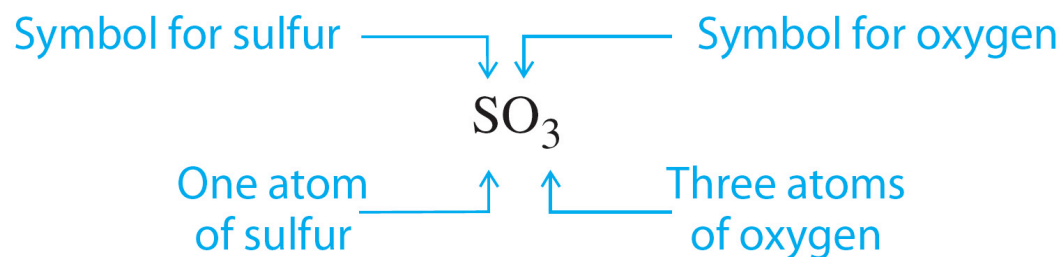


Ch 5. Molecules and Compounds

Ch 5. Molecules and Compounds

Chemical Formulas of Compounds

1. A given compound always has **the same numbers and types of atoms (constant composition)**.
2. Each atom is represented by its **element symbol**.
3. The number of each type of atom is indicated by **a subscript** to the right of the element symbol (Exception: If just one atom, no subscript).
4. Typically, the more metallic element is listed first.



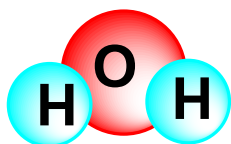
Molecular Compounds and Ionic Compounds

Ionic Compounds
Molecular Compounds and

Types of Compounds

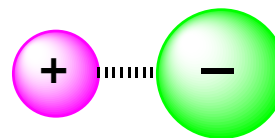
Molecular Compounds

- Covalent bond
- One unit: Molecule



Ionic Compounds

- Ionic bond
- One unit: Formula unit



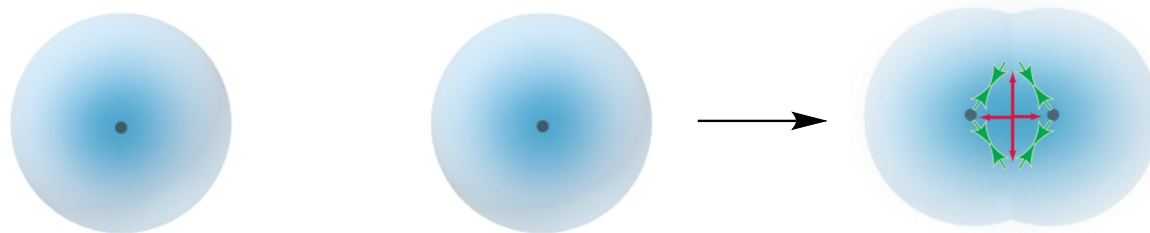
Chemical Bond

Chemical bond: A force that holds groups of atoms together and makes them function as a unit.

- Bonding involves just the electrons of atoms!

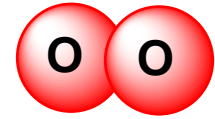
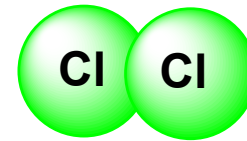
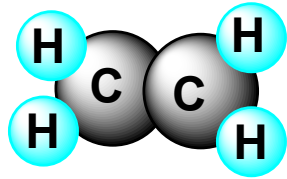
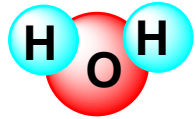
Molecular (Covalent) Compounds

- Held together through **Covalent Bonds**: Bonds in which electrons are shared between the bonded atoms.



- **Molecule**: a group of two or more atoms which are covalently bonded (a unit of molecular compound)
- **Nonmetal + Nonmetal → Molecular Compound**

Molecules



Compounds

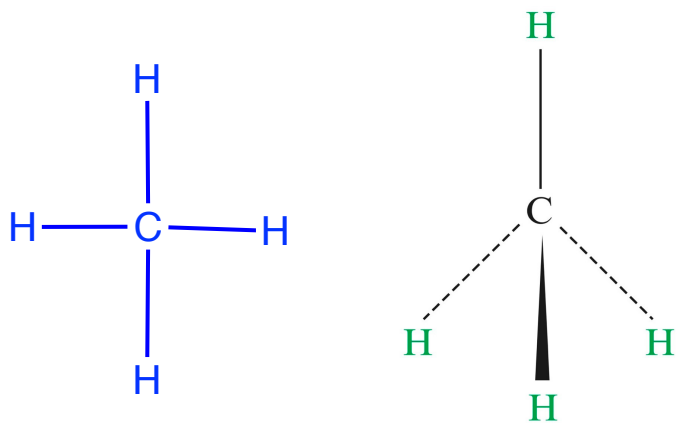
Elements

- **Note:** Both compounds (eg, H_2O) and elements (eg. O_2 , H_2) may exist as molecules.

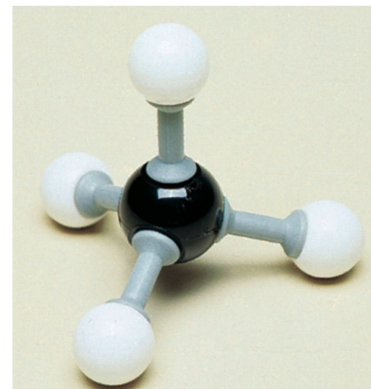
Representing Molecules



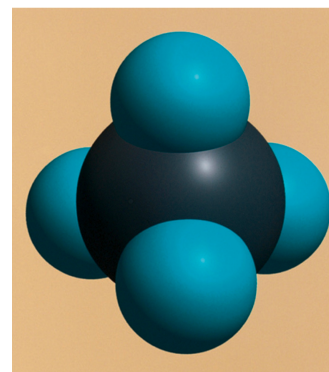
Chemical formula



Structural formula



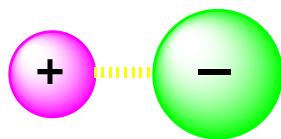
Ball-and-stick model



Space-filling model

Ionic Compounds

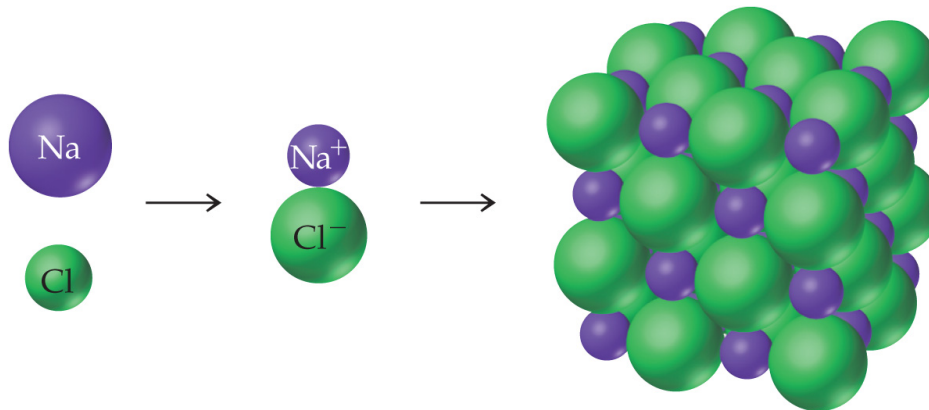
- Held together through **Ionic Bonds**: Bonds in which oppositely-charged ions are held together by electrostatic attraction between them.



- **Formula unit**: A group of two or more ions which are bound through ionic bonds (a unit of ionic compound)
- **Metal + Nonmetal → Ionic Compound**

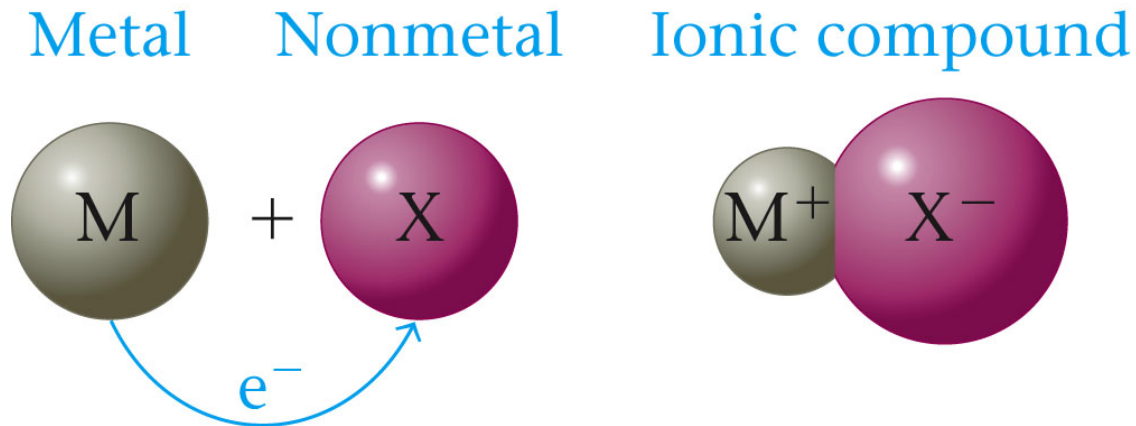
Formula Units

- Formula units exist as a part of a larger 3D array (a solid).



Ionic Compounds

- Most commonly, ionic compounds form when **metals** combine with **nonmetals** → Metal element transfers electrons to the nonmetal element.



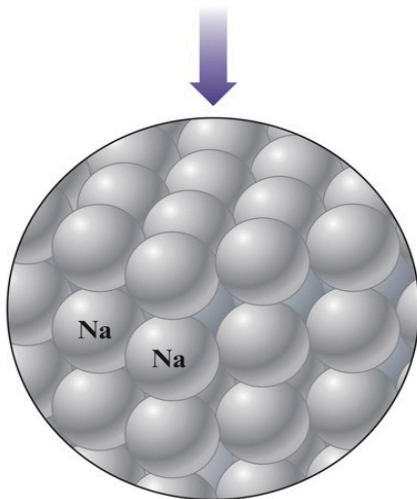
Metal cation + Nonmetal anion → ionic compound

Isolated ions don't exist!

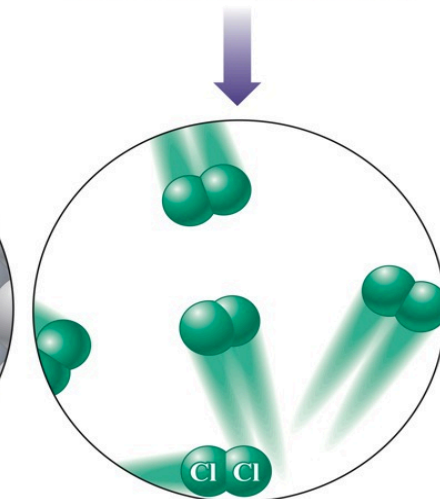
Formation of an Ionic Compound



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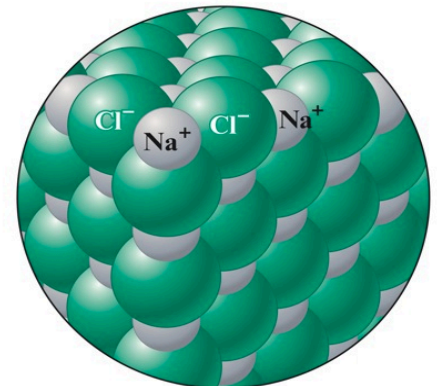


$2\text{Na}(s)$
Sodium



$\text{Cl}_2(g)$
Chlorine

+



$2\text{NaCl}(s)$
Sodium chloride

Overview:
Fundamental Components of Matter

Fundamental Components of Matter
OVERVIEW:

Matter

Pure Substances

- Elements
- Compounds

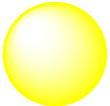
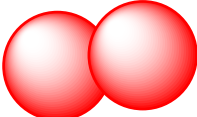
“Particles” of Matter

- Atoms
- Ions
- Molecules

Elements, Compounds, Atoms, Molecules, Ions

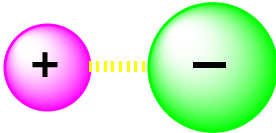
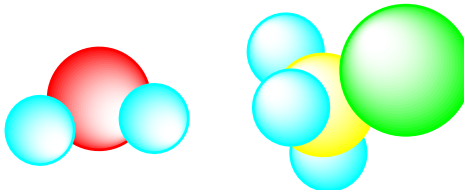
Elements

(1 type of atom)

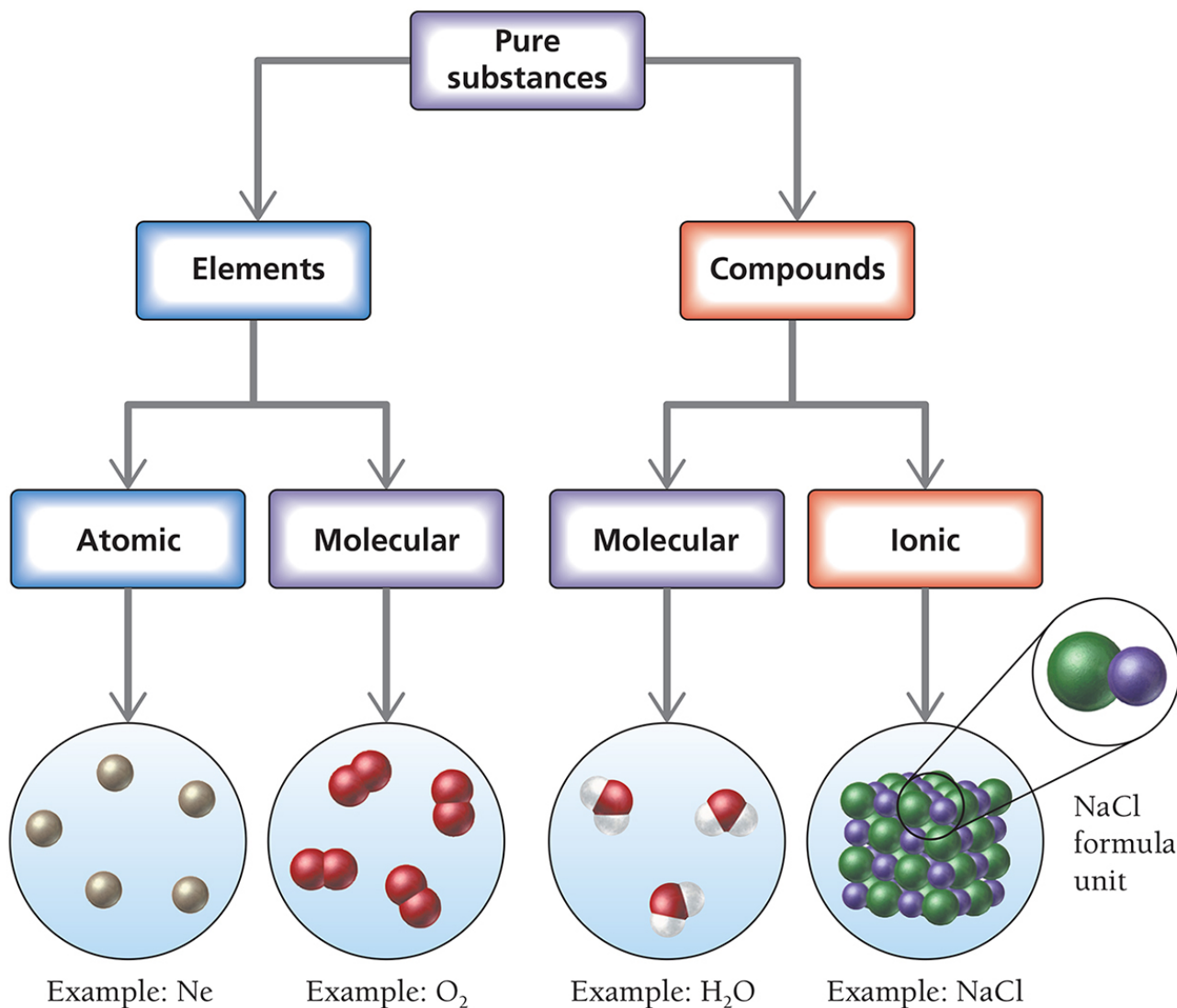
- Atomic 
- Molecular 

Compounds

(more than 1 type of atom)

- Ionic 
- Molecular 

Elements, Compounds, Atoms, Molecules, Ions



Formula (Molecular) Mass

Formula (Molecular) Mass

Formula (Molecular) Masses of Compounds

Formula mass of a compound = sum of atomic masses

eg. Molecular mass of H₂O

$$= 2(\text{atomic mass of H}) + 1(\text{atomic mass of O})$$

$$= 2(1.008 \text{ amu}) + 1(16.00 \text{ amu})$$

$$= 18.02 \text{ amu}$$

Chemical Nomenclature

Chemical Nomenclature

Chemical Nomenclature

- **Chemical Nomenclature**: a system of naming chemical substances

Common Name	Systematic Name	Formula
Grain alcohol	Ethyl alcohol	CH_3OH
Rubbing alcohol	Isopropyl alcohol	$\text{C}_2\text{H}_5\text{OH}$
Laughing gas	Dinitrogen oxide	N_2O
Milk of magnesia	Magnesium hydroxide	$\text{Mg}(\text{OH})_2$
Epsom salt	Magnesium sulfate heptahydrate	$\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$

Chemical Nomenclature

- A. Ionic Compounds (Binary and Polyatomic)
- B. Covalent Compounds (Binary)
- C. Acids

Formulas (NaCl) \longleftrightarrow Names (sodium chloride)

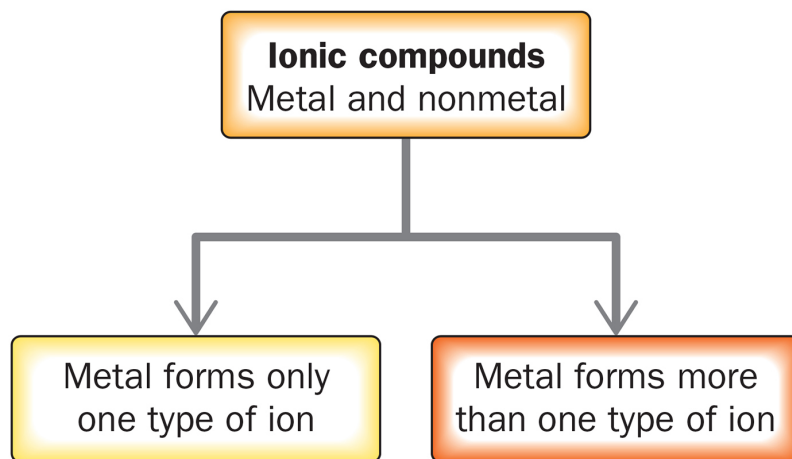
Refer to Chemical Nomenclature Handout for rules for naming and writing formulas.

Naming Compounds

Naming Compounds

Naming Binary Ionic Compounds

- The cation is always named first and the anion second.
- Remember: Ionic compound has a net charge of 0.
- **METAL + NONMETAL = ionic compound**



Naming Binary Ionic Compounds: Fixed Charge Cation

Ionic compounds containing fixed-charge metals (mostly main group metals):

1. A monatomic **cation** has the same name as that of the parent element.
2. A monatomic **anion** is named by taking the root of the element name and adding *-ide*.

- Examples

KCl

potassium chloride

MgBr₂

magnesium bromide

CaO

calcium oxide

Naming Binary Ionic Compounds: Variable Charge Cations

Ionic compounds containing variable-charge cations (mostly transition metals):

For metals that can form cations of more than one charge, the charge on the metal ion must be specified with Roman numeral in parentheses!

- Examples

CuBr Copper(I) bromide

FeS Iron(II) sulfide

PbO₂ Lead(IV) oxide

Common Ion Charges (Memorize!)

1A	2A							3A	4A	5A	6A	7A	8A
Li ⁺										N ³⁻	O ²⁻	F ⁻	
Na ⁺	Mg ²⁺							Al ³⁺			S ²⁻	Cl ⁻	
K ⁺	Ca ²⁺			Cr ²⁺	Mn ²⁺	Fe ²⁺	Co ²⁺		Cu ⁺	Zn ²⁺	Ga ³⁺		Br ⁻
				Cr ³⁺	Mn ³⁺	Fe ³⁺	Co ³⁺		Cu ²⁺				
Rb ⁺	Sr ²⁺								Ag ⁺	Cd ²⁺		Sn ²⁺	
												Sn ⁴⁺	I ⁻
Cs ⁺	Ba ²⁺									Hg ₂ ²⁺		Pb ²⁺	
										Hg ²⁺		Pb ⁴⁺	

Metals form cations.

- Groups 1A,2A,3A:
charge = group #
- Transitions metals:
Many have variable charges.

Nonmetals form anions.

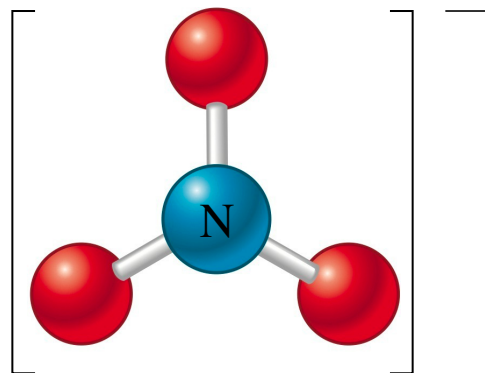
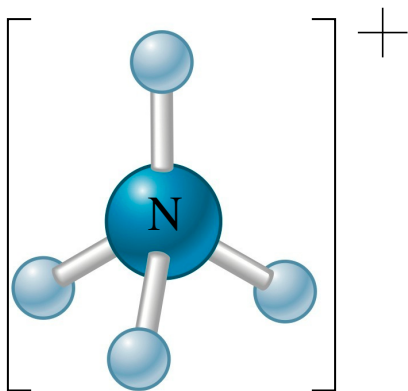
- Group 5A: charge = -3
- Group 6A: charge = -2
- Group 7A (halogens):
charge = -1
- Group 8A (noble gases):
charge = 0 Ex Probs

Naming Ionic Compounds with Polyatomic Ions

Ions can be simple (monatomic) or polyatomic.

- Simple Ions: Mg^{2+} , Li^+ , Cl^- , O^{2-}

- Polyatomic Ions:



Naming Ionic Compounds with Polyatomic Ions

Names and charges of polyatomic ions must be memorized. (Memorize the following!)

- Polyatomic cations: Names end in -ium.



- Polyatomic anions: Many contain oxygen.



Common Polyatomic Ions

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Table 2.5 Common Polyatomic Ions*

Formula	Name
Cations	
NH_4^+	ammonium
H_3O^+	hydronium
Anions	
CH_3COO^- (or $\text{C}_2\text{H}_3\text{O}_2^-$)	acetate
CN^-	cyanide
OH^-	hydroxide
ClO^-	hypochlorite
ClO_2^-	chlorite
ClO_3^-	chlorate
ClO_4^-	perchlorate
NO_2^-	nitrite
NO_3^-	nitrate
MnO_4^-	permanganate
CO_3^{2-}	carbonate
HCO_3^-	hydrogen carbonate (or bicarbonate)
CrO_4^{2-}	chromate
$\text{Cr}_2\text{O}_7^{2-}$	dichromate
O_2^{2-}	peroxide
PO_4^{3-}	phosphate
HPO_4^{2-}	hydrogen phosphate
H_2PO_4^-	dihydrogen phosphate
SO_3^{2-}	sulfite
SO_4^{2-}	sulfate
HSO_4^-	hydrogen sulfate (or bisulfate)

*Boldface ions are most common.

Naming Ionic Compounds with Polyatomic Ions

Examples of ionic compounds with polyatomic ions

- NH_4Cl ammonium chloride
- Na_2CO_3 sodium carbonate
- $\text{Mn}(\text{OH})_2$ manganese (II) hydroxide
- $(\text{NH}_4)_2\text{SO}_4$ ammonium sulfate

Naming Binary Molecular (Covalent) Compounds

NONMETAL + NONMETAL

Name first element first, second element second.

1. First element: Greek prefix + parent element (Exception: Don't use "mono-").
2. Second element: Greek prefix + parent element + "-ide" (as if it were an anion).

Table 5.3 Prefixes Used to Indicate Numbers in Chemical Names

Prefix	Number Indicated
<i>mono-</i>	1
<i>di-</i>	2
<i>tri-</i>	3
<i>tetra-</i>	4
<i>penta-</i>	5
<i>hexa-</i>	6
<i>hepta-</i>	7
<i>octa-</i>	8

Naming Binary Covalent Compounds

Examples of Binary Molecular Compounds

N_2O_5	dinitrogen pentoxide
P_4O_6	tetraphosphorus hexoxide
BF_3	boron trifluoride
NO	nitrogen monoxide
CO	carbon monoxide

Table 5.3 Prefixes Used to Indicate Numbers in Chemical Names

Prefix	Number Indicated
<i>mono-</i>	1
<i>di-</i>	2
<i>tri-</i>	3
<i>tetra-</i>	4
<i>penta-</i>	5
<i>hexa-</i>	6
<i>hepta-</i>	7
<i>octa-</i>	8

Naming Problem

Which of the following compounds is/are named **incorrectly**?

- | | | |
|-----------------------------|-------------------------|---|
| a) KNO_3 | potassium nitrate | |
| b) TiO_2 | titanium(II) oxide | ✗ |
| c) $\text{Sn}(\text{OH})_4$ | tin(IV) hydroxide | |
| d) PBr_5 | phosphorus pentabromide | |
| e) CaCrO_4 | calcium chromate | |

Strategy for Naming Compounds

Look at the formula.

Metal + Nonmetal

or

Polyatomic Ions



IONIC Compound

Name as Cation + Anion!

*(If see variable-charge cation,
include charge in Roman
numerals!)*

Nonmetal + Nonmetal



MOLECULAR
Compound

Use Greek prefixes!

Ex probs

Writing Formulas

Writing Formulas

Writing Chemical Formulas: Ionic Compounds

I. Ionic Compounds

- Balance charges, since **compounds must be neutral!**

$$\text{Positive Charge} + \text{Negative Charge} = 0$$

Examples

- magnesium bromide MgBr_2
- iron(II) sulfide FeS

Writing Chemical Formulas: Molecular Compounds

II. Binary Molecular Compounds

- Greek prefixes indicate number of atoms.

Examples

- dinitrogen pentoxide N_2O_5
- boron trifluoride BF_3

Greek Prefixes

mono	one
di	two
tri	three
tetra	four
penta	five
hexa	six

Strategy for Writing Formulas of Compounds

Look at the name.

Metal + Nonmetal

or

Polyatomic Ions



IONIC compound

Balance charges!

Nonmetal + Nonmetal

See Greek prefixes



COVALENT compound

Follow Greek
prefixes!

Nomenclature for Acids

Nomenclature for Acids

Brief Intro to Acids and Bases

Arrhenius Definition of Acids and Bases

- Acid: a substance that makes proton (H⁺) in water.



acid proton anion

- Base: a substance that makes hydroxides (OH⁻) in water.



Brief Intro to Acids and Bases

Bronsted-Lowry Definition of Acids and Bases

- Acids are proton (H^+) donors.



acid proton anion

- Bases are proton (H^+) acceptors.



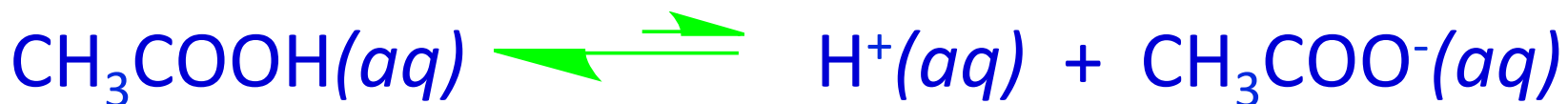
base proton cation

Strong and Weak Acids

- **Strong acid:** Completely ionized (dissociated).



- **Weak acid:** Most of the acid molecules remain intact.



equilibrium arrow

Naming Acids

*Acids always have “H” first in their formulas!

End all acid names with “acid.”

1. Binary Acids:

Name format: “hydro-” + parent element

+ “-ic acid”

Acid	Name
HF	Hydrofluoric acid
HCl	Hydrochloric acid
HBr	Hydrobromic acid
HI	Hydroiodic acid
HCN	Hydrocyanic acid
H ₂ S	Hydrosulfuric acid

Naming Acids

2. Acid with oxygen (Oxyacids):

Acid name is derived from oxoanion of that acid.

- If anion ends in “ate” → acid name ends with “ic” acid.
 - NO_3^- is nitrate → HNO_3 is nitric acid
- If anion of ends in “ite” → acid name ends with “ous” acid.
 - NO_2^- is nitrite → HNO_2 is nitrous acid

Some Oxyacids

Acid	Name
HNO_3	Nitric acid
HNO_2	Nitrous acid
H_2SO_4	Sulfuric acid
H_2SO_3	Sulfurous acid
H_3PO_4	Phosphoric acid
$\text{HC}_2\text{H}_3\text{O}_2$	Acetic acid

Common Acids (Memorize!)

Strong Acids

- HCl hydrochloric acid
- HBr hydrobromic acid
- HI hydroiodic acid
- HNO₃ nitric acid
- H₂SO₄ sulfuric acid
- HClO₄ perchloric acid

Weak Acid

- HC₂H₃O₂ or CH₃COOH acetic acid
- H₂CO₃ carbonic acid