

# Teacher Tune-up

## Quick Content Refresher for Busy Professionals

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

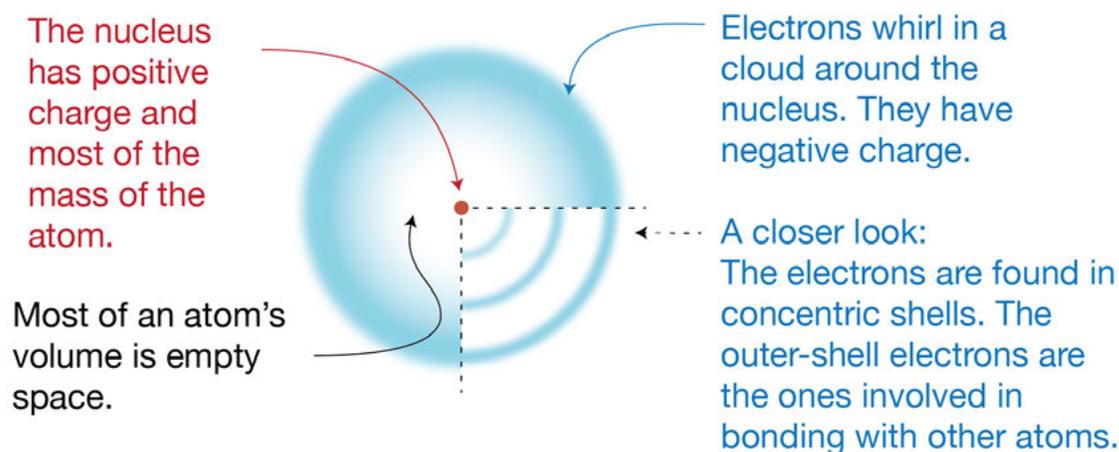
The atomic model of matter has varying degrees of complexity and detail, depending on what properties of matter you're modeling—and also on which historical edition of the model you're dusting off. In the 1700s, the Swiss physicist Daniel Bernoulli developed the kinetic theory of gases, which modeled 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?")

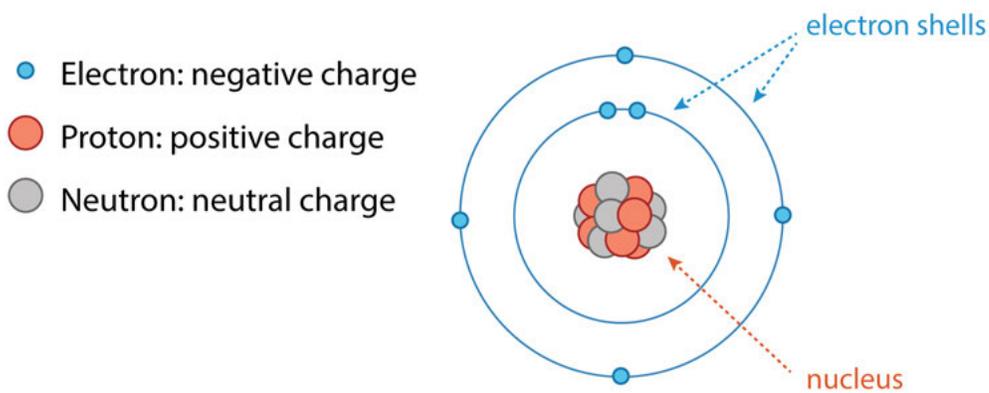
So from Bernoulli to Dalton, the model went from simple billiard balls to more complex balls that could form bonds with each other in consistent patterns. From the chaos of gases, atoms stepped into the realm of chemical architecture, and since then the atomic model has grown ever more complex and detailed.

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.

Atomic number → 79

Chemical symbol → **Au**

Name → Gold

1 H Hydrogen																	2 He Helium	
3 Li Lithium	4 Be Beryllium	← Main-block Elements →										5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon	
11 Na Sodium	12 Mg Magnesium	Transitional Metals										13 Al Aluminum	14 Si Silicon	15 P Phosphorus	16 S Sulfur	17 Cl Chlorine	18 Ar Argon	
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	57-71 La-Lu Lanthanide series		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	89-103 Ac-Lr Actinide series		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 Cn Copernicium	113 Uut Uitaniun	114 Fl Flerovium	115 Uup Ununpentium	116 Lv Livermorium	117 Uus Ununseptium	118 Uuo 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		

Lanthanide and Actinide Series

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.

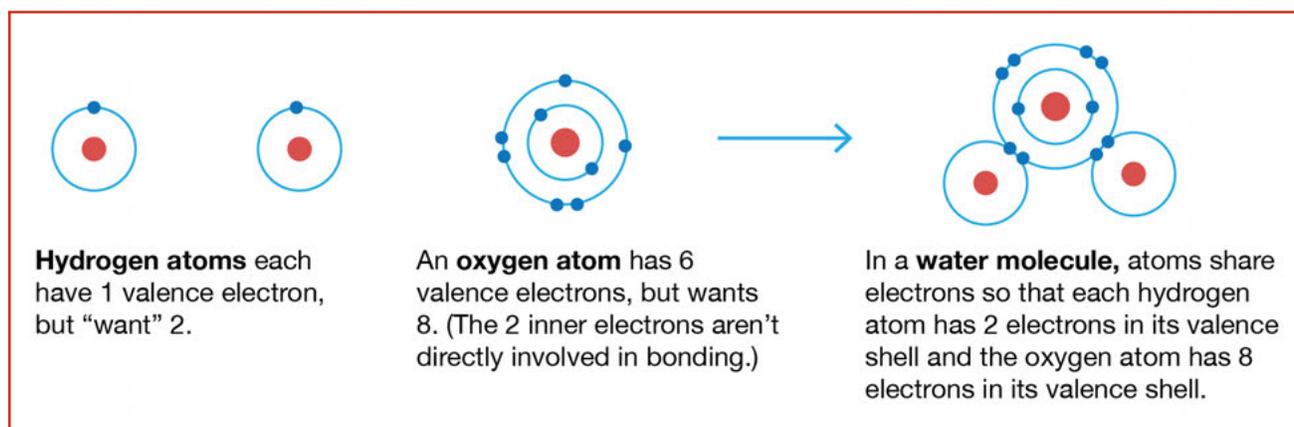
These outer electrons are called **valence electrons**, and they are the means by which atoms form chemical bonds with each other.

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.)

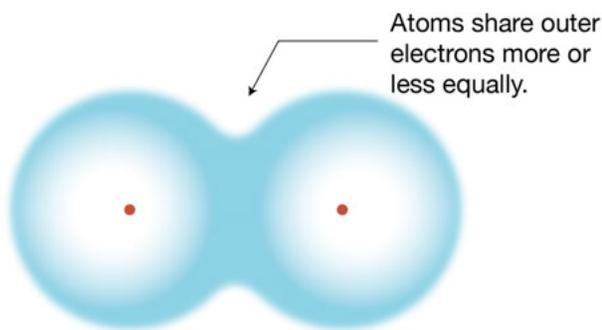
But only the elements in the rightmost column of the periodic table—the so-called noble gases like helium, neon, and argon—have their own full octet (or duet for helium) of valence electrons. Chemically stable and aloof, those self-sufficient noble gas atoms hardly ever get chemically involved with each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

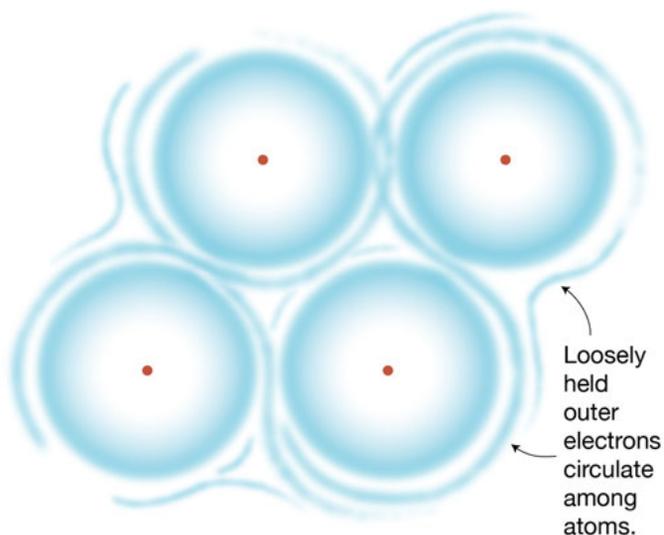
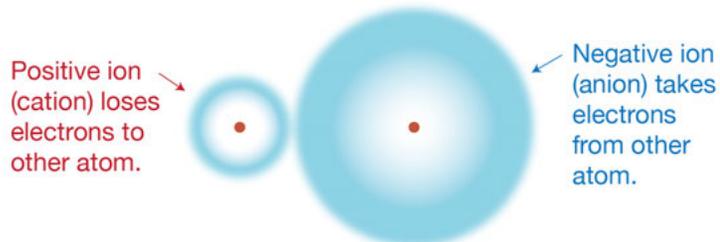
*Here's an illustration of how every atom comes out a winner in a water molecule.*



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



The opposite charges of the ions attract each other.



## 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.