Writing & Naming Formulas of Ionic & Covalent Compounds

©2006 - Douglas Gilliland
The Physical Science Series
Review of the Periodic Table

Periods = number of e- energy levels.
Groups (families) = the number of valence electrons (A - groups)

Periods:
1. H non
2. Li metal, Be metal
3. Na metal, Mg metal
4. K metal, Ca metal, Sc metal, Ti metal, V metal, Cr metal, Mn metal, Fe metal, Co metal, Ni metal, Cu metal, Zn metal
5. Rb metal, Sr metal, Y metal, Zr metal, Nb metal, Mo metal, Tc metal, Ru metal, Rh metal, Pd metal, Ag metal, Cd metal, In metal, Sn metal, Sb metal, Te metal, I metal, Xe metal
6. Cs metal, Ba metal, La metal, Hf metal, Ta metal, W metal, Re metal, Os metal, Ir metal, Pt metal, Au metal, Hg metal, Tl metal, Pb metal, Bi metal, Po metal, At metal, Rn metal
7. Fr metal, Ra metal, Ac metal, Rf metal, Db metal, Sg metal, Bh metal, Hs metal, Mt metal, Uun metal, Uuu metal, Uub metal

Groups (families):
1A - H non
2A - He non
1B - Li metal, Be metal
2B - Na metal, Mg metal
3B - K metal, Ca metal, Sc metal, Ti metal, V metal, Cr metal, Mn metal, Fe metal, Co metal, Ni metal, Cu metal, Zn metal
4B - Rb metal, Sr metal, Y metal, Zr metal, Nb metal, Mo metal, Tc metal, Ru metal, Rh metal, Pd metal, Ag metal, Cd metal, In metal, Sn metal, Sb metal, Te metal, I metal, Xe metal
5B - Cs metal, Ba metal, La metal, Hf metal, Ta metal, W metal, Re metal, Os metal, Ir metal, Pt metal, Au metal, Hg metal, Tl metal, Pb metal, Bi metal, Po metal, At metal, Rn metal
6B - Fr metal, Ra metal, Ac metal, Rf metal, Db metal, Sg metal, Bh metal, Hs metal, Mt metal, Uun metal, Uuu metal, Uub metal
7B - Th metal, Pa metal, U metal, Np metal, Pu metal, Am metal, Cm metal, Bk metal, Cf metal, Es metal, Fm metal, Md metal, No metal, Lr metal

Transition Metals:

Index
Metals have between 1 and 3 valence e- and have a loose hold on them.

Nonmetals have between 5 and 7 valence e- and have a tight hold on them.

Noble Gases

Very tight hold on valence e-.

Atomic Radii decreases (more p+)

Greater hold on valence electrons
Types of Compounds:
Ionic = Metal + Nonmetal
Covalent = 2 Nonmetals or Metalloid & Nonmetal

Metals

Metalloids

Nonmetals

Transition Metals

<table>
<thead>
<tr>
<th>Period</th>
<th>Metals</th>
<th>Metalloids</th>
<th>Nonmetals</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Li, Na</td>
<td>H, He</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Be, Mg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Al, Si</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>K, Ca</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Sc, Ti</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Y, Zr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>La, Hf</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group</th>
<th>Metals</th>
<th>Metalloids</th>
<th>Nonmetals</th>
</tr>
</thead>
<tbody>
<tr>
<td>IA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IIA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IIIA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VIA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VII A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VIII A</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Chemical Compounds

An atom consists of a positively charged nucleus (protons and neutrons) and orbiting electrons. Atoms of elements are not chemically stable until they have 8 valence electrons (octet rule). Atoms gain, lose or share electrons with other atoms to become chemically stable (have 8 valence electrons).

Six valence electrons. Not chemically stable. Oxygen Atom

Eight valence electrons. Chemically stable. Oxide Ion

Very Important!
Atoms & Ions:

Not Stable

Sodium Atom
11+
Lose 1 e-

Nitrogen Atom
7+
Gain 3 e-

Aluminum Atom
13+
Lose 3 e-

to become stable will:

Lose 1 e-

Nitride Ion
7+-3

Stable

Sodium Ion
11+-1

Nitride Ion
7+-3

Aluminum Ion
13+-3

Not Stable

Stable

index
Two Types of Compounds

- **Ionic** - occurs when a metal **loses all its valence electrons** to a nonmetal. The metal becomes a cation (+ion), while the nonmetal becomes an anion (-ion).

- **Covalent** - two nonmetals **share electrons**. Neither loses or gains electrons - they share electrons. Neither atom becomes an ion.
Ionic Compounds

Crystalline Lattice
Oxidizing Magnesium

\[ 2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO} \]

Opposite charges hold the compound together.

Magnesium Atom + Oxygen Atom → Magnesium Ion + Oxide Ion
Formation of Sodium Chloride

$2Na + Cl_2 \rightarrow 2NaCl$

Opposite charges hold the compound together.

Sodium Atom + Chlorine Atom → Sodium Ion + Chloride Ion
Ionic Compounds

- Contain a metal and a nonmetal.
- The Metal loses e- and becomes a cation (+).
- The Nonmetal gains e- and becomes an anion (-).
- Metal is listed first, followed by nonmetal.
- Change the name of the nonmetal to -ide.

Examples: nitride, sulfide, fluoride, oxide, bromide, iodide, chloride, telluride, phosphide.
The valence of an element is the charge an atom takes when it loses or gains electrons and becomes an ion.

Metal atoms lose 1, 2, or 3 electrons and become + ions (cations).

Nonmetals gain 1, 2, or 3 electrons and become - ions (anions).

Transition Metals: Multiple valences
The 5 Steps for writing an ionic compound formula:

(I) Write the symbols of the two elements.

(II) Write the valence of each as superscripts.

(III) Drop the positive and negative signs.

(IV) Crisscross the superscripts so they become subscripts.

(V) Reduce when possible.
Formula for boron oxide

1. Write the symbols of the two elements.

\[ \text{B} \quad \text{O} \]
Formula for boron oxide

2. Write the valence for each element.

\[ \text{B}^{+3} \text{O}^{-2} \]
Formula for boron oxide

3. Drop the positive & negative sign.

\[ \text{B}^{+3} \text{O}^{-2} \]
Formula for boron oxide

4. Crisscross the superscripts so they become subscripts.
Formula for boron oxide

4. Crisscross the superscripts so they become subscripts.

\[
\text{B}_2\text{O}_3
\]
Formula for boron oxide

5. Reduce subscripts when possible.
   (not possible here)

\[ \text{B}_2\text{O}_3 \]
Examples of Reduction of Subscripts:

$\text{Sr}_2\text{O}_2$ reduces to $\text{SrO}$

$\text{Al}_3\text{P}_3$ reduces to $\text{AlP}$

$\text{Pb}_2\text{O}_4$ reduces to $\text{PbO}_2$

$\text{Ba}_3\text{N}_2$ doesn’t reduce
Most Transition metals have two valences. Roman numerals are used in the name of the transition metal in the compound to show the valence on the cation.

Period 4 Transition Metals

<table>
<thead>
<tr>
<th></th>
<th>Sc</th>
<th>Ti</th>
<th>V</th>
<th>Cr</th>
<th>Mn</th>
<th>Fe</th>
<th>Co</th>
<th>Ni</th>
<th>Cu</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>+3</td>
<td>+3</td>
<td>+4</td>
<td>+5</td>
<td>+6</td>
<td>+4</td>
<td>+2</td>
<td>+2</td>
<td>+2</td>
<td>+2</td>
<td>+2</td>
</tr>
<tr>
<td>+3</td>
<td>+4</td>
<td>+3</td>
<td>+6</td>
<td>+3</td>
<td>+3</td>
<td>+3</td>
<td>+3</td>
<td>+1</td>
<td>+2</td>
<td>+2</td>
</tr>
</tbody>
</table>

Examples:

$\text{Mn}^{+4}$ Manganese(IV)    $\text{Mn}^{+6}$ Manganese(VI)
$\text{Fe}^{+2}$ Iron(II)     $\text{Fe}^{+3}$ Iron(III)
$\text{Cu}^{+1}$ Copper(I)    $\text{Cu}^{+2}$ Copper(II)
Examples of Transition Metals

Iron(II) Fe$^{+2}$
Iron(III) Fe$^{+3}$
Copper(I) Cu$^{+1}$
Copper(II) Cu$^{+2}$
Manganese(II) Mn$^{+2}$
Manganese(IV) Mn$^{+4}$
Naming binary compounds containing a transition metal.

<table>
<thead>
<tr>
<th>Formula</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe$_2$O$_3$</td>
<td>Iron(III) oxide</td>
</tr>
<tr>
<td>ZnCl$_2$</td>
<td>Zinc(II) chloride</td>
</tr>
<tr>
<td>AgCl</td>
<td>Silver(I) chloride</td>
</tr>
<tr>
<td>Cu$_3$P$_2$</td>
<td>Copper(II) phosphide</td>
</tr>
<tr>
<td>PbS$_2$</td>
<td>Lead(IV) sulfide</td>
</tr>
<tr>
<td>MnO$_2$</td>
<td>Manganese(IV) oxide</td>
</tr>
</tbody>
</table>
Polyatomic (many atom) ions are covalent molecules with a charge. They behave as if they were a one-atom ion.
## Polyatomic Ions

<table>
<thead>
<tr>
<th>Ion</th>
<th>Formula</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH(_4^+)</td>
<td>4</td>
<td>Ammonium</td>
</tr>
<tr>
<td>OH(^-)</td>
<td>1</td>
<td>Hydroxide</td>
</tr>
<tr>
<td>NO(_2^-)</td>
<td>1</td>
<td>Nitrite</td>
</tr>
<tr>
<td>NO(_3^-)</td>
<td>1</td>
<td>Nitrate</td>
</tr>
<tr>
<td>SO(_3^-2)</td>
<td>2</td>
<td>Sulfite</td>
</tr>
<tr>
<td>SO(_4^-2)</td>
<td>2</td>
<td>Sulfate</td>
</tr>
<tr>
<td>CO(_3^-2)</td>
<td>2</td>
<td>Carbonate</td>
</tr>
<tr>
<td>PO(_4^-3)</td>
<td>3</td>
<td>Phosphate</td>
</tr>
</tbody>
</table>

Note: ammonium is the only polyatomic ion with a + charge.

Treat polyatomic ions as you would any ion - crisscross to determine the formula. The only difference is that when you have more than one of a specific polyatomic ion in a formula you must encase it in parenthesis.
Writing Ternary Formulas

(Ternary compounds have 3 elements in them.)

<table>
<thead>
<tr>
<th>Cation</th>
<th>Anion</th>
<th>Compound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca$^{+2}$</td>
<td>NO$_3^{-1}$</td>
<td>Ca(NO$_3$)$_2$</td>
</tr>
<tr>
<td>Mg$^{+2}$</td>
<td>PO$_4^{-3}$</td>
<td>Mg$_3$(PO$_4$)$_2$</td>
</tr>
<tr>
<td>Ba$^{+2}$</td>
<td>OH$^{-1}$</td>
<td>Ba(OH)$_2$</td>
</tr>
<tr>
<td>Ba$^{+2}$</td>
<td>SO$_4^{-2}$</td>
<td>BaSO$_4$</td>
</tr>
</tbody>
</table>

As in all ionic compounds you must reduce subscripts, but you cannot change the formula of the polyatomic ion. You can only reduce subscripts outside the parenthesis.
Compounds with Polyatomic ions

**Carbonate $\text{CO}_3^{2-}$**
- Sodium carbonate $\text{Na}_2\text{CO}_3$
- Calcium carbonate $\text{CaCO}_3$
- Aluminum carbonate $\text{Al}_2(\text{CO}_3)_3$

**Phosphate $\text{PO}_4^{3-}$**
- Sodium phosphate $\text{Na}_3\text{PO}_4$
- Calcium phosphate $\text{Ca}_3(\text{PO}_4)_2$
- Aluminum phosphate $\text{AlPO}_4$
Covalent Compounds

Water Molecule

Hydrogen Atom  Oxygen Atom  Hydrogen Atom
Covalent Compounds

- Two nonmetals share electrons so both have 8 valence electrons. Exception: H
- Neither takes on a charge - no valence. Do not crisscross to determine formula.
- Must use prefixes in the name.
- Name tells you the formula. Example: $\text{N}_2\text{O}_4$ is dinitrogen tetroxide.
- You cannot reduce the formulas!!!
Reaction between hydrogen + oxygen

\[ 2H_2 + O_2 \rightarrow 2H_2O \]
The Space Shuttle

2H₂ + O₂ → 2H₂O

Hydrogen

Oxygen

Water Vapor

Hydrogen

Exothermic Reaction
Covalent Prefixes

Mon - 1
Di - 2
Tri - 3
Tetra - 4
Pent - 5
Hex - 6

A prefix tells you the number of atoms of that element in the compound.
Naming Covalent Compounds

\( \text{N}_2\text{O}_3 \)  Dinitrogen trioxide
\( \text{CH}_4 \)  Carbon tetrahydride
\( \text{PO}_5 \)  Phosphorus pentoxide
\( \text{S}_2\text{F}_3 \)  Disulfur trifluoride
Ionic and Covalent Structure

Ionic compounds form a crystalline lattice - a repeating pattern of ions.

- Boron nitride
  - B<sup>3+</sup> ions
  - N<sup>-3</sup> ions

Covalent compounds form individual molecules that are not connected to each other.

- Water
  - H atoms
  - O atom
Naming Binary Compounds

Does the compound have a metal?

Yes

Ionic
(Metal cation + Nonmetal anion)
Place metal first followed by nonmetal ending in -ide

Contain a Transition Metal?
Yes
Use Roman Numerals to tell the valence of the metal.
Examples:
- iron(III) oxide
- copper(II) chloride
- manganese(IV) oxide
- silver(I) chloride

No
Do not use Roman Numerals
Examples:
- sodium chloride
- magnesium nitride
- aluminum fluoride
- beryllium oxide

No

Covalent
(Two Nonmetals)
Place the nonmetal furthest to the left on the periodic table first, then the other nonmetal ending in -ide.

Use prefixes to tell the number of atoms in the compound
- mon(o)-1, di-2, tri-3, tetr(a)-4, pent(a)-5, hex-6

Examples:
- dinitrogen trioxide, nitrogen trichloride, phosphorus pentoxide, sulfur dioxide
- carbon tetrachloride, dihydrogen oxide
Name these compounds:

- $\text{CoF}_2$  cobalt(II) fluoride
- $\text{PCl}_3$  phosphorus trichloride
- $\text{Sr}_3\text{N}_2$  strontium nitride
- $\text{KOH}$  potassium hydroxide
- $\text{NH}_3$  nitrogen trihydride
<table>
<thead>
<tr>
<th>Compound</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>zinc(II) nitride</td>
<td>Zn$_3$N$_2$</td>
</tr>
<tr>
<td>lithium bromide</td>
<td>LiBr</td>
</tr>
<tr>
<td>dinitrogen pentoxide</td>
<td>N$_2$O$_5$</td>
</tr>
<tr>
<td>manganese(IV) sulfide</td>
<td>MnS$_2$</td>
</tr>
<tr>
<td>dihydrogen oxide</td>
<td>H$_2$O</td>
</tr>
</tbody>
</table>
Summing up: Ionic

- Ionic bonding occurs between a metal and a nonmetal. Metals lose all their valence e- and become cations. Nonmetals gain enough e- to fill their valence level and become anions.
- Always crisscross valences and reduce to determine the formulas of ionic compounds.
- Do not use prefixes in the names.
- Ions form a crystalline lattice.
Summing up: Covalent

- Covalent bonding occurs when two nonmetals share electrons to fill their valence energy level.
- Never use valence to determine the formula - there isn’t any valence. Since the two atoms share electrons, they do not take on a charge.
- Always use prefixes in the names.
- Atoms combine to form individual molecules.
And now -
A special type of
Covalent Compound!
Water: A Polar Molecule

Polar covalent compounds have a partial charge at each end of the molecule.

A water molecule is polar because the 8 protons in the oxygen nucleus pull the 10 electrons closer to the oxygen end of the molecule, giving it a partial negative charge.

δ - charge

The hydrogen end of the molecule becomes charged partial positive. This is due to the protons of the hydrogen atoms sticking out near that end of the molecule.

δ + charge
**Water: A Polar Molecule**

**Explanation:**

As you comb your hair you strip electrons off your hair. Your comb, collecting these electrons, becomes negatively charged. When you place a negatively charged comb near a stream of water, the partial positively charged end (hydrogen end) of a water molecule are attracted and pulled towards the comb.
Why does a comb attract a stream of water?
Surface Tension

The partially + charged hydrogen end of a water molecule is attracted to the partially - charged oxygen end of another molecule. At the surface this causes surface tension. To enter the water, one must break apart this attraction. What animal makes use of surface tension?
Chemical Formulas Index

Types of Compounds
  Ionic Compounds  Covalent Compounds
  Valence
  Transition Metals  Covalent Prefixes
Steps in Writing a Formula  Lattice & Molecules
  Naming Flowchart
Polyatomic Ions  Polar Molecules
Summing Up