

12.3 The Periodic Table of the Elements

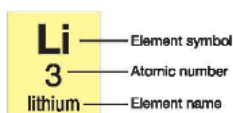
How many elements make up the universe? The only way to tell if a substance is an element is to try and chemically break it down into other substances by any possible means. A substance that can be chemically broken apart cannot be an element. As of this writing, scientists have identified 117 confirmed elements. Only about 90 of these elements occur naturally. The others are made in laboratories.

The periodic table

The modern periodic table

As chemists worked on identifying the true elements, they noticed that some elements acted like other elements. For example, the soft metals lithium, sodium, and potassium always combine with oxygen in a ratio of two atoms of metal to one atom of oxygen (Figure 12.17). By keeping track of how each element combined with other elements, scientists began to recognize repeating patterns. From this data, they developed the first periodic table of the elements. The **periodic table** organizes the elements according to how they combine with other elements due to their chemical properties.

Organization of the periodic table



The periodic table is organized in order of increasing atomic number. The lightest element (hydrogen) is at the upper left. The heaviest is on the lower right. Each element corresponds to one box in the periodic table, identified with the element symbol.

The periodic table is further divided into periods and groups. Each horizontal row is called a **period**. Across any period, the properties of the elements gradually change. Each vertical column is called a **group**. Groups of elements have similar properties. The *main group elements* are Groups 1 and 2 and Groups 13 through 18 (the tall columns of the periodic table). Elements in Groups 3 through 12 are called the *transition elements*. The inner transition elements, called *lanthanides* and *actinides*, are often shown below the bottom row of the chart in order for the chart to fit on a page.

VOCABULARY

periodic table - a chart that organizes the elements by their chemical properties and increasing atomic number.

period - a row of the periodic table.

group - a column of the periodic table.

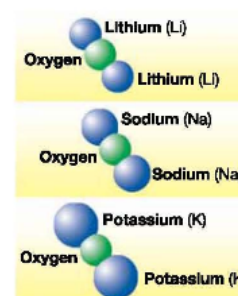


Figure 12.17: The metals lithium, sodium, and potassium all form compounds with a ratio of two atoms of the metal to one atom of oxygen. All the elements in Group 1 of the periodic table form similar compounds.

Chapter 12 ATOMS AND THE PERIODIC TABLE

Reading the periodic table

Metals, nonmetals, and metalloids

Most of the elements are **metals**. A metal is typically shiny, opaque, and a good conductor of heat and electricity as a pure element. Metals are also ductile, which means they can be bent into different shapes without breaking. **Nonmetals** are poor conductors of heat and electricity. Solid nonmetals are brittle and appear dull. With the exception of hydrogen, the nonmetals are on the right side of the periodic table. The elements on the border between metals and nonmetals are called **metalloids**. Silicon is an example of a metalloid element with properties in between those of metals and nonmetals.

VOCABULARY

metals - elements that are typically shiny and good conductors of heat and electricity.

nonmetals - elements that are poor conductors of heat and electricity.

Periodic Table of the Elements

1 H 1 hydrogen	2 He 2 helium											13 B 5 boron	14 C 6 carbon	15 N 7 nitrogen	16 O 8 oxygen	17 F 9 fluorine	18 Ne 10 neon
3 Li lithium	4 Be beryllium											13 Al aluminum	14 Si silicon	15 P phosphorus	16 S sulfur	17 Cl chlorine	18 Ar argon
11 Na sodium	12 Mg magnesium	3 Sc scandium	4 Ti titanium	5 V vanadium	6 Cr chromium	7 Mn manganese	8 Fe iron	9 Co cobalt	10 Ni nickel	11 Cu copper	12 Zn zinc	13 Ga gallium	14 Ge germanium	15 As arsenic	16 Se selenium	17 Br bromine	18 Kr krypton
19 K potassium	20 Ca calcium	21 Sc scandium	22 Ti titanium	23 V vanadium	24 Cr chromium	25 Mn manganese	26 Fe iron	27 Co cobalt	28 Ni nickel	29 Cu copper	30 Zn zinc	31 Ga gallium	32 Ge germanium	33 As arsenic	34 Se selenium	35 Br bromine	36 Kr krypton
37 Rb rubidium	38 Sr strontium	39 Y yttrium	40 Zr zirconium	41 Nb niobium	42 Mo molybdenum	43 Tc technetium	44 Ru ruthenium	45 Rh rhodium	46 Pd palladium	47 Ag silver	48 Cd cadmium	49 In indium	50 Sn tin	51 Sb antimony	52 Te tellurium	53 I iodine	54 Xe xenon
55 Cs cesium	56 Ba barium		72 Hf hafnium	73 Ta tantalum	74 W tungsten	75 Re rhenium	76 Os osmium	77 Ir iridium	78 Pt platinum	79 Au gold	80 Hg mercury	81 Tl thallium	82 Pb lead	83 Bi bismuth	84 Po polonium	85 At astatine	86 Rn radon
87 Fr francium	88 Ra radium		104 Rf rutherfordium	105 Db dubnium	106 Sg seaborgium	107 Bh bohrium	108 Hs hassium	109 Mt meitnerium	110 Ds darmstadtium	111 Rg roentgenium	112 Uub ununbium	113 Uut ununtrium	114 Uuq ununquadium	115 Uup ununpentium	116 Uuh ununhexium	117 Uus ununseptium	118 Uuh ununoctium
		57 La lanthanum	58 Ce cerium	59 Pr praseodymium	60 Nd neodymium	61 Pm promethium	62 Sm samarium	63 Eu europium	64 Gd gadolinium	65 Tb terbium	66 Dy dysprosium	67 Ho holmium	68 Er erbium	69 Tm thulium	70 Yb ytterbium	71 Lu lutetium	
		89 Ac actinium	90 Th thorium	91 Pa protactinium	92 U uranium	93 Np neptunium	94 Pu plutonium	95 Am americium	96 Cm curium	97 Bk berkelium	98 Cf californium	99 Es einsteinium	100 Fm fermium	101 Md mendelevium	102 No nobelium	103 Lr lawrencium	

Atomic mass

Atomic mass units The mass of individual atoms is so small that the numbers are difficult to work with. To make calculations easier, scientists came up with the **atomic mass unit** (amu). One atomic mass unit is about the mass of a single proton (or neutron). In laboratory units, 1 amu is 1.66×10^{-24} gram. That's 0.000000000000000000000000166 gram!

Atomic mass and isotopes The **atomic mass** is the *average* mass (in amu) of an atom of each element. Atomic masses differ from mass numbers because most elements in nature contain more than one isotope (see chart below). For example, the atomic mass of lithium is 6.94 amu. That does NOT mean there are 3 protons and 3.94 neutrons in a lithium atom! On average, out of every 100 atoms of lithium, 6 atoms are Li-6 and 94 atoms are Li-7 (Figure 12.18). The *average* atomic mass of lithium is 6.94 because of the mixture of isotopes.

Atomic number review As you learned earlier, the atomic number is the number of protons all atoms of that element have in their nuclei. If the atom is neutral, it will have the same number of electrons as well.

VOCABULARY

atomic mass unit - a unit of mass equal to 1.66×10^{-24} grams.
atomic mass - the average mass of all the known isotopes of an element, expressed in amu.

1.008 1, 2 H 1	6.941 6, 7 Li 3	9.012 9 Be 4	10.811 10, 11 B 5	12.011 12, 13 C 6	14.007 14, 15 N 7	16.999 16, 17, 18 O 8	18.998 19 F 9	20.180 20, 21, 22 Ne 10
22.990 23 Na 11	24.305 24, 26, 28 Mg 12	26.982 27 Al 13	28.086 28, 29, 30 Si 14	30.974 31 P 15	32.065 32, 33, 34, 36 S 16	35.453 35, 37 Cl 17	39.948 36, 38, 40 Ar 18	4.003 3, 4 He 2

6.941 — Average atomic mass (amu)
 6, 7 — Stable mass numbers
 Li — Element symbol
 3 — Atomic number



Figure 12.18: Naturally occurring elements have a mixture of isotopes.

Chapter 12 ATOMS AND THE PERIODIC TABLE

Groups of the periodic table

Alkali metals All of the elements in the different groups of the periodic table have similar chemical properties. The first group is known as the **alkali metals**. Some examples of this group are the elements lithium (Li), sodium (Na), and potassium (K). The alkali metals are soft and silvery in their pure form and are highly reactive. Each of them combines in a ratio of two to one with oxygen. For example, lithium oxide has two atoms of lithium per atom of oxygen.

Li 3
Na 11
K 19

Group 2 metals Some examples of Group 2 metals are beryllium (Be), magnesium (Mg), and calcium (Ca). These metals also form oxides, however, they combine one-to-one with oxygen. For example, beryllium oxide has one beryllium atom per each oxygen atom.

Be 4
Mg 12
Ca 20

Halogens The **halogens** are on the right-hand side of the periodic table. These elements tend to be toxic in their pure form. Some examples are fluorine (F), chlorine (Cl), and bromine (Br). The halogens are also very reactive and are rarely found in pure form. When combined with alkali metals, they form salts, such as sodium chloride (NaCl) and potassium chloride (KCl).

F 9
Cl 17
Br 35

Noble gases On the far right of the periodic table are the **noble gases**. Some examples of this group are the elements helium (He), neon (Ne), and argon (Ar). These elements do not naturally form chemical bonds with other atoms and are almost always found in their pure state. They are sometimes called *inert gases* for this reason.

He 2
Ne 10
Ar 18

Transition metals In the middle of the periodic table are the transition metals, including titanium (Ti), iron (Fe), and copper (Cu). These elements are usually good conductors of heat and electricity. For example, the wires that carry electricity in your school are made of copper. Figure 12.19 shows the location of the groups of elements on the periodic table.

Ti 22
Fe 26
Cu 29

metals

VOCABULARY

alkali metals - elements in the first group of the periodic table.

halogens - elements in the group containing fluorine, chlorine, and bromine, among others.

noble gases - elements in the group containing helium, neon, and argon, among others.

Figure 12.19: Groups of the periodic table.

Energy levels and the periodic table

- Period 1 is the first energy level** The periods (rows) of the periodic table correspond to the energy levels in the Bohr model of the atom (Figure 12.20). The first energy level can accept up to two electrons. Hydrogen (H) has one electron and helium (He) has two. These two elements complete the first period.
- Period 2 is the second energy level** The next element, lithium (Li), has three electrons. Lithium begins the second period because the third electron goes into the second energy level. The second energy level can hold eight electrons, so there are eight elements in the second row of the periodic table, ending with neon (Ne). Neon has 10 electrons, which completely fill the second energy level.
- Period 3 is the third energy level** Sodium (Na) has 11 electrons, and starts the third period because the eleventh electron goes into the third energy level. We know of elements with up to 118 electrons. These elements have their outermost electrons in the seventh energy level.
- Outer electrons** As we will see in the next chapter, the outermost electrons in an atom are the ones that interact with other atoms. The outer electrons are the ones in the highest energy level. Electrons in the completely filled inner energy levels do not participate in forming chemical bonds.

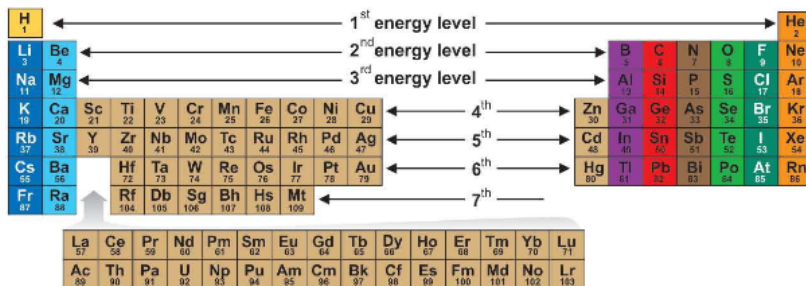
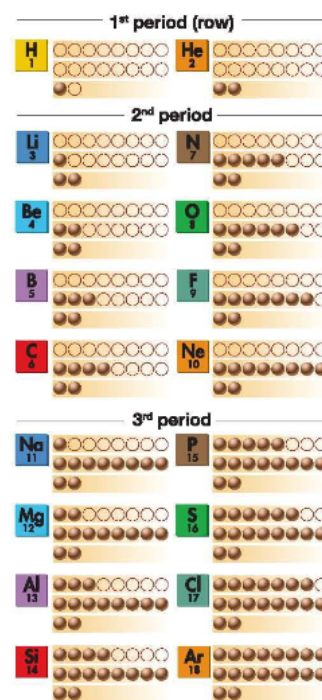


Figure 12.20: The rows (periods) of the periodic table correspond to the energy levels for the electrons in an atom.

Chapter 12 ATOMS AND THE PERIODIC TABLE

Section 12.3 Review

- Groups of the periodic table correspond to elements with:
 - the same mass number
 - the same atomic number
 - similar chemical properties
 - similar numbers of neutrons
- Which element is the atom shown in Figure 12.21?
- Name three elements that have similar chemical properties to oxygen.
- The atomic mass unit (amu) is:
 - the mass of a single atom of carbon
 - one-millionth of a gram
 - approximately the mass of a proton
 - approximately the mass of an electron
- Which element belongs in the empty space in Figure 12.22?
- The outermost electrons of the element vanadium (atomic #23) are in which energy level of the atom? How do you know?
- The elements fluorine, chlorine, and bromine are in which group of the periodic table?
 - the alkali metals
 - the oxygen-like elements
 - the halogens
 - the noble gases
- Which three metals are in the third period (row) of the periodic table?

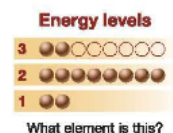


Figure 12.21: Question 2.

			He 2
N 7	O 8	F 9	Ne 10
P 15	S 16	?	Ar 18
As 33	Se 34	Br 35	Kr 36
Sb 51	Te 52	I 53	Xe 54

Figure 12.22: Question 5.