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17 Unit 4: The Nature of Matter

Chapter 17: Properties of Atoms and the Periodic Table

17.1: Structure of the Atom

17.2: Masses of Atoms

17.3: The Periodic Table

CHAPTER RESOURCES

END

Structure of the Atom

17.1 Scientific Shorthand

- Scientists have developed their own shorthand for dealing with long, complicated names.
- Chemical symbols consist of one capital letter or a capital letter plus one or two smaller letters.

Symbols of Some Elements			
Element	Symbol	Element	Symbol
Aluminum	Al	Iron	Fe
Calcium	Ca	Mercury	Hg
Carbon	C	Nitrogen	N
Chlorine	Cl	Oxygen	O
Gold	Au	Potassium	K
Hydrogen	H	Sodium	Na

CHAPTER RESOURCES

END

Structure of the Atom

17.1 Scientific Shorthand

- For some elements, the symbol is the first letter of the element's name.
- For other elements, the symbol is the first letter of the name plus another letter from its name.
- Because scientists worldwide use this system, everyone understands what the symbols mean.

CHAPTER RESOURCES

END

Structure of the Atom

17.1 Atomic Components

- An element is matter that is composed of one type of **atom**, which is the smallest piece of matter that still retains the property of the element.
- Atoms are composed of particles called protons, neutrons, and electrons.

Click image to view movie

CHAPTER RESOURCES

END

Structure of the Atom

17.1 Atomic Components

- Protons and neutrons are found in a small positively charged center of the atom called the **nucleus** that is surrounded by a cloud containing electrons.
- Protons** are particles with an electrical charge of  $1+$ .

Electron cloud

Nucleus

Atom

Neutron (No charge)

Proton (1+ charge)

Quarks

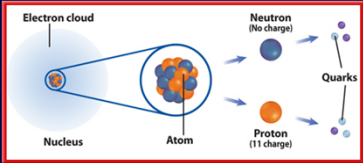
CHAPTER RESOURCES

END

Structure of the Atom

17.1 **Atomic Components**

- **Electrons** are particles with an electrical charge of  $1-$ .
- **Neutrons** are neutral particles that do not have an electrical charge.



Electron cloud

Nucleus

Atom

Neutron (No charge)

Proton (11 charge)

Quarks

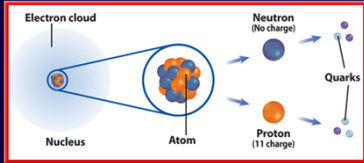
CHAPTER RESOURCES

END

Structure of the Atom

17.1 **Quarks—Even Smaller Particles**

- Protons and neutrons are made up of smaller particles called quarks.
- So far, scientists have confirmed the existence of six uniquely different quarks.



Electron cloud

Nucleus

Atom

Neutron (No charge)

Proton (11 charge)

Quarks

CHAPTER RESOURCES

END

Structure of the Atom

17.1 **Quarks—Even Smaller Particles**

- Scientists theorize that an arrangement of three quarks held together with the strong nuclear force produces a proton.
- Another arrangement of three quarks produces a neutron

CHAPTER RESOURCES

END

Structure of the Atom

17.1 **Finding Quarks**

- To study quarks, scientists accelerate charge particles to tremendous speeds and then force them to collide with—or smash into—protons. This collision causes the proton to break apart.
- The particles that result from the collision can be detected by various collection devices.

CHAPTER RESOURCES

END

Structure of the Atom

17.1 **The Sixth Quark**

- Scientists found five quarks and hypothesized that a sixth quark existed. However, it took a team of nearly 450 scientists from around the world several years to find the sixth quark.
- The tracks of the sixth quark were hard to detect because only about one billionth of a percent of the proton collisions performed shows a presence of a sixth quark.

CHAPTER RESOURCES

END

Structure of the Atom

17.1 **Models—Tools for Scientists**

- Scientists and engineers use models to represent things that are difficult to visualize—or picture in your mind.
- Scaled-down models allow you to see either something too large to see all at once, or something that has not been built yet.
- Scaled-up models are often used to visualize things that are too small to see.

CHAPTER RESOURCES

END

Structure of the Atom

17.1 **Models—Tools for Scientists**

- To study the atom, scientists have developed scaled-up models that they can use to visualize how the atom is constructed.
- For the model to be useful, it must support all of the information that is known about matter and the behavior of atoms.

CHAPTER RESOURCES

END

Structure of the Atom

17.1 **The Changing Atomic Model**

- In the 1800s, John Dalton, an English scientist, was able to offer proof that atoms exist.
- Another famous Greek philosopher, Aristotle, disputed Democritus's theory and proposed that matter was uniform throughout and was not composed of smaller particles.


CHAPTER RESOURCES

END

Structure of the Atom

17.1 **The Changing Atomic Model**

- In the 1800s, John Dalton, an English scientist, was able to offer proof that atoms exist.
- Dalton's model of the atom, a solid sphere was an early model of the atom.
- The model has changed somewhat over time.



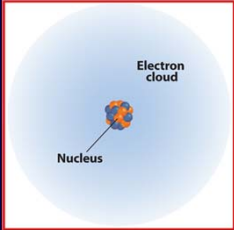
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Structure of the Atom

17.1 **The Electron Cloud Model**

- By 1926, scientists had developed the electron cloud model of the atom that is in use today.
- An **electron cloud** is the area around the nucleus of an atom where its electrons are most likely found.



CHAPTER RESOURCES

END

Structure of the Atom

17.1 **The Electron Cloud Model**

- The electron cloud is 100,000 times larger than the diameter of the nucleus.
- In contrast, each electron in the cloud is much smaller than a single proton.
- Because an electron's mass is small and the electron is moving so quickly around the nucleus, it is impossible to describe its exact location in an atom.

CHAPTER RESOURCES

END

Section Check

17.1 **Question 1**

Which is the smallest piece of matter that still retains the property of the element?

- atom
- quark
- neutron
- proton

CHAPTER RESOURCES

END

Section Check

17.1

**Answer**

The answer is A. An atom is the smallest piece of matter that still retains the property of the element.

CHAPTER RESOURCES

END

Section Check

17.1

**Question 2**

What particles are found in the nucleus of an atom?

A. protons and electrons  
B. protons and neutrons  
C. neutrons and electrons  
D. quarks and electrons

CHAPTER RESOURCES

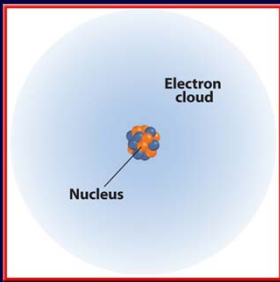
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Section Check

17.1

**Answer**

The answer is B. Electrons are located in an electron cloud surrounding the nucleus of the atom.



The diagram shows a central nucleus, which is a cluster of protons and neutrons, surrounded by a large, diffuse electron cloud. Labels 'Nucleus' and 'Electron cloud' point to their respective parts.

CHAPTER RESOURCES

END

Section Check

17.1

**Question 3**

What is the name of the small particles that make up protons and neutrons?

**Answer**

Protons and neutrons are made of smaller particles called quarks.

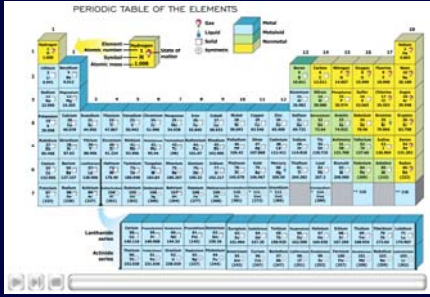
CHAPTER RESOURCES

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Masses of Atoms

17.2

**Atomic Mass**



The periodic table shows atomic masses for each element. A legend indicates that elements are color-coded by groups: Alkali Metals (blue), Alkaline Earth Metals (green), Transition Metals (yellow), and Nonmetals (orange). A note for MAC OS X users says 'click here to view'.

CHAPTER RESOURCES

END

Masses of Atoms

17.2

**Atomic Mass**

- The nucleus contains most of the mass of the atom because protons and neutrons are far more massive than electrons.
- The mass of a proton is about the same as that of a neutron—approximately

Subatomic Particle Masses	
Particle	Mass (g)
Proton	$1.6726 \times 10^{-24}$
Neutron	$1.6749 \times 10^{-24}$
Electron	$9.1093 \times 10^{-28}$

CHAPTER RESOURCES

END

Masses of Atoms

17.2 Atomic Mass

- The mass of each is approximately 1,836 times greater than the mass of the electron.

Subatomic Particle Masses	
Particle	Mass (g)
Proton	$1.6726 \times 10^{-24}$
Neutron	$1.6749 \times 10^{-24}$
Electron	$9.1093 \times 10^{-28}$

CHAPTER RESOURCES

Masses of Atoms

17.2 Atomic Mass

- The unit of measurement used for atomic particles is the atomic mass unit (amu).
- The mass of a proton or a neutron is almost equal to 1 amu.
- The atomic mass unit is defined as one-twelfth the mass of a carbon atom containing six protons and six neutrons.

CHAPTER RESOURCES

Masses of Atoms

17.2 Protons Identify the Element

- The number of protons tells you what type of atom you have and vice versa. For example, every carbon atom has six protons. Also, all atoms with six protons are carbon atoms.
- The number of protons in an atom is equal to a number called the **atomic number**.

CHAPTER RESOURCES

Masses of Atoms

17.2 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.

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	16.00 amu
Sodium	Na	11	11	12	23	22.99 amu
Copper	Cu	29	29	34	63	63.55 amu

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

CHAPTER RESOURCES

Masses of Atoms

17.2 Mass Number

- If you know the mass number and the atomic number of an atom, you can calculate the number of neutrons.

number of neutrons = mass number – atomic number

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	16.00 amu
Sodium	Na	11	11	12	23	22.99 amu
Copper	Cu	29	29	34	63	63.55 amu

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

CHAPTER RESOURCES

Masses of Atoms

17.2 Isotopes

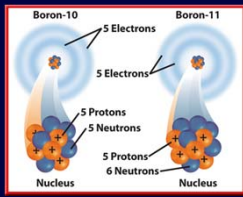
- Not all the atoms of an element have the same number of neutrons.
- Atoms of the same element that have different numbers of neutrons are called **isotopes**.

CHAPTER RESOURCES

Masses of Atoms

17.2 **Identifying Isotopes**

- Models of two isotopes of boron are shown. Because the numbers of neutrons in the isotopes are different, the mass numbers are also different.
- You use the name of the element followed by the mass number of the isotope to identify each isotope: boron-10 and boron-11.



CHAPTER RESOURCES

END

Masses of Atoms

17.2 **Identifying Isotopes**

- 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, and one out of five is boron-10.
- To find the weighted-average or the average atomic mass of boron, you would solve the following equation:

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

CHAPTER RESOURCES

END

Section Check

17.2

**Question 1**

How is the atomic number of an element determined?

**Answer**

The atomic number of an element is equal to the number of protons in an atom of that element.

CHAPTER RESOURCES

END

Section Check

17.2

**Question 2**

The element helium has a mass number of 4 and atomic number of 2. How many neutrons are in the nucleus of a helium atom?

CHAPTER RESOURCES

END

Section Check

17.2

**Answer**

Recall that the atomic number is equal to the number of protons in the nucleus. Since the mass number is 4 and the atomic number is 2, there must be 2 neutrons in the nucleus of a helium atom.

CHAPTER RESOURCES

END

Section Check

17.2

**Question 3**

How much of the mass of an atom is contained in an electron?

**Answer**

The electron's mass is so small that it is considered negligible when finding the mass of an atom.

CHAPTER RESOURCES

END

The Periodic Table

### 17.3 Organizing the Elements

- *Periodic* means "repeated in a pattern."
- In the late 1800s, Dmitri Mendeleev, a Russian chemist, searched for a way to organize the elements.
- When he arranged all the elements known at that time in order of increasing atomic masses, he discovered a pattern.

CHAPTER RESOURCES

The Periodic Table

### 17.3 Organizing the Elements

- Because the pattern repeated, it was considered to be periodic. Today, this arrangement is called a periodic table of elements.
- In the **periodic table**, the elements are arranged by increasing atomic number and by changes in physical and chemical properties.

CHAPTER RESOURCES

The Periodic Table

### 17.3 Mendeleev's Predictions

- Mendeleev had to leave blank spaces in his periodic table to keep the elements properly lined up according to their chemical properties.
- He looked at the properties and atomic masses of the elements surrounding these blank spaces.

CHAPTER RESOURCES

The Periodic Table

### 17.3 Mendeleev's Predictions

- From this information, he was able to predict the properties and the mass numbers of new elements that had not yet been discovered.

Mendeleev's Predictions	
Predicted Properties of Ekasilicon (Es)	Actual Properties of Germanium (Ge)
Existence Predicted—1871	Actual Discovery—1886
Atomic mass = 72	Atomic mass = 72.61
High melting point	Melting point = 9388C
Density = 5.5 g/cm <sup>3</sup>	Density = 5.323 g/cm <sup>3</sup>
Dark gray metal	Gray metal
Density of EsO <sub>2</sub> = 4.7 g/cm <sup>3</sup>	Density of GeO <sub>2</sub> = 4.23 g/cm <sup>3</sup>

CHAPTER RESOURCES

The Periodic Table

### 17.3 Mendeleev's Predictions

- This table shows Mendeleev's predicted properties for germanium, which he called ekasilicon. His predictions proved to be accurate.

Mendeleev's Predictions	
Predicted Properties of Ekasilicon (Es)	Actual Properties of Germanium (Ge)
Existence Predicted—1871	Actual Discovery—1886
Atomic mass = 72	Atomic mass = 72.61
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Density = 5.5 g/cm <sup>3</sup>	Density = 5.323 g/cm <sup>3</sup>
Dark gray metal	Gray metal
Density of EsO <sub>2</sub> = 4.7 g/cm <sup>3</sup>	Density of GeO <sub>2</sub> = 4.23 g/cm <sup>3</sup>

CHAPTER RESOURCES

The Periodic Table

### 17.3 Improving the Periodic Table

- On Mendeleev's table, the atomic mass gradually increased from left to right. If you look at the modern periodic table, you will see several examples, such as cobalt and nickel, where the mass decreases from left to right.

CHAPTER RESOURCES

The Periodic Table

17.3 **Improving the Periodic Table**

- In 1913, the work of Henry G.J. Moseley, a young English scientist, led to the arrangement of elements based on their increasing atomic numbers instead of an arrangement based on atomic masses.
- The current periodic table uses Moseley's arrangement of the elements.

CHAPTER RESOURCES

The Periodic Table

17.3 **The Atom and the Periodic Table**

- The vertical columns in the periodic table are called **groups**, or families, and are numbered 1 through 18.
- Elements in each group have similar properties.

CHAPTER RESOURCES

The Periodic Table

17.3 **Electron Cloud Structure**

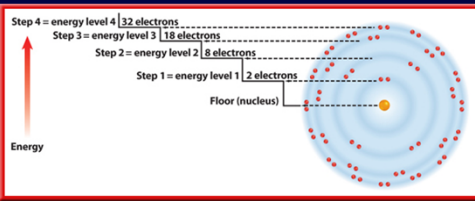
- In a neutral atom, the number of electrons is equal to the number of protons.
- Therefore, a carbon atom, with an atomic number of six, has six protons and six electrons.

CHAPTER RESOURCES

The Periodic Table

17.3 **Electron Cloud Structure**

- Scientists have found that electrons within the electron cloud have different amounts of energy.

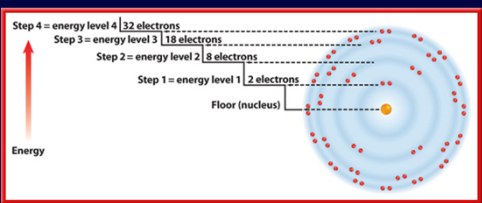


CHAPTER RESOURCES

The Periodic Table

17.3 **Electron Cloud Structure**

- Scientists model the energy differences of the electrons by placing the electrons in energy levels.



CHAPTER RESOURCES

The Periodic Table

17.3 **Electron Cloud Structure**

- Energy levels nearer the nucleus have lower energy than those levels that are farther away.
- Electrons fill these energy levels from the inner levels (closer to the nucleus) to the outer levels (farther from the nucleus).

CHAPTER RESOURCES

The Periodic Table

### 17.3 Electron Cloud Structure

- Elements that are in the same group have the same number of electrons in their outer energy level.
- It is the number of electrons in the outer energy level that determines the chemical properties of the element.

CHAPTER RESOURCES

The Periodic Table

### 17.3 Energy Levels

- The maximum number of electrons that can be contained in each of the first four levels is shown.

Step 4 = energy level 4 | 32 electrons  
 Step 3 = energy level 3 | 18 electrons  
 Step 2 = energy level 2 | 8 electrons  
 Step 1 = energy level 1 | 2 electrons  
 Floor (nucleus)

Energy

CHAPTER RESOURCES

The Periodic Table

### 17.3 Energy Levels

- For example, energy level one can contain a maximum of two electrons.
- A complete and stable outer energy level will contain eight electrons.

Step 4 = energy level 4 | 32 electrons  
 Step 3 = energy level 3 | 18 electrons  
 Step 2 = energy level 2 | 8 electrons  
 Step 1 = energy level 1 | 2 electrons  
 Floor (nucleus)

Energy

CHAPTER RESOURCES

The Periodic Table

### 17.3 Rows on the Table

- Remember that the atomic number found on the periodic table is equal to the number of electrons in an atom.

Hydrogen 1 H						Helium 2 He	
Lithium 3 Li	Beryllium 4 Be	Boron 5 B	Carbon 6 C	Nitrogen 7 N	Oxygen 8 O	Fluorine 9 F	Neon 10 Ne
Sodium 11 Na	Magnesium 12 Mg	Aluminum 13 Al	Silicon 14 Si	Phosphorus 15 P	Sulfur 16 S	Chlorine 17 Cl	Argon 18 Ar

CHAPTER RESOURCES

The Periodic Table

### 17.3 Rows on the Table

- The first row has hydrogen with one electron and helium with two electrons both in energy level one.
- Energy level one can hold only two electrons. Therefore, helium has a full or complete outer energy level.

Hydrogen 1 H						Helium 2 He	
Lithium 3 Li	Beryllium 4 Be	Boron 5 B	Carbon 6 C	Nitrogen 7 N	Oxygen 8 O	Fluorine 9 F	Neon 10 Ne
Sodium 11 Na	Magnesium 12 Mg	Aluminum 13 Al	Silicon 14 Si	Phosphorus 15 P	Sulfur 16 S	Chlorine 17 Cl	Argon 18 Ar

CHAPTER RESOURCES

The Periodic Table

### 17.3 Rows on the Table

- The second row begins with lithium, which has three electrons—two in energy level one and one in energy level two.
- Lithium is followed by beryllium with two outer electrons, boron with three, and so on until you reach neon with eight outer electrons.

Hydrogen 1 H						Helium 2 He	
Lithium 3 Li	Beryllium 4 Be	Boron 5 B	Carbon 6 C	Nitrogen 7 N	Oxygen 8 O	Fluorine 9 F	Neon 10 Ne
Sodium 11 Na	Magnesium 12 Mg	Aluminum 13 Al	Silicon 14 Si	Phosphorus 15 P	Sulfur 16 S	Chlorine 17 Cl	Argon 18 Ar

CHAPTER RESOURCES

The Periodic Table

17.3 **Rows on the Table**

- Do you notice how the row in the periodic table ends when an outer level is filled?
- In the third row of elements, the electrons begin filling energy level three.
- The row ends with argon, which has a full outer energy level of eight electrons.

Hydrogen 1 H																	Helium 2 He
Lithium 3 Li	Beryllium 4 Be											Boron 5 B	Carbon 6 C	Nitrogen 7 N	Oxygen 8 O	Fluorine 9 F	Neon 10 Ne
Sodium 11 Na	Magnesium 12 Mg											Aluminum 13 Al	Silicon 14 Si	Phosphorus 15 P	Sulfur 16 S	Chlorine 17 Cl	Argon 18 Ar

CHAPTER RESOURCES

END

The Periodic Table

17.3 **Electron Dot Diagrams**

- Elements that are in the same group have the same number of electrons in their outer energy level.
- These outer electrons are so important in determining the chemical properties of an element that a special way to represent them has been developed.

CHAPTER RESOURCES

END

The Periodic Table

17.3 **Electron Dot Diagrams**

- An **electron dot diagram** uses the symbol of the element and dots to represent the electrons in the outer energy level.
- Electron dot diagrams are used also to show how the electrons in the outer energy level are bonded when elements combine to form compounds.

H•
Li•
Na•
K•
Rb•
Cs•
Fr•

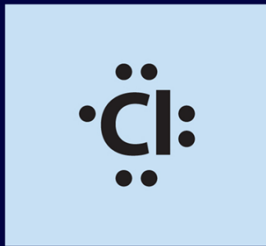
CHAPTER RESOURCES

END

The Periodic Table

17.3 **Same Group—Similar Properties**

- The elements in Group 17, the halogens, have electron dot diagrams similar to chlorine.
- All halogens have seven electrons in their outer energy levels.



CHAPTER RESOURCES

END

The Periodic Table

17.3 **Same Group—Similar Properties**

- A common property of the halogens is the ability to form compounds readily with elements in Group 1.
- The Group 1 element, sodium, reacts easily with the Group 17 element, chlorine.
- The result is the compound sodium chloride, or NaCl—ordinary table salt.

$$[\text{Na}]^+ \quad [:\ddot{\text{Cl}}:]^-$$


CHAPTER RESOURCES

END

The Periodic Table

17.3 **Same Group—Similar Properties**

- Not all elements will combine readily with other elements.
- The elements in Group 18 have complete outer energy levels.
- This special configuration makes Group 18 elements relatively unreactive.



CHAPTER RESOURCES

END

The Periodic Table

17.3 **Regions on the Periodic Table**

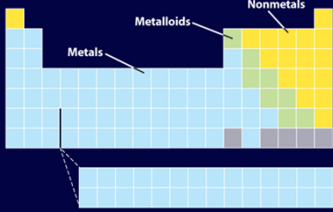
- The periodic table has several regions with specific names.
- The horizontal rows of elements on the periodic table are called **periods**.
- The elements increase by one proton and one electron as you go from left to right in a period.

CHAPTER RESOURCES

The Periodic Table

17.3 **Regions on the Periodic Table**

- All of the elements in the blue squares are metals.

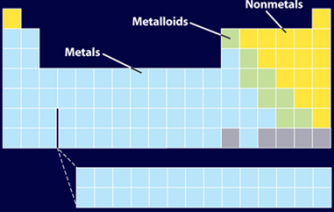


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The Periodic Table

17.3 **Regions on the Periodic Table**

- Those elements on the right side of the periodic table, in yellow, are classified as nonmetals.

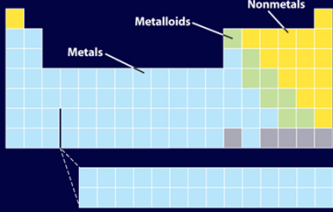


CHAPTER RESOURCES

The Periodic Table

17.3 **Regions on the Periodic Table**

- The elements in green are metalloids or semimetals.



CHAPTER RESOURCES

The Periodic Table

17.3 **A Growing Family**

- In 1994, scientists at the Heavy-Ion Research Laboratory in Darmstadt, Germany, discovered element 111.
- Element 112 was discovered at the same laboratory.
- Both of these elements are produced in the laboratory by joining smaller atoms into a single atom.

CHAPTER RESOURCES

The Periodic Table

17.3 **Elements in the Universe**

- Using the technology that is available today, scientists are finding the same elements throughout the universe.
- Many scientists believe that hydrogen and helium are the building blocks of other elements.

CHAPTER RESOURCES



Section Check

17.3

**Answer**

The dots represent the electrons in the outer energy level.

CHAPTER RESOURCES

END

Help

17

To advance to the next item or next page click on any of the following keys: mouse, space bar, enter, down or forward arrow.

- Click on this icon to return to the table of contents
- Click on this icon to return to the previous slide
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**CHAPTER RESOURCES** Click on this icon to open the resources file.

**END** Click on this icon to go to the end of the presentation.

CHAPTER RESOURCES

END

**End of Chapter Summary File**

CHAPTER RESOURCES

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