Name: _____ Period: _____ Date: _____

Chemical Bonds 2: Covalent Bonds

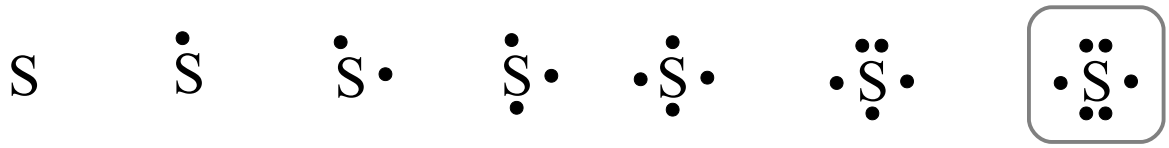
There are two main ways that elements can combine to form compounds, ionic bonds and covalent bonds. This packet will guide you through a study of covalent bonds.

Electron pairs

Recall that atoms tend to end up with their outermost energy level filled up to its capacity of 8 valence electrons. (Or, 2 valence electrons if only Level One is being used.) This is called the **octet rule**. One way for atoms to end up with a full octet is to give or take electrons to/from other atoms. But, there's another option too – atoms can share electrons.

To share electrons, both atoms have to contribute: electrons are always shared in pairs, one from each atom. But, electrons within a single atom also form pairs! Electron dot diagrams can help you figure out how many pairs there are:

- Start out by drawing the atom's symbol and looking up how many valence electrons it'll have.
- Draw dots for the valence electrons, but try to spread them out as much as you can on the four "sides" of the symbol (top, bottom, left, and right). That is, start with just one on each side before you double any of them up.
- The electrons that end up in pairs on your atom can't be shared because they're already paired. But, each "free" or single electron can be shared!



Symbol first | Add your electrons one at a time to each side... | Then double up | DONE!

The sulfur atom above has 6 valence electrons, but four of them are already in pairs. So, 2 of them are available to share with other atoms.

1) Nitrogen (N) has 5 valence electrons. Draw an electron dot diagram for nitrogen with its dots arranged properly. How many of these 5 electrons can be shared with other atoms?

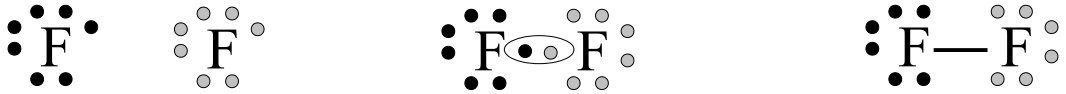
2) Bromine (Br) atoms have 7 valence electrons. Draw an electron dot diagram for bromine and state how many of its electrons can be shared.

3) Carbon (C) has 4 valence electrons. Draw an electron dot diagram for carbon with its dots arranged properly. How many of its valence electrons can be shared?

Forming a covalent bond

For two atoms to share electrons, they must have unpaired valence electrons. The unpaired electrons from each atom form a new **bonding pair** together. The electrons in the bonding pair split their time between the two atoms, giving each atom some attention. This means the atoms need to stay close together – they've become bonded. Because this type of bond involves a co-operation between two atoms to share valence electrons, it's called a **covalent bond**.

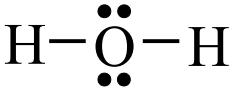
Consider the example below, showing how fluorine (F) atoms combine to form F_2 molecules. We start by drawing electron dot diagrams for both atoms, but we can rearrange them so the "free" or unpaired electrons face each other. These electrons form the bonding pair. In the final diagram the shared electrons are replaced by a line to represent the bond itself.



Both need 1 electron | Put the 'free' dots together | Replace dots with a line

In the final picture, the line counts as two electrons for both atoms. So, each atom has 6 dots and a line, for a total of 8 valence electrons – just like the octet rule says.

To the right is a diagram showing the covalent bonds in a water molecule. The oxygen has four dots and two lines, which adds up to 8 valence electrons. The hydrogen atoms have no dots, but that's OK – they only have one energy level, so 2 valence electrons is enough to fill them up.



H atoms have no extra dots!

4) The picture below shows the arrangement of atoms in a molecule of SF_2 (sulfur difluoride). Fill in dots and lines to represent the bonds and the extra electrons. Be sure that all three atoms end up with 8 valence electrons, counting the lines as two each!

F S F

5) Ammonia is a covalent compound formed from one nitrogen (N) atom surrounded by three hydrogen (H) atoms. (You drew a diagram of nitrogen in question 1.) Fill in dots and lines to represent the bonds and the extra electrons. Be sure that nitrogen ends up with 8 electrons (counting the lines as two each) and the hydrogens get 2!

H N H

H

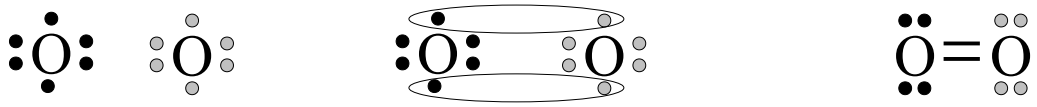
6) Do the same for this molecule of PBr_3 (phosphorus tribromide)! 8 electrons each!

Br P Br

Br

Double and triple bonds

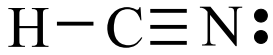
When atoms have more than one unpaired electron, they will try to form more than one bond. In this way, it's possible for more than one bond to form between two atoms! An example of this is oxygen gas. Oxygen atoms have 6 valence electrons, so they need 2 more. This means they will try to form two bonds.



Both need 2 electrons | Form 2 bonds with free electrons! | Rearrange for clarity

In the example above, both free electrons on the atoms form bonds, as shown in the middle picture. This leaves four other valence electrons on each atom. In the last picture, things have been rearranged so the bonding pairs can be replaced with lines.

Basically, if there aren't enough atoms for all the bonds you need to make, try doubling some of them up. Triple bonds are also possible, but they're uncommon. An example:



H: 1 bond = 2 electrons
C: 4 bonds = 8 electrons
N: 3 bonds, 2 dots = 6+2 = 8 electrons

7) A CO_2 (carbon dioxide) molecule has one C atom and two O atoms, connected by double bonds.
   A) How many bonds does a C atom need to make?

   B) How many bonds does each O atom need to make?

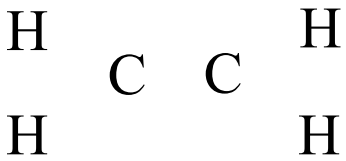
   C) Add in the needed lines and dots to this diagram! Remember that each line on an atom counts as TWO electrons for it, and all three atoms need to get to eight electrons!

O C O

8) Ethylene (C_2H_4) is a flammable gas similar to propane and methane. This molecule has a mixture of BOTH single and double bonds.
   A) How many bonds does a C atom need to make?

   B) How many bonds does an H atom need to make?

   C) Add in the needed lines and dots to this diagram. Remember that each line on an atom counts as TWO electrons for it. The C's need to have 8 electrons and the H's need 2.

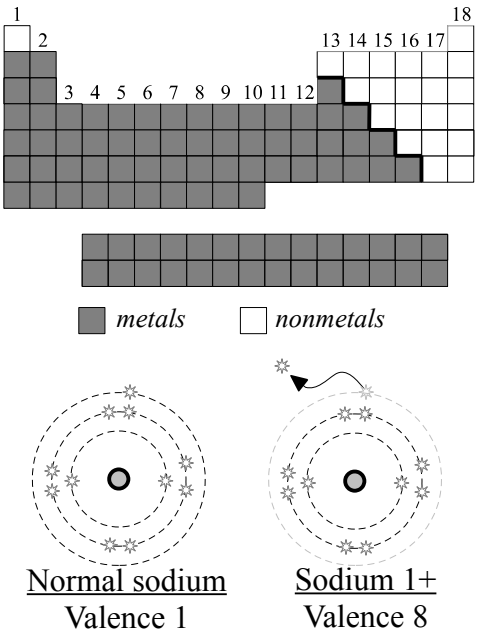


Metals and bond types

Atoms that have a lot of valence electrons can easily finish up an octet through sharing <u>or</u> by taking electrons from other atoms. But, atoms with small valence numbers are better off losing electrons to uncover a full energy level below. For example:

Sulfur atoms have valence 6 and need two electrons to get up to 8. It's not hard to take or share two electrons. Sodium has a valence of 1, so it would need seven more electrons to increase to 8. It's much easier for sodium to <u>give away</u> its 1 valence electron. This empties its top energy level completely, and exposes a lower level that's already full.

The result of all this is that nonmetals – which have high valence numbers – can form covalent bonds by sharing electrons AND form ionic bonds by taking electrons. Metals – which have low valence numbers – don't share <u>or</u> take electrons... they just them away to nonmetals. So, metal elements only form ionic bonds.



- Covalent bonds form between nonmetal elements only.
- Ionic bonds form between a metal element and a nonmetal element.
- Hydrogen is an oddball and can form both types of bond.

9) What type of bond will form between...
   A) strontium (Sr) and selenium (Se)?

   B) carbon (C) and selenium (Se)?

   C) iodine (I) and indium (In)?

   D) hydrogen (H) and oxygen (O)?

10) You've discovered a new element, Eastmoorium (Ea)! You find that when it forms chemical bonds, Eastmoorium either shares electrons or takes electrons away from other atoms. Is Eastmoorium a metal or a nonmetal? How do you know?

11) Locate beryllium (Be) on the periodic table.
   A) Is beryllium a metal or a nonmetal?

   B) Will it form ionic bonds or will form covalent bonds? (Or can it do both?)

   C) Will it be gaining electrons or losing them? How many?

Reactivity

Elements that are CLOSE to having a full set of valence electrons – whether they need to gain a couple or lose a couple – will very easily bond with other atoms to end up with an octet. These elements are said to be very **reactive** because they will easily start chemical reactions.

Elements that are further away from having an octet would need a lot more work to reach an octet, so they are less reactive. It takes a little more effort to get them to start forming bonds.

12) Find the nonmetals phosphorus (P), sulfur (S), and chlorine (Cl) on a periodic table.
   A) Since these are nonmetals, will they be gaining or losing electrons when they bond?

   B) For each element, state how many electrons the element needs gain/lose to have a full set of 8 valence electrons.

   C) Which of these three elements would be the MOST REACTIVE?

13) Find the metals potassium (K), calcium (Ca), and gallium (Ga) on a periodic table.
   A) Since these are metals, will they be gaining or losing electrons when they bond?

   B) For each element, state how many electrons the element needs gain/lose to have a full set of 8 valence electrons.

   C) Which of these three elements would be the MOST REACTIVE?

14) Look at column 18. The elements there have 8 valence electrons (except helium, which has 2 but still has a full valence level). These elements are referred to as the **noble gases** or sometimes the **inert gases**. They almost never participate in chemical reactions and do not bond with anything. Why would this be?

15) The elements in column 1 are called the **alkali metals**.
   A) How many valence electrons do alkali metals have?

   B) Would you expect the alkali metals to be reactive or non-reactive? Why?

16) The elements in column 17 are called the **halogens**.
   A) How many valence electrons do halogens have?

   B) Would you expect the halogens to be reactive or non-reactive? Why?