Learning Skills Center
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Chemical Nomenclature (Naming)
(Memorize!)

A) Nomenclature for Binary (two elements) Compounds:

1. Nomenclature for **Nonmetal-Nonmetal*** (**<u>not the same</u>** as that for Metal-Nonmetal)
   a) Use prefix to indicate how many of each of the elements there are, and change the ending of the last element to **-ide**.

Number	Prefix**	Number	Prefix**	Number	Prefix**
1	mono-,mon-	4	tetra-, tetr-	7	hepta-. hep-
2	di-	5	penta-, pent-	8	octa-, oct-
3	tri-	6	hexa-, hex-	9	nona-, non-

**The final *a* or *o* in a prefix is left off when the first letter of the element is an *a* or *o*, as in *tetroxide* (rather than *tetraoxide*,) but *tri*iodide, not *tri*odide.

b) **Examples**: nitrogen monoxide, NO (if there is no prefix on the first element, then it is understood to be mono, this is <u>not</u> true for the second element); N_2O, dinitrogen monoxide; dinitrogen trioxide, N_2O_3; trinitrogen tetroxide, N_3O_4; tetranitrogen trioxide, N_4O_3.

2. Nomenclature for **Metal-Nonmetal**
   a) The <u>net</u> charge [the sum of all the Oxidation States (ox. st.)] in a molecule must equal zero, the ending of the last element is changed to **-ide**, and if the metal has more than one common charge, the charge must be given as part of the name.

*****Rules for Assigning The Oxidation State (or Oxidation Number) (the charge) for Atoms**
Memorize and apply **<u>in order</u>!** Example, if there is a choice, rule 3 is applied before rule 4, 4 before 5, etc.

1. Free elements in their natural form (uncombined with other elements) are assigned an oxidation state (ox. st.) of 0. (e.g. Fe(s), O_2(g)...)
2. The sum of the ox. st. of all the atoms in a species (molecule, ion, isolated atom, or formula unit) must be equal to the net charge on the species.
3. Group(1 or I) elements, and Ag are assigned an ox. st. of +1 (e.g Li^+, Na^+, K^+......etc)
4. Fluorine in a compound is assigned an ox. st. of -1 (e.g. F^-)
5. Group(2 or II) elements, and also Zn and Cd are assigned an ox. st. +2 (e.g. Be^{+2}, Mg^{+2} , Ca^{+2}.....etc)
6. Hydrogen in a compound is assigned an ox. st. of +1.
7. Oxygen in a compound is assigned and ox. st. of -2.
***These rules are related to electronegativities (electronegativity is how much an atom wants to be the negative partner in a polar bond).

Some other useful Oxidation States to know

1. Group(3 or III)) elements <u>tend</u> to form +3 ions, e.g. Al^{+3}, Ga^{+3}......etc
2. Group(17 or VII) elements <u>tend</u> to form -1 ions, e.g. F^-, Cl^-, Br^-......etc
3. Group(16 or VI) elements <u>tend</u> to form -2 ions, e.g. O^{-2},S^{-2}.....etc
4. Group(15 or V) elements <u>tend</u> to form -3 ions, e.g. N^{-3},P^{-3}......etc

b) **Examples**:
calcium oxide, CaO (rule 5 Ca^{+2}, and rule 7 O^{-2} ; Total charge: (+2) + (-2) = 0)
lithium oxide, Li_2O (rule 3 Li^+, and rule 7 O^{-2} ; Total charge: (+1)x2 + (-2) = 0)
magnesium fluoride, MgF_2 (rule 4 F^-, rule 5 Mg^{+2} ; Total charge: (+2) + (-1)x2 = 0)

Transition and many other Metals have more than one common ionic charge. (Some do not as Zn^{+2},Cd^{+2}, Ag^{+})

Here are **some** common metals which have more than one common ionic charge

Metal	Ionic Charge	Symbols	Modern (systematic) Names
Chromium	+2 and +3	Cr^{+2}, Cr^{+3}	Chromium(II), Chromium(III)
Cobalt	+2 and +3	Co^{+2}, Co^{+3}	Cobalt (II), Cobalt (III)
Copper	+1 and +2	Cu^{+}, Cu^{+2}	Copper (I), Copper (II)
Gold	+1 and +3	Au^{+}, Au^{+3}	Gold (I), Gold (III)
Iron	+2 and +3	Fe^{+2}, Fe^{+3}	Iron (II), Iron (III)
Mercury	+1 and +2	Hg_2^{+2}(yes), Hg^{+2}	Mercury (I), Mercury (II)
Tin	+2 and +4	Sn^{+2}, Sn^{+4}	Tin (II), Tin (IV)
Thallium	+1 and +3	Tl^{+}, Tl^{+3}	Thallium(I), Thallium(III)

⇒ **Metals that do not have more then one charge are only** groups I and II , Zn^{+2},Cd^{+2}, Ag^{+} and Al and Ga from group 13 (or III), which are +3. All other metals can have more than one oxidation state.

c) **Examples**:

Iron(III)* oxide, Fe_2O_3 (given in the name Fe^{+3}, and rule 7 O^{-2}. Total charge (rule 2): (+3)x**2** + (-2)x**3** = 0

Iron(II)* oxide, FeO (given in the name Fe^{+2}, and rule 7 O^{-2} Total charge (rule 2): (+2)x1 + (-2)x1 = 0

*Iron can be either +2 or+3, so the charge must be indicated in the name with Roman numerals.

B) Nomenclature for Polyatomic Ions:

1. Polyatomic cations (cations are positive ions). There are only two you need to know: ammonium, NH_4^{+} , and mercury (I), Hg_2^{+2}

2. Polyatomic anions (anions are negative ions):

Here is a system that can help you memorize some of the polyatomic anions.

First memorize the **-ate** ions (**shaded**) in the first table (on the next page) and **all the ions** in the second table.
Second, memorize the rules below for naming the polyatomic ions that are related to the **-ate** ions.

Here are the rules for naming other ions if you know the -ate ions.

a) If you remove one oxygen from the **-ate** anion, you have an **-ite** anion. (e.g. brom**ate,** BrO_3^-, becomes brom**ite**, BrO_2^-)

b) If you remove one oxygen from the **-ite** anion, you have an **hypo- -ite** anion. (e.g. brom**ite**, BrO_2^-, becomes **hypo**brom**ite**, BrO^-)

c) If you add one oxygen to the **-ate** anion, you have a **per- -ate** anion. (e.g. brom**ate,** BrO_3^-, becomes **per**brom**ate,** BrO_4^-)

Here is the system for naming the corresponding acids if you know the -ate ions and the rules above.

a) The **-ate** ion makes an **-ic acid** when enough H^+'s are added to make the molecule neutral.
(e.g. brom**ate** BrO_3^-, becomes Brom**ic acid,** $HBrO_3$) (Don't forget H is plus one)

b) The **-ite** ion makes an **-ous acid** when enough H^+'s are added to make the molecule neutral.
(e.g. brom**i**te, BrO_2^-, becomes Brom**ous acid,** $HBrO_2$)

c) The **hypo -ite** ion makes a **hypo -ous acid** when enough H^+'s are added to make the molecule neutral.
(e.g. **hypo**brom**ite** BrO^-, becomes **hypo**brom**ous acid**, HBrO)

d) The **per -ate** ion makes a **per -ic acid** when enough H^+'s are added to make the molecule neutral.
(e.g. **per**brom**ate** BrO_4^-, becomes **per**brom**ic acid,** $HBrO_4$)

e) The **-ide** ion (no oxygens) makes a **hydro -ic acid** when enough H^+'s are added to make the molecule neutral.
(e.g. Brom**ide** Br^-, becomes **hydro**brom**ic acid,** $HBr_{(aq)}$). (However, the gas, $HBr_{(g)}$is called hydrogen bromide; $_{(aq)}$means in water, that is,aqueous, and $_{(g)}$ means gas phase.)

-ate **ions (must be memorized)**

Also the *-ic acids* and *-ite anions* are shown to help **show some of the rules** from the last page.

-ate Anion Name	Chemical Formula	**-ic** Acid Name	Chemical Formula	**-ite** Anion Name	Chemical Formula	Mnemonic
sulf**ate**	SO_4^{-2}	sulfur**ic** acid	H_2SO_4	Sulf**ite**	SO_3^{-2}	(Super
phosph**ate**	PO_4^{-3}	phosphor**ic** acid	H_3PO_4	phosph**ite**	PO_3^{-3}	Popeye
carbon**ate**	CO_3^{-2}	carbon**ic** acid	H_2CO_3	skip	skip	Constantly
chlor**ate**	ClO_3^{-}	chlor**ic** acid	$HClO_3$	chlor**ite**	ClO_2^{-}	Clubbed
brom**ate**	BrO_3^{-}	brom**ic** acid	$HBrO_3$	brom**ite**	BrO_2^{-}	Brutus
iod**ate**	IO_3^{-}	Iod**ic** acid	HIO_3	iod**ite**	IO_2^{-}	In
nitr**ate**	NO_3^{-}	nitr**ic** acid	HNO_3	nitr**ite**	NO_2^{-}	Nevada)

Below are more polyatomic anions whose names **must be memorized**:

Name	Formula	Name	Formula
hydroxide	OH^-	thiosulfate	$S_2O_3^{-2}$ (**thio** tells you that one of the oxygens on a sulfate has been replaced by a sulfur)
cyanide	CN^-	hydrogen sulfate	*HSO_4^- (or"bisulfate")
oxalate	$C_2O_4^{-2}$	hydrogen carbonate	*HCO_3^- (or "bicarbonate")
permanganate	MnO_4^-	chromate	CrO_4^{-2}
acetate	$C_2H_3O_2^-$ or $C_2H_3OO^-$ or CH_3COO^-	dichromate	$Cr_2O_7^{-2}$

*Note: These are not named as acids because they are charged species.

C) Nomenclature for compounds with Polyatomic ions:

1. The net charge (the sum of all the charges) in the compound must equal zero (rule 2). The name of the polyatomic ion is used. The metal is named first and if the metal has more than one common charge, the charge must be given as part of the name.

2. **Examples**:
lithium nitrate, $LiNO_3$ (rule 3 for Li^+, NO_3^- so, (+1) + (-1) = 0)
calcium nitrate, $Ca(NO_3)_{\mathbf{2}}$ (rule 5 for Ca^{+2}, NO_3^- so, (+2) + (-1)x**2** = 0)
iron(II) phosphate, $Fe_{\mathbf{3}}(PO_4)_{\mathbf{2}}$ (given in name Fe^{+2}, PO_4^{-3} so, (+2)x**3** + (-3)x**2** = 0)
iron(III) phosphate, $FePO_4$ (given in name Fe^{+3}, PO_4^{-3} so (+3)x1 + (-3)x1 = 0)
magnesium sulfate, $MgSO_4$ (rule 5 Mg^{+2}; we have memorized that sulfate is -2.)
gold(I) sulfate, Au_2SO_4 (sulfate is always -2 To find Au charge: (+X)x2 + (-2) = 0, so X = +1)
copper(II) nitrite, $Cu(NO_2)_2$ (nitrite is always -1; (+X)x1 + (-1)x2 = 0 so X = +2)
hypoiodous acid, HIO(aq) (IO_3^- is iodate, so IO^- is hypoiodite)
hydroiodic acid, HI (I^- is iodide)
chromic acid, H_2CrO_4 (CrO_4^{-2} is chromate)

Oxyacids, Their Anions, and Nomenclature

Actually, you need to learn the **acid names** and the **per-ate**, **-ate**, **-ite**, and **hypo-ite** anions referred to in the preceding (page 2). The tables below summarize many of the rules.

In the cases presented here, an acid is a compound that can donate hydrogens in water. Oxyacids are acids that contain oxygen in the anion (negative) species.

Memorize all the **-ic** acids and their corresponding **-ate** anions in **Table 1** below. Also learn the ionization equations for the acids and note that the negative charge of the anion is equal to the number of positive hydrogens that dissociate[1] from the acid.

Table 1 **Total Ionization Equations of Selected Acids**

Acid Name (*-ic* acids)	**Total Ionization Equation of Acid**	**Anion Name (*-ate* anions)**
chloric acid, $HClO_{3\ (aq)}$[2]	$HClO_{3\ (1)}$ (in H_2O) ====> $H^+_{(aq)} + ClO_3^-{}_{(aq)}$	chlorate: ClO_3^-
nitric acid, $HNO_{3\ (aq)}$	$HNO_{3\ (l)}$ (in H_2O) ====> $H^+_{(aq)} + NO_3^-{}_{(aq)}$	nitrate: NO_3^-
sulfuric acid, $H_2SO_{4\ (aq)}$	$H_2SO_{4\ (l)}$ (in H_2O) ====> $2H^+_{(aq)} + SO_4^{-2}{}_{(aq)}$	sulfate: SO_4^{-2}
carbonic acid[1], $H_2CO_{3\ (aq)}$	$H_2CO_{3\ (s)}$ (in H_2O) ====> $2H^+_{(aq)} + CO_3^{-2}{}_{(aq)}$	carbonate: CO_3^{-2}
phosphoric acid[1], $H_3PO_{4(aq)}$	$H_3PO_{4\ (s)}$ (in H_2O) ====> $3H^+_{(aq)} + PO_4^{-3}{}_{(aq)}$	phosphate: PO_4^{-3}
hydrochloric acid[3], $HCl_{\ (aq)}$	$HCl_{\ (g)}$ (bubbled into H_2O) ====>$H^+_{(aq)} + Cl^-_{(aq)}$	chloride: Cl^-

[1] Carbonic and phosphoric acids do not totally dissociate in water, but we will pretend they do in order to learn the nomenclature. The anions of these oxyacids often occur in other compounds.

[2] All oxyacids from the halogens, F, Cl, Br, and I follow the same nomenclature rules. Also note: (aq) stands for <u>aqueous</u>; it means the ionic species is dissolved in water. The (s) means solid, (l) means liquid, and (g) means gas.

[3] The chloride ion in hydrochloric acid is not polyatomic but is included for comparison. Also note that $\mathbf{HCl_{(aq)}}$, is called **hydrochloric acid if it is an aqueous** solution, **but** it is called **hydrogen chloride, $\mathbf{HCl_{(g)}}$, if it is a pure gas**. Similarly, $HBr_{(aq)}$ is called hydrobromic acid, but $HBr_{(l)}$ is called hydrogen bromide.

Once you have learned the **-ic** acids and **-ate** anions from **Table 1**, you may substitute them into the row in **Table 2** which is shaded and says **Same.** By learning the different prefixes and suffixes for acids and anions with more or fewer oxygens than the memorized **Same** species, you can predict the proper name for many related oxyacids and their corresponding anions.

Table 2 **Prefixes and Suffixes in Acid and Anion Nomenclature**

Oxygen Atoms Compared to the memorized *-ic* Acids and *-ate* Anions (above chart)	**Acid Prefix and/or Suffix (Example: name; formula)**	**Anion Prefix and/or Suffix (Example: name; formula)**
One more oxygen than **Same** (the **Same** as learned in top chart)	*per-ic* (perchloric; $HClO_4$)	*per-ate* (perchlorate; ClO_4^-)
the **Same** *-ic* acid & *-ate* anion (the **Same** as learned in top chart)	*-ic* (chloric; $HClO_3$)	*-ate* (chlorate; ClO_3^-)
One less oxygen than **Same**	*-ous* (chlorous; $HClO_2$)	*-ite* (chlorite; ClO_2^-)
Two less oxygens than **Same**	*hypo-ous* (hypochlorous; HClO or HOCl)	*hypo-ite* (hypochlorite; ClO^- or OCl^-)
No oxygens	*hydro-ic* (hydrochloric; HCl)	*-ide* (chloride; Cl^-)

D) See how you can do! (answers are given at the end)

1. Give the ox. st. for each element in each of the following (may not be needed to name these):

a) NO ox. st. Nitrogen__________ ox. st. Oxygen__________

b) N_2O ox. st. Nitrogen__________ ox. st. Oxygen__________

c) ClO_4^- ox. st. Chlorine__________ ox. st. Oxygen__________

d) K_2O_2 ox. st. Potassium___________ ox. st. Oxygen__________

e) Fe_2O_3 ox. st. Iron__________ ox. st. Oxygen__________

f) SF_6 ox. st. Sulfur__________ ox. st. Fluorine__________

g) SO_4^{-2} ox. st. Sulfur__________ ox. st. Oxygen__________

h) SO_3^{-2} ox. st. Sulfur__________ ox. st. Oxygen__________

i) $CaBr_2$ ox. st. Calcium__________ ox. st. Bromine__________

j) FeO ox. st. Iron__________ ox. st. Oxygen__________

2. Give the correct chemical formula for each of the following:

a) barium chloride _________________

b) sulfur dioxide _________________

c) disulfur tetroxide _________________

d) iron(II) bromide _________________

e) calcium nitrate _________________

f) hydrosulfuric acid _________________

g) iron(II) phosphate _________________

h) gold(I) thiosulfate _________________

i) cobalt(III) cyanide _________________

j) aluminium nitrite _________________

k) sulfur hexachloride _________________

l) nitrous acid _________________

3. Give the correct name for each of the following:

a) S_2O_3 ______________________

b) SrO ______________________

c) $Fe_2(SO_3)_3$ ______________________

d) SBr_2 ______________________

e) CoO ______________________

f) H_2CO_3(aq) ______________________

g) AgNO ______________________

h) $Co_2(S_2O_3)_3$ ______________________

i) $Al(OH)_3$ ______________________

j) K_2CrO_4 ______________________

k) $Sn_3(PO_4)_2$ ______________________

l) HNO(aq) ______________________

1) a.+2,-2 b.+1,-2 c.+7,-2 d. +1,-1 (yes, this is correct use rules) e. +3, -2 f. +6, -1 g. +6, -2 h.+4, -2 i.+2, -1 j.+2, -2
2) a. $BaCl_2$ b. SO_2 c. S_2O_4 d. $FeBr_2$ e. $Ca(NO_3)_2$ f. H_2S(aq) g. $Fe_3(PO_4)_2$ h. $Au_2S_2O_3$ i. $Co(CN)_3$ j. $Al(NO_2)_3$
k. SCl_6 l. HNO_2(aq)
3) a. disulfur trioxide b. strontium oxide c. iron(III) sulfite d. sulfur dibromide e. cobalt(II) oxide
f. Carbonic acid g. silver hyponitrite h. cobalt(III) thiosulfate i. Aluminium hydroxide j. potassium chromate
k. tin(II) phosphate l. hyponitrous acid