Renaissance High School
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Physical Science 2020-2021 Summer Packet

Welcome to Renaissance!

This is your summer assignment packet for 9th Grade Physical Science. **It will be collected for a grade on the first day of school via Teams.**

Please follow these instructions while completing the summer packet.

1) You may type your answers and digitally create your drawings or do them by hand and upload the files.
2) **Please do not upload photos.** They are often impossible to read. Scanned documents or Word files are preferred. Photos of work may not be given credit at the discretion of your instructor.
3) Answer all questions in complete sentences. Partial answers will not be given credit.
4) For drawings: Label all the parts. We need to understand *why* you chose to represent something a certain way, not just the drawing. Incomplete drawings may not receive credit.
5) **The entire assignment must be completed for credit and is due the FIRST DAY OF SCHOOL.**
6) Do your best! You may not be sure of all your answers, but do not leave blanks. Attempt every question.

If you have any questions, you can reach Dr. Unger at benjamin.unger@detroitk12.org.

The RHS Science Department & Physical Science teachers welcome you!

Dr. Benjamin Unger
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Mrs. Jasmine Lyons-Woods

section 1

Electric Charge

Reading Guide

What You'll Learn

- **Describe** how electric charges exert forces on each other.
- **Compare** the strengths of electric and gravitational forces.
- **Distinguish** between conductors and insulators.
- **Explain** how objects become electrically charged.

Why It's Important

The electrical energy that all electrical devices use comes from the forces that electric charges exert on each other.

Review Vocabulary

atom: the smallest particle of an element

New Vocabulary

- static electricity
- law of conservation of charge
- conductor
- insulator
- charging by contact
- charging by induction

Positive and Negative Charge

Why does walking across a carpeted floor and then touching something sometimes result in a shock? The answer has to do with electric charge. Atoms contain particles called protons, neutrons, and electrons, as shown in **Figure 1.** Protons and electrons have electric charge, and neutrons have no electric charge.

There are two types of electric charge. Protons have positive electric charge and electrons have negative electric charge. The amount of positive charge on a proton equals the amount of negative charge on an electron. If an atom contains equal numbers of protons and electrons, the positive and negative charges cancel out and the atom has no net electric charge. Objects with no net charge are said to be electrically neutral.

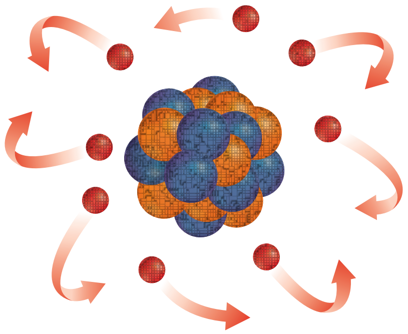


Figure 1 The center of an atom contains protons (orange) and neutrons (blue). Electrons (red) swarm around the atom's center.

Transferring Charge Electrons are bound more tightly to some atoms and molecules. For example, compared to the electrons in atoms in the carpet, electrons are bound more tightly to the atoms in the soles of your shoes. **Figure 2** shows that when you walk on carpet, electrons are transferred from the carpet to the soles of your shoes. The soles of your shoes have an excess of electrons and become negatively charged. The carpet has lost electrons and has an excess of positive charge. The carpet has become positively charged. The accumulation of excess electric charge on an object is called **static electricity.**

Before the shoe scuffs against the carpet, both the sole of the shoe and the carpet are electrically neutral.

As the shoe scuffs against the carpet, electrons are transferred from the carpet to the sole of the shoe.

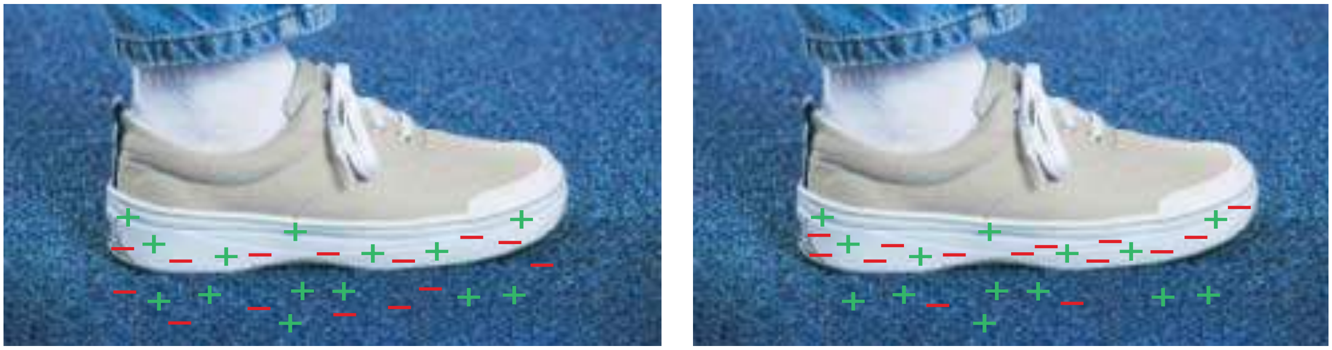


Figure 2 Atoms in the shoe's sole hold their electrons more tightly than atoms in the carpet hold their electrons.
Explain *how the sole gained charge even though charge can't be created or destroyed.*

Conservation of Charge When an object becomes charged, charge is neither created nor destroyed. Usually it is electrons that have moved from one object to another. According to the **law of conservation of charge,** charge can be transferred from object to object, but it cannot be created or destroyed. Whenever an object becomes charged, electric charges have moved from one place to another.

Reading Check *How does an object become charged?*

Charges Exert Forces Have you noticed how clothes sometimes cling together when removed from the dryer? These clothes cling together because of the forces electric charges exert on each other. **Figure 3** shows that unlike charges attract each other and like charges repel each other. The force between electric charges also depends on the distance between charges. The force decreases as the charges get farther apart.

Just as for two electric charges, the force between any two objects that are electrically charged decreases as the objects get farther apart. This force also depends on the amount of charge on each object. As the amount of charge on either object increases, the electrical force also increases.

As clothes tumble in a dryer, the atoms in some clothes gain electrons and become negatively charged. Meanwhile the atoms in other clothes lose electrons and become positively charged. Clothes that are oppositely charged attract each other and stick together.

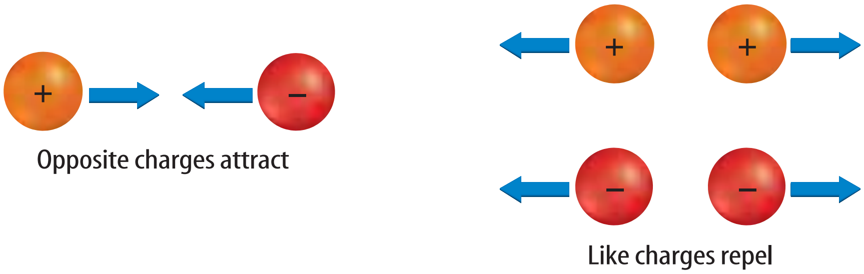


Figure 3 Positive and negative charges exert forces on each other.

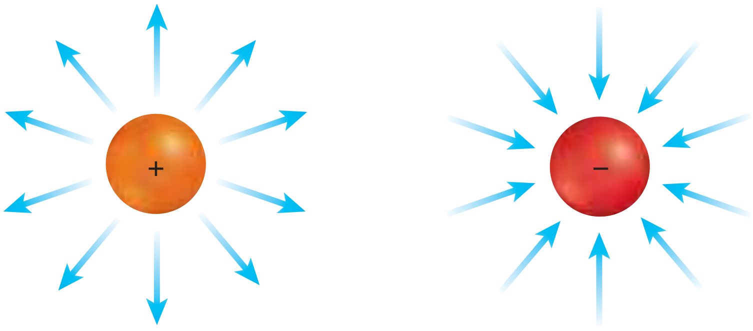


Figure 4 Surrounding every electric charge is an electric field that exerts forces on other electric charges. The arrows point in the direction a positive charge would move.

Electric Fields

You might have seen bits of paper fly up and stick to a charged balloon. The bits of paper do not need to touch the charged balloon for an electric force to act on them. If the balloon and the paper are not touching, what causes the paper to move?

An electric field surrounds every electric charge, as shown in **Figure 4,** and exerts the force that causes other electric charges to be attracted or repelled. Any charge that is placed in an electric field will be pushed or pulled by the field. Electric fields are represented by arrows that show how the electric field would make a positive charge move.

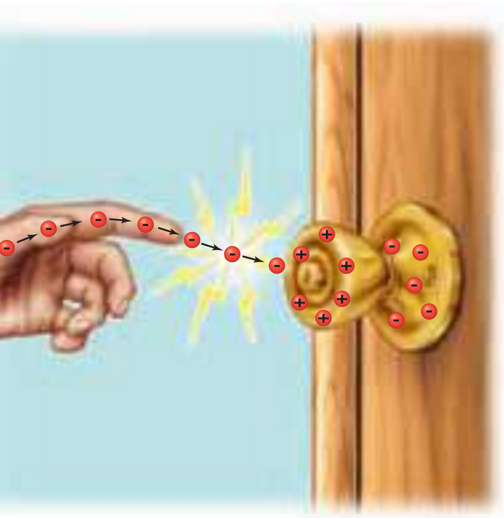
The Strength of Electric Forces

The force of gravity between you and Earth seems to be strong. Yet, compared with electric forces, the force of gravity is much weaker. For example, the attractive electric force between a proton and an electron in a hydrogen atom is about a thousand trillion trillion trillion times larger, or 10^{39} times larger, than the attractive gravitational force between the two particles.

In fact, all atoms are held together by electric forces between protons and electrons that are tremendously larger than the gravitational forces between the same particles. The chemical bonds that form between atoms in molecules also are due to the electric forces between the atoms. These electric forces are much larger than the gravitational forces between the atoms.

Reading Check *Compare the strength of electric and gravitational forces between protons and electrons.*

Figure 5 As you walk across a carpeted floor, excess electrons can accumulate on your body. When you reach for a metal doorknob, electrons flow from your hand to the doorknob and you see a spark.



Some Observable Forces are due to Electric Forces

Many of the forces that act on objects are due to the electric forces between atoms and molecules. All atoms contain electrically charged electrons and protons. When atoms or molecules get close enough, they can exert electric forces on each other that can be attractive or repulsive. For example, when you push on a door, the atoms on the surface of your hand get close to the atoms on the surface of the door. These atoms are close enough that they exert electric forces on each other. The electric forces the atoms in your hand exert on the atoms in the door cause the door to move. The frictional force between two surfaces in contact is due to the attractive electric forces between the atoms on the two surfaces. These forces cause the surfaces to stick together.

Conductors and Insulators

If you reach for a metal doorknob after walking across a carpet, you might see a spark. The spark is caused by electrons moving from your hand to the doorknob, as shown in **Figure 5.** Recall that electrons were transferred from the carpet to your shoes. How did these electrons move from your shoes to your hand?

Conductors A material in which electrons are able to move easily is a **conductor.** Electrons on your shoes repel each other and some are pushed onto your skin. Because your skin is a better conductor than your shoes, the electrons spread over your skin, including your hand.

The best electrical conductors are metals. The atoms in metals have electrons that are able to move easily through the material. Electric wires usually are made of copper because copper metal is one of the best conductors.

Insulators A material in which electrons are not able to move easily is an **insulator.** Electrons are held tightly to atoms in insulators. Most plastics are insulators. The plastic coating around electric wires, such as the one shown in **Figure 6,** prevents a dangerous electric shock when you touch the wire. Other good insulators are wood, rubber, and glass.

Charging Objects

You might have noticed socks clinging to each other after they have been tumbling in a clothes dryer. Rubbing two materials together can result in a transfer of electrons. Then one material is left with a positive charge and the other with an equal amount of negative charge. The process of transferring charge by touching or rubbing is called **charging by contact.**

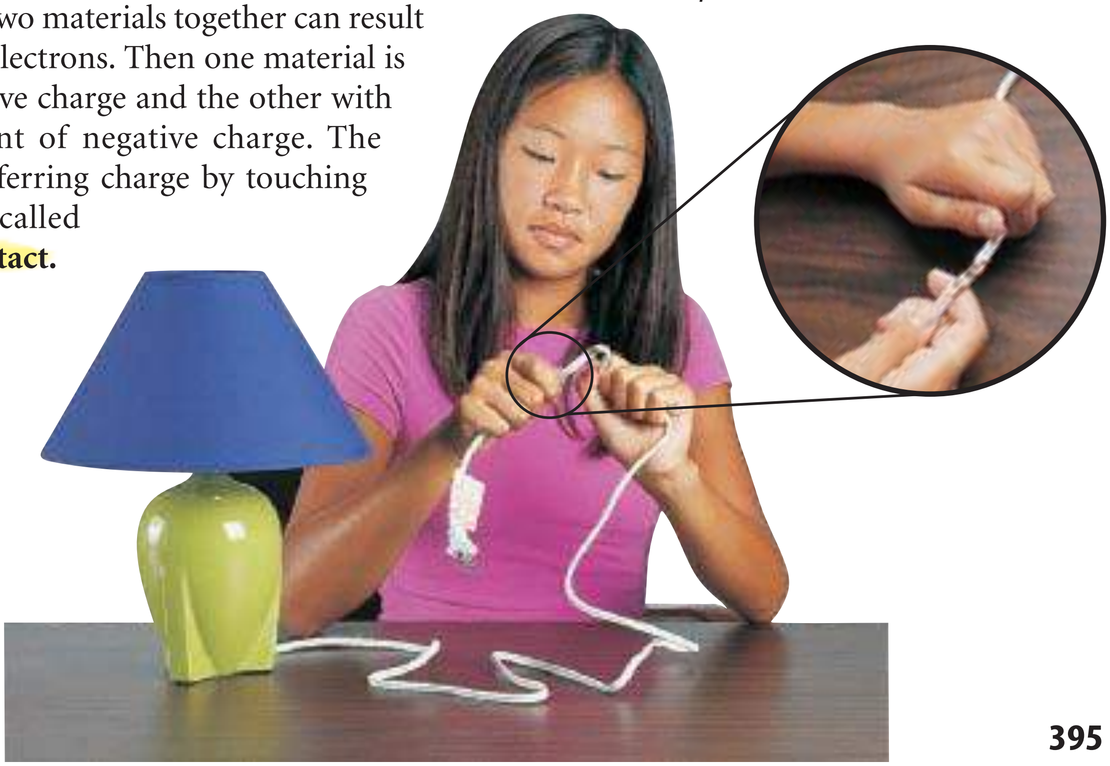


Figure 6 The plastic coating around wires is an insulator. A damaged electrical cord is hazardous when the conducting wire is exposed.
Explain *how the coating on a wire prevents an electric shock.*

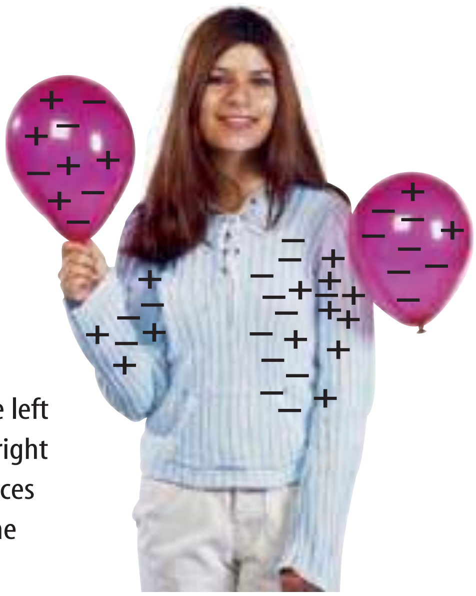


Figure 7 The balloon on the left is neutral. The balloon on the right is negatively charged. It produces a positively charged area on the sleeve by repelling electrons.
Determine *the direction of the electric force acting on the balloon.*

Charging at a Distance

Because electrical forces act at a distance, charged objects brought near a neutral object will cause electrons to rearrange their positions on the neutral object. Suppose you charge a balloon by rubbing it with a cloth. If you bring the negatively charged balloon near your sleeve, the extra electrons on the balloon repel the electrons in the sleeve. The electrons near the sleeve's surface move away from the balloon, leaving a positively charged area on the surface of the sleeve, as shown in **Figure 7.** As a result, the negatively charged balloon attracts the positively charged area of the sleeve. The rearrangement of electrons on a neutral object caused by a nearby charged object is called **charging by induction.** The sweater was charged by induction. The balloon will now cling to the sweater, being held there by an electrical force.

Lightning Have you ever seen lightning strike Earth? Lightning is a large static discharge. A static discharge is a transfer of charge between two objects because of a buildup of static electricity. A thundercloud is a mighty generator of static electricity. As air masses move and swirl in the cloud, areas of positive and negative charge build up. Eventually, enough charge builds up to cause a static discharge between the cloud and the ground. As the electric charges move through air, they collide with atoms and molecules. These collisions cause the atoms and molecules in air to emit light. You see this light as a spark, as shown in **Figure 8.**

Thunder Not only does lightning produce a brilliant flash of light, it also generates powerful sound waves. The electrical energy in a lightning bolt rips electrons off atoms in the air and produces great amounts of thermal energy. The surrounding air temperature can rise to about 25,000°C—several times hotter than the Sun's surface. The hot air in the lightning bolt's path expands rapidly, producing sound waves that you hear as thunder.

The sudden discharge of so much energy can be dangerous. It is estimated that Earth is struck by lightning about 100 times every second. Lightning strikes can cause power outages, injury, loss of life, and fires.

Science Online

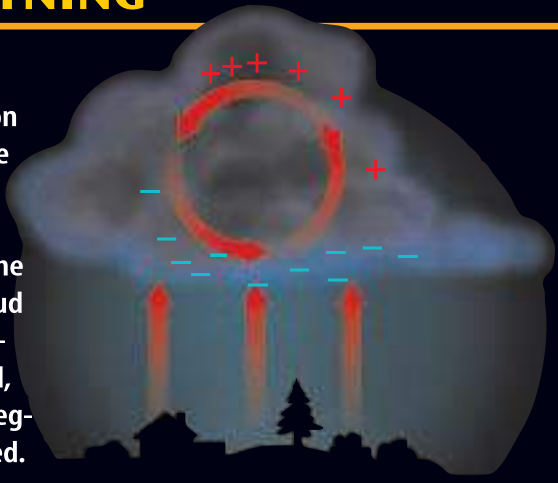
Topic: Lightning
Visit gpescience.com for Web links to information about lightning strikes.

Activity Make a table listing tips on how people can protect themselves from lightning.

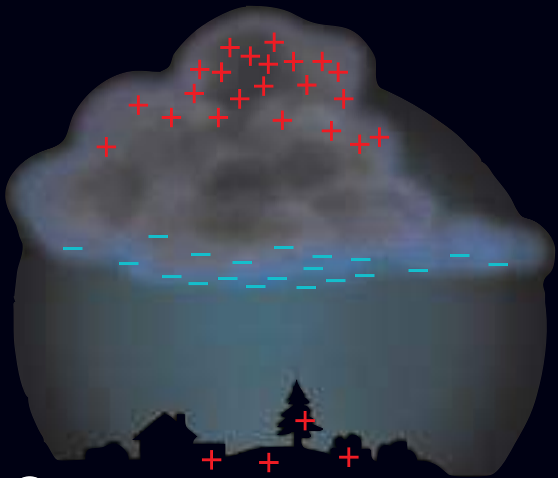
NATIONAL GEOGRAPHIC VISUALIZING LIGHTNING

Figure 8

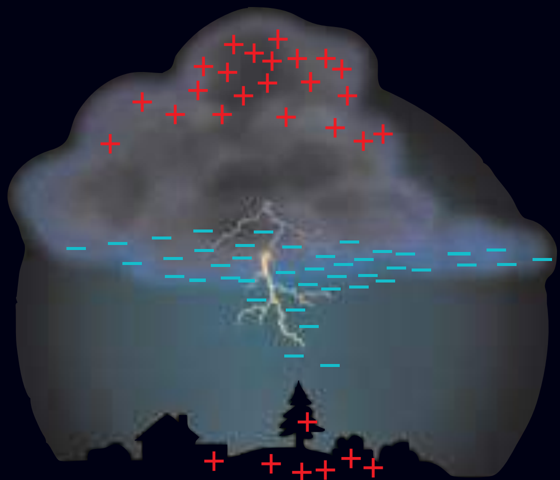
Storm clouds can form when humid, Sun-warmed air rises to meet a colder air layer. As these air masses churn together, the stage is set for the explosive electrical display we call lightning. Lightning strikes when negative charges at the bottom of a storm cloud are attracted to positive charges on the ground.



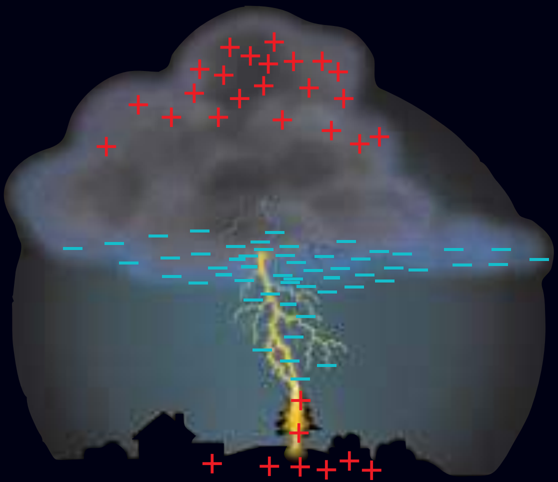
A Convection currents in the storm cloud cause charge separation. The top of the cloud becomes positively charged, the bottom negatively charged.



B Negative charges on the bottom of the cloud induce a positive charge on the ground below the cloud by repelling negative charges in the ground.



C When the bottom of the cloud has accumulated enough negative charges, the attraction of the positive charges below causes electrons in the bottom of the cloud to move toward the ground.



D When the electrons get close to the ground, they attract positive charges that surge upward, completing the connection between cloud and ground. This is the spark you see as a lightning flash.

INTRACLOUD LIGHTNING never strikes Earth and can occur ten times more often in a storm than cloud-to-ground lightning.

Figure 9 A lightning rod directs the charge from a lightning bolt safely to the ground.

Grounding The sensitive electronics in a computer can be harmed by large static discharges. A discharge can occur any time that charge builds up in one area. Providing a path for charge to reach Earth prevents any charge from building up. Earth is a large, neutral object that is also a conductor of charge. Any object connected to Earth by a good conductor will transfer any excess electric charge to Earth. Connecting an object to Earth with a conductor is called grounding. For example, to prevent damage by lightning, buildings often have a metal lightning rod that provides a conducting path from the highest point on the building to the ground, as shown in **Figure 9.**

Plumbing fixtures, such as metal faucets, sinks, and pipes, often provide a convenient ground connection. Look around. Do you see anything that might act as a path to the ground?

Detecting Electric Charge

The presence of electric charges can be detected by an electroscope. One kind of electroscope is made of two thin, metal leaves attached to a metal rod with a knob at the top. The leaves are allowed to hang freely from the metal rod. When the device is not charged, the leaves hang straight down, as shown in **Figure 10A.**

Suppose a negatively charged rod touches the knob. Because the metal is a good conductor, electrons travel down the rod into the leaves. Both leaves become negatively charged as they gain electrons, as shown in **Figure 10B.** Because the leaves have similar charges, they repel each other.

If a glass rod is rubbed with silk, electrons move away from the atoms in the glass rod and build up on the silk. The glass rod becomes positively charged.

Mini LAB

Investigating Charged Objects

Procedure

1. Complete the safety form.
2. Fold over about 1 cm on the end of a **roll of transparent tape** to make a handle. Tear off a strip of tape about 10 cm long.
3. Stick the strip to a clean, dry, smooth surface, such as a countertop. Make an identical strip and stick it directly on top of the first.
4. Pull both pieces off the counter together and pull them apart. Bring the nonsticky sides of both tapes together. What happens?
5. Stick the two strips of tape side by side on the smooth surface. Pull them off and bring the nonsticky sides near each other again.

Analysis

1. What happened when you brought the pieces close together the first time? How were they charged? What might have caused this?
2. What happened when you brought the pieces together the second time? How were they charged? What did you do that might have changed the behavior?

Try at Home

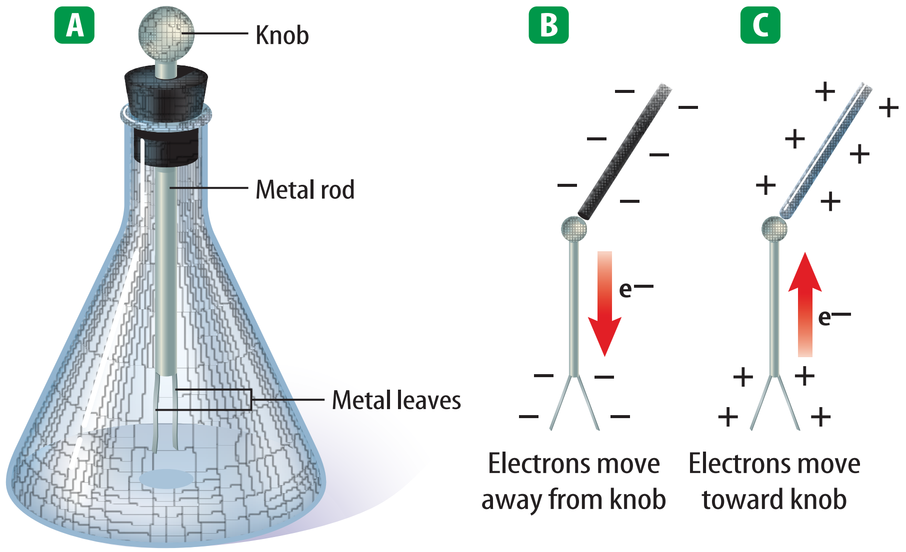


Figure 10 Notice the position of the leaves on the electroscope when they are A uncharged, B negatively charged, and C positively charged.
Infer *How can you tell whether an electroscope is positively or negatively charged?*

When the positively charged glass rod is brought into contact with the metal knob of an uncharged electroscope, electrons flow out of the metal leaves and onto the rod. The leaves repel each other because each leaf becomes positively charged as it loses electrons, as shown in **Figure 10C.**

section 1 review

Summary

Positive and Negative Charge

- There are two types of electric charge: positive charge and negative charge.
- Electric charges can be transferred between objects but cannot be created or destroyed.
- Like charges repel and unlike charges attract.
- An electric charge is surrounded by an electric field that exerts forces on other charges.

Electrical Conductors and Insulators

- A conductor contains electrons that can move easily. The best conductors are metals.
- The electrons in an electrical insulator do not move easily. Rubber, glass, and most plastics are examples of insulators.

Charging Objects

- Electric charge can be transferred between objects by bringing them into contact.
- Charging by induction occurs when the electric field around a charged object rearranges electrons in a nearby neutral object.

Self Check

1. **Define** static electricity.
2. **Describe** how lightning is produced.
3. **Explain** why electrically neutral objects can become electrically charged even though charge cannot be created or destroyed.
4. **Predict** what would happen if you touched the knob of a positively charged electroscope with another positively charged object.
5. **Think Critically** Humid air is a better electrical conductor than dry air. Explain why you're more likely to receive a shock after walking across a carpet when the air is dry than when the air is humid.

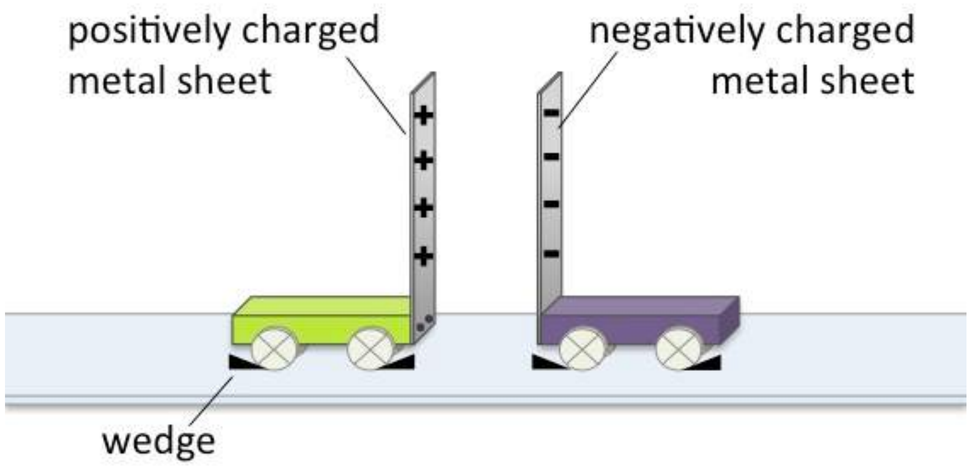
Applying Math

6. **Determine Lightning Strikes** Earth is struck by lightning 100 times each second. How many times is Earth struck by lightning in one day?
7. **Calculate Electric Force** A balloon with a mass of 0.020 kg is charged by rubbing and then is stuck to the ceiling. If the acceleration of gravity is 9.8 m/s^2, what is the electrical force on the balloon?

Interactions Pre-test Unit 1 Part 1 Fall 2017

Questions 1-3

The picture shows two wood cars with metal sheets attached. One metal sheet is positively charged, the other negatively charged. The wedges prevent the cars from moving.



Question 1
When the wedges are removed, predict which way the carts will move. Justify your prediction.

Question 2

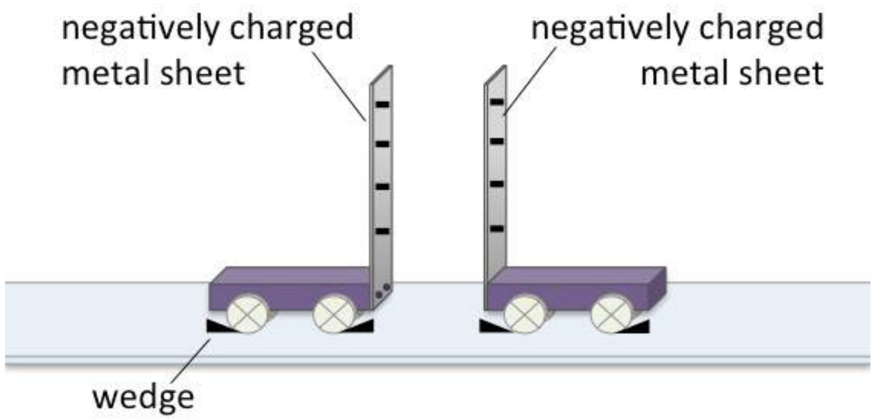
Predict how the strength of the force between the cars changes when the wedges are taken away and the cars are allowed to move. Justify your prediction.

Question 3

Predict how the force between the sheets would be different if this experiment were done with twice as much charge on each of the plates. Justify your prediction.

Question 4

The picture shows two wood cars with metal sheets attached. Both metal sheets are negatively charged. The wedges prevent the cars from moving.

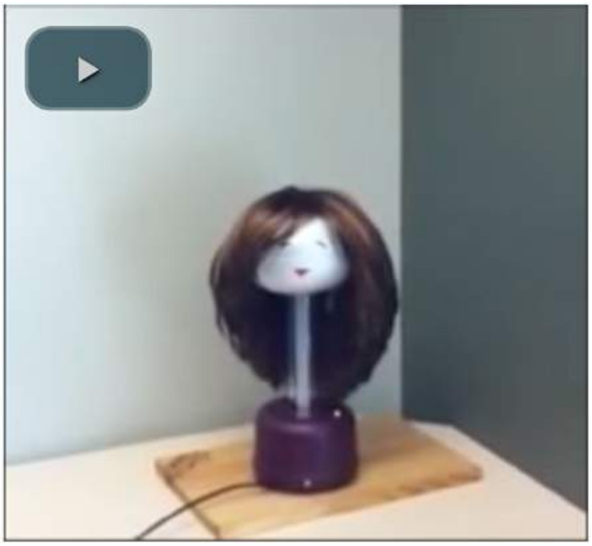


When the wedges are removed, the cars will move. Predict which direction they will move and when they will stop. Justify your prediction. Use ideas about forces and energy as appropriate.

Questions 5-8 https://youtu.be/4r4hpaaPUWk

The video shows a wig on a machine that builds up a lot of electric charge. Watch the video, then answer the questions below.

What happens during the process shown in the video? Draw a series of models to show what happens to cause the hair to stick out.



Question 5

Draw a model of the initial state before the machine is turned on. What is happening at this point? Include the interactions that are occurring. Justify your answer.

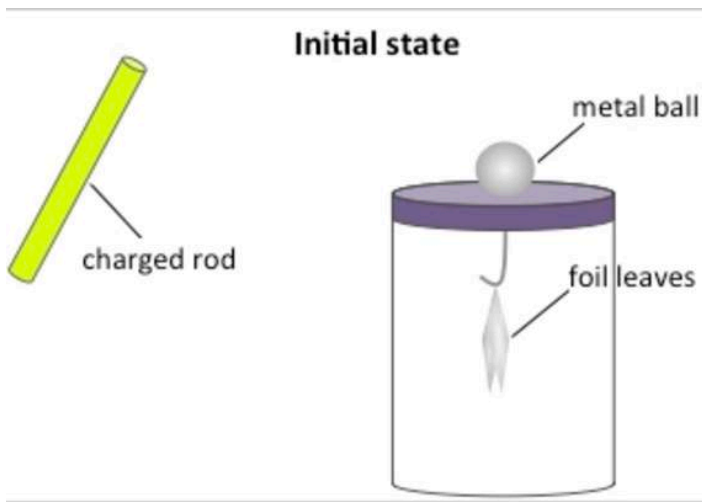
Question 6
Draw a model that shows what causes the hair to start moving out. What is happening at this point? Include the interactions that are occurring. Justify your answer.

Question 7
Draw a model that shows what is happening at the final state to cause all of the hair to be sticking out. What is happening at this point? Include the interactions that are occurring. Justify your answer.

Question 8
What changes in the **forces** and **energy** occur to cause all of the hair to stick out? Describe why those changes cause the process to occur.

Questions 9-10 https://youtu.be/Evo0sf5FztI

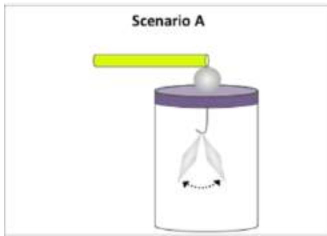
In the video shown by your teacher, when the charged rod gets close to or touches the metal ball, the foil leaves move apart.



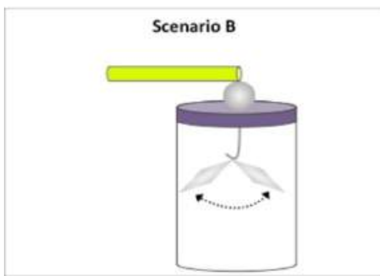
Question 9
What causes the foil leaves to move apart when the charged rod touches the metal ball? Justify your answer.

Question 10

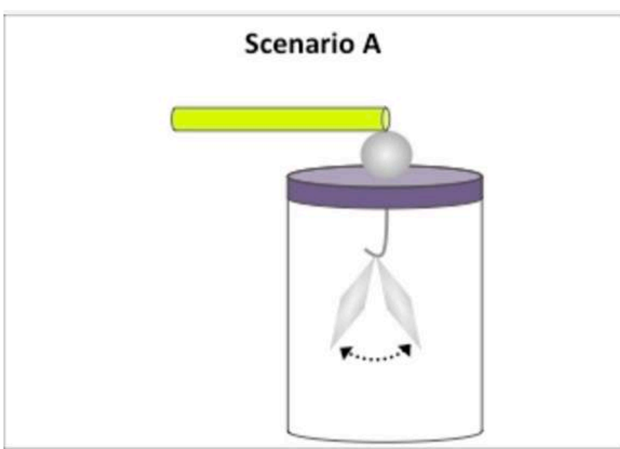
Scenario A below shows a diagram of what occurred in the video when a charged rod touched the ball.

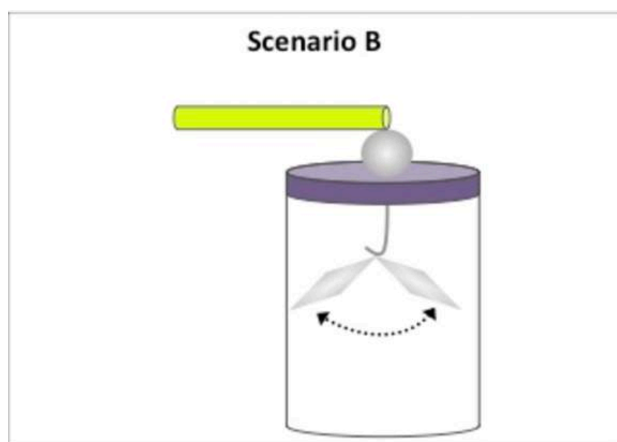


In Scenario B, a rod touches the ball and makes the leaves move much further apart.



Draw a model to show what the differences are in the rod and foil leaves in the two scenarios.





What is different about Scenario A and Scenario B? Justify your answer.

Question 11 https://youtu.be/NsxhbgCrrSQ

The video shows the effect of changing the distance between a balloon and rod that have both been rubbed with fur. Watch the video, then answer the question below.

Use electric fields to explain what causes the effect that the rod and the balloon have on each other to change as the distance between them changes.

Questions 12-13
Use the data in the table to answer the questions below.

Test Object	Charge on test object	Green Balloon	Red Balloon
Rod #1	Positive	moves toward rod	moves toward rod
Rod #2	Negative	moves away from rod	moves toward rod

Question 12
What is the charge on the green balloon? Provide evidence to justify your answer.

Question 13
What is the charge on the red balloon? Provide evidence to justify your answer.

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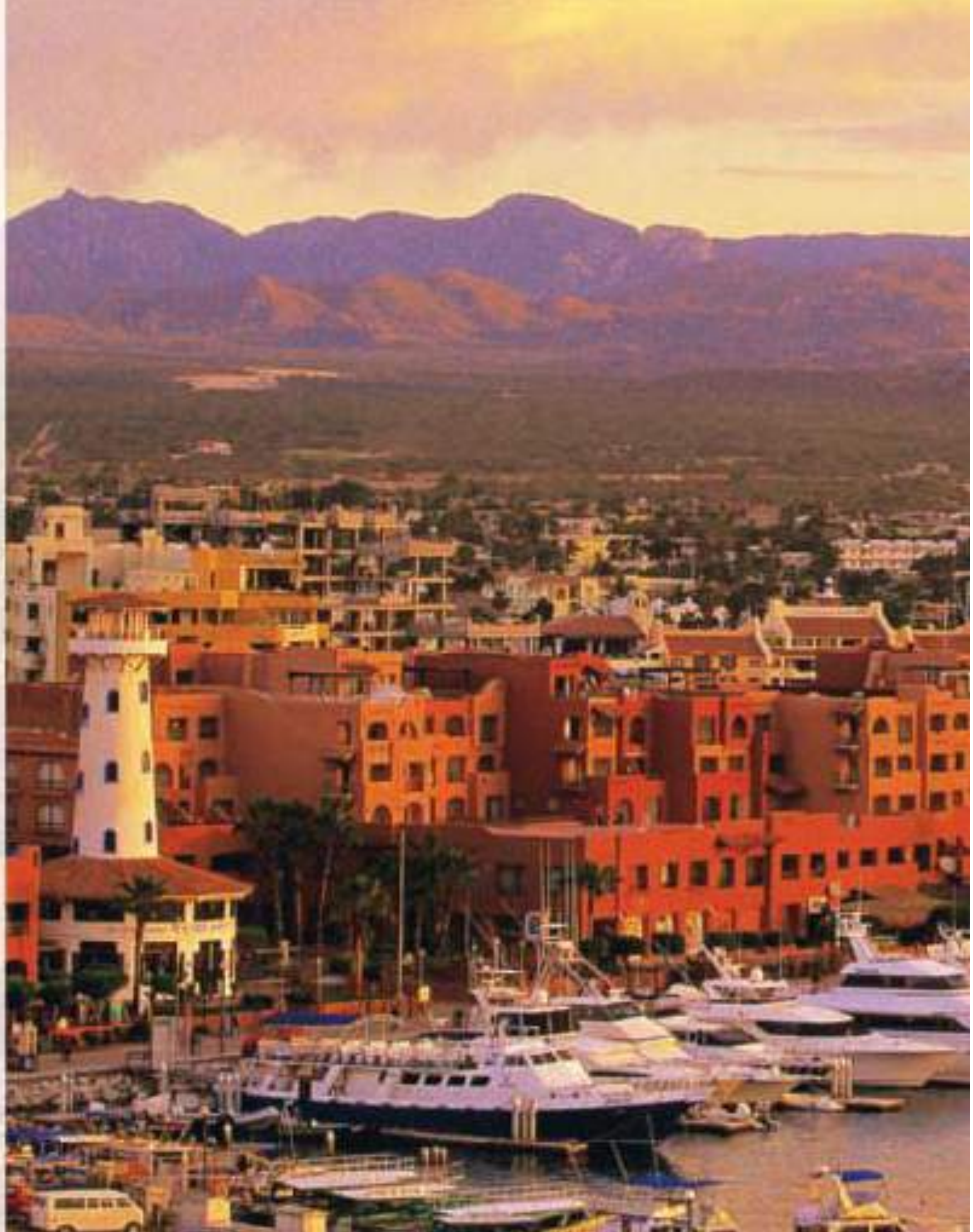
chapter 19

Properties of Atoms and the Periodic Table



BIG Idea
The properties of an element are determined by the composition of its atoms.

19.1 Structure of the Atom

MAIN Idea Protons and neutrons are located in an atom's nucleus, and electrons are located in an electron cloud surrounding the nucleus.

19.2 Masses of Atoms

MAIN Idea All atoms of the same element have the same number of protons but can have different numbers of neutrons.

19.3 The Periodic Table

MAIN Idea Atoms of elements that are in the same group on the periodic table contain the same number of outer energy level electrons.

Atoms Compose All Things —Great and Small

Everything in this photo and the universe is composed of tiny particles called atoms. You will learn about atoms and their components—protons, neutrons, electrons, and quarks.

Science Journal

In your Science Journal, write a few paragraphs about what you know about atoms.

Walter Bibikow/Index Stock Imagery, NY

Start-Up Activities

Launch LAB

Inferring What You Can't Observe

How do scientists study atoms when they cannot see them? In situations such as these, techniques must be developed to find clues to answer questions. Do the lab below to see how clues might be gathered.

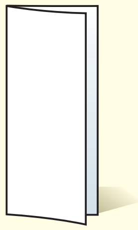
1. Complete the safety form.
2. Take an envelope and several items from your teacher.
3. Place an assortment of items in the envelope and seal it.
4. Trade envelopes with another group.
5. Without opening the envelope, try to figure out the types and number of items that are in the envelope. Record a hypothesis about the contents of the envelope in your Science Journal.
6. After you record your hypothesis, open the envelope and see what is inside.
7. **Think Critically** Describe the contents of your envelope. Was your hypothesis correct?

Science Online — Preview this chapter's content and activities at gpescience.com

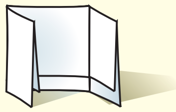
FOLDABLES™ Study Organizer

Atoms You have probably studied atoms before. Make the following Foldable to help identify what you already know, what you want to know, and what you learn about atoms.

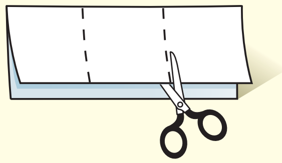
STEP 1 **Fold** a sheet of paper vertically from side to side. Make the front edge about 1.25 cm shorter than the back edge.



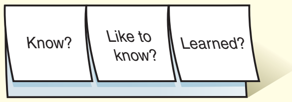
STEP 2 **Turn** lengthwise and **fold** into thirds.



STEP 3 **Unfold and cut** only the top layer along both folds to make three tabs.



STEP 4 **Label** each tab as shown.



Identify Questions Before you read the chapter, write what you already know about atoms under the left tab of your Foldable, and write questions about what you'd like to know under the center tab. After you read the chapter, list what you learned under the right tab.

Walter Bibikow/Index Stock Imagery, NY

section 1

Structure of the Atom

Reading Guide

What You'll Learn

- **Identify** the names and symbols of common elements.
- **Identify** quarks as subatomic particles of matter.
- **Describe** the electron cloud model of the atom.
- **Explain** how electrons are arranged in an atom.

Why It's Important

Everything that you see, touch, and breathe is composed of tiny atoms.

Review Vocabulary

element: substance with atoms that are all alike

New Vocabulary

- atom
- nucleus
- proton
- neutron
- electron
- quark
- electron cloud

Scientific Shorthand

Do you have a nickname? Do you use abbreviations for long words or the names of states? Scientists also do this. In fact, scientists have developed their own shorthand for dealing with long, complicated names.

Do the letters C, Al, Ne, and Ag mean anything to you? Each letter or pair of letters is a chemical symbol, which is a short or abbreviated way to write the name of an element. Chemical symbols, such as those in **Table 1,** consist of one capital letter or a capital letter plus one or two lowercase letters. For some elements, the symbol is the first letter of the element's name. For other elements, the symbol is the first letter of the name plus another letter from its name. Some symbols are derived from Latin. For instance, *argentum* is Latin for "silver." Elements have been named in a variety of ways. Some elements are named to honor scientists, for places, or for their properties. Other elements are named using rules established by an international committee. Regardless of the origin of the names, scientists derived this international system for convenience. It is much easier to write H for hydrogen, O for oxygen, and H_2O for dihydrogen oxide (water) than to write out the names. Because scientists worldwide use this system, everyone understands what the symbols mean.

Table 1 Symbols of Some Elements

Element	Symbol	Element	Symbol
Aluminum	Al	Iron	Fe
Calcium	Ca	Mercury	Hg
Carbon	C	Nitrogen	N
Chlorine	Cl	Oxygen	O
Gold	Au	Potassium	K
Hydrogen	H	Sodium	Na

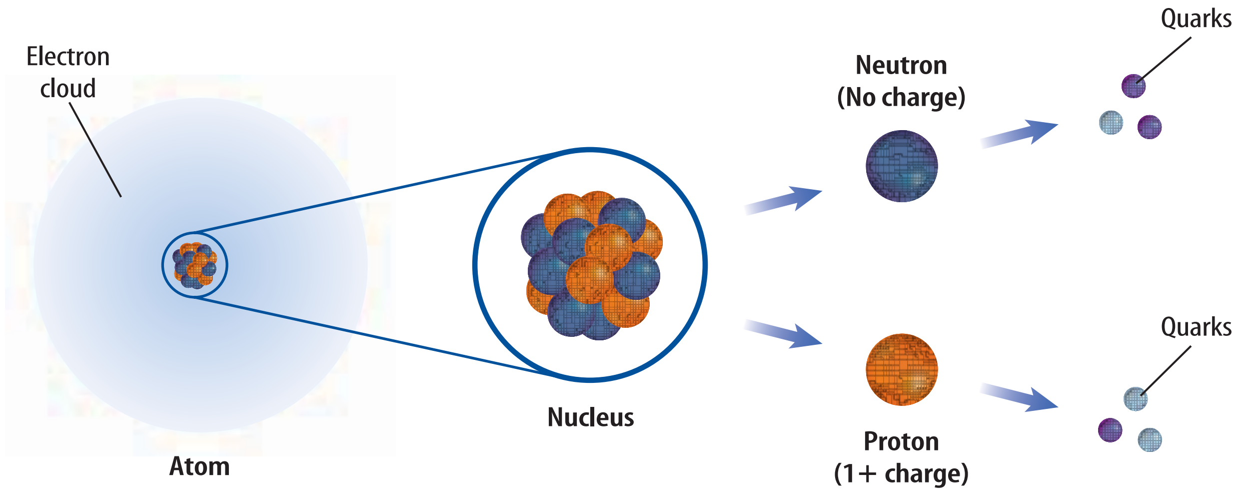


Figure 1 The nucleus of the atom contains protons and neutrons that are composed of quarks. The proton has a positive charge and the neutron has no charge. A cloud of negatively charged electrons surrounds the nucleus of the atom.
Explain *how atoms of different elements differ.*

Atomic Components

An element is matter that is composed of one type of **atom,** which is the smallest piece of matter that still retains the property of the element. For example, the element silver is composed of only silver atoms, and the element hydrogen is composed of only hydrogen atoms. Atoms are composed of particles called protons, neutrons, and electrons, as shown in **Figure 1.** Protons and neutrons are found in a small, positively-charged center of the atom called the **nucleus,** which is surrounded by a cloud containing electrons. **Protons** are particles with an electrical charge of 1+. **Neutrons** are neutral particles that do not have an electrical charge. **Electrons** are particles with an electrical charge of 1−. Atoms of different elements differ in the number of protons they contain.

Reading Check *What are the particles that make up the atom and where are they located?*

Quarks: Even Smaller Particles

Are the protons, electrons, and neutrons that make up atoms the smallest particles that exist? Scientists hypothesize that electrons are not composed of smaller particles and are one of the most basic types of particles. Protons and neutrons, however, are made up of smaller particles called **quarks.** So far, scientists have confirmed the existence of six uniquely different quarks. Scientists theorize that an arrangement of three quarks held together with the strong nuclear force produces a proton. Another arrangement of three quarks produces a neutron. The search for the composition of protons and neutrons is an ongoing effort.

Science Online
Topic: Particle Research
Visit gpescience.com for Web links to information about particle research at Fermi National Accelerator Laboratory.

Activity Write a paragraph describing the information that you found at the site.

Figure 2 The Tevatron is a huge machine. The aerial photograph of Fermi National Accelerator Laboratory shows the circular outline of the Tevatron particle accelerator. The close-up photograph of the Tevatron gives you a better view of the tunnel.
Infer *Why is such a long tunnel needed?*

Finding Quarks To study quarks, scientists accelerate charged particles to tremendous speeds and then force them to collide with—or smash into—protons. This collision causes the proton to break apart. The Fermi National Accelerator Laboratory, a research laboratory in Batavia, Illinois, houses a machine that can generate the forces that are required to make protons collide. This machine, the Tevatron, shown in **Figure 2,** is approximately 6.4 km in circumference. Electric and magnetic fields are used to accelerate, focus, and make the fast-moving particles collide.

The particles that result from the collision can be detected by various collection devices. Often, scientists use multiple collection devices to collect the greatest possible amount of information about the particles created in a collision. Just as police investigators can reconstruct traffic accidents from tire marks and other clues at the scene, scientists are able to examine and gather information about the particles, as shown in **Figure 3.** Scientists use inferences to identify the subatomic particles and to discover information about each particle's inner structure.

Figure 3 Bubble chambers can be used by scientists to study the tracks left by subatomic particles.

The Sixth Quark Finding evidence for the existence of quarks was not an easy task. Scientists found five quarks and hypothesized that a sixth quark existed. However, it took a team of nearly 450 scientists from around the world several years to find the sixth quark. The tracks of the sixth quark were hard to detect because only about one-billionth of a percent of the proton collisions performed showed the presence of a sixth quark, typically referred to as the *top* quark.

Models—Tools for Scientists

Scientists and engineers use models to represent things that are difficult to visualize or picture in the mind. You might have seen models of buildings, the solar system, or airplanes. These are scaled-down models. Scaled-down models allow you to see either something too large to see all at once or something that has not been built yet. Scaled-up models are often used to visualize things that are too small to see. To give you an idea of how small the atom is, it would take about 24,400 atoms stacked one on top of the other to equal the thickness of a sheet of aluminum foil. To study the atom, scientists have developed scaled-up models that they can use to visualize how the atom is constructed. For the model to be useful, it must support all of the information that is known about matter and the behavior of atoms. As more information about the atom is collected, scientists change their models to include the new information.

Reading Check *Explain how models can simplify science.*

The Changing Atomic Model You know now that all matter is composed of atoms, but this was not always known. Around 400 B.C., Democritus proposed the idea that atoms make up all substances. However, another famous Greek philosopher, Aristotle, disputed Democritus's theory and proposed that matter is uniform throughout and is not composed of smaller particles. Aristotle's incorrect theory was accepted for about 2000 years. In the 1800s, John Dalton, an English scientist, was able to offer proof that atoms exist.

Dalton's model of the atom, a solid sphere shown in **Figure 4,** was an early model of the atom. As you can see in **Figure 5,** the model has changed somewhat over time. Dalton's modernization of Aristotle's idea of the atom provided a physical explanation for chemical reactions. Scientists could then express these reactions in quantitative terms using chemical symbols and equations.

Mini LAB

Modeling an Aluminum Atom

Procedure

1. Complete the safety form.
2. Arrange thirteen 3-cm circles cut from **orange paper** and fourteen 3-cm circles cut from **blue paper** on a **flat surface** to represent the nucleus of an atom. Each orange circle represents one proton, and each blue circle represents one neutron.
3. Position two holes punched from **red paper** about 20 cm from your nucleus.
4. Position eight punched holes about 40 cm from your nucleus.
5. Position three punched holes about 60 cm from your nucleus.

Analysis

1. How many protons, neutrons, and electrons does an aluminum atom have?
2. Explain how your circles model an aluminum atom.
3. Explain why your model does not accurately represent the true size and distances in an aluminum atom.

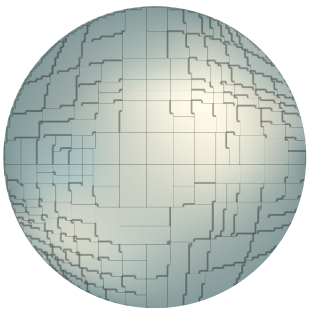
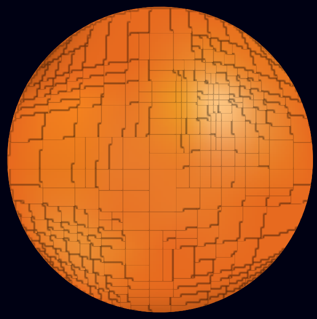


Figure 4 John Dalton's atomic model was a simple sphere.

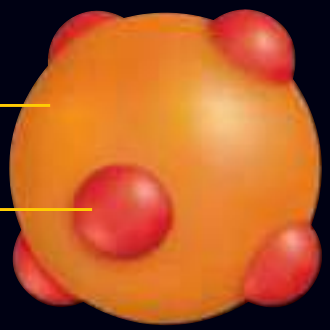
NATIONAL GEOGRAPHIC VISUALIZING THE ATOMIC MODEL

Figure 5

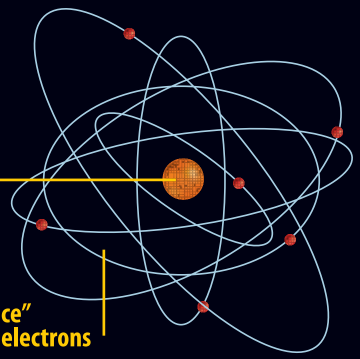
The ancient Greek philosopher Democritus proposed that elements consist of tiny, solid particles that cannot be subdivided (A). He called these particles *atomos,* meaning "uncuttable." This concept of the atom's structure remained largely unchallenged until the 1900s, when researchers began to discover through experiments that atoms are composed of still smaller particles. In the early 1900s, a number of models for atomic structure were proposed (B-D). The currently accepted model (E) evolved from these ideas and the work of many other scientists.



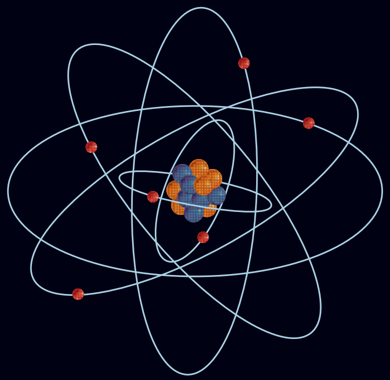
A DEMOCRITUS'S UNCUTTABLE ATOM



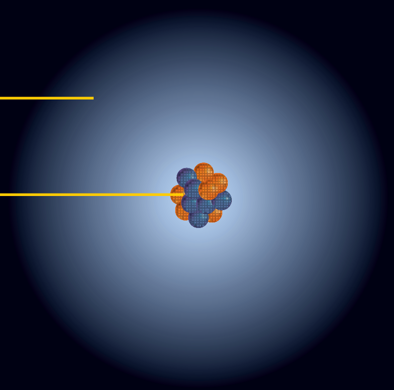
B THOMSON MODEL, 1904 English physicist Joseph John Thomson inferred from his experiments that atoms contain small, negatively charged particles. He thought these "electrons" (in red) were evenly embedded throughout a positively charged sphere, much like chocolate chips in a ball of cookie dough.



C RUTHERFORD MODEL, 1911 Another British physicist, Ernest Rutherford, proposed that almost all the mass of an atom—and all its positive charges—is concentrated in a central atomic nucleus surrounded by electrons.



D BOHR MODEL, 1913 Danish physicist Niels Bohr hypothesized that electrons travel in fixed orbits around the atom's nucleus. James Chadwick, a student of Rutherford, concluded that the nucleus contains positive protons and neutral neutrons.



E ELECTRON CLOUD MODEL, CURRENT According to the currently accepted model of atomic structure, electrons do not follow fixed orbits but tend to occur more frequently in certain areas around the nucleus at any given time.

The Electron Cloud Model By 1926, scientists had developed the electron cloud model of the atom that is in use today. An **electron cloud** is the area around the nucleus of an atom where its electrons are most likely found. The electron cloud is 100,000 times larger than the diameter of the nucleus. In contrast, each electron in the cloud is much smaller than a single proton.

Because an electron's mass is small and the electron is moving so quickly around the nucleus, it is impossible to describe its exact location in an atom. Picture the spokes on a moving bicycle wheel. They are moving so quickly that you can't pinpoint any single spoke. All you see is a blur that contains all of the spokes somewhere within it. In the same way, an electron cloud is a blur containing all of the electrons of the atom somewhere within it. **Figure 6** illustrates what the electron cloud might look like.

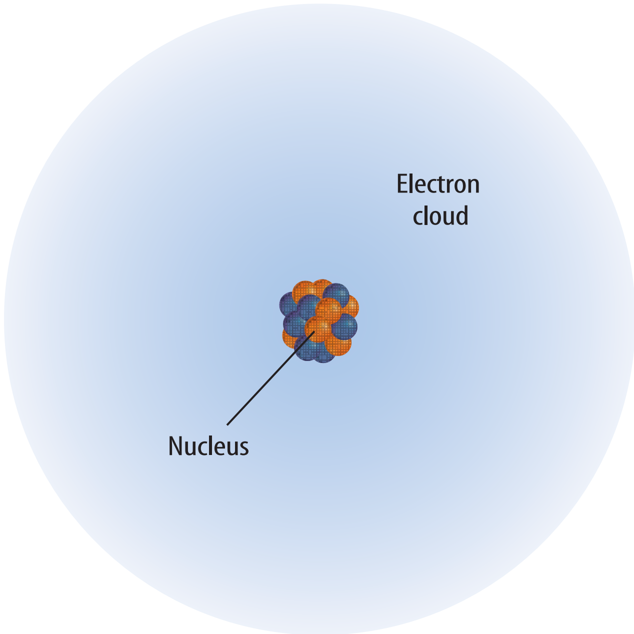


Figure 6 The electrons are located in an electron cloud surrounding the nucleus of the atom.

section 1 review

Summary

Scientific Shorthand

- Scientists use chemical symbols as shorthand when writing the names of elements.

Atomic Components

- Atoms are composed of small particles that have known charges.
- Atoms of different elements differ in the number of protons they contain.

Quarks: Even Smaller Particles

- So far, scientists have confirmed the existence of six different quarks.

Models: Tools for Scientists

- Models are used by scientists to simplify the study of concepts and things.
- The current atomic model is an accumulation of over 200 years of knowledge.
- The electron cloud model is the current atomic model.

Self Check

1. **List** the chemical symbols for the elements carbon, aluminum, hydrogen, oxygen, and sodium.
2. **Identify** the names, charges, and locations of three kinds of particles that make up an atom.
3. **Identify** the smallest particle of matter. How were these particles discovered?
4. **Describe** the electron cloud model of the atom.
5. **Think Critically** Explain how a rotating electric fan might be used to model the atom. Explain how the rotating fan is unlike an atom.

Applying Math

6. **Use Numbers** The mass of a proton is estimated to be 1.6726×10^{-24} g, and the mass of an electron is estimated to be 9.1093×10^{-28} g. How many times larger is the mass of a proton than the mass of an electron?
7. **Calculate** What is the difference between the mass of a proton and the mass of an electron?

section 2

Masses of Atoms

Reading Guide

What You'll Learn

- **Compute** the atomic mass and mass number of an atom.
- **Identify** the components of isotopes.
- **Interpret** the average atomic mass of an element.

Why It's Important

Some elements naturally exist in more than one form—radioactive and nonradioactive.

Review Vocabulary

mass: amount of matter in an object

New Vocabulary

- atomic number
- mass number
- isotope
- average atomic mass

Atomic Mass

The nucleus contains most of the mass of an atom because protons and neutrons are far more massive than electrons. The mass of a proton is about the same as that of a neutron—approximately 1.6726×10^{-24} g, as shown in **Table 2.** The mass of each is approximately 1,836 times greater than the mass of an electron. An electron's mass is so small that it is considered negligible when finding the mass of an atom.

Table 2 Subatomic Particle Masses

Particle	Mass (g)
Proton	1.6726×10^{-24}
Neutron	1.6749×10^{-24}
Electron	9.1093×10^{-28}

If you were asked to estimate the height of your school building, you probably wouldn't give an answer in kilometers. The number would be too cumbersome to use. Considering the scale of the building, you would more likely give the height in a smaller unit, meters. When thinking about the small masses of atoms, scientists found that even grams were not small enough to use for measurement. Scientists need a unit that results in more manageable numbers. The unit of measurement used for atomic particles is the atomic mass unit (amu). The mass of a proton or a neutron is almost equal to 1 amu. This is not coincidence: the unit was defined that way. The atomic mass unit is defined as one-twelfth the mass of a carbon atom containing six protons and six neutrons. Remember that the mass of the carbon atom is contained almost entirely in the mass of the protons and neutrons that are located in the nucleus. Therefore, each of the 12 particles in the nucleus must have a mass nearly equal to 1 amu.

Reading Check *Where is the majority of the mass of an atom located?*

Table 3 Mass Numbers of Some Atoms

Element	Symbol	Atomic Number	Protons	Neutrons	Mass Number	Average Atomic Mass*
Boron	B	5	5	6	11	10.81 amu
Carbon	C	6	6	6	12	12.01 amu
Oxygen	O	8	8	8	16	16.00 amu
Sodium	Na	11	11	12	23	22.99 amu
Copper	Cu	29	29	34	63	63.55 amu

*The atomic mass units are rounded to two decimal places.

Protons Identify an Element You learned earlier that atoms of different elements are different because they have different numbers of protons. In fact, the number of protons tells you what type of atom you have and vice versa. For example, every carbon atom has six protons. Also, all atoms with six protons are carbon atoms. Atoms with eight protons are oxygen atoms. The number of protons in an atom is equal to a number called the **atomic number.** The atomic number of carbon is 6. Therefore, if you are given any one of the following—the name of the element, the number of protons in the element, or the atomic number of the element—you can determine the other two.

Reading Check *Which element is an atom with six protons in the nucleus?*

Mass Number The **mass number** of an atom is the sum of the number of protons and the number of neutrons in the nucleus of the atom. Look at **Table 3** to see that this is true.

If you know the mass number and the atomic number of an atom, you can calculate the number of neutrons. The number of neutrons is equal to the atomic number subtracted from the mass number.

$$\text{number of neutrons} = \text{mass number} - \text{atomic number}$$

Atoms of the same element with different numbers of neutrons can have different properties. For example, carbon with a mass number equal to 12, or carbon-12, is the most common form of carbon. Carbon-14 is present on Earth in much smaller quantities. Carbon-14 is radioactive, while carbon-12 is not.

INTEGRATE Life Science

Carbon Dating Living organisms on Earth contain carbon. Carbon-12 makes up 99 percent of this carbon. Carbon-13 and carbon-14 make up the other one percent. Which isotopes are archaeologists most interested in when they determine the age of carbon-containing remains? Explain your answer in your Science Journal.

Isotopes

Not all the atoms of an element have the same number of neutrons. Atoms of the same element that have different numbers of neutrons are called **isotopes.** Suppose you have a sample of the element boron. Naturally occurring atoms of boron have mass numbers of 10 or 11. How many neutrons are in a boron atom? It depends upon the isotope of boron to which you are referring. Obtain the number of protons in boron from the periodic table. Then use the formula on the previous page to calculate the number of neutrons in each boron isotope. You can determine that boron can have five or six neutrons.

Reading Check ***Uranium-238 has 92 protons. How many neutrons does it have?***

Applying Science

How can radioactive isotopes help tell time?

Atoms can be used to measure the age of bones or rock formations that are millions of years old. The time it takes for half of the radioactive atoms in a piece of rock or bone to change into another element is called its half-life. Scientists use the half-lives of radioactive isotopes to measure geologic time.

Half-Lives of Radioactive Isotopes

Radioactive Element	Changes to This Element	Half-Life
Uranium-238	lead-206	4,460 million years
Potassium-40	argon-40, calcium-40	1,260 million years
Rubidium-87	strontium-87	48,800 million years
Carbon-14	nitrogen-14	5,715 years

Identifying the Problem

The table above lists the half-lives of some radioactive isotopes and into which elements they change. For example, it would take 5,715 years for half of the carbon-14 atoms in a rock to change into atoms of nitrogen-14. After another 5,715 years, half of the remaining carbon-14 atoms will change, and so on. You can use these radioactive clocks to measure different periods of time.

Solving the Problem

1. How many years would it take half of the rubidium-87 atoms in a piece of rock to change into strontium-87? How many years would it take for 75 percent of the atoms to change?
2. After a long period, only 25 percent of the atoms in a rock remained uranium-238. How many years old would you predict the rock to be? The other 75 percent of the atoms are now which radioactive element?

Identifying Isotopes Models of two isotopes of boron are shown in **Figure 7.** Because the numbers of neutrons in the isotopes are different, the mass numbers are also different. You use the name of the element followed by the mass number of the isotope to identify each isotope: boron-10 and boron-11. Because most elements have more than one isotope, each element has an average atomic mass. The **average atomic mass** of an element is the weighted-average mass of the mixture of its isotopes. For example, four out of five atoms of boron are boron-11, and one out of five is boron-10. To find the weighted-average, or the average atomic mass of boron, you would use the following equation:

$$\frac{4}{5}(11 \text{ amu}) + \frac{1}{5}(10 \text{ amu}) = 10.8 \text{ amu}$$

The average atomic mass of the element boron is 10.8 amu. Note that the average atomic mass of boron is close to the mass of its most abundant isotope, boron-11.

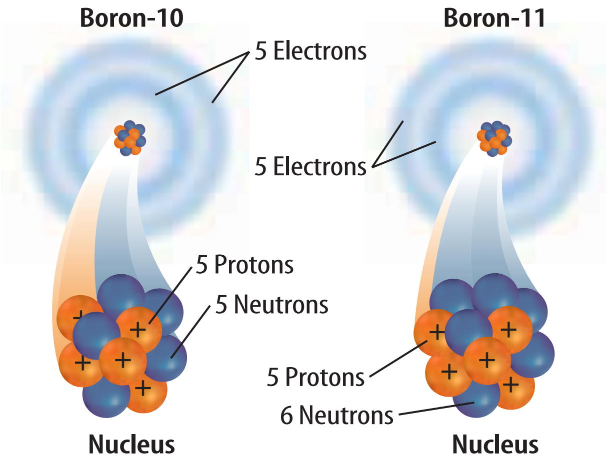


Figure 7 Boron-10 and boron-11 are two isotopes of boron. These two isotopes differ by one neutron.
Explain *why these atoms are isotopes.*

section 2 review

Summary

Atomic Mass

- The nucleus contains most of the mass of an atom.
- The masses of a proton and neutron are approximately equal.
- The mass of an electron is considered negligible when finding the mass of an atom.
- The unit of measurement for atomic particles is the atomic mass unit (amu).
- The carbon-12 isotope was used to define the atomic mass unit.
- The number of protons identifies an element.

Isotopes

- Atoms of the same element with different numbers of neutrons are called isotopes.
- The average atomic mass of an element is the weighted-average mass of the mixture of isotopes.

Self Check

1. **Identify** the mass number and atomic number of a chlorine atom that has 17 protons and 18 neutrons.
2. **Explain** how the isotopes of an element are alike and how are they different.
3. **Explain** why the atomic mass of an element is an average mass.
4. **Explain** how you would calculate the number of neutrons in potassium-40.
5. **Think Critically** Chlorine has an average atomic mass of 35.45 amu. The two naturally occurring isotopes of chlorine are chlorine-35 and chlorine-37. Why does this indicate that most chlorine atoms contain 18 neutrons?

Applying Math

6. **Use Numbers** If a hydrogen atom has two neutrons and one proton, what is its mass number?
7. **Use Tables** Use the information in **Table 2** to find the mass in kilograms of each subatomic particle.

section 3

The Periodic Table

Reading Guide

What You'll Learn

- **Explain** the composition of the periodic table.
- **Use** the periodic table to obtain information.
- **Explain** what the terms *metal, nonmetal,* and *metalloid* mean.

Why It's Important

The periodic table is an organized list of the elements that compose all living and nonliving things known to exist in the universe.

Review Vocabulary

chemical property: any characteristic of a substance that indicates whether it can undergo a certain chemical change

New Vocabulary

- periodic table
- group
- electron dot diagram
- period

Organizing the Elements

On a clear evening, you can see one of the various phases of the Moon. Each month, the Moon seems to grow larger, then smaller, in a repeating pattern. This type of change is periodic. *Periodic* means "repeated in a pattern." The days of the week are periodic because they repeat themselves every seven days. The calendar is a periodic table of days and months.

Figure 8 Mendeleev discovered that the elements have a periodic pattern in their chemical properties.

In the late 1800s, Dmitri Mendeleev, a Russian chemist, searched for a way to organize the elements. When he arranged all the elements known at that time in order of increasing atomic masses, he discovered a pattern. **Figure 8** shows Mendeleev's early periodic chart. Chemical properties found in lighter elements could be shown to repeat in heavier elements. Because the pattern repeated, it was considered to be periodic. Today, this arrangement is called the periodic table of elements. In the **periodic table,** the elements are arranged by increasing atomic number and by changes in physical and chemical properties.

Table 4 Mendeleev's Predictions

Predicted Properties of Ekasilicon (Es)	Actual Properties of Germanium (Ge)
Existence Predicted: 1871	*Actual Discovery: 1886*
Atomic mass = 72	Atomic mass = 72.61
High melting point	Melting point = 938°C
Density = 5.5 g/cm^3	Density = 5.323 g/cm^3
Dark gray metal	Gray metal
Density of EsO_2 = 4.7 g/cm^3	Density of GeO_2 = 4.23 g/cm^3

Mendeleev's Predictions Mendeleev had to leave blank spaces in his periodic table to keep the elements properly lined up according to their chemical properties. He looked at the properties and atomic masses of the elements surrounding these blank spaces. From this information, he was able to predict the properties and the mass numbers of new elements that had not yet been discovered. **Table 4** shows Mendeleev's predicted properties for germanium, which he called ekasilicon. His predictions proved to be accurate. Scientists later discovered these missing elements and found that their properties were extremely close to what Mendeleev had predicted.

Reading Check *How did Mendeleev organize his periodic table?*

Improving the Periodic Table Although Mendeleev's arrangement of elements was successful, it did need some changes. On Mendeleev's table, the atomic mass gradually increased from left to right. If you look at the modern periodic table, shown in **Table 5,** you will see several examples, such as cobalt and nickel, in which the mass decreases from left to right. You also might notice that the atomic number always increases from left to right. In 1913, the work of Henry G. J. Moseley, a young English scientist, led to the arrangement of elements based on their increasing atomic numbers instead of an arrangement based on atomic masses. This new arrangement seemed to correct the problems that had occurred in the old table. The current periodic table uses Moseley's arrangement of the elements.

Reading Check *How is the modern periodic table arranged?*

Mini LAB

Organizing a Personal Periodic Table

Procedure

1. Complete the safety form.
2. Collect as many of the following items as you can find: **feather, penny, container of water, pencil, dime, strand of hair, container of milk, container of orange juice, square of cotton cloth, nickel, crayon, quarter, container of soda, golf ball, sheet of paper, baseball, marble, leaf, paper clip.**
3. Organize these items into several columns based on their similarities to create your own periodic table.

Analysis

1. Explain the system you used to group your items.
2. Were there any items on the list that did not fit into any of your columns?
3. Infer how your activity modeled Mendeleev's work in developing the periodic table of the elements.

Try at Home

Table 5 Periodic Table of the Elements

Columns of elements are called groups. Elements in the same group have similar chemical properties.

Element — Hydrogen
Atomic number — 1
Symbol — H
Atomic mass — 1.008
State of matter

Gas
Liquid
Solid
Synthetic

The first three symbols tell you the state of matter of the element at room temperature. The fourth symbol identifies elements that are not present in significant amounts on Earth. Useful amounts are made synthetically.

Period	1	2	3	4	5	6	7	8	9
1	Hydrogen 1 H 1.008								
2	Lithium 3 Li 6.941	Beryllium 4 Be 9.012							
3	Sodium 11 Na 22.990	Magnesium 12 Mg 24.305							
4	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
5	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 102.906
6	Cesium 55 Cs 132.905	Barium 56 Ba 137.327	Lanthanum 57 La 138.906	Hafnium 72 Hf 178.49	Tantalum 73 Ta 180.948	Tungsten 74 W 183.84	Rhenium 75 Re 186.207	Osmium 76 Os 190.23	Iridium 77 Ir 192.217
7	Francium 87 Fr (223)	Radium 88 Ra (226)	Actinium 89 Ac (227)	Rutherfordium 104 Rf (261)	Dubnium 105 Db (262)	Seaborgium 106 Sg (266)	Bohrium 107 Bh (264)	Hassium 108 Hs (277)	Meitnerium 109 Mt (268)

The number in parentheses is the mass number of the longest-lived isotope for that element.

Rows of elements are called periods. Atomic number increases across a period.

The arrow shows where these elements would fit into the periodic table. They are moved to the bottom of the table to save space.

Lanthanide series	Cerium 58 Ce 140.116	Praseodymium 59 Pr 140.908	Neodymium 60 Nd 144.24	Promethium 61 Pm (145)	Samarium 62 Sm 150.36
Actinide series	Thorium 90 Th 232.038	Protactinium 91 Pa 231.036	Uranium 92 U 238.029	Neptunium 93 Np (237)	Plutonium 94 Pu (244)

Metal

Metalloid

Nonmetal

The color of an element's block tells you if the element is a metal, nonmetal, or metalloid.

Science Online

Topic: Periodic Table Updates

Visit **gpescience.com** for updates to the periodic table.

10	11	12	13	14	15	16	17	18
								Helium 2 **He** 4.003
			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
			Aluminum 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
Nickel 28 **Ni** 58.693	Copper 29 **Cu** 63.546	Zinc 30 **Zn** 65.409	Gallium 31 **Ga** 69.723	Germanium 32 **Ge** 72.64	Arsenic 33 **As** 74.922	Selenium 34 **Se** 78.96	Bromine 35 **Br** 79.904	Krypton 36 **Kr** 83.798
Palladium 46 **Pd** 106.42	Silver 47 **Ag** 107.868	Cadmium 48 **Cd** 112.411	Indium 49 **In** 114.818	Tin 50 **Sn** 118.710	Antimony 51 **Sb** 121.760	Tellurium 52 **Te** 127.60	Iodine 53 **I** 126.904	Xenon 54 **Xe** 131.293
Platinum 78 **Pt** 195.078	Gold 79 **Au** 196.967	Mercury 80 **Hg** 200.59	Thallium 81 **Tl** 204.383	Lead 82 **Pb** 207.2	Bismuth 83 **Bi** 208.980	Polonium 84 **Po** (209)	Astatine 85 **At** (210)	Radon 86 **Rn** (222)
Darmstadtium 110 **Ds** (281)	Roentgenium 111 **Rg** (272)	Ununbium * 112 **Uub** (285)		Ununquadium * 114 **Uuq** (289)				

* The names and symbols for elements 112 and 114 are temporary. Final names will be selected when the elements' discoveries are verified.

Europium 63 **Eu** 151.964	Gadolinium 64 **Gd** 157.25	Terbium 65 **Tb** 158.925	Dysprosium 66 **Dy** 162.500	Holmium 67 **Ho** 164.930	Erbium 68 **Er** 167.259	Thulium 69 **Tm** 168.934	Ytterbium 70 **Yb** 173.04	Lutetium 71 **Lu** 174.967
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)	Lawrencium 103 **Lr** (262)

INTEGRATE Career

Research Physicist The study of nuclear interactions is shared by chemists and physicists. Research physicists use their knowledge of the physical laws of nature to explain the behavior of the atom and its composition. Explain in your Science Journal why physicists would study the amount of energy that electrons contain.

The Atom and the Periodic Table

Objects often are sorted or classified according to the properties they have in common. This also is done in the periodic table. The vertical columns in the periodic table are called **groups**, or families, and are numbered 1 through 18. Elements in each group have similar properties. For example, in Group 11, copper, silver, and gold have similar properties. Each is a shiny metal and a good conductor of electricity and heat. What is responsible for the similar properties? To answer this question, look at the structure of the atom.

Electron Cloud Structure You have learned about the number and location of protons and neutrons in an atom. But where are the electrons located? How many are there? In a neutral atom, the number of electrons is equal to the number of protons. Therefore, a carbon atom, with an atomic number of 6, has six protons and six electrons. These electrons are located in the electron cloud surrounding the nucleus.

Scientists have found that electrons within the electron cloud have different amounts of energy. Scientists model the energy differences of the electrons by placing the electrons in energy levels, as in **Figure 9.** Energy levels nearer the nucleus have lower energy than those levels that are farther away. Electrons fill these energy levels from the inner levels (closer to the nucleus) to the outer levels (farther from the nucleus).

Elements that are in the same group have the same number of electrons in their outer energy levels. It is the number of electrons in the outer energy level that determines the chemical properties of an element. It is important to understand the link between the location on the periodic table, chemical properties, and the structure of the atom.

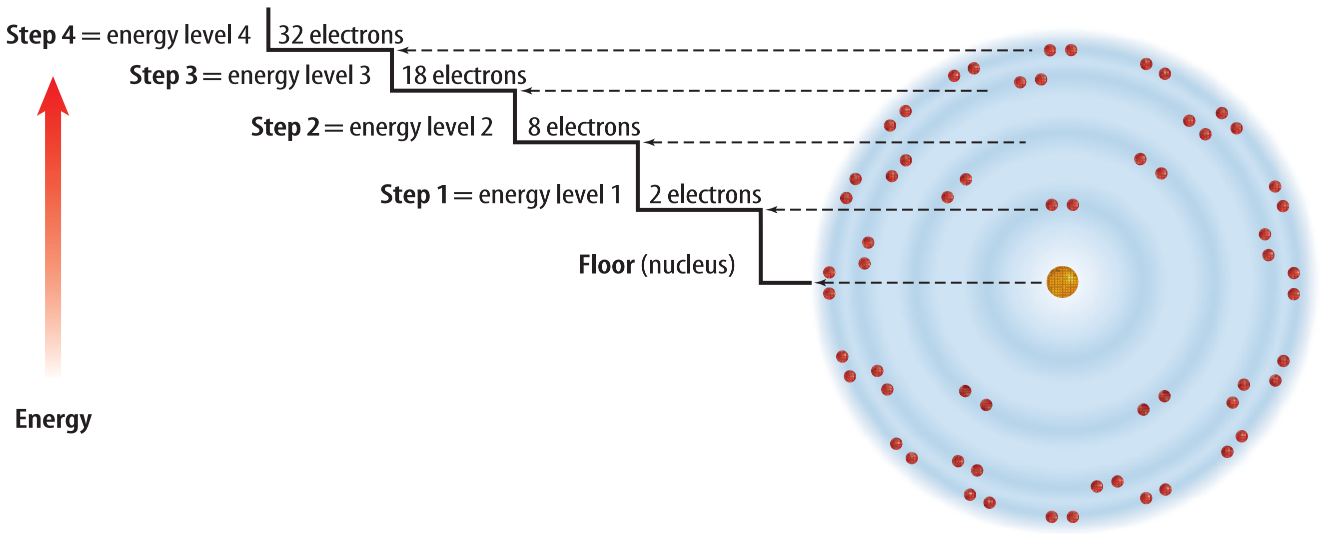


Figure 9 Energy levels in atoms can be represented by a flight of stairs. Each stair step away from the nucleus represents an increase in the amount of energy within the electrons.
Explain *what determines the chemical properties of an element.*

Energy Levels Energy levels are named using the numbers one to seven. The maximum number of electrons that can be contained in each of the first four levels is shown in **Figure 9.** For example, energy level one can contain a maximum of two electrons. Energy level two can contain a maximum of eight electrons. Notice that energy levels three and four contain several electrons. A complete and stable outer energy level will contain eight electrons. In elements in periods three and higher, additional electrons can be added to inner energy levels, although the outer energy level contains only eight electrons.

Rows on the Table Remember that an atomic number found on the periodic table is equal to the number of electrons in an atom. Look at **Figure 10.** The first row has hydrogen with one electron and helium with two electrons both in energy level one. Because energy level one is the outermost level containing an electron, hydrogen has one outer electron. Helium has two outer electrons. Recall from **Figure 9** that energy level one can hold only two electrons. Therefore, helium has a full or complete outer energy level.

The second row begins with lithium, which has three electrons, two in energy level one and one in energy level two. Lithium has one outer electron. Lithium is followed by beryllium, with two outer electrons, boron with three, and so on until you reach neon, with eight outer electrons. Again, looking at **Figure 9,** energy level two can hold only eight electrons. Therefore, neon has a complete outer energy level. Do you notice how the row in the periodic table ends when an outer energy level is filled? In the third row of elements, the electrons begin filling energy level three. The row ends with argon, which has a full outer energy level of eight electrons.

Reading Check ***How many electrons are needed to fill the outer energy level of sulfur?***

Science Online

Topic: Atomic Energy Level Structure

Visit gpescience.com for Web links to information about the structure of atomic energy levels.

Activity Draw a diagram that details how the energy levels are structured.

Figure 10 One proton and one electron are added to each element as you go across a period in the periodic table.
Explain *what the elements in the last column share in relation to their outer energy levels.*

Hydrogen 1 **H**							Helium 2 **He**
Lithium 3 **Li**	Beryllium 4 **Be**	Boron 5 **B**	Carbon 6 **C**	Nitrogen 7 **N**	Oxygen 8 **O**	Fluorine 9 **F**	Neon 10 **Ne**
Sodium 11 **Na**	Magnesium 12 **Mg**	Aluminum 13 **Al**	Silicon 14 **Si**	Phosphorus 15 **P**	Sulfur 16 **S**	Chlorine 17 **Cl**	Argon 18 **Ar**

Figure 11 The elements in Group 1 have one electron in their outer energy level. This electron dot diagram represents that one electron.
Explain *why the outer electrons of an element are important.*

Electron Dot Diagrams Did you notice that hydrogen, lithium, and sodium each have one electron in their outer energy levels? Elements that are in the same group have the same number of electrons in their outer energy levels. These outer electrons are so important in determining the chemical properties of an element that a special way to represent them has been developed. American chemist G. N. Lewis created this method while teaching a college chemistry class. An **electron dot diagram** uses the symbol of the element and dots to represent the electrons in the outer energy level. **Figure 11** shows the electron dot diagram for Group 1 elements. The electron configuration of an atom determines how that atom reacts with other atoms. Electron dot diagrams also are used to show how the electrons in the outer energy levels are bonded when elements combine to form compounds.

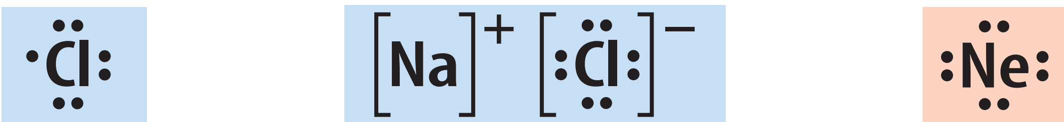
Same Group, Similar Properties The elements in Group 17, the halogens, have electron dot diagrams similar to chlorine, shown in **Figure 12.** All halogens have seven electrons in their outer energy levels. Because all of the members of a group on the periodic table have the same number of electrons in their outer energy levels, group members will undergo chemical reactions in similar ways.

A common property of the halogens is the ability to form compounds readily with elements in Group 1. Group 1 elements each have only one electron in their outer energy levels. **Figure 12** shows an example of a compound formed by one such reaction. The Group 1 element, sodium, reacts easily with the Group 17 element, chlorine. The result is the compound sodium chloride, or NaCl, ordinary table salt.

Not all elements will combine readily with other elements. The elements in Group 18 have complete outer energy levels. This special configuration makes Group 18 elements relatively unreactive. You will learn more about why and how bonds form between elements in later chapters.

Reading Check ***Why do elements in a group undergo similar chemical reactions?***

Figure 12 Electron dot diagrams show the electrons in an element's outer energy level.



The electron dot diagram for Group 17 consists of three sets of paired dots and one single dot.

Sodium combines with chlorine to give each element a complete outer energy level in the resulting compound.

Neon, a member of Group 18, has a full outer energy level. Neon has eight electrons in its outer energy level, making it unreactive.

Regions on the Periodic Table

The periodic table has several regions with specific names. The horizontal rows of elements on the periodic table are called **periods.** The elements increase by one proton and one electron as you go from left to right in a period.

All of the elements in the blue squares in **Figure 13** are metals. Iron, zinc, and copper are examples of metals. Most metals exist as solids at room temperature. They are shiny, can be drawn into wires, can be pounded into sheets, and are good conductors of heat and electricity.

Those elements on the right side of the periodic table, in yellow, are classified as nonmetals. Oxygen, bromine, and carbon are examples of nonmetals. Most nonmetals are gases, are brittle, and are poor conductors of heat and electricity at room temperature. The elements in green are metalloids or semimetals. They have some properties of both metals and nonmetals. Boron and silicon are examples of metalloids.

Reading Check ***What are the properties of the elements located on the left side of the periodic table?***

A Growing Family Scientists around the world are continuing their research into the synthesis of elements. In 1994, scientists at the Heavy-Ion Research Laboratory in Darmstadt, Germany, discovered element 111. As of 1998, only one isotope of element 111 had been found. This isotope had a life span of 0.002 s. In 1996, element 112 was discovered at the same laboratory. As of 1998, only one isotope of element 112 had been found. The life span of this isotope was 0.00048 s. Both of these elements are produced in the laboratory by joining smaller atoms into a single atom. The search for elements with higher atomic numbers continues. Scientists think they have synthesized elements 114 and 116. However, the discovery of these elements has not yet been confirmed.

Science Online

Topic: New Elements
Visit gpescience.com for Web links to information about newly synthesized elements.

Activity Write an article explaining how several new elements were synthesized and who synthesized them.

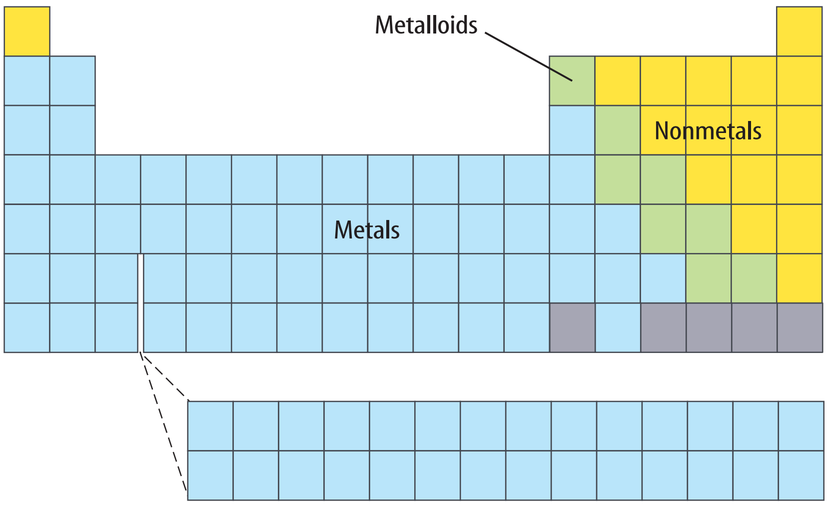


Figure 13 Metalloids are located along the green stair-step line. Metals are located to the left of the metalloids. Nonmetals are located to the right of the metalloids.

Figure 14 Scientists think that some elements are found in nature only within stars.

Elements in the Universe

INTEGRATE Astronomy

Using the technology that is available today, scientists are finding the same elements throughout the universe. They have been able to study only a small portion of the universe because it is so vast. Many scientists believe that hydrogen and helium are the building blocks of other elements. Atoms join together within stars to produce elements with atomic numbers greater than 1 or 2, the atomic numbers of hydrogen and helium. Exploding stars, or supernovas, shown in **Figure 14,** give scientists evidence to support this theory. When stars reach the supernova stage, which is characterized by a massive explosion, a mixture of elements, including the heavy elements such as iron, are flung into the galaxy. Many scientists believe that supernovas have spread the elements that are found throughout the universe. Some of these elements are found only in trace amounts in Earth's crust as a result of uranium decay. Others have been found only in stars.

section 3 review

Summary

Organizing the Elements

- Mendeleev organized the elements using increasing atomic mass and chemical and physical properties.
- Mendeleev left blank spaces in his table to allow for elements that were yet undiscovered.
- Moseley corrected the problems in the periodic table by arranging the elements in order of increasing atomic number.

The Atom and the Periodic Table

- The vertical columns in the periodic table are known as groups or families. Elements in a group have similar properties.
- Electrons within the electron cloud have different amounts of energy.

Regions of the Periodic Table

- The periodic table is divided into these regions: periods, metals, nonmetals, and metalloids.
- Scientists around the world continue to try to synthesize new elements.

Self Check

1. **Identify** Use the periodic table to find the name, atomic number, and average atomic mass of the following elements: N, Ca, Kr, and W.
2. **List** the period and group in which each of these elements is found: nitrogen, sodium, iodine, and mercury.
3. **Classify** each of these elements as a metal, a nonmetal, or a metalloid and give the full name of each: K, Si, Ba, and S.
4. **Think Critically** The Mendeleev and Mosely periodic tables have gaps for the as-then-undiscovered elements. Why do you think the table used by Mosely was more accurate at predicting where new elements would be placed?

Applying Math

5. **Make a Graph** Construct a circle graph showing the percentage of elements classified as metals, metalloids, and nonmetals. Use markers or colored pencils to distinguish clearly between each section on the graph. Record your calculations in your Science Journal.

More Section Review gpescience.com

Interactions Pre-test Unit 1 Part 2 Fall 2017

Question 1

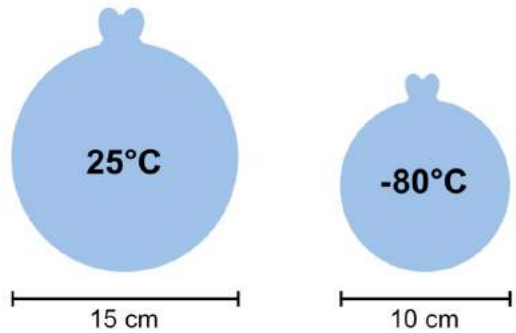
After sugar dissolves in water, the sugar is no longer visible. The mixture tastes sweet, so you know the sugar is still there.
Why can't you see the sugar anymore? Justify your answer.

Questions 2-3
Two students go to play basketball. They notice the ball is flat (it won't bounce). They decide to pump it up with air.
After it is pumped with air, will the ball have more, less, or the same amount of mass as before air was added?

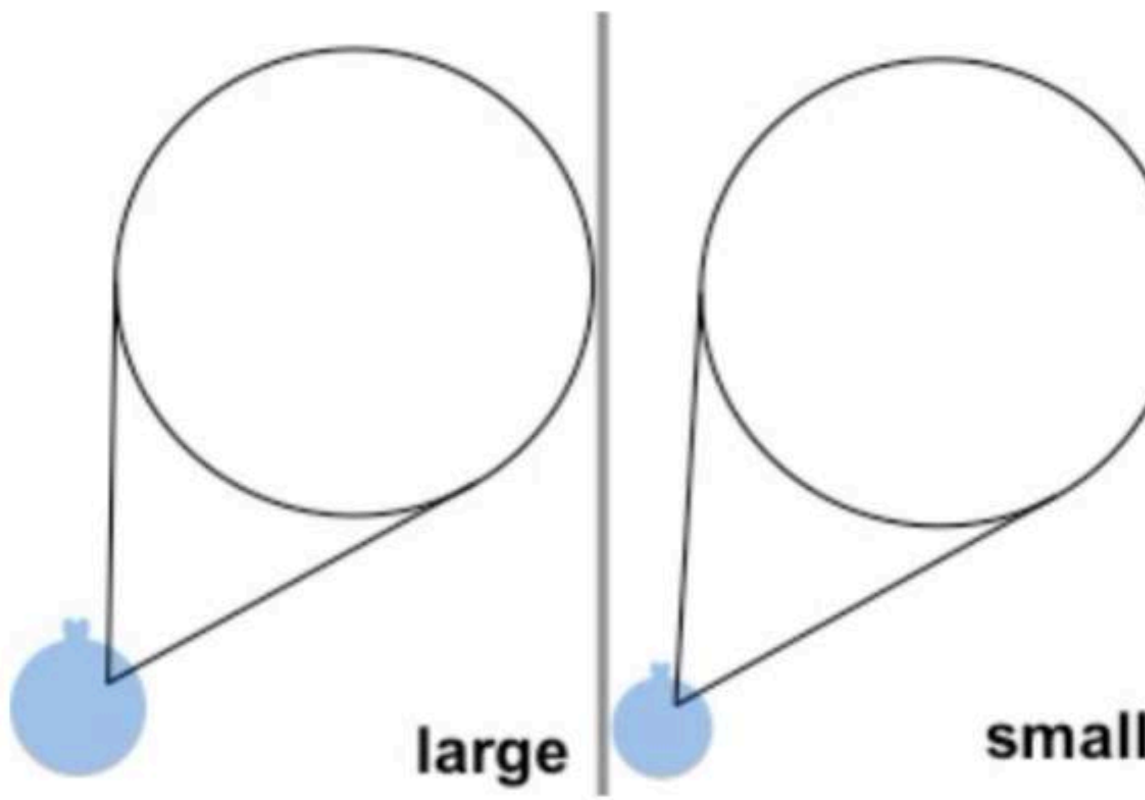
Question 2
Choose the correct statement.
A. The ball has more mass after being pumped with air.
B. The ball has less mass after being pumped with air.
C. The ball has the same amount of mass after being pumped with air.
D. Cannot determine unless we measure the mass.

Question 3
Justify your answer

Question 4
Harry blows up a balloon that is 15 cm in diameter at room temperature (25°C). When he puts it in the deep freezer (-80°C), it shrinks to 10 cm in diameter.



Imagine you had a tool that allows you to zoom in enough to see what air is made of. Draw a model that shows how the air inside the balloon is different when the balloon is large (15 cm) and small (10 cm).

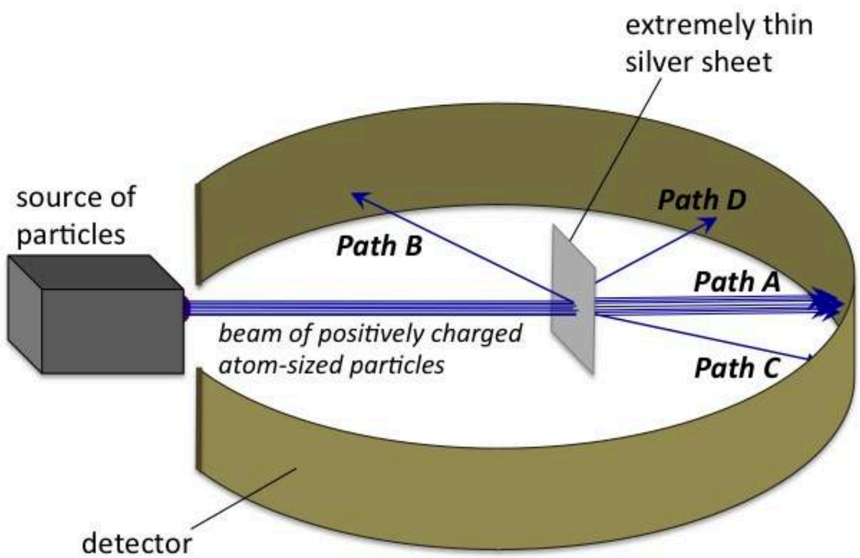


Compare and contrast the air in the large balloon and the small balloon.

Questions 5-7
Tom used the apparatus shown in the diagram to investigate the structure of an atom. Positively charged particles about the size of an atom are shot at a silver sheet much thinner than a sheet of paper.

For every 10,000 positively charged particles shot at the silver sheet,

- 9900 particles went straight through the sheet (Path A)
- 100 particles were deflected.
- 2 particles do not pass through the sheet, but are deflected bounced back (Path B)
- About 98 particles passed through the sheet, but on an angle (Paths C and D)



Question 5
Draw a model of a silver atom that is consistent with Tom's results.

Question 6
Explain why your model is consistent with the observation that almost all the particles went straight through the sheet of foil (followed Path A). Justify your answer.

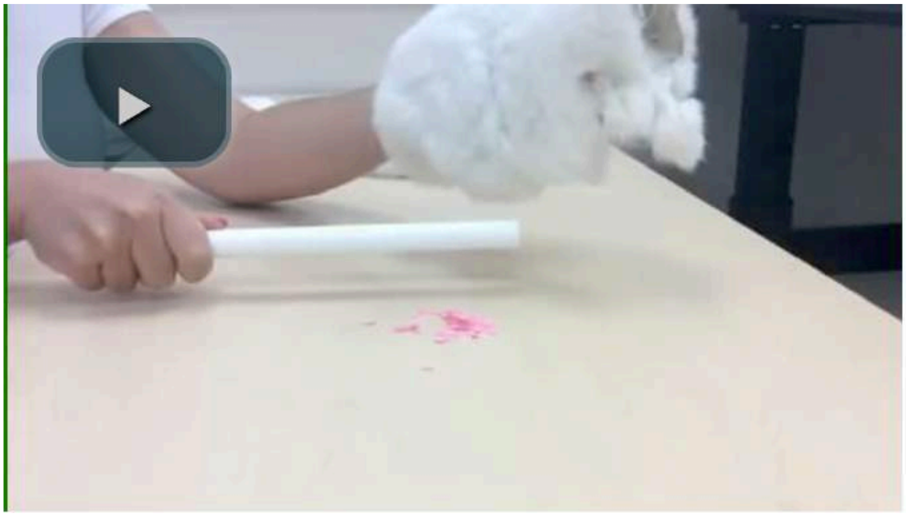
Question 7
Explain why your model is consistent with the observation that relatively few particles were deflected by the sheet of foil (followed Paths B, C, D or similar). Justify your answer.

CREATE for STEM Institute

The Concord Consortium

https://youtu.be/NsxhbgCrrSQ

Watch the video and answer Questions 8–12



Question 8
Why doesn't the paper move toward the rod before the rod is rubbed with fur. Justify your answer.

Question 9

Draw a model that shows what happens to the rod and fur when they are rubbed together. Make sure to label everything in your model.
Describe what happens to the rod and fur during the process of rubbing them together.

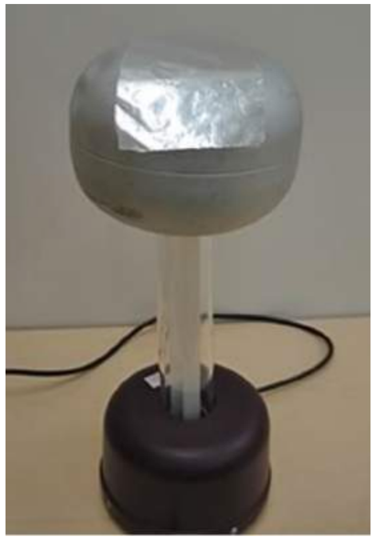
Question 10

Imagine you had an instrument that lets you zoom in enough to see what the paper and rod are made of. Draw a model that shows what happens to the neutral paper to cause it to move towards the charged rod. Make sure to label everything in your model.

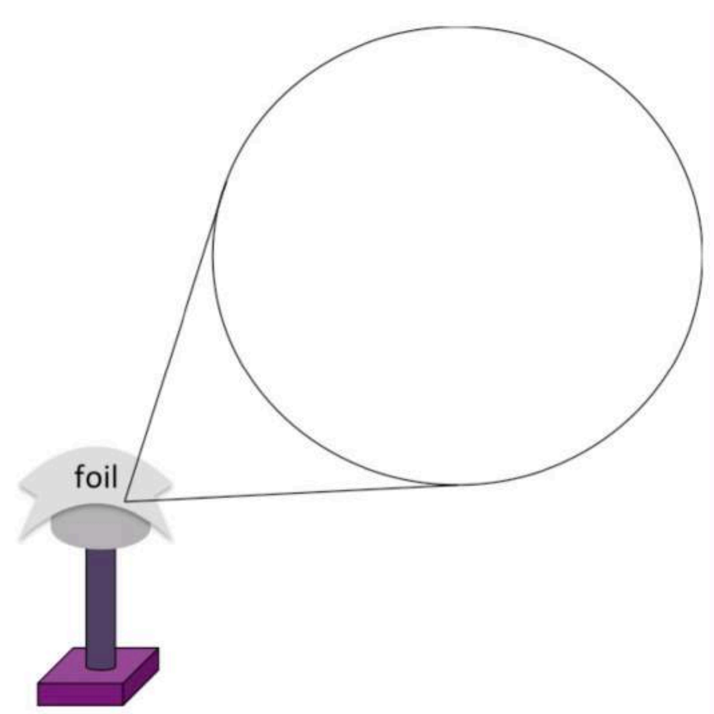
Question 11
What changes occur in the atoms that make up the paper when the charged rod is brought close to the paper? Justify your answer.

Question 12
What would happen if the fur was brought close to the paper after the rod and fur were rubbed together? Justify your answer.

Questions 13-14
A Van de Graaff generator can put a negative charge on a piece of aluminum foil.



Question 13
Imagine you have an instrument that lets you see the aluminum atoms. Draw a model that shows what you would see as the Van de Graaff generator puts a negative charge on the aluminum foil.



Describe the process of the Van de Graaff generator charging the aluminum foil.

Question 14

When the foil is negatively charged, will all the foil still be made up of aluminum atoms? Justify your answer.

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