Chapter 5: Molecules and Compounds

Compounds - a pure substance composed of *more than one type of* _____ where the _____ combine chemically in ***fixed, definite proportions***.

- Contrast a compound to a mixture where elements can have **ANY** proportion.

Law of Constant Composition (Proust) - ratio of elements in a compound is <u>always the same</u> if the compound is pure.

Ex. Two samples of pure carbon dioxide gas were broken down into their constituent elements - carbon and oxygen - and the masses of each element were measured.

Sample 1 = 4.8 g O, 1.8 g C
Sample 2 = 17.1 g O, 6.4 g

Are these results consistent with the Law of Constant Composition?

Chemical Formulas

Chemical Formulas: describe compounds by showing the number and type of each element in the simplest unit of the compound.

- Formulas use *element symbols* and *subscripts to the right of the element symbol* to describe the number of atoms of each element in the compound.

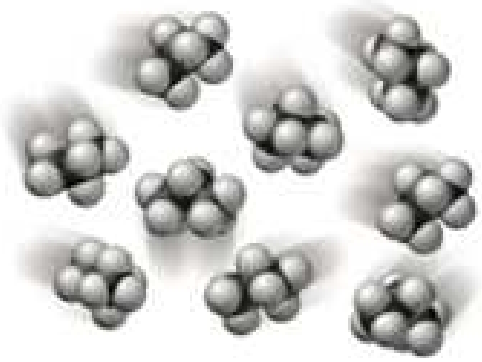
symbol for carbon and implied subscript of "1"

Ex. CO_2 ← symbol for oxygen and subscript showing 2 oxygen atoms

CO_2

Carbon dioxide

C_3H_8 - propane



Order of writing elements in a formula:

1. Metals before nonmetals (You need to know this.)
2. Nonmetals written in order shown below

C P N H S I Br Cl O F

(You DON"T need to memorize this, but be able to use it to write formula)

- Give the formula of acetone, a molecule composed of six hydrogen atoms, three carbon atoms, and one oxygen atom.

Formulas with Polyatomic Ions

Polyatomic ions: groups of atoms that act as a unit.

- Need to write these in chemical formulas in a way to indicate that the unit is kept together

Ex.

Symbol of acetate polyatomic ion (in parentheses)

$Ca(C_2H_3O_2)_2$ ← Subscript indicates two $C_2H_3O_2$ units

Calcium acetate

Implied "1" subscript on calcium

K_2SO_4

SO_4 is symbol of sulfate polyatomic ion
No parentheses for one polyatomic ion unit

Determine the number of each type of atom in $Mg_3(PO_4)_2$.

Classifying Elements and Compounds

Atomic Elements: Elements whose particles are SINGLE ATOMS.

- Most elements are atomic elements - Fe, C, Au, B, etc.

Molecular Elements : Elements whose particles are DIATOMIC MOLECULES

(molecule has **2 atoms** of the **same element**)

- Only a handful of these elements (7). They are:

H_2 N_2 O_2 Cl_2 Br_2 I_2 F_2

You need to know these

Classifying Compounds

Molecular Compounds: Compounds whose particles are molecules made of <u>two or more</u> NONMETALS.

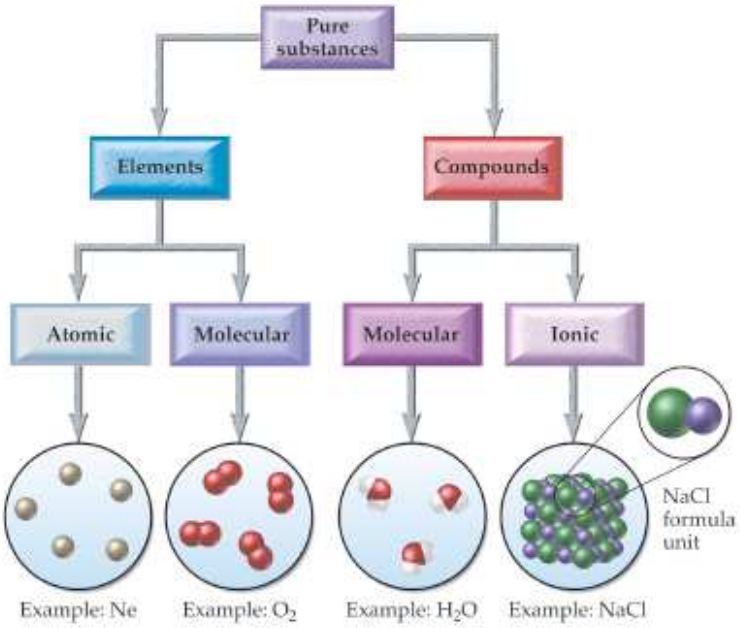
- Examples: H_2O, CS_2, $C_3H_6O_2$, NH_3, PCl_3

Ionic Compounds: Compounds whose particles are **<u>CATIONS</u> (made from metals)** and **<u>ANIONS</u>** (made from 1 or more nonmetals).

- No molecules, instead have <u>formula units</u>
- Have 3-D lattice of cations and anions held together by + & - attractive forces
- Ex. NaCl, CaO, $NiBr_2$, K_3PO_4

NaCl

<u>Classifying Elements and Compounds</u>



Classify the following as ether an atomic element, molecular element, molecular compound or ionic compound.

- O_2
- CO
- Na_2O
- Co
- N_2H_4
- $FeCl_3$

Review: Main Group Cation and Anion Charges

Recall from Chapter 4:

	Examples
Group IA metals form +1 cations	Na^+, Li^+
Group IIA metals form +2 cations	Ca^{2+}, _____
Group IIIA metals form ___ cations	_____
Group VIIA nonmetals form -1 anions	F^-, _____
Group VIA nonmetals form ___ anions	_____, _____
Group VA nonmetals form ___ anions	_____, _____

To form K^+, neutral K needs to lose/gain 1 electron

To form P^{3-}, neutral P needs to gain _____ electrons

Periodic Table of the Elements

Period	1 IA	2 IIA		3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 H 1.008																		2 He 4.003
2	3 Li 6.939	4 Be 9.012												5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.31												13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 Ca 40.08		21 Sc 44.96	22 Ti 47.90	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
5	37 Rb 85.47	38 Sr 87.62		39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.96	43 *Tc* (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.4	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.75	52 Te 127.60	53 I 126.90	54 Xe 131.29
6	55 Cs 132.91	56 Ba 137.33	57-70 *	71 Lu 174.97	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra (226)	89-102 **	103 *Lr* (257)	104 *Rf* (261)	105 *Db* (262)	106 *Sg* (271)	107 *Bh* (272)	108 *Hs* (270)	109 *Mt* (276)	110 *Ds* (281)	111 *Rg* (280)	112 *Uub* (285)	113 *Uut* (284)	114 *Uuq* (289)	115 *Uup* (288)	116 *Uuh* (292)	117	118 *Uuo* (294)

*	57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 *Pm* (147)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04
**	89 Ac (227)	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 *Np* (237)	94 *Pu* (244)	95 *Am* (243)	96 *Cm* (247)	97 *Bk* (247)	98 *Cf* (251)	99 *Es* (252)	100 *Fm* (257)	101 *Md* (258)	102 *No* (259)

Reference: http://www.webelements.com

Writing Ionic Compound Formulas

- Formulas for ionic compounds should be NEUTRAL. Ratio in which cations (+) and anions (-) combine is such that the charges cancel.

	cation	anion	charge cancellation	formula
Ex.	K^+	S^{2-}	$2K^+$ and 1 S^{2-}	K_2S
	Ba^{2+}	Cl^-		

- The symbol for the positively charge cation is written first, followed by the anion.
- CHARGES ARE NOT SHOWN in final formula
- Subscripts give the combining ratio

Problems: (Hint: need to first determine cation and anion charges)

Write the formula of an ionic compound made from:

a) Calcium (Ca) and bromine (Br)

b) Lithium (Li) and nitrogen (N)

c) Aluminum (Al) and oxygen (O)

d) Magnesium (Mg) and sulfur (S)

Type I & II Ionic Compounds

Two types of Ionic Compounds: Type I and Type II

- Type I - Metal forms only ONE TYPE of positive ion

  Group IA - IIIA metals are type I cations

  Name of cation is the same as the element

  Ex. Mg^{2+} magnesium cation
  Na^{+} sodium cation

- TYPE II - Metal forms MORE THAN ONE TYPE of positive ion

  Most transition metals are type II cations

  (exceptions: **Zn^{2+}**, Cd^{2+}, **Ag^{+}** - always these charges)

TABLE 5.4 Some Metals That Form Type II Ionic Compounds and Their Common Charges

Metal	Symbol Ion	Name
chromium	Cr^{2+}	chromium(II)
	Cr^{3+}	chromium(III)
iron	Fe^{2+}	iron(II)
	Fe^{3+}	iron(III)
cobalt	Co^{2+}	cobalt(II)
	Co^{3+}	cobalt(III)
copper	Cu^{+}	copper(I)
	Cu^{2+}	copper(II)
tin	Sn^{2+}	tin(II)
	Sn^{4+}	tin(IV)
mercury	Hg_2^{2+}	mercury(I)
	Hg^{2+}	mercury(II)
lead	Pb^{2+}	lead(II)
	Pb^{4+}	lead(IV)

Name of cation is the element name followed by charge of cation in parentheses

Ex. Fe^{3+} iron (III) cation
Cu^{2+} copper (II) cation

Anion Nomenclature

Monoatomic ANION Names

Use element's root (base) name plus "ide"

VA		VIA		VIIA	
N^{3-}	nitride	O^{2-}	oxide	F^-	fluoride
P^{3-}	_____	S^{2-}	_____	Cl^-	_____
		Se^{2-}	_____	Br^-	_____
				I^-	_____

Some Common Polyatomic Ions

Name	Formula
Acetate	**$C_2H_3O_2^-$**
Carbonate	**CO_3^{2-}**
Hydrogencarbonate (aka bicarbonate)	**HCO_3^-**
Hydroxide	**OH^-**
Nitrate	**NO_3^-**
Nitrite	NO_2^-
Chromate	CrO_4^{2-}
Dichromate	$Cr_2O_7^{2-}$
Ammonium	**NH_4^+**
Cyanide	**CN^-**

Name	Formula
Hypochlorite	$HClO^-$
Chlorite	ClO_2^-
Chlorate	**ClO_3^-**
Perchlorate	ClO_4^-
Sulfate	**SO_4^{2-}**
Sulfite	SO_3^{2-}
Hydrogen sulfate (aka bisulfate)	HSO_4^-
Hydrogen sulfite (aka bisulfite)	HSO_3^-
Phosphate	**PO_4^{3-}**

You need to know the 10 polyatomic ions in <u>BLACK</u> by quiz #2

(Know Names, formulas and charges - **See your syllabus for list there as well)**

Naming Ionic Compounds

Name cation first followed by anion

(need to determine whether cation is type I or II to name correctly)

Determine the name of the following ionic compounds from their formulas:

Na_2O _____ $FeCl_3$ _____

$CoCl_2$ _____ Li_2SO_4 _____

$CuCl$ _____ $PbBr_2$ _____

$(NH_4)_3PO_4$ _____ SnF_4 _____

$CaCO_3$ _____ BaS_____

Determine the formula for the following ionic compounds from their names:

copper (II) iodide _____ sodium cyanide _____

calcium nitride _____ zinc oxide _____

lead (II) sulfide _____ iron (III) nitrate_____

ammonium chloride_____ magnesium chlorate _____

Sodium hydroxide _____ Aluminum Phosphide _____

Naming Molecular Compounds

Molecular Compounds: contain only nonmetals and <u>have no ions</u>

Binary (2 element) molecular compounds are named from the formula using Greek prefixes to show quantity

N_2O:

N_2O_4:

CO:

NO_3:

CO_2:

S_2Cl_2:

Phosphorus trichloride

Carbon tetrachloride

Disulfur monoxide

<u>Greek prefixes</u>
(for quantity)

1: mono

2: di

3:

4:

5:

6:

Naming Acids

Acid - a molecular compound that ionizes to form H^+ when dissolved in water (H^+ is the cation).

$$HCl(g) \xrightarrow[H_2O]{} H^+_{(aq)} + Cl^-_{(aq)}$$

- To indicate an acid is dissolved in water (aq) is written after the formula i.e. $HCl_{(aq)}$
- Acid formulas are written so that the acidic hydrogens(s) is the **first atom(s) listed** in the formula.

Examples of compounds which are acids:

HNO_3	HNO_2	$HClO_4$
H_2SO_4	H_3PO_4	HCl
H_2CO_3	$HC_2H_3O_2$	HCN

Name (compound not in water) → Name (dissolved in water)

Hydrogen chloride → hydrochloric acid
HCl → (H_2O)

Hydrogen nitrate → nitric acid
HNO_3 → (H_2O)

Hydrogen nitrite → nitrous acid
→ (H_2O)

Not all compounds with H atoms are acids: ex. CH_4, NH_3

Naming Acids

anion		acid
-ate	→	-ic acid
-ite	→	-ous acid
-ide	→	hydro- -ic acid

Give the acid name for the following compounds:

HBr hydrogen bromide _____

H_2CO_3 hydrogen carbonate _____

H_2SO_3 hydrogen sulfite _____

H_2S hydrogen sulfide _____

HNO_3 hydrogen nitrate _____

$HClO_3$ hydrogen chlorate _____

HF hydrogen fluoride _____

H_3PO_3 hydrogen phosphite _____

Formula Mass

- The mass of an individual molecule or formula unit
  (also known as molecular mass or molecular weight)

- To calculate formula mass add the masses of the atoms in a single molecule or formula unit

Ex. What is the formula mass of H_2O?

2(1.008 amu) + 16.00 amu = 18.016 = **18.02 amu**

Calculate the formula mass of $Al_2(SO_4)_3$