# Inorganic Nomenclature

## A. The Chemical Elements

1. The term **"INORGANIC NOMENCLATURE"** refers to the naming of elements and inorganic compounds.

   Recall that **ELEMENTS** are the simplest form of matter that cannot be broken down by chemical processes. The elements in the periodic table can be represented by **one or two letter symbols.** The first letter in the symbol is **ALWAYS in upper case** (capitals) while the second letter, if present, is **ALWAYS** in **lower case.**

   e.g. Pb, C, Na, Cl

   Many elements use the first two letters of the element's name as their symbol.

   e.g. Al, Bi, Li

   When the first two letters have already been used with some other element, the first and third letters are used.

   e.g. Ar = **ar**gon As = **a**r**s**enic At = **a**s**t**atine

   Still other elements which where known in ancient times have symbols taken from their Latin names.

   e.g. iron = **fe**rrum = Fe lead = **p**lum**b**um = Pb

   A few elements have single letters for their symbols.

   e.g. B, C, F, H, I, K, N, O, P, S, U, V, W

2. The elements on the periodic table can be divided into two general groups, **METALS** and **NONMETALS**.

   Metallic elements are located on the **bottom left side of the periodic table** and share the following properties:

   a) high lustre (reflect light when polished)

   b) malleable (can be beaten or rolled into sheets)

   c) ductile (can be stretched into wires)

   d) high melting points

   e) good conductors of heat and electricity

   f) most are solid at room temperature

   Nonmetallic elements are located on the **upper right side of the periodic table** and share the following properties:

   a) dull and lack lustre

   b) brittle

   c) poor conductors of heat and electricity

   d) most are gases at room temperature

   There are also a number of elements that lie on the border between metals and nonmetals. These elements exhibit both metallic and nonmetallic properties and are referred to as **"SEMI–METALS"**, **"METALLOIDS"**, or **"SEMICONDUCTORS".**

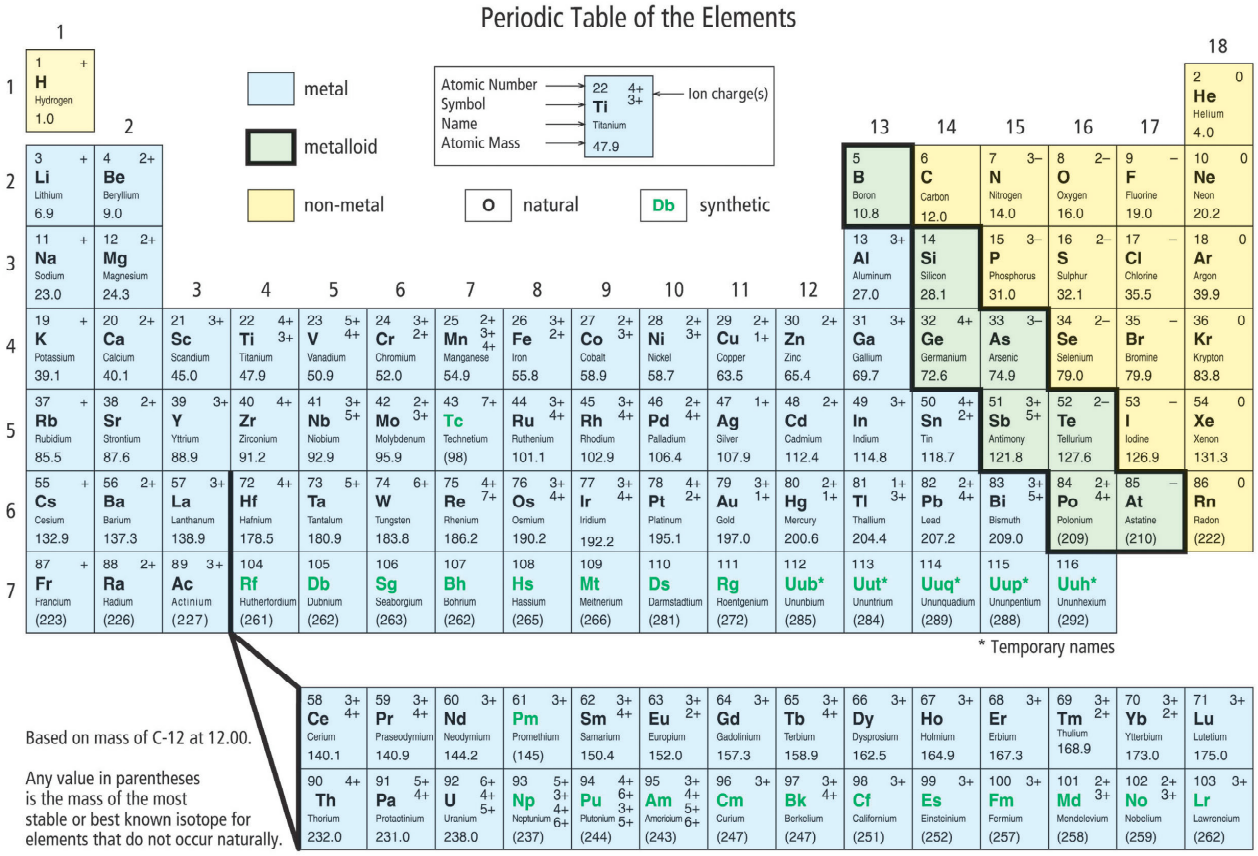
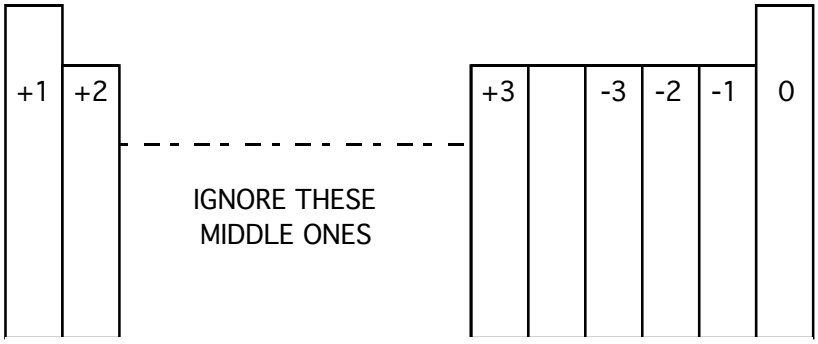



**Figure 2.13** The periodic table of the elements

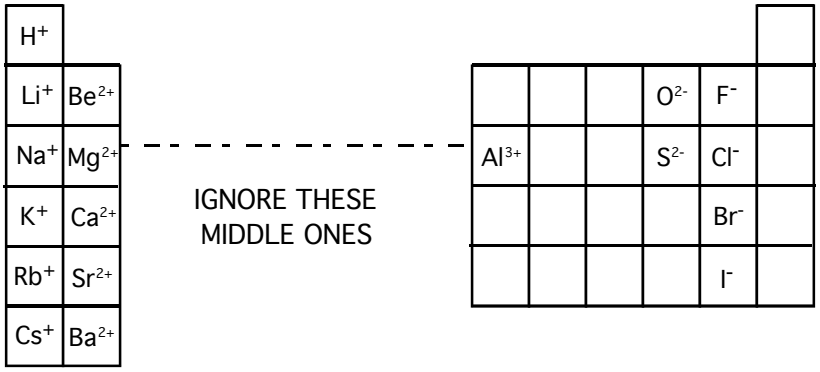
## B. Naming Ions

1. When you go across the columns in the periodic table, there is pattern found between the columns of the table and the charges of the ions (combining capacities) formed by the elements in the columns.




The elements in the middle of periodic table are ignored for now because many of them can form two or more ions with different charges. The charge of these ions are indicated in their name.

The following ions are commonly used and their charges should be memorized.



2. It is important to remember that metal ions form **POSITIVE** ions while nonmetals form **NEGATIVE** ions (Hydrogen is an exception).

   Some important terms that you should know:

   a) **ANIONS** are ions with a negative charge (e.g., $Cl^-$, $NO_3^-$, $O^{2-}$).

   b) **CATIONS** are ions with a positive charge (e.g., $Al^{3+}$, $Ba^{2+}$, $NH_4^+$).

   c) **MONATOMIC** species are made up of only one atom (e.g., Ne, He, $Li^+$, $Cl^-$).

   d) **DIATOMIC** species are made up of two atoms ($O_2$, IBr, NO, $Br_2$, $ClO^-$, $Hg_2^{2+}$).

   e) **POLYATOMIC** species are made up of many atoms, in general this term applies to any species having more than one atom (e.g., $H_3PO_4$, $NO_3^-$, $H_2O$).

3. **NAMING MONATOMIC METAL IONS**

   Use the name of the metal and add the word **"ION"**.

   e.g. sodium metal (Na) forms the sodium ion ($Na^+$)

   aluminum metal (Al) forms the aluminum ion ($Al^{3+}$)

For metals that can form ions having more than one possible charge (middle portion of periodic table), the **STOCK SYSTEM** of naming metal ions is used. For these ions, the **charge is indicated by a Roman numeral**, in parentheses, immediately following the name.

e.g. $Fe^{3+}$ = iron (III) ion $Fe^{2+}$ = iron (II) ion

$Pb^{2+}$ = lead (II) ion $Pb^{4+}$ = lead (IV) ion

## NAMING MONATOMIC NON–METAL IONS

Take off the original ending of the element's name and put on an **"IDE"** ending.

| ELEMENT NAME | ELEMENT SYMBOL | ION NAME | ION SYMBOL |
|---|---|---|---|
| fluor**ine** | F | fluor**ide** | $F^-$ |
| chlor**ine** | Cl | chlor**ide** | $Cl^-$ |
| brom**ine** | Br | brom**ide** | $Br^-$ |
| iod**ine** | I | iod**ide** | $I^-$ |
| ox**ygen** | O | ox**ide** | $O^{2-}$ |
| sulph**ur** | S | sulph**ide** | $S^{2-}$ |
| nitr**ogen** | N | nitr**ide** | $N^{3-}$ |
| phosph**orus** | P | phosph**ide** | $P^{3-}$ |

4. There are several **POLYATOMIC** ions that are commonly used. Most polyatomic ions will have the ending **"ATE"** or **"ITE"**. It is advisable to memorize that names and charges of some of the more common polyatomic ions.

| | | |
|---|---|---|
| carbonate = $CO_3^{2-}$ | chromate = $CrO_4^{2-}$ | phosphate = $PO_4^{3-}$ |
| nitrate = $NO_3^-$ | dichromate = $Cr_2O_7^{2-}$ | hydroxide = $OH^-$ |
| acetate = $CH_3COO^-$ | ammonium = $NH_4^+$ | sulphate = $SO_4^{2-}$ |
| permanganate = $MnO_4^-$ | hydrogen carbonate = $HCO_3^-$ | chlorate = $ClO_3^-$ |

## C. Writing and Naming Ionic Compounds

1. **Chemical formula** = combinations of symbols and numbers used to represent compounds.

$$CaCl_2$$

subscript
# of Chlorine

Calcium Chlorine

Chemical formulas tell us the **composition** of a compound, **the number and types of atoms** that make up the compound.

2. Ionic compounds always have **two kinds of ions** present—one negative and the other positive.

Writing formulas of ionic compounds containing two elements (binary compounds):

- Identify each ion and its charge.
- Balance the positive and negative charges (make them add up to zero).
- Determine the ratio of ions.
- Write the formula using symbols and subscripts (subscript "1" are not shown).

aluminum chloride

$Al^{3+}$ $Cl^{-}$

1 $Al^{3+}$ ion needed for every 3 $Cl^{-}$ ions

$\mathbf{AlCl_3}$

barium nitride

$Ba^{2+}$ $N^{3-}$

3 $Ba^{2+}$ ions needed for every 2 $N^{3-}$ ion

**$Ba_3N_2$**

3. **Multivalent metals** = metals that can form two or more different positive ions with different charges.

$Fe^{2+}$ = iron (II)

$Fe^{3+}$ = iron (III)

When writing the formula of compounds containing multivalent metals, the Roman numerals indicate the charge of the metal.

iron (III) oxide

$Fe^{3+}$ $O^{2-}$

2 $Fe^{3+}$ ions needed for every 3 $O^{2-}$ ions

**$Fe_2O_3$**

4. **Polyatomic ions** = groups of atoms (molecules) that collectively have a positive or negative charge.

sulphate = $SO_4^{2-}$

When writing the formulas for ionic compounds containing polyatomic ions look up the formula and the charge of the polyatomic ion on periodic table.

Remember, the names of many polyatomic ions will end in *"ate"* or *"ite"*.

calcium nitrate

$Ca^{2+}$ $NO_3^-$

1 $Ca^{2+}$ ion needed for every 2 $NO_3^-$ ion

**$Ca(NO_3)_2$**

ammonium phosphate

$NH_4^+$ $PO_4^{3-}$

3 $NH_4^+$ ions needed for every 1 $PO_4^{3-}$ ion

**$(NH_4)_3PO_4$**

| **SAMPLE PROBLEMS IV.1** | **WRITING CHEMICAL FORMULAS** |
|---|---|
| *Problem:* | Write the chemical formulas for the following compounds:<br>(a) potassium oxide<br>(b) calcium phosphide<br>(c) tin (IV) sulphate<br>(d) iron (II) phosphate |
| *Solution:* | (a) $K_2O$<br>(b) $Ca_3P_2$<br>(c) $Sn(SO_4)_2$<br>(d) $Fe_3(PO_4)_2$ |

5. Naming ionic compounds made up of two elements only (binary compounds):
   - The first part of the name is always the positive ion and is a metal atom.
   - The second part of the name is always the negative ion and is a non–metal atom.
   - The ending of the non–metal atom's name is changed to *"–ide"*

$CaCl_2$ = calcium chlor*ide*

NaO = sodium ox*ide*

$Ba_3P_2$ = barium phosph*ide*

aluminum + fluorine → aluminum fluor*ide*

6. Naming ionic compounds containing multivalent metals:
   - Identify the metal.
   - Find the possible charges for the metal.
   - Determine the ratio of ions in the formula.
   - Find the charge of the negative ion.
   - Using the ratio of ions determine what charge the metal must have to balance the negative ion.
   - Write the name of the compound using Roman numerals to indicate the charge of the metal.

$MnO_2$

Manganese (Mn)

$Mn^{2+}$ $Mn^{3+}$ $Mn^{4+}$

$MnO_2$ means 1 Mn needed for every 2 O

Mn = 2 $O^{2-}$

**manganese (IV) oxide**

7. When naming ionic compounds, no matter how complicated they appear, there are only two kinds of ions.

Divide the formula into two parts. The first part is always a metal or the ion $NH_4^+$. The second part is either a non–metal or a polyatomic ion.

$$(NH_4)_2CO_3$$

$$NH_4^+ \quad CO_3^{2-}$$

**ammonium carbonate**

| **SAMPLE PROBLEMS IV.2** | **NAMING CHEMICAL COMPOUNDS** |
|---|---|
| *Problem:* | Name the following compounds:<br>(a) $CaF_2$<br>(b) $Cu_2O$<br>(c) $Ag_2SO_4$<br>(d) $Pb(SO_4)_2$ |
| *Solution:* | (a) $CaF_2 \rightarrow$ calcium fluoride<br>(b) $Cu_2O \rightarrow (Cu^{1+})_2\ (O^{2-})_1 \rightarrow$ copper (I) oxide<br>(c) $Ag_2SO_4 \rightarrow$ silver sulphate<br>(d) $Pb(SO_4)_2 \rightarrow (Pb^{2+})_1\ (SO_4^{1-})_2 \rightarrow$<br>$(Pb^{4+})_1\ (SO_4^{2-})_2 \rightarrow$ lead (IV) sulphate |

You must memorize the "common name" for two compounds:

**$H_2O$ = water and $NH_3$ = ammonia**

## D. Writing and Naming Covalent Compounds

1. Recall that a binary compound is a compound made up of two different kinds of atoms. There are some binary compounds in which both atoms are non–metals instead of one metal and one non–metal (ionic). These **binary compounds of two non–metals** are called **COVALENT** compounds.

   The **PREFIX–NAMING SYSTEM** is used for binary compounds of two non–metals (covalent compounds).

   The rules for the Prefix–Naming system are as follows:

   i. Each compound name is made of two words, each with a suitable prefix.

   The prefixes are shown in the following table.

| Prefix | # of atoms | Prefix | # of atoms |
|---|---|---|---|
| mono | 1 | tetra | 4 |
| di | 2 | penta | 5 |
| tri | 3 | hexa | 6 |

   ii. The first word is the name of the first element, with a prefix to indicate how many of these atoms exist in each molecule.

   iii. The second word is the name of the second element, with an **"IDE"** ending on the element's name and a prefix to indicate how many of these atoms exist in each molecule.

$P_2S_3$ → **di**phosphorus **tri**sulph***ide***

$N_2O_4$ → **di**nitrogen **tetr**ox***ide*** (tetraoxide is clumsy)

iv. If there is only one of the first atom, the prefix mono is omitted.

$CO_2$ → carbon **di**oxide (not monocarbon dioxide)

| SAMPLE PROBLEMS IV.3 | PREFIX–NAMING SYSTEM |
|---|---|
| *Problem:* | Name the following compounds:<br>(a) CO<br>(b) $P_2O_5$<br>(c) $SiF_6$ |
| *Solution:* | (a) carbon monoxide<br>(b) diphosphorus pentoxide<br>(c) silicon hexafluoride |

| SAMPLE PROBLEMS IV.4 | PREFIX–NAMING SYSTEM |
|---|---|
| *Problem:* | Write the formulas for the following compounds:<br>(a) phosphorus trichloride<br>(b) tetrasulphide dinitride<br>(c) disilicon hexaiodide |
| *Solution:* | (a) $PCl_3$<br>(b) $S_4N_3$<br>(c) $Si_2I_6$ |

## E. Other Types of Inorganic Nomenclature

### 1. NAMING HYDRATES

When a crystal of an ionic compound is grown by evaporation from aqueous solution, frequently it is found that the crystal structure will include water molecules.

e.g. When copper (II) sulphate is crystallized from water, the resulting crystals are found to have the formula

$$CuSO_4 \bullet 5H_2O$$

This formula shows that 5 water molecules are included with (or attached to) every $CuSO_4$. In other words, $CuSO_4 \bullet 5H_2O$ can be thought of as "$CuSO_4 + 5H_2O$".

Molecules that include water molecules in their crystal structure are called **"HYDRATES".** The naming of hydrates involves using a prefix to indicate the number of water molecules attached.

| Prefix | # of water molecules | Prefix | # of water molecules |
|---|---|---|---|
| mono | 1 | hexa | 6 |
| di | 2 | hepta | 7 |
| tri | 3 | octa | 8 |
| tetra | 4 | nona | 9 |
| penta | 5 | deca | 10 |

| SAMPLE PROBLEMS IV.5 | NAMING HYDRATES |
|---|---|
| *Problem:* | Name the following hydrates:<br>(a) $CoCl_2 \cdot 4H_2O$<br>(b) $Al_2O_3 \cdot 3H_2O$<br>(c) $CuSO_4 \cdot 5H_2O$ |
| *Solution:* | (a) cobalt (II) chloride tetrahydrate<br>(b) aluminum oxide trihydrate<br>(c) copper (II) sulphate pentahydrate |

## 2. SOME COMMON ACIDS

A compound is called an **"ACID"** if the compound has a chemical formula starting with **"H"**. All of the following acids are assumed to be dissolved in water; that is, they are "aqueous solutions".

| | | |
|---|---|---|
| HF = hydrofluoric acid | $H_2SO_4$ = sulphuric acid | $HNO_3$ = nitric acid |
| HCl = hydrochloric acid | $H_2SO_3$ = sulphurous acid | $HNO_2$ = nitrous acid |
| HBr = hydrobromic acid | $H_3PO_4$ = phosphoric acid | HI = hydroiodic acid |

$HC_2H_3O_2$ or $CH_3COOH$ = acetic acid

Some additional facts about acids:

HF is used to “etch” or “frost” glass

HCl is present in “stomach acid” and is also called “muriatic acid”

$HNO_3$ is a very corrosive acid which reacts with most metals

$H_2SO_4$ is the acid used in automobile batteries

$H_2SO_3$ is one of the principle components of acid rain

$H_3PO_4$ is present in most Cola beverages

A 5% solution of $CH_3COOH$ is called “vinegar”