CHEM 103
Naming Compounds

Lecture Notes
February 7, 2006
Prof. Sevian

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Agenda

- How we name compounds depends on what kind of compounds they are
- Ionic compounds
- Molecular compounds
- Acids are molecular compounds that sometimes behave like ionic compounds, and the positive ion is always H^+

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Isotopes and Natural Abundances

The mass of a typical sample of an element is a weighted average of the masses of the isotopes

Isotopes of magnesium	$12\ p^+$ $12\ n^o$		$12\ p^+$ $13\ n^o$		$12\ p^+$ $14\ n^o$	This is the atomic weight on the periodic table
Natural Abundance	78.99%		10.00%		11.01%	
	×		×		×	
Mass of Isotope (amu)	23.9850		24.9858		25.9826	
	18.95	+	2.499	+	2.861	= 24.31

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Reading the Periodic Table

Atomic number → 12

Symbol → Mg

Atomic weight → 24.31

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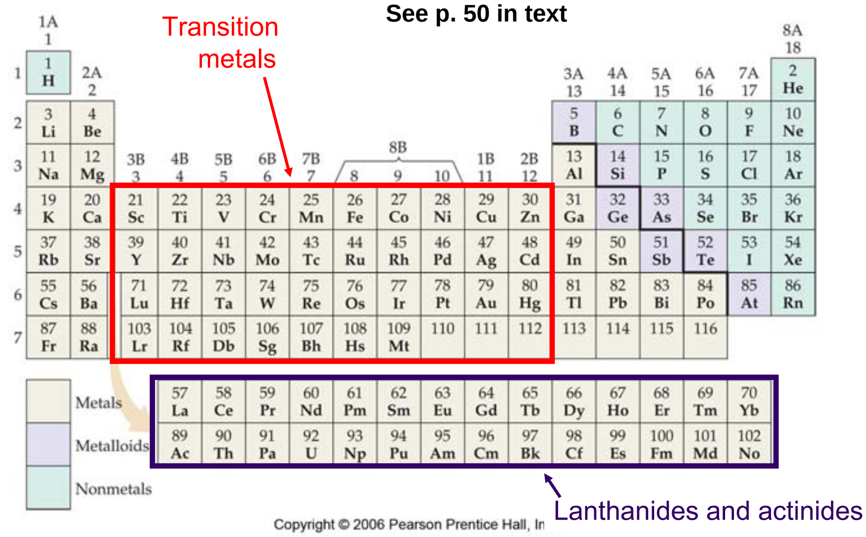
Regions of the Periodic Table

See p. 50 in text



Organization of the Periodic Table

Terminology we will use all year

- Period = row across
- Group = column down

  Several common groups
  - Group 1A: Alkali metals
  - Group 2A: Alkaline earth metals
  - Group 7A: Halogens
  - Group 8A: Noble gases
  - Groups B: Transition metals

- Early chemists (Mendeleev, Moseley) organized the Periodic Table according to properties of elements
- There are reasons why the Periodic Table is organized the way it is (stay tuned until chapters 6 and 7)

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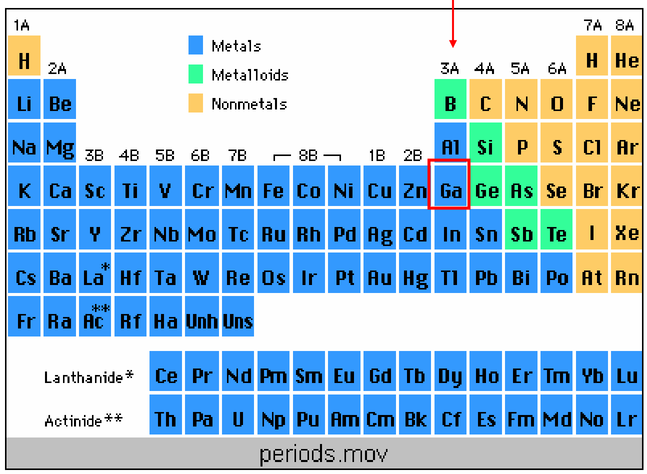
Pinpointing an Element

Group 3A

Period 4



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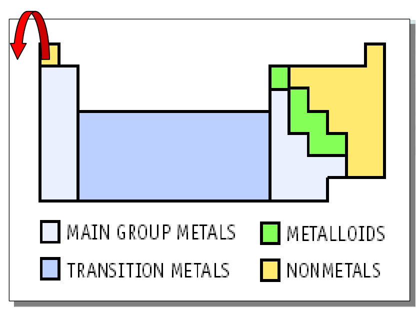
What is an Ion?

1. Hydrogen loses an electron to form H^+



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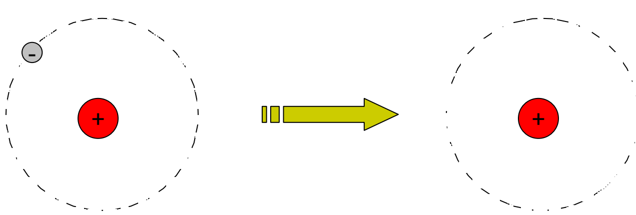

Neutral H atom

H^+ ion

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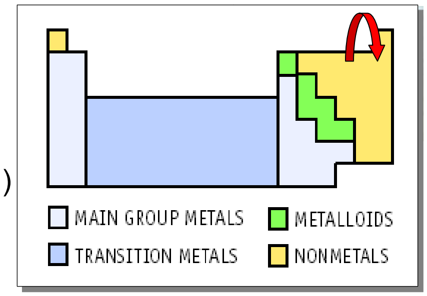
What is an Ion?

2. Nonmetals (except not usually H) gain electrons to form negatively charged ions



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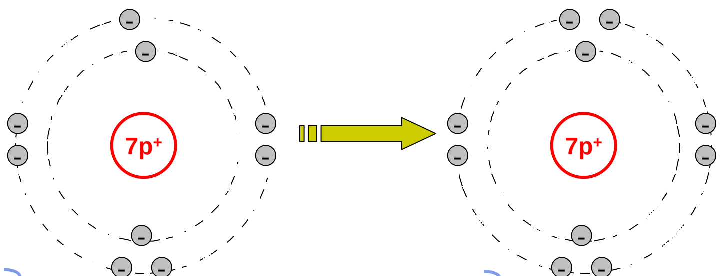

7 p^+
7 e^-
Neutral F atom

7 p^+
8 e^-
F^- ion

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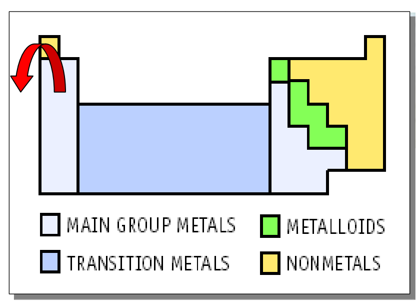
What is an Ion?

3. Metals lose electrons to form positively charged ions



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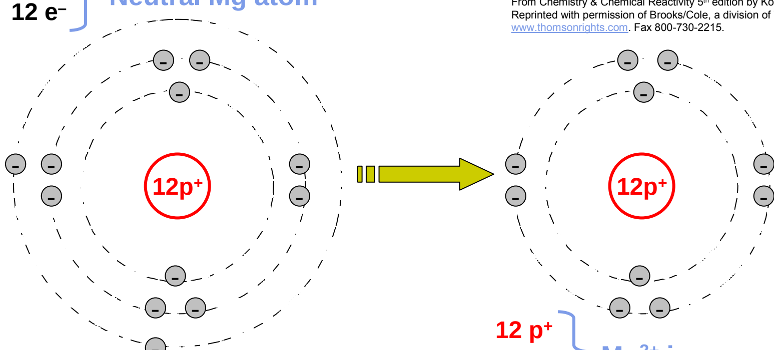
12 p^+
12 e^-
Neutral Mg atom



12 p^+
10 e^-
Mg^{2+} ion

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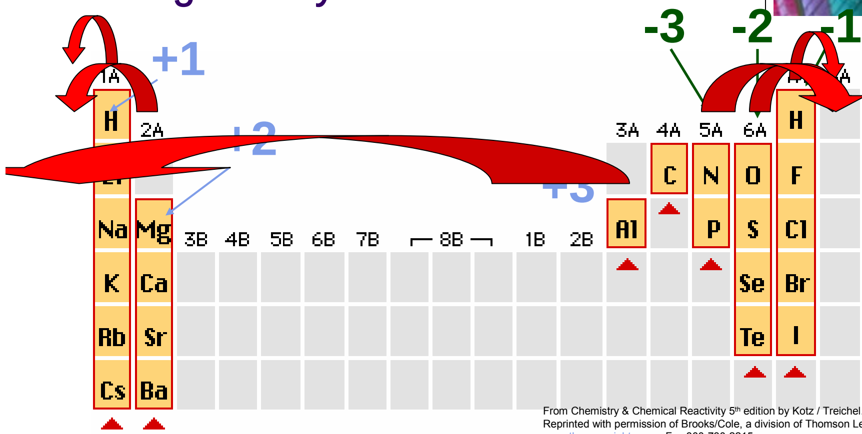
Noble gas envy



Atoms lose or gain electrons to have same number of electrons as nearest Group 8A element

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Ions and Their Names

When Protons ≠ Electrons

Neutral atom starts with balance of protons & electrons

"noble gas envy" it happens!

Positive Ions

- Metal atoms that lose electrons
- More protons than electrons
- Group A elements always lose electrons to resemble nearest noble gas
- Group B elements can have different quantities of electrons lost
- No name change (but some Group B elements must indicate charge to distinguish)

Negative Ions

- Nonmetal atoms that gain electrons
- Fewer protons than electrons
- Group A elements always gain electrons to resemble nearest noble gas
- Suffix of element name changes to "-ide"

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Names of Common Ions

Find these elements on the Periodic Table and convince yourself why they take the charges they do.

Ion	Name
Cl^{-}	chloride
Na^{+}	sodium
Mg^{2+}	magnesium
O^{2-}	oxide
N^{3-}	nitride
Sr^{2+}	strontium
Al^{3+}	aluminum

Rule

If nonmetal, change ending to

"-ide"

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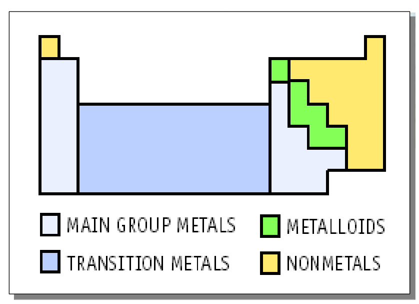
Compounds

Two or more different elements that are chemically bonded



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Kinds of bonding:

1. Ionic: usually metal ions (+) and nonmetal ions (-) held together by electrostatic attraction
2. Molecular: usually nonmetals held together because proximity of outer electrons on the atoms causes new bonding "orbitals" to exist which have more favorable conditions for electrons
3. Other

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Ionic vs. Molecular Compounds

- For simplicity, let's compare some ionic and molecular compounds in the solid state
- Ionic compounds:
  NaCl = table salt, also called sodium chloride
  NH_4Cl = ammonium chloride
- Molecular compounds:
  H_2O (*s*) = ice
  $C_{12}H_{22}O_{11}$ = sucrose

How do their macroscopic properties compare?

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What do we think an ionic compound looks like at the particle level?

- Regular, repeating lattice structure
- Positive and negative ions held by attractive electrostatic force
- Every + ion surrounded by – ions
- Every – ion surrounded by + ions

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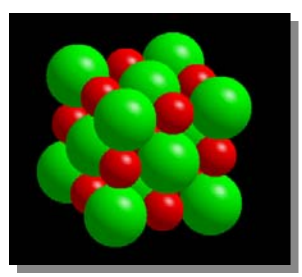
 **= Cl^- ion**

 **= Na^+ ion**



NaCl, salt

Note: Model shows a solid. Ionic bonds are very strong, so it takes a lot of energy to make them molten (liquid). In the liquid state, the ions are free to move about.

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Another Ionic Compound

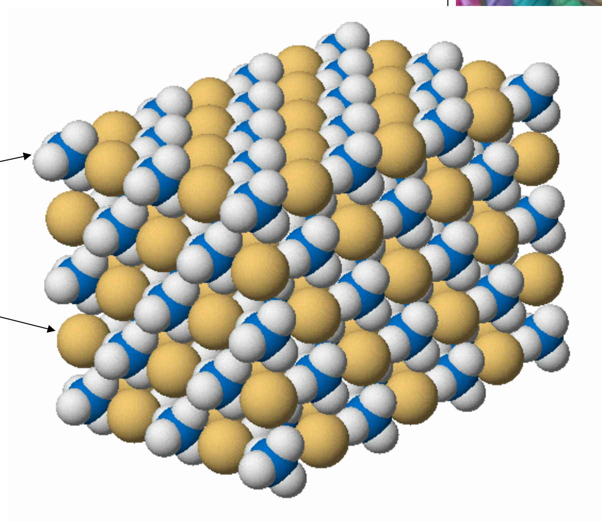
NH_4Cl

made of

NH_4^+ ions

and

Cl^- ions



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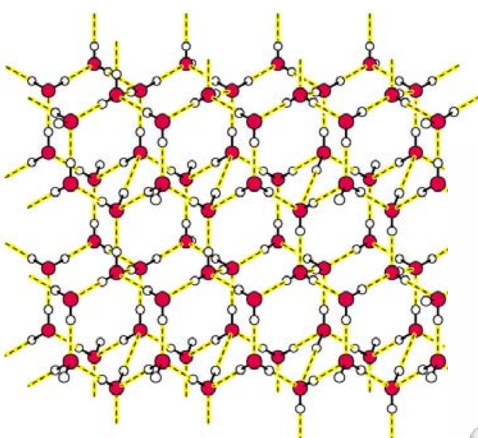
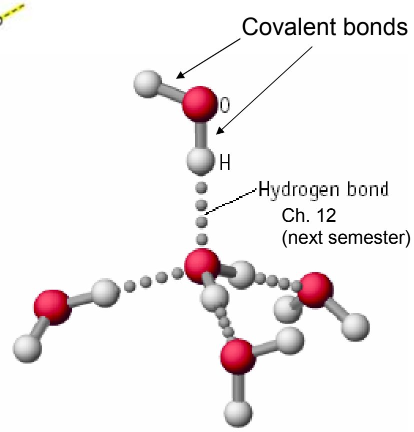
What do we think a molecular compound looks like at the particle level?



Water in the solid state

H_2O (*s*)



Ice crystal structure picture from http://cwx.prenhall.com/horton/medialib/media_portfolio/text_images/FG02_05.JPG

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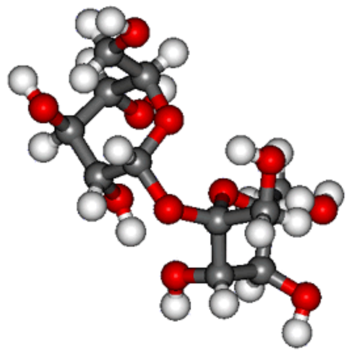
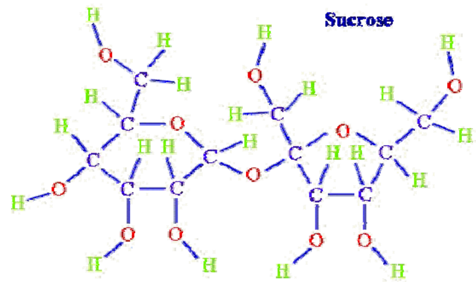
Another molecular compound



$C_{12}H_{22}O_{11}$ (*s*)



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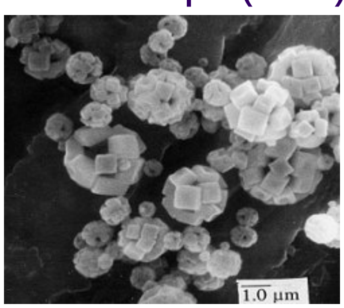
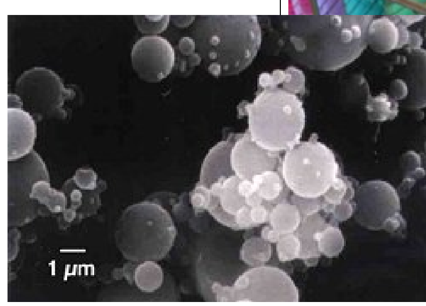
NaCl vs. Sucrose scanning electron microscope (SEM) "pictures"



NaCl (*s*) dried from a 10% aqueous solution



$C_{12}H_{22}O_{11}$ (*s*) dried from a 5% aqueous solution

1 µm = 10^{-6} m and 1 nm = 10^{-9} m

For comparison:

Na-Cl internuclear distance = 0.56 nm, therefore in 1 µm fit about 1800 Na-Cl units across

Diameter of a sucrose molecule ≈ 1 nm, therefore in 1 µm fit about 1000 sucrose molecules lengthwise

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(Images from http://www.temcoinstruments.com/applications.html)

What you need to understand about bonding for now

Ionic Compounds

- Contain ions
- Held together by electrostatic attraction between + and – ions
- Ionic formula: simply the ratio of ions present in order for the compound to be neutral, cannot separate a unique unit

Molecular Compounds

- Do not contain ions
- Molecules held together by covalent bonds in which electrons from both atoms are attracted to the nuclei of both atoms in a bond
- In a molecular solid, one molecule held to the next by weaker forces of attraction
- Molecular formula: can separate unique molecules

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What's a Chemical Formula?

- Whole-number ratio of elements present in a compound
  H_2O CO_2 $Na_2C_2O_4$ $KMnO_4$
- Parentheses indicate groups (ions, functional groups, repeating groups)
  $Mg(C_2H_3O_2)_2$ $C(CH_3)_3Cl$ $CH_3(CH_2)_4CH_3$
- Numbers follow (they don't precede)
  H_2O H_2O_2

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You need to be able to…

… distinguish between ionic and molecular compounds so that you can name them.

$AlCl_3$ NH_3 NH_4Cl

$C_6H_{12}O_6$ $NaCH_3COO$

- **Ionic compounds contain ions**
- **Molecular compounds have only nonmetals in them**

Common Ions

- Monatomic
  - Group A elements have only one possible charge
  - Group B elements (transition metals) usually have more than one possible charge
- Polyatomic
  - See pp. 62 and 64 for lists of ions you need to memorize (name, formula, charge)

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Naming Conventions

1. Ionic compounds

$NaCl$

Na_2CO_3

NH_4Br

$FeCl_3$

$FeCl_2$

$Mg(C_2H_3O_2)_2$

AgI

$CuSO_4$

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Naming Conventions

1. Ionic compounds - binary

$NaCl$	sodium chloride
$FeCl_3$	iron (III) chloride
$FeCl_2$	iron (II) chloride
AgI	silver iodide

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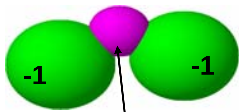
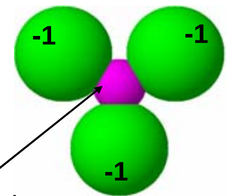
When the Metal is Multivalent

$FeCl_2$ $FeCl_3$





What charge must the Fe ion have? | What charge must the Fe ion have?

+2 | **+3**

Iron (II) chloride | **Iron (III) chloride**

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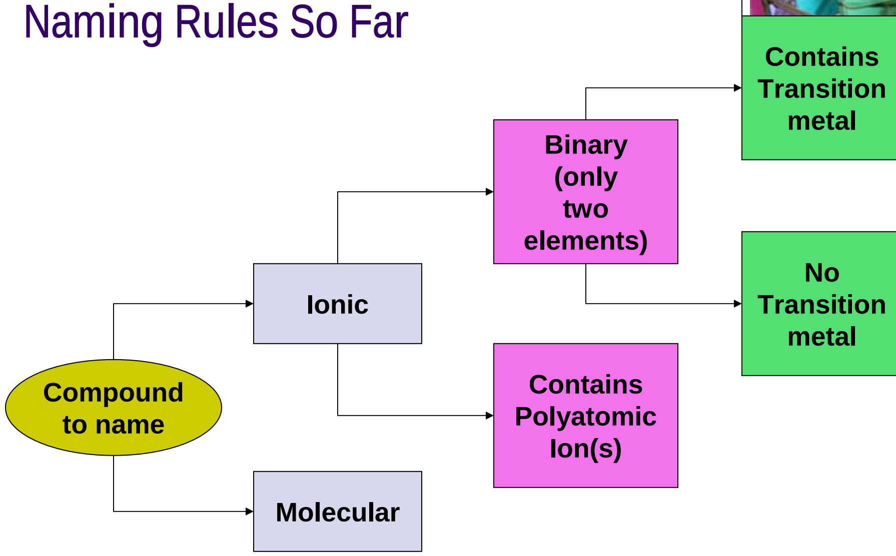
Naming Rules So Far



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Naming Conventions

1. Ionic compounds – contains polyatomic

Na_2CO_3	sodium carbonate
NH_4Br	ammonium bromide
$Mg(C_2H_3O_2)_2$	magnesium acetate
$CuSO_4$	copper (II) sulfate

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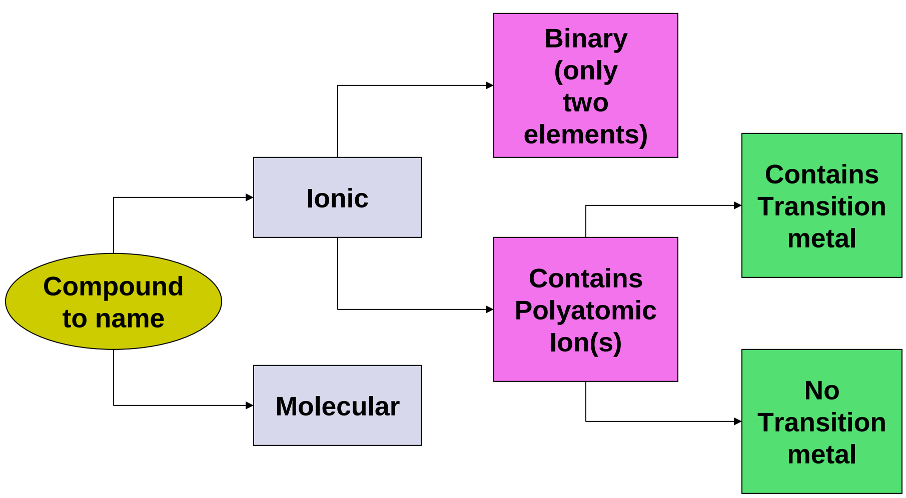
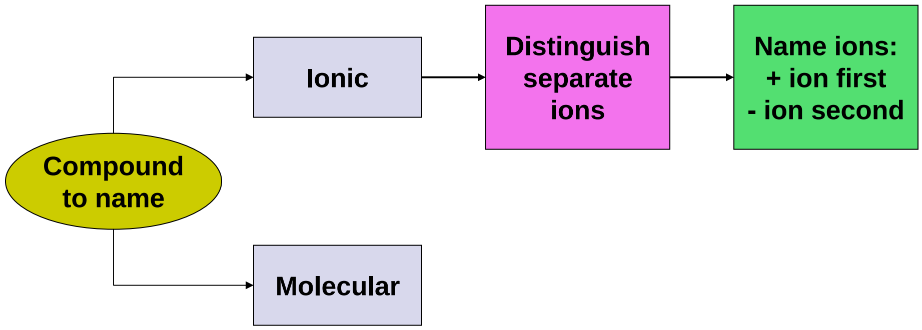
Naming Rules So Far



Naming Rules So Far



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Naming Conventions

2. Molecular compounds

NO_2	nitrogen dioxide
NO_3	nitrogen trioxide
N_2O_4	dinitrogen tetroxide
CO	carbon monoxide
CO_2	carbon dioxide
P_2O_5	diphosphorus pentoxide
CH_4	methane
C_2H_6	ethane

Read section 2.9 in your text – you will be responsible for knowing how to name simple organic compounds

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Counting to 10 in Greek to name binary molecular compounds

1. Mono
2. Bi
3. Tri
4. Tetr(a)-
5. Pent(a)-
6. Hex(a)-
7. Hept(a)-
8. Oct(a)-
9. Non(a)-
10. Dec(a)-

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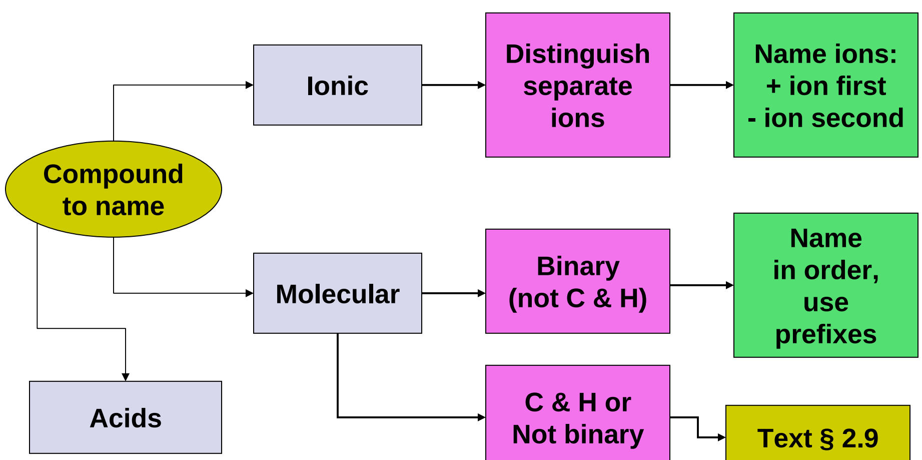
Naming Rules So Far



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Common Mistakes in Naming

- Look for ions vs. no ions

NO_3^- vs. NO_3

nitrate ion — nitrogen trioxide

- If ionic compound, regardless of how many total atoms, it has only a first name (+ ion) and a last name (- ion)

$LiHCO_3$ → Li^+ lithium; HCO_3^- hydrogen carbonate

NH_4CH_3COO → NH_4^+ ammonium; CH_3COO^- acetate

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Writing Formulas

- Formulas to names
  - Determine whether ionic or molecular
  - If ionic, name = (positive ion) (negative ion)
  - If molecular, use prefixes
  - Acids are special (name them backwards)
- Names to formulas
  - Translate the formula
  - If ionic, find ions, then balance charges
  - If molecular, read the prefixes
  - Acids are special (translate backwards)

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Names to Ionic Formulas

Potassium chloride

K^{+} Cl^{-}

+1 -1

What ratio makes a neutral ionic compound?

1:1 ratio ⇒ formula is KCl

Manganese (V) hydroxide

Mn^{5+} OH^{-}

+5 -1

What ratio makes a neutral ionic compound?

1:5 ratio ⇒

formula is $Mn(OH)_5$

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Names to Molecular Formulas

Dinitrogen pentoxide

2 of 5 of

$\mathbf{N_2O_5}$

Sulfur hexabromide

1 of 6 of

$\mathbf{SBr_6}$

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Practice

Name these compounds

- $NaNO_3$
- $(NH_4)S$
- $CrPO_4$
- N_2O

Write formulas

- Calcium iodide
- Selenium trioxide
- Strontium hypochlorite
- Iron (III) oxalate

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Naming Conventions

3. Acids

- HCl
- H_2CO_3
- HBr
- HOCl
- HClO
- $HC_2H_3O_2$
- $C_2H_3O_2H$
- HNO_2
- HNO_3

They look like ionic compounds, except that the positive ion is always H^+

What would you name them if they were ionic compounds?

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If acids were ionic compounds…

3. Acids

HCl	Hydrogen chloride
H_2CO_3	Hydrogen carbonate
HBr	Hydrogen bromide
$HOCl$	Hydrogen hypochlorite
$HClO$	Hydrogen hypochlorite
$HC_2H_3O_2$	Hydrogen acetate
$C_2H_3O_2H$	Hydrogen acetate
HNO_2	Hydrogen nitrite
HNO_3	Hydrogen nitrate

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But they're not, so here's how to name acids properly

3. Acids

HCl	~~Hydrogen chloride~~	Hydrochloric acid
H_2CO_3	~~Hydrogen carbonate~~	Carbonic acid
HBr	~~Hydrogen bromide~~	Hydrobromic acid
$HOCl$	~~Hydrogen hypochlorite~~	Hypochlorous acid
$HClO$	~~Hydrogen hypochlorite~~	
$HC_2H_3O_2$	~~Hydrogen acetate~~	Acetic acid
$C_2H_3O_2H$	~~Hydrogen acetate~~	
HNO_2	~~Hydrogen nitrite~~	Nitrous acid
HNO_3	~~Hydrogen nitrate~~	Nitric acid

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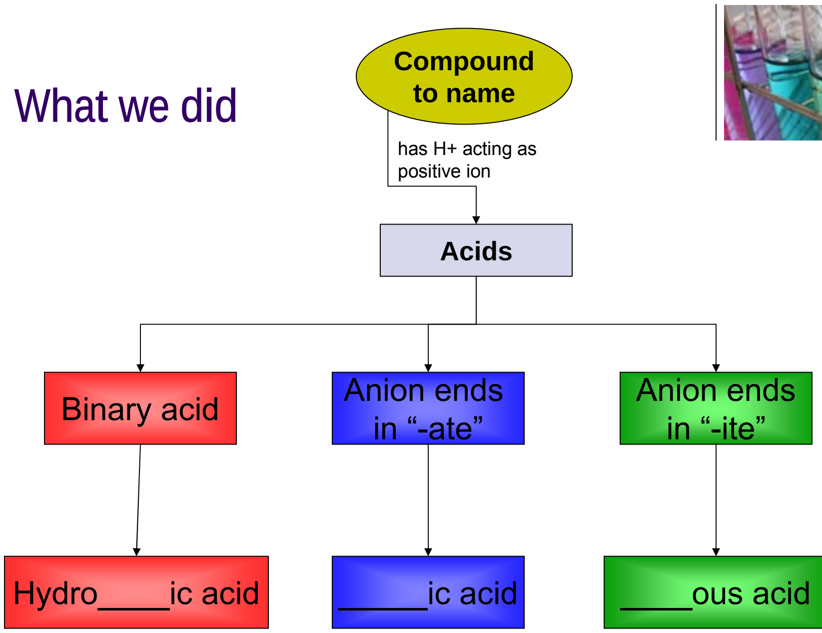
What we did



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Naming Conventions Summary

First determine if the compound is ionic, molecular, or acid.

1. Ionic compounds
   a) Binary or contain polyatomic ion(s)?
   b) Can the metal cation have more than one oxidation state?
2. Molecular compounds
   a) Binary (except not C and H)
   b) Hydrocarbons (contains C and H)
3. Acids
   a) Binary
   b) Anion ends in "-ate"
   c) Anion ends in "-ite"

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