Ch. 5 Notes: TYPES OF COMPOUNDS

I. Compounds in General
   A. compound ("cmpd.")—a substance formed from more than one element
      1) has more than one different capital letter… Al₂S₃, NaBr, Ca(OH)₂
      2) can be separated by chemical means
   B. molecule—a group of atoms with no net charge
   C. two general types of compounds
      1) molecular compound—composed of atoms
         • usually liquids or gases at room temp.
         • usually have a low melting point (m.p.) and boiling point (b.p.)
         • composed of nonmetals… like CO₂
      2) ionic compounds—composed of positive/negative ions
         • usually crystalline solids at room temp.
         • usually have a high melting point (m.p.) and boiling point (b.p.)
         • composed of metals and nonmetals… like NaCl

II. Chemical formulas
   A. chemical formula
      1) symbols representing the composition of the smallest unit of a substance
      2) shows which elements are present and how many there are
         \[ \text{H}_2\text{SO}_4 \] = hydrogen, sulfur, oxygen = 7 atoms total
   B. molecular formula—symbols representing the composition of a molecular compound
   C. formula unit—the lowest whole-number ratio of ions in an ionic compound
      1) It is improper to use the term “molecule” to describe an ionic compound.
      2) Ionic compounds occur in repeating units in their crystals (BCC, FCC, etc.).
   D. number codes
      1) subscript—a number written slightly below the symbol \[ \text{Br}_2 \]
      2) superscript—a number written slightly above the symbol \[ \text{Sr}^{2+} \]
         (In chem., a superscript is not called an exponent. Nothing is being multiplied.)

III. Common vs. Systematic Names: Why use naming rules at all?
   A. common names do not discuss chemical composition
   B. systematic names are a standardized way of naming compounds
   C. some common names for chemicals:
      asbestos = magnesium silicate
      aspirin = acetylsalicylic acid
      baking soda = sodium bicarbonate
      black lead = graphite
      borax = sodium borate
      brine = strong sodium chloride solution
      chalk = calcium carbonate
      drinking alcohol = ethanol
      Epsom salts = magnesium sulfate
      laughing gas = dinitrogen monoxide
      lime = calcium oxide
      lime, slaked = calcium hydroxide
      limewater = calcium hydroxide solution
      table salt = sodium chloride
      quicksilver = mercury
      silica = silicon dioxide
      soda ash, dry = dry sodium carbonate
      soda lye = sodium hydroxide
      soluble glass = sodium silicate
      talc or talcum = magnesium silicate
      water = H₂O
      water glass = sodium silicate
IV. Ionic Compounds

A. Metals form cations (+) nonmetals form anions (−)

B. Ionic charges of the elements

"Charge Chant": +1 +2 +3 mixed -3 -2 -1 0
+2 in the middle, unless they tell you otherwise

<table>
<thead>
<tr>
<th>Group number</th>
<th>IA</th>
<th>IIA</th>
<th>IIIA</th>
<th>IVA</th>
<th>VA*</th>
<th>VIA*</th>
<th>VIIA*</th>
<th>Vilia</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1+</td>
<td>2+</td>
<td>3+</td>
<td>M</td>
<td>3-</td>
<td>2-</td>
<td>1-</td>
<td>none</td>
</tr>
</tbody>
</table>

M: most of the Group IVA don’t usually form ions; when they do, there are mixed charges possible

C. Charge is also called oxidation number

D. Multiple charges (transition metals and others) — if an atom forms more than one charge, you must say which one it is:

1) Stock system uses number clues — this is the most common way to do it
2) Classical (Latin root) system

**IMPORTANT REFERENCE TABLE FOR IONS WITH MULTIPLE CHARGES:**

<table>
<thead>
<tr>
<th>ION FORMULA</th>
<th>STOCK NAME</th>
<th>CLASSICAL NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu⁺</td>
<td>copper(I) ion</td>
<td>cuprous ion</td>
</tr>
<tr>
<td>Cu²⁺</td>
<td>copper(II) ion</td>
<td>cupric ion</td>
</tr>
<tr>
<td>Fe²⁺</td>
<td>iron(II) ion</td>
<td>ferrous ion</td>
</tr>
<tr>
<td>Fe³⁺</td>
<td>iron(III) ion</td>
<td>ferric ion</td>
</tr>
<tr>
<td>Pb²⁺</td>
<td>lead(II) ion</td>
<td>plumbous ion</td>
</tr>
<tr>
<td>Pb⁴⁺</td>
<td>lead(IV) ion</td>
<td>plumbic ion</td>
</tr>
<tr>
<td>Sn²⁺</td>
<td>tin(II) ion</td>
<td>stannous ion</td>
</tr>
<tr>
<td>Sn⁴⁺</td>
<td>tin(IV) ion</td>
<td>stannic ion</td>
</tr>
<tr>
<td>Cr²⁺</td>
<td>chromium(II) ion</td>
<td>chromous ion</td>
</tr>
<tr>
<td>Cr³⁺</td>
<td>chromium(III) ion</td>
<td>chromic ion</td>
</tr>
<tr>
<td>Mn²⁺</td>
<td>manganese(II) ion</td>
<td>manganous ion</td>
</tr>
<tr>
<td>Mn³⁺</td>
<td>manganese(III) ion</td>
<td>manganic ion</td>
</tr>
<tr>
<td>Co²⁺</td>
<td>cobalt(II) ion</td>
<td>cobaltous ion</td>
</tr>
<tr>
<td>Co³⁺</td>
<td>cobalt(III) ion</td>
<td>cobaltic ion</td>
</tr>
<tr>
<td>Hg²⁺</td>
<td>mercury(I) ion</td>
<td>mercurous ion</td>
</tr>
<tr>
<td>Hg₂²⁺</td>
<td>mercury(II) ion</td>
<td>mercuric ion</td>
</tr>
</tbody>
</table>

3) One-charge transition metal ions: Ag⁺, Cd²⁺, Zn²⁺

VI. Binary compounds: binary ionic and binary molecular

A. Binary compound — composed of two elements

B. Binary ionic compound — ("BI") — metal cation / nonmetal anion combination

1) Compound composed of monatomic (one symbol) ions
2) Crisscross formula method is used
3) Name the cation first, then the anion (-IDE ending)
4) use Roman numerals if/when needed for the cation
5) examples:
CaBr$_2$ = calcium bromide        KI = potassium iodide        FeCl$_3$ = iron(III) chloride

C. “crisscross” formula method for ionic compounds
1) write the symbols of the two ions next to each other
2) write the charges as superscripts
3) balance the formula by crisscrossing the numbers  (net charge = 0)
4) the numbers are now subscripts, telling you how many of each symbol is in
   the formula
5) if the charges are the same, they cancel out
6) if the charges are multiples of each other, reduce them

EXAMPLE 1: calcium nitride
Ca$^{2+}$ and N$^{3-}$

EXAMPLE 2: aluminum chloride
Al$^{3+}$ and Cl$^{-}$

D. binary molecular compound— (“BM”)— nonmetal / nonmetal combination
1) no ionic charges involved (no crisscross)
2) ending in -IDE
3) since there are no charges to determine the ration of symbols, mandatory
   prefixes are used in naming:

<table>
<thead>
<tr>
<th>MONO-</th>
<th>DI-</th>
<th>TRI-</th>
<th>TETRA-</th>
<th>PENTA-</th>
<th>HEXA-</th>
<th>HEPTA-</th>
<th>OCTA-</th>
<th>NONA-</th>
<th>DECA-</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
</tbody>
</table>

(mono- is not used on the first element)

4) examples:
CCl$_4$ = carbon tetrachloride        BF$_3$ = boron trifluoride        CO = carbon monoxide

VII. Polyatomic ions
A. polyatomic ion—a group of charged atoms
B. most end in –ATE or –ITE
C. To avoid confusion, you may keep the parentheses around the polyatomic ion if
   there is only one polyatomic ion in the formula, but be aware that textbooks do not
   do this.

Example: sodium hydroxide may be written Na(OH) but will be shown in textbooks
and by the teacher as NaOH.
### POLYATOMIC IONS

Students must memorize these 20 ions.

<table>
<thead>
<tr>
<th>1⁺ CHARGE:</th>
<th>MORE 1- CHARGE:</th>
</tr>
</thead>
<tbody>
<tr>
<td>ammonium (NH₄)⁺</td>
<td>nitrite (NO₂⁻)</td>
</tr>
<tr>
<td></td>
<td>perchlorate (ClO₄⁻)</td>
</tr>
<tr>
<td></td>
<td>permanganate (MnO₄⁻)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1⁻ CHARGE:</th>
<th>2⁻ CHARGE:</th>
</tr>
</thead>
<tbody>
<tr>
<td>acetate (C₂H₃O₂⁻) or (CH₃COO)⁻</td>
<td>carbonate (CO₃)²⁻</td>
</tr>
<tr>
<td>chlorate (ClO₃⁻)</td>
<td>chromate (CrO₄)²⁻</td>
</tr>
<tr>
<td>chlorite (ClO₂⁻)</td>
<td>dichromate (Cr₂O₇)²⁻</td>
</tr>
<tr>
<td>cyanide (CN)⁻</td>
<td>silicate (SiO₃)²⁻</td>
</tr>
<tr>
<td>hydrogen carbonate or</td>
<td>sulfate (SO₄)²⁻</td>
</tr>
<tr>
<td>bicarbonate (HCO₃⁻)</td>
<td>sulfite (SO₃)²⁻</td>
</tr>
<tr>
<td>hydroxide (OH)⁻</td>
<td></td>
</tr>
<tr>
<td>hypochlorite (ClO)⁻</td>
<td></td>
</tr>
<tr>
<td>nitrate (NO₃⁻)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2⁻ CHARGE:</th>
<th>3⁻ CHARGE:</th>
</tr>
</thead>
<tbody>
<tr>
<td>nitrite (NO₂⁻)</td>
<td>phosphate (PO₄)³⁻</td>
</tr>
<tr>
<td>perchlorate (ClO₄⁻)</td>
<td>phosphite (PO₃)³⁻</td>
</tr>
<tr>
<td>permanganate (MnO₄⁻)</td>
<td></td>
</tr>
</tbody>
</table>

### VIII. Ternary Compounds

A. **ternary compound** — compound made up of three different elements

B. **ternary ionic compound** — (“TI”) — metal cation / nonmetal anion combination of three symbols, involving polyatomic ions

1) **crisscross formula method** is used

   - write the symbols of the two ions next to each other
   - be careful to keep the parentheses around the polyatomic ion
   - write the charges as superscripts
   - balance the formula by crisscrossing the numbers (net charge = 0)
   - the numbers are now subscripts, telling you how many of each symbol is in the formula
   - if the charges are the same, they cancel out
   - if the charges are multiples of each other, reduce them

**EXAMPLE 1:** strontium nitrate  
Sr²⁺ and (NO₃)⁻¹

**EXAMPLE 2:** aluminum sulfate  
Al³⁺ and (SO₄)²⁻

2) name the cation first, then the anion (-IDE ending)

3) use Roman numerals if/when needed for the cation
C. examples:
Na$_2$SO$_4$ = sodium sulfate  
KMnO$_4$ = potassium permanganate  
Fe(OH)$_3$ = iron(III) hydroxide

D. **ternary molecular compound**—(“TM”)— three nonmetals, involving polyatomic ions
1) acids are TM compounds
2) acids donate H$^+$ ions when in solution  
   HX $\rightarrow$ H$^+$ + X$^-$
3) examples:
   H$_2$SO$_4$ = sulfuric acid  
   HC$_2$H$_3$O$_2$ = acetic acid

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IX. Molecular Elements
A. diatomic elements

| \( \text{THE SEVEN DIATOMIC MOLECULES (“Super Seven”)}: \) |
|------------------|---|---|---|---|---|---|
| \( \text{H}_2 \) | \( \text{F}_2 \) | \( \text{O}_2 \) | \( \text{N}_2 \) | \( \text{Cl}_2 \) | \( \text{Br}_2 \) | \( \text{I}_2 \) |

B. **allotropes**—molecules of a single element that differ in crystalline or molecular structure
1) oxygen (O$_2$) and ozone (O$_3$)
2) C: graphite, diamond, charcoal, carbon black, linear, buckyballs (C$_{60}$)
3) P: white, red, black phosphorus
4) sulfur (S$_8$, S$_3$, S$_4$)
5) Sn: white and gray tin

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X. Hydrates
A. **water of hydration**—water molecules chemically integrated into a crystalline structure
B. **hydrate**—a compound with water in its structure
   1) general formula:  \([\text{compound}] \cdot \text{H}_2\text{O}\)
   2) naming:  \([\text{compound name}] \text{ (prefix)hydrate}\)
      - CuSO$_4$ $\cdot$ 5H$_2$O  = copper(II) sulfate pentahydrate
      - CaCl$_2$ $\cdot$ 2H$_2$O  = calcium chloride dehydrate
C. **anhydrous**—a hydrate without its water of hydration
   Na$_2$SO$_4$ $\cdot$ 2H$_2$O  $\rightarrow$  Na$_2$SO$_4$ + 2H$_2$O
   sodium sulfate dihydrate  
   anhydrous sodium sulfate + water
D. **efflorescence**—the release of water by a hydrate (heating not needed)
E. **hygroscopic**—removing water from the atmosphere
F. **deliquescence**
   1) absorbing excess water from the atmosphere to form a liquid substance
   2) this is an extreme hygroscopic condition
G. **desiccant**
   1) a **drying agent** which is hygroscopic
   2) examples:  Damp Rid; packets of silica powder in shoe boxes