9.1 Types of Electric Charge

Did You KNOW?

Dangerous Experiments

Franklin was lucky to survive his kite experiment. In fact, some scientists have suggested that Franklin survived because he never actually performed the experiment. Franklin took precautions during his experiment: he flew his kite when the thunderstorm was approaching; his kite was not struck by lightning; and he did not touch the kite's string. Other investigators were not as lucky as Franklin. Some repeated the kite experiment and died when lightning struck the kite.

LEARNING TIP

Check your understanding. Ask yourself questions about the ideas in each paragraph. How did Franklin's kite experiment work? What did he discover?

The effects of static electricity are all around you—from the static cling of clothes coming out of a dryer to the spectacular lightning show during a thunderstorm. If you walk across a carpet and touch a metal doorknob, you may get a shock. The friction of your shoes against the carpet causes you to acquire a static electric charge. A **static charge** is an electric charge at rest. The charge that you acquire as you walk across the carpet is called a static charge because it stays on you until you touch a metal doorknob. When you touch the doorknob, the charge moves from you to the door. Although some objects may keep a static charge for some time, eventually the static charge is **discharged**, or lost, to other objects or to the air. Static charges tend to last longer indoors on winter days when the heated air is very dry. The study of static electric charge is called **electrostatics**.

We cannot see electric charge directly. We can only observe the effects of electric charge. For example, when we see lightning, we are seeing the evidence of static electricity being discharged from the clouds.

Benjamin Franklin demonstrated that lightning is a form of electricity by flying a kite during a thunderstorm. His kite was made of silk and had a pointed wire tip about 30 cm long to draw the "electric fire" from approaching thunderclouds (Figure 1). Franklin flew his kite using a piece of twine tied to the ground. A metal key was tied to the twine by a ribbon of silk. Franklin held the other end of the silk ribbon inside a doorway, out of the rain. As thunderclouds approached, the loose fibres of the twine stood out from each other, and he was able to get a spark on his knuckle from the metal key. As a result of experiments by Franklin and others, it was determined that there are two types of electric charges. These charges are called positive charges and negative charges.

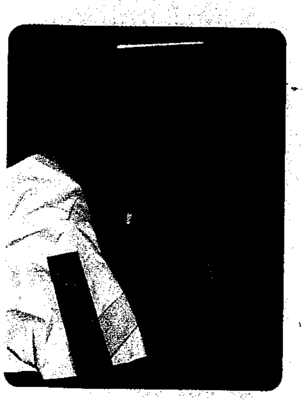
Figure 1 Franklin proved that lightning is an electrical discharge during his kite experiment.

TRY THIS: Positive and Negative Charges

Skills Focus: creating models, observing, hypothesizing, predicting

Handle the pith ball carefully.

You can show that different charges exist by rubbing plastic strips to give the strips a charge, and then watching the effect of the charged strip on a pith ball. Acetate is a clear plastic. Vinyl is a type of coloured plastic that is used for raincoats, electrical tape, vinyl siding, and records.



Materials: pith ball on a thread, stand, acetate strip, paper towels, vinyl strip (Figure 2)

Figure 2

1. Hang a pith ball by a thread tied to a stand.
2. Rub an acetate strip with a paper towel. You can assume that this gives the acetate a positive charge.
3. Bring the acetate strip toward the hanging pith ball. Observe what happens. After the pith ball touches the acetate strip, it will have a positive charge.
4. Rub the acetate strip with a paper towel again, then and bring the strip toward the pith ball. Make a prediction about how objects with similar charges behave. Observe what happens.
5. Rub a vinyl strip with a paper towel and bring it toward the positively charged pith ball. Do not let the strip touch the pith ball. Observe what happens.

A. How do you know that the pith ball has a positive charge?

B. Make a hypothesis to explain your observations. How would you test your hypothesis?

In the Try This activity, you saw that a positively charged hanging pith ball was repelled from a positively charged acetate strip, but was attracted to a charged vinyl strip. This means that the vinyl strip had a different type of charge than the acetate strip; a charged vinyl strip is negative. The activity showed that there are two types of electric charge: positive and negative. We use the + symbol to mean positive and the − symbol to mean negative. An object that has equal amounts of positive charge and negative charge has no overall, or net, charge because the charges cancel each other. An object with no net charge is neutral.

When two objects have the same type of electric charge (like charges), they repel, or push away from, each other. This means that positive repels positive and negative repels negative. However, when two objects have opposite electric charges (unlike charges), they attract each other: positive attracts negative. The **law of electric charges** states that *like charges repel and unlike charges attract.*

Benjamin Franklin imagined that an electric charge was a type of fluid. He believed that every object contained a "natural amount" of the fluid. Objects that contained their natural amount of fluid were neither attracted nor repelled by each other. However, when one object rubbed against another object, one object gained some fluid while the other object lost some fluid, and the objects were attracted to each other. Franklin used the term "positive" to indicate that an object had more than the natural amount of fluid, and "negative" to indicate that an object had less than the natural amount of fluid.

Did You KNOW?

Positive and Negative— Red and Green

Electric charge has two forms, which we now call positive and negative. However, such a naming system is completely arbitrary. The charges could have easily been called red and green. Using the terms "positive" and "negative" makes adding up the total charge easier than trying to blend colours.

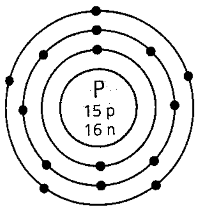


Figure 3 The Bohr diagram for a phosphorous atom

Atomic Structure and Electric Charge

Recall from Chapter 7 that according to modern atomic theory, all matter is made of atoms, and atoms are made of smaller particles (Figure 3). These particles are

protons: have a positive charge and a large mass (about 2000 times larger than an electron)

electrons: have a negative charge and a very tiny mass

neutrons: have no charge and are similar in mass to a proton

Protons and neutrons are in the nucleus of an atom and do not move from the nucleus when an atom becomes charged. Electrons move around the outside of the nucleus and can be more easily added or removed from an atom. If an atom has the same number of protons and electrons, the positive and negative charges cancel each other and the atom is neutral. If an atom does not have the same number of protons and electrons, it has an electric charge. An atom that has an electric charge is called an *ion*. A negative ion is an atom that has picked up extra electrons. A positive ion is an atom that has lost electrons. Although neutrons make up a substantial portion of an atom's mass, they do not make the atom neutral.

Table 1 The Electrostatic Series

Increasing tendency to gain electrons (↑) / Increasing tendency to lose electrons (↓)

plastic wrap
hard rubber
ebonite
vinyl
sulfur
rubber balloon
polyethylene
amber
sealing wax
Lucite
wood
cotton
paper
silk
cat fur
wool
nylon
human hair
glass
acetate
rabbit fur

Positive, Negative, and Neutral Objects

Objects are made of vast numbers of atoms. Neutral objects have equal quantities of positive and negative charges. Objects become negatively charged when they have a greater negative charge (more electrons) than positive charge (fewer protons). Objects become positively charged when they lose electrons. Remember that only electrons can move. Protons remain in the nucleus of an atom.

Electrons can be transferred from one object to another object. For example, when two objects rub against each other, one object loses electrons and the other object gains electrons. Both objects become charged.

The Electrostatic Series

Some materials are more likely than others to gain or lose electrons. Table 1 lists several materials in order of increasing attraction for electrons. For example, materials that are more likely to gain electrons are listed above materials that are less likely to gain electrons. This list is known as the electrostatic series. Paper is below vinyl, which means that if the two are rubbed together, the vinyl gains electrons from the paper and becomes negatively charged. The paper loses electrons to the vinyl and becomes positively charged. Remember that one object gains electrons from another object that loses the electrons.

TRY THIS: Attracting Neutral Objects

Skills Focus: creating models, observing

Try this activity to see if neutral objects can be attracted to charged objects.

Materials: round object such as a watch glass, 2 plastic rulers, paper towels

1. Balance a neutral plastic ruler on top of a round object, such as a watch glass (Figure 4).
2. Charge another plastic ruler by rubbing it with a paper towel.
3. Observe what happens when you bring the charged ruler toward the neutral ruler.
4. Observe what happens if you stop moving the charged ruler toward the neutral ruler.
5. Observe what happens when you move the charged ruler away from the neutral ruler.

A. What happened to the neutral (uncharged) ruler in steps 3, 4, and 5? Why do you think this happened?

B. Write a general rule about the interaction of a charged object and a neutral object.

Figure 4

Attraction of Neutral Objects to Charged Objects

A neutral object has an equal number of positive and negative charges. Neutral objects are not attracted or repelled from each other. But what happens when a charged object is brought toward a neutral object? As you saw in the Try This activity, when a positively charged ruler is brought toward a neutral ruler, the nearest end of the neutral ruler moved toward the positively charged ruler. This is because the positively charged ruler causes the electrons in the neutral ruler to shift slightly toward the positive ruler. Figure 5 shows an exaggeration of this effect. As a result of the slight shift of electrons, the end of the neutral ruler is attracted to the charged ruler. Although there is a slight shift of charges within the ruler, the ruler does not gain or lose electrons and is still neutral. This charging effect is known as an **induced charge separation.**

(a) (b)

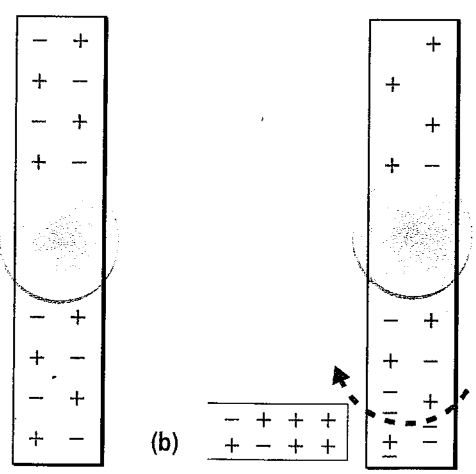


Figure 5 (a) A neutral ruler (b) The neutral ruler is attracted to a positively charged ruler.

Did You KNOW?

Thales and Amber

In 600 BCE, Thales, one of the seven sages (wise men) of Greece, discovered that when he rubbed amber, a hard tree resin, with fur, it attracted objects such as feathers and pieces of straw. The Greek word for amber is *elektron*, from which we get the word "electricity."

CHECK YOUR Understanding

1. Write a definition, in your own words, of the term "static charge."
2. Give three examples of static electricity.
3. What type of charge does amber (Figure 6) acquire when it is rubbed with a nylon cloth? What type of charge does the nylon cloth acquire? How does the size of the charge on the amber compare with the size of the charge on the nylon cloth? (Hint: Refer to the electrostatic series on page 276.)

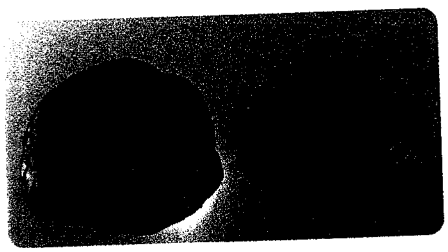


Figure 6

4. When an object is charged, does it remain charged forever? Explain your answer.
5. Is it possible to negatively charge a rod by rubbing it with a fabric without also giving the fabric a positive charge? Explain your answer.
6. If an electron is removed from a sodium atom, the atom becomes a sodium ion. What type of charge does a sodium ion have?
7. State the law of electric charges in your own words.
8. A plastic comb is used to brush the fur of a cat. The comb is then brought near some confetti lying on a table. The pieces of confetti are first attracted to the comb and then repelled. Draw diagrams to explain what happens. Make sure that you show the charges on the objects.
9. Suppose that you are given a metal sphere, a positively charged acetate strip, and a negatively charged vinyl strip. How could you determine the charge on the sphere using both strips? Why would you not be able to determine the charge using only one of the strips?
10. A student walks across a rug and notices a spark when she reaches for a metal doorknob. How could she determine whether she was positively charged or negatively charged?
11. A vinyl comb is rubbed on a wool sweater. The comb is brought toward some salt and pepper sprinkled on a countertop. The salt crystals are attracted to the comb and stick to the comb. The pepper is attracted to the comb at first, but then some of the pepper flies off. Explain the difference between salt and pepper, with respect to charges.
12. In a television, electrons travel between oppositely charged plates to the screen, as shown in Figure 7.
    (a) Would an electron move toward the negatively charged plate or toward the positively charged plate? Explain your answer.
    (b) A neutron travelling through the parallel plates is not attracted to either plate. Why?

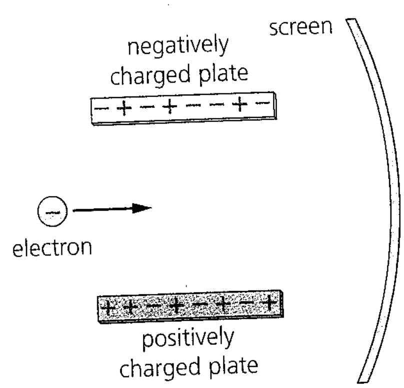


Figure 7

13. A student rubs a wooden stick with a cloth of unknown material and then brings the wooden stick near a suspended neutral pith ball. The pith ball does not respond.
    (a) What is the charge on the wooden stick?
    (b) If the material was one of the materials listed in the electrostatic series on page 276, which would it most likely be? Explain your answer.
14. If quartz is rubbed with a rubber cloth, the quartz becomes positively charged. Explain how the quartz becomes charged in terms of electron movement.