Introduction to Chemical Nomenclature

1. Atomic Symbols

The symbols of atoms and ions have the format shown below. X is the element's symbol, A is the mass number, Z the atomic number, c is the charge and n is the number of atoms.

$$^{A}_{Z}X^{c}_{n}$$

Unless one wants to specify a particular isotope, or when the element has all of its isotopes present in their natural abundance, A is omitted. For example, the symbol Fe is used for iron, unless we are interested in a specific isotope. The isotope iron-57 could be written as ^{57}Fe or $^{57}_{26}Fe$.

Z is often omitted, because it is automatically defined by the element's symbol.

The charge is written with the value of the charge first, followed by the sign of the charge (+ or -). The charge is omitted if it is 0 (the element is unionized), and the charges +1 and -1 are shortened to + and -, respectively.

Examples:

The symbol $^{200}_{80}Hg_2^{2+}$ represents a polyatomic ion of mercury with a +2 charge that contains two mercury atoms, each with a mass number of 200.

The ion $[^{200}_{80}Hg^{202}_{80}Hg]^{2+}$ has one mercury atom with a mass number of 200, and one mercury atom with a mass number of 202 (this case is rarely seen).

The compound whose chemical formula is $^{57}FeCl_3$ indicates that in this compound the iron is enriched in the iron-57 isotope.

2. Chemical Formulas

For compounds that exist as molecules, the chemical formula is used to emphasize the molecular nature of the compound. Nitrogen, for example, exists as a diatomic gas in its elemental state so we write N_2, and not N, as its chemical formula.

If an element exists in several allotropes, or phases, and this information is not relevant to the chemical reaction or whatever property is under discussion, then you can represent the element by only its elemental symbol. For example, at room temperature and atmospheric pressure sulfur exists as groupings of eight sulfur atoms, S_8, but it is often written as S in chemical reactions.

In a chemical formula, the most electropositive element is placed first. The order is: Group 1, Group 2, the transition metals, the p-block metals, and finally the non-metals. If two metals of the same group are involved, their symbols are placed in alphabetical order.

For binary compounds of non-metals the element symbols are placed in the order: Rn, Xe, Kr, B, Si, C, Sb, As, P, N, H, Te, Se, S, At, I, Br, Cl, O, F. Examples: a compound containing one xenon atom and four fluorine atoms would be written XeF_4, and the chemical formula for ammonia (containing one nitrogen and three hydrogens) is NH_3.

Acids are treated as hydrogen compounds. The acidic hydrogen(s) is(are) placed first. So, nitric acid is HNO_3, and sulfuric acid is H_2SO_4. Some acids (e. g., acetic acid) may contain hydrogen atoms that are not acidic, but the convention of always writing the acidic hydrogens first allows us to distinguish the different types. Acetic acid's chemical formula would thus be written $HC_2H_3O_2$ and not $C_2H_4O_2$.

Polyatomic ions are written as single units. Parentheses are used as needed to show the presence of any polyatomic ions. So, ammonium chloride is written NH_4Cl, but ammonium sulfate is $(NH_4)_2SO_4$ to clearly show the presence of the ammonium ion.

Exceptions to the above rules may be made to 1) show similarities between compounds, or 2) to show the order in which the atoms are attached to each other. Examples of the latter are the cyanate (OCN^-), the fulminate (ONC^-) and the isocyanate (NCO^-) ions.

In the case where two or more different atoms, or groups of atoms, are attached to a central atom, the central atom is placed first in the formula and is followed by the remaining atoms or groups in alphabetical order.

Hydrates (and solvates in general) are always written using a dot to separate the waters of hydration from the anhydrous formula, as in the chemical formula for alum: $KAl(SO_4)_2 \cdot 12H_2O$.

3. Systematic Names of Simple Inorganic Compounds

To name inorganic (compounds which do not generally contain C), one needs to know the root name of an element. The root can usually be found by dropping the *-ine* or *-ium* endings from the element's name. There are many elements that do not have these endings, and which have special roots. These special roots are tabulated at the end of this handout.

a. Cations

If a metal forms only one cation (has only one oxidation state), then the cation's name is the same as the element's. This is the case for the metals of group 1 and 2, as well as Al, Ga, Zn, and Cd. Some metals form more than one cation, but because one is rare, they are commonly named as if they only formed one cation (examples: Pb, Ag).

For metals that form more than one ion (such as the transition metals) the Stock nomenclature method is used to specify which ion is present. In this system the name of the cation is the name of the metal with the cation's charge in roman numerals following it. For example, the +2 ion formed by iron is the iron(II) ion.

The Stock system can be used any time one wants to specify which ion (or oxidation state) is present. However, it is seldom used with groups 1 and 2, Al, Ga, Zn and Cd.

Take care with the ions of mercury. The mercury(I) ion actually exists as Hg_2^{2+} and the mercury(II) ion is Hg^{2+}.

The ammonium ion is NH_4^+.

An older nomenclature (<u>not</u> officially recognized by the IUPAC) is used with metals that form two ions. The ending *-ic* is added to the element's root to name the ion that has the higher charge (oxidation state) and the ending *-ous* is used to denote the ion with the lower charge. For example, iron forms the ions Fe^{3+} and Fe^{2+}. Iron's root name is *ferr-*, so Fe^{3+} is the ferric ion and Fe^{2+} is the ferrous ion.

b. Anions

Monatomic anions are named using the element's root and adding *-ide* to the end. Examples: F^- fluoride, O^{2-} oxide.

Polyatomic anions generally consist of the central atom's stem ending in *-ate* (e. g., PF_6^- hexafluorophosphate). See additional rules under Inorganic Acids, below.

Some polyatomic anions end in *-ide* (see list at the end).

c. Inorganic Acids

Binary acids in aqueous solution are named *hydro*___________*ic acid*, where the blank is the element name's root. So an aqueous solution of HCl, written HCl (aq), is hydrochloric acid. Note that gaseous HCl, written as HCl (g), is a molecular compound and is called hydrogen chloride (see below).

The oxo acids (general formula H_nXO_m, where X is any element) use the root name of the anion and add the suffix *-ic*. Examples: HNO_3, nitric acid; H_2SO_4, sulfuric acid; H_3PO_4, phosphoric acid and $HClO_3$, chloric acid. Oxo acids containing one less oxygen atom end in *-ous* (e. g., $HClO_2$ is chlorous acid). For oxo acids with two less oxygens *-ous* is appended and *hypo-* is added as a prefix (e. g., HClO is hypochlorous acid). For oxo acids with one more oxygen the prefix is *per-* and the suffix is *-ic* (e. g., $HClO_4$ is perchloric acid).

Anions derived from the oxo acids end in *-ate*, if the anion came from an acid's name ended in *-ic*, or *-ite*, if the acid ended in *-ous*. Example: ClO_4^- is derived from $HClO_4$, perchloric acid, so it is the perchlorate ion.

Other common oxo-anions are: CO_3^{2-}, carbonate; MnO_4^-, permanganate; CrO_4^{2-}, chromate; $Cr_2O_7^{2-}$, dichromate and $C_2H_3O_2^-$, acetate.

d. Binary Covalent Compounds

The first element listed in the formula is given its full element name, and the second element is named like an anion (ends in *-ide*).

Prefixes are used to indicate the number of atoms of each element as needed, see below. The prefix *mono-* is only used when needed for clarity (for example in carbon monoxide to distinguish it from carbon dioxide). If the letter after the second "o" is a vowel (usually "o"), then the prefix *mono-* becomes *mon-*, as in carbon monoxide (not carbon monooxide).

Numerical Prefixes used in Naming Chemical Compounds

Prefix	Number	Prefix	Number
mono-	1	hepta-	7
di-	2	octa-	8
tri-	3	nona-	9
tetra-	4	deca-	10
penta-	5	undeca-	11
hexa-	6	dodeca-	12

The two common exceptions to these rules are water (H_2O) and ammonia (NH_3).

Examples: SCl_4 is sulfur tetrachloride, N_2O is dinitrogen monoxide and S_2Cl_2 is disulfur dichloride.

e. Ionic Compounds (Salts)

Simple salts are named with the cation(s) first and then the anion(s) (as written in the chemical formula). Usually prefixes are not used to indicate the number of ions because the ions' charges determine the number of each cation and anion.

Examples: $FeCl_3$ is iron(III) chloride, $ZnSO_4$ is zinc sulfate, Hg_2Cl_2 is mercury(I) chloride, and $Al(NO_3)_3$ is aluminum nitrate.

An alternate, albeit disfavored, method of naming binary ionic compounds is used that is similar to that of binary covalent compounds. For example, the systematic name of MnO_2 is manganese(IV) oxide, but it is also commonly referred to as manganese dioxide. This method is generally used for binary oxides and sulfides, but it should be avoided.

Acid salts of the general formula $M_nH_pXO_m$ are named by adding hydrogen to the name before the name of the anion (XO_m). If the hydrogen is known to be bound to the oxo anion there is no space between "hydrogen" and the anion's name. For example, $NaHCO_3$ is sodium hydrogencarbonate. The list at the end of this document has more examples of this type of ion.

f. Hydrates

Hydrates are named as per the rules given above; adding the word "hydrate" with a prefix (see above) to indicate the number of water molecules. For example, $MgSO_4{\cdot}7H_2O$ is magnesium sulfate heptahydrate.

If there are a fractional number of water molecules in the formula, the additional prefix *hemi-* is added to the appropriate prefix to indicate the number of water molecules. The compound $MgSO_4{\cdot}3.5H_2O$ would be named magnesium sulfate hemiheptahydrate.

Common Polyatomic Ions

Formula	*Name*	*Formula*	*Name*
NH_4^+	ammonium	PO_4^{3-}	phosphate
CN^-	cyanide	HPO_4^{2-}	hydrogenphosphate
OCN^-	cyanate	$H_2PO_4^-$	dihydrogenphosphate
SCN^-	thiocyanate	AsO_4^{3-}	arsenate
$C_2H_3O_2^-$	acetate	SH^-	hydrogensulfide
$C_2O_4^{2-}$	oxalate	SO_3^{2-}	sulfite
CO_3^{2-}	carbonate	HSO_3^-	hydrogensulfite (bisulfite)
HCO_3^-	hydrogencarbonate (bicarbonate)	SO_4^{2-}	sulfate
N_3^-	azide*	HSO_4^-	hydrogensulfate
NO_2^-	nitrite	ClO^-	hypochlorite
NO_3^-	nitrate	ClO_2^-	chlorite
OH^-	hydroxide	ClO_3^-	chlorate
O_2^{2-}	peroxide*	ClO_4^-	perchlorate
HO_2^-	hydroperoxide*	IO_3^-	iodate
O_2^-	superoxide*	IO_4^-	periodate
PF_6^-	hexafluorophosphate	BrO_3^-	bromate
BF_4^-	tetrafluoroborate	CrO_4^{2-}	chromate*
$Fe(CN)_6^{3-}$	ferricyanide*	$Cr_2O_7^{2-}$	dichromate*
$Fe(CN)_6^{2-}$	ferrocyanide*	MnO_4^-	permangate*

Names given in parentheses are common trivial names for these ions. Entries marked with a '*' indicate trivial names for these ions (no systematic name given).

Non-Standard Root Names of the Elements

Element	*Root*	*Element*	*Root*	*Element*	*Root*
H	hydr-	P	phosph-	As	arsen-
B	bor-	S	sulf-	Sn	stann-
C	carb-	Mn	mangan-	Sb	stib-
N	nitr-	Fe	ferr-	Au	aur-
O	ox-	Co	cobalt-	Hg	mercur-
Si	silic-	Cu	cupr-	Pb	plumb-