CHEM 103

Naming Compounds

Lecture Notes
February 7, 2006
Prof. Sevian

Agenda

- How we name compounds depends on what kind of compounds they are
- Ionic compounds
- Molecular compounds
- Acids are molecular compounds that sometimes behave like ionic compounds, and the positive ion is always H⁺
Isotopes and Natural Abundances

The mass of a typical sample of an element is a weighted average of the masses of the isotopes.

<table>
<thead>
<tr>
<th>Isotopes of magnesium</th>
<th>12 p+</th>
<th>12 n0</th>
<th>13 n0</th>
<th>14 n0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Abundance</td>
<td>78.99%</td>
<td>10.00%</td>
<td>11.01%</td>
<td></td>
</tr>
<tr>
<td>Mass of Isotope (amu)</td>
<td>23.9850</td>
<td>24.9858</td>
<td>25.9826</td>
<td></td>
</tr>
</tbody>
</table>

\[
18.95 + 2.499 + 2.861 = 24.31
\]

This is the atomic weight on the periodic table.

Reading the Periodic Table

[Diagram showing the periodic table with the symbol Mg (magnesium) and atomic number 12, atomic weight 24.31, and symbol Mg]
# Regions of the Periodic Table

See p. 50 in text

- **Transition metals**
- **Lanthanides and actinides**

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## Organization of the Periodic Table

Terminology we will use all year:
- **Period** = row across
- **Group** = column down

Several common groups:
- **Group 1A**: Alkali metals
- **Group 2A**: Alkaline earth metals
- **Group 7A**: Halogens
- **Group 8A**: Noble gases
- **Groups B**: Transition metals

- Early chemists (Mendeleev, Moseley) organized the Periodic Table according to properties of elements.
- There are reasons why the Periodic Table is organized the way it is (stay tuned until chapters 6 and 7).
Pinpointing an Element

What is an Ion?

1. Hydrogen loses an electron to form H⁺
What is an Ion?

2. Nonmetals (except not usually H) gain electrons to form negatively charged ions.

\[
\text{Neutral F atom} \quad \xrightarrow{7\text{p}^+ \to 8\text{e}^-} \quad \text{F}^- \text{ion}
\]

What is an Ion?

3. Metals lose electrons to form positively charged ions.

\[
\text{Neutral Mg atom} \quad \xrightarrow{12\text{p}^+ \to 10\text{e}^-} \quad \text{Mg}^{2+} \text{ion}
\]
Atoms lose or gain electrons to have the same number of electrons as the nearest Group 8A element.

### Ions and Their Names

**Positive Ions**
- Metal atoms that lose electrons
- More protons than electrons
- Group A elements always lose electrons to resemble the nearest noble gas
- Group B elements can have different quantities of electrons lost
- No name change (but some Group B elements must indicate charge to distinguish)

**Negative Ions**
- Nonmetal atoms that gain electrons
- Fewer protons than electrons
- Group A elements always gain electrons to resemble the nearest noble gas
- Suffix of element name changes to "-ide"

Names of Common Ions

Find these elements on the Periodic Table and convince yourself why they take the charges they do.

<table>
<thead>
<tr>
<th>Ion</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cl−</td>
<td>chloride</td>
</tr>
<tr>
<td>Na+</td>
<td>sodium</td>
</tr>
<tr>
<td>Mg2+</td>
<td>magnesium</td>
</tr>
<tr>
<td>O2−</td>
<td>oxide</td>
</tr>
<tr>
<td>N3−</td>
<td>nitride</td>
</tr>
<tr>
<td>Sr2+</td>
<td>strontium</td>
</tr>
<tr>
<td>Al3+</td>
<td>aluminum</td>
</tr>
</tbody>
</table>

**Rule**
If nonmetal, change ending to “-ide”

Compounds

Two or more different elements that are chemically bonded

Kinds of bonding:
1. Ionic: usually metal ions (+) and nonmetal ions (-) held together by electrostatic attraction
2. Molecular: usually nonmetals held together because proximity of outer electrons on the atoms causes new bonding “orbitals” to exist which have more favorable conditions for electrons
3. Other
Ionic vs. Molecular Compounds

- For simplicity, let's compare some ionic and molecular compounds in the solid state

- Ionic compounds:
  - NaCl = table salt, also called sodium chloride
  - NH₄Cl = ammonium chloride

- Molecular compounds:
  - H₂O (s) = ice
  - C₁₂H₂₂O₁₁ = sucrose

How do their macroscopic properties compare?

What do we think an ionic compound looks like at the particle level?

- Regular, repeating lattice structure
- Positive and negative ions held by attractive electrostatic force
- Every + ion surrounded by – ions
- Every – ion surrounded by + ions

Note: Model shows a solid. Ionic bonds are very strong, so it takes a lot of energy to make them molten (liquid). In the liquid state, the ions are free to move about.
Another Ionic Compound

\[ \text{NH}_4\text{Cl} \]

made of \( \text{NH}_4^+ \) ions and \( \text{Cl}^- \) ions

What do we think a molecular compound looks like at the particle level?

\( \text{H}_2\text{O} \) (s)

Water in the solid state

Covalent bonds

Hydrogen bond

Ch. 12 (next semester)
Another molecular compound

\[ C_{12}H_{22}O_{11} \] (s)

NaCl vs. Sucrose scanning electron microscope (SEM) “pictures”

NaCl (s) dried from a 10% aqueous solution

\[ 1 \, \mu m = 10^{-6} \, m \quad \text{and} \quad 1 \, nm = 10^{-9} \, m \]

For comparison:
- Na-Cl internuclear distance = 0.56 nm, therefore in 1 \( \mu \)m fit about 1800 Na-Cl units across
- Diameter of a sucrose molecule \( \approx \) 1 nm, therefore in 1 \( \mu \)m fit about 1000 sucrose molecules lengthwise

(Images from http://www.temcoinstrument.com/applications.html)
What you need to understand about bonding for now

**Ionic Compounds**
- Contain ions
- Held together by electrostatic attraction between + and – ions
- Ionic formula: simply the ratio of ions present in order for the compound to be neutral, cannot separate a unique unit

**Molecular Compounds**
- Do not contain ions
- Molecules held together by covalent bonds in which electrons from both atoms are attracted to the nuclei of both atoms in a bond
- In a molecular solid, one molecule held to the next by weaker forces of attraction
- Molecular formula: can separate unique molecules

What’s a Chemical Formula?
- Whole-number ratio of elements present in a compound
  - $\text{H}_2\text{O}$  $\text{CO}_2$  $\text{Na}_2\text{C}_2\text{O}_4$  $\text{KMnO}_4$
- Parentheses indicate groups (ions, functional groups, repeating groups)
  - $\text{Mg(C}_2\text{H}_3\text{O}_2)_2$  $\text{C(CH}_3)_3\text{Cl}$  $\text{CH}_3\text{(CH}_2)_4\text{CH}_3$
- Numbers follow (they don’t precede)
  - $\text{H}_2\text{O}$  $\text{H}_2\text{O}_2$
You need to be able to...

... distinguish between ionic and molecular compounds so that you can name them.

\[ \text{AlCl}_3 \quad \text{NH}_3 \quad \text{NH}_4\text{Cl} \]

\[ \text{C}_6\text{H}_{12}\text{O}_6 \quad \text{NaCH}_3\text{COO} \]

- Ionic compounds contain ions
- Molecular compounds have only nonmetals in them

Common Ions

- **Monatomic**
  - Group A elements have only one possible charge
  - Group B elements (transition metals) usually have more than one possible charge

- **Polyatomic**
  - See pp. 62 and 64 for lists of ions you need to memorize (name, formula, charge)
Naming Conventions

1. Ionic compounds
   - NaCl
   - Na₂CO₃
   - NH₄Br
   - FeCl₃
   - FeCl₂
   - Mg(C₂H₃O₂)₂
   - AgI
   - CuSO₄

Naming Conventions

1. Ionic compounds - binary
   - NaCl  sodium chloride
   - FeCl₃  iron (III) chloride
   - FeCl₂  iron (II) chloride
   - AgI    silver iodide
When the Metal is Multivalent

FeCl$_2$  
\[ \text{What charge must the Fe ion have?} \]  
\[ +2 \]
Iron (II) chloride

FeCl$_3$  
\[ \text{What charge must the Fe ion have?} \]  
\[ +3 \]
Iron (III) chloride

Naming Rules So Far

Compound to name

- Ionic
- Molecular

Binary (only two elements)

- Contains Transition metal
- No Transition metal

Contains Polyatomic Ion(s)
**Naming Conventions**

1. Ionic compounds – contains polyatomic

- Na$_2$CO$_3$ sodium carbonate
- NH$_4$Br ammonium bromide
- Mg(C$_2$H$_3$O$_2$)$_2$ magnesium acetate
- CuSO$_4$ copper (II) sulfate

**Naming Rules So Far**

- Compound to name
  - Ionic
  - Molecular
  - Binary (only two elements)
  - Contains Polyatomic Ion(s)
  - Contains Transition metal
  - No Transition metal
**Naming Rules So Far**

1. **Ionic**
2. **Molecular**
3. **Distinguish separate ions**
4. **Name ions:**
   - + ion first
   - - ion second

**Compound to name**

**Naming Conventions**

2. **Molecular compounds**
   - \( \text{NO}_2 \) nitrogen dioxide
   - \( \text{NO}_3 \) nitrogen trioxide
   - \( \text{N}_2\text{O}_4 \) dinitrogen tetroxide
   - \( \text{CO} \) carbon monoxide
   - \( \text{CO}_2 \) carbon dioxide
   - \( \text{P}_2\text{O}_5 \) diphosphorus pentoxide
   - \( \text{CH}_4 \) methane
   - \( \text{C}_2\text{H}_6 \) ethane

Read section 2.9 in your text – you will be responsible for knowing how to name simple organic compounds.
Counting to 10 in Greek to name binary molecular compounds

1. Mono
2. Bi
3. Tri
4. Tetr(a)-
5. Pent(a)-
6. Hex(a)-
7. Hept(a)-
8. Oct(a)-
9. Non(a)-
10. Dec(a)-

Naming Rules So Far

- **Compound to name**
  - Ionic
  - Distinguish separate ions
    - Name ions: + ion first - ion second
  - Molecular
    - Binary (not C & H)
      - Name in order, use prefixes
    - C & H or Not binary
      - Text § 2.9
  - Acids
Common Mistakes in Naming

- Look for ions vs. no ions
  - \( \text{NO}_3^- \text{ vs. NO}_3 \) nitrate ion vs. nitrogen trioxide

- If ionic compound, regardless of how many total atoms, it has only a first name (+ ion) and a last name (- ion)

\[
\begin{align*}
\text{LiHCO}_3 & \quad \text{NH}_4\text{CH}_3\text{COO} \\
\text{Li}^+ & \quad \text{HCO}_3^- & \quad \text{NH}_4^+ & \quad \text{CH}_3\text{COO}^- \\
\text{lithium} & \quad \text{hydrogen carbonate} & \quad \text{ammonium} & \quad \text{acetate}
\end{align*}
\]

Writing Formulas

- Formulas to names
  - Determine whether ionic or molecular
  - If ionic, name = (positive ion) (negative ion)
  - If molecular, use prefixes
  - Acids are special (name them backwards)

- Names to formulas
  - Translate the formula
  - If ionic, find ions, then balance charges
  - If molecular, read the prefixes
  - Acids are special (translate backwards)
Names to Ionic Formulas

Potassium chloride

\[ \text{What ratio makes a neutral ionic compound?} \]
\[ 1:1 \text{ ratio } \Rightarrow \text{formula is } \ce{KCl} \]

\[ \text{Manganese (V) hydroxide} \]

\[ \text{What ratio makes a neutral ionic compound?} \]
\[ 1:5 \text{ ratio } \Rightarrow \text{formula is } \ce{Mn(OH)5} \]

Names to Molecular Formulas

Dinitrogen pentoxide

\[ \text{N}_2\text{O}_5 \]

Sulfur hexabromide

\[ \text{SBr}_6 \]
Practice

Name these compounds
- NaNO₃
- (NH₄)S
- CrPO₄
- N₂O

Write formulas
- Calcium iodide
- Selenium trioxide
- Strontium hypochlorite
- Iron (III) oxalate

Naming Conventions

3. Acids

They look like ionic compounds, except that the positive ion is always H⁺

What would you name them if they were ionic compounds?
If acids were ionic compounds...

3. Acids

<table>
<thead>
<tr>
<th>Chemical Formula</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCl</td>
<td>Hydrogen chloride</td>
</tr>
<tr>
<td>H$_2$CO$_3$</td>
<td>Hydrogen carbonate</td>
</tr>
<tr>
<td>HBr</td>
<td>Hydrogen bromide</td>
</tr>
<tr>
<td>HOCl</td>
<td>Hydrogen hypochlorite</td>
</tr>
<tr>
<td>HClO</td>
<td>Hydrogen hypochlorite</td>
</tr>
<tr>
<td>HC$_2$H$_3$O$_2$</td>
<td>Hydrogen acetate</td>
</tr>
<tr>
<td>C$_2$H$_3$O$_2$H</td>
<td>Hydrogen acetate</td>
</tr>
<tr>
<td>HNO$_2$</td>
<td>Hydrogen nitrite</td>
</tr>
<tr>
<td>HNO$_3$</td>
<td>Hydrogen nitrate</td>
</tr>
</tbody>
</table>

But they’re not, so here’s how to name acids properly

3. Acids

<table>
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<td>Hydrogen hypochlorite</td>
</tr>
<tr>
<td>HClO</td>
<td>Hydrogen hypochlorite</td>
</tr>
<tr>
<td>HC$_2$H$_3$O$_2$</td>
<td>Hydrogen acetate</td>
</tr>
<tr>
<td>C$_2$H$_3$O$_2$H</td>
<td>Hydrogen acetate</td>
</tr>
<tr>
<td>HNO$_2$</td>
<td>Hydrogen nitrite</td>
</tr>
<tr>
<td>HNO$_3$</td>
<td>Hydrogen nitrate</td>
</tr>
</tbody>
</table>
What we did

**Compound to name**

- Acids
  - Binary acid
  - Anion ends in “-ate”
  - Anion ends in “-ite”
    - Hydro____ic acid
    - ____ic acid
    - ____ous acid

**Naming Conventions Summary**

First determine if the compound is ionic, molecular, or acid.

1. Ionic compounds
   - Binary or contain polyatomic ion(s)?
   - Can the metal cation have more than one oxidation state?

2. Molecular compounds
   - Binary (except not C and H)
   - Hydrocarbons (contains C and H)

3. Acids
   - Binary
   - Anion ends in “-ate”
   - Anion ends in “-ite”