

CHEMICAL NOMENCLATURE

I. Ionic vs. Covalent Compounds

Ionic compounds: usually form between a **metal** and **nonmetal** or a **metal** and a **polyatomic** ion. They consist of cations and anions held together by electrostatic attraction.

Covalent (molecular) compounds: usually form between **nonmetal** atoms held together by shared electrons.

II. Naming Ions

Naming ionic compounds requires knowledge of how to name the individual ions that make up the ionic compound.

A. **Monatomic Cations:**

Metal atoms lose electrons to form positively charged ions, called **cations**. A cation formed from a single atom is called a *monatomic* cation. Some metals form one ion, while others can form multiple ions.

One ion: Some metals form only one ion. Metals of groups 1, 2, 3, 13 & Zn form only one ion each. These ions are named as follows:

element name + ion

e.g. Na^+ = sodium ion Sr^{2+} = strontium ion Zn^{2+} = zinc ion

Multiple ions: Transition metals often form more than one ion. Since these atoms form more than one ion, the *charge* on the ion must be specified in the name to tell the ions apart. The Stock system is used to name transition metal cations as follows:

element name (charge as Roman numeral) + ion

e.g. Fe^{2+} = iron(II) ion Pb^{4+} = lead(IV) ion Cu^+ = copper(I) ion

B. **Monatomic Anions:**

Nonmetal atoms gain electrons to form negatively charged ions, called **anions**. An anion formed from one individual atom is a *monatomic* anion. Nonmetals form only one ion, so Roman numerals are never used to name anions.

When a nonmetal atom forms an ion, it is named as follows:

element stem name + "ide" + ion

e.g. O^{2-} = oxide ion

N^{3-} = nitride ion

Cl^{-} = chloride ion

C. Polyatomic ions:

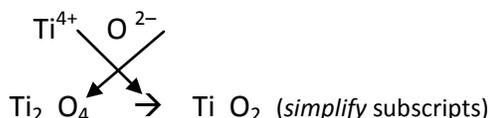
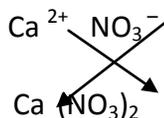
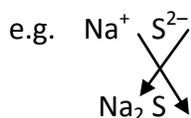
Groups of atoms that gain or lose electrons are called **polyatomic ions**. Polyatomic ions are groups of covalently bonded atoms that must *gain* or *lose* electrons to be more stable.

Nearly all polyatomic ions are anions; there is only one common polyatomic cation, NH_4^+ . Polyatomic ions do not follow a predictable naming pattern – their names must be **memorized**.

III. Nomenclature for Ionic Compounds

A. Writing Formulas for Ionic Compounds << write the ions, do the criss-cross >>

The sum of the oxidation numbers (charges) of the ions in any ionic compound = 0. The "criss-cross" method is a tool for balancing positive and negative charges in an ionic compound.



Essentially, the charge from the cation becomes the subscript for the anion and the charge from the anion becomes the subscript for the cation. Put () around polyatomic ions if there is more than one in the formula. If necessary, *simplify subscripts* to get the lowest whole number ratio of ions in the formula.

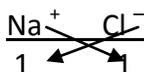
Practice A. Write the formula for the compound formed by the *combination of the ions* given. Use the criss-cross method.



7. NH_4^+ OH^- _____
8. NH_4^+ PO_4^{3-} _____
9. Ag^+ S^{2-} _____
10. Mg^{2+} CO_3^{2-} _____
11. Cu^{2+} NO_3^- _____
12. Sn^{4+} SO_4^{2-} _____
13. Ni^{2+} PO_4^{3-} _____
14. Al^{3+} OH^- _____
15. Fe^{3+} N^{3-} _____

Practice B. Write the formula for the compound given the *formula name*. Write the ions first, then create the formula using the criss-cross method.

Example: Sodium Chloride



1. Lithium fluoride _____
2. Calcium iodide _____
3. Iron(II) chloride _____
4. Iron(III) phosphide _____
5. Titanium(III) oxide _____
6. Lead(IV) bromide _____
7. Strontium carbonate _____
8. Copper(II) sulfate _____
9. Tin(IV) nitrate _____
10. Copper(II) bromate _____

B. Naming Ionic Compounds from Formulas << name the cation, name the anion >>

The rule for naming an ionic compound from its formula is easy: name the cation, and then name the anion.

If the metal forms one ion (Gp 1, 2, 3, 13 & Zn): Simply name the cation, and then name the anion.

e.g. NaCl Na⁺ sodium ion and Cl⁻ chloride ion = Sodium chloride

BaI₂ Ba²⁺ barium ion and I⁻ iodide ion = Barium iodide

Al(OH)₃ Al³⁺ aluminum ion and OH⁻ hydroxide ion = Aluminum hydroxide

If the metal forms more than one ion (transition metals): The rule is the same - name the cation, and then name the anion. *However*, to name the cation, you must *first* determine the *charge* of the cation.

-Use the charge on the *anion* to determine the overall negative charge in the compound.

-Since an ionic compound is neutral (the sum of the charges is zero), the overall positive charge must equal the overall negative charge.

-If there is more than one of the cations present, divide the overall positive charge by the number of cations present to get the charge for each cation.

-Name the cation using the charge as Roman numeral, then name the anion.

e.g. NiBr₂ Br has a 1- charge, so 2 Br⁻ ions means the overall negative charge is -2

The overall positive charge must be +2

There is one Ni ion, so its charge must be 2+

Ni²⁺ nickel(II) ion and Br⁻ bromide ion = Nickel(II) bromide

e.g. Fe₂(SO₄)₃ SO₄ has a 2- charge, so 3 SO₄²⁻ ions means the overall negative charge is -6

The overall positive charge must be +6

There are 2 Fe ions, so each Fe ion charge must be 3+ (6+ ÷ 2 = 3+)

Fe³⁺ iron(III) ion and SO₄²⁻ sulfate ion = Iron(III) sulfate

Practice C. Given the formula, write the ions present, and then name the ionic compound.

1. MgCl₂ _____ _____

2. KCl _____ _____

3. AgF _____
4. FeO _____
5. Pbl₄ _____
6. Sn(NO₃)₂ _____
7. FeN _____
8. MnF₃ _____
9. Cr₂O₃ _____
10. AlBr₃ _____
11. BaSO₄ _____
12. Al₂S₃ _____
13. Li₂O _____
14. AuF₃ _____
15. Cd(NO₃)₂ _____

Practice D. Given the formula, name the ionic compound. Remember to determine the charge on the cation

(if necessary).

1. (NH₄)₂S _____
2. ZnCO₃ _____
3. K₂SO₃ _____
4. NaOH _____
5. Ca(IO₃)₂ _____
6. Na₂SO₄ _____
7. Cu(NO₂)₂ _____
8. Al(OH)₃ _____
9. PbS _____

10. $\text{Sn}(\text{ClO}_3)_2$ _____

IV. Nomenclature for Covalent Compounds

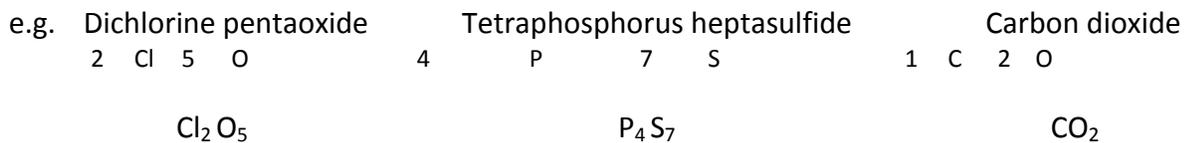
Covalent compounds are named using the Prefix system. In the Prefix system, the number of atoms present in the compound is indicated by Greek prefixes, as follows:

# of atoms	Greek prefix	# of atoms	Greek prefix
1	mono *	6	hexa
2	di	7	hepta
3	tri	8	octa
4	tetra	9	nona
5	penta	10	deca

* often omitted – see below

A. Writing Formulas for Covalent Compounds << use prefixes >>

Use the Greek prefixes in the compound name to determine the subscripts in the formula of the covalent compound, as follows:



Practice E. Write the formula for the covalent compound given the name.

1. Sulfur dioxide _____
2. Chlorine trifluoride _____
3. Dinitrogen pentachloride _____
4. Dibromine heptaoxide _____
5. Tetraphosphorus decasulfide _____

B. Naming Covalent Compounds from Formulas << use prefixes >>

Use the subscripts in the formula to determine the Greek prefixes in the compound name. The first element

in the compound uses the element name; the second element uses the element name with the ending changed to "ide", as below. The prefix *mono* is *omitted* if associated with the first element.

Greek prefix + first element name , Greek prefix + second element stem name + "ide"

e.g.	P_2O_5 di penta	SF_6 mono* hexa	CO mono* mono
	Diphosphorus pentaoxide	Sulfur hexafluoride	Carbon monoxide

Practice F. Given the formula, name the covalent compound.

1. P_2I_5 _____
2. CS_2 _____
3. PCl_5 _____
4. Cl_2O_7 _____
5. $SiBr_4$ _____

V. Nomenclature for Hydrates – a Special Case of Ionic Compounds

Hydrates: hydrates are ionic compounds that have a specific number of water molecules 'attached' to the crystalline structure of the compound. The ionic compound without the attached water molecules is called the *anhydrous salt*; the ionic compound with water attached is called the *hydrate*, or hydrated form of the compound. The attached water is called the *water of hydration*.



The water molecules get into the three-dimensional structure of the ionic compound in one of two ways. If the compound is prepared in a solution of water, and the water is evaporated slowly, some of the water is trapped in the structure of the compound. It is also possible for an anhydrous ionic compound without water to "pick up" water from the air and become hydrated.

During the process of hydration, the structure of the compound changes to include the water molecules. Often the physical appearance of the ionic compound changes, too. For example, $CuSO_4$ anhydrous is a white crystalline solid, while $CuSO_4 \cdot 5H_2O$ hydrate, which has 5 H_2O molecules for every $CuSO_4$, is aqua blue.

A. Writing Formulas for Hydrates

The general formula of a hydrate is $A \cdot n H_2O$ where A is the anhydrous salt, and $n H_2O$ represents the number, n , of water molecules loosely bound to the ionic compound.

To write the formula for a hydrate, first write the correct formula for the anhydrous compound, followed by a dot \cdot . Use the Greek prefix in the name to indicated the number of attached water molecules.

The correct method for writing the formula for a hydrate is shown below.

anhydrous formula + • + **number of water molecules** + H₂O

e.g. aluminum chloride *dihydrate* AlCl₃ + • + 2 + H₂O = AlCl₃ • 2 H₂O

e.g. magnesium sulfate *hexahydrate* MgSO₄ + • + 6 + H₂O = MgSO₄ • 6 H₂O

B. Naming Hydrates from Formulas

To name a hydrate from its formula, write the correct name of the anhydrous ionic compound first. Use Greek prefixes to indicate the number of water molecules present; the prefix is added to the word *hydrate*.

The naming of a hydrate from its formula is illustrated below.

anhydrous compound name + **Greek prefix** + **hydrate**

e.g. CaCl₂ • 2 H₂O calcium chloride + *di* + hydrate = calcium chloride *dihydrate*

e.g. CuSO₄ • 5 H₂O copper(II) sulfate + *penta* + hydrate = copper(II) sulfate *pentahydrate*

Practice G. Write the formula or name of the hydrate.

1. magnesium chloride heptahydrate _____
2. sodium carbonate trihydrate _____
3. BaCl₂ • 2 H₂O _____
4. FeF₃ • 10 H₂O _____
5. Li₂SO₄ • 4 H₂O _____

VI. Put it All Together - Mixed Ionic and Covalent Naming

Practice H. First determine if the following compounds are Ionic or Covalent. If ionic, use the Stock system to name the compound. If covalent, use the Prefix system.

1. BaCl₂ _____
2. SO₂ _____
3. NaClO₃ _____

4. $\text{Al}_2(\text{CO}_3)_3$ _____
5. PF_5 _____
6. NiBr_2 _____
7. NCl_5 _____
8. Cu_2O _____
9. FeP _____
10. sodium nitrate _____
11. silver(I) hydroxide _____
12. zinc phosphate _____
13. lead(IV) carbonate _____
14. bromine moniodide _____
15. copper(I) sulfate octahydrate _____
16. triphosphorus pentoxide _____