

7.3

There are many different ways that scientists can classify the elements. One way is to separate them by their physical properties into metals, metalloids, and non-metals. As you have learned, in general, most metals conduct electricity, have a shiny lustre, and are malleable and ductile. Most non-metals do not conduct electricity, do not have a shiny lustre, and are gases at room temperature or brittle if solid. Metalloids have some of the properties of metals and some of the properties of non-metals. In the Periodic Table in Figure 1, the metal elements are shaded blue, the non-metal elements are shaded pink, and the metalloid elements are shaded green.

Figure 1 Periodic Table showing metal (blue), non-metal (pink), and metalloid elements (green)

| | | | | | | | | | | | | | | | | | | |
|----|----|----|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|-----|-----|--|
| H | | | | | | | | | | | | | | | | | He | |
| Li | Be | | | | | | | | | | | B | C | N | O | F | Ne | |
| Na | Mg | | | | | | | | | | | Al | Si | P | S | Cl | Ar | |
| K | Ca | Sc | Ti | V | Cr | Mn | Fe | Co | Ni | Cu | Zn | Ga | Ge | As | Se | Br | Kr | |
| Rb | Sr | Y | Zr | Nb | Mo | Tc | Ru | Rh | Pd | Ag | Cd | In | Sn | Sb | Te | I | Xe | |
| Cs | Ba | La | Hf | Ta | W | Re | Os | Ir | Pt | Au | Hg | Tl | Pb | Bi | Po | At | Rn | |
| Fr | Ra | Ac | Rf | Db | Sg | Bh | Hs | Mt | Ds | Rg | Uub | Uut | Uuq | Uup | Uuh | Uus | Uuo | |
| | | | Ce | Pr | Nd | Pm | Sm | Eu | Gd | Tb | Dy | Ho | Er | Tm | Yb | Lu | | |
| | | | Th | Pa | U | Np | Pu | Am | Cm | Bk | Cf | Es | Fm | Md | No | Lr | | |

LEARNING TIP

What does Figure 2 tell you? Try reading the Periodic Table up and down (in columns), rather than left to right (in rows). Ask yourself, "How many groups are there? How are the elements in each group like members of a family?"

Another way to classify the elements is by family, based on common physical and chemical properties. The Periodic Table in Figure 2 shows the major families highlighted in different colours. A third way to classify the elements is by group. The groups are the columns in the Periodic Table, and are numbered from 1 to 18, starting at the left.

| | | | | | | | | | | | | | | | | | | |
|----|----|----|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|-----|-----|--|
| H | 2 | | | | | | | | | | | | | | | 18 | | |
| Li | Be | | | | | | | | | | | 13 | 14 | 15 | 16 | 17 | He | |
| Na | Mg | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Al | Si | P | S | Cl | Ar | |
| K | Ca | Sc | Ti | V | Cr | Mn | Fe | Co | Ni | Cu | Zn | Ga | Ge | As | Se | Br | Kr | |
| Rb | Sr | Y | Zr | Nb | Mo | Tc | Ru | Rh | Pd | Ag | Cd | In | Sn | Sb | Te | I | Xe | |
| Cs | Ba | La | Hf | Ta | W | Re | Os | Ir | Pt | Au | Hg | Tl | Pb | Bi | Po | At | Rn | |
| Fr | Ra | Ac | Rf | Db | Sg | Bh | Hs | Mt | Ds | Rg | Uub | Uut | Uuq | Uup | Uuh | Uus | Uuo | |
| | | | Ce | Pr | Nd | Pm | Sm | Eu | Gd | Tb | Dy | Ho | Er | Tm | Yb | Lu | | |
| | | | Th | Pa | U | Np | Pu | Am | Cm | Bk | Cf | Es | Fm | Md | No | Lr | | |

alkali metals

transition metals

halogens

rare earth metals

alkaline earth metals

noble gases

Figure 2 Periodic Table showing major families of elements and group numbers

The elements can also be classified according to their ion charges, atomic number, or electron arrangement. The modern Periodic Table, based on Mendeleev's design, allows us to include all of these classifications in one model. It is a model that chemists use to explain and predict the chemical and physical behaviour of the elements.

Finding Information in the Periodic Table

Examine the following sample entry below from the Periodic Table (Figure 3). Note the location of the element name, chemical symbol, atomic number, ion charge, and atomic mass.

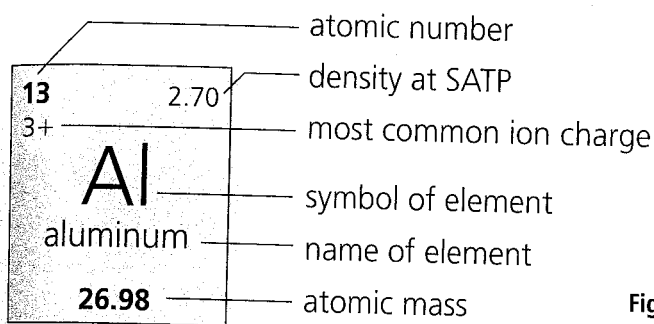


Figure 3 The entry for aluminum in the Periodic Table

What do the different parts of the entry tell you? The element name and chemical symbol tell you that Al is the chemical symbol for aluminum. The atomic number tells you the number of protons in the nucleus of the atom (13). Since the number of electrons in a neutral atom is equal to the number of protons, the atomic number also tells you the number of electrons. The ion charge of 3+ tells you that the aluminum atom will form an ion that has 3 fewer electrons than protons.

Unlike the mass number, the atomic mass is not an integer. Many elements have more than one isotope—an atom with the same number of protons, but a different number of neutrons. Therefore, the mass numbers of isotopes are different, but the atomic numbers are the same.

The **atomic mass** of an element is the average of the mass numbers of all the naturally occurring isotopes. The mass number is the mass of one particular isotope of an element. In many cases you can determine the mass number of the most common form of an element by rounding the atomic mass to the nearest whole number. The mass number of the most common form of aluminum is 27 (26.98 rounded up), so the number of neutrons in the most common form of the element is 14.

Calculating the Number of Electrons in an Ion

The number of protons in the nucleus of an atom does not change when the atom forms an ion—only the number of electrons orbiting the nucleus can change. Aluminum's atomic number is 13, so its atoms have 13 protons. Aluminum's ion charge is 3+. Therefore, an atom of aluminum has 13 electrons. An ion of aluminum will have only 10 electrons, 3 fewer electrons than protons. Oxygen's atomic number is 8, and its ion charge is 2-. Oxygen atoms have 8 electrons, but oxygen ions have 2 more electrons than protons or 10 electrons.

LEARNING TIP

Check your understanding. Examine Figure 3 closely. Then cover the labels. What vital information can you learn from Figure 3? Identify the element's name, symbol, atomic number, ion charge, and atomic mass.

To learn more about isotopes, go to

www.science.nelson.com



Did You KNOW?

Mass of Ions

The mass spectrometer is used to measure the mass of ions using electric and magnetic fields. Thomson's student, Francis Aston, constructed the first mass spectrometer in 1919 and used it (and later versions) to identify 212 of the 287 naturally occurring isotopes.

The size of the ion charge tells you the difference between the number of protons and the number of electrons in the ion. The + or - sign tells you if there are fewer (+) or more (-) electrons than protons (Table 1).

Table 1 Examples of Atoms and Ions

| Element | Atomic number | Number of electrons in the atom | Ion charge | Number of electrons in the ion |
|------------|---------------|---------------------------------|------------|--------------------------------|
| aluminum | 13 | 13 | 3+ | 10 |
| oxygen | 8 | 8 | 2- | 10 |
| sodium | 11 | 11 | 1+ | 10 |
| phosphorus | 15 | 15 | 3- | 18 |

LEARNING TIP •

Check your understanding. Work with a partner to answer the questions in the paragraph on the right.

Examine the Periodic Table at the back of the book. Can you find any other patterns in the way that information about the elements is presented? How are metals and non-metals indicated? How does ion charge change across a row or down a column? How do atomic mass and atomic number change across rows or down columns?

TRY THIS: Atoms and Ions

Skills Focus: recording, analyzing, interpreting data

You can find out a lot about an element from the Periodic Table. In this activity, you will organize the information about the first 20 elements in the Periodic Table.

1. Copy Table 2 into your notebook. Refer to the Periodic Table at the back of the book, and complete your table for the first 20 elements. Note that the elements in Group 18 usually do not form ions.

Table 2

| Atomic number | Element name | Ion charge | Number of protons | Number of electrons for atom | Number of electrons for ion |
|---------------|--------------|------------|-------------------|------------------------------|-----------------------------|
| 1 | hydrogen | 1+ | 1 | 1 | 0 |
| 2 | helium | 0 | 2 | 2 | does not form an ion |
| | | | | | |
| | | | | | |
| 19 | potassium | | | | |
| 20 | calcium | | | | |

- A. Do you see a pattern in the number of electrons in the ions of elements? Explain the pattern.

Refer to the modern Periodic Table at the back of the book to answer questions 1 to 9.

- Where on the Periodic Table are the elements that form ions with a positive charge?
- Where are the metals?
- Where are the elements that form ions with a negative charge?
- Where are the non-metals?
- Where are the metalloids?
- What shape does the arrangement of the metalloids form in the Periodic Table?
- Starting from carbon, what happens to the ion charge as you move to the right?
- Starting from carbon, what happens to the ion charge as you move to the left?
- As you move to the right, and down, what happens to the atomic mass and the atomic number? Are there any exceptions to your answers?
- What is the relationship between the number of protons in the nucleus of an atom and the atomic number of the element?
- Describe how to determine the number of electrons in the atom of an element.
- Describe how to determine the number of electrons in the ion of an element.
- A certain element has 12 protons and 14 electrons.
 - Is the element an atom or an ion?
 - Which element is it?
 - What charge, if any, does it have?
- A certain element has 34 protons and 36 electrons.
 - Is the element an atom or an ion?
 - Which element is it?
 - What charge, if any, does it have?

- A certain element has 24 protons and a charge of 3+.
 - Is the element an atom or an ion?
 - How many electrons does the element have in this form?
 - Which element is it?
- Look at the Periodic Table entry for sulfur in Figure 4.

| | |
|--------|------|
| 16 | 2.07 |
| 2- | |
| S | |
| sulfur | |
| 32.07 | |

Figure 4

- What is the atomic number?
 - What is the atomic mass?
 - What is the ion charge?
 - How many electrons does the sulfur atom have?
 - How many electrons does the sulfur ion have?
- Look at the Periodic Table entry for calcium in Figure 5.
 - What is the atomic number?
 - What is the atomic mass?
 - What is the ion charge?
 - How many electrons does the calcium atom have?
 - How many electrons does the calcium ion have?
 - Look up each of the following elements in the Periodic Table, list its atomic number and atomic mass, and state if it is a metal, non-metal, or metalloid.

| | |
|---------------|----------------|
| (a) tellurium | (e) manganese |
| (b) osmium | (f) silicon |
| (c) arsenic | (g) phosphorus |
| (d) yttrium | |

| | |
|---------|------|
| 20 | 1.54 |
| 2+ | |
| Ca | |
| calcium | |
| 40.08 | |

Figure 5