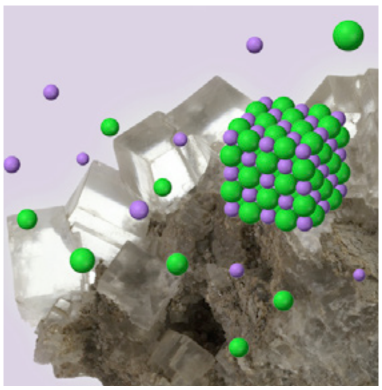
Chapter 6: Detailed Summary

How Atoms Bond



Electron-dot structures are a shorthand notation for the more elaborate shell model presented in Chapter 4. Briefly, electrons within an atom behave as though they are arranged within a series of concentric shells. Electrons in the outermost occupied shell play a significant role in determining the atom's chemical properties, including its ability to form chemical bonds. These outermost electrons are called *valence electrons*.

Electron-dot structures show valence electrons organized around the atom's atomic symbol. The electrons may be either paired or unpaired. Being paired is the preferred state for an electron. Paired electrons are relatively stable and they are sometimes called a *nonbonding pair* (because they can resist forming bonds with other atoms) or a *lone pair* (because they are happy to remain by themselves alone). Single unpaired electrons, by contrast, will do what they can to pair with an electron from another atom. This results in the formation of chemical bonds. In general, the number of chemical bonds that an atom can form is equal to the number of unpaired valence electrons it contains.

When an atom loses or gains an electron it becomes an *ion*, which is any atom that contains a different number of electrons versus protons. Electrons lost or gained tend to be the unpaired valence electrons. Atoms of elements to the left side of the periodic table tend to lose unpaired valence electrons to become positively charged ions. Atoms of elements to the right side of the periodic table (except for group 18, noble gases) tend to gain valence electrons to become negatively charged ions. Oppositely charged ions are attracted to each other and they form a chemical bond known as the *ionic bond*.

Atoms become ions by losing or gaining electrons. A molecule can become an ion by either losing or gaining a hydrogen ion, which is a proton. The result is a polyatomic ion.

All metal atoms have a tendency to lose electrons. This occurs within a metal such that there are many "lost" electrons that flow freely around many resulting metal ions. This "fluid" of electrons holds the positively charged metal ions together in a type of chemical bond known as a *metallic bond*. An *alloy* is any mixture composed of two or more metallic elements. Most metals are manufactured from *ores*, which are geologic deposits containing a relatively high concentration of metal-containing compounds.

The *covalent bond* results when two atoms are mutually attracted to electrons they share. The atoms best capable of participating in covalent bonds include those of nonmetallic elements found to the upper right of the periodic table (noble gases excluded). These atoms have a strong hold on their unpaired valence electrons, which pair up with the unpaired electrons of a neighboring atom. These paired electrons holding two atoms together are referred to as a *bonding pair*.

The number of covalent bonds an atom tends to form is equal to its number of unpaired valence electrons. Oxygen, for example, has two unpaired valence electrons and so it is able to form two covalent bonds. Carbon, with four unpaired valence electrons, can form four covalent bonds. Each covalent bond consists of two electrons—one from each atom. It is possible, however, to have four or six electrons shared between two atoms. The sharing of four electrons is a covalent *double bond*, while the sharing of six electrons is a *triple bond*.

The shape of a molecule can be deduced using a model known as *valence-shell electron-pair repulsion*. According to this model, electron pairs strive to get as far away as possible from all other electron pairs. This includes nonbonding pairs and any bonding pairs.

If two atoms in a covalent bond are identical, then they have the same nuclear charge, which means they pull on bonding electrons equally. In a covalent bond between nonidentical atoms, however, the bonding electrons are pulled closer to the nucleus with a stronger positive charge. As a result, the bonding electrons are shared unevenly. The ability of an atom to pull on a bonding electron is measured by its *electronegativity*. The electronegativity of atoms increases as you move towards the upper right of the periodic table (noble gases excluded). The greater the difference in electronegativity between two bonded atoms, the more uneven the sharing of electrons. The atom that pulls hardest on the electrons takes on a slight negative charge, while the opposite atom takes on an equal and opposite positive charge. Such a bond is classified as a *polar* covalent bond.

A molecule may be polar depending upon the polarity and orientation of the bonds within that molecule. If the molecule is highly symmetrical, as in the case of carbon dioxide, CO_2, then dipoles within bonds cancel each other and the molecule on the whole is nonpolar. If the molecule is more "lopsided," then individual dipoles may add together to make the molecule polar. The classic example is the water molecule, which, because of its bent shape, is slightly negative around the oxygen side and slightly positive around the side of the hydrogens. The more polar a molecule, the greater the electrical forces of attractions between molecules. This results in a relatively high boiling point. Carbon dioxide, consisting of nonpolar molecules, has a boiling point of –79°C, while water, consisting of polar molecules, has a boiling point of 100°C. So, carbon dioxide is a gas at room temperature while water is a liquid. This is so even though a carbon dioxide molecule (44 amu) is over twice as heavy as a water molecule (18 amu).

Summary of Terms

Alloy A mixture of two or more metallic elements.

Covalent bond A chemical bond in which atoms are held together by their mutual attraction for two or more electrons they share.

Covalent compound A substance, such as an element or chemical compound, in which atoms are held together by covalent bonds.

Dipole A separation of charge that occurs in a chemical bond because of differences in the electronegativities of the bonded atoms.

Electron-dot structure A shorthand notation of the shell model of the atom, in which valence electrons are shown around an atomic symbol. The electron-dot structure for an atom or ion is sometimes called a Lewis dot symbol while the electron-dot structure of a molecule or polyatomic ion is sometimes called a *Lewis structure*.

Electronegativity The ability of an atom to attract a bonding pair of electrons to itself when bonded to another atom.

Ion An atom having a net electrical charge because of either a loss or gain of electrons.

Ionic bond A chemical bond in which there is an electric force of attraction between two oppositely charged ions.

Ionic compound A chemical compound containing ions.

Metallic Bond A chemical bond in which positively charged metal ions are held together within a "fluid" of loosely held electrons.

Molecule The fundamental unit of a chemical compound, which is a group of atoms held tightly together by covalent bonds.

Nonbonding pairs Two paired valence electrons that are not participating in a chemical bond.

Nonpolar Said of a chemical bond or molecule that has no dipole. In a nonpolar bond or molecule, the electrons are distributed evenly.

Ore A geologic deposit containing relatively high concentrations of one or more metal-containing compounds.

Polar Said of a chemical bond or molecule that has a dipole. In a polar bond or molecule, electrons are congregated to one side. This makes that side slightly negative while the opposite side (lacking electrons) becomes slightly positive.

Polyatomic ion An ionically charged molecule.

Substituent A term used to describe an atom or nonbonding pair of electrons surrounding a centrally located atom.

Valence electron The electrons in the outermost occupied shell of an atom.

Valence shell The outermost occupied shell of an atom.

Valence-shell electron-pair repulsion A model, also known as VSEPR (pronounced ves-per), that explains molecular geometries in terms of electron pairs striving to be as far apart from one another as possible.