Writing and Naming Inorganic Compounds

Naming

IUPAC is an agency that sets standards for naming chemicals. Many compounds also have common names. Practice writing formulas from names and names from formulas using the examples below.

Inorganic compounds

Compounds that do not contain carbon, EXCEPT
CO_2 and CO_3^{2-} are considered inorganic
CO_2 is carbon dioxide
CO_3^{2-} is carbonate ion

Ionic Compounds – Definitions and examples

Contain at least one metal and at least one nonmetal.
When the metal and nonmetal atoms react, they form ions by exchanging electrons.
Metal atoms become positively charged cations. Nonmetals atoms become negatively charged anions.
The metal appears first when writing the formula or the name.
One exception is that compounds containing the ammonium ion (NH_4^+) are considered ionic.
Ionic compounds are salts made up of **formula units** (not molecules)

Ions

An ion is an atom or group of atoms with a charge
a monatomic ion is a single atom that has a charge
A polyatomic ion is a group of atoms with a charge
Cation – ion with a positive charge.
Examples: K^+ (potassium ion), NH_4^+ (ammonium ion)
Anion – ion with a negative charge.
Examples: F^- (fluoride ion), SO_4^{2-} (sulfate ion)

Naming Cations

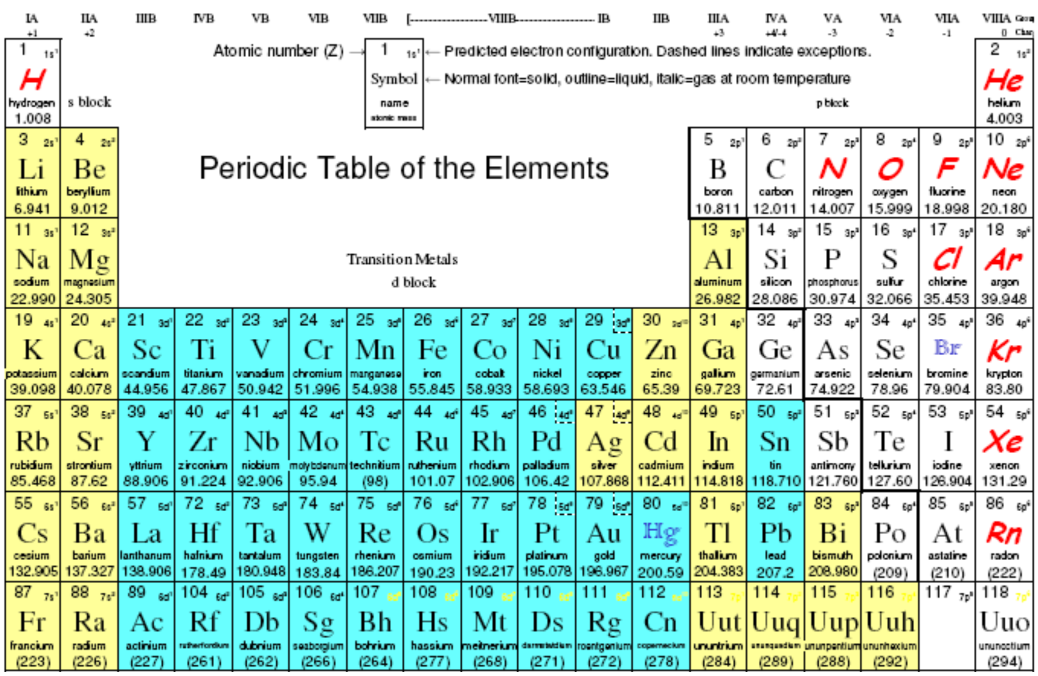
For monatomic (one atom) cations that form ions with only one charge, use the name of the metal followed by the word 'ion.'

Cations named using this system include the main group metals (except cations of Sn and Pb) as well as the transition metal ions Ag^+, Zn^{2+}, and Cd^{2+}.
All the metals named with this system are highlighted yellow in the periodic table below.
Examples:
K^+ is potassium ion
Ca^{2+} is calcium ion
Al^{3+} is aluminum ion
Ag^+ is silver ion
Zn^{2+} is zinc ion
Cd^{2+} is cadmium ion

As discussed previously, \
Group IA metals form +1 ions
Group IIA metals form +2 ions
Group IIIA metals form +3 ions

For monatomic (one atom) cations that form ions with more than one charge, use the Stock system of naming a Roman numeral gives the charge.

Use the name of the metal, a Roman numeral in parentheses, and the word 'ion'
Cations named using this system include the transition metal ions (except Ag^+, Zn^{2+}, and Cd^{2+}), as well as the main group metal ions of Sn and Pb.
All the metals named with the Stock system are highlighted blue in the periodic table below.
Transition metals form multiple ions, except for Ag, Zn, and Cd
Fe^{2+} is called the iron(II) ion
Fe^{3+} is called the iron(III) ion
Ti^{4+} is called the titanium(IV) ion
Cr^{6+} is called the chromium(VI) ion
Mn^{7+} is called the manganese(VII) ion
(Note: a few other metals form multiple ions, but not for this course)
Most transition metals form a +2 ion as well as others
The 2s valence electrons are lost when forming a +2 ion



Polyatomic (more than one atom) cations

There is only one polyatomic cation used in this course, NH_4^+ (ammonium ion). The ammonium ion forms compounds that are ionic in behavior (and naming).

Naming Anions

Monatomic (one atom) anions (nonmetals usually form anions)

Drop the ending of the name of the element and add the suffix '-ide'
The red indicates the portion that is dropped
Cl- is called chloride (chlorine)
O^{2-} is called oxide (oxygen)
N^{3-} is called nitride (nitrogen)
Se^{2-} is called selenide (selenium)
Group VIIA nonmetals form -1 ions
Group VIA nonmetals form -2 ions
Group VA nonmetals form -3 ions

Polyatomic (more than one atom) anions

A list of polyatomic ions with formulas, names, and charges can be found in handout from Week 1.
Many polyatomic anions contain oxygen – called oxyanions
Oxyanions have names that end in '-ate' or '-ite'
Examples of '-ate' oxyanions
The oxyanion NO_3^- is nitrate
The oxyanion SO_4^{2-} is sulfate
The oxyanion PO_4^{3-} is phosphate
The oxyanion ClO_3^- is chlorate
Examples of '-ite' oxyanions
Take away 1 oxygen and keep the same charge
The oxyanion NO_2^- is nitrite
The oxyanion SO_3^{2-} is sulfite
The oxyanion PO_3^{3-} is phosphite
The oxyanion ClO_2^- is chorite
Two polyatomic anions sound like elements
These have an '-ide' ending but they are not elements
The polyatomic anion CN^- is cyanide
The polyatomic anion OH^- is hydroxide

Naming and writing ionic compounds when the anion forms form an element

When writing the formula, write the chemical symbol of the metal first, then the chemical symbol of the nonmetal. Subscripts may be needed after the chemical symbols to balance the positive charge with the negative charge. The expected charge comes from the group number from the periodic table.

When writing the name, write the name of the metal first, then write the stem of the nonmetal and add an -ide ending.

Examples appear below.
KCl is potassium chloride

The cation is potassium ion, K^+
The anion is chloride, Cl^- (the anion formed from element chlorine)
One potassium ion (+1) is needed for every chloride ion (-1). Subscript values of 1 are not written in the formula.

$CaCl_2$ is calcium chloride
The cation is calcium ion, Ca^{2+}
The anion is chloride, Cl^-
Two chloride ions (-1) are needed for every calcium ion (+2)

The ammonium ion (NH_4^+), though it is not a metal, forms ionic compounds that are written and named just like those above.
$(NH_4)_2S$ is ammonium sulfide. Use parentheses to multiply a group of atoms by a subscript. Two ammonium ions (+1) are needed for each sulfide ion (-2).
NH_4Br is ammonium bromide. No parentheses are needed because subscripts of 1 are not written.

Naming and writing ionic compounds when the anion is a polyatomic ion

When writing the formula, write the chemical symbol of the metal first, then the chemical symbols for the polyatomic ion. Subscripts may be needed to balance the positive charge with the negative charge. The expected charge for the metal comes from the group number from the periodic table. The symbols and charges for common polyatomic ions come from the handout.

When writing the name, write the name of the metal first, then write the name of the polyatomic ion. Most polyatomic ions end in -ate or -ite. The two exceptions are those with an -ide ending: hydroxide and cyanide.

Example appear below.
Na_2SO_4 is sodium sulfate.
The cation is sodium ion, Na^+
The anion is is the polyatomic ion sulfate, SO_4^{2-}
Two sodium ions (+1) are needed for each sulfate ion (-2)
No parentheses are needed because the two subscript multiplies a single-atom ion (Na^+). Use parentheses to multiply a group (more than one) of atoms.

$(NH_4)_3PO_4$ is ammonium phosphate.
The cation is ammonium ion, NH_4^+
The anion is the polyatomic ion phosphate PO_4^{3-}
Three ammonium ions (+1) are needed for each phosphate ion (+3), so parentheses are needed to indicate three ammonium ions.

$Ca(C_2H_3O_2)_2$ is calcium acetate.
The cation is calcium ion, Ca^{2+}
The anion is the polyatomic ion acetate $C_2H_3O_2^-$

Two acetate ions (-1) are needed for each calcium ion (+2), so parentheses are needed to indicate two ammonium ions.

KCN is potassium cyanide.
The cation is potassium ion, K^+
The anion is the polyatomic ion cyanide CN^-. The -ide ending may make cyanide sound like an element, but it is not. Cyanide is a polyatomic ion.

More Examples of Writing and Naming Ionic Compounds

A *formula unit* is the simplest representation of an ionic compound
Total charge on the compound must be zero = cations + anions
Name the cation (usually metal or ammonium ion) first and then the anion
Charges must be balanced
$Na^+ + Cl^-$ forms NaCl – sodium chloride, where +1 + -1 = 0
$Ca^{2+} + Cl^-$ forms $CaCl_2$ – calcium chloride, where +2 + 2(-1) = 0
$Ca^{2+} + S^{2-}$ forms CaS – calcium sulfide, where +2 + -2 = 0
$Li^+ + S^{2-}$ forms Li_2S – lithium sulfide, where 2(+1) +-2 = 0
Notice the crossover rule:
1) Charge on the metal becomes the subscript on the nonmetal
2) Positive part of charge on the nonmetal becomes the subscript on the metal
3) Remember to reduce the result
Use parenthesis to indicate more than one polyatomic ion
$Al^{3+} + SO_4^{2-}$ forms $Al_2(SO_4)_3$ – aluminum sulfate
$NH_4^+ + PO_4^{3-}$ forms $(NH_4)_3PO_4$ – ammonium phosphate
$Ca^{2+} + O^{2-}$ forms CaO – calcium oxide (remember to reduce or use 1:1)
$Ti^{4+} + O^{2-}$ forms TiO_2 – titanium(IV) oxide (remember to reduce! or use 1:2)

Calculating charges for metals that form more than one ion

The total charge of the ions in an ionic compound must sum to zero
Calculate the charge on iron in Fe_2S_3
S is -2 because it is a nonmetal in Group VIA
The total charge on 3 S atoms is 3(-2) = -6
The total positive charge must be +6
The +6 charge goes to 2 iron atoms
Charge on each iron atom must be +6 / 2 or +3
Charge on each iron atom is +3
The stock name is iron(III) sulfide
Use the (III) because iron is a transition metal other than Ag, Cd, or Zn

What is the Stock name of Hg_2O?
O is -2 because it is a nonmetal in Group VIA

The total positive charge must be +2 because the overall charge must be 0
Charge on each Hg must be +2 / 2 = +1
The Stock name is mercury(I) oxide

What is the formula for Manganese(IV) oxide?
Oxide is -2
Manganese is +4
The correct formula is MnO_2 (remember to reduce!)

What is the formula for chromium(III) sulfate?
Sulfate, SO_4^{2-}, is -2
Chromium is +3
The correct compound is $Cr_2(SO4)_3$

Name Na_2CO_3 – sodium carbonate
Name $Cr(SO_4)_2$ – chromium(IV) sulfate (transition metal)

Covalent Compounds – Definitions and examples

Contain two or more different nonmetals. Recall that hydrogen is a nonmetal, even though it appears in Group IA. When hydrogen appears first (rather than a metal as in ionic compounds), the compound is covalent. Covalent compounds form **molecules** held together by covalent bonds where electrons are shared between atoms.

Covalent compounds containing carbon also have systematic names that will be discussed in organic chemistry. The text below discusses writing and naming inorganic covalent compounds (or molecules).

Binary Molecular compounds – two different nonmetal atoms

Some binary molecular compounds have common names with formulas that are written a certain way. Examples of such compounds with common names and formulas include:
NH_3 – ammonia
H_2O – water
N_2H_4 - hydrazine

Most covalent compounds have systematic names and formula-writing conventions.

When writing the formula of a binary molecular compound, write the symbol for the least electronegative element first, followed by the symbol of the more electronegative one. *(Electronegativity of atoms increases to the top and to the right of the periodic table, but it does not include noble gases. Noble gases have no electronegativity and do not easily form compound. Following this guideline, the most electronegative element is fluorine. The least electronegative element is francium. Using chemical symbols, electronegativity follows this trend F>Cl>Br>I, and*

F>O>N>C>B>Be>Li.) Unlike ionic compounds, the subscripts in binary molecular covalent compounds are not always easily predicted, so you will determine the subscripts from the name.

Writing the name of a binary molecular compound consists of three parts:
(1) write the name of less electronegative atom (the one that appears first in the formula),
(2) write the stem of the more electronegative atom (the one that appears second in the formula) and add the suffix -ide,
(3) prefix both names with a Greek prefix to indicate how many atoms are in the formula. Skip the mono prefix when there is only one of the first atom. Drop the last ‘a’ or ‘o’ from the prefixes when the element name starts with a vowel

The Greek prefixes are: mono=1, di=2, tri=3, tetra=4, penta=5, hexa=6, hepta=7, octa=8, nona=9, and deca=10.

Examples with systematic names
CO_2 is carbon dioxide
Write the word carbon first - Rule (1). Use no prefix for just one carbon - Rule (3).
Write the word oxide second - Rule (2). Prefix it with di- for two oxygen atoms.

CO is carbon monoxide
Write the word carbon first - Rule (1). Use no prefix for just one carbon - Rule (3).
Write the word oxide second - Rule (2). Prefix it with mono- for one oxygen atom - Rule (3). Dropped ‘o’ before oxide.

Dinitrogen monoxide is N_2O
Dinitrogen indicates two nitrogen atoms in a binary molecular compound.
monoxide indicates one oxygen atom in a binary molecular compound.
Practice by using the formula to write the name.

More examples
SF_6 is sulfur hexafluoride (skip prefix ‘mono-‘ for first atom)
P_4O_6 is tetraphosphorous hexoxide (note: ‘a’ is dropped from hexa)
P_4S_6 is tetraphosphorous hexasulfide
PO_5 is phosphorous pentoxide(note: ‘a’ is dropped from penta)
PS_5 is phosphorous pentasulfide

Aqueous Acids

Note that acid formulas often start with an H, but not all compounds that start with H are acids.
Acids form an aqueous solution when dissolved in water, and these are called aqueous acids.
Indicate aqueous acids by placing an (aq) after the formula.
The two acid categories below are for writing and naming aqueous acids.

Binary aqueous acids

Consist of two different atoms, where the first atom is H.
A prefix hydro- and the ending -ic acid are used. Examples appear below.
HF(aq) – hydrofluoric acid
HCl(aq) – hydrochloric acid
HBr(aq) – hydrobromic acid
HI(aq) – hydroiodic acid
H_2S(aq) - hydrosulfuric acid

Note: when there is no (aq) symbol, name these ompounds like binary molecular compounds without prefixes, so Rule (3) is not needed. HF without the (aq) would be hydrogen fluoride. HCl without the (aq) would be hydrogen chloride. H_2S would be hydrogen sulfide.

Aqueous acids with a polyatomic anion.

The first atom is still H. The anion is a polyatomic ion. Add the ending -ic acid for a polyatomic ion that ends in -ate. Add the -ous acid ending for a polyatomic ion that ends in -ite.
If the polyatomic ion uses a per- prefix, that prefix appears first in the name of the acid.
If the polyatomic ion uses a hypo- prefix, that prefix appears first in the name of the acid.

Examples
H_2SO_4(aq) is sulfuric acid
H_2SO_3(aq) is sulfurous acid
HNO_3(aq) is nitric acid
HNO_2(aq) is nitrous acid
H_3PO_4(aq) is phosphoric acid
H_3PO_3(aq) is phosphorous acid
H_2CO_3(aq) is carbonic acid
$HClO_4$(aq) is perchloric acid (from perchlorate polyatomic ion)
$HClO_3$(aq) is chloric acid (from chlorate polyatomic ion)
$HClO_2$(aq) is chlorous acid (from chlorite polyatomic ion)
HClO(aq) is hypochlorous acid (from hypochlorite polyatomic ion)