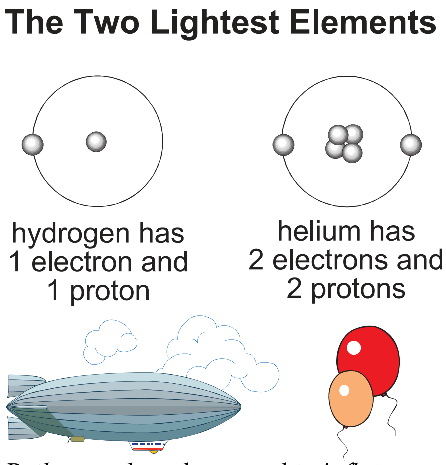
Introduction

Chemical equations are a shorthand, symbolic way of telling about a chemical reaction. In other words, they describe chemical reactions. The simplest type of reaction takes place when two or more **elements** combine to form a **compound**. There are other kinds of reactions that occur between *elements* and *compounds*. Chemical reactions are the results of the properties and arrangement of **electrons**. All reactions follow the **law of conservation of mass** discussed in Unit 5: Chemical Formulas and Equations. This unit will discuss the factors that control and affect reactions.

The Role of Electrons

Whenever a reaction takes place, *electrons* control and determine what will happen. Some **atoms** have only a few electrons, such as hydrogen (one electron) and lithium (three electrons). Other *atoms* have many electrons, such as gold (79 electrons) and lead (82 electrons). It is not just the number of electrons, however, that determine how an atom will react. Let's compare two elements, hydrogen and helium, and see how they behave.

Hydrogen has one electron and one **proton**. Helium has two electrons and two *protons*. These are the two lightest elements. You might expect for there to be many similarities between the two elements. Both are **gases** and both are colorless and odorless. Additionally, both have been used to inflate balloons and zeppelins (sometimes called blimps). In this regard, because both elements are similar, they have similar uses.

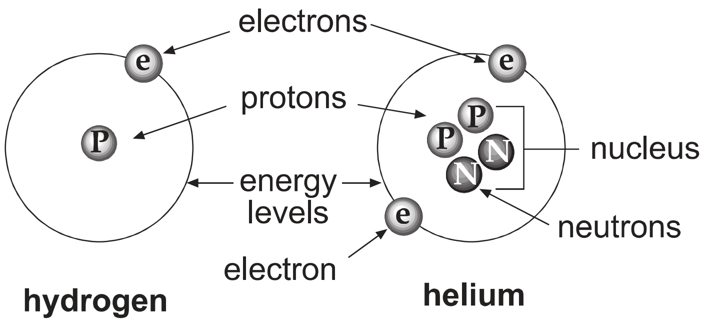


Both gases have been used to inflate balloons and zeppelins (sometimes called blimps).

If you take a moment to glance through previous chapters, though, you may notice something. Hydrogen is continually mentioned as being included in other compounds and **molecules**. The chemical symbol for helium is He. You won't find it in other compounds because of the way its electrons are configured. Hydrogen, on the other hand, is in literally thousands of compounds. Again, this is because of its **electron configuration**.

Electron Configuration

Remember that an atom's electrons are on the outside of the atom. Let's look at the *electron configurations* of hydrogen and helium:



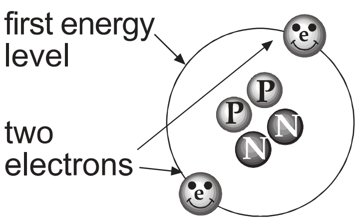
electron configurations of hydrogen and helium

The space or region that the electrons travel as they move around the **nucleus** of the atom is the **energy level**. In the cases of hydrogen and helium, there is only one *energy level*. An electron in the outermost energy level of an atom is called a **valence electron**. The *valence electrons* are the electrons that are involved in making **bonds** with other atoms. The properties of the different elements depend upon how many electrons are in the various energy levels of their atoms. The chemical bonding (combining) ability is determined by the arrangement of the electrons in the outermost energy level. Remember that it is the making and breaking of *bonds* that causes chemical reactions.

In the case of both hydrogen and helium, we can make some rules about electron configuration.

> One of the most important rules is a *tendency* to have two electrons in the first energy level.

In some ways, you can almost think of the atoms as *wanting* two electrons. When they have the two electrons, the tendency is fulfilled. In a sense, this might be compared to giving a person something that he wants. It might make him happy.



Two electrons in the first energy level compares to a happy person getting something they want.

Compare the configuration of hydrogen and helium. Helium already has two electrons. Because of this configuration, helium does not take part in chemical reactions. In fact, it is often used because it will not react. You may have heard of the *Hindenburg*. This was a large zeppelin used to transport people between Europe and the United States. While landing, the hydrogen *gas* used to inflate the zeppelin ignited. The fire spread quickly, and the zeppelin fell to the ground. Today, modern zeppelins and blimps are inflated with helium. Regardless of the amount of spark or heat, helium will not burn. This makes it safer for use in aviation.

Today, modern zeppelins and blimps are inflated with helium.

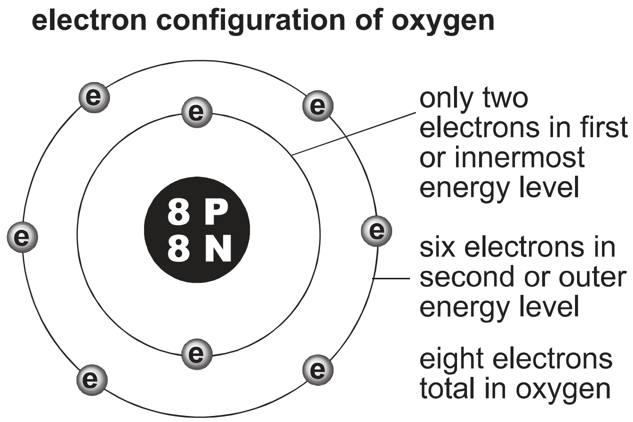
The reactivity of hydrogen is based on the fact that it has only one electron in its outermost energy level. This means that it will readily react with other atoms. By doing this it can share an electron and fulfill its tendency to have two electrons. One more rule we can make about hydrogen's and helium's electron configuration is as follows:

> They can have no more than two electrons.

Let's see how this rule works.

Making Water

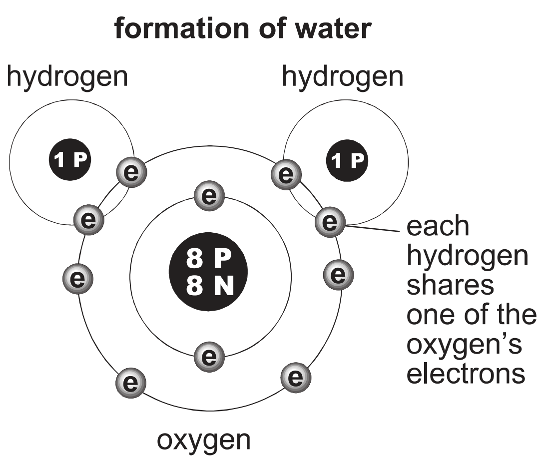
Hydrogen and oxygen combine to make water. By now, you are familiar with this reaction. To fully understand the properties of water, we must look at the way the *molecules* of water are made. Let's look at the electron configuration of oxygen.



You will see that oxygen has two electrons in its innermost energy level. Regardless of the element, there can be no more than two electrons in this first energy level. Oxygen has eight electrons, so there are six in its second energy level. There are a few other rules describing electron configuration. These apply to other atoms besides those of hydrogen and helium. These rules are as follows:

- Atoms can have up to eight electrons in their outermost energy level but no more. Atoms with eight valence electrons usually do not react.
- Atoms that have fewer than four electrons in their outermost energy level tend to give up electrons.
- Atoms that have four or more electrons in their outermost energy level tend to gain electrons.

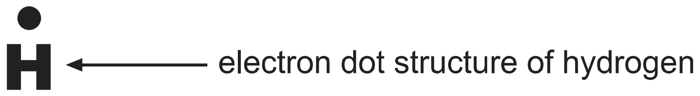
Using these rules, what predictions can you make about oxygen? If you said that it will tend to gain electrons you did well. How many electrons could hydrogen have in the case of water? If you said two, you are right.



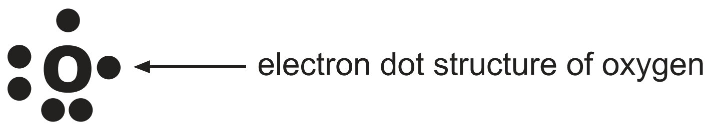
When water and hydrogen combine to form water, the oxygen shares electrons with hydrogen. The result is that each hydrogen shares one of the oxygen's electrons. This effectively gives each hydrogen two electrons in its outermost energy level. Because the electrons are being shared, oxygen shares the electrons of hydrogen. The result is that oxygen has eight electrons in its outermost energy level.

Electron Dot Structures

Picturing the way the rules on page 172 function can be difficult. Because of this, we have a model we can use called **electron dot structures**. *Electron dot structures* model atoms. The model represents the electron configuration of atoms. Electron dot structures are used to make predictions about the bonds between atoms. For instance, hydrogen has one electron. Below is the dot structure of hydrogen.

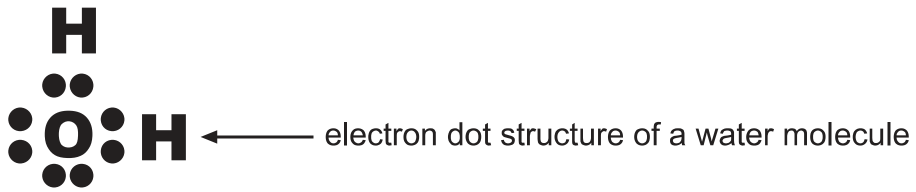


The *electron dot structure* of oxygen is below.



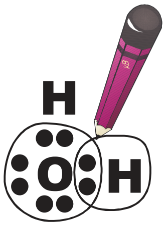
Notice that the structure only shows six electrons. This is because only six of oxygen's electrons are in its outermost energy levels. Only electrons in outermost energy levels are involved in chemical reactions. For this reason, the electron dot structure of oxygen does not show oxygen's two innermost electrons.

Now let's look at the electron dot structure of a water molecule:



- Take a pencil and draw a circle around the electrons that are on the edges of the oxygen molecule.
- Count the number of electrons. You should have counted eight electrons.

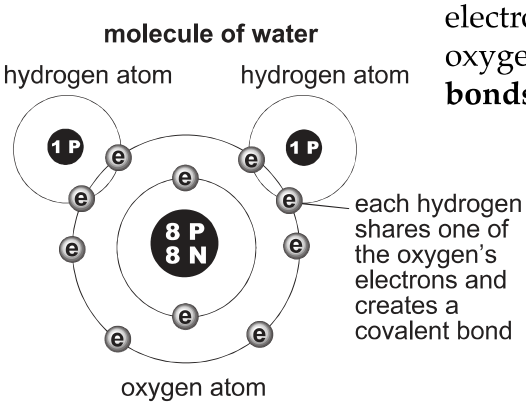
- Now, choose one of the hydrogen atoms.
- Circle the electrons that are around the hydrogen atom.
- Count them. You should have counted two electrons.



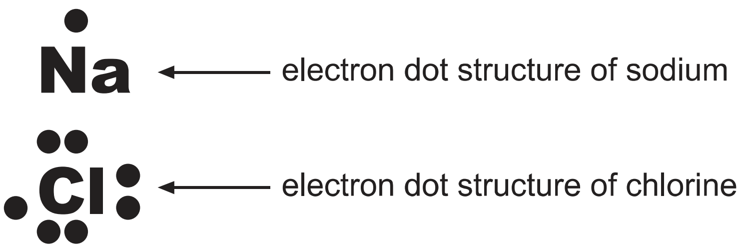
This is the way that the atoms share the electrons.

Other Bonds

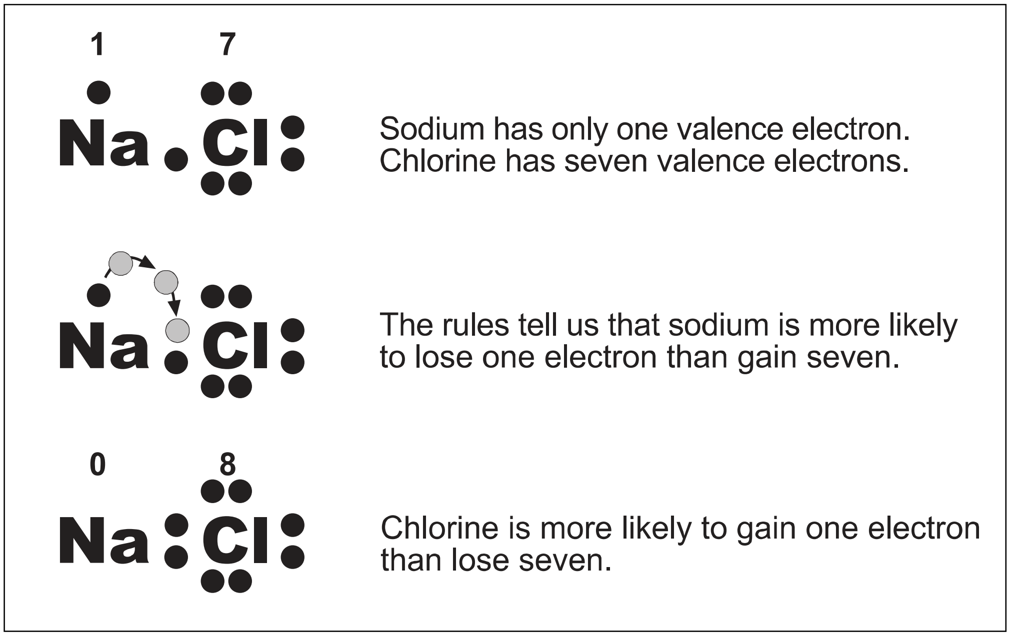
The first example we have shown was a molecule of water. Remember that a molecule is two or more atoms that share electrons. With the electron dot structures, we showed that hydrogen and oxygen share electrons. The bonds created between oxygen and hydrogen were **covalent bonds**. The valence electrons were shared.



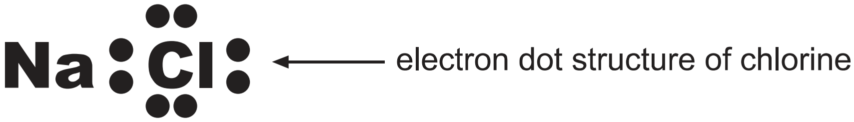
In the cases of salts, the bonds between the atoms are not covalent. In sodium chloride (table salt) chlorine does not share electrons with sodium. Instead, sodium is bonded to chlorine by an ionic attraction. An atom becomes ionized when it gains or loses electrons. If an atom gains or loses electrons, it no longer has the same number of electrons (-) as it does protons (+). Because the charges do not cancel as they did before, the **ion** that forms has a net electric charge. It is the opposite charges of the chlorine and sodium that bond them together. They have an **ionic bond**. To determine which atom has which charge, let's look at their electron dot structures:



Notice that sodium has only one valence electron. Chlorine has seven valence electrons. As our rules about electron configuration tell us, both atoms could have up to eight electrons in their outermost energy level. The rules also tell us that sodium is more likely to lose one electron than gain seven.



Chlorine, on the other hand, is more likely to gain one electron than lose seven. The structure of sodium chloride is below:



In this structure, we see that chlorine now has eight electrons. The chlorine now has one more electron than protons. Because electrons have a negative charge, the chlorine now has a negative charge. The sodium has lost an electron. It now has one more proton than electrons. The sodium has a positive charge. It is the opposite charges of the atoms that bond them.

Properties of Substances

The properties of salts and water are very different. Largely these properties are based on the bonds between the atoms. For instance, water is a molecule because it has *covalent bonds*. These bonds are stable. Water does not spontaneously change into another substance. Table salt, on the other hand, has *ionic bonds*. When this salt is put in water, the bonds are broken.

Think back to your study of the periodic table. Remember that atoms of elements in the same group have the same number of valence electrons. So these elements have similar properties.

The properties of various materials is in large part based on electrons. Electrons determine when and how bonds will be formed. They determine when a bond will release or absorb energy. They determine what the properties of the materials will be. Chemical reactions are the results of the activity of electrons.

Other Factors Affecting Chemical Reactions

Other factors affect when electrons can or cannot be involved in reactions. Certain conditions make the reactions occur more quickly and completely. These include the following:

Pressure: When gases are reacting, increasing **pressure**, or the amount of force upon the gasses, increases the chance that atoms will come in contact. The increase in *pressure* improves the speed of the reaction.

Temperature: When temperature rises, atoms more frequently come into contact. Raising temperature will increase the speed of a reaction.

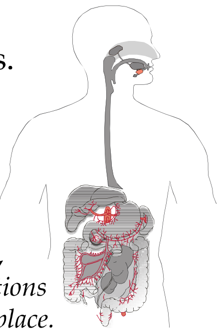
Catalyst: A **catalyst** will enable a reaction to occur at lower temperature and/or pressure. This saves effort and energy. *Catalysts* can also improve the speed and completeness of a reaction, but there are not catalysts for all reactions. The lack of a catalyst can slow other reactions that usually require a catalyst.

Concentration: By increasing the amount of substance in a solution, the speed of a reaction is increased.

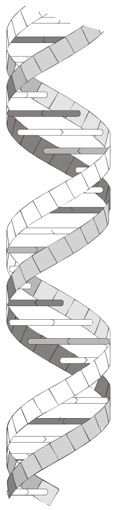
Chemistry in the Body

The factors affecting reactions are especially important in **biochemistry**. The study of the chemistry of living organisms is very complex. The human body, for instance, contains thousands of separate chemicals. In order to digest food, think, or move, many reactions must take place.

Thinking, moving, or digesting are all processes. Each is regulated by a complex series of specific chemical reactions. These reactions, however, must be controlled. Imagine what would happen if your digestive system did not function when you ate food. Your food would rot inside you. The effects would be both unpleasant and painful. Fortunately, healthy people have biochemical responses to food. They digest after they have eaten. When the food is digested, the process stops.



In order to digest food, many reactions must take place.



DNA model

You may wonder how this is all coordinated. Within your body is a chemical code that controls such processes. This code is in a complex molecule known as **DNA (*d*eoxyribo*n*ucleic *a*cid)**. Your *DNA* came from your parents. Like most other molecules in your body, it is **organic**. *Organic* molecules are produced or used by living organisms and contain the element carbon. DNA is the code that controls many of your body's functions.

As we noted, DNA is complex. You might imagine it as a thick book of instructions on how to operate a computer. The person who wrote the book didn't know how you would try to use the computer. Instead, the author tried to include instructions for every process. The result is a thick, complicated book. Now, consider the book again. It is made of only 26 letters. Although there are only 26 letters, they can make hundreds of thousands of words.

The substances that comprise DNA are like the letters in the book. They are combined in one way and then recombined in other ways. The result is that your DNA is very long and complex. This complexity allows your body to cope with all of life. Incredibly, though, there are only four basic units in DNA. That is like trying to write your book with only four letters!

These four substances, though, are like many other organic substances. They can serve many purposes. The important thing is how they are combined with other chemicals. Just like other reactions, each new combination has unique properties.

Summary

Chemical reactions occur when atoms share or transfer electrons. The sharing or transferring of electrons is based on the configuration of electrons. Electron dot structures model these configurations. The properties of substances are based on the configurations of their electrons. Factors such as temperature, concentration, pressure, and catalysts affect the speed of reactions. Reactions within a human body also follow biochemical principles. These organic chemicals can be combined and recombined in many ways.