

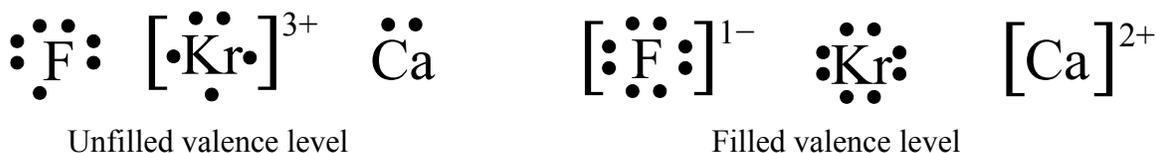
## Chemical Bonds 1: Ionic Bonds

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 ionic bonds.

### *The octet rule*

Because atoms are made of electrically charged particles, there is a lot of electric potential energy stored in every atom. The most stable – or “best” – way to arrange all this energy is when an atom's outermost energy level is full. This means having 8 valence electrons, or 2 valence electrons if the atom only has one energy level. This tendency for atoms to end up with 8 valence electrons is called the octet rule. (An “octet” is a group of eight things, just like a quartet is four.)

One way for an atom to end up with a full set of valence electrons is to gain or lose electrons, becoming a charged atom called an ion. In the electron dot diagrams below, three atoms gain or lose electrons in order to end up with 8 valence electrons:



Note that the  $\text{Ca}^{2+}$  ion is drawn with zero valence electrons because the atom's NORMAL outermost level – Level Four – is empty. Level Three in the  $\text{Ca}^{2+}$  ion is still full! When you draw electron dot diagrams for an ion, you should only draw dots for the normal outermost level.

- 1) Neutral nitrogen atoms have 5 valence electrons. How many electrons would nitrogen need to have a full valence level, and what charge would that nitrogen ion have?
  
- 2) Suppose an ion has a total of 17 electrons. How many valence electrons does it have? How many more electrons does it need to reach 8 valence electrons?
  
- 3) Neutral aluminum atoms have 13 electrons. The most common ion of aluminum has a charge of 3+. How many valence electrons would an  $\text{Al}^{3+}$  ion have? Is this a full octet or not?
  
- 4) Look at the electron dot diagram for arsenic to the right.
  - A) How many electrons would this atom need to GAIN to complete its octet?
  - B) How many electrons would this atom need to LOSE to uncover a full energy level below this one?



- 5) Silicon is element number 14. It is often found as a 4+ ion, but can also become a 4- ion. Draw electron dot diagrams for all three of these forms of silicon:

Neutral silicon:

Silicon 4+ ion:

Silicon 4- ion:

- 6) Draw an electron dot diagram for neutral oxygen. Then, draw another diagram for an oxygen ion that has gained electrons to fill up its outermost energy level. Include the square brackets and the ion's charge.

Neutral oxygen:

Oxygen ion:

## ***Ion formation***

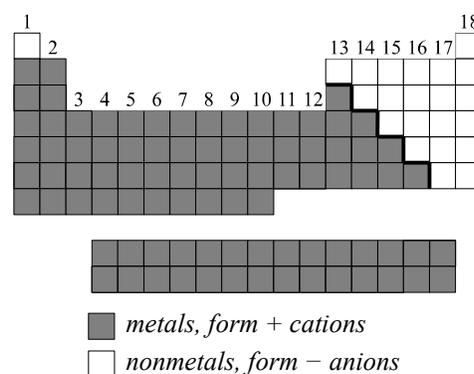
The most common way for an atom to gain or lose electrons and become an ion for one atom to give or transfer electrons to another atom.

In general, metal elements tend to give away electrons, becoming positive ions called **cations**. You can imagine the “t” in cation as being a “+” sign to help you remember this. The word metal also has a “t” in the middle!

Nonmetal elements tend to accept electrons, becoming negative ions called **anions**. You can think of the “n” in anion as standing for both “negative” and “nonmetal”.

Some examples:

- Magnesium (Mg) metal has 2 valence electrons found in Level Three. When it becomes an ion, it usually gives away both electrons to become a  $Mg^{2+}$  ion. This empties out Level Three completely, but leaves it with a full Level Two.
- Iodine (I) is a nonmetal with a valence number of 7. Because it's so close to an octet, iodine can pull an electron away from most other atoms to form an  $I^{1-}$  ion and fill up its Level Five.



- 7) The elements in column 1 of the periodic table – other than hydrogen – are called the **alkali metals**. They have 1 valence electron. When an alkali metal forms an ion, what charge will that ion have?
- 8) Locate the element barium on a periodic table. (Atomic number 56.) How many valence electrons does barium normally have? When it forms an ion, charge will it have?

- 9) Bismuth (Bi) is found in column 15, making it one of the highest-valence metals. Draw an electron dot diagram for neutral bismuth and for a bismuth ion.

Neutral bismuth:

Bismuth ion:

- 10) Pure sulfur is a yellowish, crumbly substance. It is not a metal. Normal sulfur has 6 valence electrons. What charge will a sulfur ion probably have?

### *Simple ionic bonds*

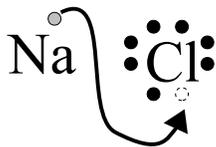
When atoms transfer electrons to become ions, one becomes positively charged and the other becomes negatively charged. Because they have opposite charges, the ions may end up held close together by electrical forces. If they do, this is called an **ionic bond**. Once they're bonded, the atoms form a *new substance with different physical and chemical properties* than they had before. Any substance with two or more elements chemically bonded together is called a **compound**.

A simple example of ionic bonds comes from the compound NaCl, which is ordinary table salt:

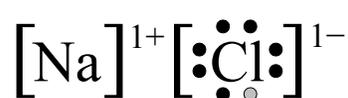
1: Neutral atoms



2: Electron donated



3: Opposite ions attract



Sodium (Na) starts with 1 valence electron. If that electron is given away, the sodium has 10 electrons (2, 8) and its Level Two is full. Meanwhile, chlorine (Cl) has 7 valence electrons in its Level Three and needs only one more. After the transfer, the sodium is a positive ion and the chlorine is a negative ion. They are attracted to each other and stay close by.

Because ionic bonds require a cation and an anion, ionic bonds usually form between one metallic element and one nonmetallic element.

- 11) In a style similar to the example, illustrate the formation of an ionic bond between potassium (K) and fluorine (F).

- 12) Which element is oxygen most likely to form an ionic bond with: nitrogen, xenon, or calcium? Explain why.

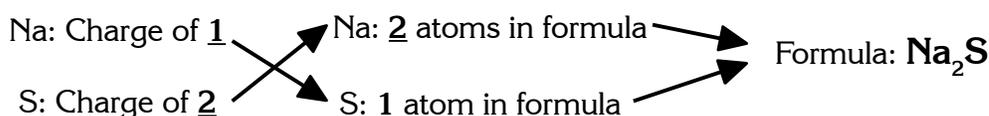
- 13) Magnesium is a column two element that usually forms +2 ions. Selenium forms -2 ions. Illustrate the formation of the compound MgSe ("magnesium selenide") by showing both of the transferred electrons.

### Complex ionic bonds

Ionic bonds can form between more than two atoms, as well. For example, a sulfur atom has 6 valence electrons, so it needs two more to fill up its outermost level. If a sulfur (S) atom receives an electron from two sodium (Na) atoms (one electron from each!), you will have two  $\text{Na}^{1+}$  ions and one  $\text{S}^{2-}$  ion. These three ions will then bond to form  $\text{Na}_2\text{S}$ .

Just like the formula  $\text{H}_2\text{O}$  that you know well, the little "2" means there are two Na atoms for every S atom. A small number written below the main line like that is called a **subscript**. Note that the subscript on the Na is the same as the charge of the S ion!

You can quickly figure out the formula for an ionic compound by doing a "criss cross" of the charge numbers (ignoring minus signs) to make the formula:



In chemical formulas, we never bother to write a "1". When you see a symbol like the S in that formula without a number on it, you can imagine a 1 is there.

If you use this method and get numbers that could be "reduced" like a fraction, you should go ahead and reduce them. For example:  $\text{Sn}_2\text{O}_4$  can be simplified to  $\text{SnO}_2$  if we divide both by 2.

- 14) Suppose ionic bonds form between atoms of potassium (K) and phosphorus (P).
- What is the charge of the potassium ions, assuming they have full octets?
  - What is the charge of the phosphorus ions, assuming they have full octets?
  - What is the formula for the compound ("potassium phosphide").
- 15) Determine the formula for the ionic compound "barium nitride" made of Ba and N ions.
- 16) Hydrogen often forms positive ions by losing its one and only electron. But, it also forms negative ions by gaining a second electron to fill up its Level One. (Remember, Level One holds a maximum of two electrons.) Find the formula for a compound of...
- ...magnesium (Mg) and hydrogen (H).
  - ...hydrogen (H) and sulfur (S).