McGraw-Hill Ryerson

BC Science Connections 9

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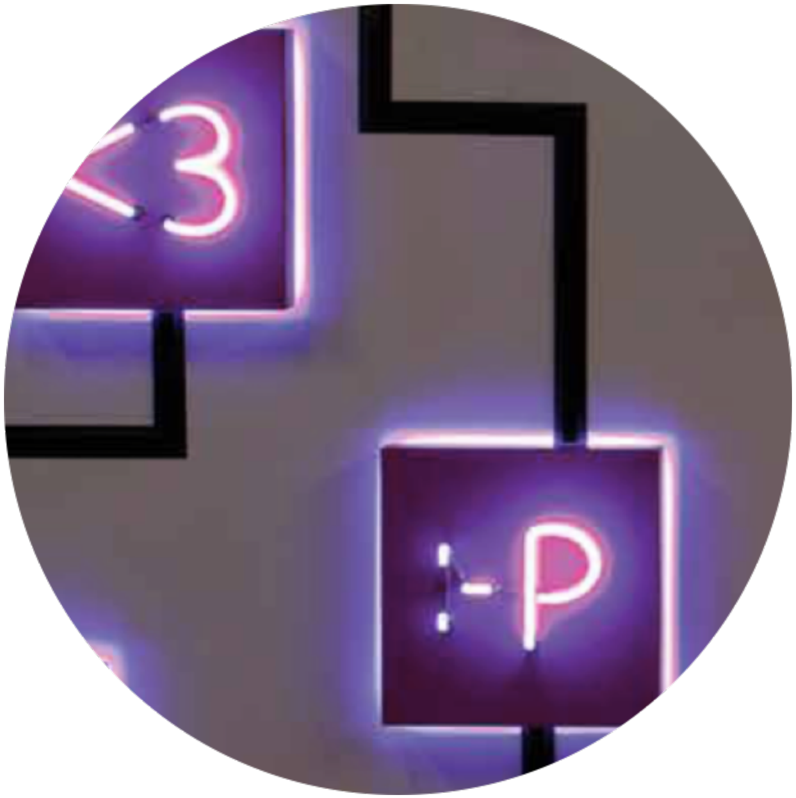
Unit 2: The electron arrangement of atoms impacts their chemical nature

Topic 2.3: How can atomic theory explain patterns in the periodic table?

- The structure of atoms can be represented using simple diagrams.
- Elements in chemical groups have similar electron arrangements.
- The periodic table shows how properties of elements change in predictable ways.



Concept 1: The structure of atoms can be represented using simple diagrams.

The atom: Smallest unit of an element that has the properties of that element

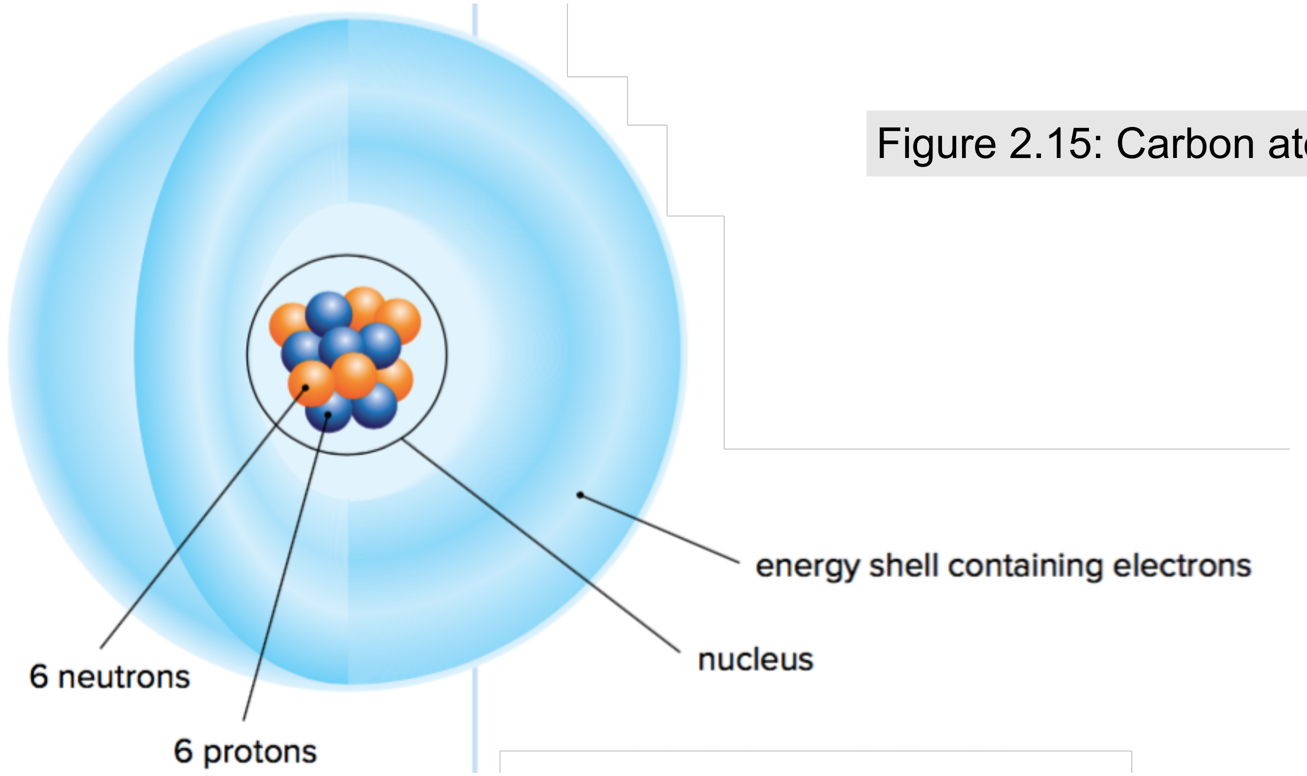


Figure 2.15: Carbon atom

Key Features of Atomic Structure

- Each atom has a tiny, dense nucleus with neutrons and protons
- Nucleus is surrounded by electrons, which exist in specific electron energy shells
- Most of the mass of the atom is in the nucleus

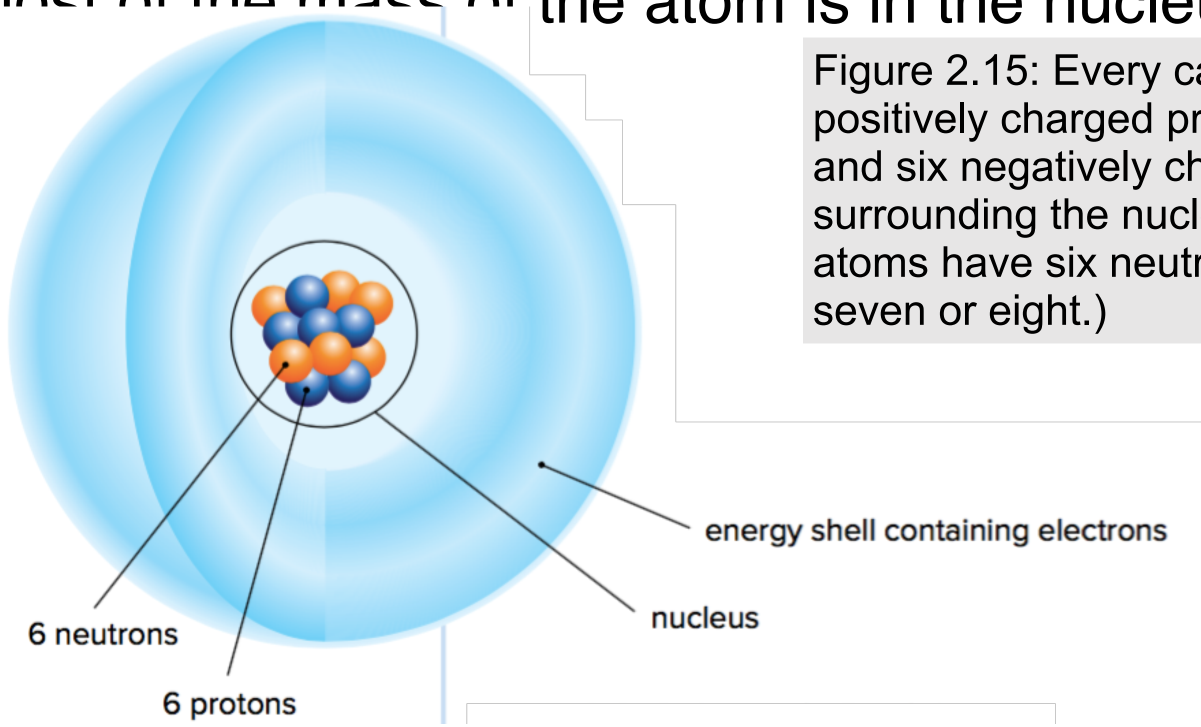


Figure 2.15: Every carbon atom has six positively charged protons in its nucleus and six negatively charged electrons surrounding the nucleus. (Most carbon atoms have six neutrons, but some have seven or eight.)

Key Features of Atomic Structure (continued)

Table 2.3 Subatomic Particles

Name	Relative Mass	Electric Charge	Symbol	Location in Atom
proton	1836	+	p^+	nucleus
neutron	1837	0	n^0	nucleus
electron	1	–	e^-	electron energy shells surrounding the nucleus

Bohr Diagrams Are a Useful Way to Model Atoms

Bohr diagrams represent the electron arrangements of atoms using energy shells

- Show how many electrons occupy each specific energy level or shell
- First energy shell: maximum two electrons
- Second and third energy shell: maximum eight electrons (for the first 20 elements)
- **Valence shell** (outermost energy shell): occupied by **valence electrons** (electrons in the outermost occupied energy shell of an atom)

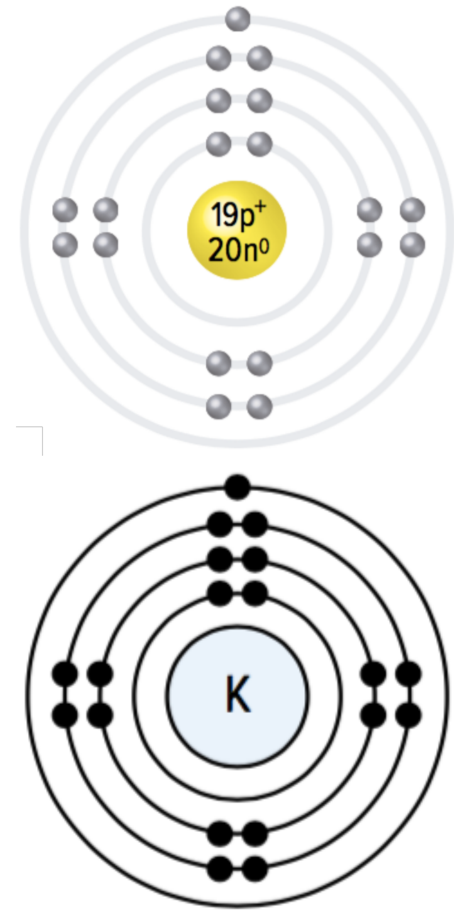
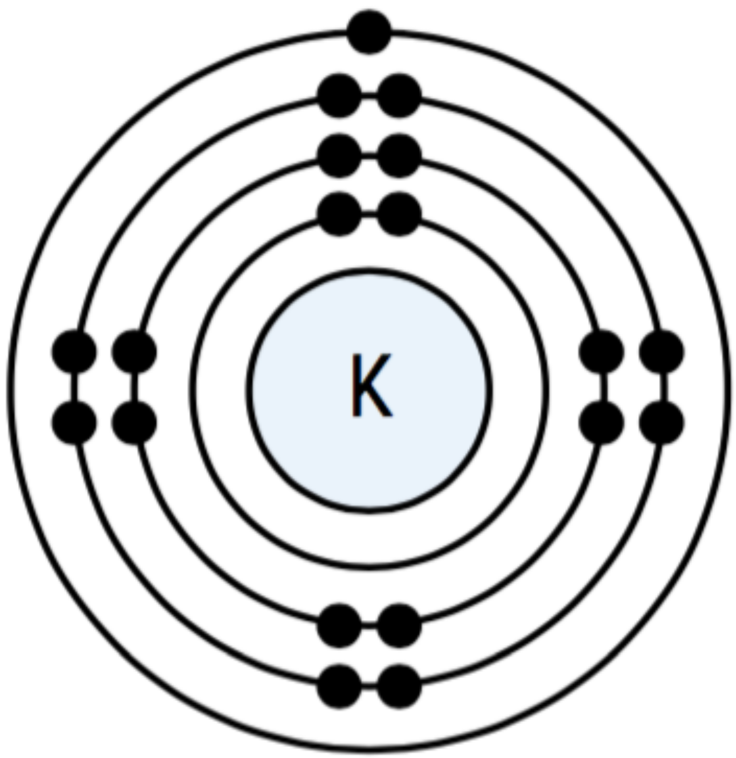


Figure 2.15: Two types of Bohr diagrams representing an atom of potassium (K).

Bohr Diagrams and Energy Shells

- First energy shell: maximum two electrons
- Second and third energy shell: maximum eight electrons (for the first 20 elements)
- **Valence shell** (outermost energy shell): occupied by **valence electrons** (electrons in the outermost occupied energy shell of an atom)



Discussion Questions

1. Draw a diagram of an atom, labelling protons, electrons, and neutrons.

2. List how many electrons can be found in the first and second energy shells.

Concept 2: Elements in chemical groups have similar electron arrangements.

Key patterns in the periodic table:

- Atoms in the same group have the same number of valence electrons
- Atoms in the same period have the same number of occupied energy shells

Patterns in the Periodic Table

Figure 2.17 Analyzing the electron arrangements of elements in the same group or period can help explain differences and similarities in the properties of the elements.

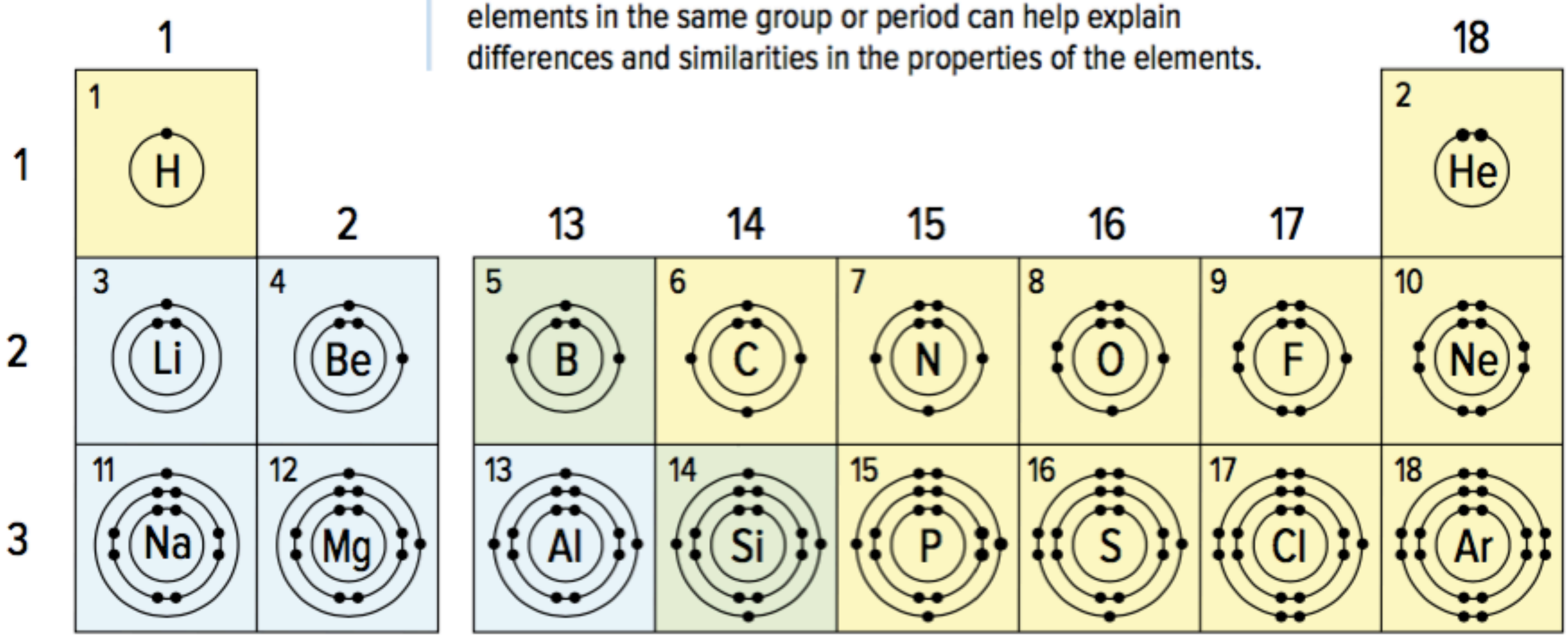
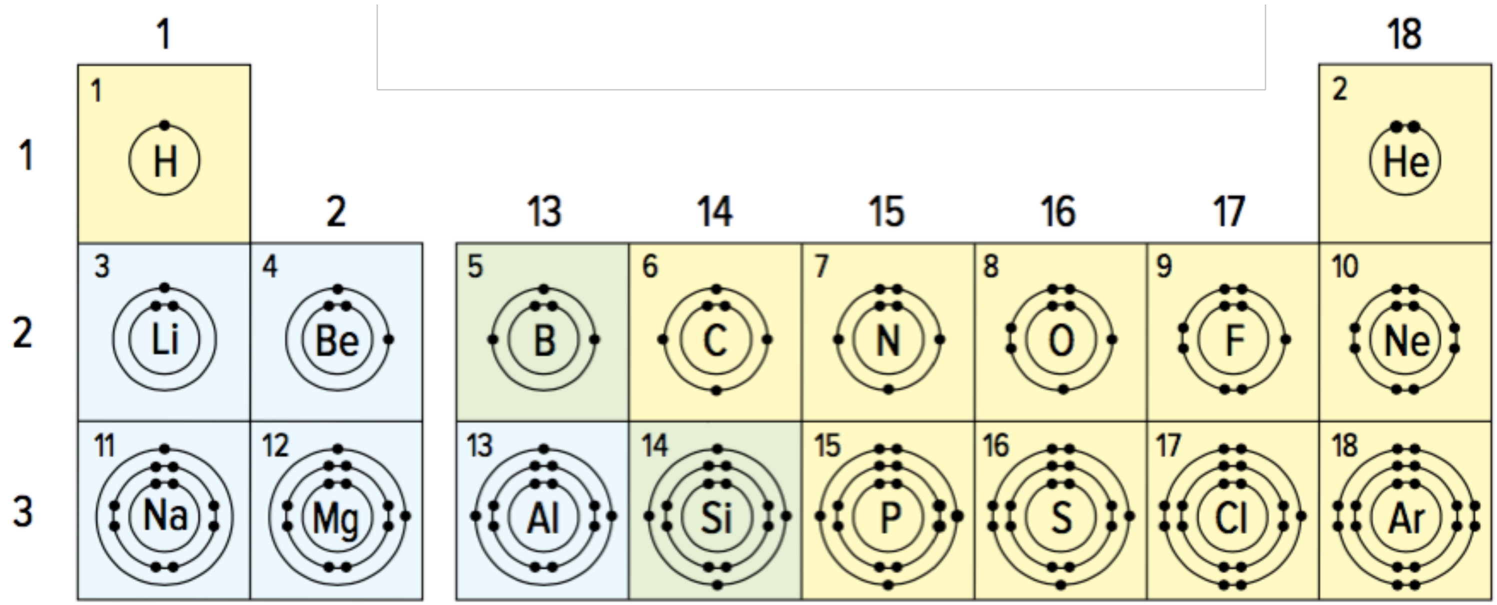


Figure 2.17

Atoms in the same group have the same number of valence electrons

Figure 2.17:

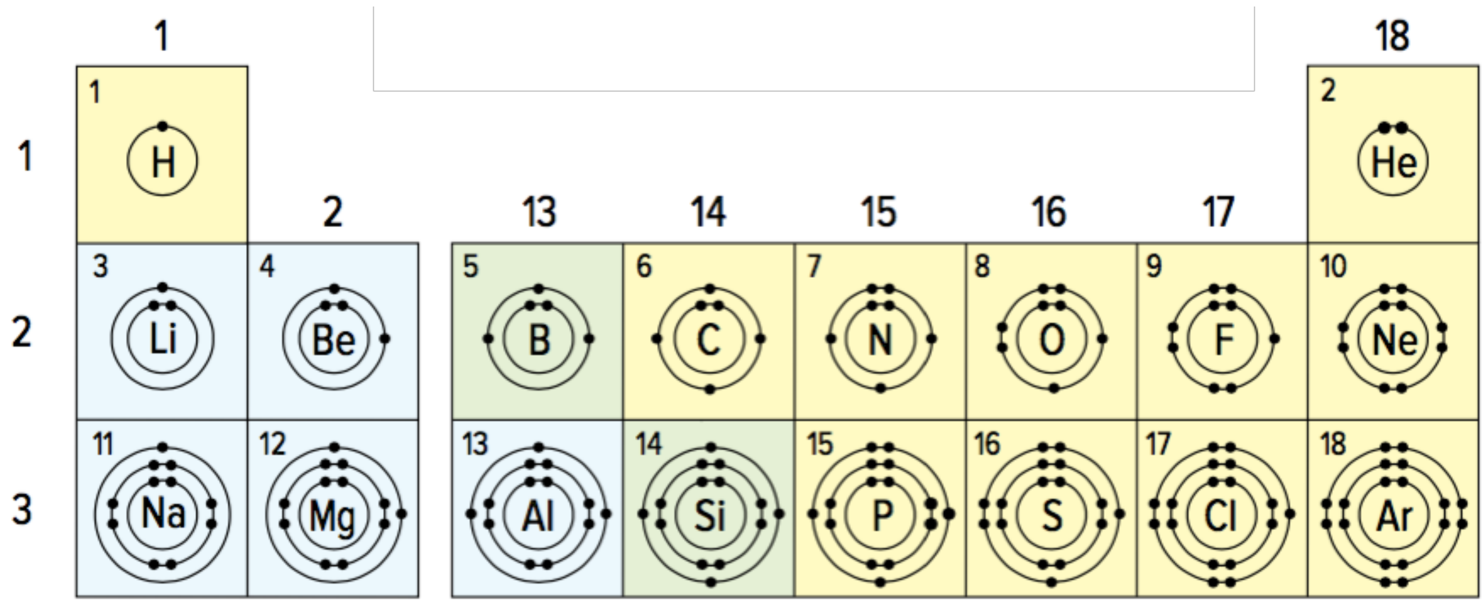
- Group 1: One valence electron
- Group 2: Two valence electrons
- Groups 13-18: 3, 4, 5, 6, 7, 8 valence electrons
- Exception: Helium has 2 valence electrons (other noble gases have 8 valence electrons)



Atoms in the same period have the same number of occupied energy shells

Figure 2.17:

- First period (hydrogen and helium): One occupied energy shell
- Second period: Two occupied energy shells
- Third period: Three occupied energy shells



Noble Gas Stability: A Full Valence Shell

Noble gases are stable (unreactive) because they have full valence shells

- Their atoms do not tend to gain, lose, or share electrons

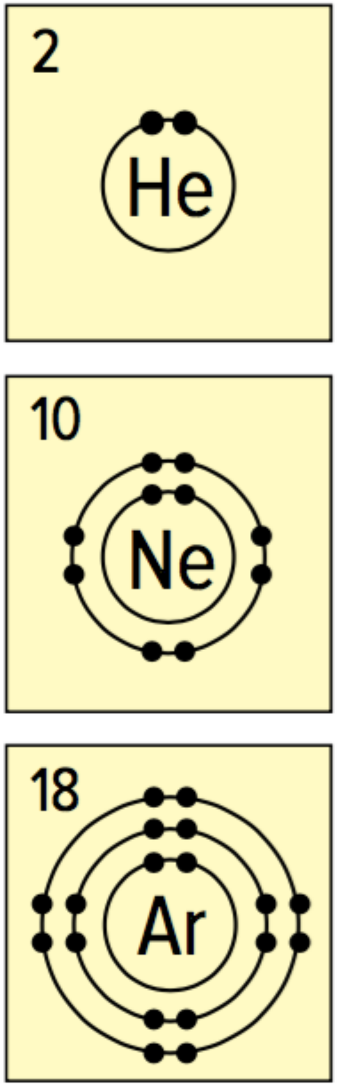


Figure 2.18: The noble gases have full valence shells.

How Other Elements Achieve Full Valence Shells

Other elements can achieve a full valence shell by gaining or losing electrons during a chemical reaction

- When a neutral atom gains or loses an electron, it becomes an **ion**
  - Loses an electron: becomes positively charged ion
  - Gains an electron: becomes a negatively charged ion

How Other Elements Achieve Full Valence Shells (continued)

Reactivity of an element is linked to how close it is to having a full valence shell

- Most reactive elements: Groups 1 and 17 (elements are only one electron away from a full valence shell)
- Example: Sodium (group 1) easily gives up an electron, since it exposes the full valence shell underneath
- Example: Fluorine (group 17) readily gains an electron, since it completes their valence shell

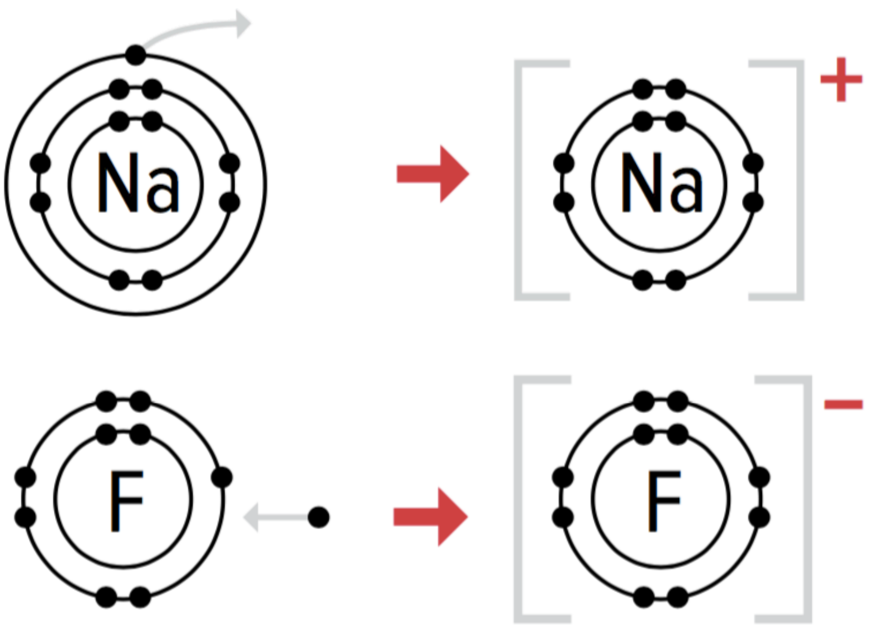


Figure 2.19: Formation of sodium (Na, top) and fluorine (F, bottom) ions.

Discussion Questions

1. Explain why metals tend to lose electrons and non-metals tend to gain them.

2. Use diagrams to compare the electron arrangements of a chloride ion, a potassium ion, and an argon atom.

Concept 3: The periodic table shows how properties of elements change in predictable ways.

Periodic trend:

- A regular variation in the properties of elements based on their atomic structure
- Periodic table can analyze these trends because it can help you compare variations in groups and periods

Atomic Size Trends: Atomic Size Increases Moving Down a Group

Atomic size increases moving down a group

- As you move down a group, elements have atoms with increasing numbers of energy shells
- The greater the number of shells, the farther the valence electrons are from the nucleus, and the larger the atom

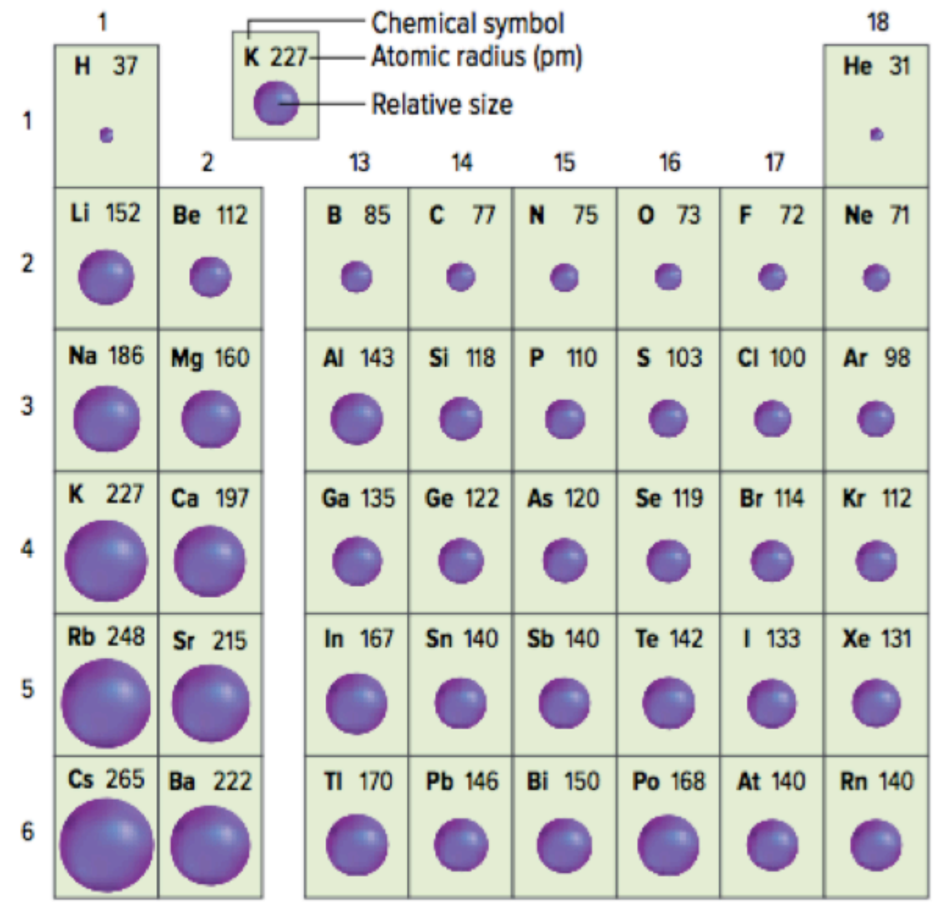


Figure 2.20: Atomic size is represented by the spheres. The number under each element is the radius of the atom in picometres (pm).

Atomic Size Trends: Atomic Size Decreases Moving Left to Right Across a Period

Atomic size decreases moving left to right across a period

- Elements have increasing numbers of electrons across a period
- Number of occupied valence shells stay the same, but the number of protons in the nucleus increases
- How does this result in decreasing atomic size across a period?

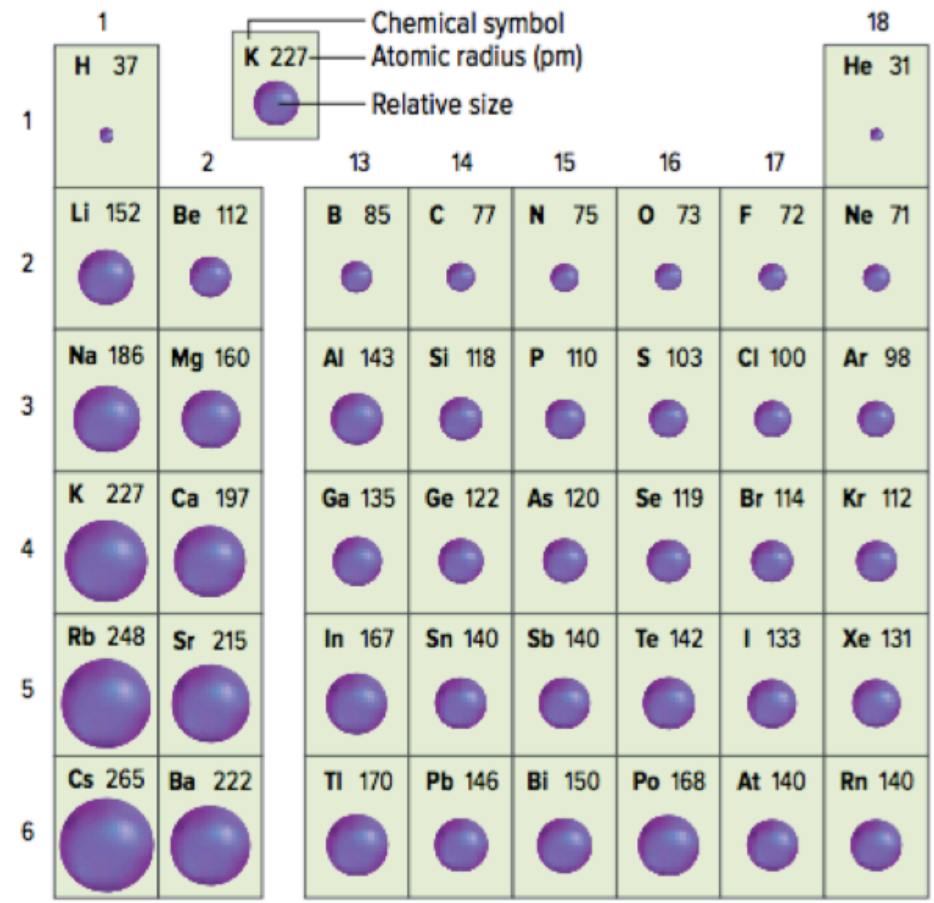


Figure 2.20: Atomic size is represented by the spheres. The number under each element is the radius of the atom in picometres (pm).

Atomic Size Trends: Atomic Size Decreases Moving Left to Right Across a Period (continued)

- Attraction between valence electrons and the nucleus increases because a greater positive charge on the nucleus pulls more strongly on the electrons
- Therefore, the electrons are pulled more tightly towards the nucleus, leading to decreasing atomic size

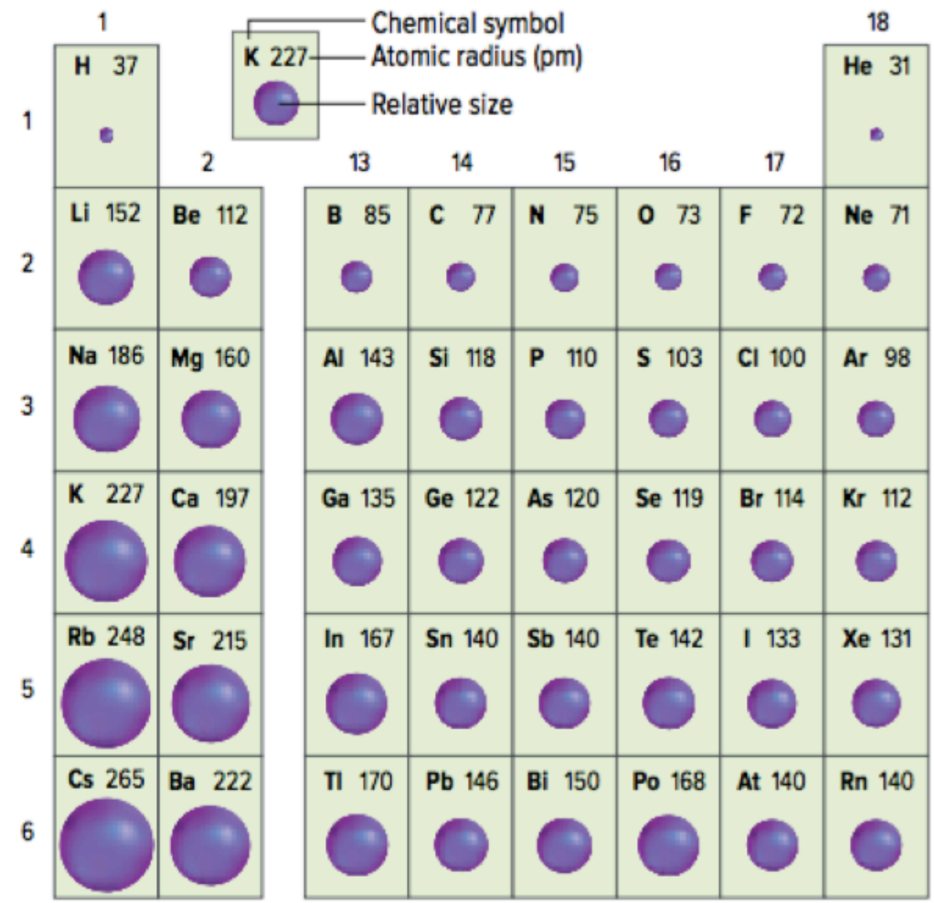


Figure 2.20: Atomic size is represented by the spheres. The number under each element is the radius of the atom in picometres (pm).

Metal Reactivity and Atom Size

Group 1 metals: Potassium is more reactive than sodium

- Both have one valence electron
- Potassium atom is larger than sodium
- Potassium atom's valence electron is farther away from the nucleus
  - Pull of the positive charge on the nucleus is weaker
  - Valence electron is easier to remove (less energy is needed to remove the electron)

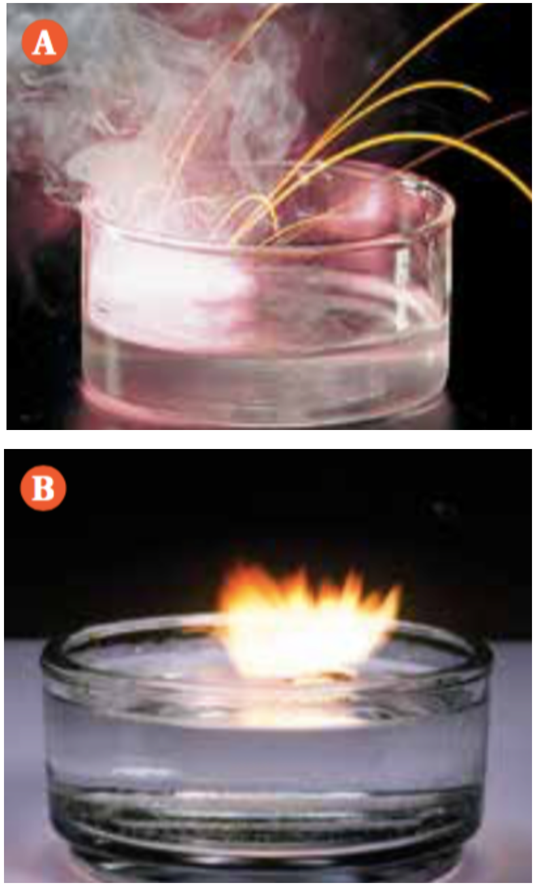


Figure 2.21: Potassium (A) is more reactive than sodium (B) because less energy is needed to remove the valence electron from potassium.

Discussion Questions

1. Explain why atoms get larger down a group on the periodic table.
2. Explain why atoms get smaller from left to right across a period on the periodic table.

Discussion Questions

3. Explain why an alkali metal is more reactive than an alkaline-earth metal in the same period.

Topic 2.3 Summary: How can atomic theory explain patterns in the period table?

- The structure of atoms can be represented using simple diagrams.
- Elements in chemical groups have similar electron arrangements.
- The periodic table shows how properties of elements change in predictable ways.