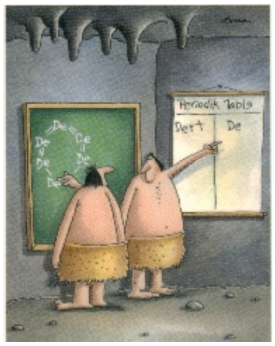
Atoms, Molecules and Ions

Chapter 2 and Chapter 3 (3.1, 3.2)
"Chapter 2 Part 2"

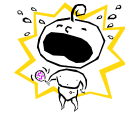
Chemistry 221
Professor Michael Russell

MAR *Last update: 4/29/24*



Early chemists describe the first dirt molecule

Poor Auntie Jane!



Auntie Jane fed Baby Nell
What she thought was calomel
What the baby really ate
was Corrosive Sublimate
Not much difference,
I confess,
Just one chlorine more
and one baby less!

calomel = HgCl *(for dysentery)*
Corrosive Sublimate = $HgCl_2$

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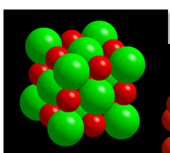
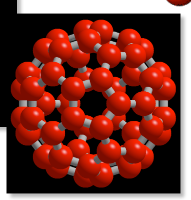
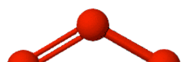
Molecules, Ions and Compounds



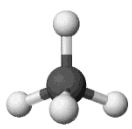
NaCl, salt



Buckyball, C_{60}



Ozone, O_3



Methane, CH_4

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Compounds and Molecules

COMPOUNDS are a combination of 2 or more elements in definite ratios by mass.

The character of each element is lost when forming a compound.

MOLECULES are the smallest unit of a compound that retains the characteristics of the compound.

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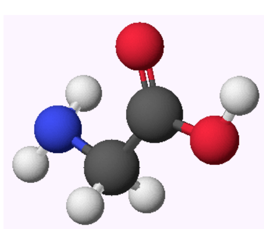
MOLECULAR FORMULA

Formula for glycine is $C_2H_5NO_2$

In one molecule there are

- **2 C atoms**
- **5 H atoms**
- **1 N atom**
- **2 O atoms**



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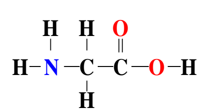
Writing Formulas

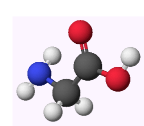
Can also write glycine formula ($C_2H_5NO_2$) as

H_2NCH_2COOH

to show atom ordering

or in the form of a structural formula





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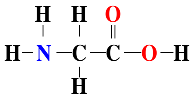
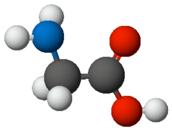
structural formulas also called "condensed" formulas

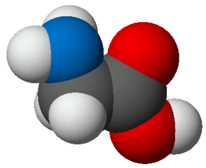
Molecular Modeling



Drawing of glycine



Ball & stick



Space-filling

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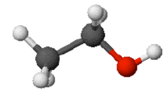
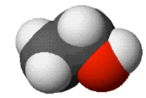
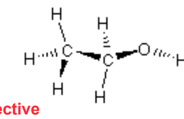
3D Perspectives: Ethanol



Ball and Stick



Space Filling



Perspective

Ethanol = CH_3CH_2OH

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Comparison of Formula Types

Compound	Molecular	Empirical	Structural
Water	H_2O	H_2O	HOH
Hydrogen Peroxide	H_2O_2	HO	HOOH
Ethylene	C_2H_4	CH_2	H_2CCH_2
Ethane	C_2H_6	CH_3	H_3CCH_3
Ethanol	C_2H_6O	C_2H_6O	H_3CCH_2OH
Dimethyl ether	C_2H_6O	C_2H_6O	H_3COCH_3

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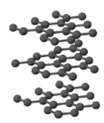
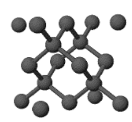
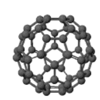
Allotropes of Elements



graphite



diamond



Buckyball (C_{60}) or Buckminsterfullerene

Most elements exist as individual atoms - ***monotomic***

Allotropes are **different versions of the same element**

Carbon *exists naturally as* **graphite, diamond and buckyballs.**

Seven elements exist as *diatomics* *(next slide)*

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Also carbon graphene

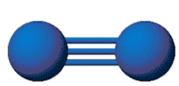
The Seven Diatomic Elements

Have
No
Fear
Of
Ice
Clear
Brew

"HONCl BrIF"

Most elements are monatomic - they exist as individual atoms - but there are these seven exceptions:

Oxygen (O_2) generated on a leaf



Nitrogen, N_2

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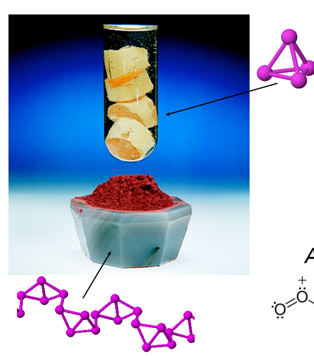
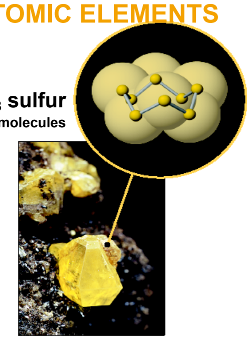
OTHER ELEMENTS THAT EXIST AS POLYATOMIC ELEMENTS

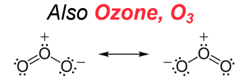


White P_4 and polymeric red phosphorus



S_8 sulfur molecules

Also Ozone, O_3



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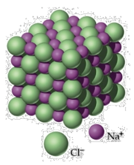
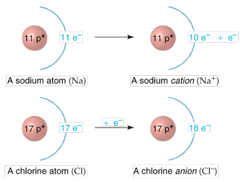
IONS AND IONIC COMPOUNDS

IONS are atoms or groups of atoms with a positive or negative charge.

Taking away electron(s) creates a CATION with a positive charge

Adding electron(s) creates an ANION with a negative charge.





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IONS AND IONIC COMPOUNDS

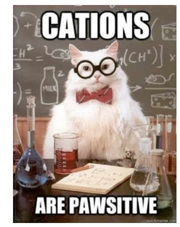
CATIONS have protons > electrons

ANIONS have electrons > protons

Remember:

CATS have PAWS

CATions are PAWSitive



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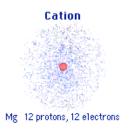
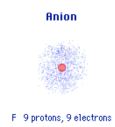
Formation of Cations and Anions



Mg --> Mg^{2+} + 2 e-

A cation forms when an atom loses one or more electrons.



F + e- --> F^-

An anion forms when an atom gains one or more electrons

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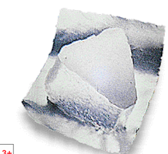
Charges on Metals

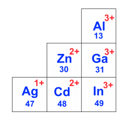


Fixed charge metals include:

Groups IA, IIA & "stairs"** ***(next slide)

****charge* = group number *(mostly)***

Na^+	sodium ion
Mg^{2+}	magnesium ion
Al^{3+}	aluminum ion
Ag^+	silver ion



the stairs

All other metals ("*variable charge*" metals) --> use Roman number to represent charge on metal

Fe^{2+}	iron(II) ion
Fe^{3+}	iron(III) ion
V^{3+}	vanadium(III) ion

No ferrous or ferric nomenclature!

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The Fixed Charge "Stairs" Metals

- Start with Al (which is +3)
- Go backwards down the "stairs"
- Decrease charge after each "stair"

		Al 13 (3+)
	Zn 30 (2+)	Ga 31 (3+)
Ag 47 (1+)	Cd 48 (2+)	In 49 (3+)

These, and Groups IA and IIA, are the "fixed charge metals", and we always know their ionic charge

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NONMETALS

NONMETAL + n e- ------> X^{n-}

where charge = Group no. - 8

webelements.com: group no. - 18

Group 4A	Group 5A	Group 6A	Group 7A
C^{4-},carbide	N^{3-}, nitride	O^{2-}, oxide	F^-, fluoride
		S^{2-}, sulfide	Cl^-, chloride
			Br^-, bromide
			I^-, iodide

Name derived by adding -ide to stem

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A "Quick and Dirty" Guide to Ionic Charges

Groups IA, IIA or "the stairs": *fixed charge metals*
Charge = positive
Magnitude = group # *mostly!*

Groups VA, VIA or VIIA: *fixed charge nonmetals*
Charge = negative
Charge = group # - 8

All Other Metals: Difficult to predict, use **Roman number** to represent positive charge,
these are the "Variable Charge metals"

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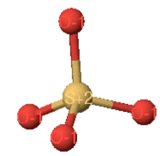
POLYATOMIC IONS



Groups of atoms with a charge.
MEMORIZE the names and formulas in your text and the "Nomenclature" lab.

Charge	Formula	Name	Formula	Name
1−	H^-	Hydride ion	**CH_3COO^-** (or $C_2H_3O_2^-$)	**Acetate ion**
	F^-	**Fluoride ion**	ClO_3^-	Chlorate ion
	Cl^-	**Chloride ion**	**ClO_4^-**	**Perchlorate ion**
	Br^-	**Bromide ion**	**NO_3^-**	**Nitrate ion**
	I^-	**Iodide ion**	MnO_4^-	Permanganate ion
	CN^-	Cyanide ion		
	OH^-	**Hydroxide ion**		
2−	**O^{2-}**	**Oxide ion**	**CO_3^{2-}**	**Carbonate ion**
	O_2^{2-}	Peroxide ion	CrO_4^{2-}	Chromate ion
	S^{2-}	**Sulfide ion**	$Cr_2O_7^{2-}$	Dichromate ion
			SO_4^{2-}	**Sulfate ion**
3−	N^{3-}	Nitride ion	**PO_4^{3-}**	**Phosphate ion**

* The most common ions are in boldface.

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Formulas and Names of Some Common Polyatomic Ions

Formula	Name	Formula	Name
CATION: Positive Ion			
NH_4^+	ammonium ion		
ANIONS: Negative Ions			
Based on a Group 4A element		***Based on a Group 7A element***	
CN^-	cyanide ion	ClO^-	hypochlorite ion
$CH_3CO_2^-$	acetate ion	ClO_2^-	chlorite ion
CO_3^{2-}	carbonate ion	ClO_3^-	chlorate ion
HCO_3^-	hydrogen carbonate ion (or bicarbonate ion)	ClO_4^-	perchlorate ion
Based on a Group 5A element		***Based on a transition metal***	
NO_2^-	nitrite ion	CrO_4^{2-}	chromate ion
NO_3^-	nitrate ion	$Cr_2O_7^{2-}$	dichromate ion
PO_4^{3-}	phosphate ion	MnO_4^-	permanganate ion
HPO_4^{2-}	hydrogen phosphate ion		
$H_2PO_4^-$	dihydrogen phosphate ion		
Based on a Group 6A element			
OH^-	hydroxide ion		
SO_3^{2-}	sulfite ion		
SO_4^{2-}	sulfate ion		
HSO_4^-	hydrogen sulfate ion (or bisulfate ion)		

Note: many O containing anions have names ending in –ate (or -ite).

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Introducing: Nick the Camel!

<u>N</u>ick *the* <u>C</u>amel <u>B</u>rat *ate* <u>I</u>cky <u>C</u>lam *for* <u>S</u>upper *in* <u>P</u>hoenix

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Nick the Camel

<u>N</u>ick *the* <u>C</u>amel <u>B</u>rat *ate* <u>I</u>cky <u>C</u>lam *for* <u>S</u>upper *in* <u>P</u>hoenix

	Consonants = Oxygen	Vowels = Charge	Polyatomic Ion
Nick = Nitrate	3	-1	NO_3^-
Camel = Carbonate	3	-2	CO_3^{2-}
Brat = Bromate	3	-1	BrO_3^-
Icky = Iodate	3	-1	IO_3^-
Clam = Chlorate	3	-1	ClO_3^-
Supper = Sulfate	4	-2	SO_4^{2-}
Phoenix = Phosphate	4	-3	PO_4^{3-}

Did Nick have <u>C</u>repes *for dessert too? :)*

Crepes = chromate	4	-2	CrO_4^{2-}

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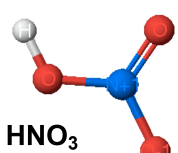
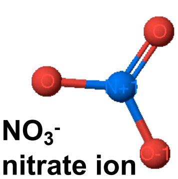
Some Common Polyatomic Ions



HNO_3
nitric acid



NO_3^-
nitrate ion

Many polyatomic ions related by a hydrogen ion (H^+) to an acid

Potassium nitrate somewhat common!

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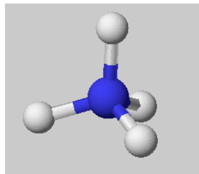
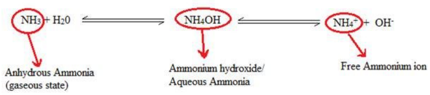
Some Common Polyatomic Ions

NH_4^+ is the ammonium ion

One of the few common polyatomic *cations*

ammonia (NH_3) *plus* acid (H^+) *gives the* ammonium cation:





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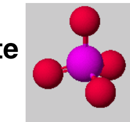
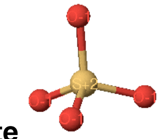
Some Common Polyatomic Ions

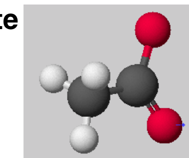
PO_4^{3-} phosphate



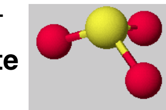
SO_4^{2-} sulfate



$CH_3CO_2^-$ acetate



SO_3^{2-} sulfite



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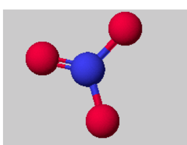
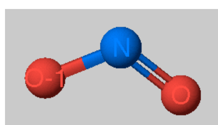
Some Common Polyatomic Ions

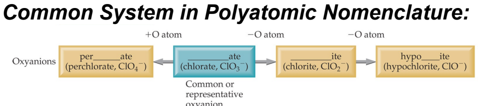
NO_3^- nitrate





NO_2^- nitrite

Common System in Polyatomic Nomenclature:



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See: "Common Polyatomic Ions and the Corresponding Acids" handout

COMPOUNDS FORMED FROM IONS *(ionic bonding)*

CATION + ANION → COMPOUND

Zn^{+2} + S^{-2} → ZnS

A neutral compound requires equal number of positive and negative charges.

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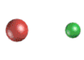
COMPOUNDS FORMED FROM IONS *(ionic bonding)*



CATION + ANION → COMPOUND

Na^+ + Cl^- → NaCl

A neutral compound requires equal number of positive and negative charges.

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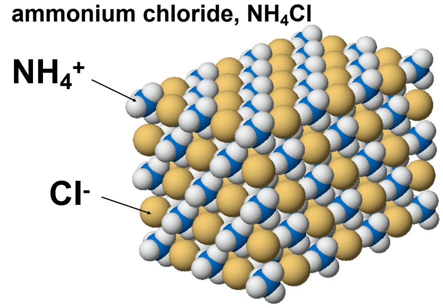
IONIC COMPOUNDS

ammonium chloride, NH_4Cl



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Some Ionic Compounds

Ca^{2+} + F^- ---> CaF_2

Name = calcium fluoride

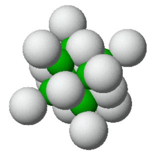
Mg^{2+} + NO_3^- ----> $Mg(NO_3)_2$

Name = magnesium nitrate

Fe^{2+} + PO_4^{3-} ----> $Fe_3(PO_4)_2$

Name = iron(II) phosphate

also: $FePO_4$ *Name* = iron(III) phosphate, *etc.*



calcium fluoride

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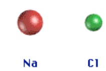
Properties of Ionic Compounds

Forming NaCl from Na and Cl_2



A metal atom can transfer an electron to a nonmetal.

The resulting cation and anion are attracted to each other by **electrostatic forces**.

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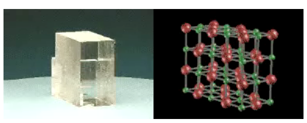
Electrostatic Forces



The oppositely charged ions in ionic compounds are attracted to one another by ELECTROSTATIC FORCES.

These forces are governed by COULOMB'S LAW.

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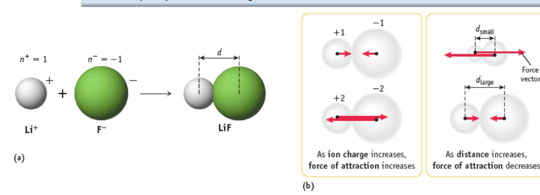
Electrostatic Forces

COULOMB'S LAW

$$\text{Force} = -k\frac{(n^+e)(n^-e)}{d^2}$$

charge on + and − ions; charge on electron; proportionality constant; distance between ions



MAR

Electrostatic Forces

COULOMB'S LAW

$$\text{Force} = -k\frac{(n^+e)(n^-e)}{d^2}$$

charge on + and − ions; charge on electron; proportionality constant; distance between ions

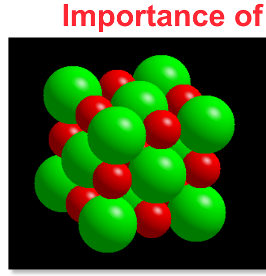
As ion charge increases, the attractive force _______________.

As the distance between ions increases, the attractive force _______________.

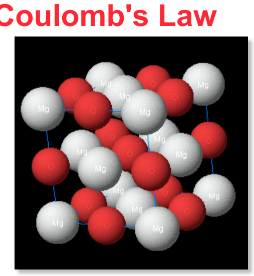
This idea is important and will come up many times in future discussions - see *handout*

MAR

Importance of Coulomb's Law



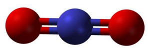
NaCl, Na^+ and Cl^-, m.p. 804 °C



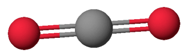
MgO, Mg^{2+} and O^{2-} m.p. 2800 °C

MAR

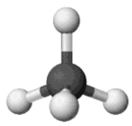
Molecular (Covalent) Compounds
Compounds without Ions



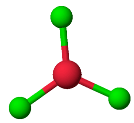
NO_2 nitrogen dioxide



CO_2 carbon dioxide



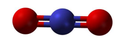
CH_4 methane



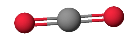
BCl_3 boron trichloride

MAR

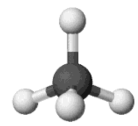
Naming Molecular (Covalent) Compounds



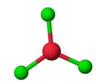
NO_2 nitrogen dioxide



CO_2 Carbon dioxide



CH_4 methane



BCl_3 boron trichloride

Covalent compounds formed from **two or more nonmetals; use Greek prefixes**

Ionic compounds generally involve a metal and nonmetal (NaCl) - ***do not use Greek prefixes with metals!***

MAR

Greek Prefixes

1	*mono*	6	*hexa*
2	*di*	7	*hepta*
3	*tri*	8	*octa*
4	*tetra*	9	*nona*
5	*penta*	10	*deca*

MAR

Three Types of Compound Naming

Fixed charge metal + nonmetal (ionic) *No Greek prefixes or Roman numbers*
Al_2O_3 - aluminum oxide

Variable charge metal + nonmetal (ionic) *Use Roman numbers*
Fe_2O_3 - iron(III) oxide
Watch variable charge: FeO = iron(II) oxide, etc.

Nonmetal + nonmetal (covalent) *Use Greek prefixes*
P_2O_3 - diphosphorus trioxide
Also P_2O_5, = diphosphorus pentoxide, etc.

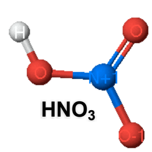
MAR

ACIDS

Acids create *hydrogen ions* in water, acidic H^+ listed *first* in compound

Some acids include:

HCl	hydrochloric
HNO_3	nitric
$HClO_4$	perchloric
H_2SO_4	sulfuric
HBrO	hypobromous



HNO_3

MAR

more in Chapter Four and Nomenclature Lab

BASES

Bases are metal hydroxides, creating OH^- in water

Some bases include:

NaOH	sodium hydroxide
KOH	potassium hydroxide
LiOH	lithium hydroxide
$Ca(OH)_2$	calcium hydroxide
$Fe(OH)_3$	iron(III) hydroxide

MAR

more in Chapter Four and Nomenclature Lab

Hydrated Compounds

When prepared in water and isolated as solids, many ionic compounds have water molecules trapped in the lattice.

"Waters of hydration" result in *beautiful* colors

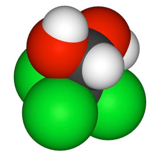
$CuSO_4 \cdot 5\ H_2O_{(s)}$ + heat
→ $CuSO_{4(s)}$ + 5 $H_2O_{(g)}$

MAR

Hydrated Compounds

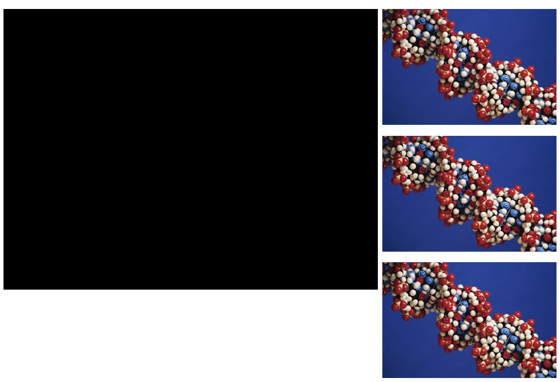
Nomenclature: use Greek prefix + "hydrate" after regular name

$CuSO_4 \cdot 5\ H_2O$ = copper(II) sulfate pentahydrate
$MgSO_4 \cdot 7\ H_2O$ = magnesium sulfate heptahydrate
$NiCl_2 \cdot 6\ H_2O$ = nickel(II) chloride hexahydrate
$CuSO_4$ *without water* called "anhydrous" copper(II) sulfate



MAR

ATOMS OVERWHELMING YOU?

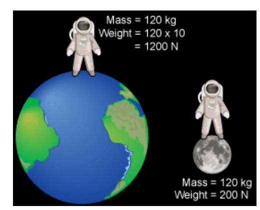


MAR

MOLECULAR WEIGHT AND MOLAR MASS

Molecular weight is the sum of the atomic weights of all atoms in the molecule.

Molar mass = molecular weight in grams



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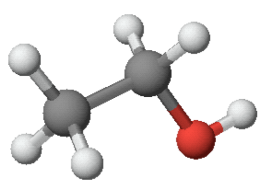
What is the molar mass of ethanol, C_2H_6O?



1 mol contains

2 mol C (12.01 g C/1 mol) = 24.02 g C

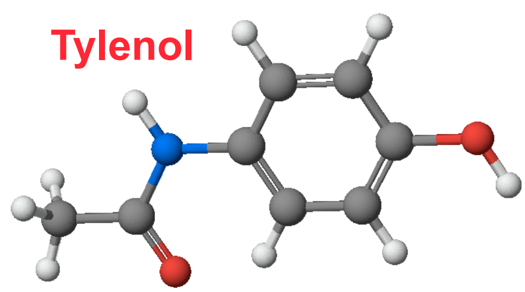
6 mol H (1.01 g H/1 mol) = 6.06 g H

1 mol O (16.00 g O/1 mol) = 16.00 g O

TOTAL = **molar mass = 46.08 g/mol**

MAR

Tylenol

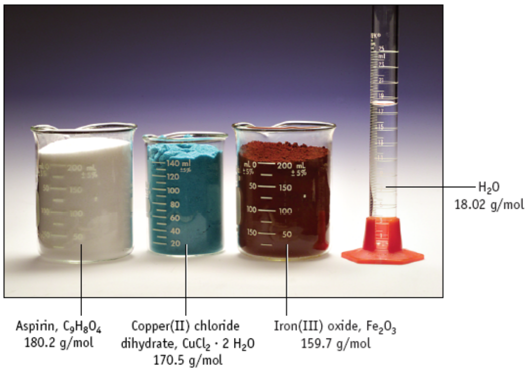


Formula = $C_8H_9NO_2$
Molar mass = 151.16 g/mol

MAR

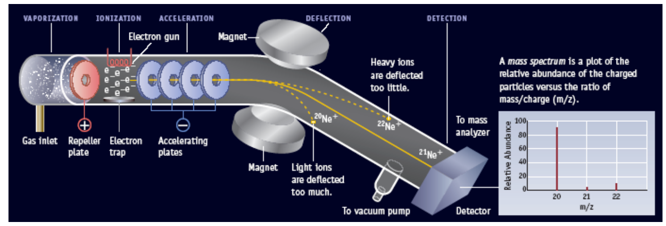
Try to use at least four sig figs for molar mass

Molar Mass



MAR

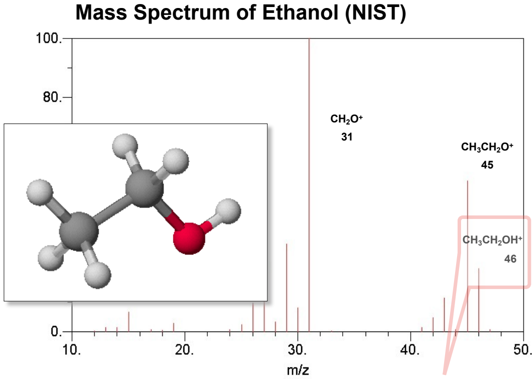
How to Determine a Formula?



Mass spectrometer

MAR

Mass Spectrum of Ethanol (NIST)



Molar mass = 46.08 g mol⁻¹

MAR

How many moles of alcohol (ethanol) are present in a "standard" can of beer if there are 21.3 g of C_2H_6O?

(a) Molar mass of C_2H_6O = 46.08 g/mol

(b) Calc. moles of alcohol

$$21.3 \text{ g} \bullet \frac{1 \text{ mol}}{46.08 \text{ g}} = 0.462 \text{ mol}$$

0.46223958...

MAR

How many molecules of alcohol (ethanol) are present in a "standard" can of beer if there are 21.3 g of C_2H_6O?

We know there are 0.462 mol of C_2H_6O.

$$0.462 \text{ mol} \bullet \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}}$$

= **2.78×10^{23} molecules**

2.78216...E23

MAR

How many atoms of C are present in a "standard" can of beer if there are 21.3 g of C_2H_6O?

We know there are 2.78×10^{23} molecules.
Each molecule contains 2 C atoms.
Therefore, the number of C atoms is

$$2.78 \times 10^{23} \text{ molecules} \bullet \frac{2 \text{ C atoms}}{1 \text{ molecule}}$$

= **5.56×10^{23} C atoms**

5.56E23

MAR

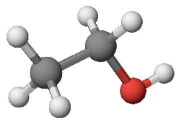
*$2.78 * 10^{23} * 9$ = **2.50×10^{24} atoms** in the 21.3 g of ethanol!*

Empirical and Molecular Formulas

A pure compound always consists of the same elements combined in the same proportions by weight.

Therefore, we can express molecular composition as PERCENT BY WEIGHT

Ethanol, C_2H_6O
52.13% C, 13.15% H, 34.72% O

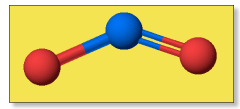


MAR

Percent Composition

Consider the nitrogen-oxygen family of compounds:

NO_2, nitrogen dioxide, and NO, nitrogen monoxide (or *nitric oxide*)



Structure of NO_2

Chemistry of NO, nitrogen monoxide

MAR

Percent Composition

Consider NO_2, Molar mass = ?

What is the weight percent of N and of O?

*To find the **weight percent** of an element in a compound:*

$$\text{Wt. \% X} = \frac{\text{g of X in compound}}{\text{molar mass of compound}} \bullet 100\%$$

In water (H_2O):

$$\text{Wt. \% O} = \frac{16.00 \text{ g O}}{18.02 \text{ g } H_2O} \bullet 100\% = 88.79 \text{ \%}$$

%H = 100 - 88.79 = 11.21%

MAR

Percent Composition

Consider NO_2, Molar mass = ?

What is the weight percent of N and of O?

$$\text{Wt. \% N} = \frac{14.01 \text{ g N}}{46.01 \text{ g } NO_2} \bullet 100\% = 30.45 \text{ \%}$$

$$\text{Wt. \% O} = \frac{2(16.00 \text{ g O})}{46.01 \text{ g } NO_2} \bullet 100\% = 69.55 \text{ \%}$$

Test yourself: What are the weight percentages of N and O in N_2O_4?

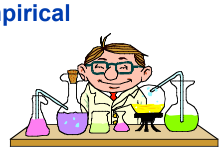
MAR

Determining Formulas

In chemical analysis we first determine the % by weight of each element in a given amount of pure compound and derive the EMPIRICAL or SIMPLEST formula.

Weight percentages lead to empirical formulas *(but **not** molecular formulas!)*

PROBLEM: A compound of B and H is 81.10% B. What is its empirical formula?



MAR

*A compound of B and H is 81.10% B. What is its **empirical** formula?*

Calculate the number of moles of each element in 100.0 g of sample.

$$81.10 \text{ g B} \bullet \frac{1 \text{ mol}}{10.81 \text{ g}} = 7.502 \text{ mol B}$$

$$18.90 \text{ g H} \bullet \frac{1 \text{ mol}}{1.008 \text{ g}} = 18.75 \text{ mol H}$$

MAR

*A compound of B and H is 81.10% B. What is its **empirical** formula?*

Take the ratio of moles of B and H. Always divide by the smaller number.

$$\frac{18.75 \text{ mol H}}{7.502 \text{ mol B}} = \frac{2.499 \text{ mol H}}{1.000 \text{ mol B}} = \frac{2.5 \text{ mol H}}{1.0 \text{ mol B}}$$

But we need a whole number ratio.

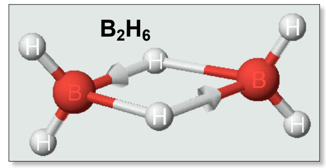
2.5 mol H/1.0 mol B = 5 mol H to 2 mol B

EMPIRICAL FORMULA = B_2H_5

MAR

The compound has an *empirical* formula of B_2H_5. What is its molecular formula?

Is the molecular formula B_2H_5, B_4H_{10}, B_6H_{15}, B_8H_{20}, etc.?



B_2H_6 is one example of this class of compounds.

MAR

The compound has an empirical formula (EF) of B_2H_5. What is its molecular formula?

To solve,* need the molar mass of the compound using a *mass spectrometer (a separate experiment)

***Next,* determine molar mass of the empirical formula**

***Compare* molar mass of the compound to the molar mass of the empirical formula to get a whole number ratio of empirical formula units in the molecular formula**

MAR

The compound has an empirical formula (EF) of B_2H_5. What is its molecular formula?

Example:

A compound has an empirical formula of **CH_2** and a molar mass of **28.1 g mol^{-1}**. Find the **molecular formula**.

Molar mass compound (28.1 g mol^{-1}) given via outside experiment.

Molar mass empirical formula (CH_2) =

12.01 + 2*1.01 = 14.03 g mol^{-1}

Now compare molar mass compound to molar mass of empirical formula:

$$\frac{28.1 \text{ g/mol}}{14.03 \text{ g/mol of } CH_2} = \frac{2 \text{ units of } CH_2}{1 \text{ mol}}$$

Molecular formula = $(CH_2)_2 = C_2H_4$

MAR

The compound has an empirical formula (EF) of B_2H_5. What is its molecular formula?

In the boron problem,

Molar mass of *compound (from mass spectrometer, a separate experiment)* = 53.3 g/mol

Molar mass of *empirical formula* (B_2H_5) = 26.67 g/mol

*(2*10.81 + 5*1.01 = 26.67 g/mol of EF)*

Now find ratio of these masses.

$$\frac{53.3 \text{ g/mol}}{26.67 \text{ g/mol of } B_2H_5} = \frac{2 \text{ units of } B_2H_5}{1 \text{ mol}}$$

Molecular formula = $(B_2H_5)_2 = B_4H_{10}$

MAR

Determining a Molecular Formula: *Overview*

***First,* convert percent by mass element values into moles *(assume 100 g)*, then compare the moles to get the empirical formula (EF)**

$$\frac{18.75 \text{ mol H}}{7.502 \text{ mol B}} = \frac{2.499 \text{ mol H}}{1.000 \text{ mol B}} = \frac{2.5 \text{ mol H}}{1.0 \text{ mol B}}$$

2.5 mol H/1.0 mol B = 5 H to 2 B = B_2H_5

***Next,* find the molar mass (MM) of the compound, then compare MM of compound to MM of EF**

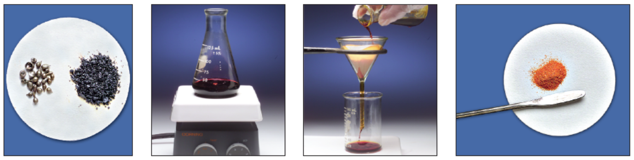
$$\frac{53.3 \text{ g/mol}}{26.67 \text{ g/mol of } B_2H_5} = \frac{2 \text{ units of } B_2H_5}{1 \text{ mol}}$$

Molecular formula = $(B_2H_5)_2 = B_4H_{10}$

MAR

Determine the formula of a compound of Sn and I using the following data.

(a) Weighed samples of tin (left) and iodine (right). (b) The tin and iodine are heated in a solvent. (c) The hot reaction mixture is filtered to recover unreacted tin. (d) When the solvent cools, solid, orange tin iodide forms and is isolated.



Mass of Sn in the beginning = 1.056 g
Mass of iodine (I_2) used = 1.947 g
Mass of Sn remaining = 0.601 g

MAR

Tin and Iodine Compound

Find the mass of Sn that combined with 1.947 g I_2.

Mass of Sn initially = 1.056 g
Mass of Sn recovered = 0.601 g
Mass of Sn used = 0.455 g

Find moles of Sn used:

$$0.455 \text{ g Sn} \bullet \frac{1 \text{ mol}}{118.7 \text{ g}} = 3.83 \times 10^{-3} \text{ mol Sn}$$

MAR

Tin and Iodine Compound

Now find the number of moles of I_2 that combined with 3.83×10^{-3} mol Sn

Mass of I_2 used = **1.947 g**

$$1.947 \text{ g } I_2 \bullet \frac{1 \text{ mol}}{253.81 \text{ g}} = 7.671 \times 10^{-3} \text{ mol } I_2$$

But we need **mol of I** for formula, *not I_2*, so convert:

$$7.671 \times 10^{-3} \text{ mol } I_2 \bullet \frac{2 \text{ mol I}}{1 \text{ mol } I_2} = 1.534 \times 10^{-2} \text{ mol I}$$

***So* 1.534 x 10^{-2} mol of iodine atoms were used in this reaction**

MAR

Tin and Iodine Compound

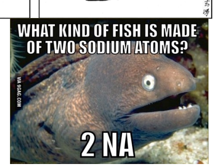
Now find the ratio of number of moles of moles of I and Sn that combined.

$$\frac{1.534 \times 10^{-2} \text{ mol I}}{3.83 \times 10^{-3} \text{ mol Sn}} = \frac{4.01 \text{ mol I}}{1.00 \text{ mol Sn}}$$

Empirical formula is SnI_4
tin(IV) iodide

MAR

End of Chapter 2 Part 2



See also:
- *Chapter Two Part 2 Study Guide*
- *Chapter Two Part 2 Concept Guide*
- *Important Equations (following this slide)*
- *End of Chapter Problems (following this slide)*

MAR

Important Equations, Constants, and Handouts from this Chapter:

- **be able to find the molar mass of any compound using the periodic table**
- **be able to convert grams of a compound into moles and/or molecules**
- **understand how to calculate empirical formula (EF) and molecular formula (MF) using the molar mass and mass percentages**

A mole = 6.022 x 10^{23}

Nomenclature: Greek prefixes, Roman numbers, nonmetal + nonmetal, fixed charge metal + nonmetal, variable charge metal + nonmetal, polyatomic ions, acids, bases, hydrated compounds, the 7 diatomics, cations, anions, covalent, ionic, the "stairs", Coulomb's Law

MAR

End of Chapter Problems: *Test Yourself*

*See practice problem set #3 and self quizzes for **nomenclature** examples and practice*

1. Determine the molar mass for aluminum chloride, iron(III) oxide and phosphorus tribromide.
2. How many grams in 0.0255 mol of propanol (C_3H_7OH)? How many molecules? How many atoms of C?
3. Calculate the weight percent of lead in PbS, lead(II) sulfide. What mass of lead (in grams) is present in 10.0 g of PbS?
4. Succinic acid has an empirical formula is $C_2H_3O_2$ and a molar mass is 118.1 g/mol. What is its molecular formula?
5. A new compound containing xenon and fluorine was isolated by shining sunlight on a mixture of Xe (0.526 g) and F_2 gas. If you isolate 0.678 g of the new compound, what is its empirical formula?
6. Direct reaction of iodine (I_2) and chlorine (Cl_2) produces an iodine chloride, I_xCl_y, a bright yellow solid. If you completely used up 0.678 g of iodine and produced 1.246 g of I_xCl_y, what is the **empirical formula** of the compound? A later experiment showed that the molar mass of I_xCl_y was 467 g/mol. What is the **molecular formula** of the compound?

MAR

End of Chapter Problems: *Answers*

1. 133 g/mol, 160. g/mol, 271 g/mol
2. 1.53 g C_3H_7OH, 1.54 x 10^{22} molecules, 4.62 x 10^{22} atoms C
3. 86.59%, 8.66 g Pb
4. $C_4H_6O_4$
5. XeF_2
6. ICl_3 , I_2Cl_6

*Be sure to view practice problem set #3 and self quizzes for **nomenclature** examples and practice*

MAR