Nomenclature Rules

Rules for naming three classes of compounds:
ionic compounds, binary covalent compounds & acids.

What type of compound is it?

IONIC COMPOUND:
Composed of cations (*metals or polyatomic ions*) and anions (*nonmetals or polyatomic ions*).

- **TYPE I:** Only one type of cation is observed.
- **TYPE II:** More than one type of cation is observed.

COVALENT COMPOUND:
Nonionic – not composed of cations & anions. Generally, only nonmetals are present.

- **TYPE III:** Covalent, nonionic.

ACID:
Produces H^+ in water. Typically the hydrogen cation is written first in the chemical formula.

- **ACIDS:** Anion does not contain oxygen.
- **OXYACIDS:** Anion does contain oxygen.

Rules for Naming Ionic Compounds

1.) Determine whether or not the compound is ionic.

How do you know the compound is ionic in the first place?

a.) If the compound **contains a metal**, then it is **most likely an ionic compound**. Metals readily lose electrons to form positive ions, called cations. Ionic compounds almost always contain a metal as a cation and a nonmetal as an anion.

b.) However, **not all ionic compounds** will contain a **metal cation**. The cation could be a **polyatomic ions**, such as **NH_4^+**.

Rules for Naming Ionic Compounds

2.) Determine whether there is only **one type of cation** possible (**Type I**) or whether there are **several cations** possible (**Type II**).

a.) If the cation is a **polyatomic ion** (e.g., ammonium, NH_4^+), then there is only one possible charge and so it is a **type I compound**.

b.) If the cation is a metal, determine if it forms only one type of cation.

Alkali metals (Group 1A)	**+1 cation**
Alkaline earth metals (Group 2A)	**+2 cation**

Transition metals (Group 1-8B) often form **more than one type of cation**.

Rules for Naming Type I Compounds

1.) The cation is named first and the anion is named second.

2.) The name of the cation is the same as the name of the element. So both the element Mg and the cation Mg^{2+} are called magnesium.

(Note: For polyatomic cations, you must memorize the names.)

3.) The anion is named by taking the root name of the element and adding the suffix -ide. For example, F is an atom of fluorine and F^{-} is the anion fluoride.

(Note: For polyatomic anions, you must memorize the names.)

So MgF_2 would be magnesium fluoride.

Rules for Naming Type I Compounds with polyatomic ions

Polyatomic ions then resemble molecules in that they contain at least two atoms bound together in a definite arrangement.

The steps for naming compounds with polyatomic ions:

1.) **The cation is listed first and the anion second.**

2.) **The polyatomic ion names must be memorized.**

3.) **No extra prefixes or suffixes are added.**

Table of Polyatomic Ions

	Symbol (*root*)	per-*root*-ate	*root*-ate	*root*-ite	hypo-*root*-ite
1	Cl (chlor)	ClO_4^-	ClO_3^-	ClO_2^-	ClO^-
2	Br (brom)	BrO_4^-	BrO_3^-	BrO_2^-	BrO^-
3	I (iod)	IO_4^-	IO_3^-	IO_2^-	IO^-
4	N (nitr)	xxx	NO_3^-	NO_2^-	xxx
5	C (carbon)	xxx	CO_3^{2-}	xxx	xxx
6	S (sulf)	*	SO_4^{2-}	SO_3^{2-}	xxx
7	Se (selen)	xxx	SeO_4^{2-}	SeO_3^{2-}	xxx
8	P (phosph)	xxx	PO_4^{3-}	PO_3^{3-}	xxx
9	As (Arsen)	xxx	AsO_4^{3-}	AsO_3^{3-}	xxx
10	Cr (Chrom)	**dichromate** $Cr_2O_7^{2-}$	CrO_4^{2-}	xxx	xxx
11	Mn (mangan)	MnO_4^-	xxx	xxx	xxx
12	Ti (titan)	xxx	TiO_3^{2-}	xxx	xxx
13	Acetate**	xxx	$C_2H_3O_2^-$	xxx	xxx
14	Formate**	xxx	CHO_2^-	xxx	xxx
15	Oxalate**	xxx	$C_2O_4^{2-}$	xxx	xxx
16	Cyanate	xxx	NCO^-	xxx	xxx
17	Thiocyanate***	xxx	SCN^-	xxx	xxx
18	Thiosulfate***	xxx	$S_2O_3^{2-}$	xxx	xxx

* Sulfur has two anions that are often referred to as persulfate. They are peroxomonosulfate (or peroxymonosulfate) ion, SO_5^{2-} and peroxodisulfate (or peroxydisulfate) ion, $S_2O_8^{2-}$.

**The organic anions.

*** Thiocyanate and thiosulfate are formed by substituting a sulfur for an oxygen into the cyanate and sulfate ions.

Nomenclature Mnemonic for Remembering "ates"

<u>N</u>ick the <u>C</u>amel <u>Ate</u> a <u>Cl</u>am <u>S</u>upper and <u>Cr</u>epes (for dessert) in <u>Ph</u>oenix

Nomenclature Mnemonic for Remembering "ates"

Nick the Camel Ate a Clam Supper and Crepes (for dessert) in Phoenix

	Consonants = Oxygen	Vowels = Charge	Polyatomic Ion
Nick = Nitrate	3	-1	NO_3^{-}
Camel = Carbonate	3	-2	CO_3^{2-}
Clam = Chlorate	3	-1	ClO_3^{-}
*(**Note:** Bromate and Iodate are the same as Chlorate.)*			
Supper = Sulfate	4	-2	SO_4^{2-}
Crepes = chromate	4	-2	CrO_4^{2-}
Phoenix = Phosphate	4	-3	PO_4^{3-}

Rules for Naming Type II Compounds

Additionally for Type II Compounds:

4.) Use a roman numeral after the cation to indicate the ionic charge of that cation.

So FeO would be called iron(II) oxide since the cation is Fe^{2+} and Fe_2O_3 would be iron(III) oxide since the cation is Fe^{3+}.

5.) Alternatively, when using traditional names atoms whose valence numbers vary, you add the suffix –*ous* to the one with the lower valence state and –*ic* to the one with the higher valence state.

So FeO would be called ferrous oxide since the cation is Fe^{2+} and Fe_2O_3 would be ferric oxide since the cation is Fe^{3+}.

Table of Type II Compounds

IUPAC	Root	Traditional -ous	-ic
copper (I) & copper (II)	cupr-	Cu^{+}	Cu^{2+}
gold (I) & gold (III)	aur-	Au^{+}	Au^{3+}
mercury (I) & mercury (II)	mercur-	Hg_2^{2+}	Hg^{2+}
chromium (II) & chromium (III)	chrom-	Cr^{2+}	Cr^{3+}
manganese (II) & manganese (III)	mangan-	Mn^{2+}	Mn^{3+}
iron (II) & iron (III)	ferr-	Fe^{2+}	Fe^{3+}
cobalt (II) & cobalt (III)	cobalt-	Co^{2+}	Co^{3+}
nickel(II) & nickel (III)	nickel-	Ni^{2+}	Ni^{3+}
tin (II) & tin (IV)	stann-	Sn^{2+}	Sn^{4+}
lead (II) & lead (IV)	plumb-	Pb^{2+}	Pb^{4+}
cerium (III) & cerium (IV)	cer-	Ce^{3+}	Ce^{4+}
arsenic (III) & arsenic (V)	arsen-	As^{3+}	As^{5+}
antimony (III) & antimony (V)	antimon-	Sb^{3+}	Sb^{5+}
bismuth (III) & bismuth (V)	bismuth-	Bi^{3+}	Bi^{5+}

Rules for Naming Binary Covalent Compounds

How do you recognize that something is a binary covalent compound (versus an ionic compound)?

1.) If a compound **contains only nonmetals** (no metals), then you can be reasonably sure that it is a **covalent** compound.

Note: Some **exceptions** would be compounds that contain polyatomic ions.

For example, ammonium bromide NH_4Br and ammonium sulfate $(NH_4)_2SO_4$ are **ionic compounds even though they contain only nonmetals**.

Type III Compounds: Binary Covalent Compounds

1.) The **first element** in the compound is named first using the **name of the element**.

2.) The **second element** is named as though it were an **anion (the root name + suffix -ide)**; even though, we know there are <u>no</u> anions in a covalent compound.

3.) **Prefixes** are used to **denote the numbers of each atom present**. Since there are no formal charges on the atoms in covalent compounds, it is more difficult to predict the proportions that the atoms combine in. (Note: the prefix mono is never used with the first element).

Type III Compounds: Binary Covalent Compounds

Examples of binary covalent compounds include water (H_2O), carbon monoxide (CO), and carbon dioxide CO_2.

Prefix	meaning
mono-	one
di-	two
tri-	three
tetra-	four
penta-	five
hexa-	six
hepta-	seven
octa-	eight
nona-	nine
deca-	ten

The naming convention for binary covalent compounds is as follows:

(prefix)-nonmetal + (prefix)-nonmetal root + "-ide.

Try naming the compound P_4O_6.

Rules for Naming Simple Acids and Oxyacids

How do we determine if something is an acid?

The acids that we will be concerned with naming are really just **a special class of ionic compounds** where the **cation is always H^+**.

*Recall that cations are written first in ionic formulas. So if the formula has **hydrogen written first**, then this usually means that the hydrogen is an **H^+ cation** and that the compound is **an acid**.*

When dissolved in water, acids produce H^+ ions. These are also called protons, because when the electron is removed from a neutral hydrogen atom, it leaves behind one proton.

If the counterion (the anion) to H^+ in the acid is a **polyatomic ion that contains oxygen** (like NO_2^- or PO_4^{3-}), the acid is called an **oxyacid**. If the **anion does not contain oxygen** (like F^- or CN^-), then a different set of rules are used for naming the acid.

Binary acids are binary compounds that contain a hydrogen atom and either a halogen (F, Cl, Br, I) or sulfur (S). It is important to note that nitrogen, phosphorus, and oxygen do not form binary acids with hydrogen.

The naming convention for binary acids is as follows:

"Hydro-" + nonmetal root + "-ic" + "acid"

The nonmetal roots are determined as follows. For the halogens, simply remove the "ine" and for sulfur remove the "ur". Thus, the roots for fluorine, chlorine, bromine and iodine are fluor-, chlor-, brom-, and iod- ; and for sulfur, sulf- .

So to determine the name for HCl:

hydro + chlor + ic + acid → hydrochloric acid

If the acid is in a gaseous form or an anhydrous form, the "-ic" is replaced by "-ide" and the "acid" suffix is removed.

So, acids are formed by adding protons to atoms or radicals with negative valence numbers. The names of acids that do not contain oxygen are formed like those of binary acids by adding the prefix *hydro-* to the root name for the element and adding the suffix *–ic* and the word "*acid*".

Formula	Acid Name
HF	hydrofluoric acid
HCl	hydrochloric acid
HBr	hydrobromic acid
HI	hydriodic acid
HCN	hydrocyanic acid
H_2S	hydrosulfuric acid
HN_3	hydrazoic acid

If only **one type of oxygen acid** is formed, then the name is that of the characteristic element plus the suffix *–ic* and the word acid.

Formula	Acid Name
H_3BO_3	boric acid
H_2CO_3	carbonic acid
H_4SiO_4	silicic acid

Acids formed from polyatomic ions have a naming system similar to that of the polyatomic ions themselves. The difference being that for **"-ate" we substitute "-ic"** and for **"-ite" we substitute "ous"** and **add the word acid.**

For example, hypochlor*-ite* then becomes hypochlor*ous acid*; and perchlor*-ate* becomes perchlor*ic acid*.

Ion Name	Ion name	Acid Formula	Acid
ClO^-	hypochlorite	$HClO$	hypochlorous acid
ClO_2^-	chlorite	$HClO_2$	chlorous acid
ClO_3^-	chlorate	$HClO_3$	chloric acid
ClO_4^-	perchlorate	$HClO_4$	perchloric acid

Note: The **number of hydrogens** added to the polyatomic ion is **equal to the charge on the cation**.

Try naming the acids formed by nitrite and nitrate ions, NO_2^- and NO_3^-, respectively.