

CHM 101 GENERAL CHEMISTRY

FALL QUARTER 2008

Section 2

Lecture Notes – 10/8/2008

(last revised: 10/7/08)

2.8 Naming Simple Chemical Compounds

- Names and Symbols for the Elements
 - Most elements have symbols that are directly constructed from the names. For example:

Symbol is First Letter of Name

| | |
|------------------|---|
| H ydrogen | H |
| N itrogen | N |
| O xygen | O |
| F luorine | F |

Symbol is First Two Letters of Name

| | |
|------------------|----|
| L ithium | Li |
| Al uminum | Al |
| S ilicon | Si |
| Br omine | Br |

Symbol is First Plus Another Letter of Name

| | |
|------------------|----|
| Cl horine | Cl |
| Cr romium | Cr |
| Mg nesium | Mg |
| Mn ganese | Mn |

- Some elements have symbols that are based on their original names instead of their current names. These require memorization:

| Current Name | Original Name | Symbol |
|---------------------|----------------------|---------------|
| Antimony | Stibium | Sb |
| Copper | Cuprum | Cu |
| Gold | Aurum | Au |
| Iron | Ferrum | Fe |
| Lead | Plumbum | Pb |
| Mercury | Hydrargyrum | Hg |
| Potassium | Kalium | K |
| Silver | Argentum | Ag |
| Sodium | Natrium | Na |
| Tin | Stannum | Sn |
| Tungsten | Wolfram | W |

- Common Names for chemical compounds: Colorful, but not very informative.
 - sugar of lead
 - blue vitriol
 - oil of vitriol
 - quicklime
 - Epsom salts
 - milk of magnesia
 - gypsum
 - laughing gas
- Need a system where the name says something about the composition.
 - Determine the name, given the formula, or...
 - Determine the formula, given the name.
- Naming of Binary Ionic Compounds: These are compounds containing monatomic ions of two elements.
 - One of the components is a monatomic anion. The names of monatomic anions are based on the names of the

elements, but the endings are changed to "-ide." Note that the ions with -1 charges are all from Group 17 (except for hydride); those with -2 charges are from Group 16; and those with -3 charges are from Group 15 of the periodic table.

- o And, as an aid to learning, let's mark our periodic tables to show the positions of each element that forms monatomic ions, with different colors for anions, Type I cations, and Type II cations.

| Anion | Name | Group |
|-----------------|-----------|-------|
| H ⁻ | Hydride | 1 |
| F ⁻ | Fluoride | 17 |
| Cl ⁻ | Chloride | 17 |
| Br ⁻ | Bromide | 17 |
| I ⁻ | Iodide | 17 |
| O ²⁻ | Oxide | 16 |
| S ²⁻ | Sulfide | 16 |
| N ³⁻ | Nitride | 15 |
| P ³⁻ | Phosphide | 15 |

- o The other component is a monatomic cation. There are two types of these ions. We consider first Type I, where the element forms only one kind of ion. Note that all of the cations from elements in Group 1 have +1 charges and that all the cations of Group 2 elements have +2 charges. Note also that the cations have names that are identical to the names of the elements.

| Cation | Name | Group |
|------------------|-----------|-------|
| H ⁺ | Hydrogen | 1 |
| Li ⁺ | Lithium | 1 |
| Na ⁺ | Sodium | 1 |
| K ⁺ | Potassium | 1 |
| Cs ⁺ | Cesium | 1 |
| Be ²⁺ | Beryllium | 2 |

| | | |
|------------------|-----------|----|
| Mg ²⁺ | Magnesium | 2 |
| Ca ²⁺ | Calcium | 2 |
| Ba ²⁺ | Barium | 2 |
| Ag ⁺ | Silver | 11 |
| Zn ²⁺ | Zinc | 12 |
| Cd ²⁺ | Cadmium | 12 |
| Al ³⁺ | Aluminum | 13 |
| Ga ³⁺ | Gallium | 13 |

- o Let's pause here and name some Binary Ionic Compounds of Type I. Here are the rules:
 - There is always one kind of monatomic cation and one kind of monatomic anion.
 - The name of the cation comes first. The name of the anion comes second.
 - The net charge on an ionic compound is 0. This means that the numbers of ions of each type must be chosen so that the charges balance.
 - Some examples:

| Compound | Ions Present | Name |
|--------------------------------|------------------------------------|------------------|
| NaCl | Na ⁺ , Cl ⁻ | Sodium chloride |
| KI | K ⁺ , I ⁻ | Potassium iodide |
| CaS | Ca ²⁺ , S ²⁻ | Calcium sulfide |
| Li ₃ N | Li ⁺ , N ³⁻ | Lithium nitride |
| CsBr | Cs ⁺ , Br ⁻ | Cesium bromide |
| MgO | Mg ²⁺ , O ²⁻ | Magnesium oxide |
| Na ₂ O | Na ⁺ , O ²⁻ | Sodium oxide |
| Al ₂ O ₃ | Al ³⁺ , O ²⁻ | Aluminum oxide |
| CsF | | |
| AlCl ₃ | | |
| LiH | | |

Cesium iodide

Lithium fluoride

Calcium phosphide

- Now we consider Type II cations. These differ from Type I in that the metals that form them by ionization can form more than one kind of ion. Take iron (Fe) for example. There are two kinds of iron chloride:
 - FeCl_2 , which contains Fe^{2+} ions. The name for this is iron (II) chloride.
 - FeCl_3 , which contains Fe^{3+} ions. The name for this is iron (III) chloride.
- The rules for naming Type II Binary Ionic Compounds are the same as for Type I, except that there is one additional rule. We use a roman numeral in the chemical name to indicate the charge on the cation.
- Here is a list of common Type II cations. You need to memorize which charges go with which elements. Note also that mercury (I) always occurs as the diatomic ion, Hg_2^{2+} .

| Cation | Name | Group |
|--------------------|----------------|--------------|
| Fe^{3+} | Iron (III) | 8 |
| Fe^{2+} | Iron (II) | 8 |
| Cu^{2+} | Copper (II) | 11 |
| Cu^+ | Copper (I) | 11 |
| Co^{3+} | Cobalt (III) | 9 |
| Co^{2+} | Cobalt (II) | 9 |
| Sn^{4+} | Tin (IV) | 14 |
| Sn^{2+} | Tin (II) | 14 |
| Pb^{4+} | Lead (IV) | 14 |
| Pb^{2+} | Lead (II) | 14 |
| Hg^{2+} | Mercury (II) | 12 |
| Hg_2^{2+} | Mercury (I) | 12 |
| Cr^{3+} | Chromium (III) | 6 |

| | | |
|------------------|-----------------|---|
| Cr^{2+} | Chromium (II) | 6 |
| Mn^{3+} | Manganese (III) | 7 |
| Mn^{2+} | Manganese (II) | 7 |

- o Now let's try naming some Type II Binary Ionic Compounds:

| Compound | Ions Present | Name |
|-------------------------|---------------------------------|----------------------|
| FeCl_3 | $\text{Fe}^{3+}, \text{Cl}^-$ | Iron (III) chloride |
| FeO | $\text{Fe}^{2+}, \text{O}^{2-}$ | Iron (II) oxide |
| CuI | Cu^+, I^- | Copper (I) iodide |
| CuO | $\text{Cu}^{2+}, \text{O}^{2-}$ | Copper (II) oxide |
| CuCl | | |
| HgO | | |
| Fe_2O_3 | | Manganese (IV) oxide |
| | | Lead (II) chloride |
| | | Mercury (I) bromide |

- o And let's try naming some more Type I and Type II Binary Ionic Compounds:

| Compound | Ions Present | Name |
|-------------------------|---------------------|-------------------------|
| CoBr_2 | | |
| CaCl_2 | | |
| Al_2O_3 | | Chromium (III) chloride |
| | | Gallium iodide |

- Naming of Ionic Compounds Containing Polyatomic Ions:

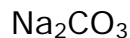
- o The hard part is memorizing the *formulas*, the *charges*, and the *names* of the common polyatomic ions, but such memorization is absolutely necessary. Here is the list:

| Cation | Name |
|--------------------|-------------|
| NH_4^+ | Ammonium |
| Hg_2^{2+} | Mercury (I) |

| Anion | Name |
|------------------------------------|----------------------|
| NO_2^- | Nitrite |
| NO_3^- | Nitrate |
| SO_3^{2-} | Sulfite |
| SO_4^{2-} | Sulfate |
| HSO_4^- | Hydrogen sulfate |
| OH^- | Hydroxide |
| CN^- | Cyanide |
| PO_4^{3-} | Phosphate |
| HPO_4^{2-} | Hydrogen phosphate |
| H_2PO_4^- | Dihydrogen phosphate |
| NCS^- | Thiocyanate |
| CO_3^{2-} | Carbonate |
| HCO_3^- | Hydrogen carbonate |
| ClO^- | Hypochlorite |
| ClO_2^- | Chlorite |
| ClO_3^- | Chlorate |
| ClO_4^- | Perchlorate |
| $\text{C}_2\text{H}_3\text{O}_2^-$ | Acetate |
| MnO_4^- | Permanganate |
| $\text{Cr}_2\text{O}_7^{2-}$ | Dichromate |
| CrO_4^{2-} | Chromate |
| O_2^{2-} | Peroxide |
| $\text{C}_2\text{O}_4^{2-}$ | Oxalate |

- o Notes on these names:
 - The hydrogen sulfate ion is often called bisulfate, and the hydrogen carbonate ion is often called bicarbonate.
 - Many of these ions contain one or more oxygens. With several exceptions (hydroxide, acetate, oxalate) these are classed as *oxyanions*. Some elements form more than one kind of oxyanion. In that case, the suffix, -ite, is attached to the ion with the lesser number of oxygens and the ending, -ate, is attached to the ion with the greater number of oxygens. Good examples are sulfate (SO_4^{2-}) and sulfite (SO_3^{2-}). Some elements form as many as four kinds of oxyanion. In that case, the prefix, hypo-, and the suffix, -ite, are attached to the name of the ion with the lowest number of oxygens, and the prefix, per-, and the suffix, -ate, are attached to the name of the ion with the highest number of oxygens. The example in the above table is the series of oxyanions of chlorine.
- o Having memorized the formulas, charges, and names of these polyatomic ions, you should find it easy to assign names to compounds that contain them. The only new rule is that if a compound contains two (or more) of the same polyatomic ion, the formula of the ion is wrapped in parentheses, and the number is appended as a subscript after the right parenthesis. An example is ammonium sulfate, shown in the first line of the next table.
- o Here are some exercises to try (fill in the blanks):

| Formula | Ions | Name |
|------------------------------|--------------------------------------|------------------|
| $(\text{NH}_4)_2\text{SO}_4$ | NH_4^+ , SO_4^{2-} | Ammonium sulfate |
| Na_2SO_4 | | |
| KH_2PO_4 | | |
| $\text{Fe}(\text{NO}_3)_2$ | | |
| $\text{Mn}(\text{OH})_2$ | | |
| Na_2SO_3 | | |



Sodium hydrogen
carbonate

Cesium perchlorate

Sodium hypochlorite

- o And here are two challenge exercises: (Hint: Use the periodic law to infer the formulas of the selenate and bromate ions.)

| Formula | Ions | Name |
|---------|------|-------------------|
| | | Sodium selenate |
| | | Potassium bromate |

- **Naming Binary Covalent Compounds** (The text calls these also Type III binary compounds)

- o Binary covalent compounds are formed between two non-metals. The rules for naming them are very similar to the rules for binary ionic compounds, even though their bonds are covalent rather than ionic.

- o The first element in the formula is named first, using the full name of the element.

- o The second element is named as if it were an anion.

- o Prefixes mono-, di-, tri-, etc., are used to indicate the numbers of each type of atom. See Table 2.6 in your text for a full list.

- o The prefix, mono-, is never applied to the first element in the name. For example, CO is carbon monoxide, and CO₂ is carbon dioxide.

TABLE 2.6 Prefixes Used to Indicate Number in Chemical Names

| Prefix | Number Indicated |
|---------------|------------------|
| <i>mono-</i> | 1 |
| <i>di-</i> | 2 |
| <i>tri-</i> | 3 |
| <i>tetra-</i> | 4 |
| <i>penta-</i> | 5 |
| <i>hexa-</i> | 6 |
| <i>hepta-</i> | 7 |
| <i>octa-</i> | 8 |
| <i>nona-</i> | 9 |
| <i>deca-</i> | 10 |

- o The letters, o, and a, on the ends of prefixes can be omitted to avoid awkward pronunciations if the name of the following element begins with a vowel.
Examples: carbon monoxide and phosphorous pentoxide.
- o Water and ammonia are always referred to by their common names, never by their systematic names based on the formulas, H₂O and NH₃.
- o Some examples for class discussion:

| Formula | Name |
|-------------------------------|----------------------|
| H ₂ O | Water |
| NH ₃ | Ammonia |
| N ₂ O | Dinitrogen monoxide |
| NO | Nitrogen monoxide |
| NO ₂ | Nitrogen dioxide |
| N ₂ O ₃ | Dinitrogen trioxide |
| N ₂ O ₄ | Dinitrogen tetroxide |
| N ₂ O ₅ | Dinitrogen pentoxide |
| PCl ₅ | |
| PCl ₃ | |
| SO ₂ | |
| | Sulfur hexafluoride |
| | Sulfur trioxide |
| | Carbon dioxide |

- **Summary: How to Name Binary Compounds**

- o Here is the flowchart from your text (Figure 2.23). (In the text, binary covalent compounds are also called Type III binary compounds):

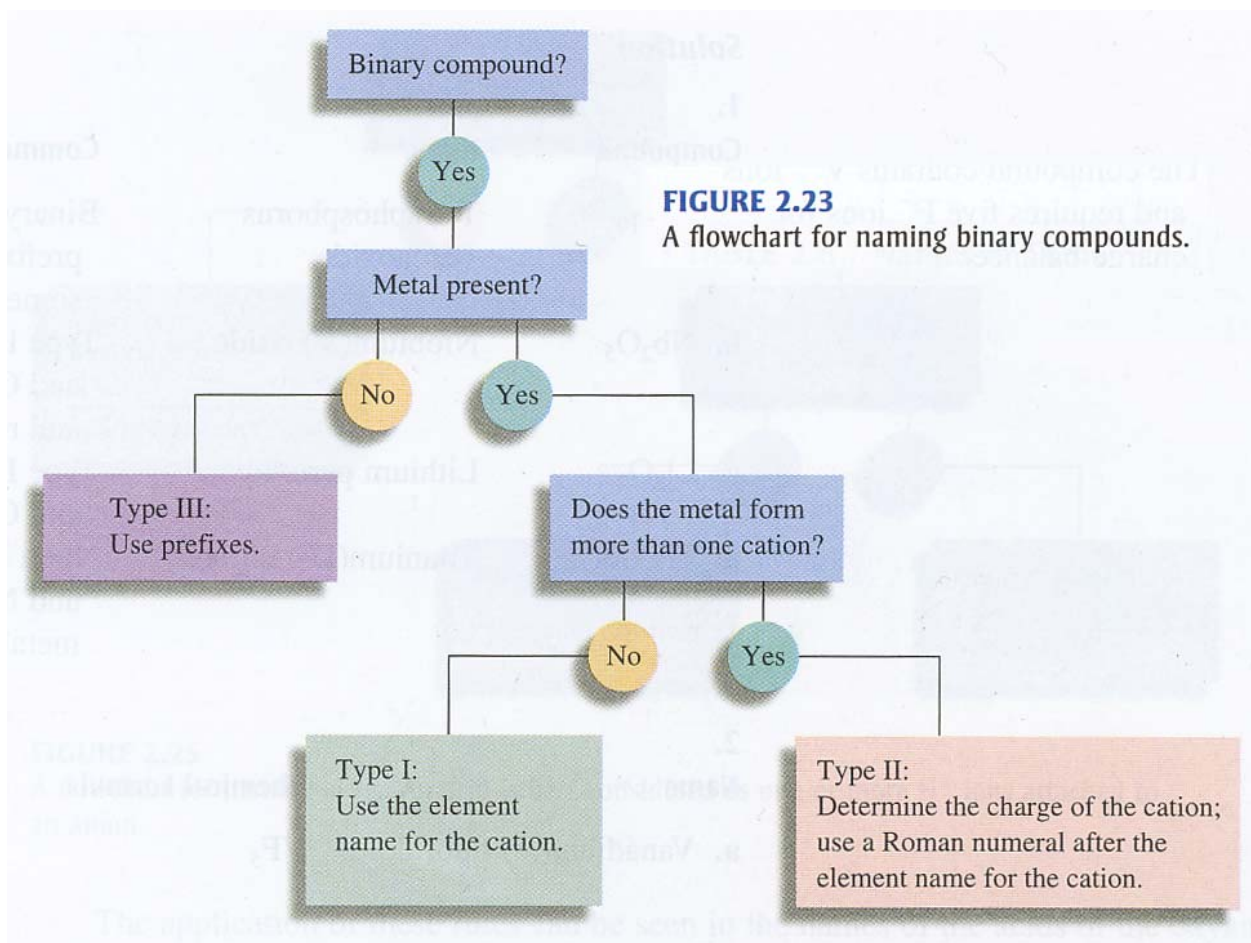
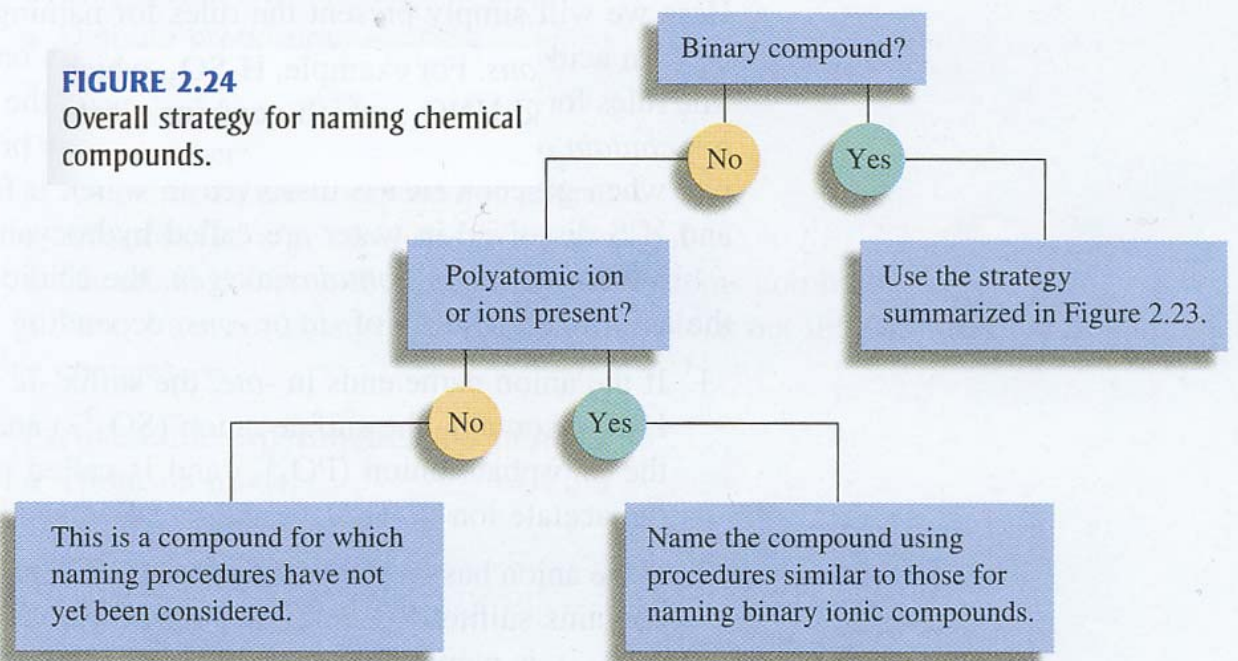


FIGURE 2.23
A flowchart for naming binary compounds.

- o Another flow chart (Figure 2.24) from your text expands the naming process to encompass compounds containing polyatomic ions:

FIGURE 2.24

Overall strategy for naming chemical compounds.



- o The following examples cover the naming of all the types of compounds we have discussed in this set of notes. You should be able to use the periodic table to deal with any ion whose name and formula you have not been asked to memorize.

| Formula | Name |
|--------------|-----------------------|
| P_4O_{10} | |
| Nb_2O_5 | |
| Li_2O_2 | |
| $Ti(NO_3)_4$ | |
| | Vanadium (V) fluoride |
| | Dioxygen difluoride |
| | Rubidium peroxide |
| | Gallium oxide |

• Names of Acids

- o Acids are so important that three entire chapters of your text (Chapters 4, 14, and 15) are devoted to them. Here we will confine the discussion to a brief definition of acid and to some rules for naming acids.

- Acids are substances that, when dissolved in water, will produce hydrogen ions (H^+). An acid can be pictured as a molecule with one or more protons (H^+) attached to an anion.
- How to name acids:

- If the anion does not contain oxygen, the acid's name includes the prefix, hydro-, and the suffix, -ic. The word, "acid," follows. For example, HCl contains a chloride anion, (Cl^-), and is named Hydrochloric acid. The most important acids of this class are listed in Table 2.7 from the text.

TABLE 2.7 Names of Acids* That Do Not Contain Oxygen

| Acid | Name |
|------------------|--------------------|
| HF | Hydrofluoric acid |
| HCl | Hydrochloric acid |
| HBr | Hydrobromic acid |
| HI | Hydroiodic acid |
| HCN | Hydrocyanic acid |
| H ₂ S | Hydrosulfuric acid |

*Note that these acids are aqueous solutions containing these substances.

- If the anion does contain oxygen, and the name of the anion ends in "-ate," the suffix, "-ic," replaces the "-ate," and the word, "acid," follows. For example, H₂SO₄ contains a sulfate anion (SO_4^{2-}), and is named sulfuric acid.
- If the anion contains oxygen and the name of the anion ends in "-ite," the suffix "-ous," replaces the "-ite," and the word, "acid," follows. For example, H₂SO₃ contains a sulfite anion (SO_3^{2-}), and is named sulfurous acid. Some examples of oxygen-containing acids are listed in Table 2.8.

TABLE 2.8 Names of Some Oxygen-Containing Acids

| Acid | Name |
|---|-----------------|
| HNO ₃ | Nitric acid |
| HNO ₂ | Nitrous acid |
| H ₂ SO ₄ | Sulfuric acid |
| H ₂ SO ₃ | Sulfurous acid |
| H ₃ PO ₄ | Phosphoric acid |
| HC ₂ H ₃ O ₂ | Acetic Acid |

- The oxyacids of chlorine illustrate these rules:

| Acid | Anion | Name |
|-------------------|--------------|-------------------|
| HClO ₄ | Perchlorate | Perchloric acid |
| HClO ₃ | Chlorate | Chloric acid |
| HClO ₂ | Chlorite | Chlorous acid |
| HClO | Hypochlorite | Hypochlorous acid |

- A flowchart for the naming of acids is given in the text (Figure 2.25).

