Naming and Writing Formulas for Ionic Compounds Using IUPAC Rules

There are three categories of ionic compounds that we will deal with.

1. **Binary ionic**
   - **simple ions (only single charges)**
   - **multivalent ions (more than one charge)**
2. **Polyatomic ions (complex ions)**
3. **Hydrates**

Binary Ionic compounds - simple ions:

Binary ionic compounds are composed of a metal ion (+) and non-metal ion (-). The word binary simply means only two ions are involved.

NaCl - the combination of a sodium ion and a chloride ion.

Rules for naming - Binary Ionic Compounds:
Naming binary ionic compound is very straight-forward, you simply identify the atoms involved. 1. Name the positive ion, (cation) (+) by writing the full name of the metal. 2. Name the negative ion, (anion) (-) by shortening the name of the atom and add the **-ide** ending.

NaCl ► sodium and chlor**ine** ► sodium chlor**ide**

CaF_2 ► calcium and fluor**ine** ► calcium fluor**ide**

K_2O ► potassium and ox**ygen** ► potassium ox**ide**

IMPORTANT: Do NOT use prefixes - they are for molecular compounds (two non-metals)

Name the following:

1. LiBr
2. $AlCl_3$
3. Rb_2S
4. Mg_3P_2

Writing Chemical Formulas for Binary Ionic Compounds:

Writing chemical formulas for binary ionic compounds relies heavily on your knowledge and understanding of ion charges in the periodic table.

Rules for Writing Binary Ionic Formulas:

1. Write down the symbols of the ions involved.
2. Determine the lowest whole number ratio of ions that will give a net charge of zero.
3. Write the formula removing all charges.

Check out the Cross-Multiply Method at the end of each sample!

Sample Exercise 1:

Write a chemical formula for a compound that contains **Potassium ions** and **Bromide ions**.

1. **Write down the symbols of the ions involved**

   Potassium (group 1 thus has a 1+ charge) K^+

   Bromide (group 17 thus has a 1- charge) Br^-

2. **Determine the lowest whole number ratio of ions that will give a net charge of zero.**

   $(K^+) \times \mathbf{1} = 1+$ $(Br^-) \times \mathbf{1} = 1-$

   (1+) + (1-) = 0 net charge

3. **Write the formula removing all charges.**

   KBr

   We normally do not write in the ones (1).

Sample Exercise 2:

Write a chemical formula for the ionic compound that contains **magnesium ions** and **bromide ions**.

1. **Write down the symbols of the ions involved**

   Magnesium (group 2, has a 2+ charge) Mg^{2+}

   Bromide (group 17, has a 1- charge) Br -

2. **Determine the lowest whole number ratio of ions that will give a net charge of zero.**

   (Mg^{2+}) x **1** = 2+ (Br^-) x **2** = 2-

   (2+) + (2 -) = 0 net charge

3. **Write the formula removing all charges.**

   $MgBr_2$

Sample Exercise 3:

Write a chemical formula for **calcium phosphide**.

1. **Write down the symbols of the ions involved**

   Calcium (group 2 thus has a 2+ charge) Ca^{2+}

   Phosphide (group 15 thus has a 3 - charge) P^{3-}

2. **Determine the lowest whole number ratio of ions that will give a net charge of zero.**

   (Ca^{2+}) x **3** = 6+ (P^{3-}) x **2** = 6 -

   (6+) + (6 -) = 0 net charge

3. **Write the formula removing all charges.**

   Ca_3P_2

If you use the cross-over method make sure your answer is in the lowest whole number ratio!

Write the chemical formula for each compound:

1. sodium sulfide
2. aluminum bromide
3. barium iodide
4. magnesium nitride
5. aluminum nitride

Multivalent Species

Ions of a certain elements can have more than one possible charge. Such elements are called **multivalent species**.

For example, copper is multivalent - its ions can have either a 1+ or a 2+ ion charge (Cu^{+} or Cu^{2+}).

If you have not already noticed, these ions and their charges are provided on the period table!

Have a look at elements with atomic numbers greater than 21

What possible charges can iron (Fe) have?

Can you think of the implications that multivalence has for naming ionic compounds?

Well how about this, when you see the name copper chloride, does it mean the compound that contains Cu^{+} ions or Cu^{2+} ions? Obviously, the name doesn't tell you which copper ion is present.

Alfred Stock resolved this problem in an interesting way. He decided to use a Roman numeral in the cation name to indicate its charge.

- $CuCl_2$ is named copper **(II)** chloride. (The copper is in the Cu^{2+} form.)
- CuCl is named copper **(I)** chloride. (The copper is in the Cu^{+} form.)

It is often the case that one ion charge is more stable and therefore more common than another. For example, Cu^{2+} is more common/stable than Cu^{+}.

This is easy to tell from the periodic table because they have the most common form of the ion written on top. Cu^{2+} is written above Cu^{+}. *{check it out on your periodic table}*

Chemical Formulas Involving Multivalent Species:

Writing formula units from names which include multivalent species uses the same approach you learned for other binary ionic compounds. The only difference is you have to indicate the charge of the multivalent species with roman numerals.

Only use Roman Numerals for metals that have more than one charge!

- **For instance silver only has one possible charge (Ag^{+}) so don't use Roman Numerals.**

Sample Exercise1:

Write the chemical formula for **iron (II) chloride**.

1. **Write down the symbols of the ions involved**

   iron (II) (the Roman Numeral tells us it has a 2+ charge) **Fe^{2+}**

   chloride (group 17 thus has a 1- charge) **Cl^{-}**

2. **Determine the lowest whole number ratio of ions that will give a net charge of zero.**

   $(Fe^{2+}) \times \mathbf{1} = 2+$ $(Cl^{-}) \times \mathbf{2} = 2-$

   $(2+) + (2-) = 0$ net charge

3. **Write the formula removing all charges.**

   $FeCl_2$

Write chemical formulas for the following compounds:

1. titanium (III) fluoride
2. titanium (IV) fluoride
3. nickel (II) oxide
4. lead (IV) sulfide
5. vandium(V) oxide

Writing names for binary ionic compounds that contain a multivalent species requires the same approach you learned earlier.

Rules For Writing Formulas for Multivalent Binary Ionic Compounds

1. Determine if the metal has more than one possible charge (multivalent).
    - consult periodic table
2. Determine charge of anion. (Anions only have one possible charge).
    - recall group number
3. Pick the metal ion that results in a net charge of zero.
4. Write the name of the compound be sure to indicate the identity of the metal ion with Roman Numerals.

Sample Exercise :

Write the IUPAC name for $SnCl_4$.

1. Determine if the metal has more than one possible charge (multivalent).

- consult periodic table

  Sn has two possible charges **Sn^{4+}** and **Sn^{2+}** .

We have to decide which charge we have.

2. Determine charge of anion. (Anions only have one possible charge).

- The chloride ion has a 1- charge because chlorine is a Group 17 element. (Cl can only have one charge 1-)

3. Pick the metal ion that results in a net charge of zero.

Since there are four chloride ions in the formula, the charge on tin ions must be 4+.

$$(Cl^{-}) \times \mathbf{4} = 4-$$

$$(Sn^{x+}) \times \mathbf{1} = 4+$$

$$\mathbf{Sn^{4+}}$$

4. Write the name of the compound but be sure to indicate the identity of the metal ion with Roman Numerals.

$SnCl_4$ is **tin (IV) chloride**.

Write the names for the following compounds:

1. $CrBr_3$
2. TiO_2
3. $AuCl_3$
4. Fe_2O_3
5. AgI

Summary

- In chemical formulas and names for ionic compounds, the cation is written first and the anion is written to its right. Always.
- All simple anion names end in -ide.
- A chemical formula for an ionic compound is electrically neutral: the total positive charge must balance the total negative charge.
- Check to see if the metal in the formula is multivalent before assigning the cation name. ONLY names for multivalent species require a Roman numeral as part of the name.