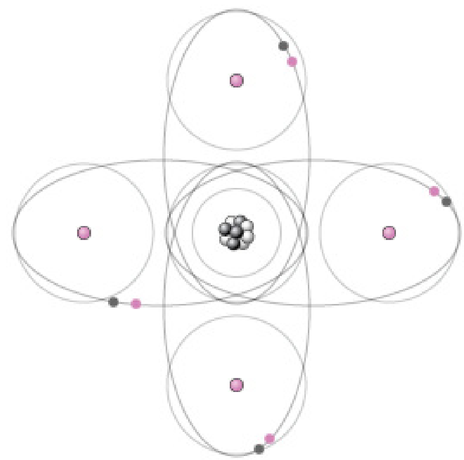
Teacher Guide: Covalent Bonds

Learning Objectives
Students will …

- Understand that atoms are most stable with a full outer energy level.
  - In a covalent bond, this can be achieved by sharing electrons.
- Model covalent bonds by shifting valence electrons between atoms.
- Build a variety of molecules using covalent bonds.
- Represent valence electrons and covalent bonds in a Lewis diagram.

Vocabulary
covalent bond, diatomic molecule, Lewis diagram, molecule, noble gases, nonmetal, octet rule, shell, valence, valence electron

Lesson Overview
Ionic bonds form when metal atoms donate electrons to nonmetal atoms. Nonmetal atoms also can share electrons to obtain a stable electron configuration. The *Covalent Bonds* Gizmo™ allows students to explore how atoms share pairs of electrons to form chemical bonds.


Methane molecule

The Student Exploration sheet contains two activities:

- Activity A – Students form a covalent bond and represent the bond with a Lewis diagram.
- Activity B – Students use covalent bonds to form a variety of molecules.

Suggested Lesson Sequence

1. **Pre-Gizmo activity: Sharing markers** (5 – 15 minutes)
   Pass each of your students a specially prepared "set" of markers or crayons, with eight different colors in a complete set. Most sets should be missing one, two, or three colors, but include a few complete sets as well.

   Ask the students to draw or copy a picture that requires all eight colors. To solve the problem, students with incomplete sets will have to find a person with their missing color(s). Working together, students can share the complementary markers to complete their drawings. (Having students sit in pairs will facilitate this organization.) Students with complete sets will be able to work alone without sharing. (These students represent noble gases, which usually do not form atomic bonds.)

   After students have completed their drawings, explain that the point of the activity was not the quality of their drawing, but their ability to share markers to get all the necessary colors. By doing this, they have discovered the secret to covalent bonding! After doing the Gizmo, you can then discuss how this simulation was similar to and different from actual covalent bonding.)

2. **Prior to using the Gizmo** (10 – 15 minutes)
   Before students are at the computers, pass out the Student Exploration sheets and ask students to complete the Prior Knowledge Questions. Discuss student answers as a class, but do not provide correct answers at this point. Afterwards, if possible, use a projector to introduce the Gizmo and demonstrate its basic operations. Demonstrate how to take a screenshot and paste the image into a blank document.

3. **Gizmo activities** (15 – 20 minutes per activity)
   Assign students to computers. Students can work individually or in small groups. Ask students to work through the activities in the Student Exploration using the Gizmo. Alternatively, you can use a projector and do the Exploration as a teacher-led activity.

4. **Discussion questions** (15 – 30 minutes)
   As students are working or just after they are done, discuss the following questions:

   - Why do nonmetal atoms share electrons? [This is an important topic—atoms do not "want" to fill their outermost energy level, they are simply most stable in that configuration.]
   - How are unshared valence electrons represented on a Lewis diagram? How are shared electrons represented?
   - Is there ever a case where two atoms share a single electron or an odd number of electrons? [This does not occur—all covalent bonds involve pairs of electrons.]
   - How is the formation of covalent bonds similar to students sharing markers? How is it different?
   - How can you predict how many covalent bonds an atom will form? [The number of bonds is equal to the number of electrons needed to fill the outermost shell.]

5. **Follow-up activity: Gumdrop molecules** (45 – 60 minutes)
   Build molecule models using gumdrops (or spice drops) and toothpicks. (Balls of clay could be substituted for gumdrops.) Each toothpick represents a single covalent bond. For example, fluorine gas (F_2) could be modeled with two purple gumdrops connected by a single toothpick: F – F. Carbon dioxide could be modeled with two blue gumdrops (O) and a black gumdrop (C): O = C = O.

   Each model can be glued to a sheet of construction paper. Students can label their models with a gumdrop color key, the chemical formula, a Lewis diagram, and a structural diagram. (A structural diagram is like a Lewis diagram but without the dots.)

Scientific Background

In any atom, negatively charged electrons are attracted to the positively charged nucleus. The strength of this attraction is determined by the number of protons in the nucleus and the distance to the electrons. Because the electrons orbit at specific distances from the nucleus, every atom will have a unique *electron affinity*, or tendency to hold on to its electrons.

Nonmetal atoms have nearly full outer shells of electrons and relatively small radii. This geometry causes nonmetals to hold their valence electrons tightly and attract more electrons until the outer shell of electrons is full. Additional electrons would be added to a new shell, much farther from the nucleus. These electrons would be held too loosely to remain with the atom.

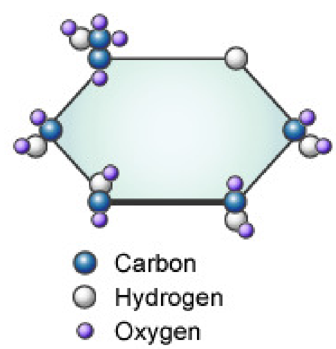
To achieve a full outermost shell, nonmetal atoms can either acquire electrons donated by metal atoms (resulting in the formation of an ionic bond) or share electrons with other nonmetal atoms. A pair of electrons that orbit the nuclei of two atoms results in a *covalent bond.*

In reality, there is a continuity between ionic and covalent bonds. Atoms differ in their *electronegativity*, or their ability to attract electrons in a covalent bond. When two atoms of equal electronegativity (such as two fluorine atoms) bond, the shared electrons spend approximately equal amounts of time orbiting each nucleus. Hydrogen has relatively low electronegativity, so that when hydrogen bonds to oxygen to form water molecules (H_2O) the shared electrons spend most of their time orbiting the oxygen atom. As a result, the hydrogen ends of the water molecule have a slight positive charge while the oxygen end has a slight negative charge. These slight charges allow water molecules to attract each other and form liquid water and ice. Water molecules are examples of *polar molecules*.

When two atoms with very different electronegativities bond, each shared electron spends nearly all of its time orbiting the nucleus with greater electronegativity. The result is an ionic bond.

The number of chemical bonds an atom can form, called *valence*, depends on the number of valence electrons. Most atoms are stable with a full complement of eight valence electrons. Atoms with seven valence electrons, such as fluorine and chlorine, can form a single covalent bond. Atoms with six valence electrons (oxygen and sulfur) form two covalent bonds, five valence electrons (nitrogen and phosphorus) yield three covalent bonds, and atoms with four valence electrons (carbon and silicon) can form four covalent bonds.

Covalent bonds are very important in *organic molecules*, the materials that make up living things. Most organic molecules have a “backbone” of carbon atoms. Carbon has a high valence (it can form up to four bonds). Because it can form so many bonds, it is able to make rings, chains, and other complex molecular structures such as the glucose molecule shown at right. In this way, the valence of carbon helps to explain the amazing diversity and complexity of living things.



Selected Web Resources
Chemical bonds: http://hyperphysics.phy-astr.gsu.edu/hbase/chemical/bond.html
Chemical bonding: http://www.visionlearning.com/library/module_viewer.php?mid=55
Atomic structure: http://library.thinkquest.org/15567/main.html
Overview of bonding: http://www.chemguide.co.uk/atoms/bondingmenu.html#top
Electronegativity: http://www.chemguide.co.uk/atoms/bonding/electroneg.html#top
Structural diagrams: http://www.chemguide.co.uk/basicorg/conventions/draw.html#top
Lewis diagrams: http://www.elmhurst.edu/~chm/vchembook/201Lewisdiag.html
Covalent bonds: http://en.wikipedia.org/wiki/Covalent_bond

Related Gizmos:
Element Builder: http://www.explorelearning.com/gizmo/id?424
Ionic Bonds: http://www.explorelearning.com/gizmo/id?514
Electron Configuration: http://www.explorelearning.com/gizmo/id?513
Dehydration Synthesis: http://www.explorelearning.com/gizmo/id?464