chapter 16

Properties of Atoms and the Periodic Table

section 2 Masses of Atoms

What You'll Learn

- the difference between the atomic mass and the mass number of an atom
- how to identify components of isotopes
- how to interpret the average atomic mass of an element

Before You Read

Which metric unit do you use to measure the amount of gas that a car's gas tank holds? Which metric unit would you use to measure the distance to the next town? Explain why you would use these units and not smaller units.

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Mark the Text

Highlight As you read the text under each heading, highlight the main ideas. After you finish reading the section, review the highlighted main ideas to help you learn the important topics of the section.

Read to Learn

Atomic Mass

Neutrons and protons are much more massive than electrons. Since the nucleus contains the neutrons and protons, it contains most of the mass of an atom. The mass of a proton is about the same as the mass of a neutron—about 1.67×10^{-24} g, as shown in the table. The mass of a proton or a neutron is about 1,800 times greater than the mass of an electron. The mass of an electron is so small that it is not even considered when finding the mass of an atom.

Subatomic Particle Masses

Particle	Mass (g)
Proton	1.6726×10^{-24}
Neutron	1.6749×10^{-24}
Electron	9.1093×10^{-28}

Applying Math

1. **Comparing Decimals** Which has a larger mass, a proton or a neutron?

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What is the atomic mass unit?

What unit would you use to estimate the height of your school building? Kilometers would be difficult to use. You probably would use a more appropriate unit, such as meters. Just as the kilometer is not the right unit for measuring the height of a building, scientists found that the gram was not the right unit for measuring the mass of an atom.

A useful unit gives numbers that are easy to work with. The unit used for measuring atomic particles is called the atomic mass unit (amu). The mass of a proton or neutron is almost equal to 1 amu. This is not a coincidence. The amu was defined that way. The amu is one-twelfth the mass of a carbon atom. A carbon atom contains six protons and six neutrons, or twelve particles. Since most of the mass of an atom is in the nucleus, each proton and neutron has a mass nearly equal to 1 amu.

How do protons identify elements?

Remember that atoms of different elements have different numbers of protons. In fact, the number of protons tells you what type of atom you have and vice versa. For example, every carbon atom has six protons. Also, every atom with six protons is carbon.

The **atomic number** of an element is the number of protons in an atom of the element. Since carbon has six protons, the atomic number of carbon is six. If you are given any one of the following for an element—its name, number of protons, or atomic number—you can find the other two.

What is the mass number?

The **mass number** of an atom is the sum of the number of protons and the number of neutrons in the nucleus of an atom. The table below shows this.

Mass Numbers of Some Atoms

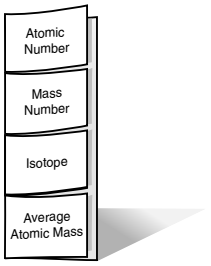
Element	Symbol	Atomic Number	Protons	Neutrons	Mass Number	Average Atomic Mass*
Boron	B	5	5	6	11	10.81 amu
Carbon	C	6	6	6	12	12.01 amu
Oxygen	O	8	8	8		16.00 amu
Sodium	Na	11	11	12		22.99 amu
Copper	Cu	29	29	34		63.55 amu

*The atomic mass units are rounded to two decimal places.

FOLDABLES™

B Find the Main Idea

Make the following Foldable to help take notes on the main ideas from this section.



Picture This

2. **Complete** the table by finding the mass numbers for oxygen, sodium, and copper.

Applying Math

3. **Apply** The element uranium has a mass number of 238, and an atomic number of 92. How many neutrons does an atom of uranium have?

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How is the number of neutrons found?

If you know the mass number and atomic number of an atom, you can find the number of neutrons it contains.

number of neutrons = mass number − atomic number

Atoms of the same element with different numbers of neutrons can have different properties. For example, carbon with a mass number of 12 is called carbon-12. Carbon-14, with a mass number of 14 is radioactive. Carbon-12 is not radioactive.

Isotopes

Not all atoms of an element have the same number of neutrons. Atoms of the same element that have different numbers of neutrons are called **isotopes**. For example, boron atoms can have mass numbers of 10 or 11. To find the number of neutrons in an isotope, you can use the formula above. Look at the table on the previous page. Notice that boron has an atomic number of five. That means it has five protons. Substitute these numbers into the formula to get $11 - 5 = 6$ and $10 - 5 = 5$. So, boron isotopes have either five or six neutrons.

Think it Over

4. **Determine** What is the same in two isotopes of an element? What is different?

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How can isotopes be used?

Atoms can be used to find the age of bones and rocks that are millions of years old. Radioactive isotopes release nuclear particles and energy as they decay into another element. The time it takes for half of the radioactive isotopes in a piece of rock or bone to change into another element is called its half life. Scientists use half lives of radioactive isotopes to measure time.

The table below lists the half-lives of some radioactive elements. It also lists the elements that the radioactive elements decay into. For example, it would take 5,715 years for half of the carbon-14 atoms in a rock to change into atoms of nitrogen-14. After another 5,715 years, half of the remaining carbon-14 atoms will change, and so on. These radioactive "clocks" can be used to measure different periods of time.

Half-Lives of Radioactive Isotope

Radioactive Element	Changes to This Element	Half-Life
uranium-238	lead-206	4,460 million years
potassium-40	argon-40, calcium-40	1,260 million years
rubidium-87	strontium-87	48,800 million years
carbon-14	nitrogen-14	5,715 years

Picture This

5. **Apply** How many years would it take half of the atoms in uranium-238 to change into lead-206?

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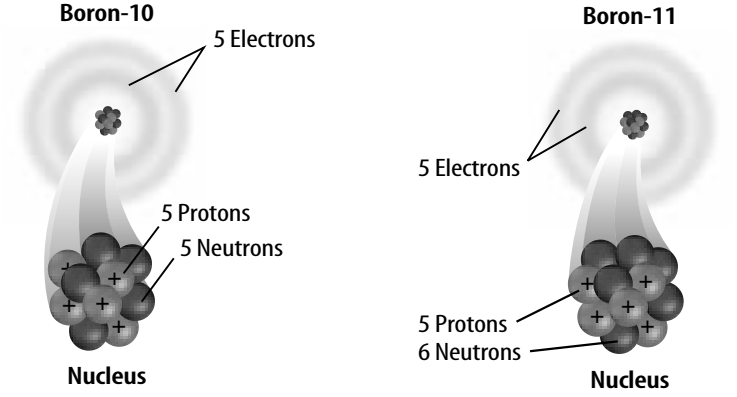
How do you identify isotopes?

The figure shows models of the two isotopes of boron. Because the numbers of neutrons in the isotopes is different, their mass numbers are different. To identify an isotope, use the name of the element followed by the mass number of the element. For example, the isotopes of boron are boron-10 and boron-11, because boron isotopes have mass numbers of either 10 or 11.



Most elements have more than one isotope. Because of this, each element has an average atomic mass. The **average atomic mass** of an element is the weighted-average mass of the mixture of its isotopes. For example, four out of five atoms of boron are boron-11. That means one out of five atoms is boron-10. To find the average atomic mass of boron, solve the following equation:

$$\frac{4}{5}(11\text{ amu}) + \frac{1}{5}(10\text{ amu}) = 10.8\text{ amu}$$

The average atomic mass of boron is 10.8 amu. You round the average atomic mass to the nearest whole number to find the most abundant isotope of an atom. For example, the average atomic mass of boron, 10.8, rounds to 11. So, the most abundant isotope of boron is boron-11.

Picture This

6. Draw and Label Carbon-12 is an isotope with 6 protons and 6 neutrons. Draw a model of carbon-12. Label the protons and neutrons.

Applying Math

7. Apply The element magnesium has an average atomic mass of 24.305. What is the most abundant isotope of magnesium?

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After You Read

Mini Glossary

atomic number: a number equal to the number of protons in an atom

average atomic mass: the weighted-average mass of the mixture of isotopes of an element

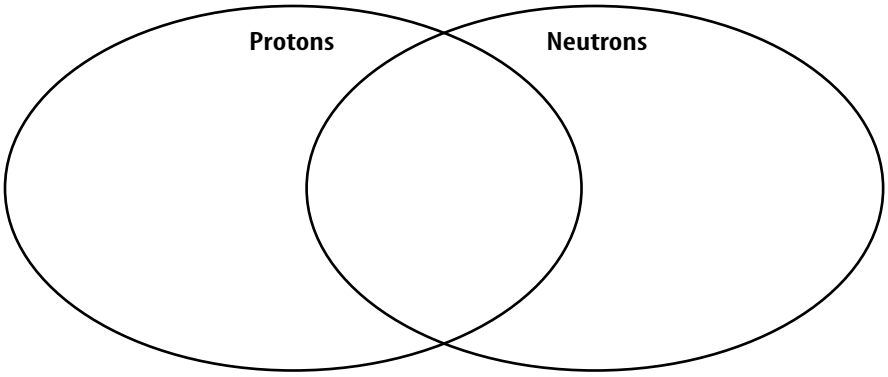
isotopes: atoms of the same element that have different numbers of neutrons

mass number: the sum of the number of protons and the number of neutrons in an atom

1. Review the terms and their definitions in the Mini Glossary. How can you find the number of protons and neutrons in an atom of an element from the atomic number and the mass number?

2. Complete the Venn diagram by writing the given phrases in the correct area.

- determines which isotope
- equals the atomic number
- equals the mass number



3. Mark the Text Tell how you could use a set of red and blue marbles to teach a friend about the atomic number and mass number of an element.

End of Section