Nomenclature of Compounds

Compounds can be shown with their formulae as well as their names. If these names were not established according to a system, we would have to memorize millons of trivial names. Therefore, a necessity of setting a standard of naming inorganic (and organic) compounds in a systematic approach. It is possible to guess the name of an unknown compound given the formula.

Naming Metal-Ametal Binary Compounds

The following rule is sought to name metal-ametal binary compounds, which have ionic character:

1) Metal's name is read without change,

2) Ametal's name is read with a suffix “ide”.

Note: Since metal ions with differing oxidation states will form different compounds, naming these compounds requires that the oxidation state of the metal is added.

Nomenclature of Metal - Ametal Binary Compounds- Examples

Note that the resulting compound is electrically neutral.

NaCl: Sodium chlor**ide**

MgI_2: Magnesium iod**ide**

Al_2O_3: Aluminum ox**ide**

Nomenclature of metal-ametal binary compounds which contain a multi-valence metal ion

$FeCl_3$: Iron(III) chloride

$FeCl_2$: Iron (II) chloride

$Hg_2(NO_3)_2$: Mercury (I) nitrate

$Hg(NO_3)_2$: Mercury (II) nitrate

Some simple ions

Positive ions (cations) with fixed oxidation state

Li^+: Lithium Na^+: Sodium *(Natrium)*

K^+: Potassium *(Kalium)* Rb^+: Rubidium

Cs^+: C(a)esium Mg^{2+} : Magnesium

Ca^{2+} : Calcium Sr^{2+} : Strontium

Ba^{2+} : Barium Al^{3+} : Aluminum

Zn^{2+} : Zinc Ag^+: Silver (*Argentum*)

Some Simple Ions

Cations with differing oxidation states

Cr^{3+} : Chromium (III) Cr^{2+} : Chromium (II)

Fe^{3+} : Iron (III) Fe^{2+} : Iron (II) *(Ferrum)*

Co^{3+} : Cobalt (III) Co^{2+} : Cobalt (II)

Cu^{2+} : Copper (II) Cu^{+}: Copper (I) *(Cuprum)*

Hg^{2+} : Mercury (II) Hg_2^{2+} : Mercury (I) *(Hydrargium)*

Sn^{4+} : Tin (IV) Sn^{2+} : Tin (II) *(Stannum)*

Pb^{4+} : Lead (IV) Pb^{2+} : Lead (II) *(Plumbum)*

Some Simple Anions

Commonly encountered negative ions (anions)

H^-: Hydride F^-: Fluoride

Cl^-: Chloride Br^-: Bromide

I^-: İodide O^{2-}: Oxide

S^{2-}: Sulfide/Sulphide N^{3-}: Nitride

Classical Naming: “ous”-”ic” system

Former naming system used to assign the suffixes “ous” for lower oxidation state and “ic” for higher one for ions which have two different oxidation states.

Example: Cuprous oxide, Cu_2O (copper (I) oxide)

Cupric oxide, CuO (copper (II) oxide)

Classical naming: “ous” and “ic” system

For ions which have more than two oxidation states, like manganese and vanadium, this system failed to assign names, and ruled out in academic sense; some chemical firms still use this nomenclature.

Metal-Ametal binary compounds: Exercises

Writing the formula of a compound with the name given:
Write the formulae of barium oxide, calcium fluoride, and iron (III) sulfide.

Metal-Ametal Binary compounds: Exercises

Barium oxide: Barium ion is written as Ba^{2+} , oxide ion as O^{2-} . Since they form in 1:1 ratio and the resulting compound is neutral, there is no need to use a coefficient.

Answer: BaO

Metal-Ametal Binary Compounds: Exercises

Calcium fluoride: Calcium ion is Ca^{2+} , fluoride ion is F^-. In order to be neutral, two fluorides are needed to bind to a calcium ion.

Answer: CaF_2

Metal-Ametal Binary Compounds: Exercises

Iron (III) sulfide: Iron (III) ion is Fe^{3+}, sulfide ion is S^{2-}. Their common denominator is 6, so two ions of iron (III) and three ions of sulfide are required.

Answer: Fe_2S_3

Metal-Ametal Binary Compounds: Questions

After working with the previous examples, write the formulae of the compounds below.

1) Lithium oxide
2) Tin (II) chloride
3) Lithium nitride
4) Aluminum sulfide
5) Magnesium nitride
6) Vanadium (III) oxide

Metal-Ametal Binary Compounds: Exercises

Finding the name of a compound with given formula:

Give systematic names for Na_2S, AlF_3 ve Cu_2O.

Metal-Ametal Binary Compounds: Exercises

Na_2S: Na ion has 1+, S ion has 2- charge. Na^+ ion is sodium, S^{2-} ion is sulfide, so the name of this compound is "**sodium sulfide**".

Metal-Ametal Binary Compounds: Exercises

AlF_3: Comprised of Al^{3+} and F^- ions, this compound is called as "**Aluminum fluoride**". Since aluminum is only present at 3+ charge, it is not necessary to call like "aluminum (III)"; the simplest form is sought.

Metal-Ametal Binary Compounds: Exercises

Cu_2O: In this compound, we have Cu^{1+} and O^{2-} ions. Cu^{1+} ion is copper (I), O^{2-} ion is oxide, so the compound's name is “copper **(I) oxide**”. Former name of this compound was “cuprous oxide”.

Metal-Ametal Binary Compounds: Questions

Write the names for the compounds below.

1) CsI

2) CaF_2

3) FeO

4) $CrCl_3$

5) CaH_2

6) CuCl

7) Ag_2S

8) Hg_2Cl_2

Binary Compounds of Two Ametals

If a compound consists of two ametal atom, the bonding has a covalent character rather than ionic. These compounds are named in a similar way to the previous one.

Binary Compounds of Two Ametals

Example 1: HCl: Hydrogen chloride
For this compound, the more positive atom is read first, and the more negative one comes later. Any coefficients are read in their Latin equivalents.

Binary Compounds of Two Ametals

Example 2: SO_2: Sulfur **di**oxide

SO_3: Sulfur **tri**oxide

In these examples, the first entity is monoatomic, so one might think that the prefix "mono" is required; but for simplicity, this is not read for first monoatomic entity. If the second atom is monoatomic too, the "mono" prefix is <u>always</u> read.

Binary Compounds of Two Ametals

Example 3: B_2Br_4: **Di**boron **tetra**bromide

In this example, we have two atoms of the first entity, so the corresponding prefix of “di” is used. The second entity has four atoms, so “tetra” prefix is required.

Binary Compounds of Two Ametals

Reminder: Latin equivalents of numbers from 1 to 10

1: Mono 2: Di 3: Tri

4: Tetra 5: Penta 6: Hexa

7: Hepta 8: Octa 9: Nona 10: Deca

Binary Compounds of Two Ametals

Some exceptions

Systematic names of some compounds are never used, since the trivial names are adopted very much.

H_2O: water (dihydrogen monoxide)*

NH_3: ammonia (trihydrogen mononitride)**

*For this example, the words mono and oxide are clipped to give the monosyllable “monoxide”.

**In this example, positively charged hydrogens are again put into the right for trivial reasons.

Some Reminders

Latin prefixes are only used for ametal-ametal binary compounds; it is not right to use those prefixes for metal-ametal binary compounds.

$MgCl_2$: Magnesium ~~dichloride~~ chloride

$FeCl_3$: Iron ~~trichloride~~ (Iron (III) chloride)

Nomenclature of Ametal-Ametal Binary Compounds- Examples

BCl_3: Boron trichloride, CCl_4: Carbon tetrachloride

CO: Carbon monoxide, CO_2: Carbon dioxide

NO: Nitrogen monoxide, NO_2: Nitrogen dioxide

N_2O: Dinitrogen monoxide, N_2O_3: Dinitrogen trioxide

N_2O_4: Dinitrogen tetroxide, N_2O_5: Dinitrogen pentoxide

PCl_3: Phosphorus trichloride, PCl_5: Phosphorus pentachloride

SF_6: Sulfur hexafluoride

Not: When a Latin prefix and the word “iodide”come together, the clipping rule is not applied; that is, “triiodide” is written instead of “triodide”.

Binary Acids (Hydrogen-Ametal Compounds)

Naming the binary hydrogen-ametal compounds uses the “ic” suffix as we remember from the older “ous”-”ic” system; the usage of “ous” suffix for these compounds is not possible.

Binary Acids (Hydrogen-Ametal Compounds)

The most important point is that these compounds are binary acids when dissolved in water, and ametal-ametal compounds when in gaseous state:

Example: $HF_{(aqueous)}$: Hydrofluoric acid

$HF_{(gaseous)}$: Hydrogen fluoride

Binary Acids (Hydrogen-Ametal Compounds)

$HCl_{(aq)}$: Hydrochloric acid

$HBr_{(aq)}$: Hydrobromic acid

$HI_{(aq)}$: Hydroiodic acid

$H_2S_{(aq)}$: Hydrosulfuric acid

Polyatomic Ions

Anions containing three different atoms, one of which is oxygen, are frequently encountered. Diatomic, non-oxygeneous anions are also known. The common example for cations is ammonium, formed by protonation of ammonia.

Polyatomic Ions

Ammonium: NH_4^+, ammonium chloride: NH_4Cl

Acetate: CH_3COO^-, sodium acetate: $NaCH_3COO$*

Carbonate: CO_3^{2-}, sodium carbonate: Na_2CO_3**

*: In order to avoid the misthought that sodium ion were bound to carbon, acetates are written like CH_3COONa or written as flipped anion, $NaOOCCH_3$.

**Protonated form of carbonate ion is hydrogen carbonate, also known as “bicarbonate”; this ion is shown as HCO_3^-.

Polyatomic Ions

Chromate: CrO_4^{2-}, ammonium chromate: $(NH_4)_2CrO_4$

Dichromate: $Cr_2O_7^{2-}$, ammonium dichromate: $(NH_4)_2Cr_2O_7$*

Cyanide: CN^-, potassium cyanide: KCN

Hydroxide: OH^-, lithium hydroxide: LiOH

Nitrite: NO_2^-, sodium nitrite: $NaNO_2$

Nitrate: NO_3^-, sodium nitrate: $NaNO_3$

*Dichromates are “dimeric” forms of chromates in acidic medium, so there is no change of oxidation state for chromium.

Polyatomic Ions

Oxalate: $C_2O_4^{2-}$**, calcium oxalate: CaC_2O_4

Permanganate: MnO_4^-, potassium permanganate: $KMnO_4$

Manganate: MnO_4^{2-}, sodium manganate: Na_2MnO_4

Phosphate: PO_4^{3-}, sodium phosphate: Na_3PO_4***

**The alternative formula of oxalate ion is $(COO^-)_2$.

***PO_4^{3-} ion is also named as “tertiary phosphate” referring to its charge; the other protonated anions are respectively “secondary phosphate” and “primary phosphate”.

Polyatomic Ions

Hydrogen phosphate: HPO_4^{2-}, sodium hydrogen phosphate: Na_2HPO_4 "sodium secondary phosphate"

Dihydrogen phosphate: $H_2PO_4^-$, sodium dihydrogen phosphate: NaH_2PO_4 "sodyum primary phosphate"

Polyatomic Ions

Sulfite: SO_3^{2-}, sodium sulfite: Na_2SO_3

Hydrogen sulfite (bisulfite): HSO_3^-, potassium hydrogen sulfite: $KHSO_3$

Sulfate: SO_4^{2-}, sodium sulfate: Na_2SO_4

Hydrogen sulfate (bisulfate): HSO_4^-, potassium hydrogen sulfate: $KHSO_4$

Thiosulfate: $S_2O_3^{2-}$, sodium thiosulfate: $Na_2S_2O_3$

Thiocyanate: SCN^-, potassium thiocyanate: KSCN*

The other name for this anion is “rhodanide”.

Halogenated oxyanions

Nomenclature of oxygen-containing compounds which have halogens of different oxidation states requires the use of some pre- and suffixes.

1) hypo (*prefix*) ... ite (*suffix*): “the least positive” state

2) ...ite (*suffix*): “One step higher than the least positive” state

3) ...ate (*suffix*): “One step lower than the most positive” state

4) per (*prefix*) ...ate (*suffix*): “the most positive” state

Oxyacids

Chlorine atom must be positive in order to form a compound with oxygen; positive oxidation states for chlorine are 1+, 3+, 5+ and 7+. Let us apply the rules outlined in the previous slide:

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

*"hypo" anions are also written as oxygen the first atom; for example, OCl^- and ClO^- are the same.

Oxyacids

Since we have to use the “ous” and “ic” naming system, the first two lower states are referred to as “ous” states, and the two higher states are the “ic” states. A further discrimination is applied by using “hypo” and “per” prefixes for the least and most positive ones.

Nomenclature Exercises

Give names for these compounds:

1) $CuCl_2$

2) ClO_2

3) HIO_4

4) $Ca(H_2PO_4)_2$

Nomenclature Exercises

1) $CuCl_2$: This compound is a metal-ametal binary compound formed between Cu^{2+} and Cl^-, taking the differing oxidation state of copper ion into account, this compound is written as “copper **(II) chloride**”.

Nomenclature Exercises

2) ClO_2: This compound is a neutral ametal-ametal binary compound. Since the positively charged chlorine is single, the prefix “mono” is omitted. This compound is named as “**chlorine dioxide**”.

Nomenclature Exercises

3) HIO_4: This compound is formed between hydrogen and an oxyanion. The positive part of the oxyanion is examined, and since it is the highest of the four available, we will use “per” prefix and “ate” suffix. If present in aqueous solution, the compound is “**periodic acid**”. If present in gaseous state, an ametal-ametal binary compound nomenclature is adopted, and “**hydrogen periodate**” is written.

Nomenclature Exercises

$Ca(H_2PO_4)_2$: This compound is formed between a metal (calcium) and an oxyanion (dihydrogen phosphate), so the name is "c**alcium dihydrogen phosphate**".

Nomenclature Questions

Give names for the following formulae:
1) SF_6, 2) HNO_2, 3) $Ca(HCO_3)_2$, 4) $FeSO_4$
5) NH_4NO_3, 6) PCl_3, 7) $HBrO$, 8) $AgClO_4$
9) $Fe_2(SO_4)_3$

Complex Compounds

The most common examples for complex compounds are hydrated compounds in which the formula unit has a definite number of water molecules coordinated.
Nomenclature of these compounds uses the metal-ametal method, followed by the Latin equivalent for the number of bound water molecules.

Complex Compounds

$CoCl_2.6H_2O$: Cobalt (II) chloride hexahydrate

$ZnSO_4.7H_2O$: Zinc sulfate heptahydrate

$Na_2CO_3.12H_2O$: Sodium carbonate dodecahydrate

$Na_2S.9H_2O$: Sodium sulfide nonahydrate