Naming Chemical Compounds

Naming compounds is an important part of chemistry. Most compounds fall into one of four categories – Ionic Compounds, Molecular Compounds, Acids and Bases, and Hydrates

Part One: Naming Ionic Compounds

Identifying Ionic Compounds

Ionic compounds consist of combinations of positively charged ions called cations (usually metals), and negatively charged ions called anions (usually non-metals). In general, you can identify an ionic compound because it contains a metal (These are usually found in the left and center areas of the periodic table) and a non-metal (these are generally found in the right hand area of the periodic table). Also, a compound will have no charge. For example, NaCl and Fe_2O_3 are ionic compounds; they each contain a metal (Na and Fe) and a non-metal (Cl and O), and they do not have charges. MnO_4^- is NOT an ionic compound; it does contain a metal (Mn) and a non-metal (O), but it has a charge. Thus, it is a polyatomic ion, not a compound. A compound will NEVER have a charge!

Naming Ionic Compounds

There are three steps involved in naming ionic compounds- naming the cation, naming the anion, and naming the entire compound.

1. Name the cation.

i. Cations formed from metal atoms have the same name as the metal.

Examples: Na^+= sodium ion; Al_3^+= aluminum ion

ii. If a metal can form ions of different charges (i.e., is one of the central transition metals), specify the charge with Roman numerals in parentheses. Examples: Fe^+= iron (I) ion; Fe^{2+}= iron (II) ion; Fe^{3+}= iron (III) ion

iii. Cations formed from nonmetal ions have names ending in *–ium*. These are not common; the main ones are NH_4^+ (ammonium ion) and H_3O^+ (hydronium ion)

2. Name the anion.

i. Monoatomic anions (those formed from a single atom) have names formed by replacing the end of the element name with *–ide*. Examples: F^- = fluoride ion; O^{2-}= oxide ion. A few simple polyatomic anions (those formed from multiples atoms) also have names ending in *–ide*. Examples: CN^- = cyanide ion; OH^- = hydroxide ion; O_2^{2-}= peroxide ion.

ii. Most polyatomic ions contain oxygen, and have names ending in -*ate* or -*ite*. They are known as oxyanions. The ending –*ate* is used for the most common oxyanion form. The ending –*ite* is used for an oxyanion that has the same charge, but one less oxygen atom. Examples: SO_4^{2-} = sulfate; SO_3^{2-} = sulfite (same charge, but one less oxygen).

iii. The suffixes *per*- and *hypo*- are added to the names of oxyanions to show the addition or subtraction of additional oxygen atoms. *Per*- indicates the addition of one oxygen to the -*ate* form. *Hypo*- indicates the subtraction of one oxygen from the –*ite* form. Thus –*ate* is the most common form, *per*-_-*ate* has one extra oxygen, -*ite* has one less oxygen, and *hypo*-_-*ite* has two less oxygen. Example: ClO_4^- = perchlorate (one more oxygen than regular form) ClO_3^- = chlorate (regular form) ClO_2^- = chlorite (one less oxygen than regular form) ClO^- = hypochlorite (two less oxygen than regular form)

iv. Anions formed by adding H^+ to an oxyanion have the word "hydrogen" in front of their names (or "dihydrogen," if two hydrogens are present.) Examples: CO_3^{2-} = carbonate ion; HCO_3^- = hydrogen carbonate ion (notice that the addition of hydrogen lessens the negative charge by one). PO_4^{3-} = phosphate ion; $H_2PO_4^-$ = dihydrogen phosphate.

3. Name the compound.

i. To name the compound, simply put the names of the ions together. The name of an ionic compound is always the cation name followed by the anion name. Examples: $CaCl_2$= calcium chloride; $Al(NO_3)_3$= aluminum nitrate

ii. If you are dealing with a transition metal, don't forget to specify its charge.

iii. If you are dealing with an oxyanion, be sure you have the right name for the form you are using. Example: $Cu(ClO_4)^2$ = copper (II) perchlorate

iv. If you are having trouble determining the charge on an ion, look at the subscript on the opposite ion. In the above example, we know that the charge on the copper ion is +2 because the subscript on the opposite ion, the perchlorate, is 2, and copper is a metal, so it always has a positive charge. The charge on the perchlorate is -1 because the subscript on the copper is 1 (subscripts of 1 are not written in formulas- thus, because the copper has no written subscript, we know that it is 1), and perchlorate is an anion, so it always has a negative charge

v. You can use this same method to determine the correct subscript when you are writing a chemical formula based on a name. Example: write the formula for magnesium bromide. This is a compound containing magnesium and bromine ions- Mg^{2+}, and Br^{-} . To determine what subscripts, if any, to use, look at the opposite charges. The subscript on bromine will be 2, because the charge on the magnesium is 2. The subscript on magnesium will be one, because the charge on bromine is -1. Thus the formula is $MgBr_2$. (Remember, subscripts of 1 are not written). Likewise, given the name Iron (III) oxide, we can determine that the iron will have a subscript of 2, because the charge on oxygen ion is -2; the oxygen will have a subscript of 3, because we have been told we are dealing with iron with a charge of 3. So the formula is Fe_2O_3. The only time this rule is not true is when the charges on the ions are equal- for example, when oxygen, with a charge of -2, bonds with magnesium, which has a charge of +2. In this case, the charge on one oxygen ion is equal to the charge on one magnesium ion, so it will only take one oxygen ion and one magnesium ion to form a compound that has no charge. Thus, this compound has the formula MgO, not Mg_2O_2. The same thing happens when calcium and oxygen combine. Calcium has a charge of +2, and oxygen has a charge of -2. Because their charges are equal, it only takes one of each to form a compound with no charge, so the formula is CaO, not Ca_2O_2.

Part Two: Naming Binary Molecular Compounds

Identifying Binary Molecular Compounds

Molecular compounds consist of combinations of non-metals. Binary molecular compounds are composed of only two elements. They are easy to identify, as they consist merely of two non-metal elements. Examples: H_2O (water), NF_3, and N_2O_4.

Naming Binary Molecular Compounds

There are four steps to name binary molecular compounds:

1. The name of the element farthest to the left in the periodic table is written first.
    i. There are occasional exceptions to this rule. The main exception is oxygen. Oxygen, except when combined with fluorine, is always written last.
2. If both elements are in the same group in the table, the lower one is written first
3. The name of the second element is given an -ide ending.
4. Greek prefixes are used to indicate the number of atoms of each element.
    i. The prefixes are as follows: Mono-= one; Di-= two; Tri-= three; Tetra-= four; Penta-= five; Hexa-= six; Hepta-= seven; Octa-= eight; Nona-= nine; Deca-= ten

ii. The prefix *mono*- is never used with the first element. If only one atom of the first element is present, do not use a prefix

Examples of binary molecular compounds and their names: Cl_2O= dichlorine monoxide NF_3=nitrogen trifluoride N_2O_4= dinitrogen tetroxide P_4S_{10}= tetraphosphorus decasulfide.

<u>Part Three: Naming Acids</u>

Identifying Acids

Acids are hydrogen containing compounds. Acids are easy to recognize- they are composed of hydrogen and an anion (the hydrogen always comes first), and they have no charge. Examples: HCl and H_2SO_4 are acids; they are made up of hydrogen and anions, and they do not have charges. HCO^{3-} is NOT an acid; it is made up of hydrogen and an anion, but it has a charge, and so it is a polyatomic ion.

Naming Acids

There are two steps involved in naming acids.

1. Acids based on anions whose names end in *–ide*.
   When an ion ending in -*ide* becomes an acid, its name changes- its suffix changes from *–ide* to *–ic*, and it gains a prefix, *hydro*-. Thus, Cl^-, the chloride ion, becomes HCl, hydrochloric acid. S_2^-, the sulfide ion, becomes H_2S hydrosulfuric acid (we add two hydrogen ions because the sulfide ion has a charge of 2-. We must add enough hydrogen ions, which have a charge of 1+, to cancel out the charge on the sulfide. One hydrogen ion would give us HS-, which is not an acid as it still has a charge).
2. Acids based on anions whose names in *–ate* or *–ite*.
   When an ion ending in *–ate* becomes an acid, its suffix changes to *–ic*, but it does not gain a prefix. If it already contains the prefix *per*- (as in perchlorate), it will retain that prefix, and will be *per*____*ic* acid. When an ion ending in -*ite* becomes an acid, its suffix changes to -*ous*. If it contains the prefix *hypo*- (as in hypochlorite), it retains that prefix, and will be *hypo*___*ous* acid. Thus, ClO_3^-, the chlorate becomes $HClO_3$, chloricacid. Perchlorate (ClO_4^-) becomes $HClO_4$, perchloric acid. Chlorite, ClO_2^-, becomes $HClO_2$, chlorous acid, while hypochlorite, ClO^-, becomes HClO, hypochlorous acid.

The naming of acids can be summarized in the following chart:

Anion	Acid
-ide anion (chloride, Cl^-)	*hydro__ic* acid (hydrochloric acid, HCl)
-ate anion (chlorate, ClO_3^-)	____*ic* acid (chloric acid, $HClO_3$)
per__ate anion (perchlorate, ClO_4^-)	*per__ic* acid (perchloric acid, $HClO_4$)
-ite anion (chlorite, ClO_2^-)	___*ous* acid (chlorous acid, $HClO_2$)
hypo__ite anion (hypochlorite, $HClO^-$)	*hypo__ous* acid (hypochlorous acid, $HClO$)

Part Four: Naming Hydrates

Identifying Hydrates

Hydrates are easily spotted by the extra water molecules that are attached to the chemical formula. If a hydrate has had its water molecules completely removed it is known as anhydrous.

Naming Hydrates

Naming hydrates involves three steps:

1. Name the salt
2. Give the numerical prefix for the number of water molecules associated
3. Add the word hydrate

Examples: $CuSO_4 \cdot 5H_2O$ = copper (II) sulfate pentahydrate
$ZnF_2 \cdot 4H_2O$ = zinc fluoride tetrahydrate

Name the following ionic compounds:	Give formulas to these ionic compound names:
1. NH_4Br 2. Cr_2O_3 3. $Co(NO_3)_2$ 4. K_2SO_4 5. $Ba(OH)_2$ 6. $FeCl_3$ 7. AlF_3 8. $Fe(OH)_2$ 9. $Cu(NO_3)_2$ 10. $Ba(ClO_4)_2$ 11. Li_3PO_4 12. Hg_2S 13. $Cr_2(CO_3)_3$ 14. K_2CrO_4 15. $(NH_4)_2SO_4$ 16. $Ca(C_2H_3O)_2$	17. Potassium sulfide 18. Calcium carbonate 19. Nickel (II) perchlorate 20. Magnesium sulfate 21. Silver (I) sulfide 22. Lead (II) nitrate 23. Copper (I) oxide 24. Aluminum hydroxide 25. Cesium fluoride carbonate 26. Magnesium iodide 27. Iron (III) carbonate 28. Sodium hypobromite 29. Cobalt (II) nitrate 30. Chromium (II) acetate 31. Copper (II) perchlorate 32. Calcium hydrogen

Name these binary molecular compounds:	Give the formula for these molecular compounds:
1. SO_2	17. Silicon tetrabromide
2. PCl_5	18. Disulfur dichloride
3. N_2O_3	19. Dinitrogen tetroxide
4. SF_6	20. Tetraphosphorus hexasulfide
5. IF_5	21. Sulfur hexafluoride
6. XeO_3	22. Phosphorus tribromide
7. N_2O_5	23. Carbon tetraiodide
8. BF_3	24. Dihydrogen monoxide
9. CCl_4	25. Phosphorus triiodide
10. P_4O_6	26. Iodine monobromide
11. SiO_2	27. Diboron trioxide
12. O_2F_2	28. Nitrogen trichloride
13. XeF_6	29. Carbon monoxide
14. $AsCl_3$	30. Silicon tetrachloride
15. P_2O_5	31. Dinitrogen pentoxide
16. $AsBr_3$	32. Nitrogen dioxide

Name the following acids:	Give Formulas for these acids:
1. HCN	17. Hypochlorous acid
2. HNO_3	18. Hydroiodic acid
3. H_2SO_4	19. Sulfurous acid
4. H_2SO_3	20. Hydrobromic acid
5. HF	21. Hydrosulfuric acid
6. HBr	22. Nitrous acid
7. HI	23. Perbromic acid
8. H_3PO_4	24. Acetic acid
9. $HC_2H_3O_2$	25. Hydroselenic acid
10. HNO_2	26. Bromous acid
11. $HBrO_3$	27. Hydrofluoric acid
12. $HBrO_4$	28. Phosphoric acid
13. H_2Se	29. Nitric acid
14. H_3PO_3	30. Hydrocyanic acid
15. HCl	31. Sulfuric acid
16. H_2CO_3	32. Carbonic acid
NOTE: Problems 11-14 all use ions that are not common. The ion in problem 11, BrO_3^-, is bromate. The ion in problem 12, BrO_4^- is perbromate. The ion in problem 13, Se^{2-}, is selenide, the ion formed by element 34, selenium. The ion in problem 14, PO_3^{3-}, is phosphate.	