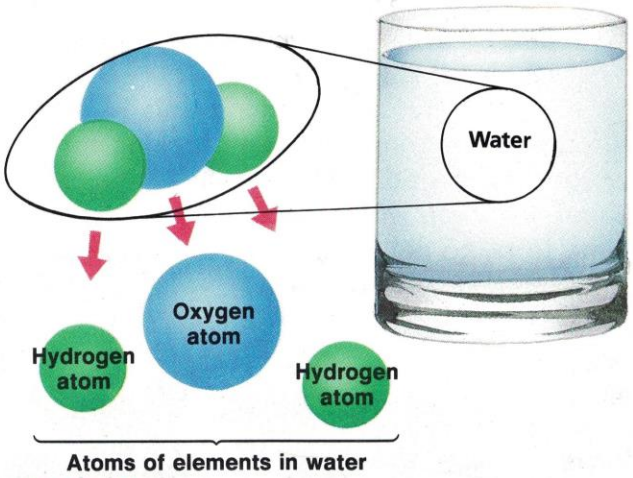
14-1 What are atoms?

Objectives ▸ Identify an atom as the smallest part of an element. ▸ List the parts of Dalton's atomic theory.

TechTerm

- **atom:** smallest part of an element that can be identified as that element

Atoms An **atom** is the smallest part of an element that can be identified as that element. Elements are simple substances that cannot be broken down into simpler substances. What happens if you keep cutting an element into smaller and smaller pieces? There is a smallest piece of an element that cannot be divided any further. This smallest piece is called an atom.



Define: What is an atom?

Democritus The first person to suggest the idea of atoms was the Greek philosopher Democritus (di-MAHK-ruh-tus). More than 2400 years ago, Democritus asked whether it is possible to divide a sample of matter forever into smaller and smaller pieces. After much thought, Democritus came to the conclusion that it is not possible to divide matter forever. At some point, a smallest piece would be reached. Democritus named this smallest piece an atom. The word "atom" comes from a Greek word that means "cannot be divided."

Democritus and his students did not know what scientists today know about atoms. However, they hypothesized that atoms were small, hard particles that were all made out of the same material. They also thought that atoms were infinite in number, that they were always moving, and that they could be joined together.

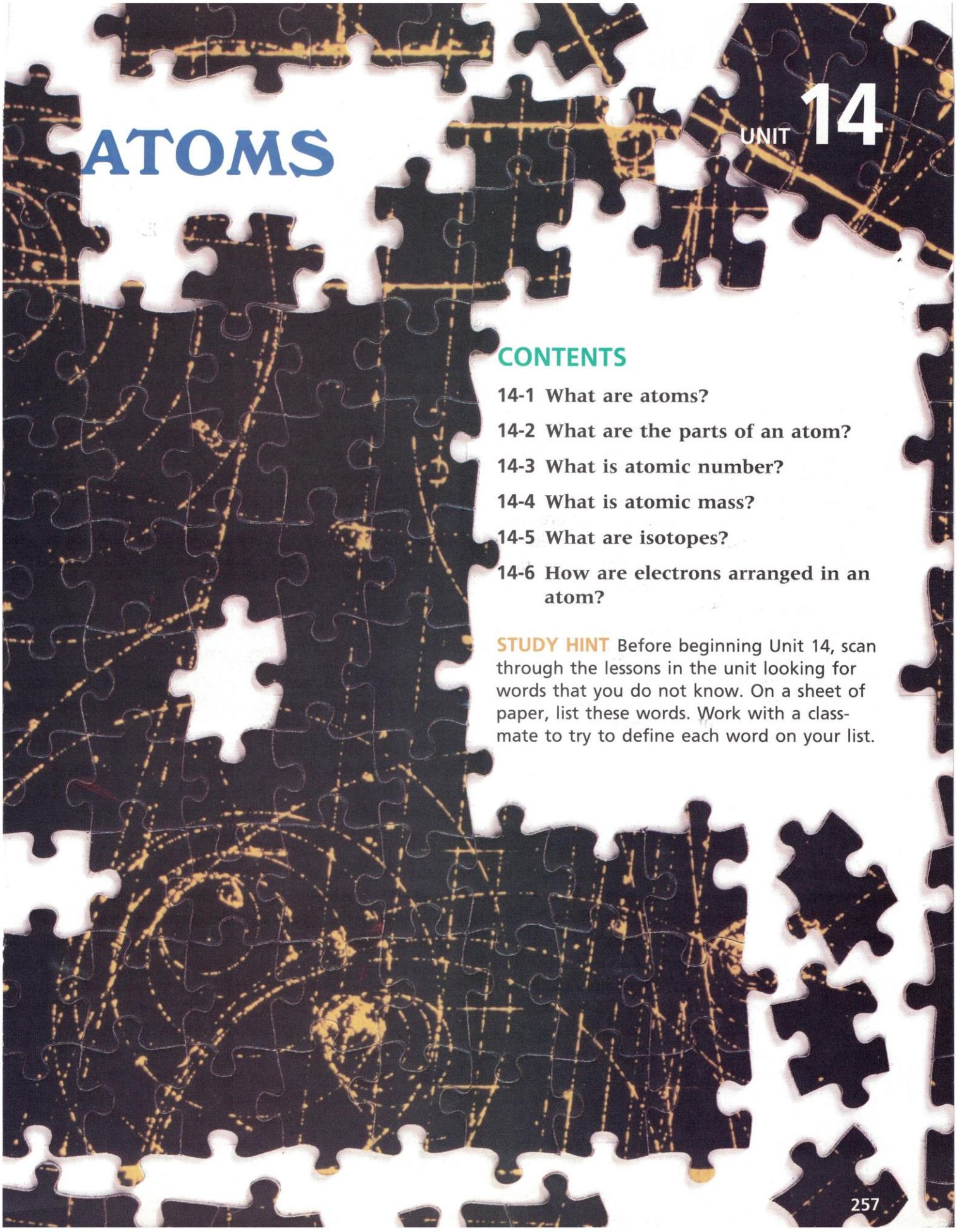
Identify: What does the word "atom" mean?

Dalton's Atomic Theory In the early 1800s, an English chemist named John Dalton did some experiments. Based on his observations, Dalton stated an atomic theory of matter. The main parts of Dalton's atomic theory are as follows:

- All elements are composed of atoms. Atoms cannot be divided or destroyed.
- Atoms of the same element are exactly alike.
- Atoms of different elements are different.
- The atoms of two or more elements can join together to form compounds.

Like Democritus, Dalton had some ideas about atoms that scientists no longer agree with. However, Dalton's atomic theory was the beginning of the modern theory of atoms.

List: What are the parts of Dalton's atomic theory?



ATOMS

UNIT 14

CONTENTS

STUDY HINT Before beginning Unit 14, scan through the lessons in the unit looking for words that you do not know. On a sheet of paper, list these words. Work with a classmate to try to define each word on your list.

LESSON SUMMARY

- An atom is the smallest part of an element that can be identified as that element.
- The first person to suggest the existence of atoms was the Greek philosopher Democritus.
- The Greeks believed that atoms were small, hard particles that were infinite in number, always moving, and could be joined together.
- In the early 1800s, the English chemist John Dalton proposed an atomic theory of matter.

CHECK *Complete the following.*

1. An atom is the smallest part of an _____ .
2. Dalton stated that atoms can join together to form _____ .
3. The first person to use the word "atom" was _____ .
4. The _____ believed that atoms were hard particles that were always moving.
5. Dalton based his atomic theory on experiments and _____ .

APPLY *Complete the following.*

6. **Compare:** How were the ideas of Democritus and Dalton similar?
7. Do you agree with Democritus that atoms are "small, hard particles"? Why or why not?
8. **Hypothesize:** What kind of information might be available to scientists today that would lead them to disagree with Dalton's atomic theory?

InfoSearch

Read the passage. Ask two questions about the topic that you cannot answer from the information in the passage.

STM Atoms are too small to be seen except with the most powerful microscopes. These microscopes are called scanning-tunneling microscopes, or STMs. This type of microscope uses electrons instead of light to observe atoms. STMs have also been used to move individual atoms from place to place on a surface.

SEARCH: Use library references to find answers to your questions.

TECHNOLOGY AND SOCIETY

PARTICLE ACCELERATORS

A particle accelerator is a device for increasing the energy of electrically charged particles. Once their energy is increased, the particles can be shot at atoms. At very high speeds, these charged particles smash into atoms and break them up. Then scientists can study the pieces that are left after the collision.

Scientists use particle accelerators to study the forces that hold matter together. The machines speed up particles and race them around and around giant circular tracks. Many accelerators have one group of particles moving in one direction and another group moving in the other direction. When the particles are traveling fast enough, they are made to crash head-on. From their work with accelerators, scientists learn information that helps them design new materials, including crystals and superconductors.

Particle accelerators are among the largest scientific instruments ever built. In Batavia, Illinois, a particle accelerator called the Tevatron is built around a 6.4-kilometer circular track. A particle accelerator in Switzerland is built in a circular underground tunnel that is 27 kilometers long.

14-2 What are the parts of an atom?

Objective ▸ Name the three basic parts of an atom.

TechTerms

- **electron:** negatively charged particle
- **neutron:** neutral particle
- **nucleus:** center, or core, of an atom
- **proton:** positively charged particle

Structure of an Atom According to modern atomic theory, an atom has a center, or core, called the **nucleus.** In the nucleus are **protons** and **neutrons.** Protons are positively charged particles. Neutrons are neutral particles. Surrounding the nucleus is a cloud of very small particles called **electrons.** Electrons are negatively charged particles.

List: What are the three types of particles in an atom?

Thomson's Model The first scientist to suggest that atoms contain smaller particles was J. J. Thomson of England. In 1897, Thomson passed an electric current through a gas. He found that the gas gave off rays made of negatively charged particles. Today, these particles are known as electrons. Because atoms are neutral, Thomson reasoned that there must also be positively charged particles in an atom. Thomson hypothesized that an atom was made up of a positively charged material with electrons scattered evenly throughout.

Identify: What type of particles did Thomson discover in atoms?

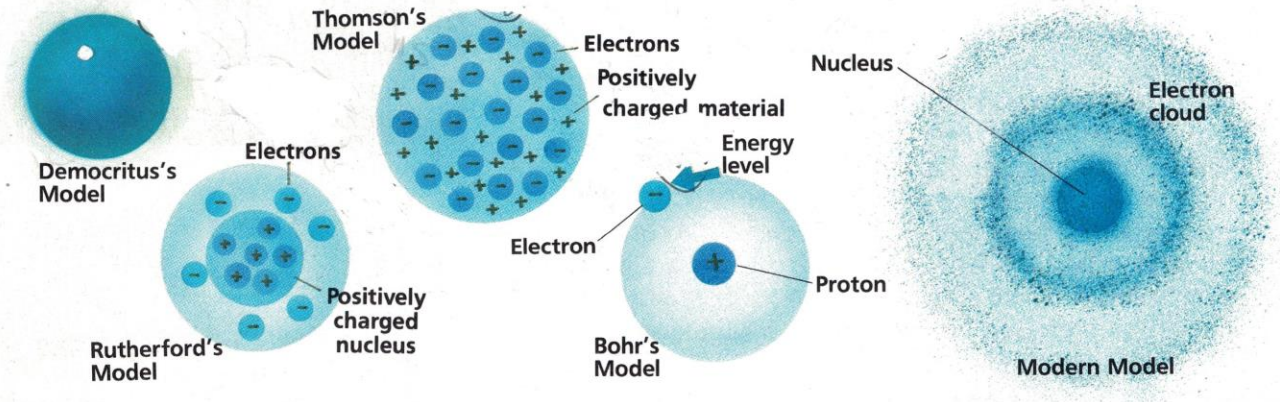
Rutherford's Model In 1908, a scientist from New Zealand named Ernest Rutherford performed an experiment to test Thomson's atomic model. Rutherford discovered that an atom is mostly empty space. He concluded that the protons are contained in a small central core. Rutherford called this core the nucleus.

Describe: What did Rutherford discover about an atom?

Bohr's Model Rutherford's model of the atom did not explain the arrangement of electrons. In 1913, the Danish scientist Neils Bohr proposed that electrons in an atom are found in energy levels. Each energy level is at a certain distance from the nucleus. Electrons in different energy levels move around the nucleus in different orbits, much as the planets move in orbits around the sun.

Scientists now know that the exact location of an electron cannot be predicted. Instead, energy levels are used to predict the place where an electron is most likely to be found outside the nucleus. This area is often called the electron cloud.

Locate: Where did Bohr say that electrons are found in an atom?



LESSON SUMMARY

- Atoms are made up of protons, neutrons, and electrons.
- The first scientist to suggest that atoms contain smaller particles was J. J. Thomson.
- Ernest Rutherford proposed that an atom is mostly empty space with a small nucleus at the center.
- Neils Bohr proposed that electrons occupy specific energy levels as they orbit the nucleus of an atom.

CHECK *Complete the following.*

1. What are electrons?
2. Where are protons found in an atom?
3. What are the neutral particles in an atom called?
4. Who first suggested that atoms are made up of smaller particles?
5. Who discovered that an atom is mostly empty space?
6. Who said that electrons are found in energy levels around the nucleus?

APPLY *Complete the following.*

7. **Contrast:** How did Rutherford's model of the atom differ from Thomson's model?
8. Suppose that you could look at the electrons in a hydrogen atom, an oxygen atom, and a carbon atom. What would the electrons look like?

Skill Builder

Analyzing In his experiment to test Thomson's model of the atom, Ernest Rutherford shot positively charged particles at a sheet of gold foil. The foil was only a few atoms thick. Rutherford observed that most of the particles went right through the foil. A few particles were deflected, or bent away, from the foil. A few particles bounced straight back from the foil. How did these results help Rutherford reach the following conclusions? (Hint: Remember that like charges repel each other.)

a. Most of an atom is empty space.
b. An atom has a dense nucleus in the center.
c. The nucleus is positively charged.

SCIENCE CONNECTION

QUARKS AND LEPTONS

In recent years, scientists have discovered that protons, neutrons, and electrons are made up of even smaller particles. Based on experiments using particle accelerators, scientists have identified two groups of subatomic particles. All matter is made up of these particles. These groups of particles are known as quarks (KWORKZ) and leptons (LEP-tahnz). The word "quark" was first used as the name of a subatomic particle by the American physicist Murray Gell-Mann. The word was invented by the writer James Joyce in his book *Finnegans Wake.* The word "lepton" comes from a Greek word that means "small" or "thin."

Quarks make up protons, neutrons, and other particles found in the nucleus of an atom. Leptons make up electrons. They also make up other particles called neutrinos (noo-TREE-nohz) and muons (MYOO-ahnz). There are six types of quarks and six types of leptons. Scientists have named the six types of quarks. Their names are strange, charm, up, down, top, and bottom. The basic particles in an atom are made up of combinations of two or three different quarks or leptons.

14-3 What is atomic number?

Objective ▸ Explain what is meant by the atomic number of an element.

TechTerm

- **atomic number:** number of protons in the nucleus of an atom

Elements and Atomic Number Atoms of different elements have different numbers of protons. The number of protons found in the nucleus of an atom is called the **atomic number.** The atoms of each element are different because each element has a different atomic number.

Define: What is atomic number?

Importance of Atomic Number The atomic number of an element is very important, because it identifies that element. No two elements have the same atomic number. Recall that the elements are arranged in order of increasing atomic number in the Periodic Table. The element with the smallest atomic number is hydrogen. Hydrogen has an atomic number of 1. This means that a hydrogen atom has one proton in its nucleus. Oxygen has an atomic number of 8. Gold has much larger atoms than either hydrogen or oxygen. Gold has an atomic number of 79. Table 1 lists the atomic numbers of some common elements.

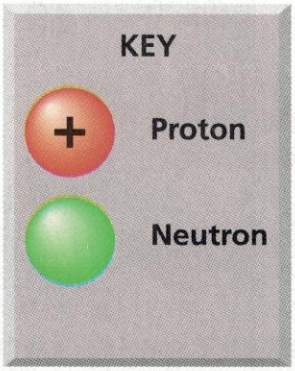
Infer: How many protons are there in the nucleus of a gold atom?

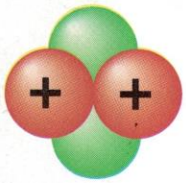
Table 1 **Atomic Numbers of Common Elements**

ELEMENT	SYMBOL	ATOMIC NUMBER
Hydrogen	H	1
Helium	He	2
Carbon	C	6
Nitrogen	N	7
Oxygen	O	8
Sodium	Na	11
Aluminum	Al	13
Sulfur	S	16
Chlorine	Cl	17
Calcium	Ca	20
Iron	Fe	26
Copper	Cu	29
Silver	Ag	47
Gold	Au	79
Lead	Pb	82

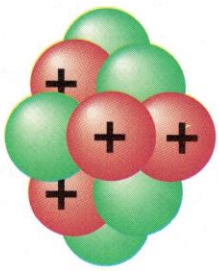
Atomic Number and Electrons If you know the atomic number of an element, you can find the number of electrons in an atom of that element. An atom is neutral. It has neither a positive nor a negative charge. In order for an atom to be neutral, the number of electrons must equal the number of protons. The positive and negative charges cancel each other. So the number of electrons is always equal to the atomic number, or the number of protons.

Calculate: How many electrons are there in an atom of an element with atomic number 14?

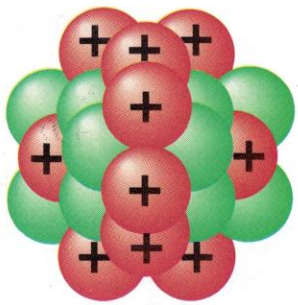




Helium
Atomic number = 2



Beryllium
Atomic number = 4



Neon
Atomic number = 10

LESSON SUMMARY

- The atomic number is the number of protons in the nucleus of an atom.
- Every element has its own atomic number which identifies that element.
- Because an atom is neutral, the number of electrons is equal to the number of protons.

CHECK *Complete the following.*

1. The atomic number is the number of _____ in the nucleus of an atom.
2. Every _____ has its own atomic number.
3. Elements are arranged in order of increasing atomic number in the _____ .
4. If an atom of an element contains 12 protons and 12 electrons, the atomic number of that element is _____ .
5. An atom is _____ because the negative charges and the positive charges cancel.
6. The number of protons in an atom is equal to the number of _____ .

APPLY *Use Table 1 on page 262 to identify each of the following elements.*

7. Atoms of this element contain 17 protons.
8. This element has an atomic number of 20.
9. The atoms of this element have 8 protons and 8 electrons.
10. An atom of this element has 10 more protons than an atom of sulfur.

Complete the following.

11. **Analyze:** What is wrong with this statement? An atom of iron contains 13 protons and 13 electrons.

Skill Builder

Interpreting a Chart Use the Periodic Table on pages 234–235 to answer the following questions.

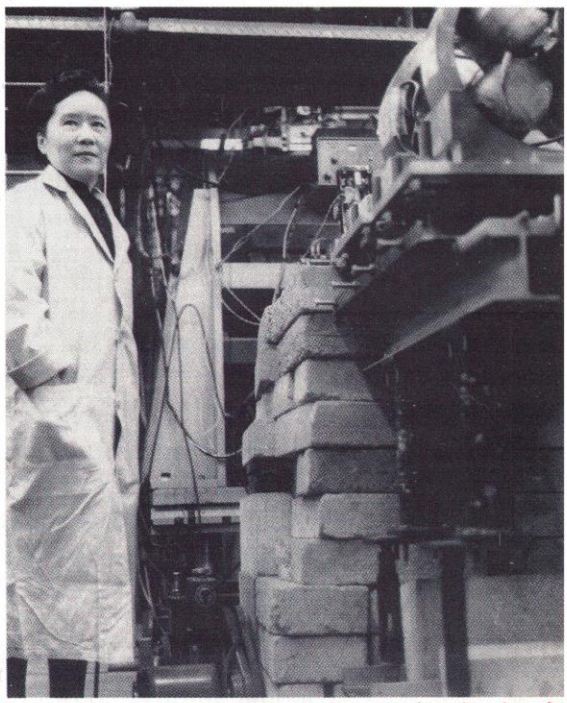
1. What is the atomic number of copper?
2. How many protons are there in an atom of chromium?
3. How many electrons are there in an atom of silicon?
4. What are the atomic numbers of the first three elements in Group 1?
5. In which group is the element with the highest known atomic number found? What is the atomic number of this element?

PEOPLE IN SCIENCE

CHIEN-SHIUNG WU (1912–1997)

Chien-Shiung Wu was born in Liu Ho, China. She was a theoretical physicist. Chien-Shiung Wu came to America in 1936 to study for a doctorate in physics. She received her Ph.D. from the University of California at Berkeley. During World War II, she taught physics at Smith College and at Princeton University. After the war, she went to Columbia University to do research in nuclear physics. She became a professor of physics at Columbia in 1957.

Chien-Shiung Wu's area of specialization was beta decay. Beta decay is a form of radioactivity. In beta decay, the nucleus of an atom gives off electrons. This causes the atom to change into another element. Chien-Shiung Wu made many important contributions to scientists' present knowledge of the atom. Her experiments on beta decay confirmed a theory proposed by two other scientists. These scientists, Tsung Dao Lee and Chen Ning Yang, later won a Nobel Prize for their theory. Chien-Shiung Wu was the first woman to receive the Comstock Prize from the National Academy of Sciences.



14-4 What is atomic mass?

Objective ▸ Explain how to find the atomic mass and mass number of an atom.

TechTerms

- **atomic mass:** total mass of the protons and neutrons in an atom, measured in atomic mass units
- **mass number:** number of protons and neutrons in the nucleus of an atom

Mass of an Atom The mass of an atom is very small. Scientists cannot measure the mass of an atom in grams. In order to measure the mass of an atom, scientist have developed a special unit. This unit is called the atomic mass unit, or amu. One amu is equal to the mass of one proton. Neutrons and protons have the same mass. Therefore, one amu is also equal to the mass of one neutron. The mass of an electron is equal to 1/1836 amu. Because electrons are so small, only the masses of protons and neutrons are used to find the mass of an atom.

Infer: What is the mass, in amu, of an atom with one proton and two neutrons?

Atomic Mass Because atoms of different elements have different numbers of protons and neutrons, they also have different masses. The total mass of the protons and neutrons in an atom is called the **atomic mass.** Atomic mass is measured in atomic mass units.

Define: What is atomic mass?

Mass Number The total number of protons and neutrons in the nucleus of an atom is called the **mass number.** Each element has its own mass number. The mass number is equal to the atomic mass rounded off to the nearest whole number. You can find the number of neutrons in an atom by using this formula:

neutrons = mass number (protons + neutrons) − atomic number (protons)

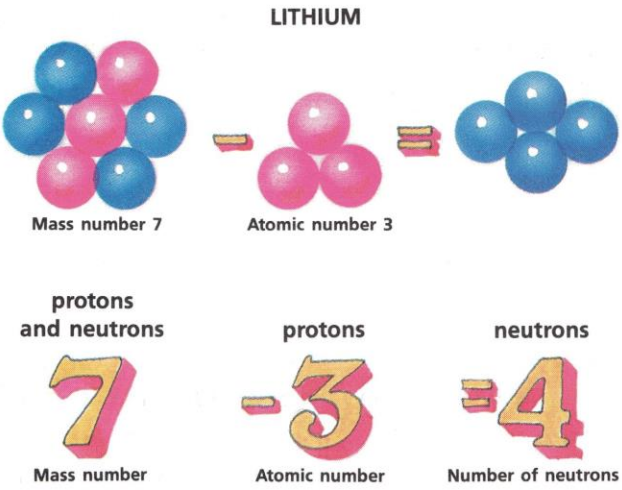


Table 1 lists the atomic numbers and mass numbers of some common elements. You can use this information to determine the number of protons, neutrons, and electrons in an atom of an element.

Table 1 **Atomic Number and Mass Number**

ELEMENT	SYMBOL	ATOMIC NUMBER	MASS NUMBER
Hydrogen	H	1	1
Helium	He	2	4
Carbon	C	6	12
Nitrogen	N	7	14
Oxygen	O	8	16
Sodium	Na	11	23
Aluminum	Al	13	27
Sulfur	S	16	32
Chlorine	Cl	17	35
Calcium	Ca	20	40
Iron	Fe	26	56
Copper	Cu	29	64
Silver	Ag	47	108
Gold	Au	79	197
Lead	Pb	82	207

Analyze: How many neutrons are in the nucleus of an atom of chlorine?

14-5 What are isotopes?

Objectives ▸ Explain what an isotope of an element is. ▸ Compare the three isotopes of hydrogen.

TechTerm

- **isotope** (Y-suh-tohp): atom of an element with the same number of protons but a different number of neutrons

Different Atomic Masses The atomic number of an element never changes. All atoms of the same element have the same atomic number. Thus, all atoms of an element have the same number of protons in the nucleus. However, all atoms of the same element may not have the same atomic mass. The difference in atomic mass is caused by a different number of neutrons in the nuclei of the atoms.

State: What causes atoms of the same element to have different atomic masses?

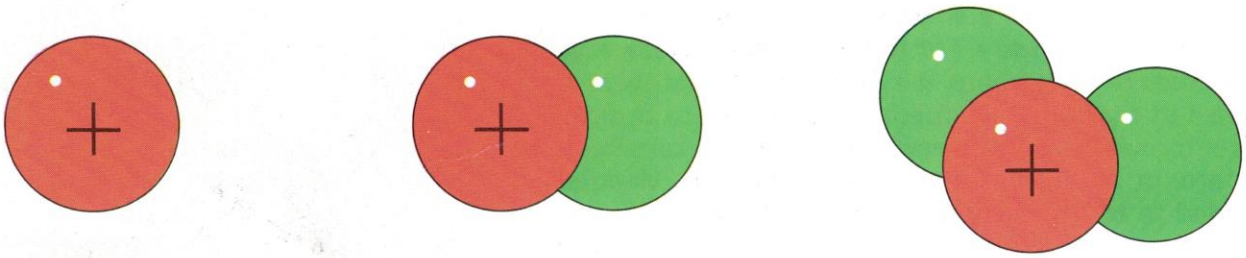
Isotopes Atoms of the same element that have different atomic masses are called **isotopes** (Y-suh-tohps). An isotope is an atom of an element with the same number of protons but a different number of neutrons. The Periodic Table of the Elements gives the mass number of the most common isotope of an element. The atomic mass of an element is an average of the atomic masses of all the isotopes of the element. That is why an element's atomic mass is not a whole number.

Define: What is an isotope?

Isotopes of Common Elements Most elements have two or more isotopes. An example of an element with three isotopes is hydrogen. The three isotopes of hydrogen are known as hydrogen-1, hydrogen-2, and hydrogen-3. The numbers 1, 2, and 3 represent the mass numbers of the isotopes. Sometimes the three isotopes of hydrogen are called protium (PROHT-ee-um), deuterium (doo-TIR-ee-um), and tritium (TRIT-ee-um). An atom of hydrogen-1 has only one proton and no neutrons in its nucleus. An atom of hydrogen-2 has one proton and one neutron. An atom of hydrogen-3 has one proton and two neutrons. The only difference among the three isotopes is the number of neutrons.

Other familiar elements that have isotopes include carbon, nitrogen, and uranium. Two isotopes of carbon are carbon-12 and carbon-14, or C-12 and C-14. Nitrogen-15 is an isotope of nitrogen. Two important isotopes of uranium are U-235 and U-238.

List: What are the three isotopes of hydrogen called?



Isotopes of hydrogen

LESSON SUMMARY

- The mass of an atom is measured in atomic mass units, or amu.
- The total mass of the protons and neutrons in an atom is the atomic mass.
- The mass number of an element is equal to the number of protons and neutrons in the nucleus of an atom of that element.
- The number of neutrons in an atom can be found by subtracting the atomic number from the mass number.

CHECK *Write true if the statement is true. If the statement is false, change the underlined term to make the statement true.*

1. The mass of a <u>neutron</u> is the same as the mass of a proton.
2. Because they are so small, <u>neutrons</u> are not counted when measuring the mass of an atom.
3. The <u>gram</u> is the unit used by scientists to measure the mass of an atom.
4. The <u>mass number</u> tells the number of protons and neutrons in the nucleus of an atom.
5. If the atomic number of an element is 8 and the mass number is 16, the number of neutrons in an atom of that element is <u>24</u>.

APPLY *Complete the following.*

6. **Calculate:** The atomic number of element X is 30 and the mass number is 65. Find the number of protons, neutrons, and electrons in an atom of element X.
7. **Hypothesize:** A few of the heavier elements have the same mass number. How is this possible, if no two elements have the same atomic number?

Skill Builder

Interpreting a Table Use Table 1 on page 264 to answer the following questions.

a. Which element has no neutrons in the nuclei of its atoms?

b. Which element has atoms containing 20 electrons and 20 neutrons?

c. Which element has 30 neutrons in its atoms?

d. Which elements have atoms with the same number of neutrons as protons? How can you tell?

e. Can atoms of different elements contain the same number of protons? Explain.

PEOPLE IN SCIENCE

DMITRI MENDELEEV (1834–1907)

Dmitri Mendeleev (men-duh-LAY-uf) was a Russian chemist. He was a professor of chemistry at St. Petersburg University. Mendeleev also held the important position of Director of the Bureau of Weights and Measures.

Mendeleev is best known for developing the first periodic table of the elements. He wrote a book called *Principles of Chemistry.* For this book, Mendeleev collected thousands of facts about the 63 elements that were known at that time. He tried to find a way to organize this information. Mendeleev thought that a certain pattern, or order, of the elements must exist. Mendeleev decided to test his hypothesis. He wrote the name of each element and the properties of that element on an index card. Then he tried different arrangements of the cards for the 63 elements. When he arranged the cards in order of increasing atomic mass, the elements fell into groups with similar properties.

LESSON SUMMARY

- Different atoms of the same element may have different atomic masses.
- Atoms of the same element that have different numbers of neutrons are called isotopes.
- Most elements have two or more isotopes.

CHECK *Find the sentence in the lesson that answers each question. Then write the sentence.*

1. What causes some atoms of the same element to have different atomic masses?
2. What is an isotope?
3. How many isotopes do most elements have?
4. What are some familiar elements that have isotopes?

APPLY *Complete the following.*

5. How many neutrons are there in an atom of hydrogen-1? Of hydrogen-2? Of hydrogen-3?
6. Why is the atomic mass of an element not a whole number?
7. **Calculate:** The atomic number of carbon is 6. How many protons and neutrons are there in an atom of carbon-12? Of carbon-14?
8. **Analyze:** The mass number of oxygen is 16. Its atomic mass is 15.999. The atomic number of oxygen is 8. Which of the following statements about the isotopes of oxygen are true? Why?
   a. All of the isotopes have 8 neutrons.
   b. All of the isotopes have 8 or more neutrons.
   c. Some of the isotopes have fewer than 8 neutrons.
   d. All of the isotopes have fewer than 8 neutrons.

InfoSearch

Read the passage. Ask two questions about the topic that you cannot answer from the information in the passage.

Radioisotopes Some isotopes of certain elements give off particles or rays. These isotopes are called radioactive isotopes, or radioisotopes. Radioisotopes are very useful in medicine. They are helpful in diagnosing cancer. They are also used to treat cancer with radiation therapy.

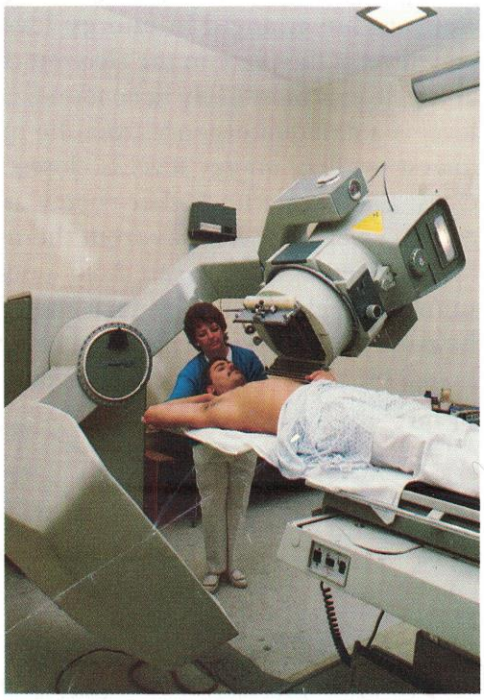
SEARCH: Use library references to find answers to your questions.

CAREER IN PHYSICAL SCIENCE

RADIATION THERAPIST

Radiation therapy is an important form of cancer treatment. People who give radiation therapy to cancer patients are called radiation therapists. Radiation therapists prepare patients for treatment, position the patient properly under radiation equipment, and then operate the equipment. Radiation therapy can produce harmful side effects. For this reason, radiation therapists must watch a patient's reactions closely and keep doctors informed of the patient's condition. Radiation therapists must also follow important safety measures. Radioactive substances must be handled with great care.

Most radiation therapists work in hospitals. Others work in doctors' offices, clinics, and laboratories. Many part-time jobs are also available in this field. To become a radiation therapist, a person must finish high school and complete a training program in radiation therapy. Training programs are offered by hospitals, vocational or technical schools, and colleges and universities.



14-6 How are electrons arranged in an atom?

Objective ▸ Describe how the electrons in an atom are arranged in energy levels.

TechTerm

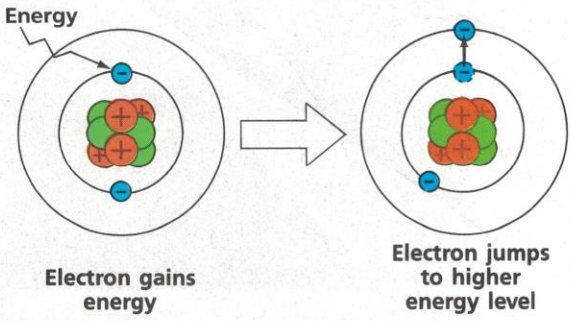
- **energy level:** place in an atom where an electron is most likely to be found

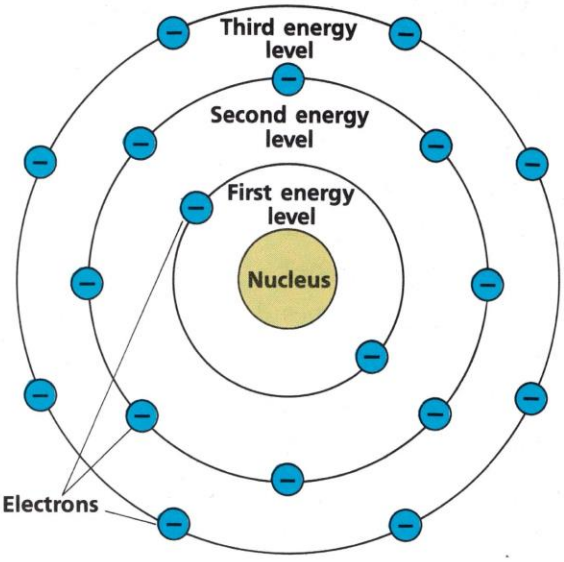
Electron Cloud Model For many years, scientists thought that electrons circled the nucleus of an atom in much the same way as planets orbit the sun. Scientists now know that it is not possible to predict the exact path of an electron. The area in an atom where electrons are likely to be found is often called the electron cloud. Scientists use the word "cloud" because they know that they cannot predict the exact location of electrons at any given time. The electron cloud is often compared to bees buzzing around a beehive.

Describe: What is the electron cloud?

Energy Levels In the modern atomic theory, electrons are arranged in **energy levels.** An energy level is the place in the electron cloud where an electron is most likely to be found. Each energy level is a different distance from the nucleus. The lowest, or first, energy level is closest to the nucleus. Electrons with higher energy are found in energy levels farther away from the nucleus.

Each energy level can hold only a certain number of electrons. The first energy level can hold only 2 electrons. The second energy level can hold 8 electrons. Energy levels beyond the second



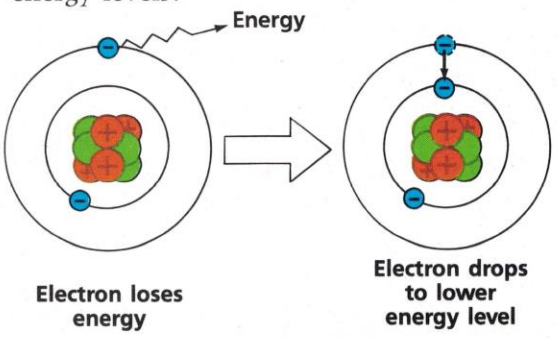


level can hold up to 32 electrons. For the first 20 elements, the electrons in an atom of an element fill up the energy levels in order, beginning with the lowest. An atom of helium has 2 electrons. These 2 electrons fill the first energy level. An atom of lithium has 3 electrons. Two of these electrons fill the first energy level. The third electron occupies the second energy level.

Predict: Where would you expect to find the 6 electrons in an atom of carbon?

Changing Energy Levels Electrons can move from one energy level to another. If an electron gains enough energy, it jumps to a higher energy level. If an electron loses enough energy, it drops back to a lower energy level.

Analyze: What causes an electron to change energy levels?



LESSON SUMMARY

- The area in an atom where electrons are likely to be found is called the electron cloud.
- An energy level is the place in the electron cloud where an electron is most likely to be found.
- Each energy level in an atom can hold a certain number of electrons.
- An electron can change energy levels if it gains or loses a certain amount of energy.

CHECK *Complete the following.*

1. The term _____ refers to the area in an atom where electrons are likely to be found.
2. An energy level is the place where an _____ is most likely to be found in an atom.
3. The _____ energy level is located closest to the nucleus of an atom.
4. The second energy level can hold _____ electrons.
5. Some energy levels far from the nucleus can hold up to _____ electrons.
6. An electron will drop to a lower energy level when it _____ energy.

APPLY *Complete the following.*

7. **Analyze:** The atoms of a certain element have the first and second energy levels filled with electrons. What is the atomic number of this element? How can you tell?
8. **Infer:** What is the relationship between the amount of energy that an electron has and its distance from the nucleus of an atom?

InfoSearch

Read the passage. Ask two questions about the topic that you cannot answer from the information in the passage.

Orbitals Energy levels of an atom are divided into sublevels called orbitals. Orbitals can be thought of as more specific areas in which electrons are likely to be found. The first energy level has only one orbital, called an s orbital. The shape of an s orbital is a sphere. The second and third energy levels have one s orbital and three p orbitals. The p orbitals are dumbbell-shaped. Each orbital can hold a maximum of two electrons. These electrons must have opposite spins.

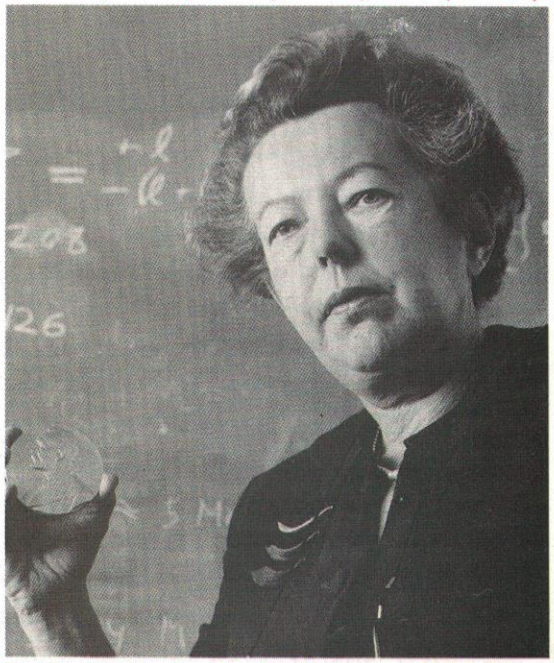
SEARCH: Use library references to find answers to your questions.

PEOPLE IN SCIENCE

MARIA GOEPPERT MAYER (1906–1972)

Maria Goeppert Mayer came from a German family with seven generations of university professors. She received her doctorate at the age of 24. Goeppert Mayer had to study for the exams by herself, because the only school that prepared women for the university had closed.

Maria Goeppert Mayer worked with some of the most important physicists and chemists of the twentieth century, including the famous German physicist Max Born. Born's work helped describe the structure of atoms and the motion of atomic particles. Goeppert Mayer was interested in atomic structure. She proposed a shell model for the nucleus of the atom. For this work, she won a Nobel Prize in 1963. Maria Goeppert Mayer was the second woman in history to win a Nobel Prize in physics. At the time of her death in 1972, Maria Goeppert Mayer was on the faculty of the University of California at San Diego.



UNIT 14 Challenges

STUDY HINT Before you begin the Unit Challenges, review the TechTerms and Lesson Summary for each lesson in this unit.

TechTerms

atom (258)
atomic mass (264)
atomic number (262)
electron (260)
energy level (268)
isotope (266)
mass number (264)
neutron (260)
nucleus (260)
proton (260)

TechTerm Challenges

Matching *Write the TechTerm that matches each description.*

1. number of protons and neutrons in the nucleus of an atom
2. negatively charged particle in an atom
3. number of protons in the nucleus of an atom
4. positively charged particle in an atom
5. place where an electron is most likely to be found
6. smallest part of an element
7. neutral particle in the nucleus of an atom
8. has the same number of protons but a different number of neutrons

Fill In *Write the TechTerm that best completes each statement.*

1. The small, dense core of an atom is called the _____ .
2. A proton and a _____ have the same mass.
3. The _____ of an element is an average of all the isotopes of that element.
4. You can find the number of neutrons in an atom by subtracting the atomic number from the _____ .
5. The mass of an _____ is only 1/1836 amu.
6. Every neutral atom has the same number of _____ and electrons.

Content Challenges

Multiple Choice *Write the letter of the term or phrase that best completes each statement.*

1. The first person to suggest that matter is made up of atoms was
   a. Dalton. **b.** Rutherford. **c.** Democritus. **d.** Bohr.
2. The Greeks believed all of the following about atoms except that
   a. atoms are small. **b.** atoms are always moving. **c.** atoms can be joined together. **d.** atoms contain smaller particles.
3. In the early 1800s, an atomic theory of matter was developed by
   a. Democritus. **b.** Dalton. **c.** Rutherford. **d.** Thomson.
4. The first scientist to discover that atoms contain smaller particles was
   a. Thomson. **b.** Rutherford. **c.** Bohr. **d.** Dalton.
5. J. J. Thomson pictured atoms as being made up mostly of
   a. empty space. **b.** positively charged material. **c.** electrons. **d.** the nucleus.
6. Rutherford's model of the atom included
   a. a small, dense nucleus. **b.** a positive material studded with electrons. **c.** energy levels for electrons. **d.** neutrons.