IONIC COMPOUNDS versus MOLECULAR COMPOUNDS

**ionic compound:** consist of **cations** (positive ions) and **anions** (negative ions) held together by electrostatic attraction
- usually **metal + nonmetal(s)**
- made of monatomic ions, polyatomic ions, and/or both
  - **monatomic ions:** consist of a single atom
  - **polyatomic ions:** consist of more than one atom

**molecular compound:** consist of **nonmetal atoms** bonded together by shared electrons (covalent bonding)
- **acid:** a molecular compound that releases hydrogen ions (H⁺) when dissolved in water

NAMING MONATOMIC CATIONS:

Metal atoms lose valence electrons to form positively charged ions, called **cations**.

An ion formed from an individual atom is a **monatomic** (or monoatomic) **cation**.

I. Groups IA, IIA, IIIA elements silver (Ag), and zinc (Zn) form only one type of ion:
- Group IA elements form +1 ions: H⁺, Li⁺, Na⁺, K⁺
- Group IIA elements form +2 ions: Be²⁺, Mg²⁺, Ca²⁺, Sr²⁺, Ba²⁺
- Group IIIA elements form +3 ions: Al³⁺
- silver ion = Ag⁺; zinc ion = Zn²⁺

When a Group IA, IIA, IIIA element, silver, or zinc forms an ion, it is named:

**element name + ion**

- e.g. Na⁺ = sodium ion
- Sr²⁺ = strontium ion
- Zn²⁺ = zinc ion
II. The **Stock system** is used to name transition metals and other metals that form more than one ion:
- iron (Fe) forms two ions: Fe$^{+2}$ and Fe$^{+3}$
- lead (Pb) forms two ions: Pb$^{+2}$ and Pb$^{+4}$

When a metal can form more than one ion, each ion is named:

```
element name (charge in Roman numerals) + ion
```

<table>
<thead>
<tr>
<th>Charge</th>
<th>Element Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe$^{+2}$</td>
<td>iron (II) ion</td>
</tr>
<tr>
<td>Fe$^{+3}$</td>
<td>iron (III) ion</td>
</tr>
<tr>
<td>Pb$^{+2}$</td>
<td>lead (II) ion</td>
</tr>
<tr>
<td>Pb$^{+4}$</td>
<td>lead (IV) ion</td>
</tr>
<tr>
<td>Cu$^{+}$</td>
<td>copper (I) ion</td>
</tr>
<tr>
<td>Cu$^{+2}$</td>
<td>copper (II) ion</td>
</tr>
</tbody>
</table>

Name each of the following monatomic cations:

- Li$^+$ = _________________________
- Ba$^{+2}$ = _________________________
- Ag$^+$ = _________________________
- Cu$^{+2}$ = _________________________
- Al$^{+3}$ = _________________________
- Mg$^{+2}$ = _________________________
- Mn$^{+2}$ = _________________________
- Sn$^{+4}$ = _________________________
- H$^+$ = _________________________
- Co$^{+3}$ = _________________________
- Fe$^{+3}$ = _________________________
- Na$^+$ = _________________________
- K$^+$ = _________________________
- Ti$^{+4}$ = _________________________
- Ca$^{+2}$ = _________________________
- Ni$^{+2}$ = _________________________
NAMING MONATOMIC ANIONS:

Nonmetal atoms gain valence electrons to form **negatively charged ions** called anions.

When a nonmetal forms an ion, it is named:

\[
\text{element stem name} + \text{“ide”} + \text{ion}
\]

e.g.  
\[O = \text{oxygen atom} \Rightarrow O^{-2} = \text{oxide ion}\]
\[N = \text{nitr} \text{ogen atom} \Rightarrow N^{-3} = \text{nitr} \text{ide ion}\]

Name each of the following monatomic anions:

\[F^- = \underline{\text{__________________________}}\]
\[Cl^- = \underline{\text{__________________________}}\]
\[Br^- = \underline{\text{__________________________}}\]
\[S^{2-} = \underline{\text{__________________________}}\]
\[I^- = \underline{\text{__________________________}}\]
\[P^{3-} = \underline{\text{__________________________}}\]

NAMING POLYATOMIC IONS:

Ions made up of more than one atom are **polyatomic ions**:

- only one polyatomic cation: \(\text{NH}_4^+ = \text{ammonium ion}\)
- many polyatomic anions: see table below

<table>
<thead>
<tr>
<th>Polyatomic Ions</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\text{OH}^- = \text{hydroxide ion})</td>
</tr>
<tr>
<td>(\text{CN}^- = \text{cyanide ion})</td>
</tr>
<tr>
<td>(\text{CrO}_4^{2-} = \text{chromate ion})</td>
</tr>
<tr>
<td>(\text{Cr}_2\text{O}_7^{2-} = \text{dichromate ion})</td>
</tr>
<tr>
<td>(\text{HCO}_3^- = \text{hydrogen carbonate ion or bicarbonate ion})</td>
</tr>
</tbody>
</table>
Name each of the following polyatomic ions:

\[
\begin{align*}
\text{CN}^- & = \underline{\text{_______________}} & \text{CrO}_4^{2-} & = \underline{\text{_______________}} \\
\text{SO}_4^{2-} & = \underline{\text{_______________}} & \text{NO}_3^- & = \underline{\text{_______________}} \\
\text{OH}^- & = \underline{\text{_______________}} & \text{PO}_4^{3-} & = \underline{\text{_______________}} \\
\text{NH}_4^+ & = \underline{\text{_______________}} & \text{C}_2\text{H}_3\text{O}_2^- & = \underline{\text{_______________}}
\end{align*}
\]

**WRITING CHEMICAL FORMULAS GIVEN INDIVIDUAL IONS**

Compounds must be neutral \(\Rightarrow\) total +ve charge = total –ve charge

1. If the two ions have exactly opposite charges (+1 and –1, +2 and –2, +3 and –3) \(\Rightarrow\) formula of the compound contains one of each ion

\[
\begin{align*}
\text{e.g.} & \quad \text{Na}^+ + \text{Cl}^- \Rightarrow \text{NaCl} & \quad \text{K}^+ + \text{NO}_3^- \Rightarrow \text{KNO}_3 \\
& \quad \text{Ca}^{2+} + \text{S}^{2-} \Rightarrow \text{CaS} & \quad \text{Ba}^{2+} + \text{SO}_4^{2-} \Rightarrow \text{BaSO}_4 \\
& \quad \text{Al}^{3+} + \text{N}^{3-} \Rightarrow \text{AlN} & \quad \text{Fe}^{3+} + \text{PO}_4^{3-} \Rightarrow \text{FePO}_4
\end{align*}
\]

Combine each pair of ions to get the formula of the compound they form:

\[
\begin{align*}
\text{NH}_4^+ + \text{F}^- & \Rightarrow \underline{\text{_______________}} & \text{Li}^+ + \text{CN}^- & \Rightarrow \underline{\text{_______________}} \\
\text{Sr}^{2+} + \text{CO}_3^{2-} & \Rightarrow \underline{\text{_______________}} & \text{Al}^{3+} + \text{PO}_4^{3-} & \Rightarrow \underline{\text{_______________}} \\
\text{Na}^+ + \text{C}_2\text{H}_3\text{O}_2^- & \Rightarrow \underline{\text{_______________}} & \text{K}^+ + \text{OH}^- & \Rightarrow \underline{\text{_______________}} \\
\text{Ni}^{2+} + \text{CrO}_4^{2-} & \Rightarrow \underline{\text{_______________}} & \text{Fe}^{3+} + \text{N}^{3-} & \Rightarrow \underline{\text{_______________}} \\
\text{Cu}^{2+} + \text{SO}_4^{2-} & \Rightarrow \underline{\text{_______________}} & \text{Co}^{3+} + \text{P}^{3-} & \Rightarrow \underline{\text{_______________}}
\end{align*}
\]
2a. If two monatomic ions have different charges
   ⇒ use crossover rule to get formula of the compound
   – superscript for cation becomes subscript for anion
   – superscript for anion becomes subscript for cation
   – simplify subscripts to get lowest ratio of atoms
   (Note: Only the numbers cross down, not the signs!)

\[
\begin{align*}
\text{Na}^+ & \quad \text{S}^{2-} \\
\text{Na}_2\text{S} & \\
\text{Ba}^{2+} & \quad \text{N}^{3-} \\
\text{Ba}_3\text{N}_2 & \\
\text{Ti}^{4+} & \quad \text{O}^{2-} \\
\text{TiO}_2 & \\
\end{align*}
\]

\text{Ti}_2\text{O}_4 \text{ is simplified!}

b. If two ions have different charges and at least polyatomic ion is involved
   ⇒ use crossover rule to get formula of the compound
   – if more than one of polyatomic ion in formula, use parentheses
   – simplify subscripts to get lowest ratio of atoms
   (Note: Again only the numbers cross down, not the signs!)

\[
\begin{align*}
\text{NH}_4^+ & \quad \text{O}^{2-} \\
(\text{NH}_4)_2\text{O} & \\
\text{Ca}^{2+} & \quad \text{NO}_3^{-} \\
\text{Ca(NO}_3)_2 & \\
\text{Pb}^{4+} & \quad \text{CO}_3^{2-} \\
\text{Pb}_2(\text{CO}_3)_4 & \text{ is simplified!}
\end{align*}
\]

Combine each pair of ions to get the formula of the compound they form:

\[
\begin{align*}
\text{Cu}^{+} & \quad \text{O}^{-2} \\
\text{Sn}^{4+} & \quad \text{SO}_4^{-2} \\
\text{K}^{+} & \quad \text{P}^{-3}
\end{align*}
\]

\[
\begin{align*}
\text{Li}^{+} & \quad \text{CO}_3^{-2} \\
\text{Fe}^{3+} & \quad \text{S}^{-2} \\
\text{Ni}^{2+} & \quad \text{PO}_4^{-3}
\end{align*}
\]
CHEMICAL FORMULAS AND NAMES FROM INDIVIDUAL IONS

Compounds are named from the individual ions they come from.

Name the cation and the anion, then remove “ion” from each name:

<table>
<thead>
<tr>
<th>Ion</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na⁺</td>
<td>sodium ion</td>
</tr>
<tr>
<td>Cl⁻</td>
<td>chloride ion</td>
</tr>
<tr>
<td>K⁺</td>
<td>potassium ion</td>
</tr>
<tr>
<td>CO₃⁻²</td>
<td>carbonate ion</td>
</tr>
<tr>
<td>Fe³⁺</td>
<td>iron (III) ion</td>
</tr>
<tr>
<td>NO₃⁻</td>
<td>nitrate ion</td>
</tr>
<tr>
<td>Ag⁺</td>
<td>silver ion</td>
</tr>
<tr>
<td>S⁻²</td>
<td>sulfide ion</td>
</tr>
</tbody>
</table>

Combine each pair of ions to get the chemical formula, then name the compound:

<table>
<thead>
<tr>
<th>Individual ions</th>
<th>Compound Formula</th>
<th>Compound Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mg⁺²</td>
<td>F⁻</td>
<td>MgF₂</td>
</tr>
<tr>
<td>Ni⁺²</td>
<td>S⁻²</td>
<td></td>
</tr>
<tr>
<td>Ca⁺²</td>
<td>Br⁻</td>
<td></td>
</tr>
<tr>
<td>Al⁺³</td>
<td>P⁻³</td>
<td></td>
</tr>
<tr>
<td>Co⁺²</td>
<td>NO₂⁻</td>
<td></td>
</tr>
<tr>
<td>K⁺</td>
<td>CrO₄⁻²</td>
<td></td>
</tr>
<tr>
<td>Fe⁺³</td>
<td>O⁻²</td>
<td></td>
</tr>
</tbody>
</table>
GIVEN THE CHEMICAL FORMULA, NAME THE COMPOUND

1. If the metal is in Groups IA–IIIA, silver, cadmium, or zinc, then just name the metal cation and the anion:

   e.g. \( \text{NaCl} \) ⇒ Na = \text{sodium} and Cl = \text{chloride} ⇒ \text{sodium chloride}
   
   \( \text{BaI}_2 \) ⇒ \( \text{Ba} = \text{barium} \) and \( \text{I} = \text{iodide} \) ⇒ \text{barium iodide}
   
   \( \text{Al(OH)}_3 \) ⇒ \( \text{Al} = \text{aluminum} \) and \( \text{OH} = \text{hydroxide} \) ⇒ \text{aluminum hydroxide}
   
   \( \text{ZnSO}_4 \) ⇒ \( \text{Zn} = \text{zinc} \) and \( \text{SO}_4 = \text{sulfate} \) ⇒ \text{zinc sulfate}

2. If the metal can form more than one ion,
   a. Determine the charge on the cation using the charge on the anion.
   b. Name the cation and the anion, then remove “ion” from both

   e.g. \( \text{NiBr}_2 \) ⇒ Since the ion formed is \( \text{Br}^- \), then 2 Br’s have an overall negative charge of \( -2 \). To get an overall charge of zero for the compound, the overall positive charge must be \( +2 \). Thus, Ni must have a charge of \( +2 \), so the ion nickel forms is \( \text{Ni}^{+2} \).

   ⇒ \( \text{Ni}^{+2} = \text{nickel (II) ion} \) \quad \text{Br}^- = \text{bromide ion}

   ⇒ \( \text{NiBr}_2 = \text{nickel (II) bromide} \)

   c. If a polyatomic ion is involved, remember that more than one polyatomic is shown in parentheses—i.e. \text{DO NOT multiply the charge of the polyatomic ion with the subscript of the atoms in a polyatomic ion.}

   \( \text{CuSO}_4 \) ⇒ There is only ONE Cu and ONE SO\(_4\)\(^{2-}\), so get the charge for the Cu based on the SO\(_4\)\(^{2-}\). The formula is SO\(_4\)\(^{2-}\), and there is only ONE SO\(_4\)\(^{2-}\), so Cu’s charge here must be \( +2 \) for the compound to have an overall charge of zero.

   ⇒ \( \text{Cu}^{+2} = \text{copper (II) ion} \) \quad \text{SO}_4^{2-} = \text{sulfate ion}

   then ⇒ \( \text{CuSO}_4 = \text{copper (II) sulfate} \)
Give the name for each compound given its chemical formula:

<table>
<thead>
<tr>
<th>Formula</th>
<th>Individual Ions</th>
<th>Name of Compound</th>
</tr>
</thead>
<tbody>
<tr>
<td>MgCl₂</td>
<td>Mg⁺² Cl⁻</td>
<td>magnesium chloride</td>
</tr>
<tr>
<td>LiOH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZnCO₃</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K₂S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FePO₄</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SnO₂</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CuBr₂</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ag₃N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mn(CN)₂</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AgC₂H₃O₂</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

WRITING CHEMICAL FORMULAS GIVEN THE COMPOUND NAME

Get the individual ions from the name, then combine them using the crossover rule:

- e.g. barium chloride ⇒ barium = Ba⁺² chloride = Cl⁻
- Ba⁺² Cl⁻ ⇒ BaCl₂

- aluminum sulfate ⇒ aluminum = Al⁺³ sulfate = SO₄⁻²
- Al⁺³ SO₄⁻² ⇒ Al₂(SO₄)₃
Give the chemical formula for each compound given its name:

<table>
<thead>
<tr>
<th>Name of Compound</th>
<th>Individual ions</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>lithium cyanide</td>
<td>Li⁺  CN⁻</td>
<td>LiCN</td>
</tr>
<tr>
<td>iron (III) sulfate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>calcium iodide</td>
<td></td>
<td></td>
</tr>
<tr>
<td>tin (IV) dichromate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>silver nitrite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>copper (II) acetate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>zinc carbonate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>lead (II) phosphide</td>
<td></td>
<td></td>
</tr>
<tr>
<td>potassium sulfite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cobalt (II) nitride</td>
<td></td>
<td></td>
</tr>
<tr>
<td>nickel (II) permanganate</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NAMING MOLECULAR COMPOUNDS

Indicate number of atoms of each element with **Greek prefix** before element name:

<table>
<thead>
<tr>
<th># of atoms</th>
<th>Greek Prefix</th>
<th># of atoms</th>
<th>Greek Prefix</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>mono (usually omitted)</td>
<td>6</td>
<td>hexa</td>
</tr>
<tr>
<td>2</td>
<td>di</td>
<td>7</td>
<td>hepta</td>
</tr>
<tr>
<td>3</td>
<td>tri</td>
<td>8</td>
<td>octa</td>
</tr>
<tr>
<td>4</td>
<td>tetra</td>
<td>9</td>
<td>nona</td>
</tr>
<tr>
<td>5</td>
<td>penta</td>
<td>10</td>
<td>deca</td>
</tr>
</tbody>
</table>
For the **first element**: Greek prefix + element name
For the **second element**: Greek prefix + element name stem + “-ide”

**Note:** Mono is generally omitted, except in common names like 

\[ CO = \text{carbon monoxide} \]

Name the following molecular compounds:

\[ \text{SO}_3 = \quad \text{SiBr}_4 = \]
\[ \text{XeF}_6 = \quad \text{ClF}_3 = \]
\[ \text{N}_2\text{O}_4 = \quad \text{Cl}_2\text{O}_7 = \]
\[ \text{PCl}_5 = \quad \text{P}_4\text{O}_{10} = \]

**DETERMINING FORMULAS OF MOLECULAR COMPOUNDS**

Use Greek prefix(es) to determine number of atoms of each element in formula.

Get **elements** and **number of atoms** of each from name:

\[ \text{tetraposophorus hexasulfide} \]

\[ \text{P}_4\text{S}_6 \]
Give the formulas for each of the following molecular compounds:

- nitrogen trichloride
- dibromine heptaoxide
- dinitrogen pentasulfide

### DETERMINING FORMULAS AND NAMES OF ACIDS FROM IONS

Given an ion, we can get the formula of an acid by:
- Adding H atoms equal to the negative charge on the ion.
- Depending on the suffix of the ion name.

<table>
<thead>
<tr>
<th>Ion</th>
<th>Formula of Acid</th>
<th>Name of Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>F(^{-})</td>
<td>H(_2)F(_2) (aq)</td>
<td>hydrofluoric</td>
</tr>
<tr>
<td>NO(_2)(^{-})</td>
<td>H(_2)NO(_2) (aq)</td>
<td>nitrous</td>
</tr>
<tr>
<td>SO(_4)(^{-2})</td>
<td>H(_2)SO(_4) (aq)</td>
<td>sulfuric</td>
</tr>
</tbody>
</table>

Name each of the following ions, and determine the formula and name of the corresponding acid that forms from the ion.

<table>
<thead>
<tr>
<th>Name of Ion</th>
<th>Formula of Acid</th>
<th>Name of Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO(_3)(^{-2})</td>
<td>H(_2)CO(_3) (aq)</td>
<td>carbonic</td>
</tr>
<tr>
<td>Cl(^{-})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SO(_3)(^{-2})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PO(_4)(^{-3})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NO(_3)(^{-})</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Name each of the following acids:

- HBr (aq) = _________________
- H₂CrO₄ (aq) = _________________
- H₂S (aq) = _________________
- HC₂H₃O₂ (aq) = _________________
- HF (aq) = _________________
- H₂SO₄ (aq) = _________________

Give the formula for each of the following acids: [Don’t forget to indicate (aq)!!]

- phosphoric acid = ___________
- nitrous acid = ___________
- hydroiodic acid = ___________
- carbonic acid = ___________
- sulfurous acid = ___________
- nitric acid = ___________

PUTTING IT ALL TOGETHER:

Name each of the following compounds:

- BaCl₂ _____________________
- NiBr₂ _____________________
- HNO₃(aq)___________________
- SO₂ _____________________
- AgF _____________________
- PbS₂ _____________________
- CuSO₃ _____________________
- PF₅ _____________________
- K₂SO₄ _____________________
- Cr(C₂H₃O₂)₃ _________________
- FeP _____________________
- Al₂(CO₃)₃ _____________________
- NiSO₄ _____________________
- Zn(OH)₂ _____________________
- KMnO₄ _____________________
- Sn(CN)₂ _____________________