2.9: Nomenclature of Simple Compounds

Generally, there are two types of inorganic compounds that can be formed: ionic compounds and molecular compounds. Nomenclature is the process of naming chemical compounds with different names so that they can be easily identified as separate chemicals. Inorganic compounds are compounds that do not deal with the formation of carbohydrates, or simply all other compounds that do not fit into the description of an organic compound. For example, organic compounds include molecules with carbon rings and/or chains with hydrogen atoms (see picture below). Inorganic compounds, the topic of this section, are every other molecule that does not include these distinctive carbon and hydrogen structures.

Compounds between Metals and Nonmetals (Cation and Anion)

Compounds made of a metal and nonmetal are commonly known as Ionic Compounds, where the compound name has an ending of ***–ide***. Cations have positive charges while anions have negative charges. The net charge of any ionic compound must be zero which also means it must be electrically neutral. For example, one Na^+ is paired with one Cl^-; one Ca^{2+} is paired with two Br^-. There are two rules that must be followed through:

- The **cation** (metal) is always named first with its name unchanged
- The **anion** (nonmetal) is written after the cation, modified to end in ***–ide***

Table 1: Cations and Anions:

+1 Charge	+2 Charge	-1 Charge	-2 Charge	-3 Charge	-4 Charge
Group 1A elements	**Group 2A elements**	**Group 7A elements**	**Group 6A elements**	**Group 5A elements**	**Group 4A elements**
Hydrogen: H^+	Beryllium: Be^{2+}	Hydride: H^-	Oxide: O^{2-}	Nitride: N^{3-}	Carbide: C^{4-}
Lithium: Li^+	Magnesium: Mg^{2+}	Fluoride: F^-	Sulfide: S^{2-}	Phosphide: P^{3-}	
Soduim: Na^+	Calcium: Ca^{2+}	Chloride: Cl^-			
Potassium: K^+	Strontium: Sr^{2+}	Bromide: Br^-			
Rubidium: Rb^+	Barium: Ba^{2+}	Iodide: I^-			
Cesium: Cs^+					

Example 1

$Na^+ + Cl^- = NaCl$; $Ca^{2+} + 2Br^- = CaBr_2$

Sodium + Chlorine = Sodium Chlor**ide; **Calcium + Bromine = Calcium Brom**ide**

The transition metals may form more than one ion, thus it is needed to be specified which particular ion we are talking about. This is indicated by assigning a Roman numeral after the metal. The Roman numeral denotes the charge and the oxidation state of the transition metal ion. For example, iron can form two common ions, Fe^{2+} and Fe^{3+}. To distinguish the difference, Fe^{2+} would be named iron (II) and Fe^{3+} would be named iron (III).

Table of Transition Metal and Metal Cations:

+1 Charge	+2 Charge	+3 Charge	+4 Charge
Copper(I): Cu^+	Copper(II): Cu^{2+}	Aluminum: Al^{3+}	Lead(IV): Pb^{4+}
Silver: Ag^+	Iron(II): Fe^{2+}	Iron(III): Fe^{3+}	Tin(IV): Sn^{4+}
	Cobalt(II): Co^{2+}	Cobalt(III): Co^{3+}	
	Tin(II): Sn^{2+}		
	Lead(II): Pb^{2+}		
	Nickel: Ni^{2+}		

+1 Charge	+2 Charge	+3 Charge	+4 Charge
	Zinc: Zn^{2+}		

Example 2

Ions:	Fe^{2+} + $2Cl^{-}$	Fe^{3+} + $3Cl^{-}$
Compound:	$FeCl_2$	$FeCl_3$
Nomenclature	Iron (II) Chloride	Iron (III) Chloride

However, some of the transition metals' charges have specific Latin names. Just like the other nomenclature rules, the ion of the transition metal that has the lower charge has the Latin name ending with **-ous** and the one with the the higher charge has a Latin name ending with **-ic**. The most common ones are shown in the table below:

Transition Metal Ion with Roman Numeral	Latin name
Copper (I): Cu^{+}	Cuprous
Copper (II): Cu^{2+}	Cupric
Iron (II): Fe^{2+}	Ferrous
Iron (III): Fe^{3+}	Ferric
Lead (II): Pb^{2+}	Plumbous
Lead (IV): Pb^{4+}	Plumbic
Mercury (I): Hg_2^{2+}	Mercurous
Mercury (II): Hg^{2+}	Mercuric
Tin (II): Sn^{2+}	Stannous
Tin (IV): Sn^{4+}	Stannic

Several exceptions apply to the Roman numeral assignment: Aluminum, Zinc, and Silver. Although they belong to the transition metal category, these metals do not have Roman numerals written after their names because these metals only exist in one ion. Instead of using Roman numerals, the different ions can also be presented in plain words. The metal is changed to end in ***–ous*** or ***–ic***.

- ***-ous*** ending is used for the **lower** oxidation state
- ***-ic*** ending is used for the **higher** oxidation state

Example 3

Compound	Cu_2O	CuO	$FeCl_2$	$FeCl_3$
Charge	Charge of copper is +1	Charge of copper is +2	Charge of iron is +2	Charge of iron is +3
Nomenclature	Cuprous Oxide	Cupric Oxide	Ferrous Chloride	Ferric Chloride

However, this **-ous/-ic** system is inadequate in some cases, so the Roman numeral system is preferred. This system is used commonly in naming acids, where H_2SO_4 is commonly known as Sulfuric Acid, and H_2SO_3 is known as Sulfurous Acid.

Compounds between Nonmetals and Nonmetals

Compounds that consist of a nonmetal bonded to a nonmetal are commonly known as **Molecular Compounds**, where the element with the positive oxidation state is written first. In many cases, nonmetals form more than one binary compound, so **prefixes** are used to distinguish them.

# of Atoms	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Prefixes	Mono-	Di-	Tri-	Tetra-	Penta-	Hexa-	Hepta-	Octa-	Nona-	Deca-

Example 4

CO = carbon ***mon***oxide BCl_3 = boron***tri***chloride

CO_2 = carbon ***di***oxide N_2O_5 =***di***nitrogen ***pent***oxide

The prefix ***mono-*** is not used for the first element. If there is not a prefix before the first element, it is assumed that there is only one atom of that element.

Binary Acids

Although HF can be named hydrogen fluoride, it is given a different name for emphasis that it is an acid. An acid is a substance that dissociates into hydrogen ions (H^+) and anions in water. A quick way to identify acids is to see if there is an H (denoting hydrogen) in front of the molecular formula of the compound. To name acids, the prefix ***hydro-*** is placed in front of the nonmetal modified to end with ***–ic***. The state of acids is aqueous (aq) because acids are found in water.

Some common binary acids include:

HF (g) = hydrogen fluor**ide** -> HF (aq) = ***hydro***fluor***ic*** acid

HBr (g) = hydrogen brom**ide** -> HBr (aq) = ***hydro***brom***ic*** acid

HCl (g) = hydrogen chlor**ide** -> HCl (aq) = ***hydro***chlor***ic*** acid

H_2S (g) = hydrogen sulf**ide** -> H_2S (aq) = ***hydro***sulfur***ic***acid

It is important to include (aq) after the acids because the same compounds can be written in gas phase with hydrogen named first followed by the anion ending with ***–ide***.

Example 5

hypo____ite ____ite ____ate per____ate

ClO^- ClO_2^- ClO_3^- ClO_4^-

hypo*chlor*ite *chlor*ite *chlor*ate per*chlor*ate

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As indicated by the arrow, moving to the right, the following trends occur:

Increasing number of oxygen atoms

Increasing oxidation state of the nonmetal

(Usage of this example can be seen from the set of compounds containing Cl and O)

This occurs because the number of oxygen atoms are increasing from hypochlorite to perchlorate, yet the overall charge of the polyatomic ion is still -1. To correctly specify how many oxygen atoms are in the ion, prefixes and suffixes are again used.

Polyatomic Ions

In **polyatomic ions**, polyatomic (meaning two or more atoms) are joined together by **covalent bonds**. Although there may be a element with positive charge like H^+, it is not joined with another element with an ionic bond. This occurs because if the atoms formed an ionic bond, then it would have already become a compound, thus not needing to gain or loose any electrons. Polyatomic anions are more common than polyatomic cations as shown in the chart below. Polyatomic anions have negative charges while polyatomic cations have positive charges. To indicate different polyatomic ions made up of the same elements, the name of the ion is modified according to the example below:

Table: Common Polyatomic ions

Name: Cation/Anion	Formula
Ammonium ion	NH_4^+
Hydronium ion	H_3O^+
Acetate ion	$C_2H_3O_2^-$
Arsenate ion	AsO_4^{3-}
Carbonate ion	CO_3^{2-}
Hypochlorite ion	ClO^-
Chlorite ion	ClO_2^-
Chlorate ion	ClO_3^-
Perchlorate ion	ClO_4^-
Chromate ion	CrO_4^{2-}
Dichromate ion	$Cr_2O_7^{2-}$
Cyanide ion	CN^-
Hydroxide ion	OH^-
Nitrite ion	NO_2^-
Nitrate ion	NO_3^-
Oxalate ion	$C_2O_4^{2-}$
Permanganate ion	MnO_4^-
Phosphate ion	PO_4^{3-}
Sulfite ion	SO_3^{2-}
Sulfate ion	SO_4^{2-}
Thiocyanate ion	SCN^-
Thiosulfate ion	$S_2O_3^{2-}$

To combine the topic of acids and polyatomic ions, there is nomenclature of aqueous acids. Such acids include sulfuric acid (H_2SO_4) or carbonic acid (H_2CO_3). To name them, follow these quick, simple rules:

1. If the ion ends in **-ate** and is added with an acid, the acid name will have an **-ic** ending. Examples: nitrate ion (NO_3^-) + H^+ (denoting formation of acid) = nitr**ic** acid (HNO_3)
2. If the ion ends in **-ite** and is added with an acid, then the acid name will have an **-ous** ending. Example: nitite ion (NO_2^-) + H^+ (denoting formation of acid) = nitr**ous** acid (HNO_2)

References

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Problems

1. What is the correct formula for Calcium Carbonate?

a. $Ca^{+} + CO_2^{-}$

b. $CaCO_2^{-}$

c. $CaCO_3$

d. $2CaCO_3$

2. What is the correct name for FeO?

a. Iron oxide

b. Iron dioxide

c. Iron(III) oxide

d. Iron(II) oxide

3. What is the correct name for $Al(NO_3)_3$?

a. Aluminum nitrate

b. Aluminum(III) nitrate

c. Aluminum nitrite

d. Aluminum nitrogen trioxide

4. What is the correct formula of phosphorus trichloride?

a. P_2Cl_2

b. PCl_3

c. PCl_4

d. P_4Cl_2

5. What is the correct formula of lithium perchlorate?

a. Li_2ClO_4

b. $LiClO_2$

c. LiClO

d. None of these

6. Write the correct name for these compounds.

a. BeC_2O_4:

b. NH_4MnO_4:

c. CoS_2O_3:

7. What is $W(HSO_4)_5$?

8. How do you write diphosphorus trioxide?

9. What is H_3P?

10. By adding oxygens to the molecule in number 9, we now have H_3PO_4? What is the name of this molecule?

Answer

1.C; Calcium + Carbonate --> Ca^{2+} + CO_3^{2-} --> $CaCO_3$

2.D; FeO --> Fe + O^{2-} --> Iron must have a charge of +2 to make a neutral compound --> Fe^{2+} + O^{2-} --> Iron(II) Oxide

3.A; $Al(NO_3)_3$ --> Al^{3+} + $(NO_3^-)_3$ --> Aluminum nitrate

4.B; Phosphorus trichloride --> P + 3Cl --> PCl_3

5.D, $LiClO_4$; Lithium perchlorate --> Li^+ + ClO_4^- --> $LiClO_4$

6. a. Beryllium Oxalate; BeC_2O_4 --> Be^{2+} + $C_2O_4^{2-}$ --> Beryllium Oxalate

b. Ammonium Permanganate; NH_4MnO_4 --> NH_4^+ + MnO_4^- --> Ammonium Permanganate

c. Cobalt (II) Thiosulfate; CoS_2O_3 --> Co + $S_2O_3^{2-}$ --> Cobalt must have +2 charge to make a neutral compund --> Co^{2+} + $S_2O_3^{2-}$ --> Cobalt(II) Thiosulfate

7. Tungsten (V) hydrogen sulfate

8. P_2O_3

9. Hydrophosphoric Acid

10. Phosphoric Acid

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