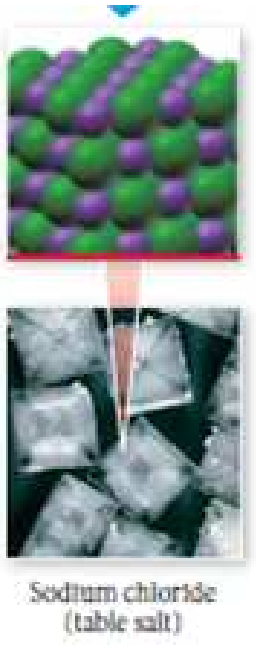
Chemical bonding is the true difference between compounds and mixtures

Ionic bond: attraction of oppositely charged ions

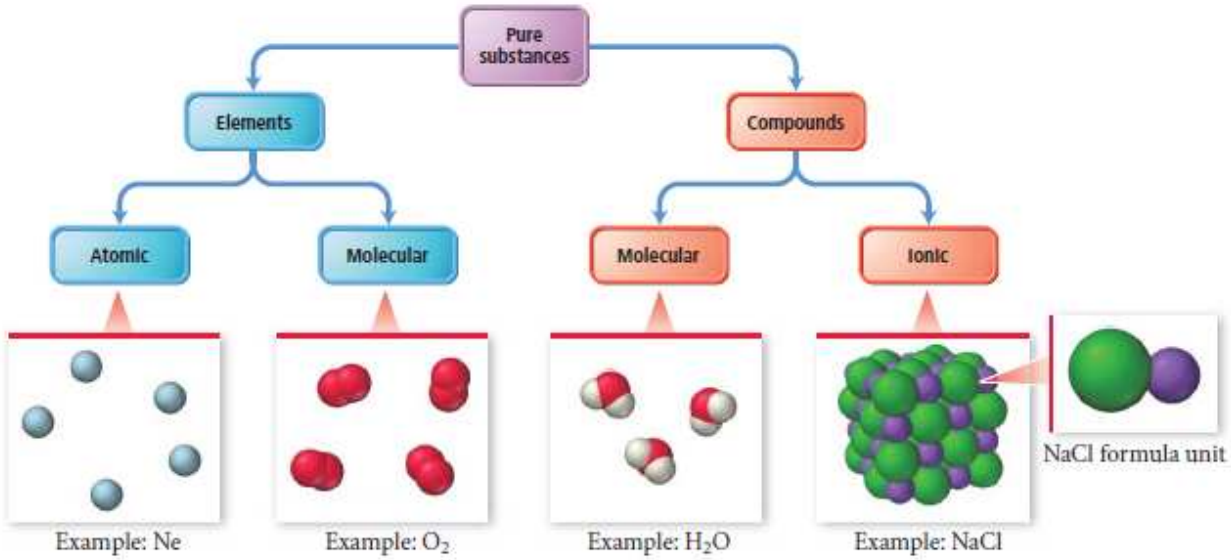
(Metal cation and nonmetal anion)



Covalent bond: shared pair of electrons

(Between 2 nonmetal atoms only)

Elements and compounds



Atomic elements:

Molecular elements:

- diatomic:
- polyatomic:

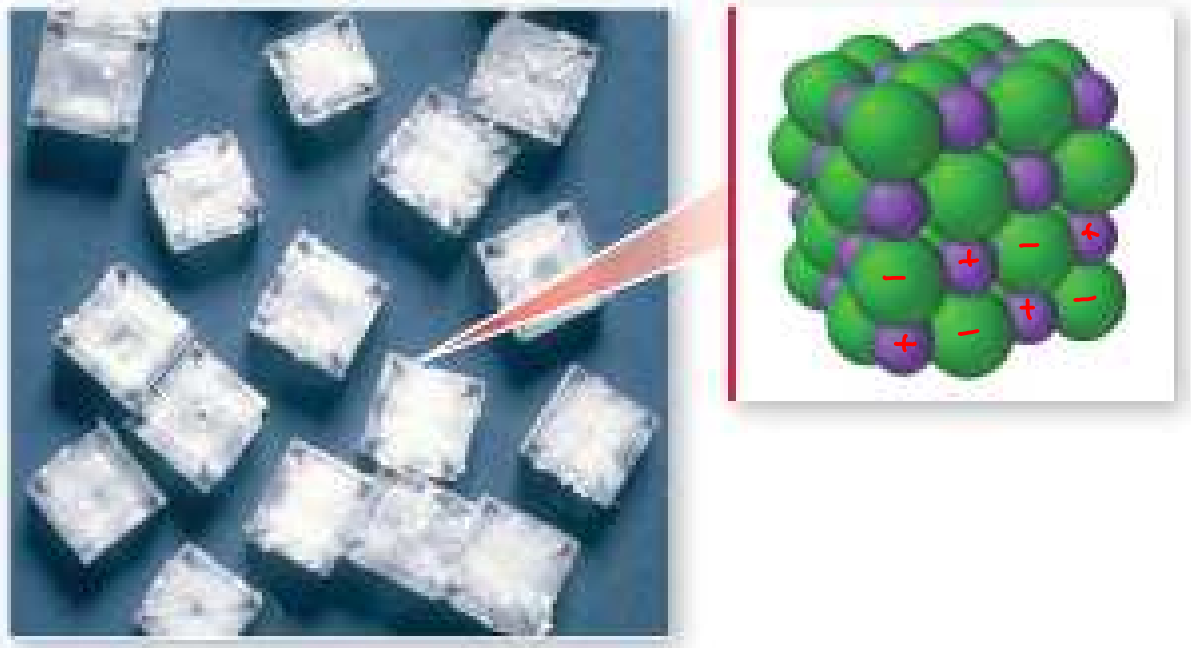
Molecular compounds: 2 or more covalently bonded nonmetals, grouped as molecules

- Molecular formula: exact number of atoms per molecule

- Empirical formula: simplest ratio of atoms in compound

- Structural formula: shows how atoms are bonded, with lines for covalent bonds

Ionic compounds are made from a lattice of positively and negatively charged ions



Formula unit: smallest neutral collection of ions

Polyatomic ion: ion composed of 2 or more atoms (a charged molecule)

Forms ionic compounds with an oppositely-charged ion

Ionic compounds:

- positive and negative ions
- charge-neutral overall (+ charges in formula must equal - charges)
- simplest whole-number ratio of ions in formula

Formula: NaCl

Ion pair:

Calcium and chlorine:

Fe^{3+} / O^{2-} :

Ca^{2+} / SO_4^{2-} :

∴

Naming ionic compounds

1. Is it an ionic compound?

2. Does the metal have fixed charge or variable charge?
   - Fixed charge: group IA, IIA, Al^{3+}, Zn^{2+}, Ag^{+}
   - Variable charge: all other metals

3. Write the ion pair
   - If metal is variable-charge, you must figure out its charge from the formula

4. Name the compound <u>from the ion pair!</u>
   - Fixed charge metal cations are just named for the element
     Na^{+} :
     Ag^{+} :
   - Variable charge metal cations use a roman numeral to show charge
     Fe^{2+} :
     Fe^{3+} :
   - Monoatomic nonmetal anions are named with the element root + ide
     Cl^{-} :
     N^{3-} :
     S^{2-} :
     P^{3-} :

Naming binary ionic compounds

CaO ion pair:

name:

$NiCl_2$ ion pair:

name

WS_3 ion pair:

name:

vanadium (I) oxide ion pair:

formula:

silver nitride ion pair:

formula:

calcium phosphide ion pair:

formula:

Polyatomic ions: charged molecules, multi-atom ions

Acetate	$C_2H_3O_2^-$
Ammonium	NH_4^+
Bicarbonate	HCO_3^-
Carbonate	CO_3^{2-}
Chlorate	ClO_3^-
Hydroxide	OH^-
Nitrate	NO_3^-
Phosphate	PO_4^{3-}
Sulfate	SO_4^{2-}

Removing one oxygen changes ending to -ite:

Addition of H^+ reduces negative charge by 1

If >2 oxyanions in a series, use hypo- or per-

$CuSO_4$ ion pair:

name:

cobalt (II) nitrite ion pair:

formula:

$Mn(PO_4)_2$ ion pair:

name:

Hydrates: contain a certain number of water molecules per formula unit

$CuSO_4 \bullet 5\ H_2O$ =

Naming binary molecular compounds

1. Is it a molecular compound?

2. Binary molecular compounds use Greek prefixes in name to show how many atoms are in the formula

Greek prefixes for quantity	
1	(mono)
2	di
3	tri
4	tetra
5	
6	
7	hepta
8	
9	nona
10	deca

NO_2

N_2O_4

CO

CO_2

P_2O_7

3. First element: prefix (not mono) then element name

4. Second element: prefix then element root + ide

5. Avoid "ao" and "oo" combinations - drop first vowel

Acid: formula with H as first element

- release H^+ ions when dissolved in water
- named as normal binary molecular compounds when pure

Binary acids contain just H and one other nonmetal.

- Names of binary acids start with hydro-
  and end with -ic acid

HCl (*g*) = pure binary molecular compound

HCl (*aq*) = binary acid

HF (*aq*)

HBr (*aq*)

HI (*aq*)

Oxyacids contain hydrogen and an oxyanion
(polyatomic ion w/ a nonmetal and oxygen)

Use the oxyanion to name the oxyacid:

oxyanion	acid
-ate	-ic acid
-ite	-ous acid

HNO_3

HNO_2

H_3PO_4

$HClO_3$

$HClO_2$

HClO

Formula mass of a compound is the sum of the atomic masses of all atoms in the compound, multiplied by their subscripts. Unit = amu

$Fe_2(SO_4)_3$ = 1 formula unit of iron (III) sulfate

formula mass =

Molar mass of a compound is just the formula mass with units of g/mol.

How many H_2O molecules are in 25 mg of H_2O?

Mass percent of element in a compound:

$$\text{Mass \%} = \frac{\text{mass of element}}{\text{total mass of compound}} \times 100\%$$

To get this from a chemical formula,

- assume 1 mol of compound
- (use molar masses!)

What is the mass % of C and H in octane, C_8H_{18}?

Molar mass C_8H_{18} =

1 mol C_8H_{18} contains ___ mol C and ___ mol H.

Mass % C =

Mass % H =

If you're given a mass percent, you can use it as a conversion factor between the element and the compound

A 3.5 kg sample is found to contain 2.6% Pb. How many grams of lead are present?

Mass percent = per 100 grams

100 g sample : ____ g Pb

Chemical formulas give the ratio of atoms in a compound

- This can also be used to construct **mole ratios**

1 mol $Fe_2(SO_4)_3$ contains: _____ mol Fe

_____ mol S

_____ mol O

How many O atoms are in 8.6 mol $Fe_2(SO_4)_3$?

How many grams S are in 2.50 mol $Fe_2(SO_4)_3$?

How many grams Fe are in 18.25 g $Fe_2(SO_4)_3$?

to convert from mass compound to g element, use

mass cpd → mol cpd → mol element → mass element

Determining a chemical formula from element masses

You are given:
- the elements present in a compound
- masses OR mass percentages of elements

You can calculate:
- The empirical formula

A compound made of C, H, and O is found to contain 68.8% C, 5.0% H, and 26.2% O. What is the empirical formula?

1. If given percentages, convert them to grams per 100 g sample. If you're missing one element's mass, subtract from a given total mass.

2. Convert each mass to moles using the molar mass of elements

3. Use moles to make a formula, divide by smallest numbe

4. Make the subscripts whole numbers by multiplying all by 2, 3, 4, or 5.

You are given:
- empirical formula
- molar mass

You can calculate:
- molecular formula

Molecular formulas are always whole-number multiples of empirical formulas

Molecular: C_3H_6 Empirical:

( ) x n = C_nH_{2n} - For this molecule, n =

C_3H_6 formula mass = 47.028 g/mol
CH_2 formula mass = 14.026 g/mol
$= n =$

Mass spectrometry can be used to determine molar mass of a compound experimentally.

A compound with empirical formula of CH_2O has a molar mass of 60.05 g/mol. What is its molecular formula?

$$n = \frac{\text{molar mass}}{\text{empirical formula mass}} =$$

Combustion analysis

Combustion: compound + $O_2 \rightarrow CO_2 + H_2O$

You are given:
- masses of CO_2 and H_2O produced
- which elements are in the sample
- total sample mass (if elements other than C and H present)

You can calculate:
- empirical formula
- (molecular formula if a molar mass is given)

A 4.30 mg sample containing C, H, and O produces 8.59 mg CO_2 and 3.52 mg H_2O upon combustion. What is its empirical formula?

1. Convert masses of CO_2 and H_2O to mol C and mol H

2. If elements other than C and H, calculate masses of C and H, subtract from the total to get mass of other element, and calculate moles of the other element.

3. Use moles of each element to calculate the empirical formula as before.

Difficult combustion problem

A 6.54 mg sample of a compound containing C, H, N, and O produced 8.29 mg CO_2, 4.53 mg H_2O, and 1.76 mg N_2 upon combustion. Its molar mass was found to be 208.2 g/mol. What is the molecular formula of this compound?

A **chemical equation** represents a chemical reaction with chemical formulas.

Phase/state labels: (*s*)
(*l*)
(*g*)
(*aq*)

Reactants: substances that will react (on left side of equation)
Products: substances resulting from reaction (on right side of equation)

Write the chemical equation with phase labels:
Solid calcium reacts with chlorine gas to produce solid calcium chloride:

Balancing chemical equations: add coefficients in front of formulas so that the number of each type of atom is the same on the reactants side and products side

1. Only add coefficients, never change subscripts
2. Save elements (O_2, Cl_2, Na, etc) for last
3. Multiply fractions through so coefficients are simplest whole numbers
4. Count polyatomic ions together if they don't react, but count atoms if the polyatomic ion does react

____ C_4H_{10} + ____ O_2 → ____ CO_2 + ____ H_2O

____ Fe + ____ O_2 → ____ Fe_2O_3

Write a balanced chemical equation:
Sodium carbonate solid reacts with aluminum chloride to form aluminum carbonate and sodium chloride.