Teacher Tune-up

Quick Content Refresher for Busy Professionals

What does atomic structure have to do with how atoms bond with each other?

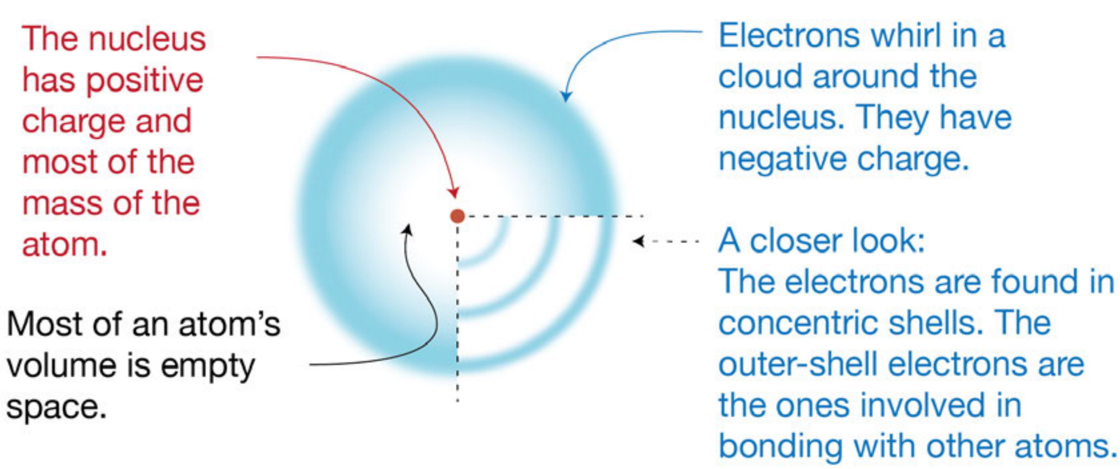
The atomic model of matter has varying degrees of complexity and detail, depending on what properties of matter you're modeling—and also on which historical edition of the model you're dusting off. In the 1700s, the Swiss physicist Daniel Bernoulli developed the kinetic theory of gases, which modeled gas pressure and temperature as effects of invisible, tiny balls flying around in random directions, having perfectly elastic collisions like idealized billiard balls. This atomistic picture of matter jumped from physics to chemistry in 1803 when John Dalton used atoms to account for the ratios of elements found in different compounds. (See Tune-up M1t1, "What evidence first led chemists to adopt the modern atomic theory of matter?")

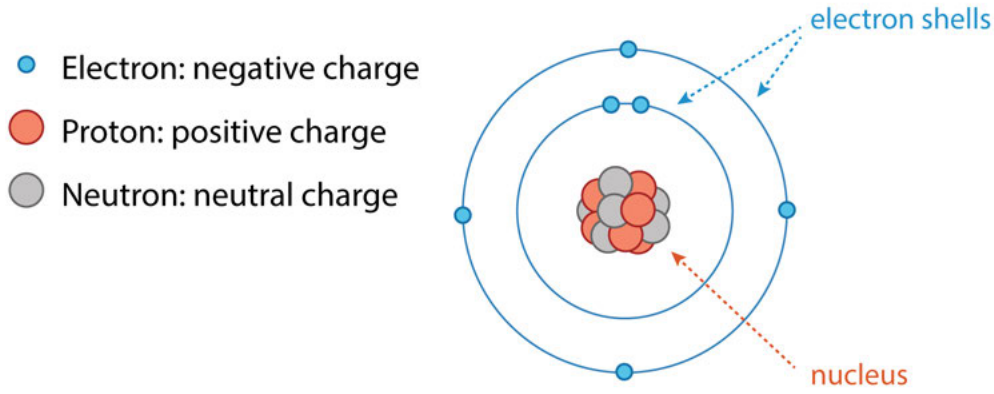
So from Bernoulli to Dalton, the model went from simple billiard balls to more complex balls that could form bonds with each other in consistent patterns. From the chaos of gases, atoms stepped into the realm of chemical architecture, and since then the atomic model has grown ever more complex and detailed.

What parts and rules govern the architecture of atoms, both their internal structure and the consequent structural relations between atoms? Hang on tight for a whirlwind tour of the atomic model!

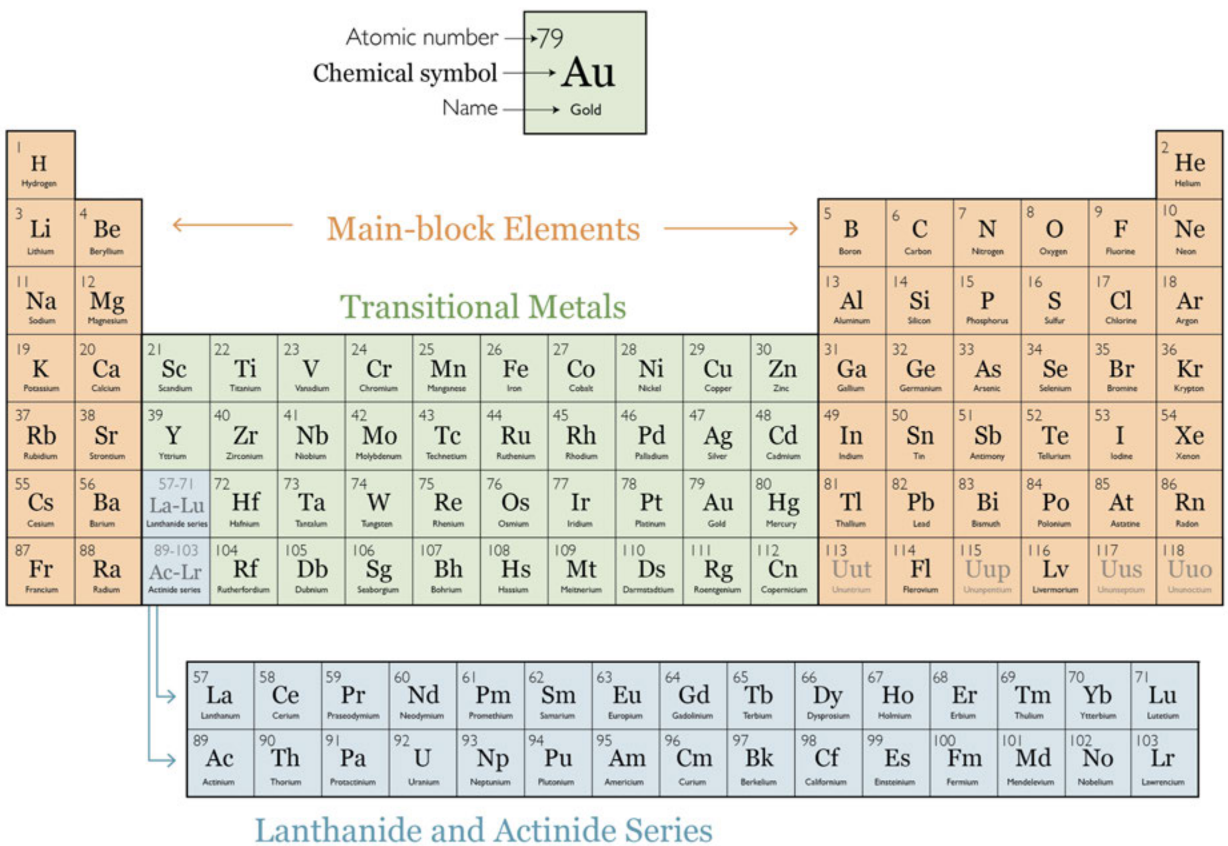
Atoms aren't just solid spheres. They are mostly empty space, with negatively charged electrons whizzing around a central kernel, a positively charged nucleus.

That nucleus in the middle is made of two kinds of particles, protons and neutrons. They make up most of the mass of the atom. The neutrons have no electrical charge, but each proton has a positive electrical charge, equal in magnitude to the negative charge of the much less massive electrons. Protons, neutrons, and electrons—these are the three basic **subatomic particles** of which atoms are made.





The number of protons in an atom determines what *kind* of atom—what **element**—it is. If an atom has one proton, it's a hydrogen atom. If it has two protons, it's a helium atom. If it has… okay, that's enough, our tour is moving on. To learn more about different elements and their number of protons, you can check any periodic table of the elements. Here's one.



The **atomic number** for each element, shown in the upper left corner of each square, is the number of protons in the atoms of that element.

What's so important about an element's atomic number? Well, each proton attracts one electron (because a proton and an electron have equal but opposite charges). And the electrons orbiting the nucleus of an atom determine how that atom will interact with other atoms. Depending on the number and arrangement of their electrons, atoms may either grasp or fend off certain other atoms. The number of protons determines the number and arrangement of electrons, which determines how atoms interact to make or break bonds with each other.

The last stop on our tour is a closer look at those electrons. They aren't just buzzing around the nucleus like a bunch of honey-drunk bees. There's a method to their madness, a pattern in the cloud. In an atom with more than a couple of protons, some electrons are pulled closer to the nucleus, held tight by their strong attraction to the protons. Depending on the element, there may be multiple concentric layers, or **shells**, of electrons. (Counting from the top, an element's row in the periodic table tells you how many electron shells it has.) Farther out, the positive charge of the nucleus is diluted by the inner electrons. So the electrons in the outermost shell zip around paying less attention to the nucleus and correspondingly more attention to other nearby atoms.

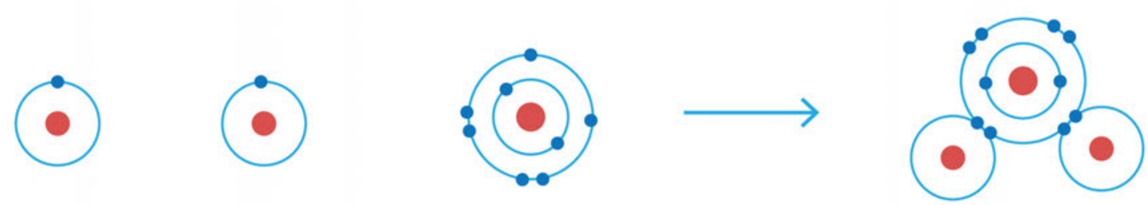
These outer electrons are called **valence electrons**, and they are the means by which atoms form chemical bonds with each other.

For a bunch of mindless particles, atoms are pretty good at doing simple arithmetic. Among the main-block elements (shown in orange in the table above), atoms usually use their electron glue according to a so-called **octet rule**: The atoms of these elements are most stable when they have a complete set of 8 electrons in their valence shell. (Exceptions: hydrogen and helium are satisfied with just 2 valence electrons; and non–main-block elements don't always follow the octet rule.)

But only the elements in the rightmost column of the periodic table—the so-called noble gases like helium, neon, and argon—have their own full octet (or duet for helium) of valence electrons. Chemically stable and aloof, those self-sufficient noble gas atoms hardly ever get chemically involved with each other or with other kinds of atoms.

The other elements, however, are on the make, eager to achieve a stable set of valence electrons. How? Lacking the right number of protons to pack their inner electron shells and top it all off with a complete valence shell, they must complete their valence shells by *sharing electrons* with other atoms. Elements mix and match in various combinations and proportions to form compounds where all the atoms can feel like well-dressed noble gases, with just the right number of valence electrons, no more and no less.

Here's an illustration of how every atom comes out a winner in a water molecule.

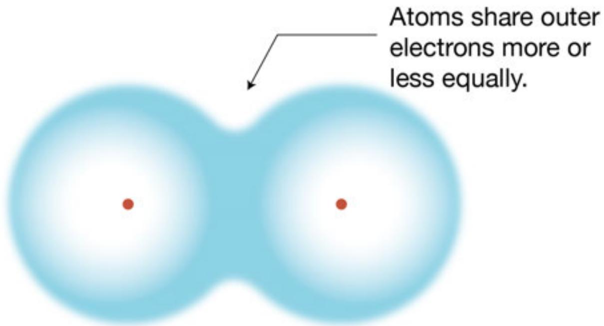


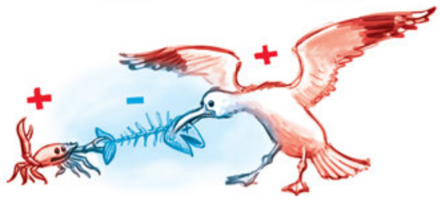
Hydrogen atoms each have 1 valence electron, but "want" 2.

An **oxygen atom** has 6 valence electrons, but wants 8. (The 2 inner electrons aren't directly involved in bonding.)

In a **water molecule,** atoms share electrons so that each hydrogen atom has 2 electrons in its valence shell and the oxygen atom has 8 electrons in its valence shell.

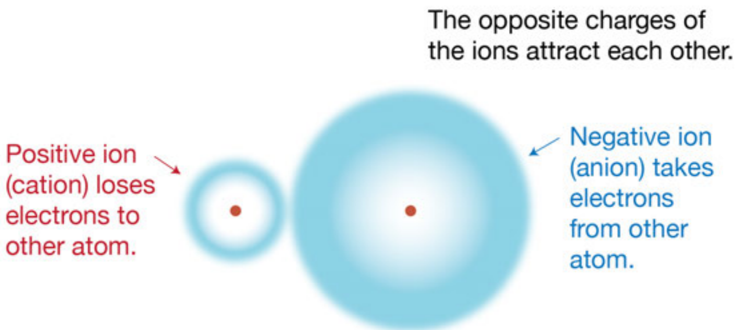
Depending on which elements are involved, atoms share electrons in three basic ways: covalent, ionic, and metallic bonding.





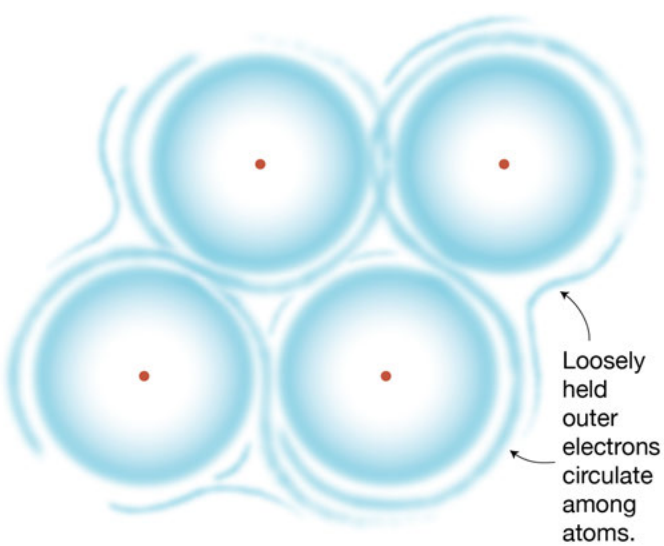
COVALENT BONDS

In covalent bonds, the electrons are shared more or less evenly. Covalent bonds hold atoms together in molecular substances like water and sugar, and also in indefinitely extended covalent structures like diamond.



IONIC BONDS

In ionic bonds, one atom grabs all the electrons, becoming a negatively charged ion (because now it has more electrons than protons). The other atom becomes a positive ion (because now it has more protons than electrons). The opposite charges of these ions attract, so the ions stick together. (In this arrangement, both ions gain stable, noble-gas–like valence shells: the negative ion looks like the noble gas to its right in the periodic table, and the positive ion looks like the noble gas from the previous row, which—for the smallest ions—may be helium with its 2-electron exception to the octet rule.) Salts are ionic compounds.



METALLIC BONDS

Metallic bonding is a looser affair. Shared electrons slip relatively easily from atom to atom, so that the atoms are held together in a sea of itinerant electrons. This arrangement makes metals good electrical conductors.