Chemistry Lecture #35: Names and Formulas for Ionic Compounds.

Monatomic ion: single atom with a + or - charge. Examples: Na⁺, Cl⁻.

Positive monatomic ions, like Na⁺ or Ca²⁺ are simply called "sodium ion" or "calcium ion." They could also be called "sodium cation" or "calcium cation."

Negative monatomic ions end with "ide." For example, the chlorine anion, Cl⁻, is called "chloride," and the S⁻² ion is called "sulfide."

Fe²⁺ and Fe³⁺ could each be called "iron cation" but this name does not distinguish the two. To distinguish them, we use Roman numerals. Fe²⁺ is called "iron (II) ion" and Fe³⁺ is called "iron (III) ion."

An older form of naming would use the Latin name of the element, and the endings "ous" and "ic" to distinguish the oxidation states. The ion with lower oxidation state would end in "ous" and the one with the higher state would end in "ic." Thus, we would call Fe²⁺ "ferrous ion" and Fe³⁺ "ferric ion."

Below are further examples of how the older Latin system would be used to distinguish transition metal ions:

<table>
<thead>
<tr>
<th>Symbol</th>
<th>name</th>
<th>older Latin name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sn²⁺</td>
<td>tin (II) ion</td>
<td>stannous ion</td>
</tr>
<tr>
<td>Sn⁴⁺</td>
<td>tin (IV) ion</td>
<td>stannic ion</td>
</tr>
<tr>
<td>Cu⁺</td>
<td>copper (I) ion</td>
<td>cuprous ion</td>
</tr>
<tr>
<td>Cu²⁺</td>
<td>copper (II) ion</td>
<td>cupric ion</td>
</tr>
</tbody>
</table>
Binary ionic compounds are made of 2 types of monatomic ions: one metal ion and one nonmetal ion.

In naming a binary ionic compound, the positive ion (metal) is named first, followed by the negative ion (nonmetal).

<table>
<thead>
<tr>
<th>Ionic compound</th>
<th>name</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaCl</td>
<td>sodium chloride</td>
</tr>
<tr>
<td>Cs₂O</td>
<td>cesium oxide</td>
</tr>
<tr>
<td>SrF₂</td>
<td>strontium fluoride</td>
</tr>
</tbody>
</table>

All binary ionic compounds end with "ide."
Binary ionic compounds with transition metals or group 4A elements often require the use of Roman numerals since these metals have variable oxidation states.

For example, CuO and Cu₂O could both be called copper oxide. But the oxidation state of Cu in CuO is +2, and the oxidation state of Cu in Cu₂O is +1. We use the Roman numerals II and I to distinguish CuO and Cu₂O.

\[
\text{Cu}^{2+} \quad \text{O}^{2-} \quad \text{CuO} \quad \text{copper (II) oxide}
\]
\[
\text{Cu}^{+1} \quad \text{O}^{2-} \quad \text{Cu}_2\text{O} \quad \text{copper (I) oxide}
\]

Sometimes the older Latin names are used to distinguish binary ionic compounds with transition metals.

\[
\text{Sn}^{2+} \quad \text{F}^{-} \quad \text{SnF}_2 \quad \text{tin (II) fluoride or stannous fluoride}
\]
\[
\text{Sn}^{4+} \quad \text{F}^{-} \quad \text{SnF}_4 \quad \text{tin (IV) fluoride or stannic fluoride}
\]
\[
\text{Fe}^{2+} \quad \text{O}^{-2} \quad \text{FeO} \quad \text{iron (II) oxide or ferrous oxide}
\]
\[
\text{Fe}^{3+} \quad \text{O}^{-2} \quad \text{Fe}_2\text{O}_3 \quad \text{iron (III) oxide or ferric oxide}
\]
\[
\text{Cr}_2\text{O}_3 \quad \text{chromium (III) oxide}
\]
Chromium must have a +3 charge since oxygen has a -2 charge, and \(2(+3) + 3(-2) = 0\)

\[
\text{CrO} \quad \text{chromium (II) oxide}
\]
Chromium must have a +2 charge since oxygen has a -2 charge, and \(1(+2) + 1(-2) = 0\)
The compounds below have transition elements, yet they have no Roman numerals.

AgCl  silver chloride
NiBr$_2$  nickel bromide
ZnS  zinc sulfide

Silver, nickel and zinc are transition elements which do not have variable oxidation states. You need to memorize that silver ion is Ag$^+$, nickel ion is Ni$^{2+}$, and zinc ion is Zn$^{2+}$.

If the compound has more than two types of atoms, it means that the cation is attached to a polyatomic ion. To name the compound, you give the name of the cation and the name of the polyatomic ion. You need to have the formulas for the polyatomic ions memorized so that you can recognize them on sight.

For example, to name KNO$_3$, you start with the name of K, which is potassium. If you’ve done your homework, you’ll recognize that NO$_3$ is nitrate. So the name of the compound is potassium nitrate.

KNO$_3$  potassium nitrate
Na$_3$PO$_4$  sodium phosphate
CaSO$_4$  calcium sulfate

Be sure to include Roman numerals if the cation is a transition element or group 4A element. For example,

Pb$_3$(PO$_4$)$_2$  lead (II) phosphate
Fe(OH)$_3$  iron (III) hydroxide
The formula of a binary ionic compound can be derived from its name. Write the element symbols with their oxidation numbers, then crisscross the numbers to get the number of each type of atom.

Aluminum oxide $\text{Al}^{3+} \text{O}^{2-} \rightarrow \text{Al}_2\text{O}_3$

Calcium bromide $\text{Ca}^{2+} \text{Br}^{-} \rightarrow \text{CaBr}_2$ or $\text{CaBr}_2$

The same procedure is used if polyatomic ions are used.

Calcium nitrate $\text{Ca}^{2+} \text{NO}_3^{-} \rightarrow \text{Ca(NO}_3)_2$

Strontium sulfate $\text{Sr}^{2+} \text{SO}_4^{2-} \rightarrow \text{SrSO}_4$

If a Roman numeral is given in the name, use it to assign an oxidation number to the cation.

Tin (IV) phosphate $\text{Sn}^{4+} \text{PO}_4^{3-} \rightarrow \text{Sn}_3(\text{PO}_4)_4$

If the cation is a transition element and no oxidation number is given, it is probably a transition element that does not have variable oxidation states. You need to have the oxidation number for this element memorized. For example, silver is a transition element.

Silver nitrate $\text{Ag}^{+} \text{NO}_3^{-} \rightarrow \text{AgNO}_3$