Chapter 5
Molecules and Compounds

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Chem 118
Introductory Chemistry

Map: Introductory Chemistry (Tro) https://chem.libretexts.org/@go/page/45050 (accessed Mar 25, 2022).

Molecules and Compounds

- Salt
  - ✓ Sodium—shiny, reactive, poisonous.
  - ✓ Chlorine—pale yellow gas, reactive, poisonous.
  - ✓ Sodium chloride—table salt.
- Sugar
  - ✓ Carbon—pencil or diamonds.
  - ✓ Hydrogen—flammable gas.
  - ✓ Oxygen—a gas in air.
  - ✓ Combine to form white crystalline sugar.

Law of Constant Composition

Law of Constant Composition

- All pure substances have constant composition.
  - ✓ All samples of a pure substance contain the same elements in the same percentages (ratios).
  - ✓ Mixtures have variable composition.

Compounds Display Constant Composition

If we decompose water by electrolysis, we find 16.0 grams of oxygen to every 2.00 grams of hydrogen.

Water has a constant mass ratio of oxygen to hydrogen of 8.0.

$$\text{Mass Ratio} = \frac{\text{mass of oxygen}}{\text{mass of hydrogen}}$$

$$= \frac{16.0\text{ g}}{2.0\text{ g}} = 8.0$$

Example 5.1—Show that Two Samples of Carbon Dioxide Are Consistent with the Law of Constant Composition.

Given:	Sample 1: 4.8 g O, 1.8 g C; Sample 2: 17.1 g O, 6.4 g C
Find:	proportion O:C
Solution Map:	element masses → compound composition
Relationships:	composition = mass O : mass C
Solution:	Sample 1: $\frac{4.8\text{ g O}}{1.8\text{ g C}} = 2.7$ Sample 2: $\frac{17.1\text{ g O}}{6.4\text{ g C}} = 2.7$
Compare:	Since both samples have the same proportion of elements, carbon dioxide shows constant composition.

Example 5.1—Show that Two Samples of Hematite Are Consistent with the Law of Constant Composition.

Given:	Sample 1: 7.2 g Fe, (10.0-7.2) = 2.8 g O; Sample 2: 18.1 g Fe, 6.91 g O
Find:	proportion Fe:O
Solution Map:	element masses → compound composition
Relationships:	composition = mass Fe : mass O
Solution:	Sample 1: $\frac{7.2\text{ g Fe}}{2.8\text{ g O}} = 2.6$ Sample 2: $\frac{18.1\text{ g Fe}}{6.91\text{ g O}} = 2.61$
Compare:	Since both samples have the same proportion of elements, hematite shows constant composition.

Why Do Compounds Show Constant Composition?

- The smallest piece of a compound is called a **molecule**.
- Every molecule of a compound has the same number and type of atoms.
- Since all the molecules of a compound are identical, every sample will have the same ratio of the elements.
- Since all molecules of a compound are identical, every sample of the compound will have the same properties.

Chemical Formulas

Formulas Describe Compounds

- A compound is a distinct substance that is composed of atoms of two or more elements.
- Describe the compound by describing the number and type of each atom in the simplest unit of the compound.
  - ✓ Molecules or ions.
- Each element is represented by its letter symbol.
- The number of atoms of each element is written to the right of the element as a subscript.
  - ✓ If there is only one atom, the 1 subscript is not written.
- Polyatomic groups are placed in parentheses.
  - ✓ If more than one.

Formulas Describe Compounds, Continued

Water = H_2O ∴ two atoms of hydrogen and 1 atom of oxygen

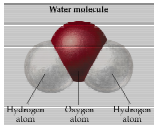
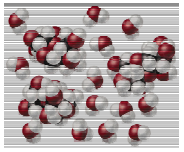


Table sugar = $C_{12}H_{22}O_{11}$ ∴12 atoms of C, 22 atoms of H and 11 atoms O



Order of Elements in a Formula

- Metals are written first.
  - ✓ NaCl
- Nonmetals are written in order from Table 5.1.
  - ✓ CO_2
  - ✓ There are occasional exceptions for historical or informational reasons.
    - ➢ H_2O, but NaOH .

Table 5.1 Order of Listing Nonmetals in Chemical Formulas	C	P	N	H	S	I	Br	Cl	O	F

Practice—Write Formulas for Each of the Following Compounds.

- Hematite—Composed of four oxide ions for every three iron ions. Fe_3O_4
- Acetone—Each molecule contains six hydrogen atoms, three carbon atoms, and one oxygen atom. C_3H_6O

Polyatomics

- Certain groups of atoms are bonded together to form what is called a polyatomic ion that acts as a single unit

Table 5.5.1: Some Polyatomic Ions

Name	Formula
ammonium ion	NH_4^+
acetate ion	$C_2H_3O_2^-$ (also written $CH_3CO_2^-$)
carbonate ion	CO_3^{2-}
chromate ion	CrO_4^{2-}
dichromate ion	$Cr_2O_7^{2-}$
hydrogen carbonate ion (bicarbonate ion)	HCO_3^-
cyanide ion	CN^-
hydroxide ion	OH^-
nitrate ion	NO_3^-
nitrite ion	NO_2^-
permanganate ion	MnO_4^-
phosphate ion	PO_4^{3-}
hydrogen phosphate ion	HPO_4^{2-}
dihydrogen phosphate ion	$H_2PO_4^-$
sulfate ion	SO_4^{2-}
hydrogen sulfate ion (bisulfate ion)	HSO_4^-
sulfite ion	SO_3^{2-}

Molecules with Polyatomic Ions

Symbol of the polyatomic ion called **nitrate**.

$Mg(NO_3)_2$

Compound called magnesium nitrate.

Implied "1" subscript on magnesium.

Parentheses to group two NO_3s.

Symbol of the polyatomic ion called **sulfate**.

$CaSO_4$

Compound called calcium sulfate.

Implied "1" subscript on calcium.

No parentheses for one SO_4.

Molecules with Polyatomic Ions, Continued

Subscript indicating two NO_3 groups.

$Mg(NO_3)_2$

Compound called magnesium nitrate.

Implied "1" subscript on nitrogen, total 2 N.

Stated "3" subscript on oxygen, total 6 O.

No subscript indicating one SO_4 group.

$CaSO_4$

Compound called calcium sulfate.

Implied "1" subscript on sulfur, total 1 S.

Stated "4" subscript on oxygen, total 4 O.

Practice—Determine the Total Number of Atoms or Ions in One Formula Unit of Each of the Following.

- $Mg(C_2H_3O_2)_2$ 1 Mg + 4 C + 6 H + 4 O = 15
- $Hg_6(PO_4)_2$ 6 Hg + 2 P + 8 O = 16

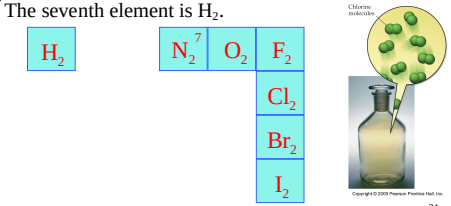
Material Classifications

Classifying Materials

- **Atomic elements** = Elements whose particles are single atoms.
- **Molecular elements** = Elements whose particles are multi-atom molecules.
- **Molecular compounds** = Compounds whose particles are molecules made of only nonmetals.
- **Ionic compounds** = Compounds whose particles are cations and anions.

Molecular Elements

- Certain elements occur as diatomic molecules.
- 7 diatomic elements—The Rule of 7s
  - ✓Find the element with atomic number 7, N.
  - ✓Make a figure 7 by going over to Group 17, then down.
  - ✓The seventh element is H_2.

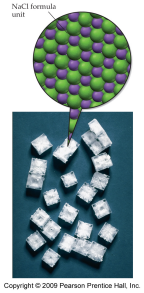


Molecular Compounds

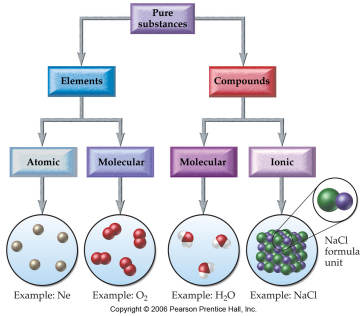
- Two or more nonmetals.
- Smallest unit is a molecule.

Ionic Compounds

- Metals + nonmetals.
- No individual molecule units, instead have a 3-dimensional array of cations and anions made of **formula units**.



Molecular View of Elements and Compounds



Classify Each of the Following as Either an Atomic Element, Molecular Element, Molecular Compound, or Ionic Compound.

- Aluminum, Al.
- Aluminum chloride, $AlCl_3$.
- Chlorine, Cl_2.
- Acetone, C_3H_6O.
- Carbon monoxide, CO.
- Cobalt, Co.

Classify Each of the Following as Either an Atomic Element, Molecular Element, Molecular Compound, or Ionic Compound, Continued.

- Aluminum, Al = Atomic element.
- Aluminum chloride, $AlCl_3$ = Ionic compound.
- Chlorine, Cl_2 = Molecular element.
- Acetone, C_3H_6O = Molecular compound.
- Carbon monoxide, CO = Molecular compound.
- Cobalt, Co = Atomic element.

Ionic Compound Formulas

Ionic Compounds

- Ionic compounds are made of ions.
- Ionic compounds always contain cations and anions.
  - ✓Cations = + charged ions; anions = − charged ions.
- The sum of the + charges of the cations must equal the sum of the − charges of the anions.
- If Na^+ is combined with S^{2-}, you will need 2 Na^+ ions for every S^{2-} ion to balance the charges, therefore the formula must be Na_2S.

Writing Formulas for Ionic Compounds

1. Write the symbol for the metal cation and its charge.
2. Write the symbol for the nonmetal anion and its charge.
3. Charge (without sign) becomes subscript for the other ion.
4. Reduce subscripts to smallest whole-number ratio.
5. Check that the sum of the charges of the cation cancels the sum of the anions.

Write the Formula of a Compound Made from Aluminum Ions and Oxide Ions.

1. Write the symbol for the metal cation and its charge. Al^{+3} (Group 13)
2. Write the symbol for the nonmetal anion and its charge. O^{2-} (Group 16)
3. Charge (without sign) becomes subscript for the other ion. $Al^{+3}\ O^{2-}$
4. Reduce subscripts to smallest whole-number ratio. Al_2O_3
5. Check that the total charge of the cations cancels the total charge of the anions. Al = (2)·(+3) = +6; O = (3)·(-2) = -6

Practice—What Are the Formulas for Compounds Made from the Following Ions?

- Potassium ion with a nitride ion.
- Calcium ion with a bromide ion.
- Aluminum ion with a sulfide ion.

Practice—What Are the Formulas for Compounds Made from the Following Ions?, Continued

- K^+ with N^{3-} K_3N
- Ca^{+2} with Br^- $CaBr_2$
- Al^{+3} with S^{2-} Al_2S_3

Formula-to-Name Step 1

Is the compound one of the exceptions to the rules?

Common Names—Exceptions

- H_2O = Water, steam, ice.
- NH_3 = Ammonia.
- CH_4 = Methane.
- NaCl = Table salt.
- $C_{12}H_{22}O_{11}$ = Table sugar.

Formula-to-Name Step 2

What major class of compound is it?
Ionic or Molecular?

Major Classes

- Ionic compounds.
  - ✓Metal + nonmetal(s).
    - ➢Metal first in formula.
  - ✓Binary ionic or compounds with polyatomic ions.
- Molecular compounds.
  - ✓2 or more nonmetals.
  - ✓Binary molecular (or binary covalent).
    - ➢2 nonmetals.
  - ✓***Acids*—**Formula starts with H.
    - ➢Though acids are molecular, they behave as ionic when dissolved in water.
    - ➢May be binary or oxyacid.

Formula-to-Name Step 3

What major subclass of compound is it?
Binary Ionic, Ionic with Polyatomic Ions,
Binary Molecular,
Binary Acid, or Oxyacid?

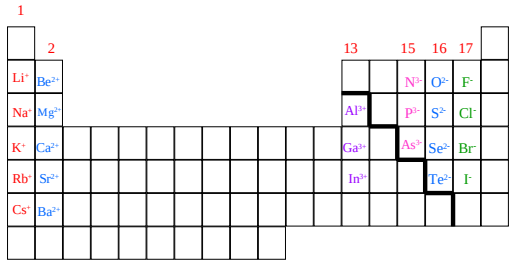
Classifying Compounds

- Compounds containing a metal and a nonmetal = ***Binary ionic.***
  - ✓Type I and II.
- Compounds containing a polyatomic ion = ***Ionic with polyatomic ion.***
- Compounds containing two nonmetals = ***Binary molecular compounds.***
- Compounds containing H and a nonmetal = ***Binary acids.***
- Compounds containing H and a polyatomic ion = ***Oxyacids.***

Formula-to-Name Step 4

Apply rules for the class and subclass.

Formula-to-Name Ionic Compounds



Formula-to-Name Rules for Ionic

- Made of cation and anion.
- Name by simply naming the ions.
  - ✓If cation is:
    - ➢Type I metal = Metal name.
    - ➢Type II metal = Metal name (charge).
    - ➢Polyatomic ion = Name of polyatomic ion.
  - ✓If anion is:
    - ➢Nonmetal = Stem of nonmetal name + ***-ide***.
    - ➢Polyatomic ion = Name of polyatomic ion.

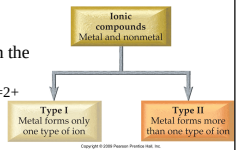
Monatomic Nonmetal Anion

- Determine the charge from position on the periodic table.
- To name anion, change ending on the element name to ***–ide***.

15 = -3	16 = -2	17 = -1
N = Nitride	O = Oxide	F = Fluoride
P = Phosphide	S = Sulfide	Cl = Chloride

Metal Cations

- Type I
  - ✓Metals whose ions can only have one possible charge.
    - ➢1, 2, (Al, Ga, Zn, etc.)
  - ✓Determine charge by position on the periodic table.
    - ➢1 = +, 2 = 2+, Al = 3+, Ga=3+ Zn=2+
  - ✓Some need to be memorized.
    - ➢Zn = 2+, Ag = +.
- Type II
  - ✓Metals whose ions can have more than one possible charge.
  - ✓Determine charge by charge on anion.



How do you know a metal cation is Type II?

Determine if the Following Metals are Type I or Type II. If Type I, Determine the Charge on the Cation it Forms.

- Lithium, Li.
- Copper, Cu.
- Gallium, Ga.
- Tin, Sn.
- Strontium, Sr.

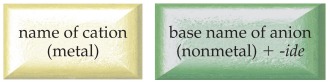
Determine if the Following Metals are Type I or Type II. If Type I, Determine the Charge on the Cation it Forms, Continued.

• Lithium, Li	Type I	1+
• Copper, Cu	Type II	
• Gallium, Ga	Type I	3+
• Tin, Sn	Type II	
• Strontium, Sr	Type I	2+

Type I Binary Ionic Compounds

- Contain metal cation + nonmetal anion.
- Metal listed first in formula and name.

1. Name metal cation first, name nonmetal anion second.
2. Cation name is the metal name.
3. Nonmetal anion named by changing the ending on the nonmetal name to ***–ide.***



Example—Naming Binary Ionic, Type I Metal, CsF

1. Is it one of the common exceptions?
   H_2O, NH_3, CH_4, NaCl, $C_{12}H_{22}O_{11}$ = No!
2. Identify major class.
   Cs is a metal because it is on the left side of the periodic table.
   F is a nonmetal because it is on the right side of the periodic table.
   ∴ Ionic.
3. Identify the subclass.
   2 elements, ∴ Binary ionic.
4. Is the metal Type I or Type II?
   Cs is in Group 1, ∴ Type I.

Example—Naming Binary Ionic, Type I Metal, CsF, Continued

5. Identify cation and anion.
   $Cs = Cs^+$ because it is Group 1.
   $F = F^-$ because it is Group 17.
6. Name the cation.
   Cs^+ = cesium.
7. Name the anion.
   F^- = fluoride.
8. Write the cation name first, then the anion name.
   cesium fluoride.

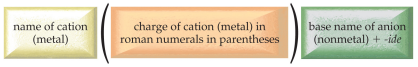
Practice—Name the Following Compounds.

- KCl **potassium chloride**
- $MgBr_2$ **magnesium bromide**
- Al_2S_3 **aluminum sulfide**

Type II Binary Ionic Compounds

- Contain metal cation + nonmetal anion.
- Metal listed first in formula and name.

1. Name metal cation first, name nonmetal anion second.
2. Metal cation name is the metal name followed by a roman numeral in parentheses to indicate its charge.
   - ✓ Determine charge from anion charge.
   - ✓ Common Type II cations in Table 5.7.1.
3. Nonmetal anion named by changing the ending on the nonmetal name to ***–ide***.



Determining the Charge on a Variable Charge Cation—Au_2S_3

1. Determine the charge on the anion.
   Au_2S_3 - the anion is S, since it is in Group 16, its charge is 2−.
2. Determine the total negative charge.
   Since there are 3 S in the formula, the total negative charge is −6.
3. Determine the total positive charge.
   Since the total negative charge is −6, the total positive charge is +6.
4. Divide by the number of cations.
   Since there are 2 Au in the formula and the total positive charge is +6, each Au has a 3+ charge.

Example—Writing Formula for a Binary Ionic Compound Containing Variable Charge Metal, Manganese(IV) Sulfide

1. Write the symbol for the cation and its charge. Mn^{+4}
2. Write the symbol for the anion and its charge. S^{2-}
3. Charge (without sign) becomes subscript for the other ion. $Mn^{+4}S^{2-}$ Mn_2S_4
4. Reduce subscripts to smallest whole-number ratio. MnS_2
5. Check that the total charge of the cations cancels the total charge of the anions. Mn = (1)·(+4) = +4, S = (2)·(-2) = -4

Practice—What Are the Formulas for Compounds Made from the Following Ions?

1. Copper(II) ion with a nitride ion.
2. Iron(III) ion with a bromide ion.

Practice—What Are the Formulas for Compounds Made from the Following Ions?, Continued

1. Cu^{2+} with N^{3-} Cu_3N_2
2. Fe^{+3} with Br^- $FeBr_3$

Practice—Name the Following Compounds, Continued.

- $TiCl_4$ **Titanium(IV) chloride**
  Cl = 4(−1) = −4
  Ti = +4 = 1(4+)
- $PbBr_2$ **Lead(II) bromide**
  Br = 2(−1) = −2
  Pb = +2 = 1(2+)
- Fe_2S_3 **Iron(III) sulfide**
  S = 3(−2) = −6
  Fe = +6 = 2(3+)

Compounds Containing Polyatomic Ions

- Polyatomic ions are single ions that contain more than one atom.
- Name any ionic compound by naming cation first and then anion.
  - ✓ Non-polyatomic cations named like Type I and II.
  - ✓ Non-polyatomic anions named with ***–ide***.

Some Common Polyatomic Ions

Name	Formula
Acetate	$C_2H_3O_2^-$
Carbonate	CO_3^{2-}
Hydrogencarbonate (aka bicarbonate)	HCO_3^-
Hydroxide	OH^-
Nitrate	NO_3^-
Nitrite	NO_2^-
Chromate	CrO_4^{2-}
Dichromate	$Cr_2O_7^{2-}$
Ammonium	NH_4^+

Name	Formula
Hypochlorite	ClO^-
Chlorite	ClO_2^-
Chlorate	ClO_3^-
Perchlorate	ClO_4^-
Sulfate	SO_4^{2-}
Sulfite	SO_3^{2-}
Hydrogen sulfate (aka bisulfate)	HSO_4^-
Hydrogen sulfite (aka bisulfite)	HSO_3^-

Example—Writing Formula for an Ionic Compound Containing Polyatomic Ion, Iron(III) phosphate

1. Write the symbol for the cation and its charge. Fe^{+3}
2. Write the symbol for the anion and its charge. PO_4^{3-}
3. Charge (without sign) becomes subscript for the other ion. $Fe^{+3}PO_4^{3-}$ $Fe_3(PO_4)_3$
4. Reduce subscripts to smallest whole-number ratio. $FePO_4$
5. Check that the total charge of the cations cancels the total charge of the anions. Fe = (1)·(+3) = +3, PO_4 = (1)·(-3) = -3

Practice—What Are the Formulas for Compounds Made from the Following Ions?

1. Aluminum ion with a sulfate ion.
2. Chromium(II) with hydrogencarbonate.

Practice—What Are the Formulas for Compounds Made from the Following Ions?, Continued

1. Al^{+3} with SO_4^{2-} $Al_2(SO_4)_3$
2. Cr^{+2} with HCO_3^- $Cr(HCO_3)_2$

Patterns for Polyatomic Ions

1. Elements in the same column form similar polyatomic ions.
   - ✓ Same number of Os and same charge.
   ClO_3^- = chlorate ∴ BrO_3^- = bromate.
2. If the polyatomic ion starts with H, the name adds ***hydrogen***- prefix before it and 1is added to the charge.
   CO_3^{2-} = carbonate ∴ HCO_3^{-1} = hydrogencarbonate.

Periodic Pattern of Polyatomic Ions *-ate* Groups

3A	4A	5A	6A	7A
BO_3^{-3}	**CO_3^{-2}**	**NO_3^{-1}**		
	SiO_3^{-2}	**PO_4^{-3}**	**SO_4^{-2}**	**ClO_3^{-1}**
		AsO_4^{-3}	SeO_4^{-2}	BrO_3^{-1}
			TeO_4^{-2}	IO_3^{-1}

Patterns for Polyatomic Ions

- ***-ate*** ion.
  - ✓ Chlorate = ClO_3^{-1}.
- ***-ate*** ion + 1 O ⇒ same charge, ***per-*** prefix.
  - ✓ Perchlorate = ClO_4^{-1}.
- ***-ate*** ion – 1 O ⇒ same charge, ***-ite*** suffix.
  - ✓ Chlorite = ClO_2^{-1}.
- ***-ate*** ion – 2 O ⇒ same charge, ***hypo-*** prefix, ***-ite*** suffix.
  - ✓ Hypochlorite = ClO^{-1}.

Example—Naming Ionic with Polyatomic Ion, Na_2SO_4

1. Is it one of the common exceptions?
   H_2O, NH_3, CH_4, NaCl, $C_{12}H_{22}O_{11}$ = No!
2. Identify major class.
   Na is a metal because it is on the left side of the periodic table.
   SO_4 is a polyatomic ion.
   ∴ Ionic
3. Identify the subclass.
   Compound has 3 elements ∴ Ionic with polyatomic ion.
4. Is the metal Type I or Type II?
   Na is in Group 1, ∴ Type I.

Example—Naming Ionic with Polyatomic Ion, Na_2SO_4, Continued

5. Identify the ions.
   $Na = Na^+$ (Group 1)
   $SO_4 = SO_4^{2-}$ (Polyatomic Table)
6. Name the cation.
   Na^+ = sodium
7. Name the anion.
   SO_4^{2-} = sulfate
8. Write the name of the cation followed by the name of the anion.
   sodium sulfate

Example—Naming Ionic with Polyatomic Ion, $Fe(NO_3)_3$

1. Is it one of the common exceptions?
   H_2O, NH_3, CH_4, NaCl, $C_{12}H_{22}O_{11}$ = No!
2. Identify major class.
   Fe is a metal because it is on the left side of the periodic table.
   NO_3 is a polyatomic ion because it is in ( ).
   ∴ Ionic.
3. Identify the subclass.
   There are 3 elements ∴ Ionic with polyatomic ion.
4. Is the metal Type I or Type II?
   Fe is not in Group 1, 2, or (Al, Zn, Ag) ∴ Type II.

Example—Naming Ionic with Polyatomic Ion, $Fe(NO_3)_3$, Continued

5. Identify the ions.
   $NO_3 = NO_3^-$ a polyatomic ion.
   $Fe = Fe^{3+}$ to balance the charge of the 3 NO_3^-.
6. Name the cation.
   Fe^{3+} = iron(III) (Type II).
7. Name the anion.
   NO_3^- = nitrate.
8. Write the name of the cation followed by the name of the anion.
   iron(III) nitrate.

Practice—Name the Following

1. NH_4Cl
2. $Ca(C_2H_3O_2)_2$
3. $Cu(NO_3)_2$

Practice—Name the Following, Continued

1. NH_4Cl Ammonium chloride.
2. $Ca(C_2H_3O_2)_2$ Calcium acetate.
3. $Cu(NO_3)_2$ Copper(II) nitrate.
   $NO_3 = 2(-1) = -2$
   $Cu = +2 = 1(2+)$

Formula-to-Name Rules for Molecular Compounds

Binary Molecular Compounds of Two Nonmetals

1. Name first element in formula first.
   ✓ Use the full name of the element.
2. Name the second element in the formula with an ***–ide,*** as if it were an anion.
   ✓ However, remember these compounds do not contain ions!
3. Use a prefix in front of each name to indicate the number of atoms.
   ✓ Never use the prefix ***mono-*** on the first element.

Subscript—Prefixes

- 1 = ***mono-***
  ✓ Not used on first nonmetal.
- 2 = ***di-***
- 3 = ***tri-***
- 4 = ***tetra-***
- 5 = ***penta-***
- 6 = ***hexa-***
- 7 = ***hepta-***
- 8 = ***octa-***
- Drop last "a" if name begins with vowel.

Example—Naming Binary Molecular, BF_3

1. Is it one of the common exceptions?
   H_2O, NH_3, CH_4, NaCl, $C_{12}H_{22}O_{11}$ = No!
2. Identify major class.
   B is a nonmetal because it is on the right side of the periodic table.
   F is a nonmetal because it is on the right side of the periodic table.
   ∴ Molecular.
3. Identify the subclass.
   2 elements, ∴ Binary molecular.

Example—Naming Binary Molecular, BF_3, Continued

4. Name the first element.
   boron.
5. Name the second element with an ***–ide.***
   Fluorine ⇒ fluoride.
6. Add a prefix to each name to indicate the subscript.
   monoboron trifluoride.
7. Write the first element with prefix, then the second element with prefix.
   ✓ Drop prefix ***mono-*** from first element.
   boron trifluoride.

Practice—Name the Following Continued

- NO_2 Nitrogen dioxide.
- PCl_5 Phosphorus pentachloride.
- I_2F_7 Diiodine heptafluoride.

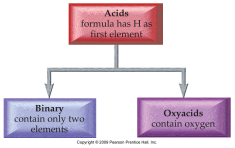
Acids

Acids

- Acids are molecular compounds that form H^+ when dissolved in water.
  ✓ To indicate the compound is dissolved in water, (*aq*) is written after the formula.
  ➢ Not named as acid if not dissolved in water.
- Sour taste.
- Dissolve many metals.
  ✓ Like Zn, Fe, Mg, but not Au, Ag, Pt.
- Formula generally starts with H.
  ✓ E.g., HCl, H_2SO_4.

Acids, Continued

- Contain H^{+1} cation and anion.
  ✓ In aqueous solution.
- Binary acids have H^{+1} cation and nonmetal anion.
- Oxyacids have H^{+1} cation and polyatomic anion.



Writing Formulas for Acids

- When name ends in ***acid***, formulas starts with ***H***.
- ***Hydro-*** prefix means it is binary acid, no prefix means it is an oxyacid.
- For an oxyacid, if ending is ***–ic***, polyatomic ion ends in ***–ate***; if ending is ***–ous***, polyatomic ion ends in ***–ite***.

Example—Binary Acids, Hydrosulfuric Acid

1. Write the symbol for the cation and its charge. H^+ — In all acids, the cation is H^+.
2. Write the symbol for the anion and its charge. S^{2-} — ***Hydro-*** means binary.
3. Charge (without sign) becomes subscript for the other ion. H^+S^{2-} H_2S
4. Add (*aq*) to indicate dissolved in water. H_2S (*aq*)
5. Check that the total charge of the cations cancels the total charge of the anions. $H = (2)\cdot(+1) = +2$ $S = (1)\cdot(-2) = -2$

Example—Oxyacids, Carbonic Acid

1. Write the symbol for the cation and its charge.
2. Write the symbol for the anion and its charge.
3. Charge (without sign) becomes subscript for the other ion.
4. Add (*aq*) to indicate dissolved in water.
5. Check that the total charge of the cations cancels the total charge of the anions.

H^+

CO_3^{2-}

In all acids, the cation is H^+. No ***hydro-*** means polyatomic ion.

-ic means ***-ate*** ion.

$H^+ CO_3^{2-}$ H_2CO_3

$H_2CO_3(aq)$

$H = (2)\cdot(+1) = +2$

$CO_3 = (1)\cdot(-2) = -2$

Example—Oxyacids, Sulfurous Acid

1. Write the symbol for the cation and its charge.
2. Write the symbol for the anion and its charge.
3. Charge (without sign) becomes subscript for the other ion.
4. Add (*aq*) to indicate dissolved in water.
5. Check that the total charge of the cations cancels the total charge of the anions .

H^+

SO_3^{2-}

In all acids, the cation is H^+. No ***hydro-*** means polyatomic ion.

-ous means ***-ite*** ion.

$H^+ SO_3^{2-}$ H_2SO_3

$H_2SO_3(aq)$

$H = (2)\cdot(+1) = +2$

$SO_3 = (1)\cdot(-2) = -2$

Practice—What Are the Formulas for the Following Acids?

1. Chlorous acid
2. Phosphoric acid
3. Hydrobromic acid

Practice—What Are the Formulas for the Following Acids?, Continued

1. H^+ with ClO_2^- $HClO_2$
2. H^+ with PO_4^{3-} H_3PO_4
3. H^+ with Br^- HBr

Naming Binary Acids

- Write a ***hydro-*** prefix.
- Follow with the nonmetal name.
- Change ending on nonmetal name to ***–ic***.
- Write the word ***acid*** at the end of the name.

Example—Naming Binary Acids, HCl

1. Is it one of the common exceptions?

   H_2O, NH_3, CH_4, NaCl, $C_{12}H_{22}O_{11}$ = No!
2. Identify major class.

   First element listed is H, ∴ Acid.
3. Identify the subclass.

   2 elements, ∴ Binary acid.

Example—Naming Binary Acids, HCl, Continued

4. Identify the anion.

   $Cl = Cl^-$ (Group 17)
5. Name the anion with an ***–ic*** suffix.

   Cl^- = **chloride ⇒ chloric**
6. Add a ***hydro-*** prefix to the anion name.

   hydrochloric
7. Add the word ***acid*** to the end.

   hydrochloric acid

Naming Oxyacids

- If polyatomic ion name ends in ***–ate***, then change ending to ***–ic*** suffix.
- If polyatomic ion name ends in ***–ite***, then change ending to ***–ous*** suffix.
- Write word ***acid*** at end of all names.

Example—Naming Oxyacids, H_2SO_4

1. Is it one of the common exceptions?

   H_2O, NH_3, CH_4, NaCl, $C_{12}H_{22}O_{11}$ = No!
2. Identify major class.

   First element listed is H, ∴ Acid.
3. Identify the subclass.

   3 elements in the formula, ∴ Oxyacid.

Example—Naming Oxyacids, H_2SO_4,Continued

4. Identify the anion.

   $SO_4 = SO_4^{2-}$ = **sulfate.**
5. If the anion has ***–ate*** suffix, change it to ***–ic***. If the anion has ***–ite*** suffix, change it to ***–ous.***

   SO_4^{2-} = **sulfate ⇒ sulfuric**.
6. Write the name of the anion followed by the word ***acid.***

   sulfuric acid

   (This is kind of an exception, to make it sound nicer!)

Example—Naming Oxyacids, H_2SO_3

1. Is it one of the common exceptions?

   H_2O, NH_3, CH_4, NaCl, $C_{12}H_{22}O_{11}$ = No!
2. Identify major class.

   First element listed is H, ∴ Acid.
3. Identify the subclass.

   3 elements in the formula, ∴ Oxyacid.

Example—Naming Oxyacids, H_2SO_3, Continued

4. Identify the anion.

   $SO_3 = SO_3^{2-}$ = sulfite
5. If the anion has ***–ate*** suffix, change it to ***–ic***. If the anion has ***–ite*** suffix, change it to ***–ous.***

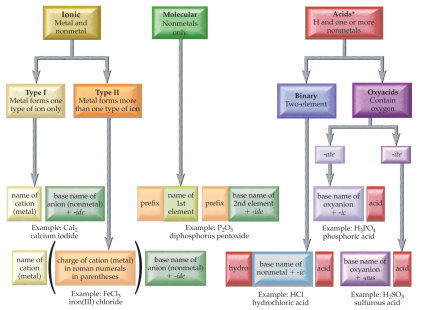
   SO_3^{2-} = **sulfite ⇒ sulfurous**
6. Write the name of the anion followed by the word ***acid.***

   sulfurous acid

Practice—Name the Following

1. H_2S **hydrosulfuric acid**
2. $HClO_3$ **chloric acid**
3. HNO_2 **nitrous acid**

Formula-to-Name Flowchart



Formula Mass

- The mass of an individual molecule or formula unit.
- Also known as molecular mass or molecular weight.
- Sum of the masses of the atoms in a single molecule or formula unit.

Mass of 1 molecule of H_2O?

$(2\ \text{H} \times 1.008\ \text{amu}) + (1\ \text{O} \times 16.00\ \text{amu}) = 18.02\ \text{amu}$

Practice—Calculate the Formula Mass of $Al_2(SO_4)_3$.

Al	=	2×	26.98 amu
S	=	3×	32.07 amu
O	=	12×	16.00 amu
$Al_2(SO_4)_3$	=		342.17 amu