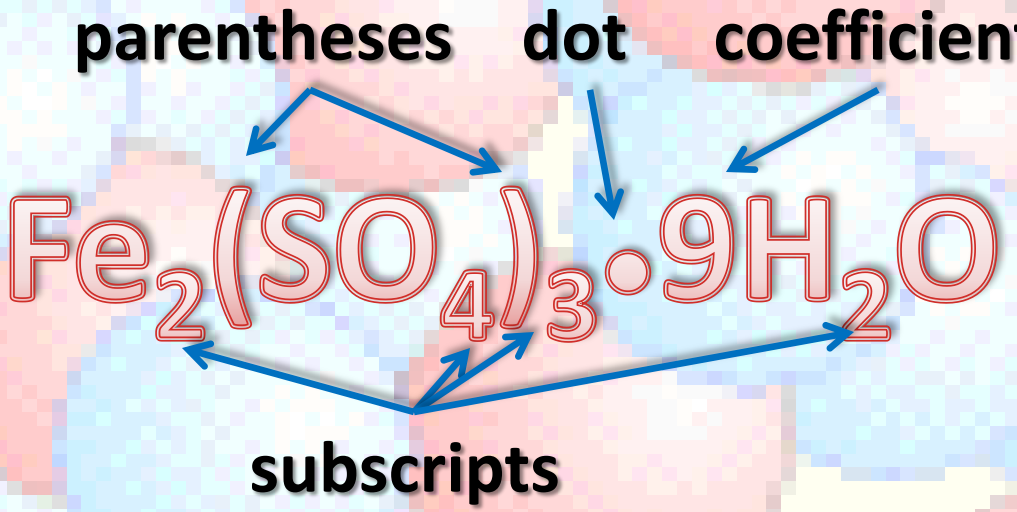
Chemical Formulas

How to Write and Interpret Them

Interpreting Chemical Formulas

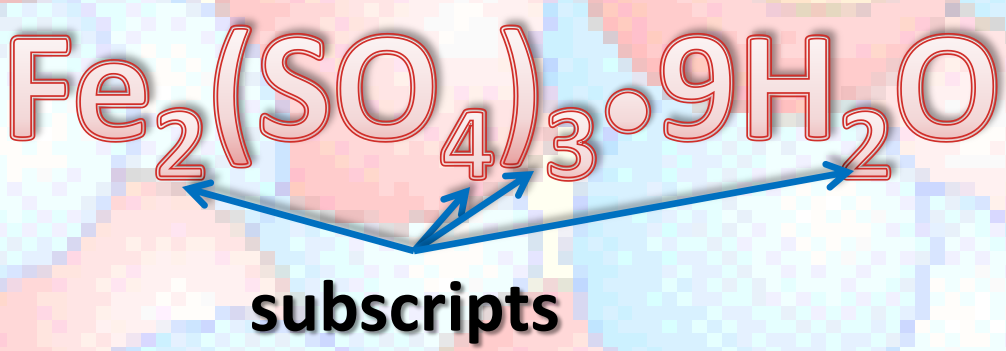
- Consider the formula below:



- The formula has subscripts, parentheses, a coefficient, and a dot.
- Each of these has a function.

Subscripts

- A subscript is a small number written to the lower right of the symbol.



- It shows the number of atoms or *polyatomic ions* in a formula.
- A subscript 1 (one) is never written. It is understood.
- How many iron atoms are in the formula above?

2

Parentheses

- Parentheses are written around *polyatomic ions* when there are more than one of the ion.

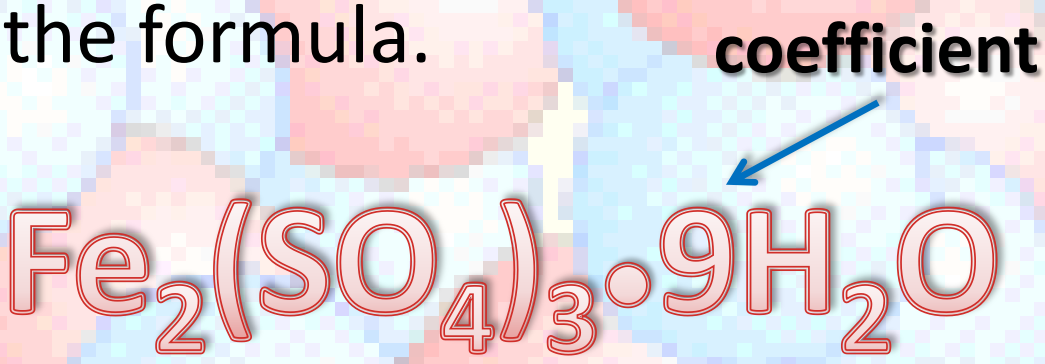
parentheses

$$Fe_2(SO_4)_3 \cdot 9H_2O$$

- Polyatomic ions are charged groups of atoms.
- Some polyatomic ions are found on the *Reference Tables*.
- How many sulfate ions are in the formula above? **3** How many sulfur atoms? **3** How many oxygen atoms are in the sulfates? **12**

Coefficients

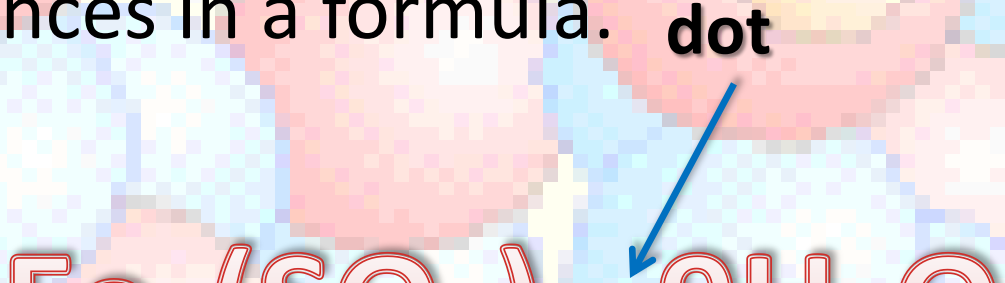
- Coefficients are large numbers written to the left of the formula.



- Normally, they only show the number of formula units and are not part of a formula.
- The formula above is for a hydrated crystal. A formula unit iron III sulfate [$Fe_2(SO_4)_3$] is associated with 9 molecules of water.

The Dot

- The dot is used as a separator between two substances in a formula.



- Mathematically, the dot acts like a plus sign.
- A plus sign has another function in chemistry, so it cannot be used in a formula.
- How many oxygen are in $Fe_2(SO_4)_3 \cdot 9H_2O$? **21**

Counting Atoms

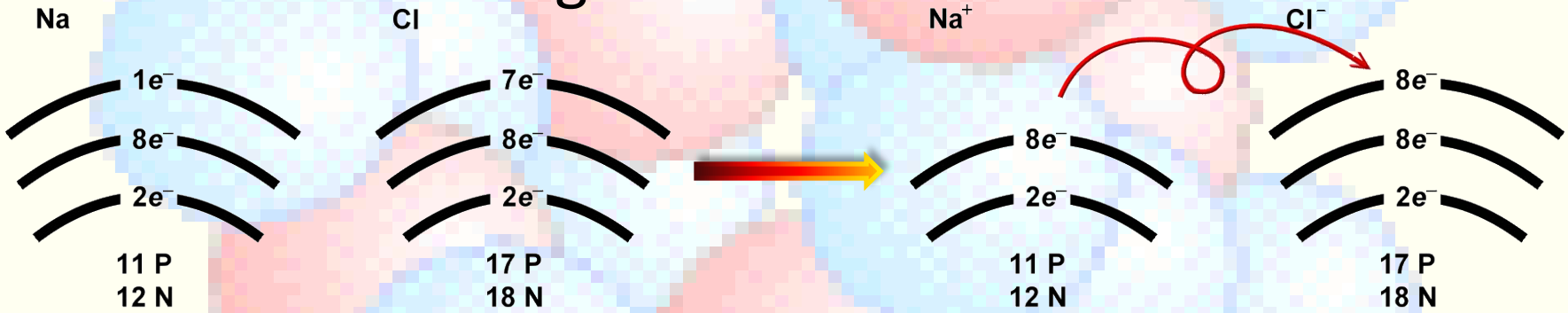
- How many atoms of each element are in the formula below and what is the total number of atoms:

$$5Fe_2(SO_4)_3 \cdot 9H_2O$$

Element	Coefficient	×	Subscript	×	Parentheses Subscript	=	Sub total	Total
Fe	5	×	2	×		=		10
S	5	×	1	×	3	=		15
	5	×	4	×	3	=	60	
O	5 × 9	×	1			=	45	
						=		105
H	5 × 9	×	2			=		90
TOTAL								220

Bonding Ratios

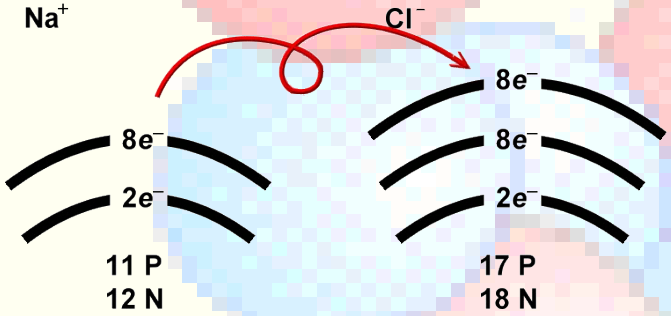
- What kind of bond does sodium form with chlorine? **It forms an ionic bond.**
- Draw a Bohr diagram of each atom.



- Which atom loses electrons and which one gains?
  Sodium loses and chlorine gains.
- How many electrons are transferred?
  1 electron is transferred.
- Draw a Bohr diagram of each ion.

More on Bonding Ratios

- What is the charge on each ion?



Element	Sodium	Chlorine
Nuclear Charge	+11	+17
Charge on Electrons	-10	-18
Total Charge	+1	-1

Na is +1. Cl is – 1.

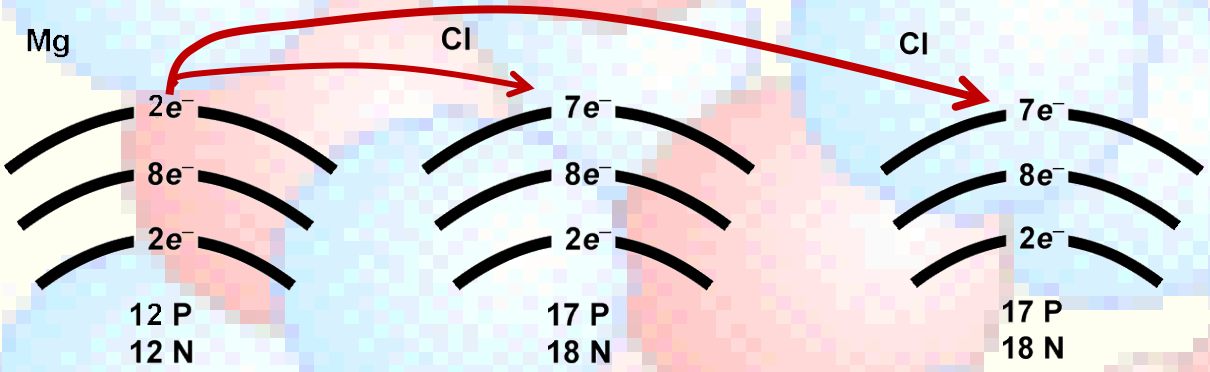
- How does the charge on the ion compare to the ion's oxidation state?

The charge is the same as the oxidation state.

- What is the total charge on the compound? **0**
- What is the sum of the oxidation states. **0**

Bonding Ratios for other Ions

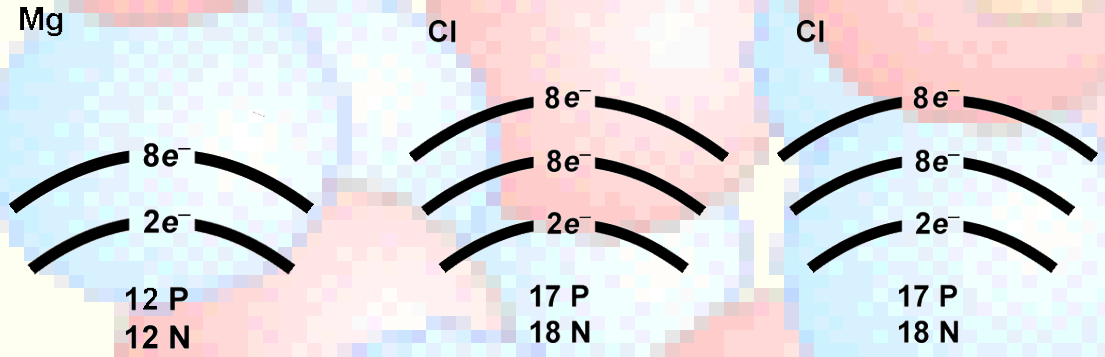
- Sodium and chlorine bond in a 1 to 1 ratio by transferring 1 electron. What happens with magnesium and chlorine?
- Draw Bohr diagrams.



- Magnesium has two electrons to lose, but chlorine has room to gain only one.
- The solution is to bond to a second chlorine.

More about other Ions

- Draw Bohr diagrams of the magnesium and chloride ions.

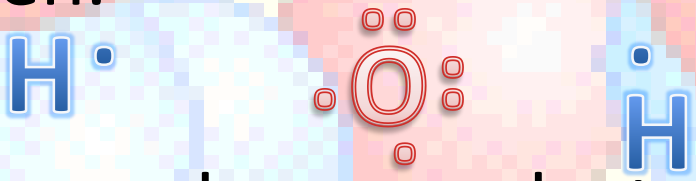


- What are the charges on the ions? **Mg = +2; Cl = –1**
- What are the oxidation states of the ions?

  Mg = +2; Cl = –1
- What is the formula for the compound? **$MgCl_2$**
- What is the sum of the oxidation states of the compound? **Zero**

Covalent Bonds are Similar

- Draw electron dot diagrams of hydrogen and oxygen.



- Hydrogen has one electron to share. Oxygen needs two.
- The solution is to bond two hydrogens to one oxygen to form water.
- What are the oxidation states of hydrogen and oxygen? **H = +1; O = –2**
- What is the sum of the oxidation states in water? **Zero**

Pictures vs Oxidation States

- A picture of an atom can show how many electrons are lost, gained, or shared.
- An element's oxidation state also tells the number of electrons lost, gained, or shared.
- Just as it is possible to tell how atoms combine using pictures, it is also possible using oxidation states.
- The trick is to make sure the oxidation states add up to zero as we have already seen.

Using Oxidation States

- Example 1: Hydrogen and chlorine

  H^{+1} Cl^{-1}

  +1 −1 = 0

  - The formula is HCl

- Example 2: Barium and fluorine

  Ba^{+2} F^{-1}

  F^{-1}

  +2 −2 = 0

  - The formula is BaF_2

- Example 3: Aluminum and oxygen

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

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

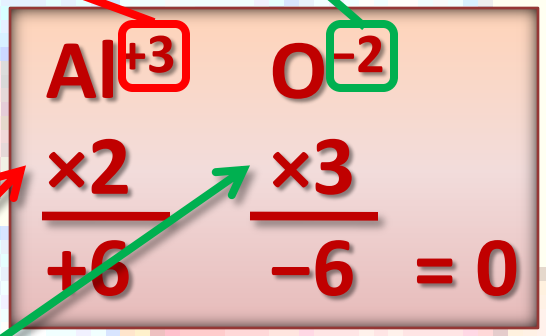
  O^{-2}

  +6 −6 = 0

  - The formula is Al_2O_3

Getting More Sophisticated

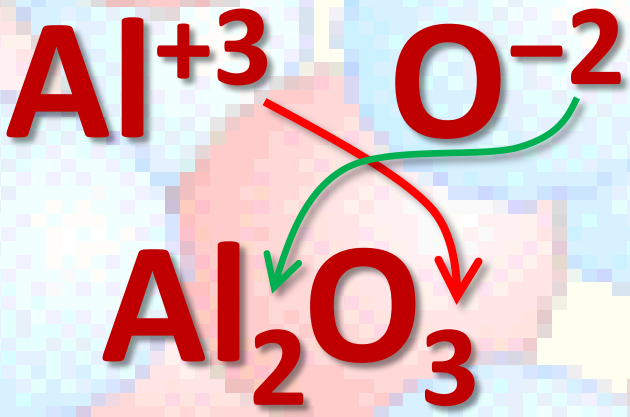
- It isn't necessary to go back and forth by trial and error until the sum of the oxidation states is zero.
- Find the lowest common multiple instead.
- What is the lowest common multiple of 3 and 2? **6**
- How many 3's are in 6? **2**
- How many 2's are in 6 **3**



The formula is Al_2O_3.

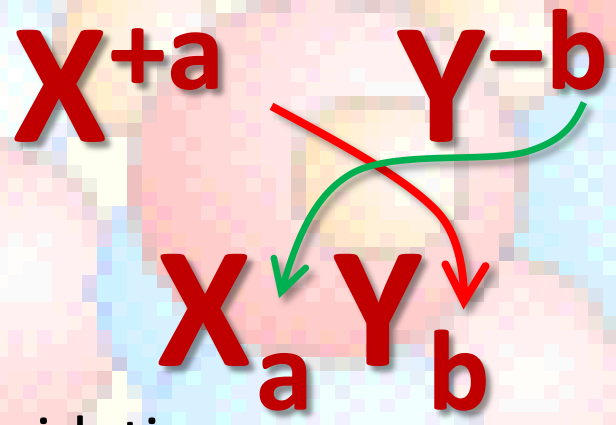
The Crossover Rule

- Crossing over gives the same result as finding the lowest common multiple.



More Crossover Rule

- The general rule is:



- Exceptions
  - equal and opposite oxidation states add up to zero so the ratio is 1 to 1
    - $Mg^{+2} + O^{-2} \rightarrow MgO$
    - $Al^{+3} + P^{-3} \rightarrow AlP$
  - oxidation states that are multiples of each other must be reduced to lowest terms: $C^{+4} + O^{-2} \rightarrow CO_2$ NOT C_2O_4
- polyatomic ions
  - see *Table for oxidation state*
  - enclose in parentheses if there is more than one
    - $NH_4^{+1} + CO_3^{-2} \rightarrow (NH_4)_2CO_3$