Nomenclature

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Long before chemists knew the formulas for chemical compounds, they developed a system of **nomenclature** that gave each compound a unique name. Today we often use chemical formulas, such as NaCl, $C_{12}H_{22}O_{11}$, and $Co(NH_3)_6(ClO_4)_3$, to describe chemical compounds. But we still need unique names that unambiguously identify each compound.

Common Names

Some compounds have been known for so long that a systematic nomenclature cannot compete with well-established common names. Examples of compounds for which common names are used include water (H_2O), ammonia (NH_3), and methane (CH_4).

Naming Ionic Compounds

(Metals with Non-metals)

The names of ionic compounds are written by listing the name of the positive ion followed by the name of the negative ion.

NaCl	sodium chloride
$(NH_4)_2SO_4$	ammonium sulfate
$NaHCO_3$	Sodium bicarbonate

We therefore need a series of rules that allow us to unambiguously name positive and negative ions before we can name the salts these ions form.

Naming Positive Ions

Monatomic positive ions have the name of the element from which they are formed.

Na^{+}	sodium	Zn^{2+}	zinc
Ca^{2+}	calcium	H^{+}	hydrogen
K^{+}	potassium	Sr^{2+}	strontium

Some metals form positive ions in more than one oxidation state. One of the earliest methods of distinguishing between these ions used the suffixes *-ous* and *-ic* added to the Latin name of the element to represent the lower and higher oxidation states, respectively.

Fe^{2+}	ferrous	Fe^{3+}	ferric
Sn^{2+}	stannous	Sn^{4+}	stannic
Cu^{+}	cuprous	Cu^{2+}	cupric

Chemists now use a simpler method, in which the charge on the ion is indicated by a Roman numeral in parentheses immediately after the name of the element.

Fe^{2+}	iron(II)	Fe^{3+}	iron (III)
Sn^{2+}	tin(II)	Sn^{4+}	tin(IV)
Cu^{+}	copper(I)	Cu^{2+}	copper(II)

Polyatomic positive ions often have common names ending with the suffix *-onium*.

H_3O^{+}	hydronium
NH_4^{+}	ammonium

Naming Negative Ions

Negative ions that consist of a single atom are named by adding the suffix *-ide* to the stem of the name of the element.

F^{-}	fluoride	O^{2-}	oxide
Cl^{-}	chloride	S^{2-}	sulfide
Br^{-}	bromide	N^{3-}	nitride
I^{-}	iodide	P^{3-}	phosphide
H^{-}	hydride	C^{4-}	carbide

Practice Problem 4

Predict the formula of the compound that forms when magnesium metal reacts with nitrogen to form magnesium nitride.

Mg_2N_3

Common Polyatomic Negative Ions

		–1 ions	
HCO_3^-	bicarbonate	HSO_4^-	hydrogen sulfate (bisulfate)
$CH_3CO_2^-$	acetate	ClO_4^-	perchlorate
NO_3^-	nitrate	ClO_3^-	chlorate
NO_2^-	nitrite	ClO_2^-	chlorite
MnO_4^-	permanganate	ClO^-	hypochlorite
CN^-	cyanide	OH^-	hydroxide
		–2 ions	
CO_3^{2-}	carbonate	O_2^{2-}	peroxide
SO_4^{2-}	sulfate	CrO_4^{2-}	chromate
SO_3^{2-}	sulfite	$Cr_2O_7^{2-}$	dichromate
$S_2O_3^{2-}$	thiosulfate	HPO_4^{2-}	hydrogen phosphate
		–3 ions	
PO_4^{3-}	phosphate	AsO_4^{3-}	arsenate
BO_3^{3-}	borate		

Naming Polyatomic Ions

At first glance, the nomenclature of the polyatomic negative ions in the table above seems hopeless. There are several general rules, however, that can bring some order out of this apparent chaos.

The name of the ion usually ends in either *-ite* or *-ate*. The *-ite* ending indicates a low oxidation state. Thus, the NO_2^- ion is the nitrite ion.

The *-ate* ending indicates a high oxidation state. The NO_3^- ion, for example, is the nitrate ion.

The prefix *hypo*- is used to indicate the very lowest oxidation state. The ClO^- ion, for example, is the hypochlorite ion.

The prefix *per*- (as in hyper-) is used to indicate the very highest oxidation state. The ClO_4^- ion is therefore the perchlorate ion.

There are only a handful of exceptions to these generalizations. The names of the hydroxide (OH^-), cyanide (CN^-), and peroxide (O_2^{2-}) ions, for example, have the *-ide* ending because they were once thought to be monatomic ions.

Practice Problem 5

The bone and tooth enamel in your body contain ionic compounds such as calcium phosphate and hydroxyapatite. Predict the formula of calcium phosphate, which contains Ca^{2+} and $PO4^{3-}$ ions. Calculate the value of *x*, if the formula of hydroxyapatite is $Ca_x(PO_4)_3(OH)$.

$Ca_3(PO_4)_2$; x = 5

BrO_4^{1-} **Perbromate ion**	BrO_3^{1-} **Bromate ion**	BrO_2^{1-} **Bromite ion**	BrO^{1-} **Hypobromite ion**
CO_4^{2-}	CO_3^{2-} **Carbonate ion**	CO_2^{2-}	CO^{2-}
ClO_4^{1-}	ClO_3^{1-} **Chlorate ion**	ClO_2^{1-}	ClO^{1-}
IO_4^{1-}	IO_3^{1-} **Iodate ion**	IO_2^{1-}	IO^{1-}
NO_4^{1-}	NO_3^{1-} **Nitrate ion**	NO_2^{1-}	NO^{1-}
PO_5^{3-}	PO_4^{3-} **Phosphate ion**	PO_3^{3-}	PO_2^{3-}
SO_5^{2-}	SO_4^{2-} **Sulfate ion**	SO_3^{2-}	SO_2^{2-}
1 more oxygen	***"normal"***	***1 less oxygen***	***2 less oxygen***

Naming Simple Covalent Compounds

(Non-metals with non-metals)

Oxidation states also play an important role in naming simple covalent compounds. The name of the atom in the positive oxidation state is listed first. The suffix *-ide* is then added to the stem of the name of the atom in the negative oxidation state.

HCl	hydrogen chloride
NO	nitrogen oxide
BrCl	bromine chloride

As a rule, chemists write formulas in which the element in the positive oxidation state is written first, followed by the element(s) with negative oxidation numbers.

The number of atoms of an element in simple covalent compounds is indicated by adding one of the following Greek prefixes to the name of the element.

1 mono-	6 hexa-
2 di-	7 hepta-
3 tri-	8 octa-
4 tetra-	9 nona-
5 penta-	10 deca-

The prefix *mono-* is seldom used because it is redundant. The principal exception to this rule is carbon monoxide (CO).

Naming Acids

Simple covalent compounds that contain hydrogen, such as HCl, HBr, and HCN, often dissolve in water to produce acids. These solutions are named by adding the prefix *hydro-* to the name of the compound and then replacing the suffix *-ide* with *-ic*. For example, hydrogen chloride (HCl) dissolves in water to form hydrochloric acid; hydrogen bromide (HBr) forms hydrobromic acid; and hydrogen cyanide (HCN) forms hydrocyanic acid.

Many of the oxygen-rich polyatomic negative ions in Table 2.1 form acids that are named by replacing the suffix *-ate* with *-ic* and the suffix *-ite* with *-ous*.

Acids containing ions ending with ***ide*** often become			***hydro -ic acid***
Cl^-	chloride	HCl	hydrochloric acid
F^-	fluoride	HF	hydrofluoric acid
S^{2-}	sulfide	H_2S	hydrosulfuric acid

Acids containing ions ending with ***ate*** usually become			***-ic acid***
CH_3CO^{2-}	acetate	CH_3CO_2H	acetic acid
CO_3^{2-}	carbonate	H_2CO_3	carbonic acid
BO_3^{3-}	borate	H_3BO_3	boric acid
NO_3^-	nitrate	HNO_3	nitric acid
SO_4^{2-}	sulfate	H_2SO_4	sulfuric acid
ClO_4^-	perchlorate	$HClO_4$	perchloric acid
PO_4^{3-}	phosphate	H_3PO_4	phosphoric acid
MnO_4^-	permanganate	$HMnO_4$	permanganic acid
CrO_4^{2-}	chromate	H_2CrO_4	chromic acid
ClO_3^-	chlorate	$HClO_3$	chloric acid

Acids containing ions ending with ***ite*** usually become			***-ous acid***
ClO_2^-	chlorite	$HClO_2$	chlorous acid
NO_2^-	nitrite	HNO_2	nitrous acid
SO_3^{2-}	sulfite	H_2SO_3	sulfurous acid
ClO^-	hypochlorite	HClO	hypochlorous acid

Complex acids can be named by indicating the presence of an acidic hydrogen as follows.

$NaHCO_3$	sodium hydrogen carbonate (also known as sodium bicarbonate)
$NaHSO_3$	sodium hydrogen sulfite (also known as sodium bisulfite)
KH_2PO_4	potassium dihydrogen phosphate