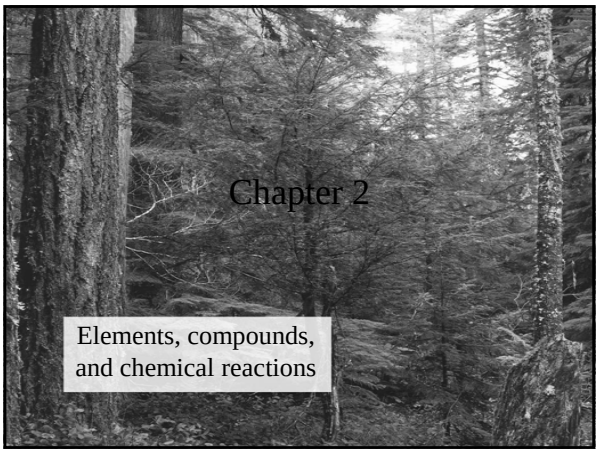


2.1 Dalton's Atomic Theory

- Concept of atoms --- nearly 2500 years ago.
- Greek Philosophical reasoning: *atomos*
- Modern atomic theory was developed from experimental observations.

2

Law of

- Conservation of Mass: no detectable gain or loss of mass occurs in chemical reactions.

and

- Definite Proportions: in a given chemical compound, the elements are always combined in definite proportions by mass.
- These served as the experimental foundation for:

3

Dalton's Atomic Theory

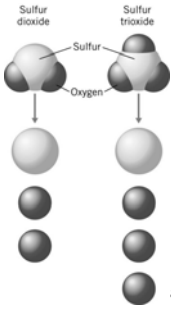
Dalton reasoned that if atoms exist, they must have certain properties to account for the laws.

- Matter consists of tiny particles called atoms.
- Atoms are indestructible.
- In any sample of a pure element, all the atoms are identical in mass and other properties.
- The atoms of different elements differ in mass and other properties.
- When atoms of different elements combine to form a specific compound, new and more complex particles form, but the atoms are always present in a fixed ratio.

4

Law of Multiple Proportions

- Derived from Dalton's theory
- Whenever two elements form more than one compound, they combine in a ratio of small whole numbers



Relative Atomic Masses

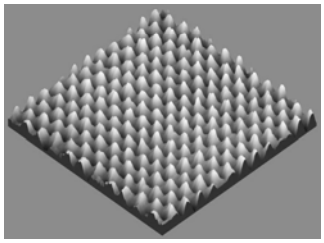
- From Dalton's theory
  - An element has a constant, characteristic atomic mass (or atomic weight)
- Individual atoms are of course difficult to weigh
- Instead, we sometimes look at the relative masses of elements in a compound
  - H:F is always 1:19 by mass

6

http://www.physics.purdue.edu/nanophys/stm.html

Actual Proof of Atomic Theory?

- Modern experimental evidence using scanning tunneling microscopes (graphite)



7

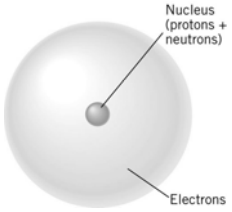
2.2 Atoms are composed of subatomic particles

- There are three elementary particles that make up all atoms:
  - Protons – positively charged
  - Electrons – negatively charged
  - Neutrons – no charge
- In a neutral atom, the number of electrons must equal the number of protons.

8

The Nucleus

- The nucleus is the central core of an atom that is positively charged and the nucleus is surrounded by electrons.
- Protons and neutrons are contained within the nucleus
- Nucleons – sub-atomic particles found in the nucleus



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Properties of Subatomic Particles

TABLE 2.1 Properties of Subatomic Particles

Particle	Mass (g)	Electrical Charge	Symbol
Electron	9.109383×10^{-28}	1−	${}^{0}_{-1}e$
Proton	$1.6726217 \times 10^{-24}$	1+	${}^{1}_{1}H^{+}$, ${}^{1}_{1}p$
Neutron	$1.6749273 \times 10^{-24}$	0	${}^{1}_{0}n$

Read Facets of Chemistry 2.1 and 2.2 on pages 41 – 43, 47 in your book. There will be an essay question on the test on this material.

10

Atomic numbers and mass numbers describe isotopes

- Atomic number (Z) – the number of protons in an atom, *determines the identity of the element*.
- Mass number (A) – sum of all the protons and neutrons in an atom.
- Isotopes of the same element have the same number of protons, but different numbers of neutrons.

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Atomic Notation

$${}^{A}_{Z}X$$

- A – atomic mass
  - # of protons + # of neutrons
- Z – atomic number
  - # of protons
- X – element symbol

12

Problems

- What is the mass number of (a) an atom with 47 p, 47 e^-, and 62 neutrons (b) an atom with 91 p, 91 e^- and 139 neutrons?
- What are the elements in (a) and (b)?
- What is the atomic number of Zirconium (Zr) and mercury (Hg)? How many protons does an atom of each have?

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Isotopes and Isotopic Abundances

- Isotopes: atoms of the same element that have a different mass.
- Each isotope has a specific percent abundance.
- What is percent abundance?
- The percent abundances must add up to 100%.
- Chemically, isotopes have nearly identical properties.

TABLE 2.2 Abundance of Hydrogen Isotopes

Hydrogen Isotope	Mass	Percentage Abundance
^1H	1.007825 u	99.985
^2H	2.0140 u	0.015

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Carbon – 12

- Symbolized by ^{12}C
- Most abundant isotope of carbon.
- The mass standard to which all atoms are compared.
- One atom of Carbon – 12 has exactly *12 atomic mass units (amu or u)*

1 atom ^{12}C has a mass of 12 u

1 u = 1.66×10^{-27} kg

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Average atomic masses can be calculated from isotopic abundances.

Naturally occurring boron is composed of 19.8% of ^{10}B and 80.2% of ^{11}B. Atoms of ^{10}B have a mass of 10.0129 u and those of ^{11}B have a mass of 11.0093 u. Calculate the average atomic mass of boron.

16

2.3 The Periodic Table

- Each chemical element has characteristic chemical properties.
- Certain groups of elements display similar properties.
- Mendeleev arranged the elements by increasing atomic mass.
- The modern periodic table (by Mosely) arranges elements by atomic number.

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Mendeleev's Periodic Table

	Group I	Group II	Group III	Group IV	Group V	Group VI	Group VII	Group VIII
1	H 1							
2	Li 7	Be 9.4	B 11	C 12	N 14	O 16	F 19	
3	Na 23	Mg 24	Al 27.3	Si 28	P 31	S 32	Cl 35.5	
4	K 39	Ca 40	— 44	Ti 68	V 51	Cr 52	Mn 55	Fe 56, Co 59 Ni 59, Cu 63
5	(Cu 63)	Zn 65	— 68	— 72	As 75	Se 78	Br 80	
6	Rb 85	Sr 87	?Yt 88	Zr 90	Nb 94	Mo 96	— 100	Ru 104, Rh 104 Pd 105, Ag 108
7	(Ag 108)	Cd 112	In 113	Sn 118	Sb 122	Te 128	I 127	
8	Cs 133	Ba 137	?Di 138	?Ce 140	—	—	—	— —
9	—	—	—	—	—	—	—	
10	—	—	?Er 178	?La 180	Ta 182	W 184	—	Os 195, Ir 197 Pt 198, Au 199
11	(Au 199)	Hg 200	Tl 204	Pb 207	Bi 208	—		
12	—	—	—	Th 231	—	U 240	—	— —
								— —

Periods

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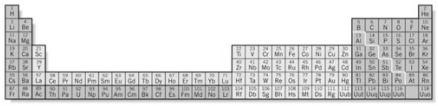
Arrangement



- Arranged in order of increasing atomic number, the periodic table looks like this.
- The columns are called groups – elements in the same group have similar chemical properties.
- The rows are called periods.

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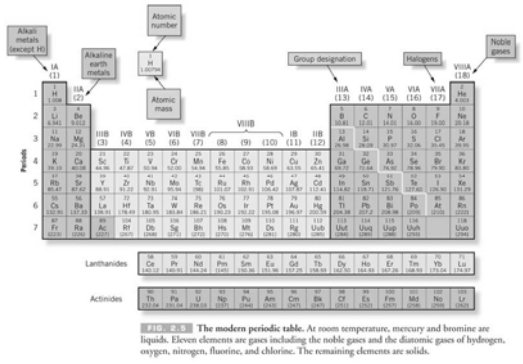

FIG. 2.5 **The modern periodic table.** At room temperature, mercury and bromine are liquids. Eleven elements are gases including the noble gases and the diatomic gases of hydrogen, oxygen, nitrogen, fluorine, and chlorine. The remaining elements are solids.

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2.4 Elements can be metals, nonmetals or metalloids

- Metals –usually good conductors of electricity and heat, are malleable (able to be hammered into flat sheets), ductile (able to be drawn into thin wires)
- Nonmetals – do not conduct electricity
- Metalloids – elements that share properties of both metals and nonmetals, sometimes called semiconductors

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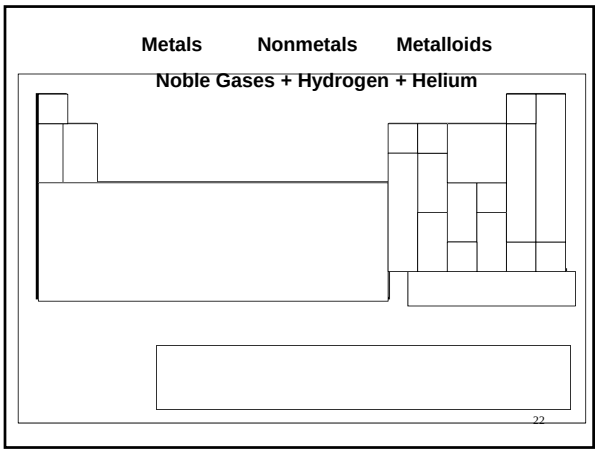
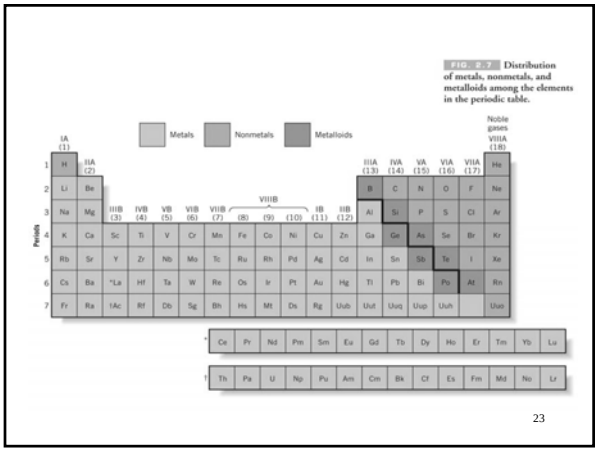




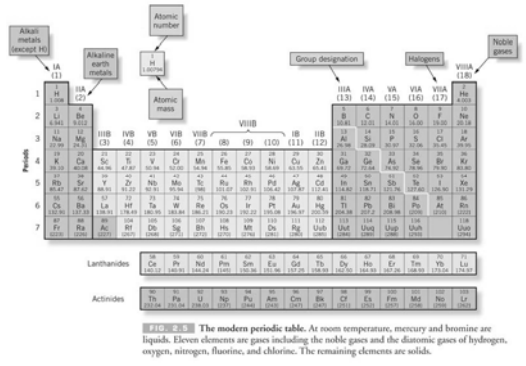
Periodic Properties

- Main group elements – those in the A groups
- Transition elements – those in the center (mostly B groups)
- Inner transition elements: 58 – 71 (lanthanides) and 90 – 103 (actinides)
- Post-transition elements: Ga, In, Sn, Tl, Pb, Bi, Uut, Uuq, Uup, and Uuh

24

- Group IA (1) – Alkali Metals
  - Shiny solids
- Group IIA (2) – Alkaline Earth Metals
- Group VIIA (17) – Halogens
  - Exist as diatomic molecules (F_2, Cl_2, Br_2, I_2)
- Group VIIIA* (18) – Noble Gases
  - Exist in nature as gases

25



The modern periodic table. At room temperature, mercury and bromine are liquids. Eleven elements are gases including the noble gases and the diatomic gases of hydrogen, oxygen, nitrogen, fluorine, and chlorine. The remaining elements are solids.

26

2.5 Formulas and equations describe substances and their reactions

- Essentially all elements can combine to form compounds.
- Two main types:
  - Molecular: which involve shared electrons and consist of electrically neutral, discrete particles called *molecules*
  - Ionic: which involve electron transfer and charged particles called *ions*

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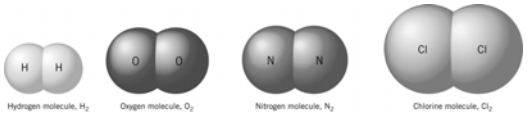
- Chemical formula: specifies the composition of the substance
  - Free elements – simply use chemical symbol
    - Not combined with other elements in a compound
    - Examples: Fe (iron), Na (sodium), and K (potassium)
  - Many nonmetals occur as diatomic molecules
    - Two atoms each
    - 7 important ones: H_2, N_2, O_2, F_2, Cl_2, Br_2, and I_2



Chemical Formulas: Examples

- NaCl is composed of the elements sodium and chlorine in a 1:1 ratio
- Fe_2O_3 is composed of the elements iron and oxygen in a 2:3 ratio
  - Subscripts
- $CO(NH_2)_2$ expands to CON_2H_4, but there are good reasons to write some compounds with parentheses.

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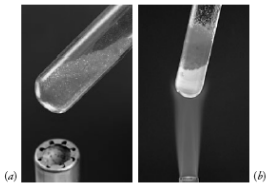
Hydrates

- Hydrates are crystals that contain water molecules.
- $CuSO_4 \cdot 5H_2O$
  - When all the water is removed (by heating), the solid that remains is said to be anhydrous (without water)
  - Anhydrous $CuSO_4$ can absorb water, removing it from the air



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Counting Atoms

- How many atoms of each element are represented by the formulas?

(a) $Al_2(SO_4)_3$

(b) $CoCl_2 \cdot 6H_2O$

31

Chemical Equations

Hydrogen and oxygen react to yield water

Hydrogen + Oxygen → Water

$2\ H_2 + O_2 \rightarrow 2\ H_2O$

Note: reactants appear on the left and products appear on the right.

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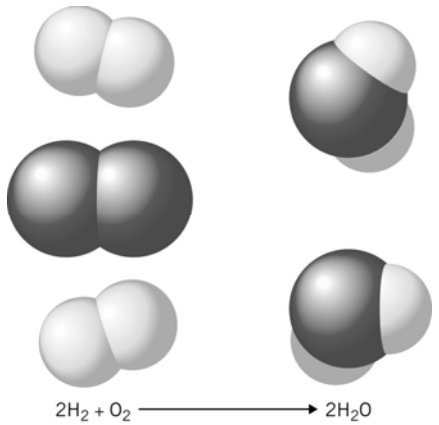

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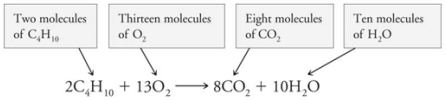
A balanced equation

- You must follow the law of conservation of mass
- Remember?
- The numbers in front of the formulas are called coefficients.



- The reactants are consumed in a reaction, while the products are produced.

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Equations and States of Matter

- It is sometimes useful to include the physical state of reactants and products
- Solids use s
- Liquids use l
- Gases use g
- Aqueous solutions use aq.
  - What is an aqueous solution?

$2\ HCl\ (aq) + CaCO_3\ (s) \rightarrow CaCl_2\ (aq) + H_2O\ (l) + CO_2\ (g)$

35

2.6 Molecular compounds

- Held together by chemical bonds
  - Electrical attractions between atoms, results from the sharing of electrons
- Usually form between **nonmetallic** elements.
- Many contain hydrogen.
- It is possible to predict the formulas of hydrogen containing compounds using the periodic table.
  - Use Group VIIIA as a reference
  - How far is the element from VIIIA?


Ammonia, NH_3


Water, H_2O


Hydrogen fluoride, HF

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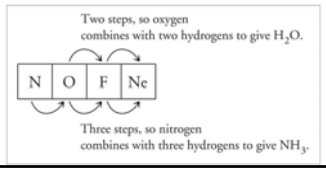
Hydrogen containing compounds

TABLE 2.4 Simple Hydrogen Compounds of the Nonmetallic Elements

	Group			
Period	IVA	VA	VIA	VIIA
2	CH_4	NH_3	H_2O	HF
3	SiH_4	PH_3	H_2S	HCl
4	GeH_4	AsH_3	H_2Se	HBr
5		SbH_3	H_2Te	HI



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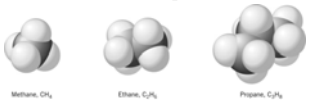
Organic Chemistry

- Deals with compounds containing mostly carbon and hydrogen
- Pure hydrocarbons contain only hydrogen and carbon.
- Alkanes are the simplest hydrocarbons
  - General formula is C_nH_{2n+2}
  - Will cover more in Chapter 22



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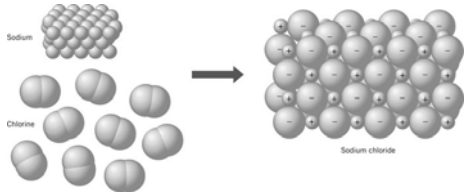
2.7 Ionic Compounds – **The other type**

- Compounds composed of electrically charged particles called ions.
- Ions are formed by the loss or gain of electrons.
- Can be formed by the reaction of a **metal** with a **nonmetal.**



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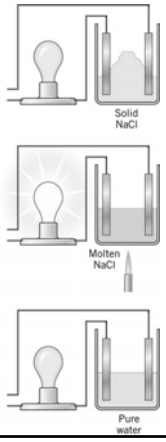
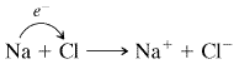
Electrical Conductivity



- Requires the movement of electrical charge
- Ionic compounds:
  - Do not conduct electricity in the solid state
  - Do conduct electricity in the liquid state because the ions are free to move in the liquid state
- Molecular compounds:
  - Do not conduct electricity in the solid or liquid state because molecules are comprised of uncharged particles

2.8 Predicting Ionic Formulas

- In the reaction seen on the previous slide, sodium lost one electron and chlorine gained one electron.



- A positive ion = cation
- A negative ion = anion

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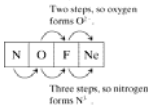
Cations

- **Metals** tend to form cations by losing electrons.
- Meaning, they have more protons than electrons resulting in a **positive** charge.
- Let's look at the metals in A groups of the periodic table.
- The positive charge on these metals is usually equal to the group number.
- What is the charge on…?

42

Anions

- **Nonmetals** tend to form anions by gaining electrons.
- Meaning, they have more electrons than protons resulting in a **negative** charge.
- Let's look at the nonmetals in A groups of the periodic table
- The negative charge on these nonmetals is usually equal to the number of spaces to the right that we have to move in the periodic table to get a noble gas.
- What is the charge on…?



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Charges on the Most Common Ions

TABLE 2.6 Some Ions Formed from the Representative Elements

Group Number						
IA	IIA	IIIA	IVA	VA	VIA	VIIA
Li^+	Be^{2+}		C^{4-}	N^{3-}	O^{2-}	F^-
Na^+	Mg^{2+}	Al^{3+}	Si^{4-}	P^{3-}	S^{2-}	Cl^-
K^+	Ca^{2+}				Se^{2-}	Br^-
Rb^+	Sr^{2+}				Te^{2-}	I^-
Cs^+	Ba^{2+}					

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Rules for Writing Ionic Formulas (of course there are rules!)

1. The **cation** is given first in the formula.
2. The subscripts in the formula must produce an **electrically neutral** formula unit.
3. The subscripts should be the set of smallest whole numbers possible
4. The charges on the ions are **NOT** included in the finished formula of the substance.

MOST IMPORTANT: All ionic compounds must be electrically neutral.

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Aluminum Chloride

- What is the charge on aluminum ion?
- What is the charge on chloride ion?

- Resulting compound = $AlCl_3$

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Practice Problems

- Write the formulas for the ionic compounds formed from:
  - Na and F
  - Na and O
  - Mg and F
  - Al and C

What about transition elements?

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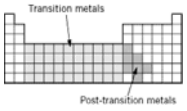

Transition Metals, etc..

- Transitions metals tend to form **cations**.
- They can form multiple charges
- You cannot predict the charges using the group number
- We must use something else…WHAT?

TABLE 2.7 Ions of Some Transition Metals and Post-transition Metals

Transition Metals	
Chromium	Cr^{2+}, Cr^{3+}
Manganese	Mn^{2+}, Mn^{3+}
Iron	Fe^{2+}, Fe^{3+}
Cobalt	Co^{2+}, Co^{3+}
Nickel	Ni^{2+}
Copper	Cu^{+}, Cu^{2+}
Zinc	Zn^{2+}
Silver	Ag^{+}
Cadmium	Cd^{2+}
Gold	Au^{+}, Au^{3+}
Mercury	Hg_2^{2+}, Hg^{2+}
Post-transition Metals	
Tin	Sn^{2+}, Sn^{4+}
Lead	Pb^{2+}, Pb^{4+}
Bismuth	Bi^{3+}

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Transition/Post-transition Elements

- Can have multiple charges
- Therefore, you are NOT responsible for memorizing them.
- You should be able to predict the charge given enough information.
- Stock system – using Roman numerals to indicate charge, used only for transition/post-transition elements.
  - Iron(III) = Fe^{3+}
  - Copper(I) = Cu^{1+}
- What other types of ions exist?

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Polyatomic Ions

- Ions that are composed of one or more elements
- They are usually composed of nonmetals (but can have metals) and they have a **charge**.
- Thus, the are called ions.

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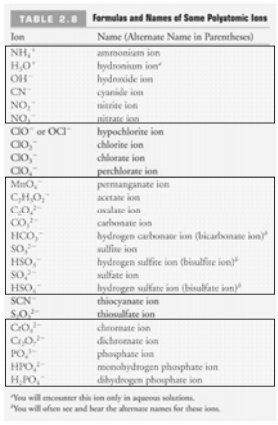

TABLE 2.8 Formulas and Names of Some Polyatomic Ions

Ion	Name (Alternate Name in Parentheses)
NH_4^+	ammonium ion
H_3O^+	hydronium ion[a]
OH^-	hydroxide ion
CN^-	cyanide ion
NO_2^-	nitrite ion
NO_3^-	nitrate ion
ClO^- or OCl^-	hypochlorite ion
ClO_2^-	chlorite ion
ClO_3^-	chlorate ion
ClO_4^-	perchlorate ion
MnO_4^-	permanganate ion
$C_2H_3O_2^-$	acetate ion
$C_2O_4^{2-}$	oxalate ion
CO_3^{2-}	carbonate ion
HCO_3^-	hydrogen carbonate ion (bicarbonate ion)[b]
SO_3^{2-}	sulfite ion
HSO_3^-	hydrogen sulfite ion (bisulfite ion)[b]
SO_4^{2-}	sulfate ion
HSO_4^-	hydrogen sulfate ion (bisulfate ion)[b]
SCN^-	thiocyanate ion
$S_2O_3^{2-}$	thiosulfate ion
CrO_4^{2-}	chromate ion
$Cr_2O_7^{2-}$	dichromate ion
PO_4^{3-}	phosphate ion
HPO_4^{2-}	monohydrogen phosphate ion
$H_2PO_4^-$	dihydrogen phosphate ion

[a]You will encounter this ion only in aqueous solutions.
[b]You will often see and hear the alternate names for these ions.

Polyatomic Ions

Need to memorize

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Practice Problems

- Write the formula of the following ionic compounds
  - Sodium ion with nitrate ion
  - Iron(III) ion with oxide ion
  - Calcium ion with oxalate ion
  - Barium ion with acetate ion
  - Cobalt(II) ion with nitride ion
  - Cu (II) ion with nitrate ion

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2.9 Naming Molecular and Ionic Compounds

- Nomenclature = Naming
- Several naming systems and they depends on the type of compound
  1. Binary nonmetallic compounds (Molecular)
  2. Ionic compounds
  3. Organic compounds (Won't learn this semester)

NOTE: You must be able to recognize the type of compound.

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Naming Binary Nonmetallic Compounds (Molecular)

1. The element that appears first in the chemical formula retains its elemental name.
2. The second element begins with a root derived from its element name and ends with the suffix "–ide". (oxygen becomes oxide, nitrogen, becomes nitride, etc…)
3. When there is more than one atom of a given element in the formula, the name of the element usually contains a prefix to specify the number of atoms present

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Name of Second Element

Chemical Symbol	Stem	Name As Second Element
O	Ox-	Oxide
S	Sulf-	Sulfide
N	Nitr-	Nitride
P	Phosph-	Phosphide
F	Fluor-	Fluoride
Cl	Chlor-	Chloride
Br	Brom-	Bromide
I	Iod-	Iodide

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When to use prefixes

- Specify number of atoms in **BINARY NONMETALLIC** compounds using Greek prefixes

mono- = 1 (omitted on 1st atom)	hexa- = 6
di- = 2	hepta- = 7
tri- = 3	octa- = 8
tetra- = 4	nona- = 9
penta- = 5	deca- = 10

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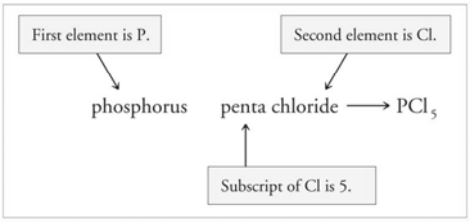
PCl_5



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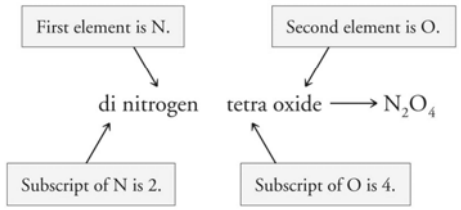
N_2O_4



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Let try some problems

- $SeCl_3$
- PCl_3
- SO_2
- Cl_2O_7
- Trichlorine tetraoxide
- Arsenic pentaiodide
- Sulfur hexafluoride
- Disulfur dibromide

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Naming Ionic Compounds

1. The cation name is given first followed by the anion name.
2. If the metal forms only one positive ion, the cation name is the element name.
3. If the metal forms more than one positive ion (transition/post-transitional elements), the cation name is the English name followed, *without a space*, by the numerical value of the charge written as a Roman numeral in parentheses.
4. For monoatomic anions, the name is created by adding the "*–ide*" suffix to the stem name for the element.
5. For polyatomic ions, use the names in Table 2.8
6. DO NOT USE PREFIXES

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Naming the negative monoatomic ions

TABLE 2.9 Monatomic Negative Ions

H^-	hydride	N^{3-}	nitride	O^{2-}	oxide	F^-	fluoride
C^{4-}	carbide	P^{3-}	phosphide	S^{2-}	sulfide	Cl^-	chloride
Si^{4-}	silicide	As^{3-}	arsenide	Se^{2-}	selenide	Br^-	bromide
				Te^{2-}	telluride	I^-	iodide

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How to name Hydrates

- Name ionic compound and then indicate the number of water molecules using correct prefix
- $MgSO_4 \cdot 4H_2O$ would be magnesium sulfate tetrahydrate.

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Practice Problems

- Name the following ionic compounds
  - NH_4HSO_4
  - $SrBr_2$
  - $MnCl_2$
  - Mg_3P_2
  - Li_2CO_3
  - $CuSO_4 \cdot 5H_2O$
  - $Fe(OH)_3$

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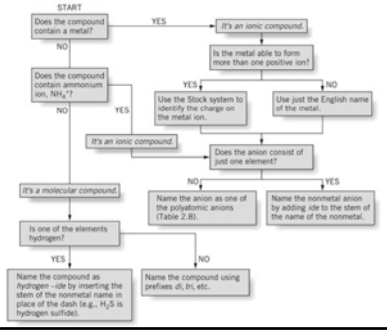
Naming Flow Chart



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1. $BaCl_2$
2. S_2Cl
3. IBr_4
4. $Ca(HSO_3)_2$
5. $Sr_3(PO_4)_2$
6. H_2S
7. SCl_2
8. IF_5
9. $Fe(OH)_2$

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10. NO
11. NaH_2PO_4
12. N_2O_3
13. SO_2
14. SeO_3
15. PH_3
16. $(NH_4)_2HPO_4$
17. $BrCl_5$
18. $Pb(C_2H_3O_2)_2 \cdot 2H_2O$

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