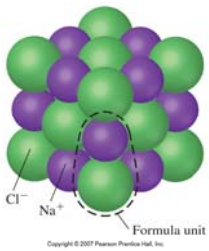
Atoms, Molecules and Compounds

Classes of Compounds:

- **Ionic:** Held together by electrostatic attraction described by Coulomb's law (ionic bonds)
  - Smallest unit: formula unit
  - Salts (NaCl)
  - Typically contain metals (not always!)



- **Covalent:** Held together by sharing of electrons (covalent bonds)
  - Smallest unit: molecule
  - Water, methane, carbon dioxide
  - Typically do not contain metals (not always!)

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Representing Molecules

Working at a "symbolic" level

Empirical Formula:

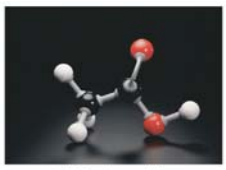
- Simplest whole-number ratios for atoms in compound

Molecular Formula:

- Represents the number and type of atoms in a molecule
- Provides little (if any structural information)

Example: C_4H_8

Visualizing Molecules:

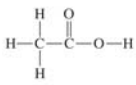


Molecular model:
("ball-and-stick")

Empirical formula: CH_2O

Molecular formula: $C_2H_4O_2$

Structural formula:



Molecular model:
("space-filling")

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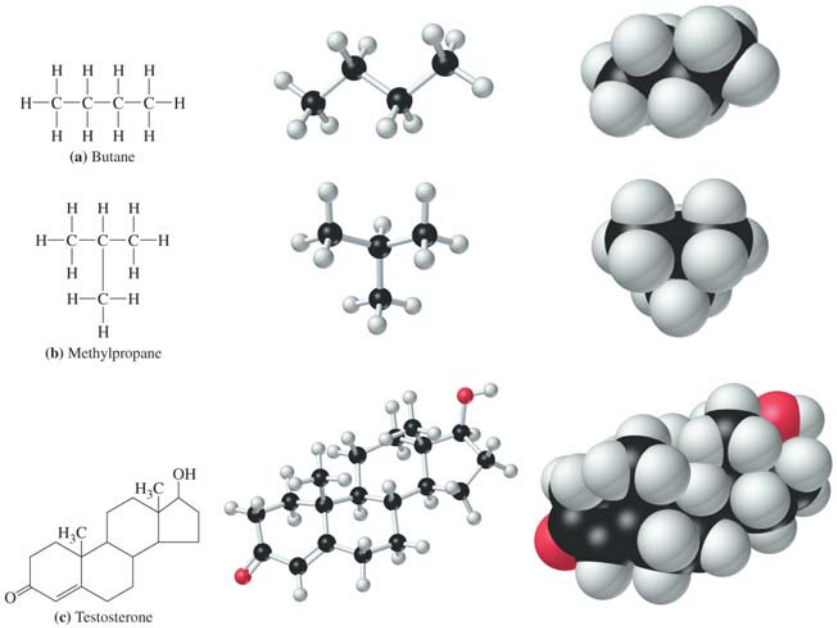

Moles apply to compounds, too!

Molar Mass and Molecular (or *Formula*) Weight:

- Translate definition of atomic weight to molecules.
- Sum up individual masses of the atoms in the compound

EXAMPLE: What is the molar mass (molecular weight) of Freon-12 (CF_2Cl_2)?

- Using Molar Masses:

EXAMPLE: How many grams of carbon are present in 25.0 g of Freon-12?

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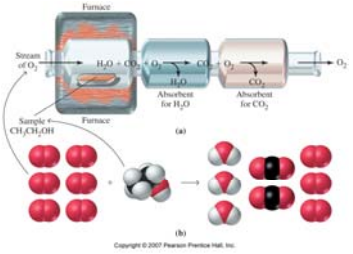
Percent Composition of Compounds

% Composition: Fraction of the total mass of a given compound that is made due to a single element.

- We can use % Composition to determine an empirical formula (best we can do without a molar mass)
- Remember, the **Empirical Formula** conveys only the relative number of atoms in a compound

EXAMPLE: Propylene glycol, a non-toxic alternative antifreeze, has a molar mass of 76.10 g/mol and contains 47.45% C and 10.60% H, with the remainder being oxygen. What are the empirical and molecular formulas for propylene glycol?



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More Compounds and Moles

Given the masses of the elements involved in a reaction, one can find the formula of the product by converting mass to moles.

EXAMPLE: Analysis shows that 0.586 g of potassium can combine with 0.480 g of O_2 gas to give a white solid with a formula of K_xO_y. What is the formula of this solid?

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Ionic Compounds

Formation of ions

- Cation vs anion formation (monatomic)
  - Cation
  - Anion
- Valence Electrons and the Noble Gas Configuration
  - Predicting Ionic Charge
  - Oxidation states (Section 3-4)
- Polyatomic Ions - **KNOW Table 3.3**

Formation of ionic compounds

- Main criteria is that the compound must be *neutral*:
  - total positive charge = total negative charge.
- Formula describes the ratio of
- When writing the formula for an ionic compound, always write the cation first, anion second.

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TABLE 3.3 Some Common Polyatomic Ions

Name	Formula	Typical Compound	Name	Formula	Typical Compound
Cation			**Anions**		
Ammonium ion	NH_4^+	NH_4Cl	Nitrite ion	NO_2^-	$NaNO_2$
Anions			Nitrate ion	NO_3^-	$NaNO_3$
Acetate ion	$C_2H_3O_2^-$	$NaC_2H_3O_2$	Oxalate ion	$C_2O_4^{2-}$	$Na_2C_2O_4$
Carbonate ion	CO_3^{2-}	Na_2CO_3	Permanganate ion	MnO_4^-	$NaMnO_4$
Hydrogen carbonate ion[a] (or bicarbonate ion)	HCO_3^-	$NaHCO_3$	Phosphate ion	PO_4^{3-}	Na_3PO_4
			Hydrogen phosphate ion[a]	HPO_4^{2-}	Na_2HPO_4
Hypochlorite ion	ClO^-	$NaClO$	Dihydrogen phosphate ion[a]	$H_2PO_4^-$	NaH_2PO_4
Chlorite ion	ClO_2^-	$NaClO_2$	Sulfite ion	SO_3^{2-}	Na_2SO_3
Chlorate ion	ClO_3^-	$NaClO_3$	Hydrogen sulfite ion[a] (or bisulfite ion)	HSO_3^-	$NaHSO_3$
Perchlorate ion	ClO_4^-	$NaClO_4$			
Chromate ion	CrO_4^{2-}	Na_2CrO_4	Sulfate ion	SO_4^{2-}	Na_2SO_4
Dichromate ion	$Cr_2O_7^{2-}$	$Na_2Cr_2O_7$	Hydrogen sulfate ion[a] (or bisulfate ion)	HSO_4^-	$NaHSO_4$
Cyanide ion	CN^-	$NaCN$			
Hydroxide ion	OH^-	$NaOH$	Thiosulfate ion	$S_2O_3^{2-}$	$Na_2S_2O_3$

[a]These anion names are sometimes written as a single word—for example, hydrogencarbonate, hydrogenphosphate, and so forth.

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Rules for naming compounds: Ionic

I. Naming cations

- Monatomic cations (M^{n+}) are named as "element name" + "ion"
- If a metal can form more than one ion, the name becomes: "element name (Roman numeral for n)" + "ion"

II. Naming Anions

- For monatomic anions, (A^{n-}), remove the ending of the element name and add "*ide*"
- Polyatomic anions, can't get away from memorizing. **Table 3.3 -** *Guidelines for oxoanions*

III. Naming Ionic Compounds

- Write the name of the cation first, followed by the name of the anion.

EXAMPLES:

Copper (II) Hydroxide =

$Fe(NH_4)(SO_4)_2$ =

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Rules for naming compounds: Molecular (binary compounds of nonmetals)

<u>Binary compound</u>: made of two elements

1. List elements in order of increasing group number (left to right)
2. If more than one atom of an element is present in the compound precede its name with the appropriate prefix (di-, tri-, tetra-, etc.).
3. Replace the ending of the last element with "*ide*"

EXAMPLES (more in Table 3.2):

CS_2 =

N_2O_5 =

Sulfur Hexafluoride =

Note: some binary compounds (like water) are referred to by common names; you will learn these through experience!

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Other Compounds

- Oxoacids: H^+ + Oxoanion
- Hydrates: $CuSO_4 \cdot 5H_2O$
- Organic Compounds
  - **Functional Group chemistry**
  - **Lots of naming rules!**

TABLE 3.4 Nomenclature of Some Oxoacids and Their Salts

Oxidation State	Formula of Acid[a]	Name of Acid[b]	Formula of Salt[b]	Name of Salt
Cl: +1	$HClO$	*Hypochlorous* acid	$NaClO$	Sodium *hypochlorite*
Cl: +3	$HClO_2$	Chlor*ous* acid	$NaClO_2$	Sodium chlor*ite*
Cl: +5	$HClO_3$	Chlor*ic* acid	$NaClO_3$	Sodium chlor*ate*
Cl: +7	$HClO_4$	*Perchloric* acid	$NaClO_4$	Sodium *perchlorate*
N: +3	HNO_2	Nitr*ous* acid	$NaNO_2$	Sodium nitr*ite*
N: +5	HNO_3	Nitr*ic* acid	$NaNO_3$	Sodium nitr*ate*
S: +4	H_2SO_3	Sulfur*ous* acid	Na_2SO_3	Sodium sulf*ite*
S: +6	H_2SO_4	Sulfur*ic* acid	Na_2SO_4	Sodium sulf*ate*

[a] In all these acids, H atoms are bonded to O atoms, not the central nonmetal atom. Often formulas are written to reflect this fact, for instance, HOCl instead of HClO and HOClO instead of $HClO_2$.
[b] In general, the *-ic* and *-ate* names are assigned to compounds in which the central nonmetal atom has an oxidation state equal to the periodic table group number minus 10. Halogen compounds are exceptional in that the *-ic* and *-ate* names are assigned to compounds in which the halogen has an oxidation state of +5 (even though the group number is 17).

TABLE 26.2 Some Classes of Organic Compounds and Their Functional Groups

Class	General Structural Formula[a]	Example	Name of Example
Alkane	R—H	$CH_3CH_2CH_2CH_2CH_2CH_3$	Hexane
Alkene		$CH_2{=}CHCH_2CH_2CH_3$	1-Pentene
Alkyne	—C≡C—	$CH_3C{\equiv}CCH_2CH_2CH_2CH_3$	2-Octyne
Alcohol	R—OH	$CH_3CH_2CH_2CH_2OH$	1-Butanol
Alkyl halide	R—X[b]	$CH_3CH_2CH_2CH_2CH_2CH_2Br$	1-Bromohexane
Ether	R—O—R	$CH_3—O—CH_2CH_2CH_3$	1-Methoxypropane (methyl propyl ether)[c]
Amine	R—NH_2	$CH_3CH_2CH_2—NH_2$	1-Aminopropane (propylamine)[c]
Aldehyde		$CH_3CH_2CH_2C(=O)H$	Butanal (butyraldehyde)[c]
Ketone		$CH_3CH_2CCH_2CH_3$	3-Hexanone (ethyl propyl ketone)[c]
Carboxylic acid		$CH_3CH_2CH_2C(=O)OH$	Butanoic acid (butyric acid)[c]
Ester		$CH_3CH_2CH_2C(=O)OCH_3$	Methyl butanoate (methyl butyrate)[c]
Amide		$CH_3CH_2CH_2C(=O)NH_2$	Butanamide (butyramide)[c]
Arene	Ar—H[d]		Ethylbenzene
Aryl halide	Ar—X[b]		Bromobenzene
Phenol	Ar—OH		4-Chlorophenol (p-chlorophenol)[c]

[a] The functional group is shown in red. R stands for an alkyl group.
[b] X stands for a halogen atom; F, Cl, Br, or I.
[c] Common name.
[d] Ar stands for an aromatic (aryl) group such as the benzene ring.