Topic 2.4

How are properties of atoms used to organize elements into the periodic table?

Key Concepts

- Elements are made up of atoms, which are made up of subatomic particles.
- Elements are arranged in the periodic table according to their atomic structure and properties.
- Elements in the same family (group) share similar physical and chemical properties.

Key Skills

Inquiry

Key Terms

atom
proton
neutron
electron
nucleus
atomic number
periodic table
period
family

Elements are the building blocks of which all matter on Earth is made. But what makes up the carbon in the coal that is burned as fuel, the oxygen in the air you breathe, or the silver and gold used to make fine works of art such as those shown here?

Imagine any element—gold, for example. Imagine cutting a piece of gold into smaller and smaller pieces until you can't chop it up any further. What you are left with is a bit of gold that is so small that the most powerful microscopes in the world are needed to magnify it enough to be able to view it. Nevertheless, this extremely tiny bit of gold still has all the properties of a piece of gold the size of the Bill Reid sculpture. The smallest unit of any element that still has all the properties of that element is called an atom.

All atoms of silver are the same as all other atoms of silver.

Grizzly Bear bracelet, 1975
(Courtesy Bill Reid Foundation Collection C #08)

Atoms of gold are different from atoms of silver. As well, atoms of gold and of silver are different from atoms of all other elements.

Starting Point Activity

Use the information in the "call-out" labels around the photos to answer these questions.

1. How do atoms of one element compare to atoms of another element?
2. Imagine that you are looking at Bill Reid's gold sculpture. How do gold atoms around Raven's mouth compare to gold atoms deep in the centre of the sculpture?
3. Imagine that you are looking at Bill Reid's gold sculpture and this 3600 year old gold mask thought to show the face of the ancient king of Mycenae, Agamemnon. How do atoms of gold around Raven's mouth compare to atoms of gold around Agamemnon's mouth?
4. Describe an atom using what you have learned.

▲ The gold mask of Agamemnon.

Famed Haida artist, Bill Reid (1920–1998), created this work of art from gold. It is called *The Raven and the First Men* and is only 7 cm by 6.9 cm by 5 cm. (Courtesy Bill Reid Foundation Collection C #25)

All atoms of gold are the same as all other atoms of gold.

Any atom is a million times smaller in diameter than the thinnest human hair.

Even the thinnest piece of gold or silver that you can imagine is about 200 000 atoms thick.

Elements are made up of atoms, which are made up of subatomic particles.

atom: the smallest unit of an element that displays the properties of that element

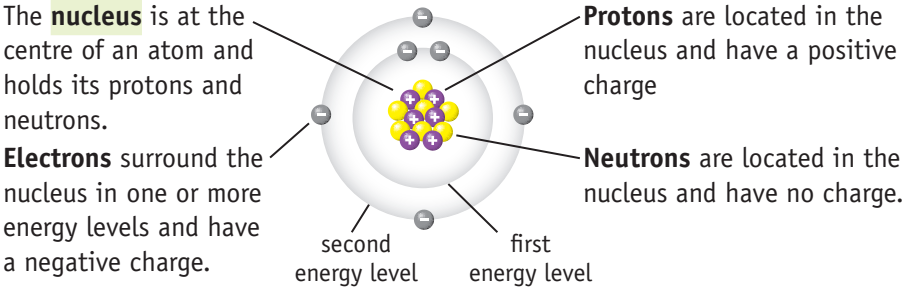
proton: a positively charged particle that is part of the atomic nucleus

neutron: an uncharged particle that is part of the atomic nucleus

electron: a negatively charged particle that surrounds the nucleus

nucleus: the positively charged centre of an atom

An **atom** is the smallest unit of an element that has the properties of that element. Figure 2.7 and Table 2.5 show that atoms are made up of even smaller subatomic particles: **protons**, **neutrons**, and **electrons**. The organization of subatomic particles in an atom is called the *atomic structure*.



▲ **Figure 2.7** This model shows the subatomic particles of an atom. (The atom in this case is a carbon atom.)

Table 2.5 Subatomic Particles of Atoms

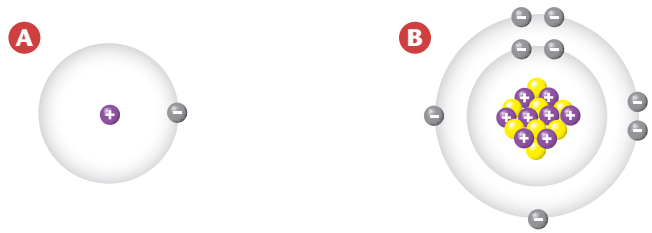
Name	Electrical Charge	Symbol	Location in an Atom	Relative Mass
proton	+	p^+	nucleus	about 1
electron	–	e^-	region around the nucleus	about $\frac{1}{2000}$
neutron	0	n^0	nucleus	about 1

The following statements are true for any atom.

- The number of protons is equal to the number of electrons.
- The number of protons that an atom of any element has is called the **atomic number**. For example, all hydrogen atoms have one proton. All oxygen atoms have 8 protons. The atomic number distinguishes the atoms of one element from the atoms of other elements. See Figure 2.8.
- The regions around an atom's nucleus are called *energy levels*. Atoms of each element have a different number of electrons in their energy levels. The number of energy levels ranges from one to seven. Two electrons can fit in the space of the first energy level. Eight electrons can fit in the second energy level. More electrons can fit into higher energy levels.

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

Go to **scienceontario** to find out more



◀ **Figure 2.8** The atomic number of hydrogen (A) is 1. The atomic number of oxygen (B) is 8. Count the protons in each nucleus to confirm this.

LEARNING CHECK

1. What does an atomic number represent?
2. Use a double bubble organizer to compare and contrast the atoms shown in **Figure 2.8**.
3. Use **Figure 2.7** as a guide to draw a beryllium atom.

Inquiry Focus

Activity 2.7

BUILDING ATOMS

In this activity, you will use common materials to make models that represent your understanding of what atoms look like.

What You Need

variety of materials to represent protons, neutrons, and electrons

What To Do

1. Choose one of the elements from this list. Use the information on page 122 to build a model for an atom of your element.

Element	Atomic Number	Subatomic Particles	Element	Atomic Number	Subatomic Particles
Hydrogen	1	1 p^+, 1 e^-, 0 n^0	Sodium	11	11 p^+, 11 e^-, 12 n^0
Helium	2	2 p^+, 2 e^-, 2 n^0	Magnesium	12	12 p^+, 12 e^-, 12 n^0
Lithium	3	3 p^+, 3 e^-, 4 n^0	Aluminum	13	13 p^+, 13 e^-, 14 n^0
Beryllium	4	4 p^+, 4 e^-, 5 n^0	Silicon	14	14 p^+, 14 e^-, 14 n^0
Boron	5	5 p^+, 5 e^-, 6 n^0	Phosphorus	15	15 p^+, 15 e^-, 16 n^0
Carbon	6	6 p^+, 6 e^-, 6 n^0	Sulfur	16	16 p^+, 16 e^-, 16 n^0
Nitrogen	7	7 p^+, 7 e^-, 7 n^0	Chlorine	17	17 p^+, 17 e^-, 18 n^0
Oxygen	8	8 p^+, 8 e^-, 8 n^0	Argon	18	18 p^+, 18 e^-, 22 n^0
Fluorine	9	9 p^+, 9 e^-, 10 n^0	Potassium	19	19 p^+, 19 e^-, 20 n^0
Neon	10	10 p^+, 10 e^-, 10 n^0	Calcium	20	20 p^+, 20 e^-, 20 n^0

Elements are arranged in the periodic table according to their atomic structure and properties.

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9	Group 10	Group 11	Group 12	Group 13	Group 14	Group 15	Group 16	Group 17	Group 18
Period 1	H																	He
Period 2	Li	Be											B	C	N	O	F	Ne
Period 3	Na	Mg											Al	Si	P	S	Cl	Ar
Period 4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Period 5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Period 6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn

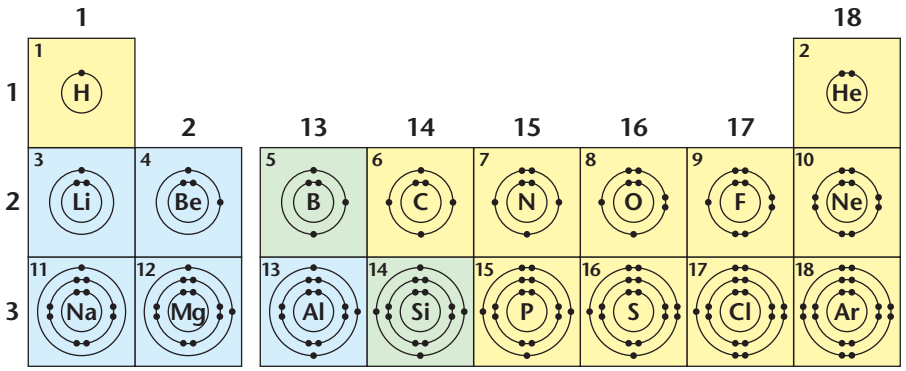
▲ **Figure 2.9** A simplified version of the periodic table of the elements. Short forms of the names of the elements are used. (You will learn more about the short forms in Topic 2.5.)

Figure 2.9 shows a simplified version of the **periodic table**. The place in the periodic table where each element appears depends on its atomic number and its properties.

Periods (rows on the periodic table) represent the number of energy levels that contain electrons. For instance, the elements in Period 1 have electrons in only the first energy level.

Families (columns or groups on the periodic table) represent the number of electrons in the outermost energy level. Many of the properties of elements are determined by these electrons. As you can see in **Figure 2.10**, atoms in the same family have the same number of electrons in their outer energy level. As a result, elements in the same family tend to have similar properties and react in a similar way.

Figure 2.11 on pages 126 and 127 shows a full, pictorial version of the periodic table. You can see a text version of it on page 434.



▶ **Figure 2.10** Several patterns are visible in the number and arrangements of the electrons of atoms of the first 18 elements.

Elements in the same family (group) share similar physical and chemical properties.

When the elements are organized in order of their atomic number and atomic structure, a variety of patterns emerge. The periodic table is developed so that each family (group) of elements has similar chemical and physical properties. This occurs because the atomic structure of an element determines its chemical and physical properties.

Another pattern that emerges when elements are sorted by atomic number involves metals and non-metals. As you can see in **Figure 2.9**, all metals (shown in blue) are on the left side of the periodic table. The most reactive metals are all in group 1. The reactivity of the elements in group 1 increases as you go down the column. So the most reactive metal in this group is at the bottom. It is cesium (Cs).

The non-metals (shown in yellow) are on the right side of the periodic table. The most reactive non-metals are all in group 17. The reactivity of the elements in group 17 increases as you go up the column. So the most reactive non-metal is at the top. It is fluorine (F).

The eight elements in green in **Figure 2.9** are metalloids. They share some properties of metals and some properties of non-metals.

periodic table: a chart in which elements are listed horizontally in order of their atomic number and in which elements with similar properties are arranged vertically

period: a horizontal row of elements in the periodic table

family: a vertical column of elements in the periodic table

Inquiry Focus

Activity 2.8

PATTERNS IN THE PERIODIC TABLE

Refer to **Figure 2.9** and **2.10**, and the index cards from Activity 2.6.

1. Look closely at the properties of the elements that are near each other vertically (up and down) and horizontally (beside each other). Describe any patterns that you see in the properties.
2. Explain how the atomic structure of an element is linked to its position in the periodic table and to its properties.

LEARNING CHECK

1. What determines an element's chemical and physical properties?
2. In the periodic table, what pattern emerges when elements are grouped into families?
3. Refer to **Figure 2.10**. What is the most reactive metal in group 2? What is the most reactive non-metal in group 16?

Periodic Table

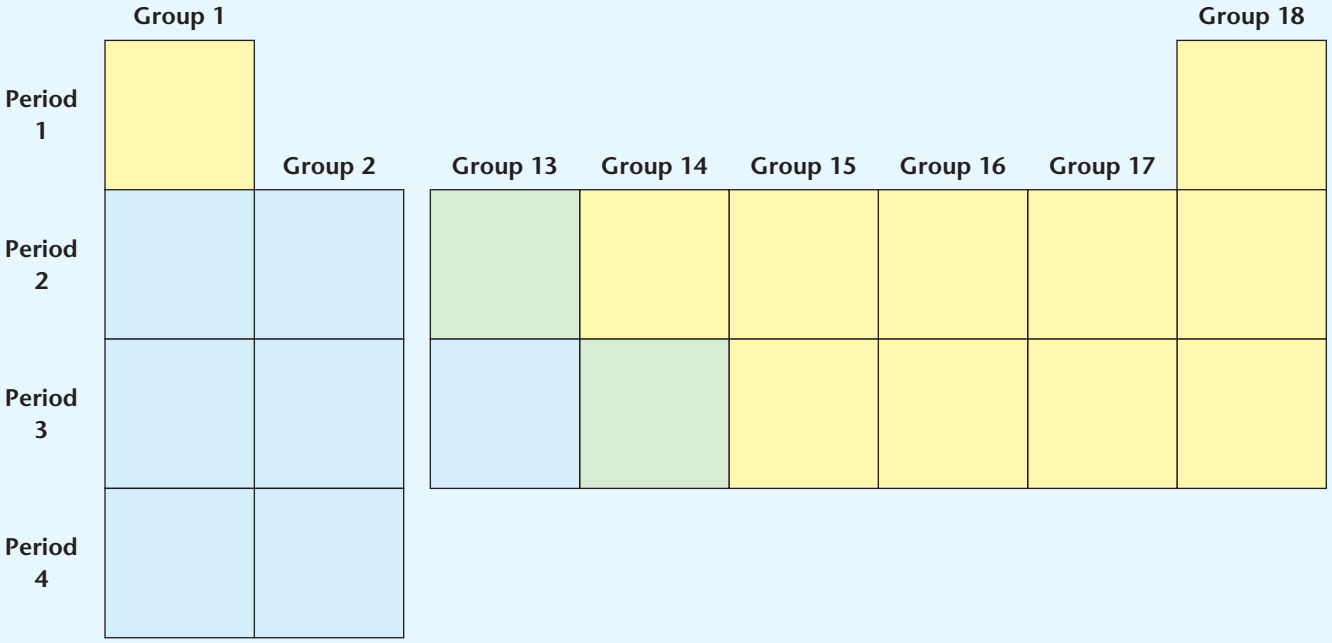
▲ **Figure 2.11** This pictorial version of the full periodic table includes photos of common uses of elements, as well as faces of important people who either discovered elements or added to our understanding of them.


He 2 Helium
B 5 Boron
C 6 Carbon
N 7 Nitrogen
O 8 Oxygen
F 9 Fluorine
Ne 10 Neon
Al 13 Aluminum
Si 14 Silicon
P 15 Phosphorus
S 16 Sulfur
Cl 17 Chlorine
Ar 18 Argon
Ni 28 Nickel
Cu 29 Copper
Zn 30 Zinc
Ga 31 Gallium
Ge 32 Germanium
As 33 Arsenic
Se 34 Selenium
Br 35 Bromine
Kr 36 Krypton
Pd 46 Palladium
Ag 47 Silver
Cd 48 Cadmium
In 49 Indium
Sn 50 Tin
Sb 51 Antimony
Te 52 Tellurium
I 53 Iodine
Xe 54 Xenon
Pt 78 Platinum
Au 79 Gold
Hg 80 Mercury
Tl 81 Thallium
Pb 82 Lead
Bi 83 Bismuth
Po 84 Polonium
At 85 Astatine
Rn 86 Radon
Ds 110 Darmstadtium
Rg 111 Roentgenium
Uub 112 Ununbium
Uut 113 Ununtrium
Uuq 114 Ununquadium
Uup 115 Ununpentium
Uuh 116 Ununhexium
Uus 117 Ununseptium
Uuo 118 Ununoctium
Gd 64 Gadolinium
Tb 65 Terbium
Dy 66 Dysprosium
Ho 67 Holmium
Er 68 Erbium
Tm 69 Thulium
Yb 70 Ytterbium
Lu 71 Lutetium
Cm 96 Curium
Bk 97 Berkelium
Cf 98 Californium
Es 99 Einsteinium
Fm 100 Fermium
Md 101 Mendelevium
No 102 Nobelium
Lr 103 Lawrencium

Inquiry Focus

Activity 2.9

BUILD A PERIODIC TABLE



In this activity, you will use the atomic models you built in Activity 2.7 to make your own periodic table based on the organization of the protons, neutrons, and electrons in the atom. Recall that the organization of the protons, neutrons, and electrons in an atom is called the atomic structure.

What To Do

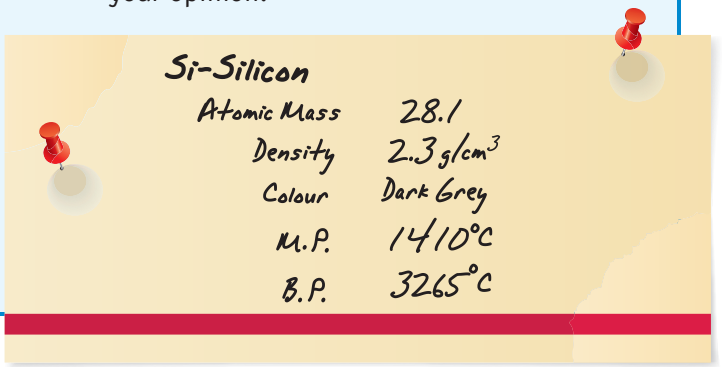
1. Work in pairs or small groups. Use your atomic models, the template above, and the information that you have learned about the periodic table to place your elements in the correct location based on the atomic structure of their atoms.
2. When you have placed all of your elements, check your periodic table with your teacher. Reorganize your elements if necessary.

What Did You Find Out?

1. What do the rows of the periodic table mean?
2. What do the columns of the periodic table mean?

Inquire Further

1. The periodic table of the elements is a human invention. In the 1800s, over a period of several decades, scientists from different countries tried to sort the elements that were known at the time. The scientist whose sorting method worked the best was a Russian chemist named Dmitri Mendeleev. He recorded properties of each element on cards. The picture shows the kind of information that Mendeleev wrote on his property cards.
   a) Find out how chemists of the time reacted to Mendeleev's ideas.
   b) Do you think that scientists in today's world still sometimes experience prejudice from their colleagues? Give reasons to justify your opinion.



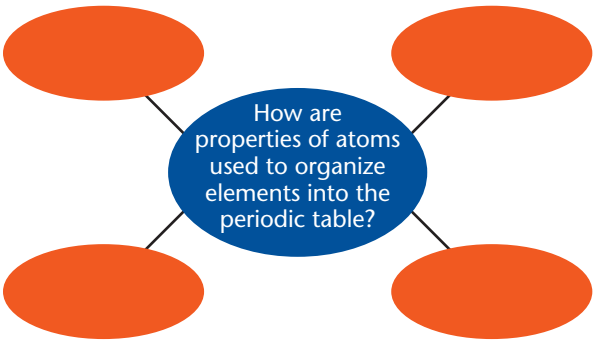
Topic 2.4 Review

Key Concept Summary

- Elements are made up of atoms, which are made up of subatomic particles.
- Elements are arranged in the periodic table according to their atomic structure and properties.
- Elements in the same family (group) share similar physical and chemical properties.

Review the Key Concepts

1. K/U Answer the question that is the title of this topic. Copy and complete the graphic organizer below in your notebook. Fill in four examples from the topic using key terms as well as your own words.



2. K/U Use a concept map to summarize the three parts of an atom. Include each part's charge, where each part is found, and the mass of each part compared to the other parts (relative mass).

3. T/I Compare an atom of sulfur with an atom of magnesium in terms of the number of protons, electrons, and neutrons. Use the table in Activity 2.7 on page 123 to help you.

4. K/U Why is the periodic table one of the most useful tools used by chemists and science students?

5. K/U List three elements found in period 2 of the periodic table.

6. K/U List two elements found in group 17 of the periodic table.

7. C The atomic number for nitrogen is 7.

a) How many protons and electrons does an atom of nitrogen have?

b) Nitrogen has 7 neutrons. Use the information from a) above and this new information to draw a diagram showing the structure of a nitrogen atom. (Hint: 2 electrons occupy the first energy level and then up to 8 electrons occupy the next energy level.)

8. A Sodium is a metal element found in group 1 of the periodic table. It is a soft metal that can be cut with a knife. Sodium reacts violently with water, as you can see in the photo below. Potassium is another element found in group 1 of the periodic table. Based on the information given for sodium and your knowledge of properties of elements in the same group of the periodic table, predict the properties of potassium.