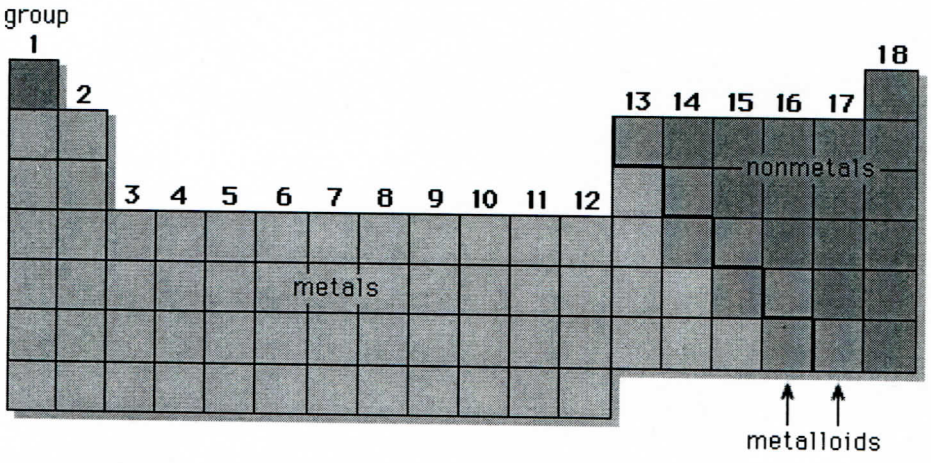
Chemistry Lecture #34: Ionic Compounds

If one atom transfers its electrons to another, they will stick together because one atom will have a positive charge and the other will have a negative charge. Electrostatic force is the force of attraction between opposite charges. Thus, anions and cations will stick together due to the electrostatic force.

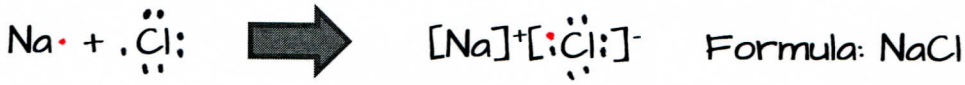
The bond formed between anions and cations is called an ionic bond. The new substance formed by the union of an anion and cation is called an ionic compound.

Ionic compounds are made from metal cations and nonmetal anions. Remember that metals are to the left of the jagged line on the periodic chart, and nonmetals are to the right of the jagged line. If a substance is made of a metal and nonmetal, it is an ionic compound.

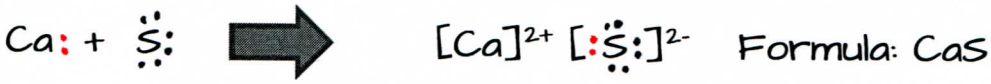


For example, Na is a group 1A metal with one valence electron that wants to lose this electron to achieve an octet. Cl is a group 7A nonmetal with 7 valence electrons that wants to steal an electron to achieve an octet.

Na will transfer its one electron to Cl. Na becomes Na^+, Cl becomes Cl^-. These two ions will now stick together because one is positive and the other is negative.

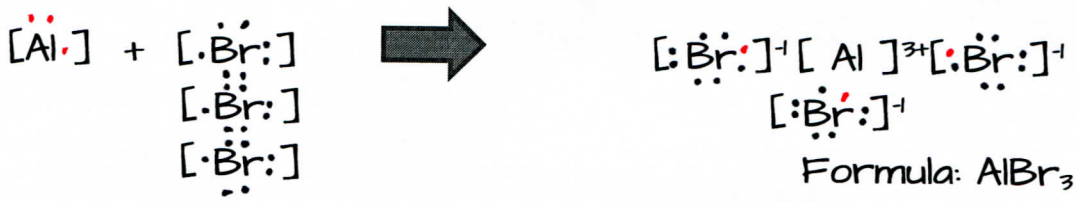


Here's another example: Ca is a group 2A metal with two valence electrons it wants to get rid of. S is a group 6A nonmetal with 6 valence electrons that wants to steal 2 electrons. Ca will give 2 electrons to S and form CaS.



Notice that the number of electrons lost by one atom equals the number of electrons gained by the other atom. In all ionic compounds, the total amount of positive charge on one particle must equal the total amount of negative charge on the other particle, giving a net charge of zero.

What would the formula for a compound made of aluminum and bromine look like? Al is in group 3A and wants to lose 3 electrons. Bromine is in group 7A and wants to steal one electron. This creates a problem. How can Al get rid of 3 electrons when bromine only wants one? The solution is to get three bromine atoms, and each one takes an electron from Al.



The formula for a compound made of aluminum and bromine is $AlBr_3$. When writing formulas for ionic compounds, the cation is written first, and the anion is written second. Also, the number of ions is written in subscripts to the lower right. There are 3 bromine ions, so 3 is written in subscripts below "Br."

Notice that the total amount of positive charge = total amount of negative charge. Al has an oxidation number of +3, and there are 3 bromine ions, each with a charge of -1, giving the total amount of negative charge as -3, thus,

$+3 + 3(-1) = 0.$

Determining the formula of an ionic compound is easy if the ions have equal but opposite charges. You just stick the element symbols together (with the cation listed first). For example,

Na^+ Cl^- ➡ NaCl

Ca^{2+} S^{2-} ➡ CaS

Al^{3+} N^{3-} ➡ AlN

If the oxidation numbers are not equal and opposite, criss-cross the numbers and take the absolute value. For example, Ga is in

group 3A and has a +3 oxidation number. Oxygen is in group 6A and has an oxidation number of -2.

Ga^{+3} O^{-2}

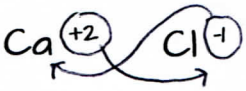
Change the -2 to 2, and move it below Ga. Take the 3 and move it below the oxygen.

Ga_2O_3

This works because the two Ga each have a +3, and three O each have -2, giving

$2(+3) + 3(-2) = 0.$

What is the formula for a compound made out of Ca and Cl?

Ca^{+2} Cl^{-1} → 

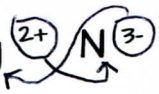
→ $CaCl_2$ or $CaCl_2$

What is the formula for a compound made out of K and P?

K^{+1} P^{3-} → 

→ K_3P_1 or K_3P

What is the formula for a compound made out of Mg and N?

Mg^{2+} N^{3-} → 

→ Mg_3N_2

$CaCl_2$, K_3P, and Mg_3N_2 are all examples of binary ionic compounds. These are ionic compounds that are made out of two types of elements: one metal and one nonmetal.

We've been getting the oxidation numbers of the elements by using the periodic chart. We know that groups 1A-3A have values of +1, +2, and +3. We know that that groups 5A-7A have values of -3, -2, and -1. Most of the transition elements have two or more oxidation numbers. For example, Fe can exist as Fe^{2+} or Fe^{3+}.

There are a few transition elements that have only one oxidation state. You need to memorize the oxidation states of these elements listed below:

Sc^{+3}, Ni^{2+}, Zn^{2+}, Ag^{+}, Cd^{2+}

So if I ask you to write a nickel ion, you'd write Ni^{2+}.

There is a type of ion called a polyatomic ion. This is a group of atoms that are bonded together, and have stolen or lost electrons. They behave like a single atom with a charge.

Listed below are the names and formulas of commonly used polyatomic ions. You need to memorize the names and formulas of these ions.

Name	Formula
Hydroxide	OH^-
Carbonate	CO_3^{2-}
Nitrate	NO_3^-
Phosphate	PO_4^{3-}
Sulfate	SO_4^{2-}
Ammonium	NH_4^+
Iodate	IO_3^-
Acetate	$C_2H_3O_2^-$ or CH_3COO^-
Chromate	CrO_4^{2-}

Notice that ammonium is the only polyatomic listed that has a positive charge. Notice also that acetate can be written two different ways. The second way, CH_3COO^-, gives information about the structure of the ion.

Writing formulas of ionic compounds with polyatomic ions is identical to writing binary ionic compounds. When starting put parentheses around the polyatomic ion with the charge outside the parentheses. Criss cross the oxidation numbers and put the number from the cation in subscripts outside the parentheses of the polyatomic ion.

For example, write the formula for a compound made of zinc and nitrate.

Zn^{2+} NO_3^- ⇒ Zn^{2+} $(NO_3)^{-1}$ ⇒ $Zn_1(NO_3)_2$ or $Zn(NO_3)_2$

Write the formula for a compound made of sodium and sulfate.

Na^{+1} $(SO_4)^{2-}$ ➡ $Na_2(SO_4)_1$ or Na_2SO_4

Write the formula of a compound made of strontium and sulfate.

Sr^{2+} $(SO_4)^{2-}$ ➡ $Sr(SO_4)$ or $SrSO_4$. Ions have equal and opposite charges, so just stick them together.

Write the formula for a compound made of aluminum and carbonate.

Al^{3+} $(CO_3)^{2-}$ ➡ $Al_2(CO_3)_3$

Write the formula for a compound made of magnesium and hydroxide.

Mg^{2+} $(OH)^{-1}$ ➡ $Mg_1(OH)_2$ or $Mg(OH)_2$

If you wrote $MgOH_2$, that's wrong! You need parentheses since there is more than one OH^- attached to the Mg.

Write the formula for a compound made of (a). ammonium and nitrate, and (b) ammonium and sulfate.

a. $(NH_4)^{+1}$ $(NO_3)^{-1}$ ➡ $(NH_4)_1(NO_3)_1$ or NH_4NO_3

b. $(NH_4)^{+1}$ $(SO_4)^{-2}$ ➡ $(NH_4)_2(SO_4)_1$ or $(NH_4)_2SO_4$