CHEMISTRY
& ECOLOGY

Properties of Atoms & Molecules

1:1
Answers IN GENESIS™

GOD'S DESIGN®

4th Edition

by Debbie & Richard Lawrence

God's Design® for Chemistry and Ecology is a complete chemistry and ecology curriculum for grades 3–8. The books in this series are designed for use in the Christian school and homeschool, and provide easy-to-use lessons that will encourage children to see God's hand in everything around them.

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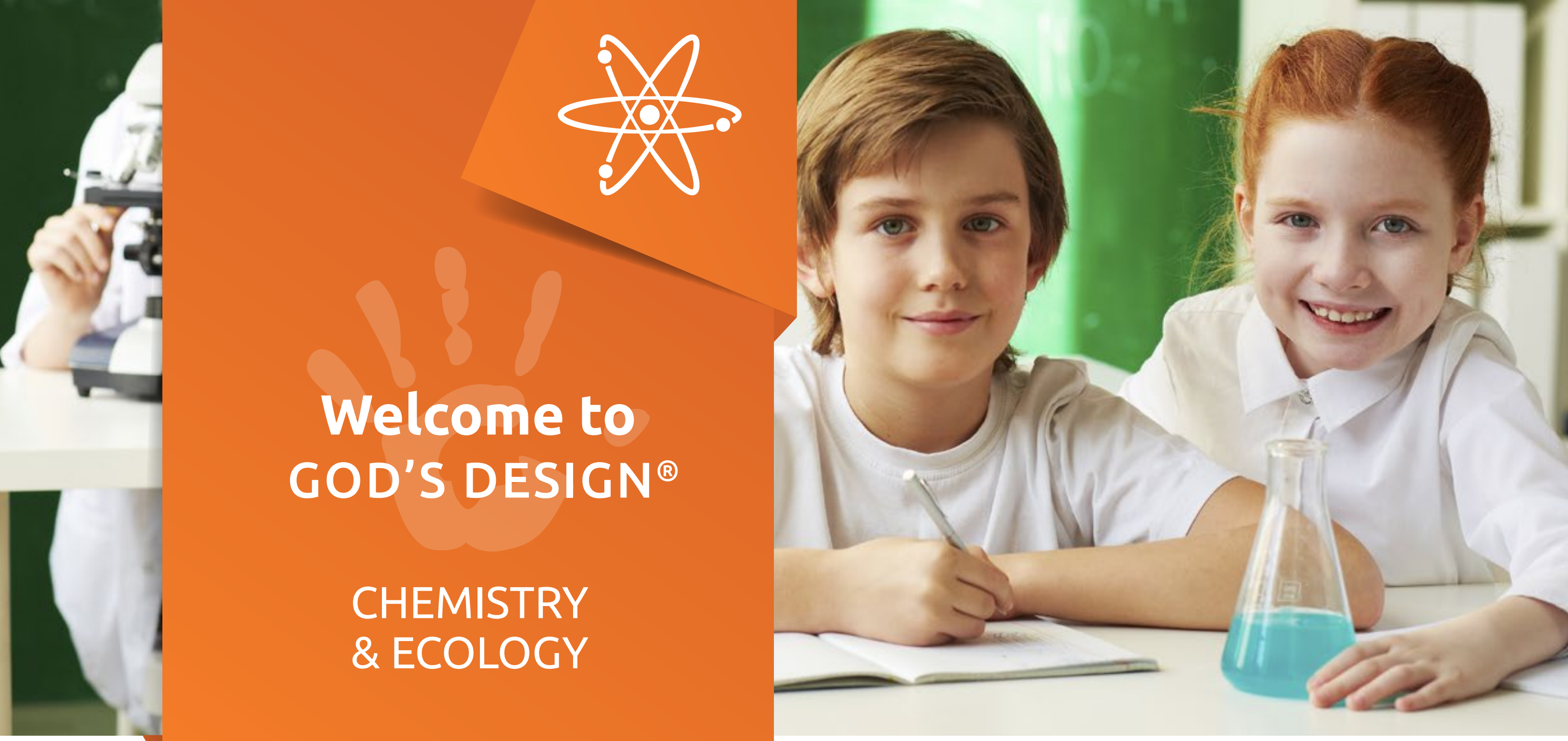

Welcome to GOD'S DESIGN®

CHEMISTRY & ECOLOGY

You are about to start an exciting series of lessons on chemistry and ecology. *God's Design® for Chemistry & Ecology* consists of three books: *Properties of Atoms & Molecules*, *Properties of Matter*, and *Properties of Ecosystems*. Each of these books will give you insight into how God designed and created our world and the universe in which we live.

No matter what grade you are in, third through eighth grade, you can use this book.

3rd–5th grade

Read the lesson.

- Do the activity in the light blue box (worksheets will be provided by your teacher).
- Test your knowledge by answering the **What did we learn?** questions.
- Assess your understanding by answering the **Taking it further** questions.

Be sure to read the special features and do the final project.

There are also unit quizzes and a final test to take.

6th–8th grade

Read the lesson.

- Do the activity in the light blue box (worksheets will be provided by your teacher).
- Test your knowledge by answering the **What did we learn?** questions.
- Assess your understanding by answering the **Taking it further** questions.
- Do the Challenge section in the light green box. This part of the lesson will challenge you to do more advanced activities and learn additional interesting information.

Be sure to read the special features and do the final project.

There are also unit quizzes and a final test to take.

When you truly understand how God has designed everything in our universe to work together, then you will enjoy the world around you even more. So let's get started!

UNIT 1

Atoms & Molecules

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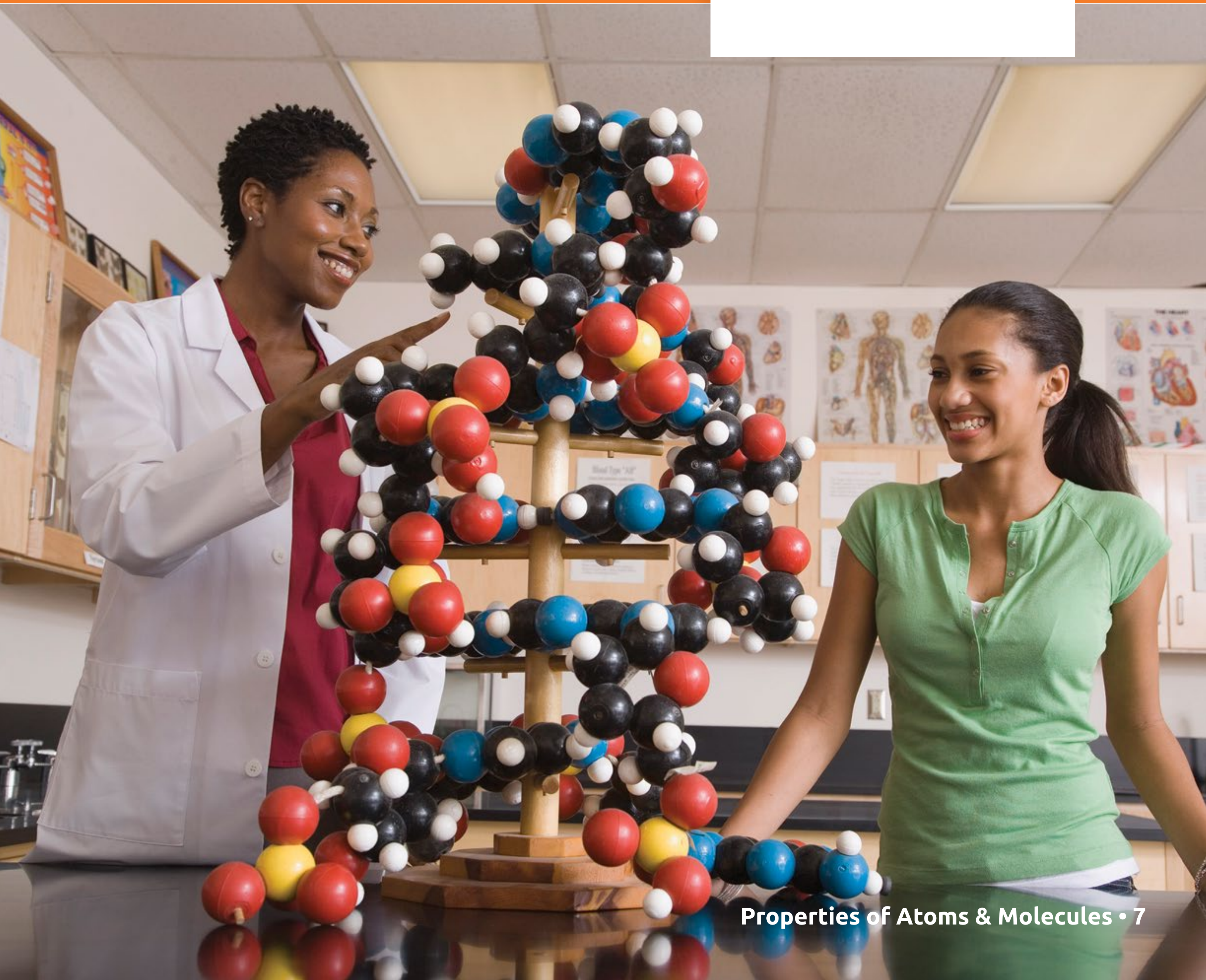
2 Atoms • 10
3 Atomic Mass • 13
4 Molecules • 17

- ◊ **Identify** and **describe** the parts of an atom using diagrams.
- ◊ **Use** the periodic table to determine the characteristics of atoms.
- ◊ **Describe** the relationship between atoms and molecules.



1

Introduction to Chemistry

The study of matter and molecules

What is chemistry?

Words to know:

chemistry
chemist
matter

Chemistry may sound like a big word and a difficult subject to study, but it's not. **Chemistry** is simply the study of matter, and **matter** is anything that has mass and takes up space. Some examples of matter are water, wood, air, food, paper, your pet skunk, or your little brother. So if you are interested in learning more about anything around you, then you are ready to learn about chemistry.

Chemists are scientists who study what things are made of, how they react to each other, and how they react to their environment. Chemistry is the study of the basic building blocks of life and the world.

In chemistry you will learn about atoms and molecules. You will learn about how substances combine to make other substances. You will find out how a substance changes form and you will discover that God created our world with such intricate designs that we may never fully understand how everything works.

God has established laws that govern how chemicals react and how matter changes. Many of these laws seem mysterious because they happen on an atomic level. Although these changes cannot be seen with the naked eye, the results of these laws can be seen all around us. As you study atoms and molecules you will begin to understand these laws and appreciate the beauty of God's design on the atomic level.

What did we learn?

- What is matter?
- Does air have mass?
- What do chemists study?

Taking it further

- Would you expect to see the same reaction each time you combine baking soda and vinegar?

Chemistry is fun

As you will learn in the upcoming lessons, some materials are very stable and do not change easily. Other materials are very reactive and easily combine with other substances to make a new substance.

Purpose: To see a chemical reaction

Materials: baking soda, drinking cup, vinegar

Procedure:

1. Place 1 teaspoon of baking soda in a drinking cup.
2. Pour 1 tablespoon of vinegar into the cup. Now watch the reaction!

Conclusion: Vinegar is an acid and baking soda is a base. Acids and bases easily combine together to form salts. In this reaction they also produce a gas. Can you guess what that gas might be? It is carbon dioxide.

Soda fountain

For an even more impressive reaction, you can make a Mentos and diet soda fountain. This chemical reaction is very messy so this experiment must be done outside. This experiment happens quickly so you want to have everything ready before you start. Read through the directions below before you try the experiment so you know what to do.

Purpose: To make a diet soda fountain

Materials: 2-liter bottle of diet cola, heavy paper, tape, toothpick, Mentos® mints

Procedure:

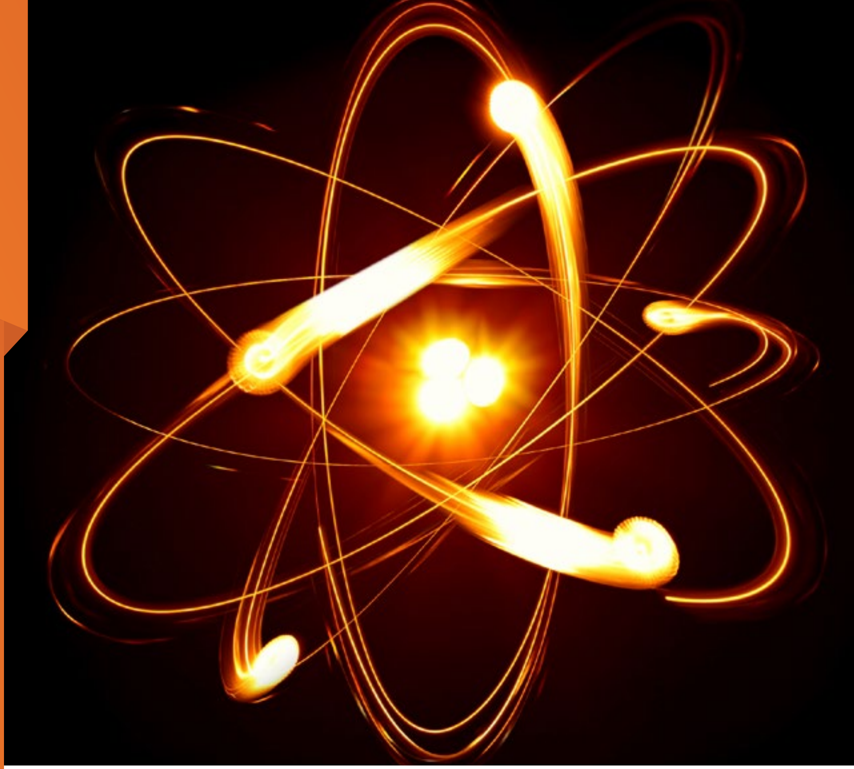
1. Remove the cap from a 2-liter bottle of diet cola.
2. Make a tube to hold the mints: roll a piece of heavy paper into a tube that just fits around the mouth of the soda bottle. Tape the paper so it stays rolled up.
3. Use a toothpick to punch holes through the bottom of the tube just above the mouth of the bottle so that the toothpick goes through the tube and holds the mints in place.
4. Load up your tube with four or more mints.
5. Quickly remove the toothpick and step back so you don't get sprayed. You should see a fountain of soda. Be sure to clean up your mess when you are done.

Conclusion: This reaction is partially a chemical reaction and partially a physical reaction between the mints and the soda. Soda contains a gas called carbon dioxide. This gas is trapped between the liquid molecules. The mints have many tiny pits on their surfaces which allows the gas to collect very quickly and escape the liquid. There is also a chemical reaction between the mints and soda that further allows the gas to escape quickly producing a fountain of foam. Now, don't you think chemistry is fun?

2

Atoms

Basic building blocks



What are the basic building blocks of matter?

Words to know:

atom
proton
neutron
electron
nucleus
electron energy level
valence electron

Everything around you is made of matter. But what is matter made of? This is a question that has interested scientists for thousands of years. It is obvious that water is a different kind of substance than a rock and that a person is very different from a tree. But what makes each thing unique? As scientists considered this question, they began to try to separate and break down different substances to understand what they were made of. Eventually, scientists have discovered that everything in the universe is made of very small particles called atoms. **Atoms** are the smallest part of matter that cannot be broken down by ordinary chemical means. Atoms are so small that we cannot see them, even with the best microscope. But we can see how different types of atoms behave and see how they combine with other atoms.

Because atoms are so small, scientists have had to develop models to describe what an atom is like. Have you every played with a toy truck or airplane? That toy was a model of the real thing. It allowed you to see the basic parts of the vehicle, but it was not the same size or as complex as the real thing. In the same way, models of atoms help us to understand the basic parts of an atom, but they are not the same size or as complex as a real atom.

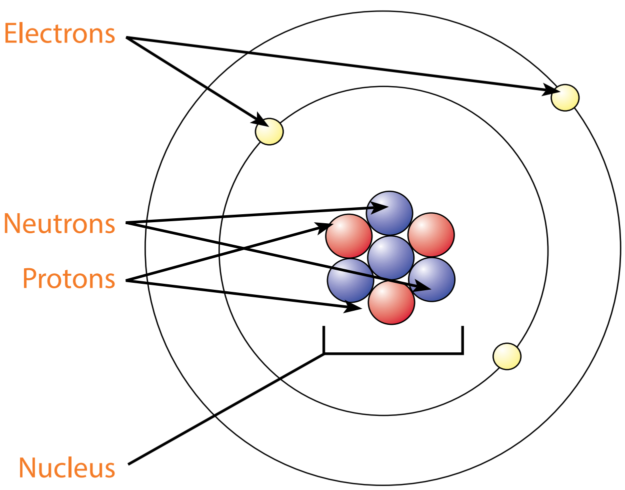
The earliest written ideas showing that matter was made of atoms come from the Greeks around 400 BC. The Greek scientists believed that matter was made of very small particles. But they did not try to describe those particles. Work on an actual atomic model did not really begin until the 1700s when experimental science became more popular. Early experiments showed that different atoms had different masses. In 1897 it was discovered that atoms consisted of electrically charged particles and

Fun Fact

The models used to represent atoms do not accurately show the size relationship between the nucleus and the electrons. If the nucleus of the atom was the size of a tennis ball, the electrons would be orbiting about 1 mile away.

that some particles in the atom were smaller than others. By 1911 a scientist named Ernest Rutherford discovered that atoms consisted of a positively-charged nucleus with negatively-charged particles whirling around it. And finally, Neils Bohr discovered that the electrons whirling around the nucleus had different energy levels.

All of these discoveries have helped in the development of the current atomic model. Today scientists describe an atom as having three parts: protons, neutrons, and electrons. **Protons** are positively charged particles. **Neutrons** are neutral; they do not have a positive or negative charge. And **electrons** are negatively charged particles. All of the parts of an atom are extremely small; however, electrons are much smaller than protons and neutrons. Protons and neutrons are approximately 1,800 times more massive than electrons.



Solar system model of a lithium atom

The protons and neutrons in an atom are combined together in a tight mass called the **nucleus**. The electrons move very quickly around the nucleus. Some electrons orbit more closely to the nucleus than others. It is believed that the electrons in an atom occupy different levels, or distances, from the nucleus depending on how much energy they have. These levels are often referred to as the **electron energy levels**. The electrons that are in the level farthest away from the nucleus are called the **valence electrons**.

The model of a lithium atom below shows its nucleus containing four neutrons and three protons. It also shows three electrons orbiting the nucleus. Two electrons orbit closer to the nucleus, and the third electron orbits farther away, thus lithium has one valence electron.

The number of protons in the nucleus of an atom determines what kind of atom it is. If an atom loses or gains a neutron, or loses or gains an electron, it is still the same type of atom. But if the atom loses or gains a proton, it becomes a different type of material. Regardless of the number of neutrons or electrons that a lithium atom may have, a lithium atom always has three protons.

As research into the structure of atoms continues, scientists continue to gain more understanding of the complexity of the atom. It is believed that protons, neutrons, and electrons are made of smaller particles called quarks, but because of their extremely small size, they are difficult to study. This complexity continues to amaze scientists and shows God's mighty hand in the design of the universe.

What did we learn?

- What is an atom?
- What are the three parts of an atom?
- What electrical charge does each part of the atom have?
- What is the nucleus of an atom?
- What part of the atom determines what type of atom it is?
- What is a valence electron?

Taking it further

- Why is it necessary to use a model to show what an atom is like?
- On your worksheet, you colored neutrons blue and protons red. Are neutrons actually blue and protons actually red in a real atom?

Atomic models

Color the parts of the atoms on the "Atomic Models" worksheet.

Energy levels

In all atoms, the lowest electron energy level, that which is closest to the nucleus, is filled with electrons first. If a level is full, electrons will occupy the next level. The first level can hold up to two electrons. If an atom has more than two electrons, two electrons will orbit close to the nucleus, and the others will begin to fill the next layer. The following chart shows how many electrons scientists believe that each energy level can hold. Note, however, that although scientists believe that certain levels can hold more electrons, the highest number of electrons that has been determined to be in any energy level is 32. Other than in level one, an inner energy level does not have to be full before the next level begins to fill up. For example, even though the fourth level can hold 32 electrons, the fifth level begins filling up after the fourth level has only 8 electrons in it.

The electrons orbiting in the energy level farthest from the nucleus of an atom are called valence electrons. The lithium model on the previous page shows that lithium has one valence electron. Valence electrons play a vital role in how an element behaves. Neutral atoms are ones in which the number of electrons equals the number of protons. However, atoms can gain or lose valence electrons. The ability to gain, lose, or share valence electrons is what allows atoms to bond with each other to form new substances.

Look at the periodic table of the elements on page 24. The small numbers in the bottom of each box show the electron configuration for each element. For example, look at the box for lithium (Li), element number 3. The numbers at the bottom of the box are 2, 1. This means there are 2 electrons in the first energy level and 1 electron in the second energy level. This corresponds to the model earlier in this lesson.

Let's look at another example. Look at Potassium (K), which is element number 19. The numbers for the electron configuration are 2, 8, 8, 1. This means that there are 2 electrons orbiting close to the nucleus. There are 8 electrons orbiting in the next level out. There are 8 electrons orbiting in the third level out, and there is 1 electron in the outermost layer. We will learn more about why these electron configurations are so important as we learn about how atoms bond with each other.

Complete the "Energy Levels" worksheet to help you better understand how electrons are distributed in atoms.

Chart of Maximum Electrons in Each Energy Level

Energy Level	Maximum Number of Electrons
1	2
2	8
3	18
4	32
5	50
6	72
7	98

3

Atomic Mass

How big is an atom?

How do you measure an atom's mass?

Words to know:

atomic number
atomic mass
mass number
atomic mass unit (amu)

Challenge words:

isotope

As you learned in the previous lesson, an atom consists of three parts: protons, neutrons, and electrons. You also learned that the number of protons determines the type of element the atom will be. Therefore, the number of protons in an atom is called the **atomic number**. Hydrogen, which only has one proton, has an atomic number of 1. Oxygen, which has eight protons in its nucleus, has an atomic number of 8. The atomic number of an atom is very useful in identifying the type of atom.

The number of electrons in an atom typically equals the number of protons. However, an atom may lose or gain electrons. When this happens it is called an ion. You'll learn about ions in Lesson 11.

The mass of an atom is also an important characteristic to know about the atom. The mass of an atom is determined by the number of protons and neutrons in the atom. Electrons are so small and contribute such a tiny amount to the mass that their mass can be ignored. The **mass number** or **atomic mass** of an element is found by adding the number of protons and the number of neutrons in the atom. For example, hydrogen has only one proton and no neutrons so its atomic mass is one. Oxygen, which usually has eight protons and eight neutrons, has an atomic mass of 16.

On the other hand, if you are given the atomic number and atomic mass for an element you can figure out how many protons, electrons, and neutrons that element has. The atomic number given at the top of the square on a periodic table tells you how many protons the element has. The number of electrons is equal to the number of protons. Then to calculate the number of neutrons you subtract the number of protons from the atomic mass.

Because the mass of a proton or neutron is so small, it would not make sense to measure an atom's mass in grams. Therefore a special unit has been defined for measuring the mass of an atom. This unit is an **atomic mass unit**, or **amu** (it is also called *unified atomic mass unit* and abbreviated as u). An amu is defined as $1/12$ the mass of a carbon atom. A carbon atom has six protons and six neutrons, and thus has an atomic mass of 12 amu.

Protons and neutrons have nearly identical masses, so for most applications an amu can be used to describe the mass of either type of particle. The mass of an electron is 1,800 times smaller than that of a proton or neutron, so we usually say its mass is negligible—it can be ignored.

What did we learn?

- What are the three particles that make up an atom?
- What is the atomic number of an atom?
- What is the atomic mass of an atom?
- How can you determine the number of electrons, protons, and neutrons in an atom if you are given the atomic number and atomic mass?

Taking it further

- What does a hydrogen atom become if it loses its electron?
- Why are electrons ignored when calculating an element's mass?

Learning about atoms

Complete the "Learning About Atoms" worksheet.

Isotopes

If you look up the atomic mass for an element on the periodic table, you find that most are not listed as whole numbers. This does not mean that an atom has only part of a proton or part of a neutron. It means that even though all atoms of a particular element have the same number of protons, some have different numbers of neutrons. Each variety of atom is called an **isotope** of that element.

To help you understand this better, let's look at carbon. On most periodic tables, the atomic mass of carbon is listed as 12.01 amu. This is an average mass for carbon atoms that naturally occur. All carbon atoms have 6 protons or they would not be carbon atoms. Ninety-nine percent of all carbon atoms also have 6 neutrons giving them a mass of 12 amu. However, a little less than 1% of all carbon atoms have 7 neutrons so they have a mass of 13 amu; and a very small percentage of carbon atoms have 8 neutrons and a mass of 14 amu. When you average the mass for all isotopes of carbon the average mass is 12.01 amu. Some elements have only a few known isotopes while others have many. Chlorine has 24 known isotopes, but only two are common. The most common has an atomic mass of 35 amu, and the second most common has a mass of 37 amu.

Now that you have a better understanding of what atomic number, atomic mass, and isotopes mean, use a periodic table to fill in the "Understanding Atoms" worksheet. Round the atomic mass from the periodic table to find the most common number of neutrons, in other words the most common isotope, for each element. You may use the periodic table on page 24.

Madame Curie

1867–1934

SPECIAL FEATURE

Atoms, isotopes, and radioactive decay are the things that Marie Curie is best known for. But who was she? When she was born in 1867, her last name was Sklodowska. She was born in Warsaw, Poland, an area that was controlled by the czar of Russia at that time. Because of their pro-Polish leanings, Marie's parents lost their jobs and her father was forced into a series of lower academic posts. The family was poor and took in students as boarders to help pay the rent. When Marie was eight, her oldest sister died, and less than three years later her mother also died. This made the family turn to each other for strength.

As they were growing up, their father read them classics and exposed them to science. Marie graduated from high school at the age of 15, at the top of her class. But, women were not allowed to attend the University of Warsaw, so Marie went to a floating university, named so because it changed locations frequently to hide it from the Russian authorities. This schooling was not a high quality education, so Marie made a pact with her older sister. Marie would work and help send her sister to Paris for medical school, and then her sister would work to send her to school. For two years, Marie worked as a teacher and then, to make more money, she became a governess and sent as much money as she could to her sister.

Eventually, Marie went back home and because of her father's new job she was able to leave for Paris in 1891, when she was 24 years old. There, life was hard for her. In the winters, she would wear every piece of clothing she had to keep herself warm. And sometimes she would get so absorbed in her studies she would forget to eat and she would pass out. In later years, Marie said it was very common for the Polish students to be poor.

In Paris, Marie found that she was ill prepared for college. She was lacking in both math and science, plus her technical French was behind where it needed to be. She overcame this by working hard, and it paid off. She finished first in her class for her master's degree in physics and second in her class in math the following year.

In 1894 Marie began sharing lab space with a man named Pierre Curie. Their work drew them together, and in July 1895 the two were married in a simple ceremony. In September of 1897 their first child was born—a baby girl. Pierre's father delivered the baby. A few weeks later Pierre's mother died and Pierre's father, along with Marie, Pierre, and baby Irene moved into a house together. Marie kept working in the lab and found her father-in-law to be the perfect babysitter.

About six months after Marie and Pierre were married, a German scientist name Wilhelm Conrad Roentgen discovered X-rays. He discovered that X-rays could travel through wood and flesh and produce an image on photographic paper. A few months later a French physicist named Henri Becquerel discovered that uranium produced similar rays.

These discoveries prompted Marie and Pierre to start working with uranium. They soon discovered other materials that also emitted strong rays and they called this characteristic *radioactivity*. One element they discovered was polonium, named for Marie's home country of Poland, but the most important radioactive material discovered by the Curies was radium. It wasn't long before radium was in demand. In cheap novels, it was touted as "a magical substance whose rays could cure all ills, power wondrous machines, or destroy a city at one blow." This obviously was quite an exaggeration; however, the damaging effects radioactivity has on tissues was soon used on cancer cells. These damaging effects also took their toll on both Marie and her husband. Pierre developed sores on his body and was constantly fatigued. Marie lost 20 pounds and her fingertips were scarred from the radiation, but they had no knowledge of the long-term effects. While they noted Pierre's loss of good health and the severe pains he experienced, they did not link this to their work.

In 1903 both Pierre and Marie were invited to England to be honored for their work at the Royal Institution. Because it was not customary for women to speak there, Lord Kelvin showed his support for Marie by sitting next to her as her husband gave his speech. Later, when Pierre was nominated for the Nobel Prize in Physics for his and Marie's discovery of radium, he said it would be a travesty if his wife was not also included; so she was. In 1911 Marie received a second Nobel Prize, this one in chemistry, for the discovery of the atomic mass of radium.

After Pierre was killed by a horse-drawn wagon in 1906, Marie continued to carry on their work. A little while later, she was offered and accepted her husband's academic post at the Sorbonne, becoming the first woman to teach at this prestigious French college. Over the next few years, with the help of some wealthy friends and the French government, she was able to found the Radium Institute where research into the uses of radium in treating cancer and other illnesses was to be conducted.

When war came to France in 1914, the Radium Institute was complete, but Marie had not moved in yet. The other researchers who worked there were drafted to fight the Germans, and Marie also wanted to help. She knew X-rays could help save soldiers' lives by showing the doctors where the bullets or shrapnel were located, and they could see how the bones were broken. So she helped design 20 radiology vans to be taken into the field to treat the wounded. Since no one else was trained to use the X-ray equipment, Marie learned how to drive and she and her very mature 17 year old daughter, along with a doctor, made the first trip to the front lines in the fall of 1914. By 1916 Marie was training other women to work in the 20 mobile units and at the 200 stationary units.

After the war, Marie went back to work at the Radium Institute, and between 1919 and her death from leukemia in 1934, the Institute published 483 works, including 31 papers and books by Marie. Both of her daughters also achieved distinction. Irene and her husband won a Nobel Prize, and her daughter Eve was recognized for her writings. But the Curies will continue to be best known for their discovery of radioactivity.