Atoms are the smallest, electrically neutral assemblies of energy and matter that we know exist in the universe. It is important to understand what "electrically neutral" means.

This force results when tiny, charged particles called **electrons** flow from one place to another; for example, along a wire. Physicists say that the electrons carry a negative charge—the electrical force that we exploit to power the world. Electrons move in directions that allow them to balance out, or "neutralize" their charges. In atoms, electron charges are neutralized as the electrons crowd in around a central core of "positively charged" **protons.** The core, or **nucleus** of the atom, also contains **neutrons**.

An element is defined by the number of protons in its nucleus. The composition of the crust is shown in the table below although there are about 90 stable elements, all but less than one and one - half percent of the crust is composed of only eight elements.

Table 3–1 The eight most abundant chemical elements in the earth's crust

Element	Symbol	Weight Percent	Atom Percent	Volume Percent
Oxygen	O	46.60	62.55	93.8
Silicon	Si	27.72	21.22	0.9
Aluminum	Al	8.13	6.47	0.5
Iron	Fe	5.00	1.92	0.4
Calcium	Ca	3.63	1.94	1.0
Sodium	Na	2.83	2.64	1.3
Potassium	K	2.59	1.42	1.8
Magnesium	Mg	2.09	1.84	0.3
Total		98.59	100.00	100.00

Atomic Number, Atomic Mass Number, Isotopes, and Atomic Weight

The number of protons in an atom controls the "behavior" of an element more than does the number of other subatomic particles.

The **atomic number** of an element is the number of protons in each atom. As per our earlier definition of an element, each atom of an element has the same number of protons.

The **atomic mass number** is the total number of neutrons and protons in an atom. Heavier elements have more neutrons and protons than do lighter ones. For example, the heavy element gold has an atomic mass number of 197, whereas helium has an atomic mass number of only 4.

Isotopes of an element are atoms containing different numbers of neutrons but the same number of protons. Isotopes are either stable or unstable. An unstable, or radioactive, isotope is one in which protons or neutrons are, over time, spontaneously lost from the nucleus. The subatomic particles that unstable isotopes emit are what Geiger counters detect. This is radioactivity, which we know can be hazardous in high doses.

A stable isotope is an isotope that will retain all of its protons and neutrons through time. During recent years, stable isotopes have become increasingly important to geology and related sciences.

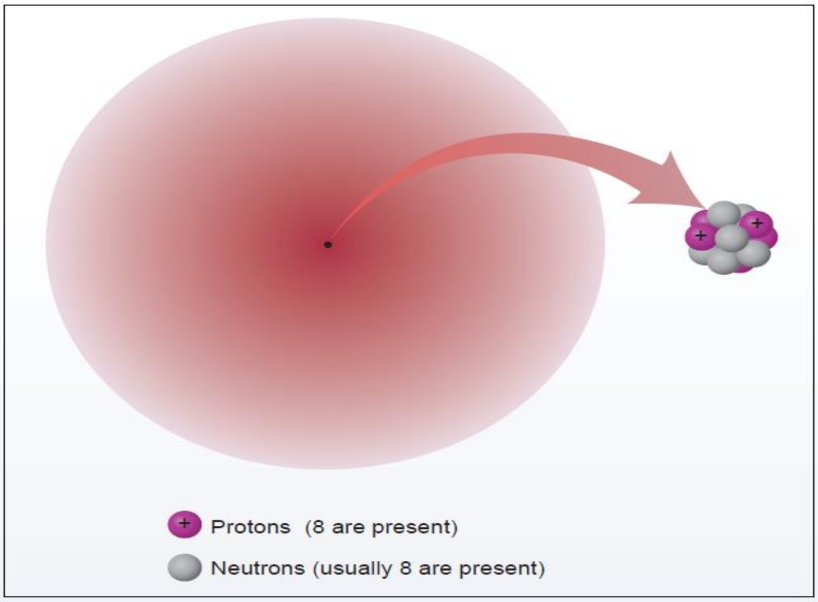

Figure 3.1 Model of an oxygen atom and its nucleus.

Atomic weight is the weight of an average atom of an element, given in atomic mass units. Because sodium has only one naturally occurring isotope, its atomic mass number and its atomic weight are the same—23. On the other hand, chlorine has two common isotopes, with mass numbers of 35 and 37. The atomic weight of chlorine, which takes into account the abundance of each isotope, is about 35.5 because the lighter isotope is more common than the heavier one.

Bonding

Ions may be regarded as tiny spheres that behave much like magnets. Positively charged ions attract negatively charged ions so that their electrical charges can be neutralized. In saltwater, equal numbers of sodium ions (Na+) and chlorine ions (Cl-) move about freely. The electrical neutrality of the water is maintained because positive sodium ions exactly balance negative chlorine ions. If the water evaporates, the sodium and chlorine are electrically attracted to each other and crystallize into halite.

A chlorine ion and a sodium ion are fixed in place by their electrical attraction to each other. This is called **ionic bonding** because it is brought about by an attraction between positively and negatively charged ions.

However, in most minerals the bonds between atoms are not purely ionic. Atoms are also commonly bonded together by **covalent bonding,** or bonding in which adjacent atoms share electrons.

Graphite, like diamond, is pure carbon. Graphite is used in pencils and as a lubricant. Amazingly, the hardest mineral and one of the softest have the same composition. The distinction is in the bonding.

A third type of bonding, **metallic bonding**, is not as important to geology. In metals, such as iron or gold, the atoms are closely packed and the electrons move freely throughout the crystal so as to hold the atoms together.

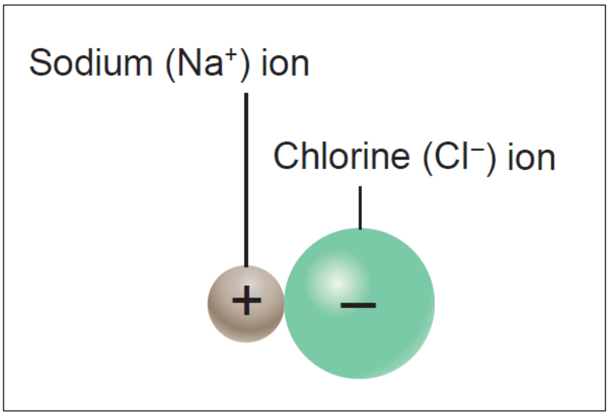

Figure 3.2 Ionic bonding between sodium (Na_) and chlorine (Cl_).

Isolated Silicate Structure

Silicate minerals that are structured so that none of the oxygen atoms is shared by tetrahedrons have an isolated silicate structure. The individual silicon-oxygen tetrahedrons are bonded together by positively charged ions (figure 10.6). The common mineral olivine, for example, contains two ions of either magnesium (Mg+2) or iron (Fe+2) for each silicon-oxygen tetrahedron. The formula for olivine is (Mg,Fe)2SiO4.

Chain Silicates

A chain silicate structure forms when two of a tetrahedron's oxygen atoms are shared with adjacent tetrahedrons to form a chain (figures 10.5 and 10.7). Each chain, which extends indefinitely, has a net excess of negative charges. Minerals may have a single- or double-chain structure.

A double-chain silicate is essentially two adjacent single chains that are sharing oxygen atoms.

Chain silicates tend to be shaped like columns, needles, or even fibers. The long structure of the external form corresponds to the linear dimension of the chain structure. Fibrous aggregates of certain minerals are called asbestos.

Sheet Silicates

In a sheet silicate structure each tetrahedron shares three oxygen atoms to form a sheet . The positive ions that hold the sheets together are “sandwiched” between the silicate sheets.

Framework Silicates

When all four oxygen ions are shared by adjacent tetrahedrons, a framework silicate structure is formed. Quartz and feldspar are framework silicate mineral. However, its structure is slightly more complex because aluminum substitutes for some of the silicon atoms in some of the tetrahedrons.

Nonsilicate Minerals

Although not as abundant in Earth, nonsilicates, minerals that do not contain silica, are nevertheless important. The carbonates have CO3 in their formulas. Calcite, CaCO3, is a member of this group and is one of the most abundant minerals at the Earth’s surface where it occurs mainly in limestone.

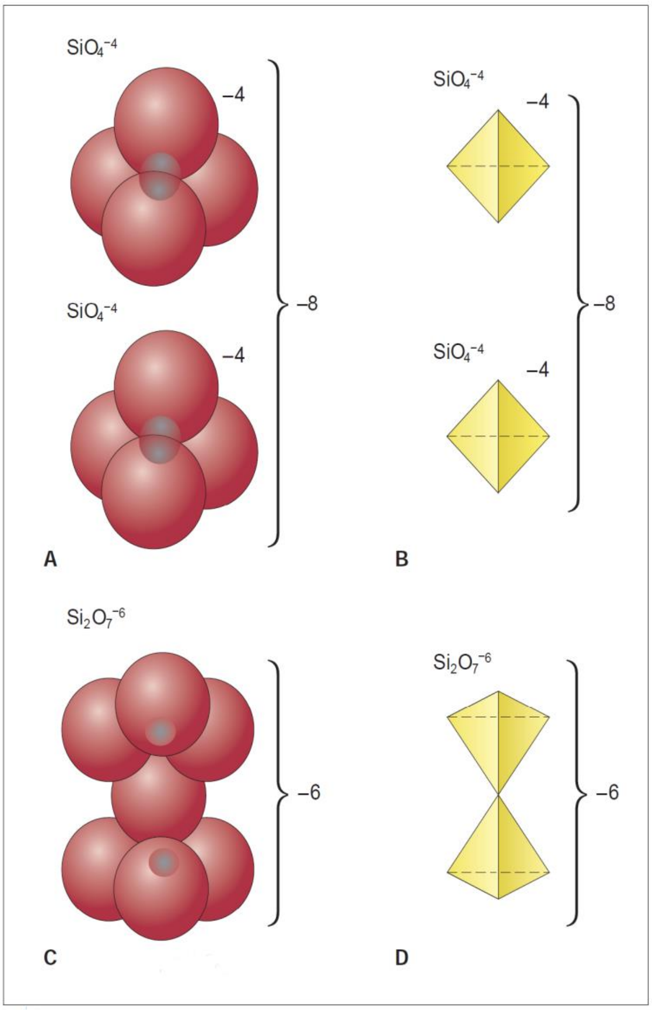

Figure 3.3 Two single tetrahedrons (A and B) require more positively charged ions to maintain electrical neutrality than two tetrahedrons sharing an oxygen atom (C and D). B and D are the schematic representations of A and C,

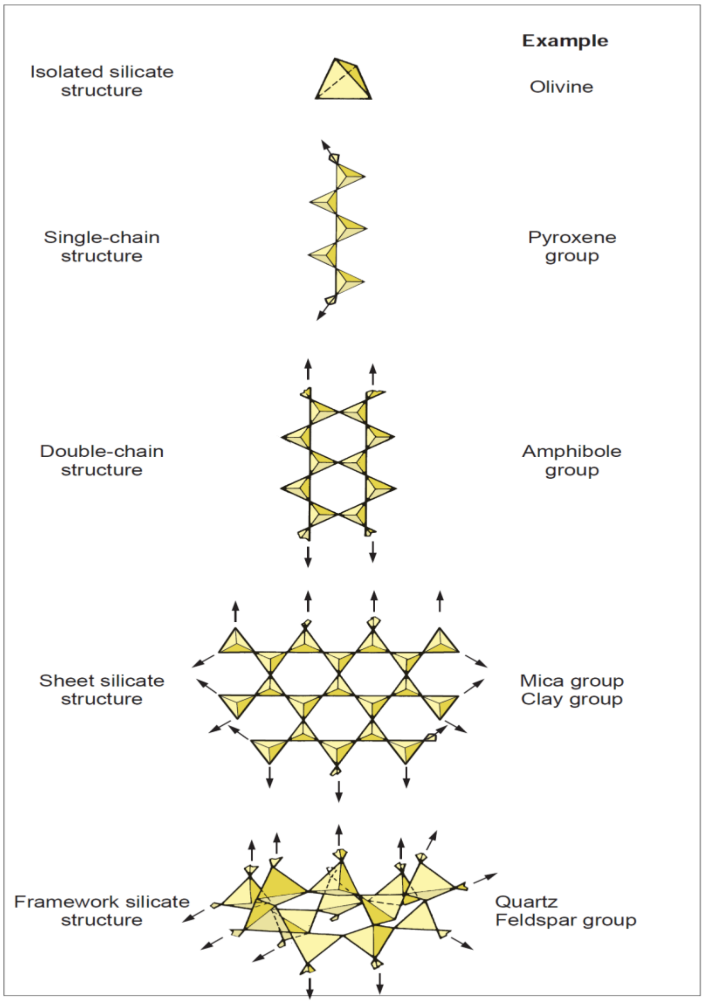

Figure 3.4 Common silicate structures. Arrows indicate directions in which structure repeats indefinitely.