Naming Compounds

Naming compounds is an important part of chemistry. Most compounds fall in to one of three categories- ionic compounds, molecular compounds, or acids.

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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-} = sulf*ate*; SO_3^{2-} = sulf*ite* (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^- = *per*chlor*ate* (one more oxygen than regular form)
ClO_3^- = chlor*ate* (regular form)
ClO_2^- = chlor*ite* (one less oxygen than regular form)
ClO^- = *hypo*chlor*ite* (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= *di*chlorine *mono*oxide
- NF_3= nitrogen *tri*fluoride
- N_2O_4= *di*nitrogen *tetr*oxide
- P_4S_{10}= *tetra*phosphorus *deca*sulfide.

Part Three: Naming Acids

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_2S0_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 chlor*ide* ion, becomes HCl, *hydro*chlor*ic* acid. S^{2-}, the sulf*ide* ion, becomes H_2S *hydro*sulfur*ic* 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 chlor*ate* becomes $HClO_3$, chlor*ic* acid. *Per*chlor*ate* (ClO_4^-) becomes $HClO_4$, *per*chlor*ic* acid. Chlor*ite*, ClO_2^-, becomes $HClO_2$, chlor*ous* acid, while *hypo*chlor*ite*, ClO^-, becomes HClO, *hypo*chlor*ous* 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, ClO^-)	*hypo*__*ous* acid (hypochlorous acid, HClO)

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Practice Problems- Ionic Compounds
Name the following ionic compounds:

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. $Ca(C_2H_3O)_2$

Now go the other way- give the formulas for the following names:

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
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 carbonate

Practice Problems- Molecular Compounds
Name these binary molecular compounds:

1. SO_2
2. PCl_5
3. N_2O_3
4. SF_6
5. IF_5
6. XeO_3
7. N_2O_5
8. BF_3
9. CCl_4
10. P_4O_6
11. SiO_2
12. O_2F_2
13. XeF_6
14. $AsCl_3$
15. P_2O_5
16. $AsBr_3$

Provide formulas for the following binary molecular compounds:

17. Silicon tetrabromide
18. Disulfur dichloride
19. Dinitrogen tetroxide
20. Tetraphosphorus hexasulfide
21. Sulfur hexafluoride
22. Phosphorus tribromide
23. Carbon tetraiodide
24. Dihydrogen monoxide
25. Phosphorus triiodide
26. Iodine monobromide
27. Diboron trioxide
28. Nitrogen trichloride
29. Carbon monoxide
30. Silicon tetrachloride
31. Dinitrogen pentoxide
32. Nitrogen dioxide

Practice Problems- Acids
Name the following acids:

1. HCN
2. HNO_3
3. H_2SO_4
4. H_2SO_3
5. HF
6. HBr
7. HI
8. H_3PO_4
9. $HC_2H_3O_2$
10. HNO_2
11. $HBrO_3$
12. $HBrO_4$
13. H_2Se
14. H_3PO_3
15. HCl
16. H_2CO_3

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.

Provide formulas for the following acids:

17. Hypochlorous acid
18. Hydroiodic acid
19. Sulfurous acid
20. Hydrobromic acid
21. Hydrosulfuric acid
22. Nitrous acid
23. Perbromic acid
24. Acetic acid
25. Hydroselenic acid
26. Bromous acid
27. Hydrofluoric acid
28. Phosphoric acid
29. Nitric acid
30. Hydrocyanic acid
31. Sulfuric acid
32. Carbonic acid

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Answer Key- Ionic Compounds

Names from formulas:

1. Ammonium bromide
2. Chromium (III) oxide
3. Cobalt (II) nitrate
4. Potassium sulfate
5. Barium hydroxide
6. Iron (III) chloride
7. Aluminum fluoride
8. Iron (II) hydroxide
9. Copper (II) nitrate
10. Barium perchlorate
11. Lithium phosphate
12. Mercury (I) sulfide
13. Chromium (III) carbonate
14. Potassium chromate
15. Ammonium sulfate
16. Calcium acetate

Formulas from names:

17. K_2S
18. $CaCO_3$
19. $Ni(ClO_4)_2$
20. $MgSO_4$
21. Ag_2S
22. $Pb(NO_3)_2$
23. Cu_2O
24. $Al(OH)_3$
25. CsF
26. MgI_2
27. $Fe_2(CO_3)_3$
28. $NaBrO$
29. $Co(NO_3)_2$
30. $Cr(C_2H_3O_2)_2$
31. $Cu(ClO_4)_2$
32. $Ca(HCO_3)_2$

Answer Key- Molecular Compounds

Names from formulas:

1. Sulfur dioxide
2. Phosphorus pentachloride
3. Dinitrogen trioxide
4. Sulfur hexafluoride
5. Iodine pentafluoride
6. Xenon trioxide
7. Dinitrogen pentoxide
8. Boron trifluoride
9. Carbon tetrachloride
10. Tetraphosphorus hexoxide
11. Silicon dioxide
12. Dioxide difluoride
13. Xenon hexafluoride
14. Arsenic trichloride
15. Diphosphorus pentoxide
16. Arsenic tribromide

Formulas from names:

17. $SiBr_4$
18. S_2Cl_2
19. N_2O_4
20. P_4S_6
21. SF_6
22. PBr_3
23. CI_4
24. H_2O
25. PI_3
26. IBr
27. B_2O_3
28. NCl_3
29. CO
30. $SiCl_4$
31. N_2O_5
32. NO_2

Answer Key- Acids

Names from formulas:

1. Hydrocyanic acid
2. Nitric acid
3. Sulfuric acid
4. Sulfurous acid
5. Hydrofluoric acid
6. Hydrobromic acid
7. Hydroiodic acid
8. Phosphoric acid
9. Acetic acid
10. Nitrous acid
11. Bromic acid
12. Perbromic acid
13. Hydroselenic acid
14. Phosphorous acid
15. Hydrochloric acid
16. Carbonic acid

Formulas from names:

17. $HClO$
18. HI
19. H_2SO_3
20. HBr
21. H_2S
22. HNO_2
23. $HBrO_4$
24. $HC_2H_3O_2$
25. H_2Se
26. $HBrO_2$
27. HF
28. H_3PO_4
29. HNO_3
30. HCN
31. H_2SO_4
32. H_2CO_3