout. The tests include putting something in water, trying to cut it with a knife, throwing it on the floor, etc. Ask students to make a list of all the tests mentioned.

4. These types of tests are the heart of classifying matter. All known substances in the world have a "properties" sheet available for reference. If you have internet access in your classroom, look up gold on Wikipedia. (http://en.wikipedia.org/wiki/Gold) On the right side of the page, you will see a chart that lists General Properties, Physical Properties, and Atomic Properties. These are statistics for a substance, like your name, age, weight, where you live. Properties are basic information about substances in the world that help us to identify those substances.

5. Call up the BBC website on properties, and choose a material (paper, metal, rubber, etc.). Perform a few "tests" on it to learn about its properties. Ask students what the "test" is and what property the material shows in response to the test. Ask students to pick a second material to test.
http://www.bbc.co.uk/schools/scienceclips/ages/7_8/characteristics_materials.shtml

Use physical properties to identify mystery substances.

6. Tell students that they are going to solve a mystery by using physical properties. Set out the three bottles of liquids, if you haven't already. Give each pair of students 3 small plastic cups and a few paper towels. Tell them that you have a bottle each of soap, hair conditioner, and lotion, but the manufacturer forgot to label the bottles. Have each pair of students label their cups 1-3 and take a small amount of each mystery substance (a few tablespoons). (Make sure they label their cups BEFORE they take the substances.)

7. Distribute the packet. Ask them make observations of each fluid. Is one thicker or thinner than the others? Is the color a pearly white or a flat white? What about odor? Does the substance feel sticky or slick? (Reassure students that all substances are safe to touch.) Students should take specific notes. Encourage them to think of good adjectives to describe the substances, like "gloppy." They don't have to be "scientific" words.

8. Next, have them brainstorm how to tell the difference between these three fluids. Focus on the kinds of testing they will need to do. After they all have time to come up with some ideas, come together as a class to share ideas. Tell them that everyone will share ideas and that if they hear a good idea for a test from another group, they are allowed to use it, too.

9. After they all have their plan, they should go do testing. Give them a time limit—10-15 minutes. Make sure they take notes on their tests and results.

10. Once they make notes, allow them to meet with another pair to compare results and discuss their hypothesis. Tell them it's okay to disagree.

Introduce physical change.

11. Define physical change as a change in a physical property that doesn't change the identity of the substance. For example, you might have a 12 inch piece of string. You might cut it into 6 inch pieces. One property of the string is now different—the length—but it's still string. It hasn't been changed to a new substance.
12. Take out the piece of foil and ask students to describe its physical properties. Next, ask them what kind of physical changes you could do to the foil. (For example, crumpling it up or just changing its shape.)

13. Distribute the handout Physical Changes. Have students work with a partner.

Summarize.

14. Distribute the Summary handout and have students select the best summary. Talk about what's wrong with the other summary. Tell students to hold on to this example, because they are going to start to write their own summaries soon.

Homework

Two readings: “Matter has observable properties.” and “Properties are used to identify substances.”

Vocabulary

- Substance
- Physical properties
- Physical change

Quiz #3: Scale, Atomic Theory, and Matter

1. **Organize these things on the arrow:**

Cell
Atom
Sandwich
Blueberry
The sun
Subway

micro ↔ macro

2. **Which things are NOT matter? Circle them.**

Air a dog a cell light sound oxygen helium gas

3. **True or false?**

All of matter has mass, volume, and is made up of particles called atoms.

Lesson #4: What is it?

Use the physical properties below to guess what each substance is. Work with a partner.

1. This is a clear, colorless solid. When I pour water on it, the water beads up and rolls off of it. I can't bend it or make it into a different shape. I can't cut it with a knife. It seems heavy for its size. When I throw it on the floor, it breaks into many little sharp pieces.

   What am I? ______________________________

2. This is a thick liquid with a pale yellow color. It has a slippery feeling. When I tried to mix it with water, it floated on top of the water.

   What am I? ______________________________

3. This is a silver, smooth solid. When I shone a light on it, it reflected the light back. I can bend it. It crumples when I squeeze it with my hand.

   What am I? ______________________________

4. This is a white solid. It's very lightweight for its size. I can break it apart with my hands, and it's crumbly. I can cut it with a knife. When I threw it in a pool of water, it floated on top. When I put it in the microwave, it shrunk.

   What am I? ______________________________

5. This is another white solid. It's also lightweight, and I can break it apart with my hands. It leaves white powder on my hands after I handle it. It's a smoother texture than the other white solid.

   What am I? ______________________________

6. This is a gray, damp solid with an earthy smell. I can mold it into any shape and it keeps that shape. I can cut it with a knife. It dissolves in water if I mix it for a long time. When I leave it to sit out, it dries out and gets hard and crumbly, and the color gets lighter.

   What am I? ______________________________

7. This is a pink, smooth solid. I can bend it but it goes back to its original shape. When I throw it on the floor, it bounces. I can cut it with a knife. It has a slightly chemical odor. I can press my finger into it a little bit but it bounces back.

   What am I? ______________________________

8. This is a soft black solid. It's very lightweight and dry. I can break it apart with my hands. It leaves black smudge marks on everything it touches. What a mess!

   What am I? ______________________________

What kind of tests did the person do on each of the substances listed above? For example, one test was to try to cut the substance with a knife. Make a list here of all the tests performed.

Lesson #4: Use physical properties to solve a mystery!

Imagine that you have three identical unlabeled bottles. Each bottle contains a white liquid. You know that one of them is soap, another is hair conditioner, and another is lotion. How would you figure out which is which?

Drawing on your past experiences, discuss with a partner how you would go about deciding which bottle contained which substance. What tests would you perform? Make notes on your plan here.

Lesson #4: Use physical properties to solve a mystery!

Take notes below on each of the three mystery substances. Be as specific as possible. Under "observations," write your initial observations of the substance, considering how it looks, smells, and feels. Under "Tests and Results," describe what test you performed and what the result was. Under "My Hypothesis," write what you think the substance is.

Substance #1

Observations (Consider how it looks, smells, and feels)	
Tests and Results	
My Hypothesis	

Substance #2

Observations (Consider how it looks, smells, and feels)	
Tests and Results	
My Hypothesis	

Substance #3

Observations (Consider how it looks, smells, and feels)	
Tests and Results	
My Hypothesis	

Lesson #4: Physical Changes

Define physical change here.

Physical change =

With a partner, make a list of physical changes that you could do to each material.

Material	Physical changes
Play doh	
String	
Aluminum foil	
A rubber band	
Ice	
A glass	

Lesson #4: Summary

Which is the best summer of today's class? Why?

#1

Different types of matter have different properties, which are like characteristics or traits. Some examples are color, mass, texture, and size. You can use these properties to identify things. We did a handout where we had to guess what the substance was based on its properties, and then we had to figure out if some liquids were soap, hair conditioner, or lotion. We also talked about physical change, which is a surface-level change like cutting a string or ripping a piece of paper. After you cut the string, it's still string, so that means it's a physical change.

#2

This lesson was about physical changes and properties. Atoms have physical properties that let them change into different materials. We compared the properties of lotion, soap, and hair conditioner and saw that each one behaves differently in water because of their atoms. We compared the properties of soap, conditioner, and lotion to show that all liquids have properties that are different from solids.

Lesson #5: An Important Physical Change: Change of State

Note to the Teacher:

This is a long lesson—allow 2-3 hours for it. It's the first lesson that introduces a form of energy—heat. The most important concept in this lesson is that heat makes particles[1] move faster. When we touch something and that object's particles are moving rapidly, the object feels hot to us.

When particles move fast, they are zipping around, banging into other particles and therefore they take up more space than slower, colder particles. Slower particles are able to sit closer together and vibrate against each other, which is why solids are usually denser than liquids. Gas particles are moving really fast, and they don't stay close to each other at all. This is why you can't contain gas easily—its particles are just flying all over the place.

This lesson encompasses the main theme of this lesson set, Matter, Energy, and Interactions. A change in state (also called a change in phase) comes about when you add heat to matter. This *interaction* is particularly important since it results in a radical change—a change between solid, liquid, gas, and plasma.

This lesson draws on concepts discussed in previous lessons, including:

- What an interaction is,
- Matter is made up of particles,
- Physical properties.

Plasma will probably not be tested on the TASC, but it's fascinating and the most common form of matter in the universe. At temperatures of 1000 degrees Celsius and above, matter has so much energy and motion that the electrons are torn off of the atoms, leaving a hot soup of ions and electrons. The sun is made of plasma, as is lightning and fire. Feel free to skip all this business about plasma!

There's a lot of vocabulary in this lesson. If you have the time, it's worth having students create a vocabulary sheet including words/phrases listed here. (I assume that they already know what freezing and melting are.)

- Change in state/change in phase
- Gas
- Liquid
- Plasma
- Solid

[1] "Particles" is used here as a general term to refer to really small things, in the same way that we would talk about a particle of dust. This is just a way to talk about molecules and atoms without having to use the word molecule since we haven't taught students what molecules are yet. The discussion of what heat does to particles applies to atoms and molecules.

- Particle
- Evaporation
- Vaporization
- Condensation
- Sublimation
- Melting point
- Boiling point

Exception!

There are a few important exceptions to be aware of when teaching this lesson. Not everything melts—sometimes things burn! Burning is a combustion reaction, and it is not the same thing as melting. The core difference here is that a change of state means that the molecules or atoms remain exactly the same—they don't change or break down. A molecule of water is the same whether it is ice, water, or water vapor. It is just moving faster or slower.

When you burn something, the molecules change into a new substance. This is a chemical reaction, and the molecular formula of the burned material is not the same as the molecular formula of the original material. When you burn something, you make a new substance and you can't return to the original substance just by cooling it down. Imagine you burn wood or sugar. You can cool it as much as you want, but it doesn't go back to the unburned state. Whereas if you cool down melted butter, you can go back to the unmelted state.

A common misconception:

Dissolving is not the same as melting. Dissolving is creating a mixture because you are combining two different substances. For example, if you mix sugar + water, the sugar will dissolve. You've made sugar water, which is a mixture, because you mixed together two forms of matter. You didn't melt the sugar. If you put dry sugar on a hot pan, you can melt it. This is not a mixture because you aren't adding another form of matter; you are adding energy in the form of heat. Here is the difference in the interactions:

matter + matter = MIXTURE (or chemical reaction)
matter + heat = CHANGE IN STATE (or burning)

Objectives

- Students learn that heat is a form of energy that makes particles of matter move faster
- Students learn how heat causes a change in state
- Students learn the vocabulary of the changes in state, and melting point, boiling point
- Students make close observations
- Students explain how an experiment done in class demonstrates a principle

Materials

- Quiz
- Handout: Why is the outside of this glass wet?
- Handout: Solid, Liquid, Gas, and Plasma
- Handout: Food coloring in hot and cold water
- 2 clear glasses
- white paper
- 1 cup ice water
- 1 cup very hot water
- 2 bottles of food coloring
- Handout: Heat and Change of State
- Reading "Matter exists in different physical states."
- Reading "Changes of state are physical changes."

Lesson Steps

Give the quiz.

Introduction activity: A dewy glass of cold water.

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1. Distribute the handout "Why is the outside of this glass wet?" You can also bring in a glass of ice water and set it up on your desk for students to look at. Ask students to think about where that water on the outside of the glass comes from. Why does it collect there? Is it always cold water, or can it collect on the outside of a mug of hot coffee? Let them talk for a few minutes and then come back together as a group to share ideas.

Introduce states of matter: solids, liquids, gases, and plasma.

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2. Today we're going to be learning about States of Matter: Solids, Liquids, Gases, and Plasma. A change of state or a change in phase means changing from a solid to a liquid, or changing from a gas to a liquid. This is an example of a physical change. Ask students to recall from the last lesson what a physical change is.

3. Distribute the handout and ask students to work with a partner to complete it. They should ignore Plasma right now. Emphasize the idea that they are trying to describe what liquid is to an alien—someone who has never experienced liquid before. For

example, you can say about liquid that you can't pick it up easily with your hands—or, you can if you cup your hands together, but it will all run out of your hands if you uncup them. Whereas with a solid, you can easily pick it up and it stays together.

4. How do you change between solid, liquid, or gas? Give the students a chance to talk about this for a few minutes. They will come up with the answer—it has to do with heat. Write HEAT in huge letters on the board. Ask students if heat is matter. (No: heat is a form of energy.)

5. Connect back to the main theme Matter, Energy, and Interactions. This is our first example an interaction that is matter + energy. We know that ice + heat = liquid water.

6. The next question is: *How* does heat do this? Brainstorm crazy ideas for a few minutes. "Because heat makes things hot" is not an explanation about why a solid changes into a liquid when heated.

Find out what heat does to particles.

7. We know that heat is behind the change in state. So we need to know more about what heat does to matter. Set up a glass of very hot water and a glass of very cold water on a white piece of paper. This demonstration is best when the temperatures are as extreme as possible, so you might bring a cup of ice water (take the ice out of the glass for the demonstration) and a thermos of very hot water (an electric tea kettle is even better). Tell students that you are going to add food coloring to each glass. Ask them what they think will happen. Hand out Lesson #5: Food Coloring in Hot & Cold Water (handout) for observation notes after the demonstration.

8. If possible, put two drops of food coloring into the glasses at the exact same moment. Ask students to tell you what's happening. Ask them if the food coloring is spreading out the same way in both glasses. (The food coloring should spread out faster in the hot water.)

9. Ask student to sit down and discuss why they think this happened. Review what they know: that water is matter, so that means that it is made up of particles. Ask them to make a list of what could be causing the difference in movement of the food coloring.

10. The explanation: Heat makes particles move faster. The more heat, the more the particles move. So hot matter has particles that are moving really fast, and cold matter has particles that are only vibrating a little bit. When you add heat, you make the particles move more. When you remove heat, particles slow down. (Be sure to emphasize that the particles in cold matter are still moving a little bit—they are vibrating in place.)

Heat causes a change of state in matter by causing particles to move faster and spread out.

11. Draw a thermometer on the board. Draw four boxes next to the thermometer—one at the lowest temperature, one at the highest, and two in the middle. Ask students to think of water. At the coldest temperature, which phase of matter is water in, solid, liquid, or gas? In the box, draw particles very close together. Ask the students if the particles are moving, and how much. (They aren't moving much but they are vibrating.) Write SOLID next to this box.

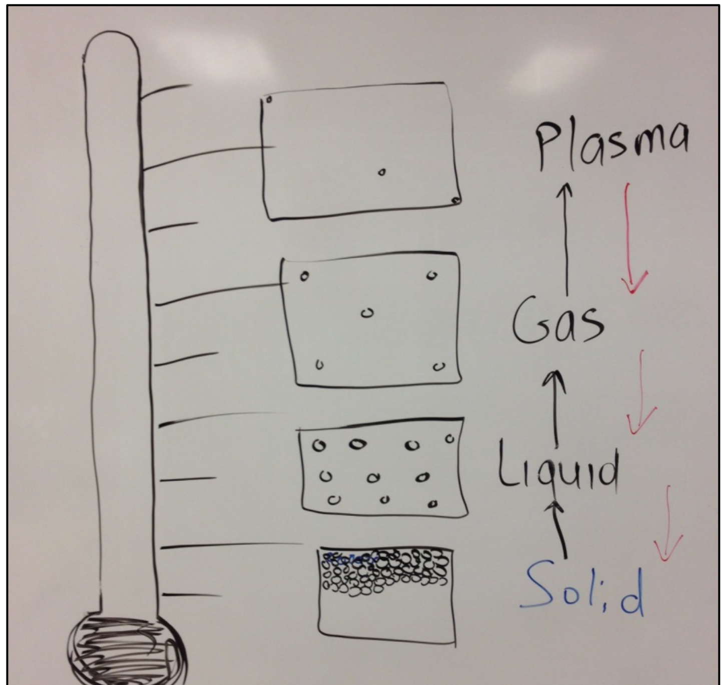

Figure 1: From Jane Parkerton's class at La Guardia Community College

12. Ask students how to turn this ice into liquid. (Add heat.) Move up to the next box. Ask students if the particles will be closer or further away from each other if they are moving faster. (Further away.) Draw the particles further away. Label the box LIQUID.

13. Ask how to turn this liquid into a gas. Draw the gas in the next box up, only a few particles far apart from each other. Label it GAS.

14. If you have internet access in class, you might show students one of these visualizations how the particles look and move in gas, liquids, and solids:

http://www.pbs.org/wgbh/nova/physics/states-of-matter.html
http://phet.colorado.edu/en/simulation/states-of-matter

15. You are left with a fourth box at the top. Write PLASMA next to it. Explain that at very, very high temperature, 1000 degrees Celsius, such as in the sun, lightning, or fire, the atoms break down and form something called plasma. (This is not on the TASC, so don't spend a lot of time on it. But it's interesting to mention. Plasma is when there is so much heat energy that electrons actually separate from atoms, leaving the ions.)

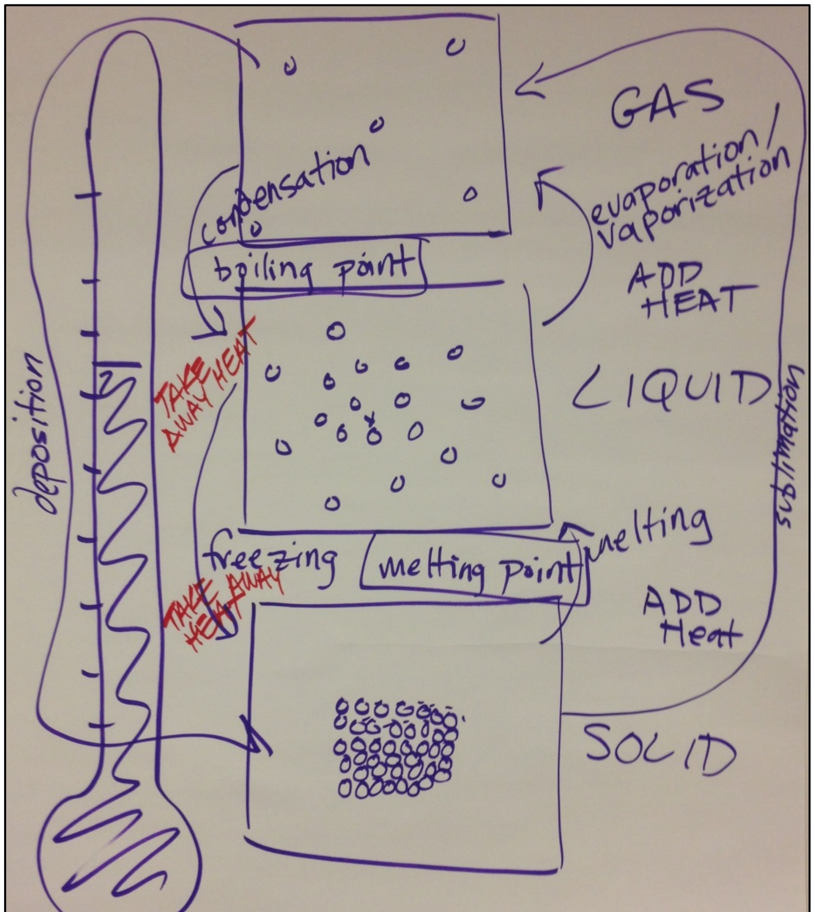

Figure 2: From Eric Appleton's notes at CUNY Science Institute

16. Return to the introduction activity. Why does water form on the outside of a glass of cold water? Draw the glass on the board. Tell students that there is water vapor—the gas state of water—in the air. With this information, ask them to think about why water appears on the outside of a glass of cold water, but not water. (The water vapor is cooled when it touches the cold glass, so the particles slow down so much that they changed from a gas to a liquid state. This is an example of condensation. Another example of condensation is dew.)

Review terms for the changes of state.

17. Review the terms for the change in state. Draw an arrow from solid to liquid and ask students what that is called (melting). Do the same for evaporation/vaporization, condensation, freezing, and sublimation. (Sublimation is when a solid goes directly to gas, skipping the liquid step. For example, if you leave ice in the freezer for a long time, it will get smaller. That's because some of the molecules got warm enough to change into the gas state.)

Melting point and boiling point are physical properties.

18. The temperatures at which things melt or boil are physical properties. They don't change. Water boils at 100 degrees Celsius, and it freezes at 0 degrees Celsius. That never changes. (Okay, yes, this changes at different altitudes. *We don't need to get into this with students.* The short version is that liquid boils when the liquid's vapor pressure equals the atmospheric air pressure. Do not waste class time going into this confusing, low-yield topic! If you want to know more, Google "vapor pressure.")

19. Challenge/trick question! Ask students: If you try to boil one cup of water in one pan, and one gallon of water in another pan, at what temperature will each pan start boiling? They will both boil at 100 degrees Celsius, but the larger pan will take a longer time to reach that temperature.

20. Different substances have different melting and boiling points. Ask students which they think has the highest and lowest melting temperature:

a. Water
b. Steel
c. Chocolate
d. Butter

If you have Internet access in the room, you can call up this fun tool to demonstrate different melting points:

http://www.bbc.co.uk/schools/scienceclips/ages/8_9/solid_liquids.shtml

Summarize.

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21. Students should write one paragraph that explains the food coloring in the water experiment. This paragraph should explain why the food coloring spread out faster in the hot water and slower in the cold water. It is essential that they are able to articulate how demos and experiments in class connect to scientific ideas.

22. Ask students to work with a partner to write a summary of today's ideas. To help them, tell them that they must use the following terms in their summary:

- Solid
- Liquid
- Gas
- Plasma
- Heat
- Evaporation
- Condensation
- Physical change
- Melting point

- Boiling point
- Physical property

Homework/Exit Slip

Readings: "Matter exists in different physical states." & "Changes of state are physical changes."

Vocabulary

Vocabulary for this unit is listed in the Note to Teachers.

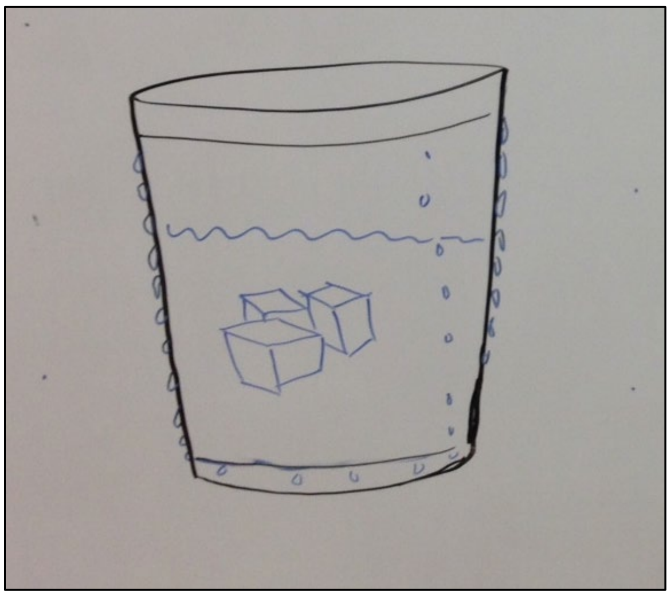


Figure 3: Water in three states, drawn by Elesa Mackhan, assistant teacher at La Guardia Community College

Quiz #4: Physical Properties and Physical Change

1. What are two examples of physical properties?

2. List two physical properties of coal:

3. What are two different physical changes you could do to a piece of aluminum foil?

Lesson #5: Why is the outside of this glass wet?

Why does water gather on the outside of a glass of cold water? Discuss with a partner and come up with a hypothesis.

Lesson #5: Solids, Liquids, Gas, & Plasma

Imagine that an alien joined our class today. This alien just arrived on earth and has no idea how solids, liquids, and gases are different. How would you explain it to the alien?

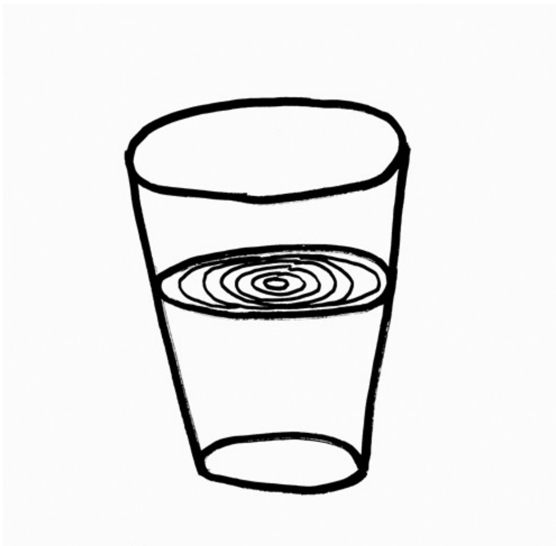
Ignore plasma for now!! We will come back to it later.

Plasma	
Gas	
Liquid	
Solid	

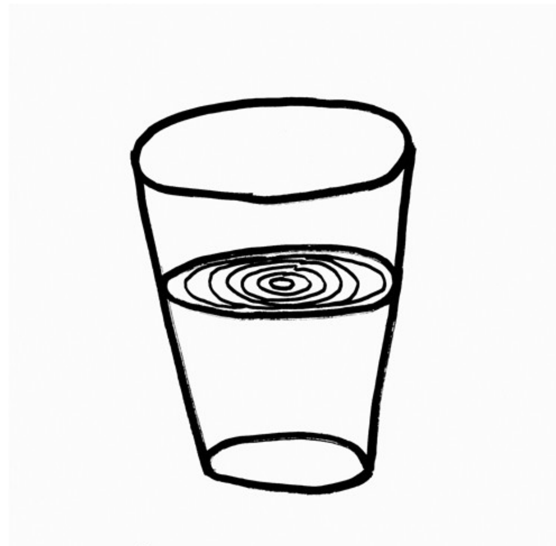
How can you change between solid, liquid, and gas?

Lesson #5: Food Coloring in Hot & Cold Water

Take notes on what happens when you add food coloring to hot and cold water.



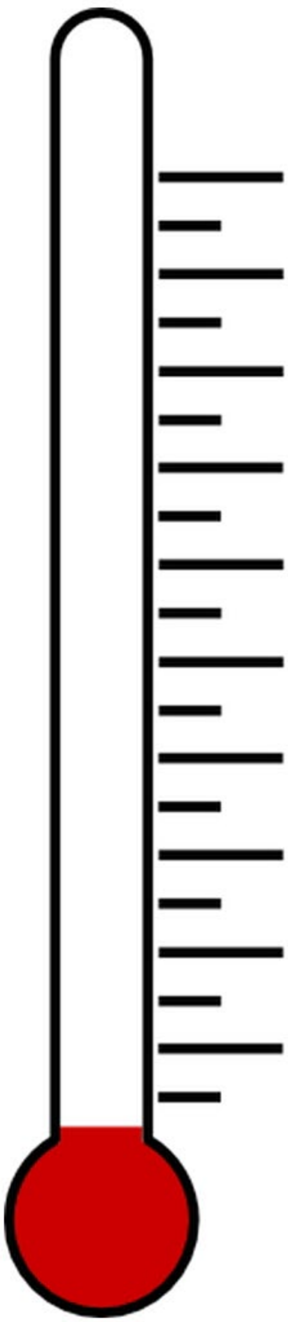
HOT WATER



COLD WATER

Lesson #5: Heat and Change of State

What does heat do to particles of matter? Explain here.



Lesson #6: An Important Property: Electrical Charge

Note to the Teacher:

This is not a typical topic, but it's an essential one. Electrical charge is the foundation for how the atom stays together; how neurons allow you to think; why your heart beats; how electricity, lightning, and batteries work; why some things dissolve and other don't; why the sun produces energy; why water is the basis of our world and life as we know it; and why chemical reactions occur, among other things!

Here is the cheat sheet of the content of this lesson:

Electrical charge is a property of matter that some matter has. (Not all matter has this property. That matter is electrically neutral.) There are two varieties—positive and negative. There is nothing essentially good about positively-charged particles and there is nothing essentially bad about negatively-charged particles. Humans just needed some way to refer to these two opposite varieties, and they chose the words positive and negative. Like charges repel each other and actually move away from each other, while opposite charge attract and move towards each other. (A push or a pull is called a force, and this is the electromagnetic force. Other examples of forces include gravity and pushing a chair across the floor.) One positive charge exactly balances out one negative charge. The closer the charges are to each other, the stronger they feel pushed/pulled. The push/pull gets weaker when they get further away. If you have three positive charges, you need three negative charges in order to be neutral. Matter is made up of lots of positive, negative and neutral charged particles. Sometimes the particles can be rubbed off—usually, it is the negative charges. If that happens, the object is now overall positive instead of neutral, and it will quickly attract some loose negative charges. So matter can lose particles. Also, the particles can move around INSIDE of an object. So if you hold a positively-charged bar next to a wall, all the positive charged particles in the wall will recede and all the negatively charged particles will come to the surface of the wall—but the wall is overall still neutral. This is called polarization.

For a great explanation of lightning, see this set of videos on Youtube by Derek Owens (Physics 12.1.6a – Lightning, Part 1):

https://www.youtube.com/watch?v=JJubgrI0T0g

A few connections my students have made during this lesson: Is this the same as magnets? Is this the same as when you get a shock? Is this related to a battery? Yes, yes, and yes.

Objectives

- Student will make observations on natural phenomena and use their observations to develop questions and hypotheses.
- Students will be able to define electrical charge and explain how positive and negative charges interact.
- Students will learn that charged particles are able to move between objects, but they are also able to move within an object. When they move within an object, the object remains neutral overall, but a polarization has occurred.
- Students will be able to describe lightning in terms of electrical charge.

Materials

- Image of a rainbow
- Video of lightning
- Observation/Question/Hypotheses graphic organizer
- +/- handouts
- 8 feet of ribbon or rope
- *Neutral and Charged Objects* reading
- balloons

Lesson Steps

Give the quiz.

Practice making observations, questions, and hypotheses.

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1. Model using the Observation/Question/Hypotheses graphic organizer with the image of a rainbow.

2. Play a short video of lightning. (A good one on Youtube is "Epic Lightning Storm in Georgia.") Students make observations about the lightning. Students compare their answers with a partner, and then develop questions and hypotheses together. Teacher asks for some examples and records them on the board. Tell them that today's lesson on electrical charge will explain what lightning is and why it happens.

Define electrical charge.

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3. Tell students that you are going to give them a short lecture and that they need to take notes. Write on the board:

   Electrical charge is a property of matter that …

   Stop to review the definitions of matter and property. Remind students that you also reviewed physical change at the end of the last lesson. Elicit a definition of physical change. Review that some physical properties can be changes, like the mass, shape, or size of something. For example, you can cut string or crumple foil, and they are different lengths and shapes, but they are still string and foil. But other physical properties can't be removed and changed. You can't remove the orange color from an orange, for example. Electrical charge is like this—a permanent property of some particles.

4. **Charged matter behaves in a peculiar way**. Understanding charge explains why the matter behaves in this way. So let's see an example of what this behavior is, and we'll come back to finish our definition in a moment.

5. **Charge comes in two varieties—positive and negative**. (There is also uncharged matter.) We'll start by talking about particles. (Particle is a generic term for a small piece of matter. We don't talk about atoms here since later we'll see that it's these charged particles that make up atoms.) Two particles with the same charge will repel each other so much that they actually move apart. Draw on the board two + particles moving away from each other, and two – particles moving away from each other. Two particles of the opposite charge attract each other so much that they actually move together. Opposites attract. Draw on the board a + and a – particle moving towards each other. **It's not just that these charged particles feel attracted or repulsed—they actually will physically move in response to another charged particle.**

6. Distribute the positive and negative signs. Ask everyone to get up and spread out across the room, holding their charge sign up so that others can see it. Ask them to move around the room, reacting to the other charges in the room appropriately. Move around the room to see if students are reacting to like charges and opposite charges correctly. Encourage drama!

7. Bring a positively-charged student and the negatively-charged student to move next to each other. They should act relieved. Explain that they are now **neutral**—one positive and one negative effectively cancel each other out and create neutral matter. (Most matter in the world is neutral.) Now if a lone positive charge comes along, it won't react to the neutral matter.

8. Return to the definition of electrical charge. Ask students to take a few minutes to try to complete the definition. This is difficult work but I think it's worth allowing them to work on it for a few minutes. Ask for ideas and eventually try to come to a definition that looks like:

   Electrical charge is a property of matter that causes a particle to move towards a particle with the opposite charge or away from a particle of the same charge.

The distance between charged particles is important.

9. There are two more qualities of charge that we're going to learn about today. One of them is about distance, and the other is about number of charges.

10. First, we'll learn about distance. Stand in the doorway of the classroom and ask students to imagine that you are holding a plate of delicious food. Ask where the smell of the food is the strongest. The people sitting near the door experience the smell of the food in a stronger way than the people who are sitting far away. The push of an opposite charged particle is like this, like a cloud. It emanates out from matter invisibly. The closer two charged particles are, the stronger the push or pull between them. The further they are away, the weaker the push or pull, just like if you were a mile away from a pizza, you wouldn't be able to smell it.

11. Ask everyone to stand up again with their charge signs. Ask them to find the person who is the CLOSEST to them. That is the charged particle that they will respond to first, whether it is to be pulled together or pushed apart.

12. Position two positive charges and one negative charge like the three points of an equilateral triangle. Charges can feel force from multiple locations. Ask how the negative charge will move in this situation. (The negative charge will be pulled equally from both charge and move up so that it is hovering right between the two positive charges.)

The number of charges is important.

13. Bring 3 positive charged people up to the front of the room. Ask the class to describe how these charged particles feel and what they are doing when standing close together. (They are repelling each other.)

14. Say that when two things push or pull on each other, they are exerting a force on each other. The charged particles are exerting a force on each other, but you can also exert other kinds of forces. For example, you can push a chair. That's a force. Define force on the board as "a push or pull between two or more pieces of matter." There are other kinds of forces in the world too, such as contact forces or gravity. There is a mysterious force called the strong force. This force is so strong that it can bind like charges together. (This is what holds the nucleus of an atom together, as we'll review in the next lesson.)

15. Hold up the ribbon as say that this is the strong force. Use the ribbon/strong force to bind three positive students together.

16. Now ask the negative students to stand up. Ask the class which of the standing negative charges will be most pulled towards the bundle of 3 + charges at the front of the room. (Whoever is standing the closest.) Have that person be "pulled" up and attach to the bundle. Ask the students if the bundle is now neutral. (No—one of the + charges is neutralized, but there are two more. You need two more – charges to neutralize this bundle.) Have the next two closest negative students come up and attach to the bundle.

17. What is you had bound six positive students together? What about 100 positive students together? Make sure that it is clear that positive and negative charges must be in a 1:1 ratio in order to be neutral. If you have 5+ and 4 -, you are overall +.

18. Ask everyone to sit down to take notes on how distance and number are related to electrical charge.

Charged particles can move between objects, but they can also move within an overall neutral object.

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19. Distribute the reading "Neutral and Charged Objects." As students read it, they should write a few notes in the margin about the main idea of paragraphs 2 & 3. Do the first paragraph together as a class. Ask student to compare notes after they have finished. Ask students what new information was presented in the reading. Clarify any misunderstandings.

20. Distribute balloons and have students rub them on their hair. They are rubbing negatively-charged particles off their hair onto the balloons. See if you can stick them on the wall. Draw a balloon on the board, and draw some negative charges on a patch of it. Did we add or remove particles from the balloon? What is the balloon's overall charge? (You put extra negative charges on the balloon, so now it has an overall – charge.)

21. But why did it stick to the wall? Draw the wall on the board. Draw the – charged balloon next to the wall. Draw some + and – charges inside the wall—these are the particles that made up the wall. Ask what happens to the wall particles when the balloon gets closer and closer. (The – particles recede and the + charged come to the surface.) When you hold the balloon right against the wall, it allows the + and – charges to come together and the strong pull between these opposite charges is strong enough to actually hold the balloon on the wall. (In dry weather! Humidity can doom this demonstration because the loose negative charges are attracted to the water molecules in the air.)

What does this have to do with lightning?

22. Draw clouds and the ground below it. Explain that during a storm, due to water and air particles, heat and cold, and wind, negatively-charged particles gather on the bottom of the clouds. Draw these negative charges along the bottom of the cloud.

23. Draw some structures on the ground below the clouds—a tall building, a tree, maybe a sailboat on the water. Ask what happens inside these objects with the looming, negatively charged cloud above. (The negative charges in the object retreat, leaving more positive charges on the top.)

24. Lightning is the "jump" of these negatively-charged particles from the clouds to the ground below it. The pull of attraction between positive and negative is so strong that it actually rips particles out into the air. This jump releases some energy which creates light and sound. Review that distance matters, which is why lightning is more likely to hit a tall building than an ant on the ground.

(If you are uncomfortable explaining lightning, show students the Derek Owens video lectures mentioned in the Note to Teachers sections.) https://www.youtube.com/watch?v=JJubgrI0T0g

Summarize.

Students should work together to write a summary of today's lesson, using the following vocabulary:

- Electrical charge
- Physical property
- Positive charge
- Negative charge
- Attract
- Repel
- Neutral
- Particle

Homework

Students should write up an explanation of how lightning happens. They can watch the Derek Owens series of videos on lightning on YouTube to review the concepts. (Physics 12.1.6a – Lightning, Part 1):

https://www.youtube.com/watch?v=JJubgrI0T0g

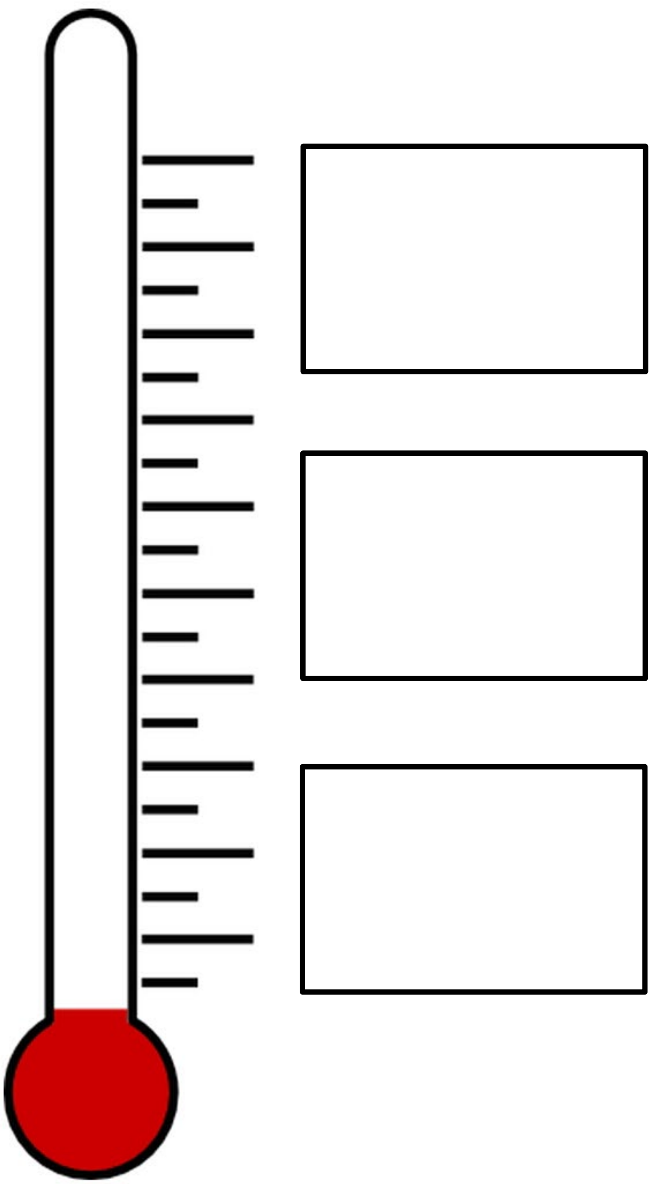
Vocabulary

As listed above in the Summarize step, along with "polarization."

Quiz #5: Change of State

What does heat do to particles of matter? Explain here.

Draw a picture of the particles of a solid, liquid, and gas at the appropriate place on the thermometer. Be sure that the particles in each state of matter are close or far away from each other, depending on what state you are drawing. Label each box SOLID, LIQUID, or GAS.



Lesson #6: Making Observations, Questions, and Hypotheses

My Observations (Describe what you see/hear/smell/taste.)	
Questions (What, where, when, how, why, who)	
Hypotheses (Scientists make wrong hypotheses all the time—you can too! Don't worry about being right here.)	

[redacted]

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Lesson #6: Neutral and Charged Objects

All of matter—air, earth, water, people, animals, plants—is made up of positively-charged particles, negatively-charged particles, and neutral particles. In most things, there is a balance between positive and negative charges, so the object is neutral overall. Neutral particles do not affect the balance of positive and negative charges.

However, some matter is not neutral overall. If matter has more positively-charged particles than negatively charged particles, it will have a positive charge overall. This means that it will attract outside negative charges and repel outside positive charges. If matter has more negatively-charged particles, it will attract outside positive charges and repel outside negative charges.

Electrical charge can't be created or destroyed, but it can move around. A neutral object could become charged if some of its charged particles leave. Usually it's the negatively-charged particles that move around. These very small particles can be brushed or rubbed off. For example, when you walk across the room, some negatively-charged particles will come off of your shoes and stick to the floor. This happens all the time. Right now, as you are reading this, particles are moving around. *Charged particles can move between objects.*

There is a second way that an overall neutral object can change in terms of charge. Every object contains many positive and negative particles. These particles do not sit still—they move around all the time within the object and respond to their environment. If I bring a negatively-charged object near a neutral object, the charged particles inside of the neutral object will respond. The negatively-charged particles in the neutral object will be repelled and move away from the surface of the object. The positively-charged particles inside the neutral object will be attracted to the surface of the object. The object is still neutral overall. No charges have been added or removed. But the charges within the object have shifted around, leaving a positively-charged patch on the surface. *This is called polarization.*

Lesson #7: The Atom

Note to the Teacher:

This is an unusual lesson in that the teacher feeds information to the students in a very specific order. There are a few reasons for this. The concept of the atom is very abstract, especially since we don't have any pictures of atoms. Students can't draw on their past experiences for this lesson, like they can for the other lessons. (They've all see water boil, and they know it has to do with heat.) Finally, there is a lot of new, unfamiliar, confusing vocabulary in this lesson: proton, neutron, electron, nucleus, element, periodic table, atomic mass, and atomic number. And the periodic table alone is enough to make anyone run screaming from a classroom!

It's my past experience (of many flopped lessons!) that led to the current format of the lesson. In the past, I've introduced the three particles first: the proton, neutron, and electron. But students got confused when the "nucleus" came up later. This version starts with a broader view of the atom by just seeing the nucleus surrounded by a cloud, and then we zoom in on those two parts. This lesson draws on the previously taught concepts of scale, atomic theory, mass, and electric charge. In brief, here is an overview of how the atom is introduced to students:

1. Atoms have a basic model of a heavy nucleus surrounded by a cloud. Between the nucleus and the cloud, there is a huge amount of empty space.
2. The nucleus is composed of two particles, the proton and neutron.
    a. More detail on protons.
    b. More detail on neutrons.
3. The cloud is composed of electrons.
    a. More detail on electrons.
    b. More details on the structure of the cloud—there are layers/orbitals/shells.
4. Students build models of two atoms, helium and oxygen.
5. Students apply their knowledge to figure out atomic mass.
6. Students learn about the differences between elements.
7. Students learn how to use the periodic table.

The periodic table overwhelms students (and many of us). The "sorting" activity of the element cards isn't much of an activity—there aren't many ways to sort them. But the idea of that activity is just to give the students control over those cards first, and to look closely at the type of information that they include. It's a step that I hope prepares them to face the real periodic table. It's also to give them an experience that will help them remember how the periodic table is organized.

This lesson goes into some detail about the electron cloud that surrounds the nucleus of an atom. This is to prepare for the next lesson on molecular bonding, which depends on an understanding of the structure of the electron cloud.

Objectives

- Students understand the structure of an atom.
- Students apply the concept of electric charge to the structure of the atom.
- Students understand how elements are different from each other.
- Students can use the periodic table to find the structure of each element.
- Students understand the difference between atomic mass and atomic number.
- Students understand that electrons fill orbitals in a specific order.

Materials

- Handout: Content Review
- Marbles, one per student
- Handout: Why do helium balloons float?
- Handout: Taking notes
- Handout: Basic Model of an Atom
- Handout: Build an atom of helium/Build a model of oxygen.
- Color coding labels (Avery 5463, for example) in three colors
- Handout: Atomic Mass
- Sets of element cards: Cut out and mix them up before class. One set per pair of students.
- Handout: Elements/Periodic Table
- Reading: "Atoms are the smallest form of elements."

Lesson Steps

Instead of a quiz, do a content review.

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1. This is a review of the science concepts discussed so far. Allow students to work with a partner or small groups of 3 to take notes on each topic. They should write down what they remember about each topic. Encourage them to exercise their memories and not consult their notes while doing this. Once you see everyone start to reach the end of their memories, ask them to mark concepts that they didn't remember and need to review. Then allow them to take out notes and fill in the blanks.

Introduction: Why do helium balloons float?

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2. Distribute the handout "Why do helium balloons float?" Ask students to discuss with a partner and think of a hypothesis. Give them a few minutes to get started and then move around the room to hear what they are postulating.

3. Come back together as a whole group and elicit some ideas. Take a few notes on the board on their hypotheses. Don't explain it right now—wait until the end of class.

Introduce the basic model of the atom = a nucleus surrounded by a cloud.

4. Ask students, "What is the atomic theory?" Come back to the idea that all of matter (whether solid, liquid, gas, or plasma) is made up of atoms. Today, you will learn more about atoms.

5. Distribute the note-taking template. Tell them to take notes on each topic as you talk about it.

6. Tell students you will start with the basic model of the atom, and then you will get more detailed later. To illustrate what you mean by "basic model," draw a building on the board. The basic model of a building has walls, a roof, and a door or some way to get inside. Explain that you could get more detailed, but a basic model just gives you the basics. Ask students what a basic model of a car would include. (Wheels, somewhere to sit, an engine?)

7. If you have marbles, give every student a marble. Tell them that the basic model of an atom has two parts: a heavy, dense nucleus, which is surrounded by a cloud. Write "basic model of an atom = nucleus + cloud" on the board. Ask them to imagine that their marble is the nucleus. Remind students that atoms are extremely tiny, so you want to give them a way to visualize the proportions of the nucleus and the cloud of an atom. Ask them to imagine that they are holding their marble and they are standing in the center of Yankee Stadium (or any stadium). Describe the large green field spreading out all around them, and then the huge, tall stands of seats rising up at the edge of the green field. If their marble is the size of a nucleus, the cloud would be at the edges of the stadium. So there is a huge amount of empty space between the nucleus and the cloud. Illustrate this on the board or write up some notes on the board.

8. If it seems useful as a mnemonic, you can add that "nuc" of nucleus is similar to the word "nut." (And this is the origin of the word.) The nut that we eat is the internal part, and is surrounded by a shell. The nucleus is the internal part of the atom, surrounded by the cloud.

9. Ask students to compare their notes with the person next to them.

Give more details on the nucleus.

10. The nucleus is made up of two different kinds of particles. These two kinds of particles weigh exactly the same but they have different properties.

    a. Protons = Protons are in the nucleus. They have a positive charge. Protons are very important because the number of protons gives the atom its identity. Protons weigh 1 amu.
    b. Neutrons = Neutrons are in the nucleus. Neutrons are uncharged. Neutrons weigh 1 amu.

11. Draw a helium nucleus on the board. (2 protons, 2 neutrons) Ask students to think back to the electric charge lesson. Using what they know about electric charge, what do they notice about this nucleus? (There is a problem having all those positively-charged particles so close together. They would push away from each other.) Explain that there are two things that keep these protons trapped together in the nucleus:

a. The neutrons provide a slight buffer between the protons.

b. There is something called the strong force which holds the nucleus all together. Review that a force is a push or a pull—other forces include contact forces, such as pushing a chair across the floor, and electromagnetic force, which is the pushing apart of two positively-charged protons. Another force is gravity, pulling down on you. The strong force is an extremely strong force that is like a rope, holding all of those protons and neutrons together. (Skip this part if it seems like too much!)

12. Ask students: how are protons and neutrons similar? How are they different?

13. Ask students to compare their notes again. Walk around to see how they are doing with notes.

Give more details on the cloud.

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14. The cloud of that atom is made up of only one kind of particle—electrons. Ask students if they want to guess what kind of electrical charge electrons have.

a. Electrons = Electrons are in the cloud of the atom—*outside* the nucleus. They have a negative charge. Electrons only weight 1/2000 amu, which is so light that we ignore the weight of electrons. You can think of electrons as being weightless. Electrons are zooming around the nucleus very fast.

15. The cloud is only made up of one particle, but it has a more complicated structure than the nucleus does. This is important because it determines if the atom can bond or join to another atom. Basically, the cloud has layers, and only a certain number of electrons can fit in each layer. I like to describe it as rows in a theater. Imagine you go to the movies, and the first row has only two seats. Only two people can sit in this row—no one else will fit. The second row has eight seats. Only eight people can sit in this row—no more can fit. This is part of the basic model of atoms. The first layer of the electron cloud can only hold two electrons. The second layer of the electron cloud can only hold eight electrons. Bigger atoms with more electrons need more rows, but we only need to worry about the small atoms in this class.

16. One more detail about the "layers" of the cloud—electrons file into their seats in a very organized way! The first electron sits in the first seat in the first layer. The second electron sits in the second seat in the first layer. The second electron NEVER EVER leaves that seat empty and goes to sit in the second layer/row.

17. Add electrons to your illustration on the board. (Helium does not have the second "row" of empty seats for electrons since it only has two electrons.)

18. That's it! That's all we know about the structure of the atom. Tell students that this is essential stuff—if there is one topic you are sure will be on the TASC, it's the atom. Say that you really want them to have this concept down cold, so you are going to spend the rest of the day practicing. First, have students compare their notes with a partner. Walk around to take a look at their notes and see where students are confused. Spend a little time here to talk about taking clear notes.

19. Distribute the handout "Basic Model of an Atom" and have students discuss it with a partner.

Students build atoms.

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20. Distribute the handouts "Build an atom of helium/oxygen." Explain that these are "empty" models—they show an outline of a nucleus and an outline of the layers of the electron cloud, but they are missing protons, neutrons, and electrons. Tell the students that they are going to add the protons, neutrons, and electrons in the form of stickers. Create a key on the board, red for protons, yellow for neutrons, blue for electrons (or whatever).

21. Do helium together. Ask if the helium atom is overall charged or overall neutral. (It's overall neutral, since it has two protons and two electrons.)

22. With a reminder about the electron levels, have students build oxygen themselves. Move around the classroom to help and clarify.

Students apply their knowledge of mass and atomic particles to **atomic mass**.

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23. Distribute the handout "Atomic Mass." Ask students to discuss the questions with a partner.

24. Review as a class. Atomic mass is calculated by adding up the number of protons and neutrons in the atom. Electrons are too small to make a difference.

25. Which atom is lighter, helium or oxygen? At this point, you can return to the introduction activity about why helium balloons float. Air is 78% nitrogen, 21% oxygen, and a little bit of other things like carbon dioxide and water vapor. One atom of nitrogen weighs 14 amu (amu stands for atomic mass unit, the unit used to measure mass at the atomic scale), but because nitrogen comes in a molecule of two nitrogen atoms, the nitrogen molecules actually weigh 28 amu. Similarly, one atom of oxygen weighs 16 amu, but they come in pairs, so the oxygen molecules actually weigh 32 amu. Helium, on the other hand, is a loner and stays single, and one helium atom only weighs 4 amu. Helium is much lighter than the other gasses that make up air, so it floats.

Introduce the elements and atomic number.

26. Give one pack of element cards to every pair of students. (Prepare the cards by cutting them up and mixing them up—make sure not to give them out in the correct order.)

27. Say that you have already looked at two different kinds of atoms—a helium atom and an oxygen atom. Elicit how they are different from each other. (Different number of protons, electrons, and neutrons; different atomic mass; different name; oxygen has two "rows" in its electron cloud and helium only has one.)

28. Define as **element** as being a substance with only one specific kind of atom in it with the same number of protons. PROTONS define what element that atom is. Helium and oxygen are both elements—all helium atoms have exactly 2 protons, all oxygen atoms have exactly 8 protons. It's possible that the number of neutrons and electrons might change in certain circumstances, but as long as the atom has 8 protons, it's oxygen no matter what. (One metaphor to atom/element is dog/breed. An atom and a dog refer to the same basic model, whereas element and breed are more specific. Carbon, oxygen, and helium are all elements, or specific varieties of atom. Poodles and Labradors are both breeds, or specific varieties of dog.)

29. Since elements are defined by the number of protons, the number of protons is a type of synonym for the element and can also be used to identify the atom. The number of protons is also called the **atomic number**. Helium has an atomic number of 2. (Atomic mass and atomic number can get confusing. Point out that they already know that mass refers to how heavy something is, so they need to trust that when they see "atomic mass.')

30. Distribute the Elements handout. Draw the periodic table card of helium on the board. Ask students what they think each part of the card means. Have students work on the rest of the questions with a partner. Review as a class.

2
He
Helium
4.003

Introduce the periodic table.

30. Ask students to look at their collection of element cards and think of different ways to organize them. They should make a list of different ways. For example, they could order them by putting them in alphabetical order. Once they have a few options, which way do they think is best? Why?

31. Collect some answers and then distribute the periodic table. Have them compare their organizational methods with the method used in the table.

Summarize

32. Ask students to work with a partner to write a summary of today's class. Their summary should use these vocabulary words: atom, nucleus, cloud, proton, neutron, electron, atomic mass, atomic number, element, periodic table.

Homework

Reading: "Atoms are the smallest form of elements."

Vocabulary

Nucleus
Proton
Neutron
Electron
Atomic mass
Atomic number
Element
Periodic table

Lesson #7: Content Review

Instead of a quiz, we're going to review all the content we've learned so far. With a partner, discuss each topic listed below, and take notes on what you remember about each topic. Exercise your memory and do this without using your notes.

Interaction	
Matter	
Mass	
Volume	
Atom	
Physical property	
Physical change	
Change of state	

Heat	
Melting point	
Electric charge	
Neutral	
force	

Lesson #7: Why do helium balloons float?

Discuss this with a partner. Don't worry about being wrong—this is about trying out theories and ideas.

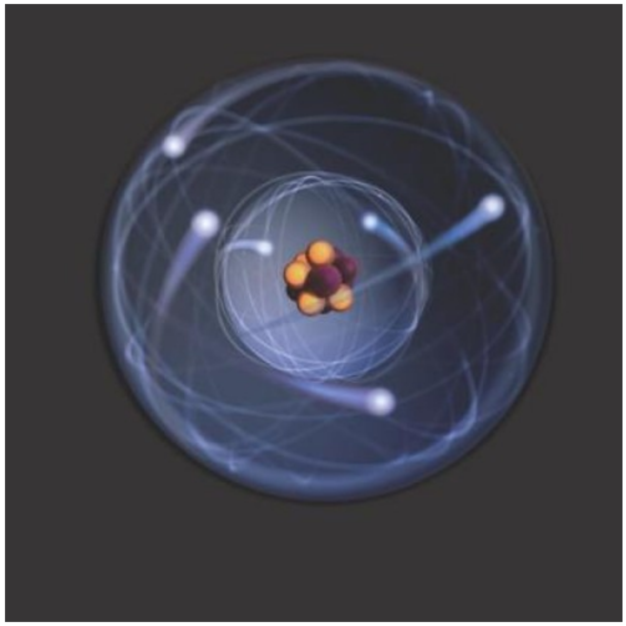
Lesson #7: Taking Notes

Take notes on each of the topics listed below as your teacher explains.

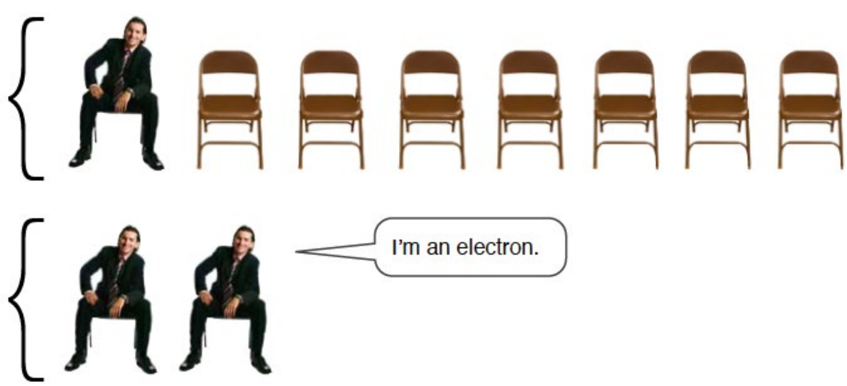
Basic structure of an atom	
Nucleus	
Cloud	

Lesson #7: Basic Model of an Atom

Label the nucleus and the cloud of this atom. Then, label protons, neutrons, and electrons.

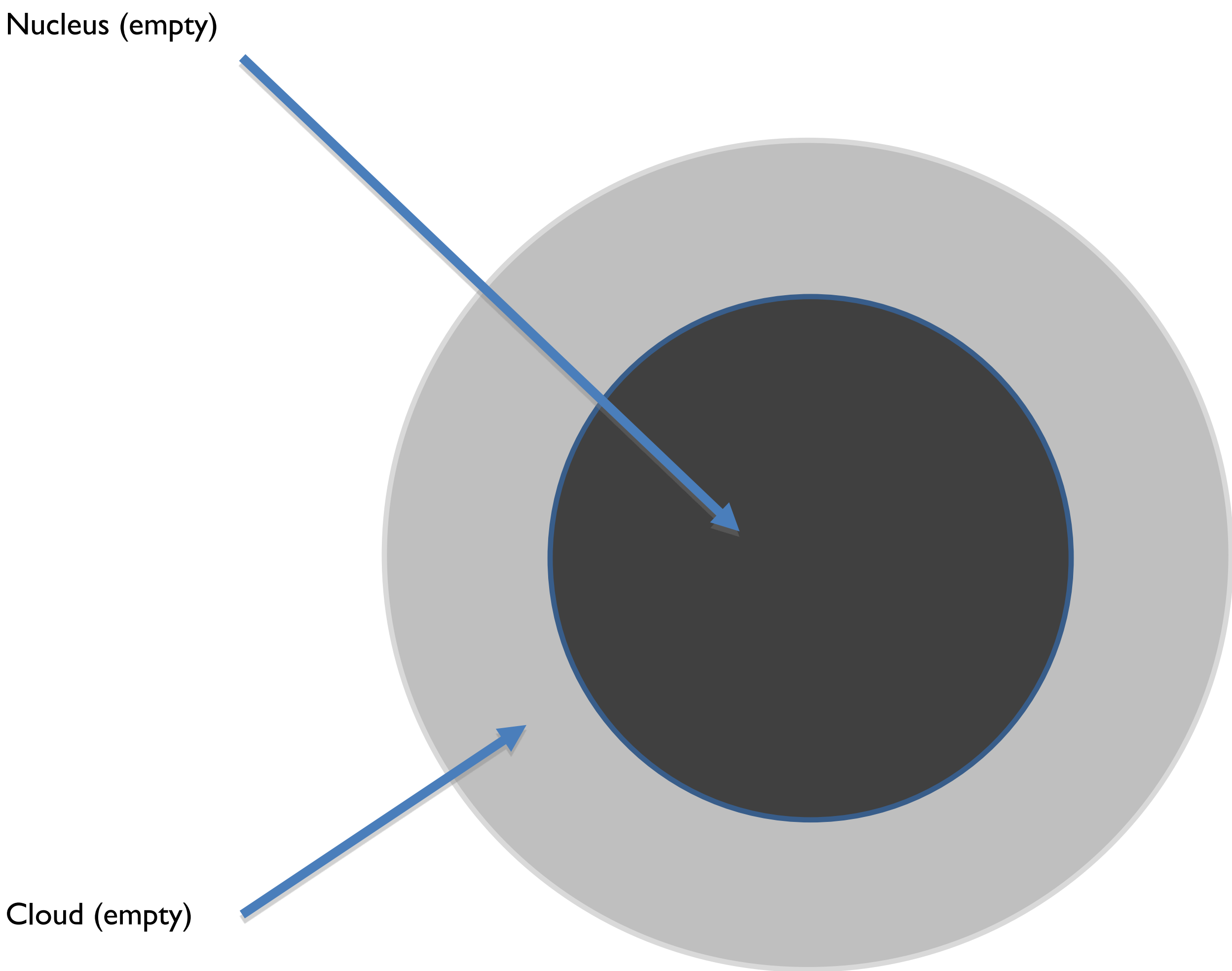


How is this picture related to the cloud?



Lesson #7: Basic Model of an Atom

This is the form of an atom we'll use in class. The black core is the nucleus. Each ring around the black core is one level of the cloud.

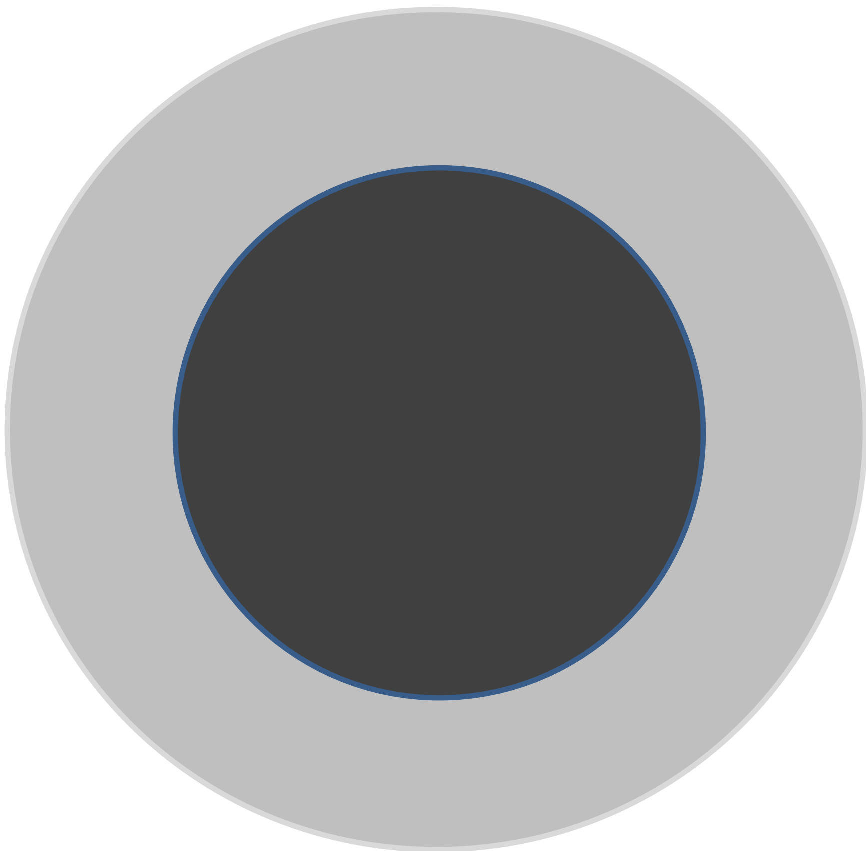


1. What goes in the nucleus?

2. What goes in the cloud?

Lesson #7: Build an atom of helium.

Helium has 2 protons, 2 neutrons, and 2 electrons. Use stickers to build a molecule of helium. Put a + on the stickers that are protons. Put – on the stickers that are electrons. Put N on the stickers that are neutrons.



Lesson #7: Build an atom of oxygen.

Oxygen has 8 protons, 8 neutrons, and 8 electrons. Use stickers to build a molecule of oxygen. Put a + on the stickers that are protons. Put – on the stickers that are electrons. Put N on the stickers that are neutrons.

There's only one electron cloud, but it has two layers. The **first layer**, closest to the nucleus, can hold a total of **2 electrons**. So this first layer has two "empty chairs" for electrons in it. When you are filling in an electron cloud, always put electrons in this layer first.

The **second layer** can hold a total of **8 electrons**. So the second layer has eight "empty chairs" for electrons. Only put electrons in this layer after the first layer is filled up.

The "layers" of the electron cloud are also called orbitals or shells.

Lesson #7: Atomic Mass

Discuss these questions with a partner.

1. First, compare the atom of helium with the atom of oxygen. How are they similar and different? Write down at least two similarities and two differences.

Similarities	Differences

2. ATOMIC MASS is the mass of one atom. Use what you know about the particles that make up an atom to figure out how to calculate atomic mass. Take notes here on how to do it.

3. Using your method, what is the atomic mass of helium? What is the atomic mass of oxygen?

    a. Atomic mass of helium =

    b. Atomic mass of oxygen =

Lesson #7: Element Cards

1 **H** Hydrogen 1.008	2 **He** Helium 4.003	3 **Li** Lithium 6.94	4 **Be** Beryllium 9.012
5 **B** Boron 10.81	6 **C** Carbon 12.01	7 **N** Nitrogen 14.01	8 **O** Oxygen 16.00

1 **H** Hydrogen 1.008	2 **He** Helium 4.003	3 **Li** Lithium 6.94	4 **Be** Beryllium 9.012
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Lesson #7: Elements

Label each piece of information: element's name, abbreviation, atomic mass, and atomic number.

2
He
Helium
4.003

How do you figure out how many protons are in an atom?

How do you figure out how many electrons are in an atom?

How do you figure out how many neutrons are in an atom?

Use your pack of element cards to find this information.

	How many protons?	How many neutrons?	How many electrons?
Hydrogen			
Helium			
Beryllium			
Carbon			
Nitrogen			
Oxygen			

Lesson #7: Periodic Table

hydrogen 1 H 1.0079																		helium 2 He 4.0026
lithium 3 Li 6.941	beryllium 4 Be 9.0122												boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
sodium 11 Na 22.990	magnesium 12 Mg 24.305												aluminium 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
potassium 19 K 39.098	calcium 20 Ca 40.078		scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80
rubidium 37 Rb 85.468	strontium 38 Sr 87.62		yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29
caesium 55 Cs 132.91	barium 56 Ba 137.33	57-70 *	lutetium 71 Lu 174.97	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]
francium 87 Fr [223]	radium 88 Ra [226]	89-102 * *	lawrencium 103 Lr [262]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	ununnilium 110 Uun [271]	unununium 111 Uuu [272]	ununbium 112 Uub [277]		ununquadium 114 Uuq [289]				

*Lanthanide series	lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
* *Actinide series	actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]

Lesson #8: How Atoms Bond to Make Molecules

Note to the Teacher:

So far in this lesson set, we've worked our way down, down, down to tiny particles and atoms. Now, we start to build back UP. If atoms make up all of matter, everything around us, how do they stick together to build larger and larger things? How do they stick together so well that we are made of atoms? What is the atomic "glue"?

This lesson starts off with a little embedded review, in that student build two more atoms: carbon and hydrogen. If students don't have their oxygen and helium atoms from the preview lesson, they should also rebuild those so that they can be used later in the lesson.

If you spent a good amount of time discussing the structure of the electron cloud in the previous lesson, you should be in good shape to introduce bonding. Atoms form molecules by bonding to each other. Bonding is driven by the octet rule, which states that atoms really want to have full electron layers/orbitals/shells. For example, hydrogen has only one electron, but it has two electron "seats" in its electron cloud. So it will form a bond as soon as possible in order to fill that empty seat. The number of empty seats an atom has is the number of bonds that is can make. Oxygen has two empty seats in its outer orbital, so it can form two bonds.

When two hydrogen atoms bond, the electron of the first atom half-occupies both its original seat and the empty seat on the other hydrogen atom. The electron on the second atom does the same—it half-occupies both its original seat and the empty seat in the other atom. What's really driving this is an attraction between the electron of one atom to the positively-charged nucleus of the other hydrogen atom.

That is the meat of this lesson. The next lesson focuses on chemical reactions, which are the forming and breaking of chemical bonds. So the formation of a molecule is a chemical reaction.

There is some terminology to introduce related to bonding. Once two or more atoms bond, the total thing is now called a molecule. So anytime someone says "molecule," you know that more than one atom and a chemical bond are involved.

Another terminology distinction: a compound is a molecule that contains more than one type of element. H_2O is a compound because it contains both hydrogen and oxygen. But H_2 is not a compound, since it contains only one type of element.

This lesson ends by introducing molecular formulas. This is a tricky concept that rears itself again when teaching chemical reactions and photosynthesis. Right now, just introduce the "shorthand" way to write a molecule: H_2O, H_2, and how to notate TWO of these molecules: $2H_2O$, **2**H_2.

Objectives

- Students understand how electrons drive chemical bonds.
- Students understand what atoms will and will not form chemical bonds, and how many chemical bonds.
- Students understand the vocabulary molecule and compound.
- Student can write basic molecular formulas.

Materials

- Quiz
- Handout, What do these things have in common?
- Handout, How Atoms Bond
- Handout, Chemical Bonds
- Handout, Is it a molecule?
- Handout, How many molecules?

Lesson Steps

Give the quiz.

How do atoms stick together to build everything in the world, including you?

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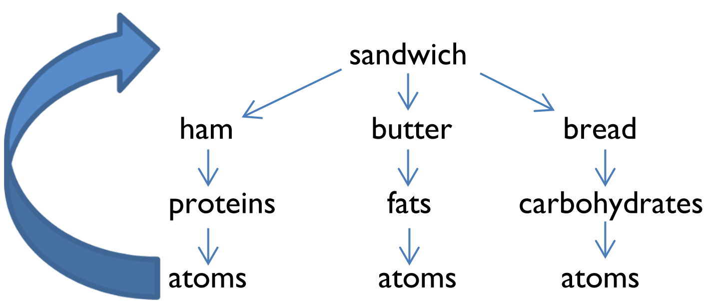
1. Distribute (or project on the board) the handout "What do they have in common?" Give students one minute to discuss. All the things on the page connect or bind things together. Make a list of any more synonyms that students use—connect, bind, tie together, etc. This is today's theme. Today, we're talking about how to connect things.

2. Previously, we talked a lot about getting down to the smallest possible piece of matter, the atom. Write the following diagram on the board, starting at the top and breaking it down into ham, butter, and bread, and then breaking the ham down to proteins, and them to atoms. But today, we're going to go from atoms UP to larger things. Add a big arrow up.



3. If the world were just single atoms, it would be like Atom Soup. In order to build cells, humans, cities, and oceans, atoms need to connect to each other. Today we will learn how atoms connect to each other.

Build a few atoms.

---

4. Distribute the atomic models and stickers. We need to build a few more atoms to use to form bonds. (If students have their models of helium and oxygen from the previous lesson, they don't need to rebuild those two, but they still need to build carbon and hydrogen.) Review quickly: What goes inside the nucleus? What goes in the cloud? Can you put the electrons anywhere in the cloud? Why not? Walk around the class to see who needs help. Remind students to use their periodic tables from last week to decide how many of each atomic particle goes in each element.

5. (Note that hydrogen is unique in that it does not have any neutrons. Because it doesn't have more than one proton in the nucleus, it doesn't need that buffering action of neutrons to stabilize the nucleus.)

6. Ask students to look at their models of atoms. How could these things connect to each other? ***Which parts of the atom do they think are most likely involved in connecting to other atoms?*** Have them brainstorm for a few minutes. (Usually, the edges of things touch, which would suggest that the electron clouds are the parts that connect.)

Discuss chemical bonds.

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7. Define CHEMICAL BOND on the board as the connection or "glue" between two atoms. Add that ELECTRONS and the ELECTRON CLOUD determine chemical bonds. Bonds are formed by electrons being attracted to another (positively-charged) nucleus.

8. Distribute the handout How Atoms Bond. Start by identifying what is what in the first image. The black center with the H is the nucleus of a hydrogen atom—we can assume that there is one proton in this nucleus since we know that a hydrogen atom has one proton. This is surrounded by a gray electron cloud. In the cloud, there is one electron (in black, with a negative charge) and there is one empty electron seat (the white circle). Atoms are driven by two overwhelming desires: they want to be NEUTRAL and they want to have ALL ELECTRON SEATS FILLED. We ask two questions:

    a. Is it neutral overall? Do the total protons equal the total electrons? (In this case, yes. There is one proton and one electron.)
    b. Are all the electron seats filled? (No. There is one open electron seat in this hydrogen atom.)

9. Atoms really, really don't like to have empty seats in their electron clouds. They want to fill them up as soon as possible. But they can't just grab random electrons, because them they would become charged overall, and lose their neutrality. (You can illustrate an example here quickly with hydrogen acquiring an electron, but then it would have an overall charge of negative one since it has one proton and two electrons.)

10. Go to the second image. Here we have two hydrogen atoms close to each other. They are so close that the electron in one atom will start to feel attracted to the nucleus of

the other hydrogen atom. (Go ahead and suggest that this electron isn't being completely loyal to its wedding vows.)

11. Go to the third image. The way that two hydrogen atoms solve their empty seat problem is to overlap their clouds and share electrons. One electron fills two seats—one seat in its original cloud, and one seat in the cloud of the other atom. For example, the two hydrogen atoms can share their two electrons, so that each atom of hydrogen feels like it has both of its empty seats filled. (The reality is that the two electrons start to orbit BOTH hydrogen atoms, forming something called a "molecular orbital.")

12. Two things drive bonding:

a. Atoms want to fill any empty electron seats. They ***can't*** bond if they don't have any empty seats. The number of empty seat determines how many bonds the atom can form. (One empty seat, one bond.)
b. Atoms want to be neutral overall.

13. So what is actually holding these two atoms together? It's the attraction between the electrons of one atom and the protons of the other atoms.

14. This is now called a **molecule**. Define molecule as two or more atoms bonded together. When a chemical bond is formed or broken, this is called a **chemical reaction**.

15. Ask students to write captions for each of the three images, explaining what is happening. They can work together. (You can do the first as an example, by writing, "This is a single hydrogen atom. It is neutral overall, but it has space for one more electron. It can't pick up a loose electron because it will not be neutral anyone. So, it will try to bond with another atom."

16. Distribute the handout Chemical Bonds and ask students to work together. This is challenging, so you will need to walk around and offer help. Review it as a class when most people are done. Ask students to compare the elements listed on the handout. Who is the best "connector" and why? (Carbon can form four bonds, more than most elements, and this is why it's the basis for complex structures on Earth.)

Introduce molecular formulas.

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17. Scientist wanted a shorthand way to describe "two hydrogen atoms bonded together," since this is long and clumsy to say. So they gave each element an abbreviation (one or two letters), which you can see on the periodic table. They use these letters in molecular formulas, which is a shorthand way to write what atoms are in a molecule. Molecular formulas are counterintuitive—the numbers come AFTER the thing that they describe. Write H_2 on the board and explain that the 2 means that there are two hydrogen atoms bonded together. Write 2H on the board, and explain that this is NOT a molecule of hydrogen. This means two separate, individual atoms of hydrogen.

18. Distribute "Is it a molecule?" and have students work in pairs.

19. Distribute "How many molecules?" and have students work in pairs. Note that if there is no coefficient in front of the molecular formula, it is assumed to be one.

Introduce compounds.

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20. One last term that is good to know: compound. A compound is a molecule made out of more than one element. Water is a compound, but H_2 is not a compound.

21. Point out that these are still really, really small molecules. You aren't anywhere near making a cell or a person. In order to do that, you have to attach molecules together though more chemical reactions, which we will discuss next week.

Summarize.

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22. To help students summarize today's lesson, ask them to write a summary that addressed these three questions:

a. What is a chemical bond?
b. What drives atoms to form chemical bond?
c. What is **CH_4** and why, specifically, does it bond with this ratio of atoms?

Homework

Reading, "Elements combine to form compounds."

Vocabulary

- Chemical bond
- Molecule
- Compound
- Molecular formula

Quiz #6: The Atom

1. All of matter is made up of ____.

2. What does heat make atoms do?

3. Three examples of elements are:

   a.

   b.

   c.

4. What's the periodic table?

5. An atom has 24 protons. In order to be neutral, how many electrons does it need?

6. What's inside an atom's nucleus?

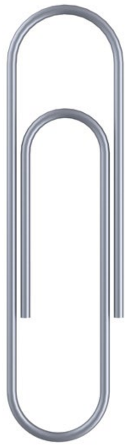
7. The atomic number of gold is 79. The atomic mass of gold is 197.

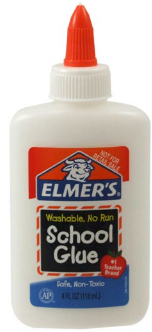
   a. How many protons does gold have?

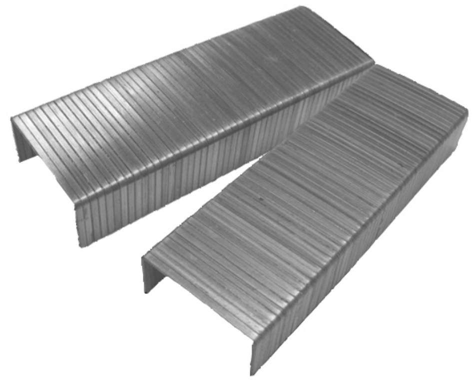
   b. How many electrons does gold have?

   c. How many neutrons does gold have?

Lesson #8: What do these things have in common?



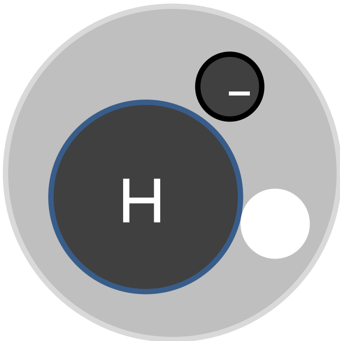

ELMER'S
Washable, No Run
School Glue
Safe, Non-Toxic

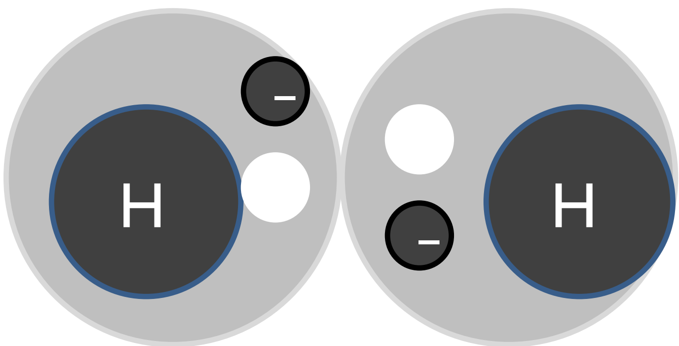


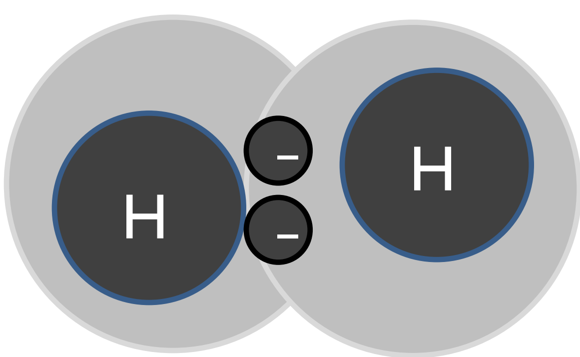

Scotch
Scotch

Lesson #8: How Atoms Bond

Next to each picture, explain what's going on.







Lesson #8: Chemical Bonds

How many bonds can each of these atoms form?

H =

He =

C =

O =

Make a series of three drawings here to show how two hydrogen atoms can bond to one oxygen atom. Use the handout "How Atoms Bond" as a guide.

1. Three separate atoms: two hydrogen atoms and one oxygen atom.

2. The two hydrogen atoms get close to the oxygen atom. The hydrogen electrons start to feel attracted to the positively-charged oxygen nucleus.

3. The hydrogen atoms overlap their clouds with the cloud of the oxygen atom.

Lesson #8: Is it a molecule?

Is it an atom or a molecule? Check the correct box.

	atom	molecule	If it is a molecule, how many atoms are in the molecule?
He			
H			
CO_2			
H_2O			
H_2			There are two hydrogen atoms in one molecule of **H_2**.
C			
CH_4			
O_2			

Lesson #8: How many molecules?

Look at each formula. How many atoms or molecules is it talking about? How do you know? How many total ATOMS are there in that number of molecules?

	How many molecules?	How many total atoms?
4 CO_2	Four separate molecules of CO_2	4 carbon atoms + 8 oxygen atoms = 12 atoms total
5 H_2O		
2 H_2		
CH_4		
3 O_2		

Which of the molecules listed above are COMPOUNDS?

Lesson #9: Chemical Reactions

Note to the Teacher:

The main idea of this lesson is that chemical reactions are what allow tiny molecules like carbon dioxide and water to react to build larger and larger things, like sugar molecules, proteins, membranes, cells, plants and animals. This lesson prepares students to encounter reactions again later during lessons on photosynthesis and respiration.

The most important thing to learn is that a chemical reaction means that molecular bonds were broken or formed. Therefore, something new was produced. So chemical reaction and a chemical change basically mean the same thing. Draw a clear distinction between this and a physical change, where NO bonds were broken or formed, and NO new substance was produced.

This Bozeman lecture is a good, brief discussion on chemical reactions.
https://www.youtube.com/watch?v=AKiAjW7xHOc

Objectives

- Student understand that a chemical reaction occurs when bonds are formed or broken.
- Students understand chemical properties and chemical change.

Materials

- Quiz
- Handout, The Hindenburg
- Handout, Did a chemical reaction take place?
- Legos
- Chemical reactions!
- Reading, "Chemical reactions alter arrangements of atoms."

Supplies for chemical reaction #1:

- Baking soda
- Vinegar
- Empty water bottle
- Balloon
- A spoon (the handle end is helpful for getting baking soda inside of the balloon)

Supplies for chemical reaction #2:

- Ziplock baggies (1 per student)
- 6 packages of instant, dry yeast
- two bottles of hydrogen peroxide
- paper towels

Supplies for chemical reaction #3:

- Borax
- Elmer's glue (all-purpose, not the "school glue"), about 2 tablespoons per students
- Water
- Small plastic cups
- Popsicle sticks or plastic spoons
- Food coloring (optional but fun)
- Ziplock baggies (1 per student)

Lesson Steps
Give the quiz.

Introduction activity: the Hindenburg.

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1. Project a photo of the Hindenburg explosion in the classroom. Ask students to look closely at the picture and discuss with a partner what they think is happening. Emphasize that there is no right or wrong answer—they are just practicing your observation skills to look closely and think about possible explanations.

2. Moderate a brief discussion about what they see in the photo. This is a time for students to talk, not the teacher, so respond to comments with comments like, "Did any other group have a similar idea? Did anyone have a different idea? What else did you see or notice in the picture that we haven't talked about yet? What do you see in the picture that makes you say that?"

3. Ask if there are any ideas about how this is connected to science.

Introduce chemical reactions.

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4. Write on the board $H_2 + O_2 \rightarrow H_2O$

   This is a chemical equation. The things on left go in (these are called reactants), and things on right come out (these are called products). New material is formed: the products. We didn't have water before the reaction occurred, but now we do. Define a chemical reaction as molecules or atoms running into each other and bonds are either broken or formed. This is the chemical reaction that destroyed the Hindenburg. Chemical reactions can be very dangerous because they can absorb or create a lot of energy. This reaction released a lot of energy in the form of an explosion.

5. Distribute the Hindenburg handout. Students should work in pairs.

6. What is and isn't a chemical reaction? (A new substance must be formed.) Distribute "Did a chemical reaction take place?" Discuss with a partner.

Balance a chemical equation (with Legos!).

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7. The chemical equation shows you what reaction happened. It shows you what new substance was formed. Look again at $H_2 + O_2 \rightarrow H_2O$.

8. Give out the Lego molecules. Ask students to set up the reaction on their desk. Two blue blocks are an H_2 molecule and two red blocks are an O_2 molecule. (Or whatever.) Have students undo the two molecules so they have only atoms. Then, use those same atoms to build the product—water. Students will have one extra oxygen atom.

9. Tell students that this reaction won't happen unless all atoms are accounted for. Atoms are very particular—they want their electron seats totally filled, and they will only react when all atoms are accounted for. Ask for any ideas about how to do this reaction but use up all the atoms. Give students a hint that they can't use half of any molecules—they aren't available like that. However, they can use multiple of certain molecules. Ask them to work with a partner to try to figure out how many of each molecule will make it all come out evenly. ($2H_2 + O_2 \rightarrow 2H_2O$) Write the final equation on the board and label it BALANCED.

10. Point out that you CAN change the number of molecules that you have, but you CAN'T change the number of atoms in one molecule (i.e., the subscripts).

11. Put another equation on the board: $Fe + Cl_2 \rightarrow FeCl_3$ and ask students to figure out if this is a balanced or unbalanced equation.

12. Put another equation on the board: $CH_4 + O_2 \rightarrow CO_2 + H_2O$. Ask students to figure out if this is a balanced equation. (No.) Ask them to work with a partner to figure out how to balance this equation. They can use Legos, or not, whatever they prefer. You might also suggest drawing the molecules. ($CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$)

Chemical properties and chemical change.

13. Ask students to recall what physical properties and physical change are. Emphasize that a physical change does not change the identity of the substance—if you start with string, and cut it in half, you end with string.

14. Reiterate this essential point: chemical reactions rearrange molecules. They break bonds and reform bonds. They create new substances. If you start and end with H_2O, a chemical reaction has not occurred. That's why a change of state is not a chemical reaction—there has been no change in the molecular structure. So a chemical change is the same as a chemical reaction. A physical change is a change in shape or size or something like that, but a chemical change is a chemical reaction.

15. A chemical property is about the substance's reactivity. A chemical property would be about how the substance reacts. For example, a chemical property of H_2 is that it can react chemically with O_2 if the temperature is high enough.

16. *Optional but interesting*: Chemical reactions are dependent on the molecules crashing into each other with enough speed/energy. So if you increase the temperature, molecules move faster and faster, and reactions are more likely to happen since the molecules are more likely to crash into each other with sufficient energy. To return to the Hindenburg—H_2 and O_2 only react at high enough temperatures. A spark or some kind of fire is what set off the explosion—it had flown for quite a while before the explosion occurred.

Do some chemical reactions!

17. For each of these reactions, students should first make observations of the reactants. Make a list of physical properties of each reactant. (For example, baking soda is a white powdery solid.) Once the reaction starts happening, students should take notes on what they observe. Finally, they should observe the final product and its properties.

18. Chemical reaction #1 (Do this as a demo for the whole class): Put baking soda into a balloon, and vinegar into an empty water bottle. Affix the balloon onto the mouth of the bottle without dumping the baking soda in. Once the balloon is tightly on, dump the baking soda in. Ask students to discuss why the balloon inflated. (One of the new products formed in this chemical reaction is a gas! CO_2 is formed. The reaction is $NaHCO_3 + HC_2H_3O_2 \rightarrow NaC_2H_3O_2 + H_2O + CO_2$)

19. Chemical reaction #2 (Students do it.): Put a little yeast (1/4 teaspoon or less) into a Ziploc bag. Pour a little hydrogen peroxide (2 tablespoons) into the bag. (Hold the top closed.) Use your hands to mix it up. Ask students to observe what happens. (As it reacts, it gives off heat, which students should observe. Giving off heat is a telltale sign of a chemical reaction. This reaction is EXOthermic. Exo- means "out," which they can remember because it looks like "exit.")

20. Chemical reaction #3 (Students do it.): Mix 2 tablespoons of glue with 2 tablespoons of water into a small plastic cup. They can use a few drops of food coloring to dye their glue. Meanwhile, the teacher will mix 2 cups of water with 4 teaspoons of Borax. Students will add a little of the Borax solution at a time to their glue, stirring constantly. Students should keep adding Borax solution to their mixture until they have something that resembles Silly Putty. They can take it out and knead it with their hands when it becomes stiff enough. (The product has very different properties than the reactants do.) Provide baggies for students to take their product home.

Summarize.

By themselves, ask students to make a few notes about what you discussed in class today. Have students compare their notes with a partner.

Homework

Reading, "Chemical reactions alter arrangements of atoms."

Vocabulary

- Chemical reaction
- Reactant
- Product
- Chemical property
- Chemical change

Quiz #7: Chemical Bonds

1. What is a molecule?

2. What is a compound?

3. What determines if a chemical bond will form or not?

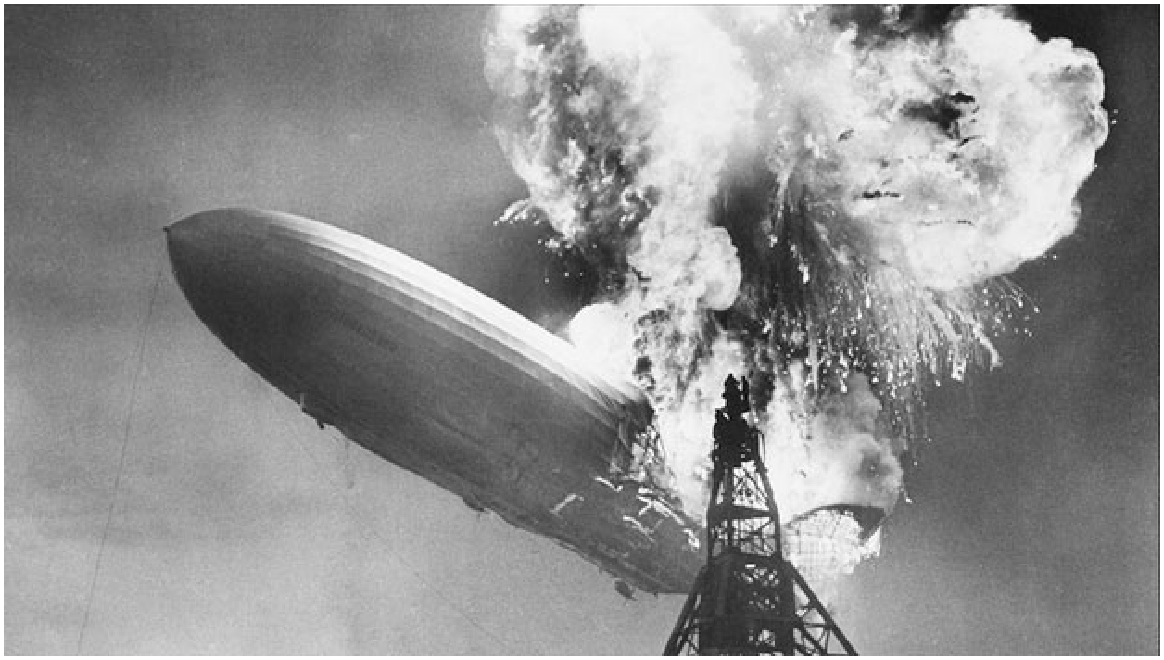
4. A few questions about **$5\ H_2O$**

    a. How many molecules of water is this?

    b. How many atoms of hydrogen are above?

    c. How many atoms of oxygen are above?

Lesson #9: The Hindenburg



The Hindenburg was an airship that caught fire and was destroyed in 1937. It was filled with hydrogen gas (H_2), which made it float in the air. Draw a molecule of H_2 here.

Why did hydrogen gas make this ship float?

Lesson #9: Did a chemical reaction take place?

Chemical reactions happen when bonds are formed or broken. New products are made. If you start and end with a molecule of water and nothing else, no reaction has taken place. But if you start with a molecule of water and end with oxygen gas and hydrogen gas, a chemical reaction has taken place—the bonds of the water molecule were broken.

For each situation below, did a chemical reaction take place? You might not know for sure, but take your best guess given the evidence.

1. You boil salt water until all the water boils out. A layer of salt is left on the bottom of the pan.
2. A metal garbage can starts to rust.
3. You get your hair cut.
4. Fireworks explode on the fourth of July.
5. You drive your car.
6. Your stomach digests a sandwich.
7. You bake a cake.
8. You paint a wall red.
9. You stir sugar into coffee.

Lesson #9: Chemical Reactions!

For each chemical reaction, make observations of the reactant before we mix them together. Then, take notes on what happens during the reaction. Finally, make observations of the final product(s). Write a few sentences explaining the procedure.

Chemical Reaction #1

Describe the reactants.	What happened during this reaction?	Describe the products.

Briefly explain how to do this reaction.

Chemical Reaction #2

Describe the reactants.	What happened during this reaction?	Describe the products.

Briefly explain how to do this reaction.

Chemical Reaction #3

Describe the reactants.	What happened during this reaction?	Describe the products.

Briefly explain how to do this reaction.

Lesson #10: The Conservation of Matter and the Water Cycle

Note to the Teacher:

This lesson introduces a few new ideas, but it also encompasses a review of many of the concepts previously covered in this lesson set. The fact that carbon atoms have been around for millions of years is bizarre but true, and it seems funny to me that science classes didn't make a bigger deal out of this idea that you could have a carbon atom in your hand that used to be part of a dinosaur, or Miles Davis, or the Titanic. This conservation of matter also sets up the idea of conservation, which will return in the next lesson set about energy. Both matter and energy are conserved.

This lesson also introduced the idea of cycles. Cycles of matter, energy, and information (in the form of DNA) are central to how our world operates. This is the first lesson that begins to broaden out to ecosystems

Objectives

- Students learn that atoms aren't made and destroyed easily, but that they last for many years in many different forms.
- Students learn what an ecosystem is.
- Students learn what the water cycle is.

Materials

- Handout, Reading, The Star In You
- Handout, Track a hydrogen atom.
- Reading, Matter cycles through ecosystems

Lesson Steps

Intro activity: Why is the ocean salty?

1. Write this question on the board and have students discuss. Ask them to make a list of possible reasons. It's okay to be wrong! We're just talking here.

Reading on how the elements were formed.

2. Distribute copies of the NOVA article "The Star in You." Ask students to read it and write a sentence or two on the main idea. (The atoms that make up our world were made in stars billions of years ago.)

3. Ask students to work with a partner to make a list of things that the article mentioned that we've learned about in this science class. (atoms, elements, protons, electrons, H_2O)

Track a hydrogen atom.

4. We're going to trace the progress of one of the billions-years-old hydrogen atoms here on earth. The handout tells you what form and where this hydrogen atom is, but the students have to describe how the hydrogen atom moved to the next form/location. For example, a single, unbonded hydrogen formed after the Big Bang is later found in the form of H_2 in the Hindenburg. How did it get there? It bonded with another hydrogen atom. Students should use words like condensation, evaporation, chemical bond, and chemical reaction.

5. Have a few groups share their paths.

Introduce the conservation of matter.

6. Distribute the reading "Matter cycles through ecosystems." Ask students to write the main idea of each paragraph in the margin.

7. Ask, "How does new matter get made? How do we get new carbon or water?" We don't get new matter—we just recycle, recycle, recycle. Chemical reactions convert matter from one thing to another, but *it doesn't get destroyed or created, it only changes form*. As it turns out, as we will discover in the next section of this curriculum, the exact same thing is true of energy—energy also never gets created or destroyed, it only changes form.

Return to introduction activity.

8. When water molecules rain down onto the earth, there are lots of salts and other minerals in earth, and the water can dissolve those salts. Water then runs downhill (obeying gravity) until it joins a river, and then a lake or back into the ocean. So this runoff water carries lots of salts and minerals into the ocean. But when water evaporated from the ocean, it doesn't carry the salts out. Any salt or minerals carried into the ocean will stay there. Over millions of years, that makes the ocean pretty salty!

Summarize

Ask students to make notes on their own about what we did in this lesson, and then have them compare notes.

Vocabulary

- Conservation
- Water cycle
- ecosystem

Lesson #10: Reading

The Star In You

- By Peter Tyson
- Posted 12.02.10
- NOVA scienceNOW

"Our planet, our society, and we ourselves are built of star stuff."—Carl Sagan, *Cosmos*

Here's an amazing fact for your next cocktail party: Every single atom in your body—the calcium in your bones, the carbon in your genes, the iron in your blood, the gold in your filling—was created in a star billions of years ago. All except atoms of hydrogen and one or two of the next lightest elements. *They* were formed even earlier, shortly after the Big Bang began 13.7 billion years ago.

It's true, according to astrophysicists. You and everything around you, every single natural and man-made thing you can see, every rock, tree, butterfly, and building, comprises atoms that originally arose during the Big Bang or, for all but the lightest two or three elements, from millions of burning and exploding stars far back in the history of the universe. You live because stars died; it's that simple.

How is this so? How can you possibly be a walking galaxy of fossil stardust? Well, the story is not a new one, but it bears retelling, if only because its working out was one of the finest achievements of 20th-century astrophysics—and because it's so astonishing.

The start of it all

The story begins at the beginning, as in the Big Bang. That is when, astrophysicists say, *all* the hydrogen in the universe came into being. Initially it was just protons, and then, as the young universe expanded and cooled, these became bound to electrons, forming hydrogen atoms. The very hydrogen atoms in the H_2O that makes up over half your body were born then. They didn't come from your parents; they came from the early universe. Did you have any idea you have atoms in your body that are over 13 billion years old?

If you could separate one hydrogen atom from one molecule of water in your body, shrink down to its atomically tiny size like the scientists in *Fantastic Voyage*, then reverse time and follow it back to through its unimaginable lifetime, you would find yourself in the immediate aftermath of the Big Bang. That very hydrogen atom, an atom now inside you as you read this, has remained unchanged since the beginning of time.

The Big Bang also churned out helium, the next lightest element. You don't have any helium in you, unless you just sucked the gas out of a birthday balloon. But helium is the second most common element after hydrogen. Together they make up more than 98 percent of the matter in the universe. (Luminous matter, that is; dark matter is a whole other story.) A smattering of lithium (element 3) and one or two other of the lightest elements also formed in the Bang, but these were negligible.

Everything else, every other chemical element, including carbon, oxygen, nitrogen, and all the other elements essential for your life, is thought to have been fabricated in stars.

Lesson #10: Track a hydrogen atom.

Using everything you know from this class, describe how this hydrogen atom moved between each step in its path. Use detail to describe how it might have reacted with other molecules to form new molecules or changed state.

1. A single, unbonded hydrogen atom is created after the Big Bang, millions of years ago.
2. This hydrogen atom is now part of a H_2 molecule in the Hindenburg.
3. This hydrogen molecule is now part of a gaseous molecule of water.
4. This molecule is now part of a raindrop.
5. This molecule is being boiled in a pot of water on your stove and is absorbed by a noodle.
6. This molecule is now part of your body.
7. This molecule is part of a cloud.
8. This molecule is now part of the ocean.
9. This molecule is now snow.

