EIT Chemistry Review
S2012
Dr. Mack

***Download available at:***

www.csus.edu/indiv/m/mackj/

Or look for Jeffrey Mack under CSUS faculty web pages

Part 1

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Chemistry is really…

***Chem is try***

*To do chemistry, you must:*

Practice

Practice

Practice

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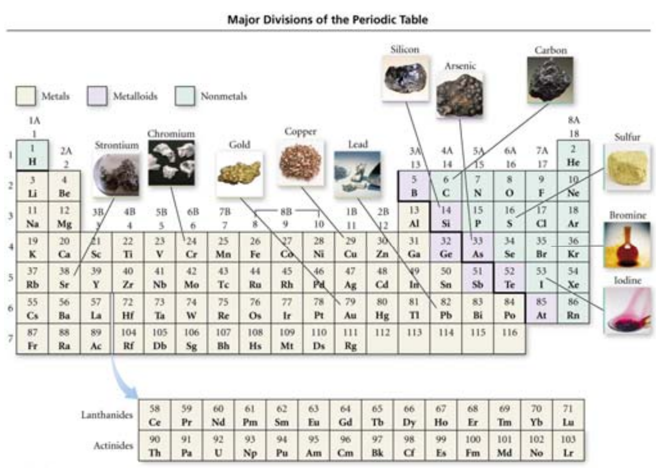
Where do we begin… The Periodic Table

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## The Modern Periodic Table

The modern organization of the periodic table came about as a result of the work of Dimitri Mendeleyev

**Characteristics:**

- Ordered elements by atomic mass
- Repeating pattern of properties
- Elements with similar properties in the same column

**Periodic Law** – when the elements are arranged in order of increasing atomic mass, certain sets of properties recur periodically.

Patterns used to predict properties of undiscovered elements

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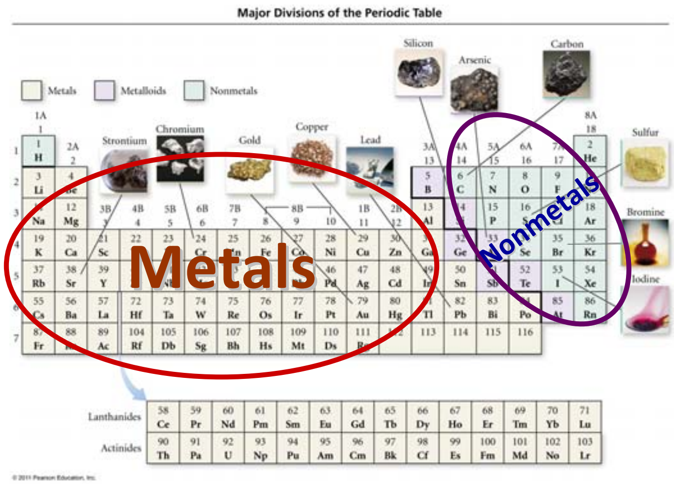
## The Periodic Table: Metals and Nonmetals

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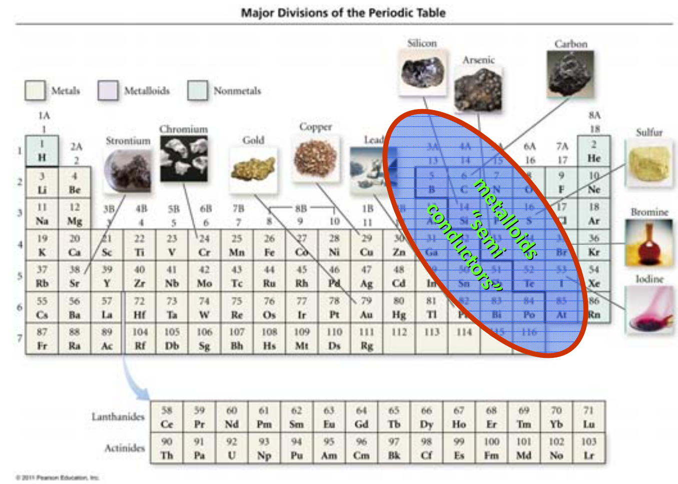
## The Periodic Table: Metaloids

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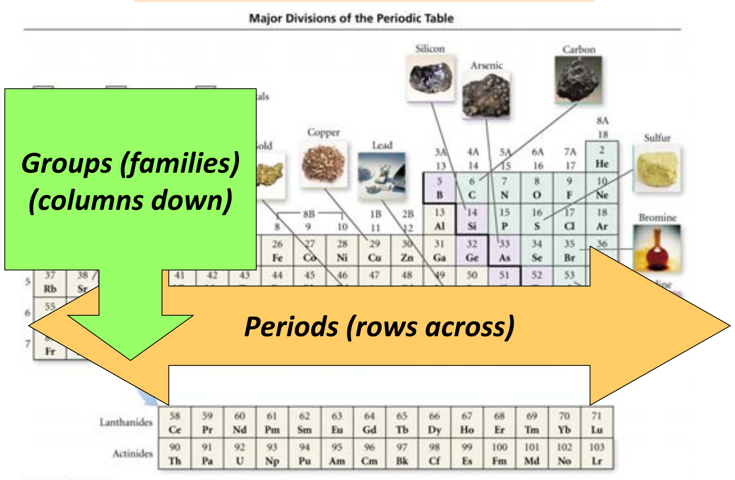
**The modern periodic table is defined by:**

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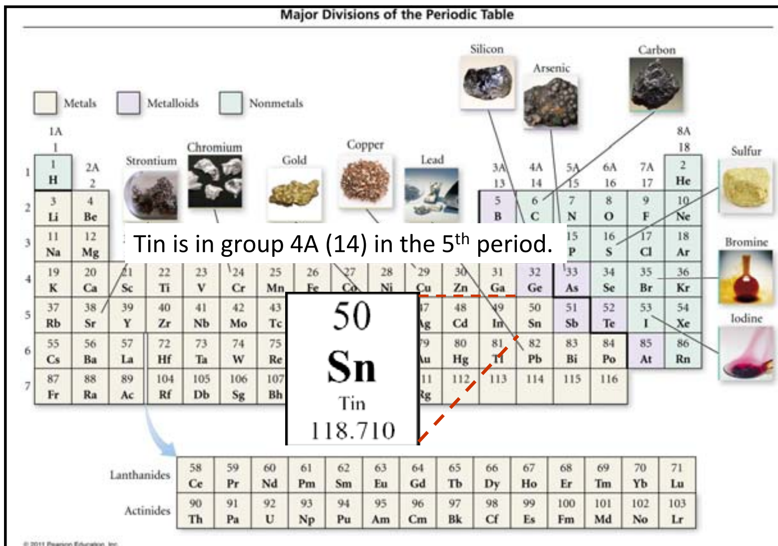


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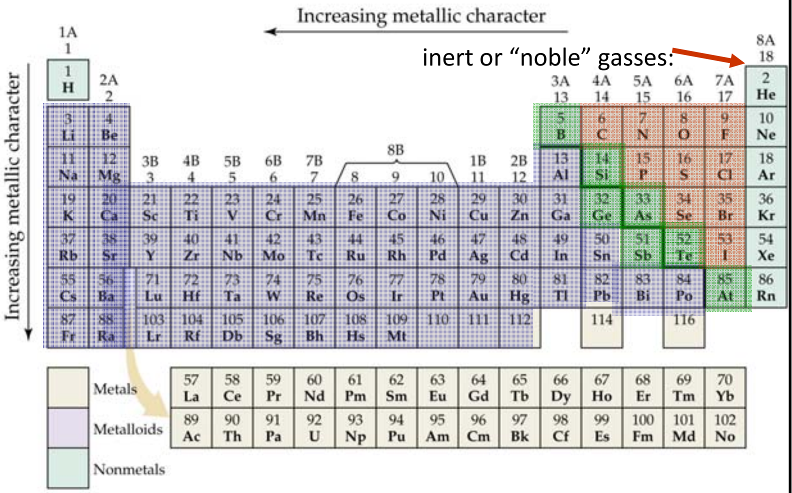


Metals form Cations non-metals form anions Metalloids can do both

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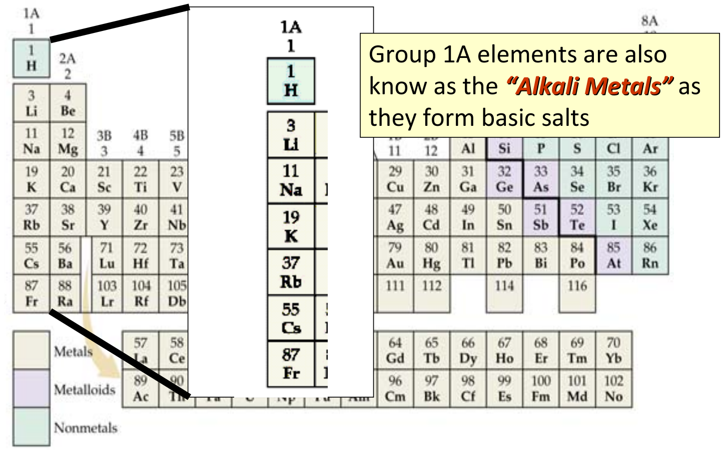
Today's Periodic table

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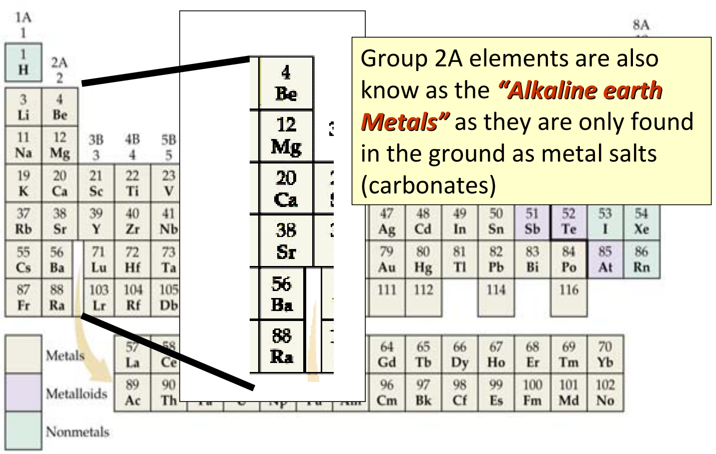
Today's Periodic table

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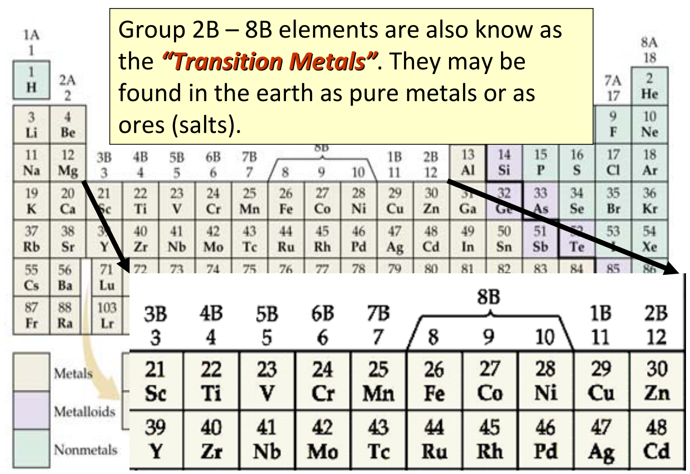
Today's Periodic table

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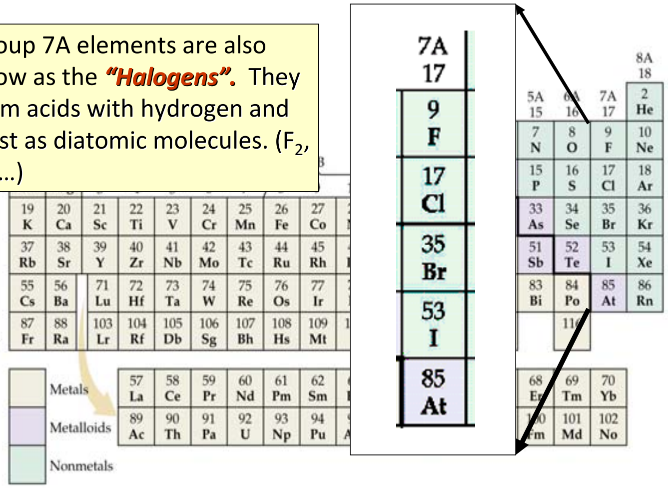
Today's Periodic table

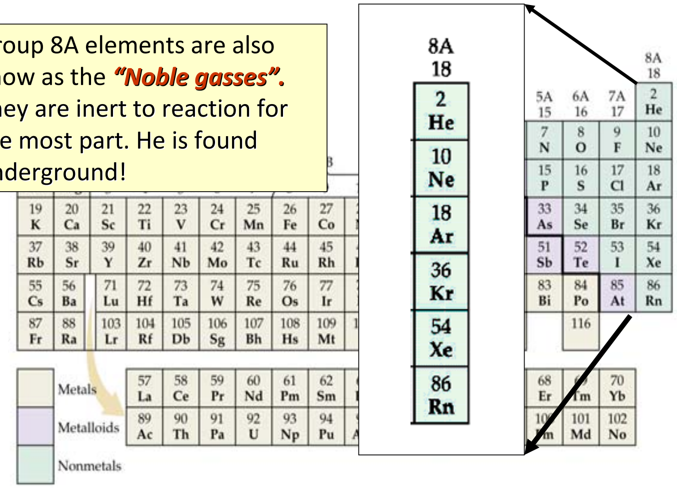
Group 7A elements are also know as the ***"Halogens".*** They form acids with hydrogen and exist as diatomic molecules. ($F_2$, $Cl_2$…)






Today's Periodic table

Group 8A elements are also know as the ***"Noble gasses".*** They are inert to reaction for the most part. He is found underground!






## The Representation of Matter:

In chemistry we use chemical formulas and symbols to represent matter.

Why?

We are "***macroscopic***": large in size on the order of 100's of cm

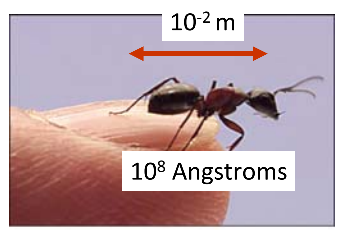
Atoms and molecules are "***microscopic***":

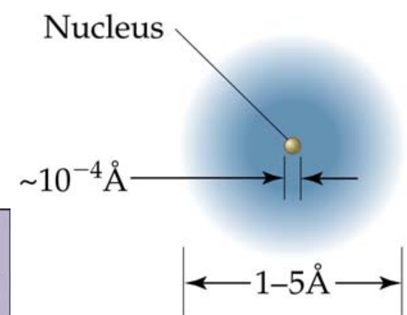
on the order of $10^{-12}$ cm



Why do scientists use chemical symbols like **C**, **Al** and **Fe** to represent atoms?

***Because atoms are really small!***

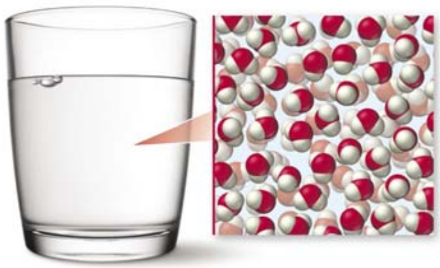



1Angstrom = $10^{-10}$ m

## Chemical Symbols and Formulas:

What we observe… To what we can't see!



Chemical symbols ($H_2O$) allow us to connect…



## Chemical Symbols and Formula:

<u>Elements:</u>

H = hydrogen

O = oxygen

C = carbon

<u>Molecules:</u>

$H_2$ = hydrogen

$O_2$ = oxygen

$H_2O$ = water

$CH_4$ = methane

***some of the names are not systematic!***

***Uh-Oh! this is confusing…***

***Yes it is… Get over it and get used to it!***



| | |
|---|---|
| Al | Aluminum |
| B | Boron |
| Cr | Chromium |
| Co | Cobalt |
| Cu | Copper |
| F | Fluorine |
| Fe | Iron |
| Au | Gold |
| Pb | Lead |
| Ag | Silver |
| Hg | Mercury |
| P | Phosphorus |
| K | Potassium |
| Na | Sodium |
| S | Sulfur |



## Atoms, Compounds, Molecules and Ions:

An ***atom*** is the smallest indivisible indistinguishable unit of a pure element.

An ***ion*** is an atom (or molecule) with a formal electrical charge.

An ***anion*** is an atom (or molecule) that has a negative charge.

The number of electrons > number of protons

A ***cation*** is an atom (or molecule) has a positive charge

The number of electrons < number of protons

**Compounds:**

A compound is a distinct substance that contains two or more elements combined in a definite proportion by weight.

Atoms of the elements that constitute a compound are always present in simple whole number ratios.

They are never present as fractional parts.

***Examples:*** $AB$ $A_2B$ $AB_2$

Never: $A_{½}B$

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## Molecules and Ionic Compounds:

A molecule is the smallest uncharged individual unit of a compound formed by two or more atoms.

Ionic compounds are made of positively and negatively charged ions.

A ***molecule*** can exist as an entity on its own.

An ***ionic compound*** is represented by a formula unit that describes the simplest ratio of *cations* to *anions*.

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Compounds fall into one of two classes:

| **Inorganic Salts** | **Molecules** |
|---|---|
| metal cation | non-metal |
| + | + |
| non-metal or polyatomic anion | non-metal (no cations or anions) |

The two use different formalisms for naming…

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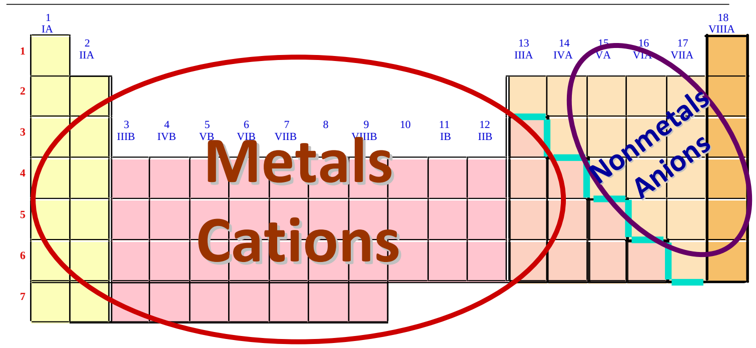
Ionic or Inorganic Compounds:

Metals and Nonmetals

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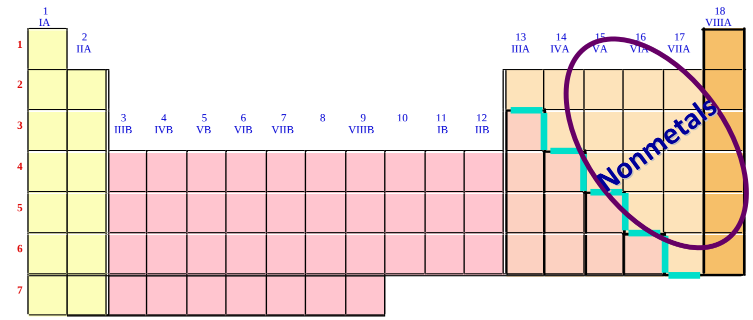
## Molecular Compounds:

Nonmetals and Nonmetals

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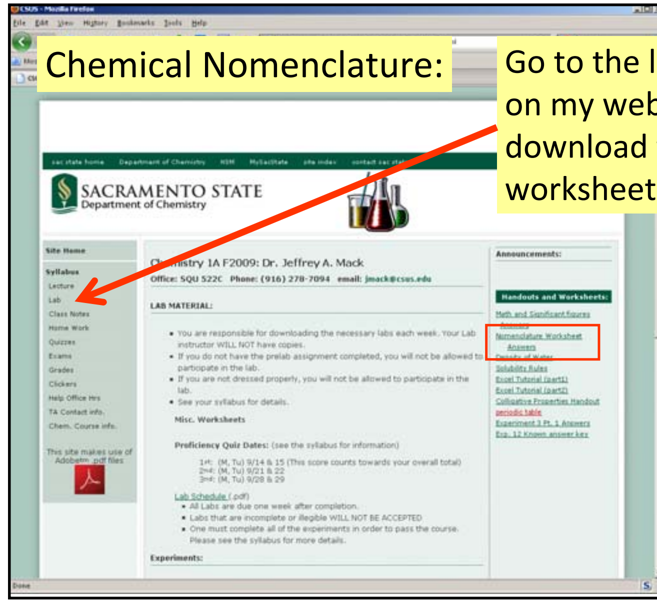
## Chemical Nomenclature:




Go to the lab page on my website and download the worksheet!

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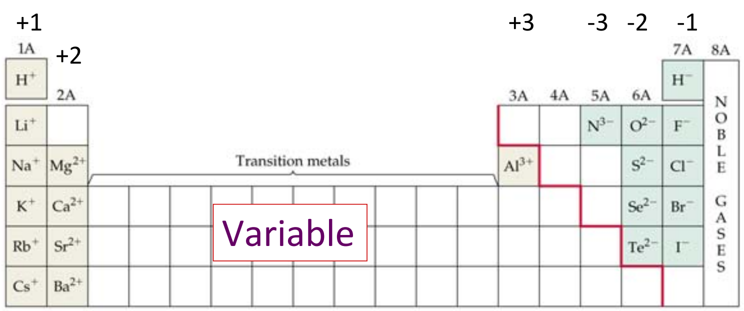
## Ion Charges:

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## Binary Compounds: Metal & non-Metal

Metal of fixed oxidation (charge) state combined with a non-metal.

*Examples:* non-metal takes on "*ide*" suffix

| Cation | Anion | Formula | Name |
|---|---|---|---|
| $K^+$ | $Cl^-$ | KCl | Potassium chlor*ide* |
| $Ca^{2+}$ | $O^{2-}$ | CaO | Calcium Oxide |
| $Na^+$ | $S^{2-}$ | $Na_2S$ | Sodium sulfide |
| $Al^{3+}$ | $S^{2-}$ | $Al_2S_3$ | Aluminum sulfide |

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Metals of variable charge (transition) with a non-metal

*Examples:* *modify transition metal name with roman numeral*

| Cation | Anion | Formula | Name |
|---|---|---|---|
| $Pb^{2+}$ | $Cl^{-}$ | $PbCl_2$ | lead (II) chloride<br>pronounced: *lead - two - chloride* |
| $Pb^{4+}$ | $Cl^{-}$ | $PbCl_4$ | lead (IV) chloride |
| $Fe^{3+}$ | $O^{2-}$ | $Fe_2O_3$ | Iron (III) oxide |

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Some common polyatomic ions:

| | |
|---|---|
| $NH_4^{+}$ | ammonium |
| $H_3O^{+}$ | hydronium |
| $CO_3^{2-}$ | carbonate |
| $HCO_3^{2-}$ | hydrogen carbonate<br>or bicarbonate |
| $NO_2^{-}$ | nitrite |
| $NO_3^{-}$ | nitrate |
| $SO_4^{2-}$ | sulfate |
| $SO_3^{2-}$ | sulfite |
| $PO_4^{3-}$ | phosphate |
| $C_2H_3O_2^{-}$ | acetate |

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**Ternary Compounds:** Those with three different elements

metal of fixed charge with a complex ion

| Cation | Anion | Formula | Name |
|---|---|---|---|
| $K^{+}$ | $OH^{-}$ | $KOH$ | Potassium hydroxide |
| $Ca^{2+}$ | $OH^{-}$ | $Ca(OH)_2$ | Calcium hydroxide |
| $Na^{+}$ | $SO_4^{2-}$ | $Na_2SO_4$ | Sodium sulfate |
| $Al^{3+}$ | $SO_4^{2-}$ | $Al_2(SO_4)_3$ | Aluminum sulfate |

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Metal of variable charge transition with a complex ion

| Cation | Anion | Formula | Name |
|---|---|---|---|
| $Fe^{3+}$ | $NO_3^{-}$ | $Fe(NO_3)_3$ | Iron (III) nitr***ate*** |
| $Fe^{2+}$ | $NO_2^{-}$ | $Fe(NO_2)_2$ | Iron (II) nitr***ite*** |

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## Non-metal with a non-metal

When non-metals combine, they form molecules. They may do so in multiple forms:

CO CO$_2$

Because of this we need to specify the number of each atom by way of a prefix.

1 = mono 2 = di 3 = tri 4 = tetra

5 = penta 6 = hexa 7 = hepta

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***Examples:***

| Formula | Name: |
|---|---|
| $BCl_3$ | boron ***tri***chlor***ide*** |
| $SO_3$ | sulfur ***tri***oxide |
| NO | nitrogen ***mon***oxide |
| we don't write: | nitrogen ***mono***oxide<br>or ***mon***onitrogen ***mon***oxide |
| $N_2O_4$ | ***di***nitrogen ***tetra***oxide |

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| | |
|---|---|
| $CO_2$ | carbon dioxide |
| carbon monoxide | CO |
| $P_2O_5$ | diphosphorous pentaoxide |
| nitrogen trihydride | $NH_3$<br>(ammonia) |

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## Writing formulas for acids and Bases

- An ***acid*** is a substance that produces $H^+$ when dissolved in water.
- Certain gaseous molecules become acids when dissolved in water.

- A ***base*** produces $OH^-$ when dissolved in water.
- Bases often are Group I and Group II hydroxide salts.

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**Type I Acids:** Acids derived from *–ide* anions.

The names for these acids follows the formula:

"hydro" + the root of the ***ide*** anion + ***ic*** "acid"

| Anion: | Acid: | Name: |
|---|---|---|
| chlor***ide*** | HCl | ***hydro***chlor***ic*** acid |
| fluor***ide*** | HF | ***hydro***fluor***ic*** acid |

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$H^+$ and $S^{2-}$

↓ *it takes 2 $H^+$ to cancel one $S^{2-}$*

$H_2S$

***hydro*** sulfur***ic*** acid

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***Examples:*** **Oxy Acids:** Those derived from –***ate*** anions.

| | Anion: | Acid: | Name: |
|---|---|---|---|
| (nitrate) | $NO_3^-$ | $HNO_3$ | nitr***ic*** acid |
| (chlorate) | $ClO_3^-$ | $HClO_3$ | chlor***ic*** acid |
| (sulfate) | $SO_4^{2-}$ | $H_2SO_4$ | sulfur***ic*** acid |
| (acetate) | $C_2H_3O_2^-$ | $HC_2H_3O_2$ | acet***ic*** acid *vinegar* |

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**Oxy Acids:** Those derived from –***ite*** anions.

root name of the anion with –***ous*** replacing the -***ite***

| | Anion: | Acid: | Name: |
|---|---|---|---|
| (nitrite) | $NO_2^-$ | $HNO_2$ | nitr***ous*** acid |
| (chlorite) | $ClO_2^-$ | $HClO_2$ | chlor***ous*** acid |
| (sulfite) | $SO_3^{2-}$ | $H_2SO_3$ | sulfur***ous*** acid |

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**Bases:**

| | |
|---|---|
| $Ba(OH)_2$ | barium hydroxide |
| sodium hydroxide | $NaOH$ |
| $NH_4OH$ | ammonium hydroxide |

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**Common Names:**

| | |
|---|---|
| $H_2O$ | water |
| ammonia | $NH_3$ |
| $CH_4$ | methane |
| $NO$ | nitric oxide |
| $N_2O$ | nitrous oxide |

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**Practice:**

| | |
|---|---|
| $N_2SO_4$ | sodium sulfate |
| barium carbonate | $BaCO_3$ |
| $FeO$ | Iron (II) oxide |
| zinc phosphide | $Zn_3P_2$ |
| $NiBr_2$ | nickel (II) bromide |

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## Modern Atomic Theory:

- Atoms are made of protons, neutrons and electrons.
- The nucleus of the atom carries most of the mass.
- It consists of the protons and neutrons surrounded by a cloud of electrons.

The charge on the electron is –1

The charge on the proton is +1

There is no charge on the neutron

The ***Atomic Number*** or number of protons in the nucleus defines an element.

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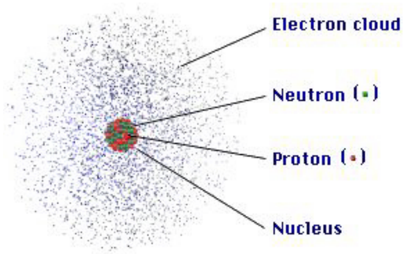
## The Composition of an Atom:

**The atom is mostly empty space**




- **protons and neutrons in the nucleus.**
- **the number of electrons is equal to the number of protons.**
- **electrons in space around the nucleus.**

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## Atomic Number, Z

An element's identity is defined by the number of protons in the nucleus: Z

| | |
|---|---|
| **13** | **Atomic number** |
| **Al** | **Atom symbol** |
| **26.981** | **Atomic weight** |

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Ch. 2

### Isotopes, Atomic Numbers, and Mass Numbers

Elemental Isotopic Symbols: For a given element "*X*", an isotope is written by:

***Atomic number*** (Z) = number of protons in the nucleus.

***Mass number*** (A) = total number of nucleons in the nucleus (i.e., protons and neutrons).

One nucleon has a mass of 1 amu (*Atomic Mass Unit*) a.k.a "*Dalton*" or u

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

Isotopes have the same Z but different total number of nucleons (A).

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## **Example: Selenium-75**

75 protons + neutrons → $^{75}_{34}Se$

34 protons → $^{75}_{34}Se$

protons = 34 electrons = 34

neutrons = 75-34 = 41

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Ch. 2

The ***average weighted*** atomic mass is determined by the following mathematical expression:

| *Average mass of a Cl atom* | | *mass of a Cl-35 atom* | | *fraction that are Cl-35* | | *mass of a Cl-37 atom* | | *fraction that are Cl-37* |
|---|---|---|---|---|---|---|---|---|
| m Cl (u) | = | m Cl-35 | × | abundance of Cl-35 | + | m Cl-37 | × | abundance of Cl-37 |

35.45 u $= 34.96885\text{u} \times 0.7553 + 36.96590 \times 0.2447$
*(4 sig. fig)*

This is the value that is reported on the periodic table.

Note that: 0.7553 + 0.2447 = 1.0000 (100%)



## Avogadro's Number and the Mole

Ch. 2

The concept of a mole is defined so that we may equate the amount of matter (mass) to the number of particles (mole).

The Standard is based upon the C-12 isotope.

The mass of one $^{12}$C-atom is $1.99265 \times 10^{-23}$ g.

The atomic mass of $^{12}$C is defined as exactly 12 u.

Therefore: 1u = (the mass of one $^{12}$C atom ÷12)
= $1.66054 \times 10^{-24}$g
= $1.66054 \times 10^{-27}$ kg



## *Avagagro's Number*

Ch. 2

Since one mole of $^{12}$C has a mass of 12g (exactly), 12g of $^{12}$C contains $6.022142 \times 10^{23}$ C-12 atoms.

But carbon exists as 3 isotopes: C-12, C-13 &C-14

The average atomic mass of carbon is 12.011 u.

From this we conclude that 12.011g of carbon contains $6.022142 \times 10^{23}$ C-atoms

***Is this a valid assumption?***

***Yes, since $N_A$ is so large, the statistics hold.***



## Molar Masses

Ch. 2

Since we can equate mass (*how much matter*) with moles (*how many particles*) we now have a ***conversion factor*** that relates the two.

mols × molar mass (g/mol) = grams

The Molar Mass of a substance is the amount of matter that contains one-mole or $6.022 \times 10^{23}$ particles.

*aka:* Avogadro's number ($N_A$)

The atomic masses on the Periodic Table also represent the molar masses of each element in grams per mole (g/mol)

Ch. 2

So if you have 12.011g of carbon…

you have $6.022\times10^{23}$ carbon atoms!

So if you have 39.95g of argon…

you have $6.022\times10^{23}$ argon atoms!

if you have a mole of dollar bills… you are Bill Gates…

you have $6.022\times10^{23}$ bucks!

and if you have $6.022\times10^{23}$ avocados…

you have… ***a "guacamole"***

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**Grams, Moles and Molar Mass:**

The molar mass of an atom is a conversion factor that relates ***mass*** (grams) to ***moles*** and vice versa.

(how much matter) (number of atoms)

grams ÷ molar mass = moles

$$\not{g} \times \frac{mol}{\not{g}} = mol$$

***Avogadro's number*** ($N_A$) relates moles numbers of individual particles:

$$1\ \not{mol} \times \frac{6.022\times10^{23}\ \text{particles}}{\not{mol}} = 6.022\times10^{23}\ \text{particles}$$

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Ch. 2

***Question:*** How many magnesium atoms are there in 150.0 g of magnesium?

***Solution:*** Use the molar mass of Mg from the periodic table.

$$150.0\text{g Mg} \times \frac{1\ \text{mol Mg}}{24.305\text{g Mg}} \times \frac{6.022\ \text{x}\ 10^{23}\ \text{Mg atoms}}{1\ \text{mol Mg}}$$

$$= 3.717\times10^{24}\ \text{Mg atoms}$$

***(4 sig figs) big number as expected!***

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Ch. 2

The molar mass of an ***ionic compound*** is the molar mass of one formula unit of the compound.

For the compound $Al_2(SO_4)_3$ the molar mass would be:

| | |
|---|---|
| 2 × (26.98 g/mol) | 2 Al's |
| + 3 × (32.07 g/mol) | 3 S's |
| + 3 × 4 × (16.00g/mol) | 3 × 4 O's |

**342.17 g/mol**

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How many oxygen atoms are there in 25.1g of chromium (III) acetate?

***step 1:*** write the correct chemical formula…

$Cr^{3+}$ & $C_2H_3O_2^-$ → $Cr(C_2H_3O_2)_3$

***step 2:*** calculate the molar mass… 229.13 g/mol

***step 3:*** use dimensional analysis to solve the problem…

*3×2 = 6*

$$25.1\text{g } Cr(C_2H_3O_2)_3 \times \frac{1\text{mol } Cr(C_2H_3O_2)_3}{229.13\text{g } Cr(C_2H_3O_2)_3} \times \frac{6\text{mol O}}{1\text{mol } Cr(C_2H_3O_2)_3} \times \frac{6.022\times10^{23}\text{ O}-\text{atoms}}{1\text{mol O}} =$$

$3.96 \times 10^{23}$ O-atoms *3 sf*

Ch. 2



(a) How many grams of nitrogen will be needed to produce 0.384 mols of ammonia?

$$N_2(g) + 3H_2(g) \longrightarrow 2\,NH_3(g)$$

$$0.384\text{ mols } NH_3 \times \frac{1\text{mol } N_2}{2\text{mol } NH_3} \times \frac{28.02\text{g } N_2}{1\text{mol } N_2} = 5.38\text{g } N_2$$

(b) How many moles of hydrogen are needed to combine with 5.84g of nitrogen?

$$5.84\text{g } N_2 \times \frac{1\text{mol } N_2}{28.02\text{ g}N_2} \times \frac{3\text{mol } H_2}{1\text{mol } N_2} = 0.625\text{mols } H_2$$



How many grams of nitrogen are needed to completely react with 0.525 g of hydrogen in the formation of ammonia?

To answer this question, one must go through moles.

$$N_2(g) + 3H_2(g) \longrightarrow 2\,NH_3(g)$$

The equation relates moles, not mass.

g $H_2$ → mols $H_2$ → mols $N_2$ → g $N_2$



How many grams of nitrogen are needed to completely react with 0.525 g of hydrogen in the formation of ammonia?

$$N_2(g) + 3H_2(g) \longrightarrow 2\,NH_3(g)$$

$$0.525\text{g}H_2 \times \frac{1\text{ mol } H_2}{2.02\text{g } H_2} \times \frac{1\text{mol } N_2}{3\text{mol } H_2} \times \frac{28.02\text{g } N_2}{1\text{mol } N_2} = 2.43\text{g } N_2$$

How many grams of ammonia form?

$$0.525\text{g}H_2 \times \frac{1\text{ mol } H_2}{2.02\text{g } H_2} \times \frac{2\text{ mol } NH_3}{3\text{mol } H_2} \times \frac{17.04\text{g } NH_3}{1\text{mol } NH_3} = 2.95\text{g } NH_3$$

How many grams of $O_2$ will result form the decomposition of 15.6g of potassium chlorate?

Step 1. Write the chemical equation

$$2\,KClO_3(s) \longrightarrow 3\,O_2(g) + 2KCl(s)$$

Step 2: Balance

Step 3: Set up the solution

$$g\,KClO_3 \longrightarrow mols\,KClO_3 \longrightarrow mols\,O_2 \longrightarrow g\,O_2$$



How many grams of $O_2$ will result form the decomposition of 15.6g of potassium chlorate?

$$2\,KClO_3(s) \longrightarrow 3\,O_2(g) + 2KCl(s)$$

$$15.6g\,KClO_3 \times \frac{1mol\,KClO_3}{122.55g\,KClO_3} \times \frac{3mol\,O_2}{2mol\,KClO_3} \times \frac{32.00g\,O_2}{1mol\,O_2}$$

$$= 61.1g\,O_2$$



## Chemical Reactions

Ch. 3

A ***chemical reaction*** can be described by a ***chemical equation***.
All chemical equations have three parts:

**Reactants** → **Products**

When a chemical changes occurs:

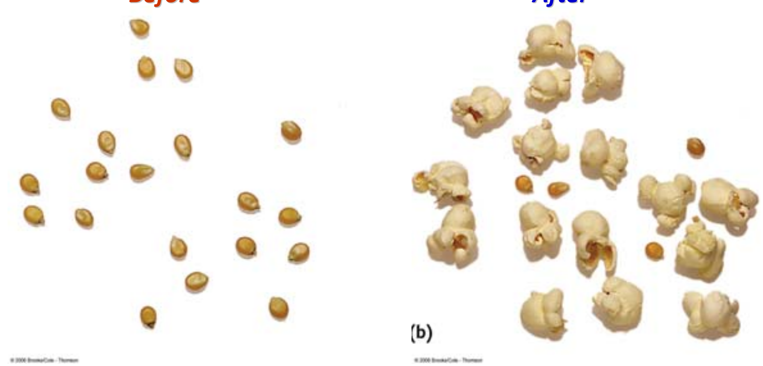
Atoms, Compounds or Molecules → New Compounds, Molecules or atoms



Ch. 3

How does one know when a reaction has occurred?
Generally, what you end up with looks nothing like what you started with.

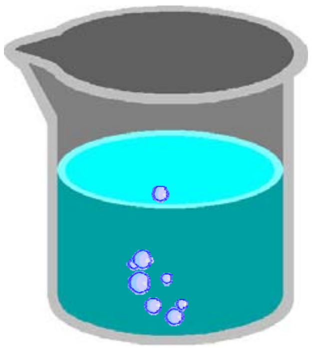
***Before*** ***After***



Ch. 3

## Indicators of a Chemical Reaction:

**Gas Evolution**



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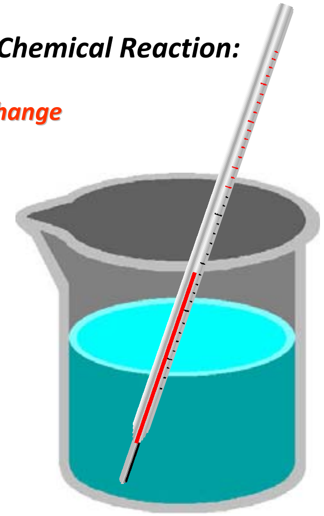
## Indicators of a Chemical Reaction:

**Temperature change**



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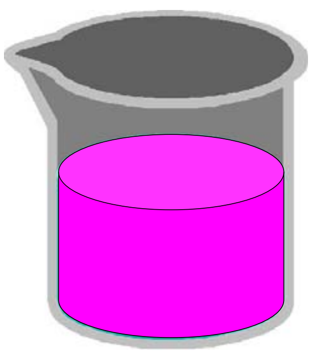
## Indicators of a Chemical Reaction:

**Color Change**



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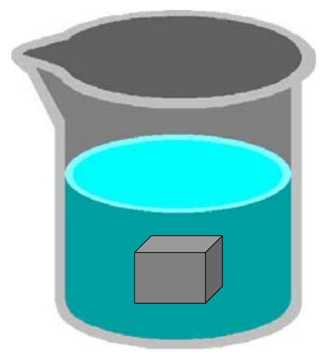
## Indicators of a Chemical Reaction:

**Precipitate Formation**



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### *Quantitative Information About Chemical Reactions*

*Mass must be conserved in a chemical reaction.*

**Total mass of reactants** **=** **Total mass of products**

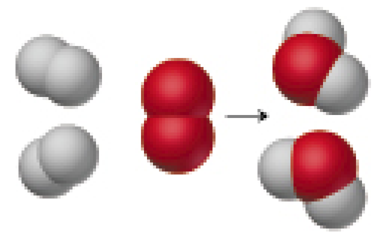
Chemical equations must therefore be balanced for mass.

Numbers of atoms on the reactant side = Numbers of atoms on the product side



**The chemical equation for the formation of water can be visualized as two hydrogen molecules reacting with one oxygen molecule to form two water molecules:**

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



11.2g + 88.8g → 100.0g

mass is conserved!



Balancing Chemical Reactions: Example

$C_2H_6$ + $O_2$ → $CO_2$ + $H_2O$

2 C's & 6 H's — 2 O's — 1 C & 2 O's — 2 H's & 1 O

***balance last***

***balance H first***

**2** $C_2H_6$ + $O_2$ → $CO_2$ + **6** $H_2O$

***balance C next***

$2C_2H_6$ + $O_2$ → **4** $CO_2$ + $6H_2O$

***balance O***

$2C_2H_6$ + **7** $O_2$ → $4CO_2$ + $6H_2O$

*4 C's 12 H's 14 O's* — *4 C's 12 H's 14 O's*



Ch. 3

When writing chemical reactions one starts with:

Reactants ⟶ products

$N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$

Some reactions can also run in ***reverse***:

$2NH_3(g) \longrightarrow N_2(g) + 3H_2(g)$

Under these conditions, the reaction can be written:

$$3H_2(g) + N_2(g) \rightleftarrows 2NH_3(g)$$

Dynamic Equilibrium!