2.3 The Periodic Table and Atomic Theory

In a Bohr model diagram, electrons are arranged in shells in a specific pattern around the nucleus. The electrons in the outermost electron shell are called valence electrons. The number of valence electrons in an atom determines many of its chemical and physical properties. The atoms of all alkali metals have one valance electron; an atom of each alkaline earth metal has two valence electrons; and an atom of each halogen has seven valence electrons. Noble gas atoms have filled valence shells, which makes them chemically stable. All noble gas elements have eight valence electrons except helium, which is stable with two valence electrons.

Words to Know

Bohr model
electron shells
valence electron
valence shell

The periodic table is full of patterns. For example, non-metals appear on the right. This is no accident. Patterns occur as a result of regular changes in the structure of the atoms of these elements. Elements with similar properties line up in columns because all those elements are similar in the arrangement of their electrons.

One way to show the arrangement of electrons in an atom is with a Bohr model diagram. A **Bohr model** diagram shows how many electrons are in each shell surrounding the nucleus (Figure 2.21). This type of diagram is named after Niels Bohr (Figure 2.22), the Danish physicist whose model of the atom you studied in section 1.3. The regions surrounding the nucleus of an atom are sometimes called **electron shells**. The shell nearest the nucleus can hold 0, 1, or 2 electrons. The next two shells outward can each hold up to 8 electrons. Any remaining electrons will fill the fourth shell, to a maximum of 18. This pattern of 2, 8, 8, and 18 applies to all atoms, although not all atoms have that many electrons.

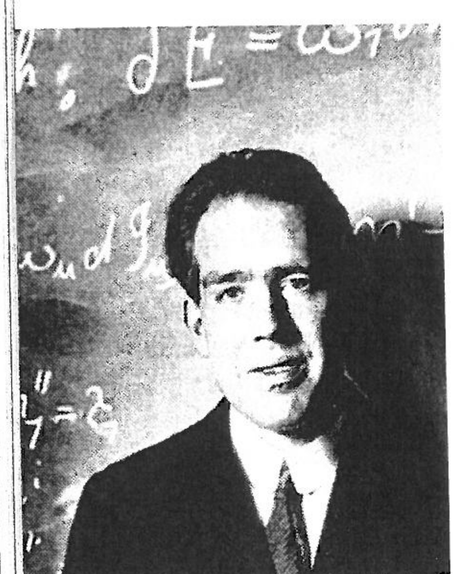


Figure 2.22 Niels Bohr

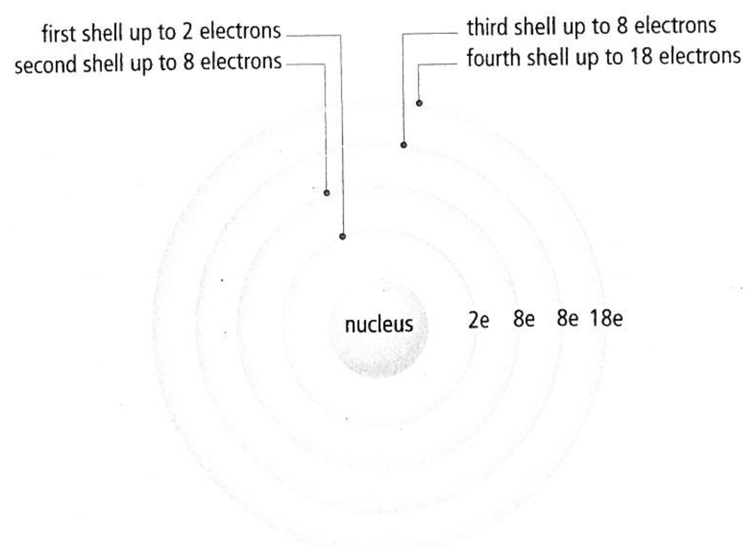
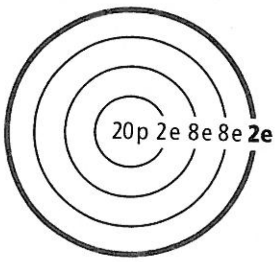


Figure 2.21 A Bohr model showing electron shells

2-3A Looking for Patterns in Atoms

Think About It

The number of electrons in an atom is always equal to the number of protons. The protons are in the nucleus, while the electrons surround the nucleus in energy levels or shells. In this activity, you will compare the electron arrangements in various atoms.



The arrangement of electrons in a calcium atom

Material

- coloured pencils or felt pens

What to Do

1. Your teacher will assign you several atoms to sketch using a Bohr model diagram. Use a periodic table to look up the atomic number of each atom. Record this number in the centre of the paper to represent the nucleus of the atom, as shown in the diagram.
2. Determine the number of electrons in the atom. Start with the shell nearest the nucleus and put in up to two electrons. Once the first shell is full, fill the second shell with up to eight electrons. The third shell can also have up to eight electrons. Put any remaining electrons into the last shell, which will hold up to 18 electrons.
3. Highlight the circle containing the outermost electrons with a distinctive colour or a heavy line.
4. Highlight the number of electrons in the outermost circle that contains electrons.
5. Compare your atoms with those of others in the class. Look for similarities between atoms of the same family.
6. Arrange all the sketches on the wall just as they appear in the periodic table.

What Did You Find Out?

1. What is the pattern in the arrangement of electrons as you move down a family?
2. What is the pattern in the arrangement of electrons as you move across a period from left to right?

Bohr Model Diagrams

A Bohr model diagram usually contains the element symbol, the number of protons in the atom, and a way to show where the electrons are. Some diagrams show the electrons as dots. Others just have figures indicating the number of electrons in each shell. Figure 2.23 shows three ways you could draw a Bohr model diagram for the element potassium (atomic number 19).

Did You Know?

Alchemists could not turn lead into gold, but in 1980, Nobel Prize winning physicist Glen Seaborg did just that. He used nuclear reactions to make microscopic amounts, and the cost was much greater than mining for gold. His remarkable achievement added to our understanding of how atoms work.

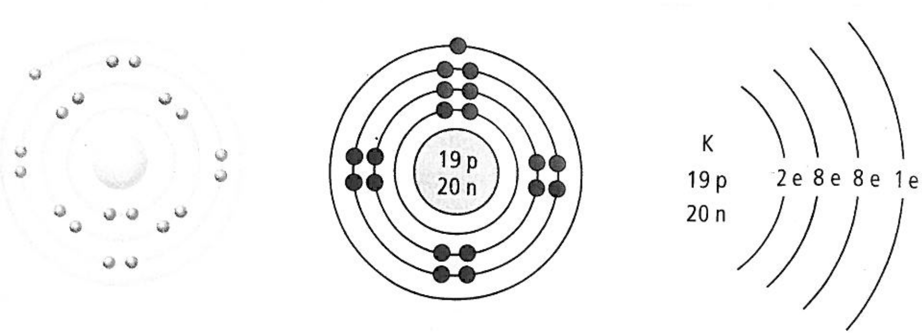


Figure 2.23 Each of these diagrams representing an atom of potassium is a Bohr model diagram.

Valence Electrons and Chemical Families

Figure 2.24 below shows how the electrons are arranged in each atom of the first 18 elements. Notice that the first electron shell is filled (2 electrons) before the second electron shell is filled. Likewise, the second electron shell is filled (8 electrons) before the third shell. The third shell is filled (8 electrons) before the fourth shell, which can hold up to 18 electrons.

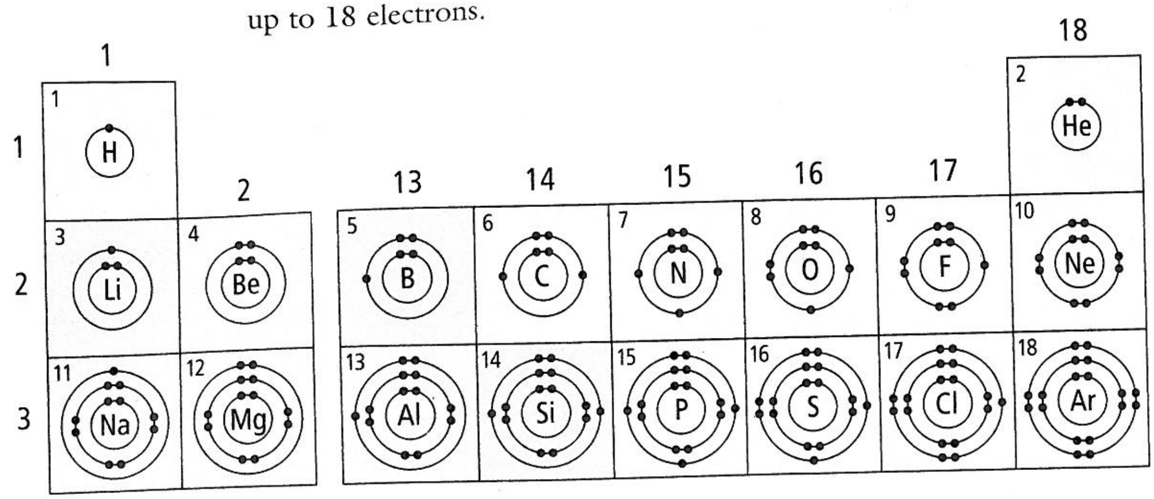


Figure 2.24 Electron arrangements in the first 18 elements

Did You Know?

Dalton was not quite correct when he said that all atoms of an element are identical. For instance, all carbon atoms have six protons, but the number of neutrons can vary from six to eight. These different varieties are called "isotopes."

The electrons in the outermost shell (those farthest from the nucleus) have the strongest influence on the properties of an atom. These electrons in the outermost shell are called **valence electrons**. The shell that contains the outermost electrons is called the **valence shell**.

You will notice several striking patterns in Figure 2.24.

- Most elements in the same family have the same number of valence electrons. For example, halogens have seven valence electrons. Helium, a noble gas, is an exception to the pattern with only two valence electrons.
- Elements in the same period have valence electrons in the same shell.
- The period number indicates the number of shells that have electrons.

Noble Gas Stability

The noble gases (He, Ne, Ar, Kr, Xe, Rn) are normally unreactive, which means the atoms do not form new substances with other atoms. Why? Because their atoms have filled valence shells—the maximum number of electrons in their outermost shells. That makes them stable. For two atoms to join together to make a new substance, atoms must gain, lose, or share electrons. But atoms with filled valence shells will not easily trade or share electrons. They have what we call noble gas stability.

Atoms from other families often try to achieve a kind of stability similar to the noble gases. To do this, they will gain or lose electrons. For example, metals, which usually have one, two, or three valence electrons, will often lose them all. When metals lose their valance electrons, their remaining electrons will have the same arrangement as the noble gas in their row in the periodic table.

What about non-metals? They gain one, two, or three extra electrons in order to achieve noble gas stability. They will gain exactly enough electrons to achieve the same electron arrangement as the noble gas in their row in the periodic table.

How Atoms Become Ions

Recall that an atom that has gained or lost electrons is called an ion. Ions carry an electric charge, because the number of protons (positive) in them is not equal to the number of electrons (negative). Note that:

- an atom of any metal can lose electrons and form positive ions
- an atom of any non-metal except a noble gas can gain electrons and form negative ions
- ions have the same electron arrangement as the nearest noble gas

The charge on an ion is shown on the symbol of an element by adding a superscript number followed by a plus or minus sign. Table 2.3 shows some examples of Bohr model diagrams for atoms and their ions.

Table 2.3 Bohr Model Diagrams of Lithium, Magnesium, and Chlorine

	lithium	magnesium	chlorine
Atom	Li 3 p 2, 1	Mg 12 p 2, 8, 2	Cl 17 p 2, 8, 7
Ion	Li^{+} 3 p 2	Mg^{2+} 12 p 2, 8	Cl^{-} 17 p 2, 8, 8

The charge on an ion is equal to the sum of the charges on its protons and electrons. For example, the magnesium ion Mg^{2+} has 12 protons (12+) and 10 electrons (10−) for a total charge of 2+.

Reading Check

1. How many electrons can there be in each of the first four shells surrounding an atom?
2. Draw a simple Bohr model diagram for the following elements: (a) hydrogen, (b) lithium, (c) sodium, and (d) potassium.
3. List the number of valence electrons in atoms from each family: (a) alkali metals, (b) alkaline earth metals, (c) halogens, and (d) noble gases.

Suggested Activity

Conduct an Investigation 2-3B on page 68

Explore More

Atomic radius is an estimate of the distance from the atom's nucleus to its "edge." The larger the radius, the larger the atom. But having more electrons does not always mean a larger atom. As usual with the periodic table, there is a pattern. Find out more about trends in the atomic radii of the elements at **www.bcscience9.ca.**