Patterns

in

Chemical Nomenclature

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Naming of Oxo-ions

The names of certain oxo-ions ***(ions that contain oxygen)*** composed from only oxygen and another element may vary depending on the valency ***(the charge or oxidation state/number)*** that is assigned to the central atom making up the ion.

Consequently, when naming ions, certain modifications are made depending on the valency of the central atom of the ion. The number of modifications that are made, in turn, depends on the number of varieties of these oxo-ions that exist.

In order to distinguish between 2, 3, or more oxo-ions composed from exactly the same elements, certain prefixes and suffixes are employed. The type of prefix or suffix that is employed depends on the valency (oxidation number) of the central atom.

In this pamphlet, I shall illustrate the different patterns that are involved, and also how the prefixes and suffixes are used in the naming of the oxo-ions.
I shall also discuss the oxo-ions of the non-metallic elements in groups 5, 6 and 7. I shall not go into the oxo-ions of the non-metallic elements in groups 3 and 4, because their oxo-ions exist only as a single variety. For example, Boron only has only one oxo-ion: the *borate ion*, $\mathbf{BO_3^{3-}}$ and carbon has only one variety also: i.e. the *carbonate ion*, $\mathbf{CO_3^{2-}}$ and so does Silicon: the *Silicate ion*, $\mathbf{SiO_3^{2-}}$**.** Therefore, since these elements are only able to produce one type of oxo-ion, I shall not go into explaining how the names of their oxo-ions are derived.

Oxo-ions of Group 5 elements

Let us consider the oxo-ions formed by the non-metallic elements of group 5: Nitrogen, Phosphorus and Arsenic.

Formula of oxo-ion	**Overall charge**	**Name of oxo-ion**	**Name of atom in central position**	**Valency of central atom**	**Pattern observed**
NO_2^-	-1	Nitr**ite** ion	Nitrogen	+3	…**ite**
NO_3^-	-1	Nitr**ate** ion	Nitrogen	+5	…**ate**
PO_3^{3-}	-3	Phosph**ite** ion	Phosphorus	+3	…**ite**
PO_4^{3-}	-3	Phosph**ate** ion	Phosphorus	+5	…**ate**
AsO_3^{3-}	-3	Arsen**ite** ion	Arsenic	+3	…**ite**
AsO_4^{3-}	-3	Arsen**ate** ion	Arsenic	+5	…**ate**

If you observe the table closely, you will notice that the oxo-ion that contains the central atom with a **higher** valency is assigned the **--ate** suffix, while the oxo-ion containing the central atom with the **lower** valency is assigned the **--ite** suffix. This is how the names of these ions are derived.

Now, let's take a look at some of the oxo-ions of non-metallic elements in group 6: Sulfur and Selenium.

Formula of oxo-ion	**Overall charge**	**Name of oxo-ion**	**Name of atom in central position**	**Valency of central atom**	**Pattern observed**
SO_3^{2-}	-2	Sulf**ite** ion	Sulfur	+4	…**ite**
SO_4^{2-}	-2	Sulf**ate** ion	Sulfur	+6	…**ate**
SeO_3^{2-}	-2	Selen**ite** ion	Selenium	+4	…**ite**
SeO_4^{2-}	-2	Selen**ate** ion	Selenium	+6	…**ate**

Let's now take a look at the oxo-ions of the halogens (Group 7 elements). In this case, there are more modifications to make, because there are more varieties of oxo-ions that are composed from oxygen and these elements (the halogens).

Formula of oxo-ion	Overall charge	Name of oxo-ion	Name of atom in central position	Valency of central atom	Pattern observed
ClO^-	-1	**Hypo**chlor**ite** ion	Chlorine	+1	***Hypo…ite***
ClO_2^-	-1	Chlor**ite** ion	Chlorine	+3	***…ite***
ClO_3^-	-1	Chlor**ate** ion	Chlorine	+5	***…ate***
ClO_4^-	-1	**Per**chlor**ate** ion	Chlorine	+7	***Per…ate***
BrO^-	-1	**Hypo**brom**ite** ion	Bromine	+1	***Hypo…ite***
BrO_2^-	-1	Brom**ite** ion	Bromine	+3	***…ite***
BrO_3^-	-1	Brom**ate** ion	Bromine	+5	***…ate***
BrO_4^-	-1	**Per**brom**ate** ion	Bromine	+7	***Per…ate***
IO^-	-1	**Hypo**iod**ite** ion	Iodine	+1	***Hypo…ite***
IO_2^-	-1	Iod**ite** ion	Iodine	+3	***…ite***
IO_3^-	-1	Iod**ate** ion	Iodine	+5	***…ate***
IO_4^-	-1	**Per**iod**ate** ion	Iodine	+7	***Per…ate***

I hope this table will aid you to understand the pattern with which other oxo-ions are named.
Let's now proceed to see how to name compounds that are made from the combination of these ***oxo-ions*** and hydrogen.
For the sake of simplicity, I shall define the some terms, which are adjectives that you will come across.

These terms are:
(a) **Anhydrous**---This means **not mixed or not combined with water.**
(b) **Aqueous**---This means **mixed or combined with water.**
(c) **Acid anhydrides**---These are **compounds that dissolve in water to form acids**.

Listed below are the names of the **anhydrous forms** of some acid anhydrides that are formed from the chemical combination of hydrogen and the oxo-ions that I had listed.

Formula of acid anhydride	**Name of anhydrous form**
$HNO_{2(g)}$	Hydrogen nitrite
$HNO_{3(g)}$	Hydrogen nitrate
$H_2SO_{3(g)}$	Hydrogen sulfite
$H_2SO_{4(g)}$	Hydrogen sulfate
$HClO_{(g)}$	Hydrogen hypochlorite
$HClO_{2(g)}$	Hydrogen chlorite
$HClO_{3(g)}$	Hydrogen chlorate
$HClO_{4(g)}$	Hydrogen perchlorate
$HBrO_{(g)}$	Hydrogen hypobromite
$HBrO_{2(g)}$	Hydrogen bromite
$HBrO_{3(g)}$	Hydrogen bromate
$HBrO_{4(g)}$	Hydrogen perbromate

When these acid anhydrides are mixed with water, they dissolve to form acids. Moreover, when they are in their aqueous forms (when mixed with water), their names are different from the names that they have when they exist in anhydrous forms (free from water).

Below is a list of the aqueous forms of the acid anhydrides that I mentioned above. Observe how the word " hydrogen" is **not included**. Instead, the endings of the oxo-ions in the acid anhydrides are **replaced with another suffix**. Then the word "acid" is then added after this suffix.

Formula of acid anhydride	**Name of aqueous form**
$HNO_{2(aq)}$	Nitrous acid
$HNO_{3(aq)}$	Nitric acid
$H_2SO_{3(aq)}$	Sulfurous acid
$H_2SO_{4(aq)}$	Sulfuric acid
$HClO_{(aq)}$	Hypochlorous acid
$HClO_{2(aq)}$	Chlorous acid
$HClO_{3(aq)}$	Chloric acid
$HClO_{4(aq)}$	Perchloric acid
$HBrO_{(aq)}$	Hypobromous acid
$HBrO_{2(aq)}$	Bromous acid
$HBrO_{3(aq)}$	Bromic acid
$HBrO_{4(aq)}$	Perbromic acid

This is what happens:

This ending in the anhydrous form	**Is replaced with this ending in aqueous form**
ITE	**OUS + the word "acid"**
ATE	**IC + the word "acid"**

This pattern in oxy-acids (acids that contain oxygen) is also similar to but a little different from the partern that is observed between the **aqueous** and **anhydrous** forms of binary non-oxygen-containing acid anhydrides such as HCl, HBr, HI, H_2S etc.

Here are the formulas and names of some **non-oxygen-containing** acid anhydrides.

Formula of acid anhydride	**Name of anhydrous form of acid anhydride**
$H_2S_{(g)}$	Hydrogen sulfide
$H_2Se_{(g)}$	Hydrogen selenide
$HF_{(l)}$	Hydrogen fluoride
$HCl_{(g)}$	Hydrogen chloride
$HBr_{(g)}$	Hydrogen bromide
$HI_{(g)}$	Hydrogen Iodide

When the anhydrous forms of these non-oxygen containing acid anhydrides dissolve in water to form acids, certain modifications are made to their names. The word "hydrogen" is not written out in full. Instead, it is abbreviated as "hydro" and the **--ide** ending in the anhydrous form is changed to **--ic** and the word "acid" is then added. This means that the acid anhydride is in its aqueous form (mixed with water). Take a look at the table below:

Formula of acid anhydride	**Name of aqueous form of acid anhydride**
$H_2S_{(aq)}$	Hydrosulfuric acid
$H_2Se_{(aq)}$	Hydroselenic acid
$HF_{(aq)}$	Hydrofluoric acid
$HCl_{(aq)}$	Hydrochloric acid
$HBr_{(aq)}$	Hydrobromic acid
$HI_{(aq)}$	Hydroiodic acid

Let me give a list of some common ions, and thereafter I shall explain how certain compounds that are made from the combination of these ions are named.

A list of cations (positively charged ions) with *fixed* valencies (oxidation states)

Formula of cation	**Name of cation**
H^+	Hydrogen ion
Li^+	Lithium ion
Na^+	Sodium ion
K^+	Potassium ion
Rb^+	Rubidium ion
Cs^+	Cesium ion
Be^{2+}	Beryllium ion
Mg^{2+}	Magnesium ion
Ca^{2+}	Calcium ion
Ba^{2+}	Barium ion

Al^{3+}	Aluminum ion
Ga^{3+}	Gallium ion
H_3O^+	Oxonium ion or Hydroxonium ion
NH_4^+	Ammonium ion
PH_4^+	Phosphonium ion

A List of cations (positively charged ions) with variable valencies

Formula of cation	**Name of cation**
Fe^{2+}	Iron(ii) ion
Fe^{3+}	Iron (iii) ion
Co^{2+}	Cobalt (ii) ion
Co^{3+}	Cobalt (iii) ion
Cu^+	Copper (i) ion
Cu^{2+}	Copper (ii) ion
Au^+	Gold (i) ion
Au^{3+}	Gold (ii) ion
Hg_2^{2+}	Mercury (i) ion
Hg^{2+}	Mercury (ii) ion
Sn^{2+}	Tin (ii) ion
Sn^{4+}	Tin (iv) ion
Pb^{2+}	Lead (ii) ion
Pb^{4+}	Lead (iv) ion
Bi^{3+}	Bismuth (iii) ion
Bi^{5+}	Bismuth (v) ion
Mn^{2+}	Manganese (ii) ion
Mn^{5+}	Manganese (v) ion
V^{2+}	Vanadium (ii) ion
V^{3+}	Vanadium (iii) ion
V^{5+}	Vanadium (v) ion

A list of Anions (negatively charged ions)

Formula of anion	Name of anion
N^{3-}	Nitride ion
P^{3-}	Phosphide ion
As^{3-}	Arsenide ion
O^{2-}	Oxide ion
O_2^{2-}	Peroxide ion
O_2^{-}	Superoxide ion
S^{2-}	Sulfide ion
Se^{2-}	Selenide ion
F^{-}	Fluoride ion
Cl^{-}	Chloride ion
Br^{-}	Bromide ion
I^{-}	Iodide ion
H^{-}	Hydride ion
OH^{-}	Hydroxide ion
CN^{-}	Cyanide ion
CNO^{-}	Cyanate ion
SCN^{-}	Thiocyanate ion
BO_3^{3-}	Borate ion
CO_3^{2-}	Carbonate ion
HCO_3^{-}	Hydrogen carbonate ion or bicarbonate ion
SO_3^{2-}	Sulfite ion
SO_4^{2-}	Sulfate ion
$S_2O_3^{2-}$	Thiosulfate ion
HSO_3^{-}	Hydrogen sulfite ion or bisulfite ion
HSO_4^{2-}	Hydrogen sulfate ion or bisulfate ion
HPO_4^{2-}	Hydrogen phosphate ion or biphosphate ion
$H_2PO_4^{-}$	Dihydrogen phosphate ion
PO_3^{3-}	Phosphite ion
PO_4^{3-}	Phosphate ion
NO_2^{-}	Nitrite ion
NO_3^{-}	Nitrate ion
CrO_4^{2-}	Chromate ion
$Cr_2O_7^{2-}$	Dichromate ion
MnO_4^{-}	Manganate ion
$C_2O_4^{2-}$	Oxalate ion
$C_2H_3O_2^{-}$	Acetate ion
AsO_3^{3-}	Arsenite ion
AsO_4^{3-}	Arsenate ion
SeO_3^{2-}	Selenite ion
SeO_4^{2-}	Selenate ion
SiO_3^{2-}	Silicate ion

Here is how you can name a compound that is made by combining any of the cations and anions that I have mentioned:

1. Write down the name of the cation (positively charged ion) first--this is the metallic element, hydrogen, or ammonium ion. If the metal has variable valencies, ensure that its valency in the compound that you are naming is indicated with roman numerals enclosed within brackets. If it does not have variable valency (i.e., if its valency is fixed) please do not indicate its valency.

2. Give a space and then write down the name of the anion (negatively charged ion).

Few examples are named below:

Formula of Compound	**Name**
Na_2SO_3	Sodium sulfite
Na_2SO_4	Sodium sulfate
$CaSiO_3$	Calcium silicate
$KMnO_4$	Potassium permanganate
K_2SiO_3	Potassium silicate
NaH	Sodium hydride
NaOH	Sodium hydroxide
Na_2CO_3	Sodium carbonate
$(NH_4)_2\,SO_4$	Ammonium sulfate
$Ca(NO_2)_2$	Calcium nitrite
$Ca(NO_3)_2$	Calcium nitrate
$K_2C_2O_4$	Potassium oxalate
$KC_2H_3O_2$	Potassium acetate
$Mg(NO_3)_2$	Magnesium nitrate
$NaHCO_3$	Sodium bicarbonate or Sodium hydrogencarbonate
$NaHSO_4$	Sodium bisulfate or Sodium hydrogen sulfate
$Na_2S_2O_3$	Sodium thiosulfate
K_2CrO_4	Potassium chromate
$K_2Cr_2O_7$	Potassium dichromate
NaOCl or NaClO	Sodium hypochlorite
$NaClO_2$	Sodium chlorite
NaCl	Sodium chloride
$NaClO_3$	Sodium chlorate
$NaClO_4$	Sodium perchlorate
$Ca(OCl)_2$ or $Ca(ClO)_2$	Calcium hypochlorite
$Ca(ClO_4)_2$	Calcium perchlorate
$ZnCl_2$	Zinc chloride
AgCl	Silver chloride
NaSCN	Sodium thiocyanide
NaI	Sodium iodate
NH_4Cl	Ammonium chloride
CdO	Cadmium oxide

Now, let us name a few compounds where the metallic element has variable oxidation states. **The valency of the metallic element is always indicated so that the different forms of the same element can be distinguished from each/one another.**

Formula of compound	**Name**
$FeCl_2$	Iron (ii) chloride
$FeCl_3$	Iron (iii) chloride
FeO	Iron (ii) oxide
Fe_2O_3	Iron (iii) oxide
$CoSO_4$	Cobalt (ii) sulfate
$CuSO_4$	Copper (ii) sulfate
Hg_2Cl_2	Mercury (i) chloride
$HgCl_2$	Mercury (ii) chloride
PbO	Lead (ii) oxide
PbO_2	Lead (iv) oxide
$Pb(NO_2)_2$	Lead (ii) nitrite
$SnCl_4$	Tin (iv) chloride
V_2O_5	Vanadium (v) oxide
$Pb(C_2H_3O_2)_2$	Lead (ii) acetate
Bi_2O_5	Bismuth (v) oxide
Bi_2O_3	Bismuth (iii) oxide
FeN	Iron (iii) nitride
Cu_2O	Copper (i) oxide
MnO	Manganese (ii) oxide
MnO_4	Manganese (iv) oxide
$Pb(CN)_4$	Lead (iv) cyanide
FeAs	Iron (iii) arsenide
$CoCl_2$	Cobalt (ii) chloride
$Hg_2(NO_3)_2$	Mercury (ii) nitrate
$Sn(Cr_2O_7)_2$	Tin (iv) dichromate
$Sn(CrO_4)_2$	Tin (iv) chromate
$Fe(MnO_4)_2$	Iron (ii) permanganate
$Fe(ClO)_3$	Iron (iii) hypochlorite
$Cu(ClO_4)_2$	Copper (ii) perchlorate
$FeBr_3$	Iron (iii) bromide
Cu_2S	Copper (i) sulfide
SnS	Tin (ii) sulfide
Hg_2O	Mercury (i) oxide
$Fe(OH)_3$	Iron (iii) hydroxide

Please bear in mind that though Zinc **(Zn),** Cadmium **(Cd)** and Silver **(Ag)** are transition metals (*transition metals usually exhibit variable valency),* they **[Silver, cadmium, and Zinc**] do not have variable oxidation states. So, when compounds containing them are named, their valencies in these compounds are not indicated at all.
(*Exhibiting* ***variable valency*** *means having more than one oxidation number.)*

Naming of binary compounds that are composed of non-metals only.

In binary compounds that are composed of metallic atoms and non-metallic ions, example $CaCl_2$, prefixes are not used to indicate the number of atoms of each element in the compound.
However, when a binary compound (not including hydrogen-containing acid anhydrides) is **made up of two non-metallic elements only**, prefixes are employed to indicate the number of atoms of each element making up a molecule of the compound.
Usually, if the first element in the molecule of the compound is represented by only one atom, the prefix "mono" is not used, because it is assumed to be understood.

This is how they are named:

1. Write down the name of the first element. If there is more than one atom of it, use the appropriate prefix to indicate its number of atoms in the molecule.
2. After a space, write down the name of the second element and use the appropriate prefix to indicate its number of atoms.

Before I proceed into giving you a list of names of compounds that are made of non-metallic elements only, let me list some prefixes that are employed to indicate the number of units of any given substance.

Number of Units	**Prefix Employed**
One	Mono
Two	Di
Three	Tri
Four	Tetra
Five	Penta
Six	Hexa
Seven	Hepta
Eight	Octa
Nine	Nona
Ten	Deca
Eleven	Undeca
Twelve	Duodeca

Listed below are examples of compounds that are made up of nonmetallic elements only: Observe closely how these compounds are named.

Formula of compound	**Name**
CO_2	Carbon dioxide
CO	Carbon monoxide
N_2O_5	Dinitrogen pentoxide
N_2O	Dinitrogen oxide
N_2O_4	Dinitrogen tetroxide

NO_2	Nitrogen dioxide
NO	Nitrogen monoxide
P_4O_6	Tetraphosphorus hexoxide
P_4O_{10}	Tetraphosphorus decoxide
SiF_4	Silicon tetrafluoride
PCl_3	Phosphorus trichloride
SO_2	Sulfur dioxide
SO_3	Sulfur trioxide
CBr_4	Carbon tetrabromide
ClO_2	Chlorine dioxide
IF_7	Iodine heptafluoride
BrO_2	Bromine dioxide

Always bear in mind that:

1. The valency of oxygen in most compounds is always –2, except in peroxides, where it's -1.
2. Usually, when hydrogen combines with metals, its valency is -1, but when it combines with non-metals its usual valency is +1.
3. In oxo-ions such as the sulfate and nitrite ion, the valency of the central atom is always positive. This is because it rather donates electrons to the other atoms that are attached to it.

These facts will aid you to have a better picture of the oxidation numbers of the different atoms in certain ions or compounds

Naming of Hydrated Compounds

Hydrated compounds or simply "hydrates" are those compounds that have a specific amount of water molecules that are attached or associated with each molecule of the compound.

There are two ways of naming hydrated compounds:

Method One:

1. Write down the correct name of the main compound.
2. After the name of the main compound, place a hyphen and then write down the appropriate prefix indicating the number of water molecules attached to the main compound. After this prefix, without any space, write down the word "hydrate."

Method Two:

1. Write down the correct name of the main compound.
2. After the name of the main compound, place a hyphen and then write down the number indicating the number of water molecules attached the main compound. After this number, place a hyphen and then write down the word "water."

Here is a list of hydrated compounds that are named using the two methods that I have mentioned.

Using prefixes and the word "hydrate."

Formula of Hydrate	**Name of hydrate**
$Na_2CO_3 \cdot 10H_2O$	Sodium carbonate-decahydrate
$CuSO_4 \cdot 5H_2O$	Copper(ii) sulfate-pentahydrate
$FeSO_4 \cdot 7H_2O$	Iron(ii)sulfate-heptahydrate
$MgSO_4 \cdot 7H_2O$	Magnesium sulfate-heptahydrate
$Na_2CO_3 \cdot H_2O$	Sodium carbonate-monohydrate
$CoCl_2 \cdot 6H_2O$	Cobalt(ii)chloride-hexahydrate
$FeCl_3 \cdot 6H_2O$	Iron(iii)chloride-hexahydrate
$CuSO_4 \cdot 2H_2O$	Copper(ii) sulfate-dihydrate

Using numbers and the word "water."

Formula of Hydrate	**Name of hydrate**
$Na_2CO_3 \cdot 10H_2O$	Sodium carbonate-10-water
$CuSO_4 \cdot 5H_2O$	Copper(ii) sulfate-5-water
$FeSO_4 \cdot 7H_2O$	Iron(ii)sulfate-7-water
$MgSO_4 \cdot 7H_2O$	Magnesium sufate-7-water
$Na_2CO_3 \cdot H_2O$	Sodium carbonate-1-water
$CoCl_2 \cdot 6H_2O$	Cobalt(ii) chloride-6-water
$FeCl_3 \cdot 6H_2O$	Iron(iii) chloride-6-water
$CuSO_4 \cdot 2H_2O$	Copper(ii) sulfate-2-water

Sometimes, you may be a little confused with the symbols of some elements like Iron **(Fe),** Mercury **(Hg),** Lead **(Pb),** and Antimony **(Sb).** And you may be wondering why their symbols are written the way they are. The symbols of these elements are derived by abbreviating their Greek or Latin names, using one or more letters in their Greek or Latin names.

Listed on the next page are the English names, symbols, and the Latin names of some elements whose symbols are derived this way.

English Name	***Symbol***	***Latin Name***
Silver	Ag	Argentum
Gold	Au	Aurum
Copper	Cu	Cuprum
Iron	Fe	Ferrum
Mercury	Hg	Hydragynum
Potassium	K	Kalium
Sodium	Na	Natrium
Lead	Pb	Plumbum
Antimony	Sb	Stibium
Tin	Sn	Stannum
Tungsten	W	Wolframite

I hope I have been able to explain the points that I am trying to make. If there are any misspellings or misrepresentation of information that might lead to your misinterpretation or misunderstanding of any of my explanations please do not hesitate to let me know.

You can contact me at ***ELmeuko@aol.com*** if you have any questions, comments, or suggestions. Thank you for paying your undivided attention while studying with this handout. Have a nice time.

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