Have you ever noticed that the Statue of Liberty is green? Was it painted green? Is it made of green stone? Actually, the Statue of Liberty is made of the metal copper. Copper is an element. Pennies are also made of copper. If copper usually has a shiny, metallic color, then why is the Statue of Liberty green?

Do compounds look like their elements?
Some matter around you is in the form of elements. For example, oxygen, copper, and sulfur are all elements. All three exist by themselves. They can also combine with other elements in a chemical reaction to form compounds.

When copper, sulfur, and oxygen combine in a chemical reaction, they produce the green coating like on the Statue of Liberty. This compound is copper sulfate, which is a green solid. It is nothing like the elements that combined to make it. Copper is a shiny, copper-colored solid. Sulfur is a yellow solid. Oxygen is a colorless, odorless gas. When elements combine, they form compounds with their own properties.

Do compounds have new properties?
Compounds may have different properties from the elements that form them. Sodium chloride, or table salt, is a compound made from the elements sodium and chlorine. Sodium is a shiny, soft, silvery metal that reacts violently with water. Chlorine is a greenish-yellow, poisonous gas. These two elements combine to form the salt that people use in their food.
Formulas

The formula for sodium chloride is NaCl. Na is the chemical symbol for the element sodium. Cl is the chemical symbol for the element chlorine. Written together, they make up the formula for sodium chloride. A chemical formula tells what elements are in a compound and how many atoms of each element are in one unit of the compound.

What is the formula for water?

Let’s look at the formula for a compound you use every day. H₂O is the chemical formula for water. H is the symbol for the element hydrogen. O is the symbol for the element oxygen. The number 2 in the formula is called a subscript. Subscript means “written below.” A subscript written after a symbol tells how many atoms of that element are in one unit of the compound. In H₂O, the 2 tells you there are two atoms of hydrogen in one unit of water. If there is no subscript after a symbol in a formula, there is only one atom of that element in the compound. So, in one unit of H₂O there are two hydrogen atoms and one oxygen atom.

The table shows some familiar compounds and their formulas. Notice that each kind of atom can be combined with other atoms in many different kinds of compounds. For instance, oxygen is a part of the compounds of sand, milk of magnesia, cane sugar, and vinegar.

<table>
<thead>
<tr>
<th>Familiar Name</th>
<th>Chemical Name</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>Silicon dioxide</td>
<td>SiO₂</td>
</tr>
<tr>
<td>Milk of magnesia</td>
<td>Magnesium hydroxide</td>
<td>Mg(OH)₂</td>
</tr>
<tr>
<td>Cane sugar</td>
<td>Sucrose</td>
<td>C₁₂H₂₂O₁₁</td>
</tr>
<tr>
<td>Vinegar</td>
<td>Acetic acid</td>
<td>CH₃COOH</td>
</tr>
</tbody>
</table>

Atomic Stability

Recall that protons have a positive charge and electrons have a negative charge. These opposite electric forces attract each other. They are the forces that hold atoms and molecules together. The kinds of electric forces that hold atoms together also bring atoms together to form compounds.

Picture This

1. **Explain** What does a chemical formula tell you?
   
   __________
   __________
   __________

2. **Describe** The formula for cane sugar, or sucrose, is C₁₂H₂₂O₁₁. Describe what one unit of cane sugar is made of.

   __________
   __________
Why do atoms form compounds?

Look at the periodic table on the inside back cover of this book. It lists all the known elements. Most of these elements can combine with others to form compounds that are more stable. Notice the six elements in Group 18. These elements are gases called the noble gases. Atoms of the noble gases are very stable. They are different from the other elements because they almost never combine to form compounds. Compounds that are formed with a noble gas are less stable than the original noble gas atom.

Why are the noble gases stable?

A helpful way to picture the stability of the noble gases is to look at the electron dot diagrams of those elements. An electron dot diagram shows the symbol of the element. It also shows the electrons in the outer energy level of an atom. The number of electrons in the outer energy level of an atom determines if that atom will combine to form a compound.

How do you know how many dots to put in an electron dot diagram? For elements in Groups 1 and 2 and 13 through 18, you can use the periodic table. The above shows two rows of the periodic table. Look at the outer energy level of the elements in Group 1. All elements in Group 1 have one outer electron. The elements in Group 2 have two outer electrons. Group 13 elements have three outer electrons, Group 14 elements have four, and so on. The noble gases in Group 18 have eight outer electrons.

What makes an atom stable?

An atom is chemically stable when its outermost energy level has all the electrons it can hold. If an atom is chemically stable, it does not easily form compounds with other atoms.
Stable Noble Gases The figure to the right shows electron dot diagrams of the noble gases. The first electron dot diagram is for helium. Notice that there are two electrons around the symbol for helium, He. Hydrogen and helium need only two electrons in their outer level to be stable. The outer energy levels of all the other elements are stable when they contain eight electrons.

Now look at the electron dot diagram for neon, Ne. There are eight electrons in neon’s outer energy level. Neon is stable as an atom. Neon does not become more stable if it forms a compound. The noble gases are stable because they already have the maximum number of electrons in their outer energy levels.

What elements have incomplete outer energy levels?

Hydrogen and helium are the only elements in the first row, or period, of the periodic table. Both hydrogen and helium need only two outer electrons to be stable. Helium has two electrons in its outer energy level and is stable. But hydrogen has only one electron. Its outer level is not full. Therefore, hydrogen is more stable when it is part of a compound.

Look at the periodic table again. You can see that none of the elements in Group 13 through Group 17 have full outer energy levels. These elements are more stable when they form compounds.

How do atoms become more stable?

As you have learned, hydrogen is an element that does not have a full outer energy level. How does hydrogen, or any other element become stable? Atoms that do not have a stable outer energy level can do one of three things to complete their outer level. They can gain electrons, lose electrons, or share electrons to make a full outer level. Atoms combine with other atoms that also do not have complete outer levels. This way, each atom becomes more stable.

The figure on the next page shows electron dot diagrams for sodium and chlorine. Sodium has one outer electron and chlorine has seven. When these two elements combine, sodium gives its outer electron to chlorine. Chlorine now has eight electrons in its outer level. This is a full, stable energy level. But what about sodium?
How can sodium become more stable?

Sodium gave up the only electron in its outer level when it combined with chlorine to form sodium chloride. If sodium loses the electron in the outer energy level, what is left? The next energy level of the sodium atom has eight electrons. When the one outer electron is removed, the next level becomes the new outer level. Sodium now has a complete, stable outer energy level. Sodium and chlorine exchanged an electron and are now both stable in the compound they formed.

What is another way atoms can become stable?

Remember that the formula for the compound water is $\text{H}_2\text{O}$. Hydrogen atoms need one electron in their outer level to be stable. Oxygen atoms need two electrons to be stable. In this case, neither atom can give up an electron. Instead, they share electrons. Each hydrogen atom shares one electron from an oxygen atom to complete its outer level. In turn, the oxygen atom shares each of the two hydrogen atoms’ electrons to complete its outer level. The compound water is more stable than a hydrogen atom or an oxygen atom.

Atoms gain and lose electrons to become more stable. Recall that electrons have a negative charge and protons have a positive charge. Positive charges attract negative charges like the opposite ends of a magnet. The force that holds atoms together is called a chemical bond.
After You Read

Mini Glossary

**chemical bond:** the force that holds atoms together in a compound

**chemical formula:** a formula that tells what elements and how many atoms of each element are in a compound

1. Review the terms and their definitions in the Mini Glossary. Find one chemical formula you learned about in this section and explain the parts of the formula.

2. Complete the concept web to organize the information from this section.

3. **Study Coach** As you read this section, you made flash cards for the elements mentioned in the text. Do you think that making flash cards would be a good way to learn the symbols of all the elements in the periodic table? Why or why not?