GAC AP Chemistry Summer Assignment: Instructions

I am so thrilled that you have chosen to join us in AP Chemistry next year!

Since AP Chemistry is a second-year course, I will expect that you remember much of what you learned in your first chemistry course. The slides included in this summer assignment will enable you to review the material you learned in Honors Chemistry before we begin in August.

Use the Guided Notes in this packet as you view the slides in “Slideshow” mode (so that you get the benefit of the animations). You may also want to have some extra scratch paper with you, in case you need more space for working problems. You will definitely need a periodic table and a calculator.

Take the time to work the problems before viewing the answers as you go through the slides. If you simply view and write down the answers, you will not get the benefit of thinking through the problems yourself.

If you encounter a section that is unfamiliar to you, or for which you need a refresher, there are many wonderful resources available to help you online. LibreTexts offers free chemistry textbooks with searchable indexes, and there are several YouTube channels that specialize in chemistry (Tyler Dewitt, Crash Course Chemistry, Professor Dave Explains, and Bozeman Science are all excellent).

Two grades will be associated with this assignment:

1) The completed guided notes packet will be collected on the first day of class and entered as the first homework grade.
2) There will be a quiz over the material on the first block class period of the semester.

If you did not complete an Honors-level chemistry course prior to enrolling in AP Chemistry, please contact me quickly so that we can discuss your personal situation and determine if additional study will be necessary for you.

I can’t wait to start learning with you!

- Dr. Rodgers
brodgers@gac.org

Lesson 1 Notes

In Chemistry, measurements are made using the metric system. Fill in the most common metric system prefixes to the chart below.

Common Unit	Abbreviation	Conversion Factor
Milliliter		1L = mL
Milligram		1g = mg
Micromolar		1M = µM
Nanometer		1m = nm

Most of our lab measurements are teeny tiny! We use ____________________________ in order to express them.

Practice Problem:
Change into scientific notation:

24500:__________ 356:__________ 0.000985:__________ 0.222:__________ 12200:__________

Practice Problem:
Change out of sci. not.:

4.2×10^{3}:__________ 2.15×10^{-4}:__________ 3.14×10^{-6}:__________ 9.22×10^{5}:__________ 9.57×10^{2}:__________

Practice Problem:
Density is a measure of how closely packed atoms/molecules are in a substance.
Write the equation for density:

The two possible units for density are: ______________________ or ______________________

Practice Problem:
What is the volume of a chunk of lead with a mass of 255 g and a density of 11.34 g/cm^{3}?

Dimensional analysis is a way of lining up numbers so that units (such as grams or g/cm^{3}) cancel. This allows you to know when to multiply and when to divide so that you can get the right units in your answer. Show dimensional analysis for the density problem above:

Practice Problem:
What is the volume (in µl) of ethanol if the mass is 54.0 ounces? (Density=789 mg/mL; 28.35 g/oz)? Give your answer with in scientific notation with 2 places past the decimal and show your work using dimensional analysis.

In the following numbers, circle the LEADING zero(s): 0.005 0.30 0.020190

In the following numbers, circle the CAPTIVE zero(s): 0.005 0.30 0.020190

In the following numbers, circle the TRAILING zero(s): 0.005 0.30 0.020190

Complete the sentence: Leading zeros are ____________________ significant.

Complete the sentence: Captive zeros are ____________________ significant.

Complete the sentence: Trailing zeros are only significant if there's a ____________________ ANYWHERE in the number.

Practice Problem:

How many sig figs are in the following measurements?:

5.010: ________ 0.25050: ________ 0.039010: ________ 2500: ________

Write the rule for sig figs in the answer for a multiplication/division problem:

Write the rule for sig figs in the answer for an addition/subtraction problem:

Practice Problem:

Solve the following problems with the correct number of sig figs in your answer:

11 - 3.92 = __________ 2550.0 – 31 = ___________ 25.1 x 30.11 = __________

10.2 x 2.1 = ___________

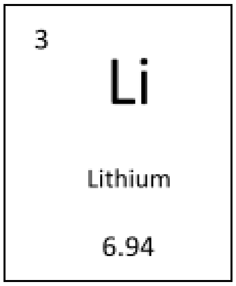
Lesson 2 Notes

List the 3 subatomic particles and the locations where they can be found within the atom.

1) ________________________________ location: ______________________________
2) ________________________________ location: ______________________________
3) ________________________________ location: ______________________________

Draw a sketch of a common atom and label the protons, neutrons, and electrons. Also label the charge of each subatomic particle.

On the block below, label the "atomic number" and "atomic mass." Define atomic number and mass.



Practice Problem:
How many protons, neutrons and electrons are found in a neutral atom of Lithium?

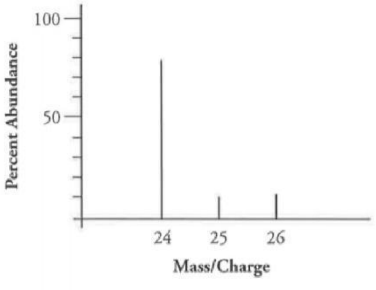
Atoms with the same atomic number but different atomic masses are called ______________________.

Silver has two isotopes. 51.839% of Silver atoms have 60 neutrons. (We say the "percent abundance" of this isotope is 51.839%). All other silver atoms have 62 neutrons.

Practice Problem:
Determine the average atomic mass of this element. (This is the mass found on the Periodic Table. It is a decimal because it is the AVERAGE mass of all isotopes of an element).

Scientific experiments are conducted to find isotopes. These experiments are done using mass spectrometry. A sample is injected into a detector, which can measure the weight and relative abundance of the individual atoms in the sample. Then, a graph is created. Sketch the graph in the space below. Label the x and y axes.

Practice Problem:
Calculate the average atomic mass and identify the element graphed below. How many isotopes does this element have?



The number 12 is called 1 dozen. We say there are 12 eggs in a dozen. The number 6.02 x 10^{23} (a REALLY LARGE number) is called a __________. We say there are 6.02 x 10^{23} atoms in a mole.

This is called ___________________________ number.

The atomic mass on the Periodic Table is the mass of 1 mole of that element. This is known as the ________________________ .

Practice Problem:
How much does 1 mole of Carbon weigh?

How about 1 mole of Calcium?

In 6.91g of Li, how many moles are there?

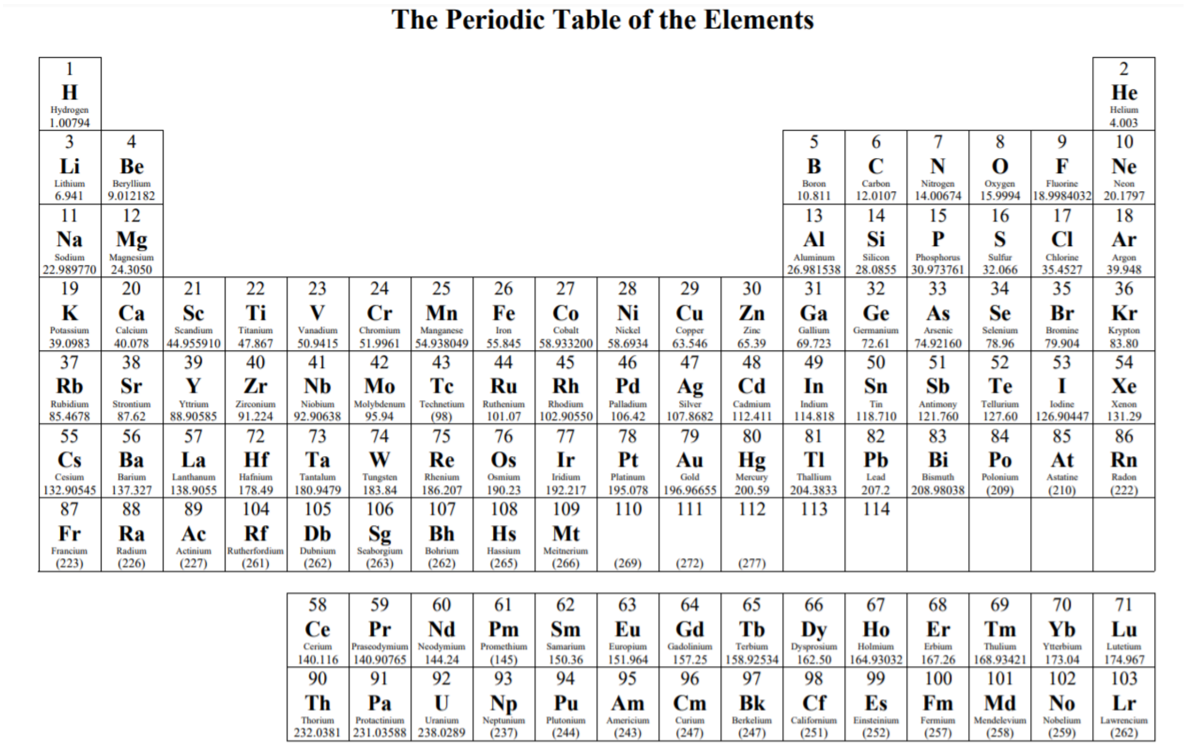
Practice Problem:
How many moles of carbon are in 46g of carbon?

Practice Problem:
What mass of lead, in grams, is equivalent to 2.50 moles of lead?

Practice Problem:
What amount of tin, in moles, is represented by 36.5 g of tin?

Practice Problem:
A graduated cylinder contains 32.0 cm^3 of mercury. If the density of mercury at 25°C is 13.534 g/cm^3, what amount of mercury, in atoms, is in the cylinder?

On the Periodic Table below, label metals, nonmetals, metalloids, alkali metals, alkaline earth metals, transition metals, main group elements, halogens, chalcogens, and noble gases.



The Periodic Table of the Elements

1 **H** Hydrogen 1.00794																	2 **He** Helium 4.003
3 **Li** Lithium 6.941	4 **Be** Beryllium 9.012182											5 **B** Boron 10.811	6 **C** Carbon 12.0107	7 **N** Nitrogen 14.00674	8 **O** Oxygen 15.9994	9 **F** Fluorine 18.9984032	10 **Ne** Neon 20.1797
11 **Na** Sodium 22.989770	12 **Mg** Magnesium 24.3050											13 **Al** Aluminum 26.981538	14 **Si** Silicon 28.0855	15 **P** Phosphorus 30.973761	16 **S** Sulfur 32.066	17 **Cl** Chlorine 35.4527	18 **Ar** Argon 39.948
19 **K** Potassium 39.0983	20 **Ca** Calcium 40.078	21 **Sc** Scandium 44.955910	22 **Ti** Titanium 47.867	23 **V** Vanadium 50.9415	24 **Cr** Chromium 51.9961	25 **Mn** Manganese 54.938049	26 **Fe** Iron 55.845	27 **Co** Cobalt 58.933200	28 **Ni** Nickel 58.6934	29 **Cu** Copper 63.546	30 **Zn** Zinc 65.39	31 **Ga** Gallium 69.723	32 **Ge** Germanium 72.61	33 **As** Arsenic 74.92160	34 **Se** Selenium 78.96	35 **Br** Bromine 79.904	36 **Kr** Krypton 83.80
37 **Rb** Rubidium 85.4678	38 **Sr** Strontium 87.62	39 **Y** Yttrium 88.90585	40 **Zr** Zirconium 91.224	41 **Nb** Niobium 92.90638	42 **Mo** Molybdenum 95.94	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.07	45 **Rh** Rhodium 102.90550	46 **Pd** Palladium 106.42	47 **Ag** Silver 107.8682	48 **Cd** Cadmium 112.411	49 **In** Indium 114.818	50 **Sn** Tin 118.710	51 **Sb** Antimony 121.760	52 **Te** Tellurium 127.60	53 **I** Iodine 126.90447	54 **Xe** Xenon 131.29
55 **Cs** Cesium 132.90545	56 **Ba** Barium 137.327	57 **La** Lanthanum 138.9055	72 **Hf** Hafnium 178.49	73 **Ta** Tantalum 180.9479	74 **W** Tungsten 183.84	75 **Re** Rhenium 186.207	76 **Os** Osmium 190.23	77 **Ir** Iridium 192.217	78 **Pt** Platinum 195.078	79 **Au** Gold 196.96655	80 **Hg** Mercury 200.59	81 **Tl** Thallium 204.3833	82 **Pb** Lead 207.2	83 **Bi** Bismuth 208.98038	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
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				58 **Ce** Cerium 140.116	59 **Pr** Praseodymium 140.90765	60 **Nd** Neodymium 144.24	61 **Pm** Promethium (145)	62 **Sm** Samarium 150.36	63 **Eu** Europium 151.964	64 **Gd** Gadolinium 157.25	65 **Tb** Terbium 158.92534	66 **Dy** Dysprosium 162.50	67 **Ho** Holmium 164.93032	68 **Er** Erbium 167.26	69 **Tm** Thulium 168.93421	70 **Yb** Ytterbium 173.04	71 **Lu** Lutetium 174.967
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Draw an arrow to show which direction *periods* run on the Periodic Table.

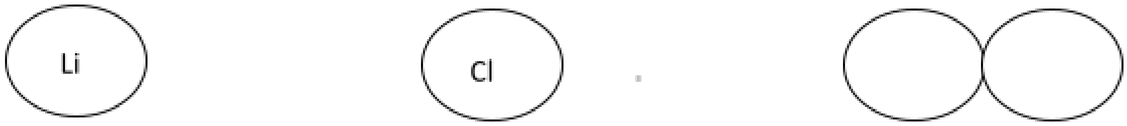
Draw an arrow to show which direction *groups/families* run on the Periodic Table.

Lesson 3 Notes

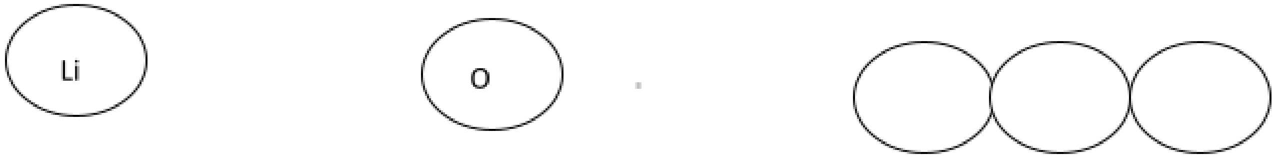
Two elements can combine and to become _______________. They do this by chemical bonding. There are two types of chemical bonds that can form: ________________ bonds and __________________ bonds.

Ionic bonds: usually form between a ________________ and a ____________________. This happens because metals give up electrons and nonmetals take those electrons. This causes the two atoms to become charged instead of being neutral, because their electrons and protons are now unequal. They are called ___________.

Example 1:



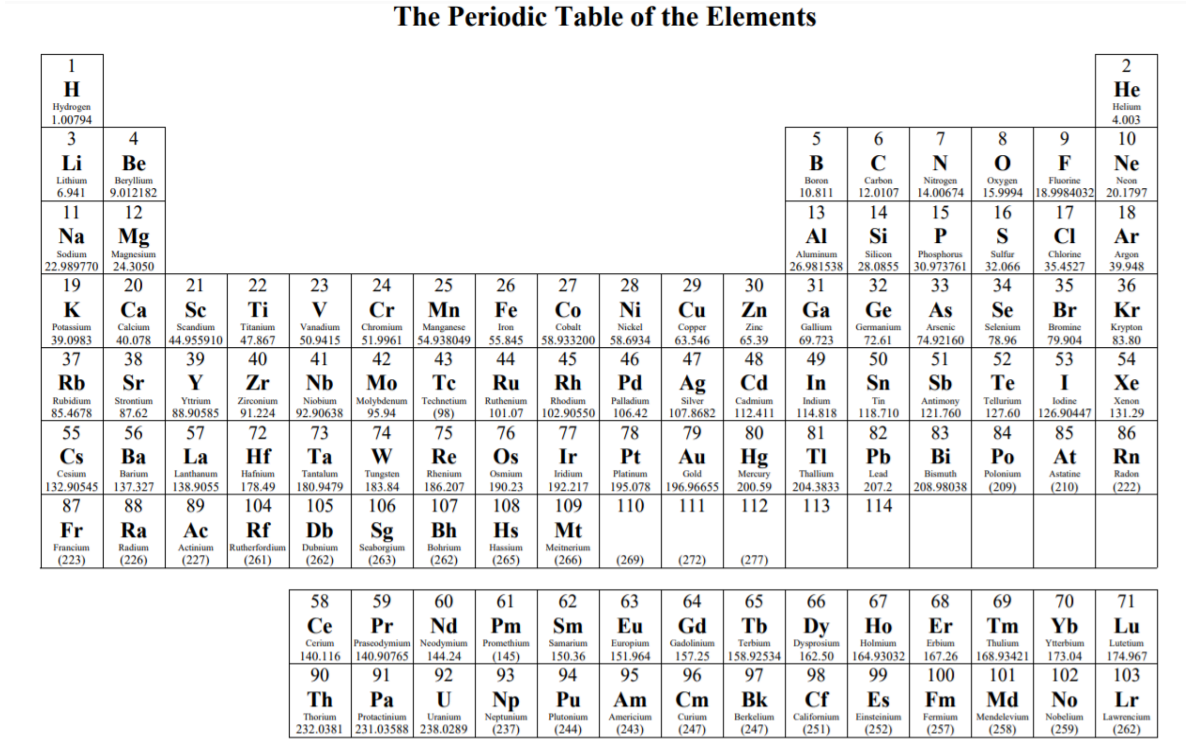
Example 2:



The atom that becomes POSITIVE is called a ________________. The atom that becomes NEGATIVE is called an ____________________. It is the OPPOSITE charges that cause the force of attraction that holds these atoms together in a bond.

How do you know how many electrons will be taken/given away? Electrons move around the atom in shells. The outer shell of electrons needs to be completely filled with electrons in order for the atom to be stable. This usually requires 8 electrons. This is called the ____________ Rule. There is a pattern of valence electrons for the atoms of elements on the Periodic Table. Write this pattern on the Periodic Table on the next page.

The charges of transition metals will vary, so there is no predictable pattern for them. However, Ag^{+1}, Zn^{+2} must be memorized.



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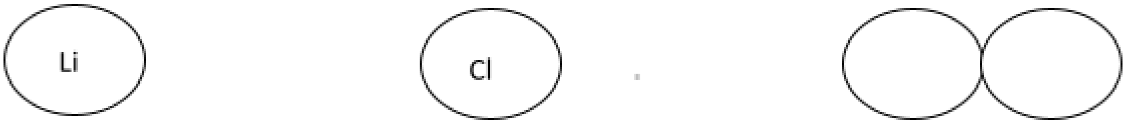
Practice Problem:
How many valence electrons can be found in an atom of Magnesium?

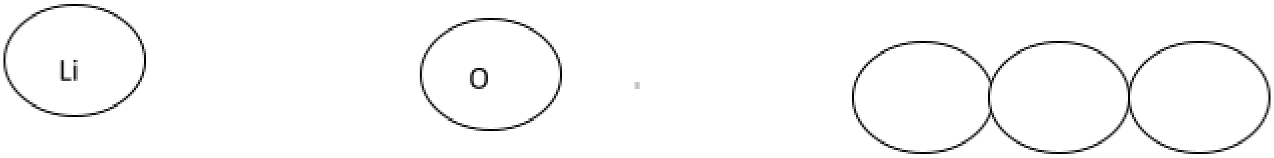
Practice Problem:
What is the charge of Magnesium during chemical bonding?

We can use these charges to predict the FORMULA of an ionic compound.

Example 1:

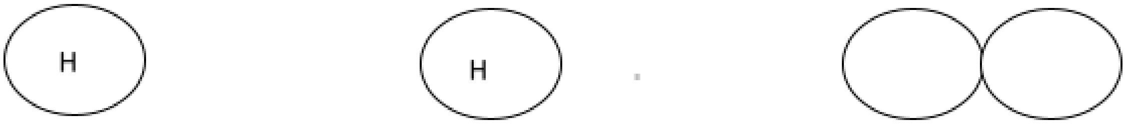


Example 2:



Covalent bonds: usually form between two ___________________________. In this type of bond, electrons are not taken/given away, but they are _______________________. The atoms do NOT become charged. They remain neutral.

Example 1:



Example 2:

Formulas can be written for covalent bonds, too, but this does NOT require balancing positive/negative charges. The attractive force that holds this bond together comes from the need for these atoms to share electrons in order to be stable, so they must remain close to each other in order to share their electrons.

Sometimes several nonmetals can form covalent bonds but end up with a charge. There are quite a few of these that we must memorize! They are called polyatomic ions. **They are listed on the next page! Memorize the highlighted ones! You will be tested over them!**

Example: OH^{-1}…….Oxygen and hydrogen are both nonmetals, so they are bonded covalently, but they have an overall charge of -1. This is the polyatomic ion called hydroxide.

Polyatomic ions can combine with elemental cations and anions to form compounds. We can write a formula for these compounds.

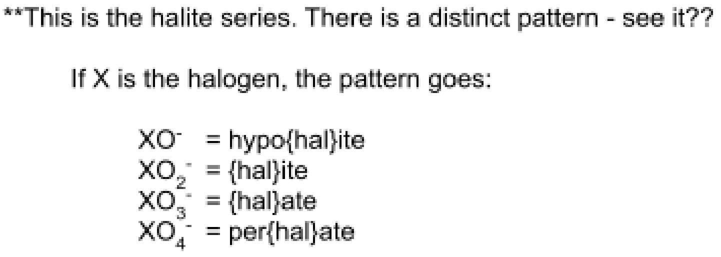
Example 1: ammonium + chlorine Example 2: ammonium + oxygen Example 3: calcium + acetate Example 4: lithium + oxalate

Practice Problem:
Write a formula for ammonium + hydroxide

Polyatomic Ions and Transition Metal Ions (the most commonly used are in yellow - memorize these, and the Halite series in pink - recognizing the pattern will make the whole series easy to memorize). Flashcards are often very helpful for this!

Symbol	**Name**	**Charge**
HSO_4	Hydrogen sulfate (bisulfate)	**-1**
NO_3	Nitrate	-1
NO_2	Nitrite	-1
OH	Hydroxide	-1
CN	Cyanide	-1
SCN	Thiocyanate	-1
HCO_3	Hydrogen carbonate (bicarbonate)	-1
ClO	Hypochlorite	-1
ClO_2	Chlorite	-1
ClO_3	Chlorate	-1
ClO_4	Perchlorate	-1
BrO	Hypobromite	-1
BrO_2	Bromite	-1
BrO_3	Bromate	-1
BrO_4	Perbromate	-1
IO	Hypoiodite	-1
IO_2	Iodite	-1
IO_3	Iodate	-1
IO_4	Periodate	-1
H_2PO_4	Dihydrogen phosphate	-1
$C_2H_3O_2$	Acetate	-1
MnO_4	Permanganate	-1
NH_2	Amide	-1
SO_4	Sulfate	**-2**
SO_3	Sulfite	-2
S_2O_3	Thiosulfate	-2
O_2	Peroxide	-2
C_2O_4	Oxalate	-2
CO_3	Carbonate	-2
CrO_4	Chromate	-2
Cr_2O_7	Dichromate	-2
HPO_4	Hydrogen phosphate	-2
PO_4	Phosphate	**-3**
PO_3	Phosphite	-3
BO_3	Borate	-3
NH_4	Ammonium	**+1**

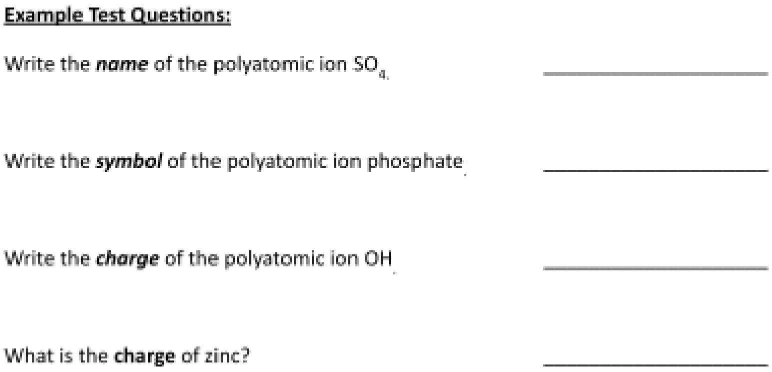
Symbol	**Name**
Ag^+	Silver
Zn^{+2}	Zinc



**This is the halite series. There is a distinct pattern - see it??

If X is the halogen, the pattern goes:

XO^- = hypo{hal}ite
XO_2^- = {hal}ite
XO_3^- = {hal}ate
XO_4^- = per{hal}ate



Example Test Questions:

Write the ***name*** of the polyatomic ion SO_4. __________________

Write the ***symbol*** of the polyatomic ion phosphate __________________

Write the ***charge*** of the polyatomic ion OH __________________

What is the **charge** of zinc? __________________

Ionic and covalent compounds can be named following a set of rules.

Example 1: NaCl		Example 2: CO_2		Example 3: $NH_4C_2H_3O_2$

For both types of compounds, change the __________________ of the ________________ part of the formula to –ide, except in the case of polyatomic ions.

For _______________________ compounds ONLY, use prefixes in the name to express the number of atoms of each element. (This is necessary because there are no positive/negative charges in covalent bonding to help us figure out the number of atoms that are needed).

Prefix	**Meaning**
Mono-	
Di-	
Tri-	
Tetra-	
Penta-	
Hexa-	
Hepta-	
Octa-	
Nona-	
Deca-	

Example 1: N_2O_5		Example 2: NO_2		Example 3: CO

Example 4: SF_6

Some ionic compounds contain transition metals. Since they are metals, they will ______________________ electrons and be _________________ charged, but we do not know what their exact charge will be without more information. (Remember there is no pattern for charges of the transition metals).

Their charges are often given as roman numerals. Fe^{+2} will be Iron (II) and Fe^{+3} will be Iron (III).

Practice Problem:

What is the formula for Iron III oxide?

Practice Problem:

What is the name for FeO?

Property	**Ionic**	**Covalent**
Melts at….		
Dissolves in water?		
Conducts electricity?		
Hard/Soft?		
Odor?		

Why is it necessary to distinguish between ionic and covalent bonding? Their _________________________ are important.

What properties would you expect for the chemical $C_6H_{12}O_6$?

Does it make sense that ionic compounds are hard while covalent compounds are soft? Why?

Coulomb's Law:

Some elements do NOT exist as a single atom. Those elements exist as a PAIR of atoms. They are called ______________.

Example: Hydrogen does not exist as H. It exists only as H_2. Elemental hydrogen is diatomic.

List the 7 diatomic elements: (Make sure you MEMORIZE these!)

If you add up the atomic mass of EVERY atom in a compound, you will have the mass of 1 MOLE of that compound. That's the mass of 6.02×10^{23} molecules of that compound!

Example 1: $C_9H_8O_4$….molar mass = (9 x 12.01) + (8 x 1..01) + (4 x 16.00) = 180.20 g/mol (Give this value with 2 places past the decimal).

Then, the molar mass can be used in calculations along with Avogadro's number.

Example 1: The compound $C_9H_8O_4$ is aspirin. If I have an aspirin tablet that weighs 0.325g, how many molecules of aspirin are in the tablet?

Example 2: You have 16.5 g of oxalic acid, $H_2C_2O_4$. How many moles of acid do you have? How many molecules are in this sample?

Since the molar mass is a __________________, we can figure out the percentage that each element makes up of the molar mass of a compound.

Example 1: $C_9H_8O_4$….molar mass = 180.2 g/mol; The carbon represents 108.09 grams of this compound (9 x 12.01). This is 59.98% (108.09/180.20 x 100).

We call these percents the _____________________________________. What is the percent composition for H and O in aspirin?

If I have 3.25 g of aspirin, how much carbon (in grams) do I have in my sample? How much oxygen? How much hydrogen?

Imagine that I dig up a rock that is made of FeO (iron ore). If the rock weighs 2500 grams, how much iron can I pull out of the rock (in grams)?

The formula $H_2C_2O_4$ represents the TRUE formula of the chemical. This is called the

______________________________ formula. If we divide each element by 2, we can simplify or reduce the formula

to HCO_2. This is called the ________________________ formula.

Practice Problem:
What is the formula of Ga_xO_y if 1.25 g of Ga react with oxygen to form 1.68 g of Ga_xO_y? Is this an empirical formula?

A _____________________ compound is one that has water attached to them. $CuCl_2{\cdot}H_2O$ is copper II chloride and it has 1 mole of water attached to it. What is the molar mass of this compound?

Practice Problem:
Find the empirical formula for a sample of 57.54% C, 3.45% H, and 39.01% F.

Practice Problem:
Copper (II) sulfate is a hydrate, but we don't know how many waters are attached to it. Suppose you measured out 1.023g of this substance ($CuSO_4{\cdot}xH_2O$) and we heat it thoroughly so that all of the waters are removed and evaporated. It now weighs 0.654 grams. What is the formula of this hydrate?

Lesson 4 Notes

When two or more chemical combine together and react, the ________________________ and atoms ________________________. This is called a chemical reaction.

Chemical reactions are expressed as chemical equations. Label the "reactants" and "products" in the equation below. Solid, liquid, gas, and "aqueous" (meaning solid dissolved in _____________) are indicated in parentheses. The little numbers (subscripts) come from writing the correct formula for the chemical. The big numbers (coefficients) come from *balancing* the equation.

$P_{4(s)} + 6Cl_{2(g)} \rightarrow 4\ PCl_{3(l)}$

In a balanced equation, the number of atoms on the left side (reactants) is equal to the number of atoms on the right side (products). Draw an illustration here to show WHY the coefficients (6 & 4) are necessary.

Example 1: $Fe + O_2 \rightarrow Fe_2O_3$

Example 2: $NH_3 + O_2 \rightarrow NO + H_2O$

The Law of _____________________________________ states that atoms/mass cannot be created or destroyed during a chemical reaction. So, the number of atoms in the reactants must equal the number of atoms in the products. Balancing equations does this for us.

The coefficients can provide a ratio for chemicals in an equation. This ratio is called the ____________________.

Practice Problem:

$P_{4(s)} + 6Cl_{2(g)} \rightarrow 4\ PCl_{3(l)}$ What is the mole ratio for P_4 and PCl_3?

If we know the mass or moles of one chemical, we can use the mole ratio to figure out the mass or moles of another chemical.

Practice Problem:

$P_{4(s)} + 6Cl_{2(g)} \rightarrow 4\ PCl_{3(l)}$ If 3.0 g of P_4 react, how many grams of PCl_3 will be formed?

There is a name for this process. When we use math to convert between moles/mass of 2 different substances in an equation, we are using ____________________________.

Practice Problem:

What mass of oxygen (in grams) is required for a complete reaction of 25.0 g of glucose, $C_6H_{12}O_6$? The balanced equation is shown below.

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

Practice Problem:

How many moles of oxygen is required for a complete reaction of 25.0 g of glucose, $C_6H_{12}O_6$? The balanced equation is shown below.

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

Practice Problem:

What mass of glucose, $C_6H_{12}O_6$, is required to form 3 moles of H_2O? The balanced equation is shown below.

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

When two chemicals are mixed together in a reaction, you might have some chemical left over and another chemical used up. We call the leftover chemical _________________ reactant. The used up chemical is called the _________________________ reactant.

You can use stoichiometry to figure out limiting and excess reactant. The one that makes LESS product will be all used up (limiting). The one that is capable of making MORE product will be leftover (excess).

Practice Problem:

Methanol, CH_3OH, can be used as a fuel. It is made by reacting carbon monoxide and hydrogen gas. Write an equation for this reaction. Balance the equation.

Practice Problem:

Suppose 356 g of CO and 65.0 g of H_2 are mixed to make the methanol. Identify the limiting and excess reactant. How much methanol will actually be made (in grams)?

Practice Problem:

$Fe_2O_3 + 2Al \rightarrow 2Fe + Al_2O_3$

Suppose 50.0 g of reactants are mixed. Identify the limiting and excess reactant. How much iron will actually be made (in grams)?

So now that we can calculate how much of a product *should* be made (called the ____________________ yield), we can compare that to the amount that we actually make. This is called the ______________________________.

Let's look back at the last two examples:

Practice Problem:

If 400.0 grams of CH_3OH are actually made, what is the percent yield?

Practice Problem:

If 30.0 grams of Fe are actually made, what is the percent yield?

There are 5 categories in the Animal Kingdom (mammal, amphibian, reptile, fish, and bird). How would you classify a rat? Why? Just like we can classify a rat as a mammal and not an amphibian, we can classify chemical equations.

There are 5 categories of chemical equations. They are called Synthesis, Decomposition, Single Displacement, Double Displacement, and Combustion.

Synthesis reactions: ____

$H_2 + O_2 \rightarrow H_2O$

Decomposition reactions: ____

$H_2O \rightarrow H_2 + O_2$

Single Displacement reactions: ____

$Al + CuCl_2 \rightarrow AlCl_3 + Cu$

Double Displacement reactions: ____

$CuCl_2 + Al(OH)_3 \rightarrow Cu(OH)_2 + AlCl_3$

Combustion reactions: ____

$CH_4 + O_2 \rightarrow CO_2 + H_2O$

Practice Problem:

Identify these types of reactions:

(a) $2Mg + O_2 \rightarrow 2MgO$ (b) $CH_3CO_2H + NaOH \rightarrow CH_3CO_2Na + H_2O$ (c) $Ni + 2HNO_3 \rightarrow Ni(NO_3)_2 + H_2$

Practice Problem:

Can you identify the type of reaction without the products? $Li + O_2 \rightarrow$

Predicting the products of a chemical reaction is an important part of Chemistry. We predict the products by "balancing" the charges of the elements in the reaction.

$H_2 + O_2 \rightarrow$

$H_2O \rightarrow$

$Al + CuCl_2 \rightarrow$

$CuCl_2 + Al(OH)_3 \rightarrow$

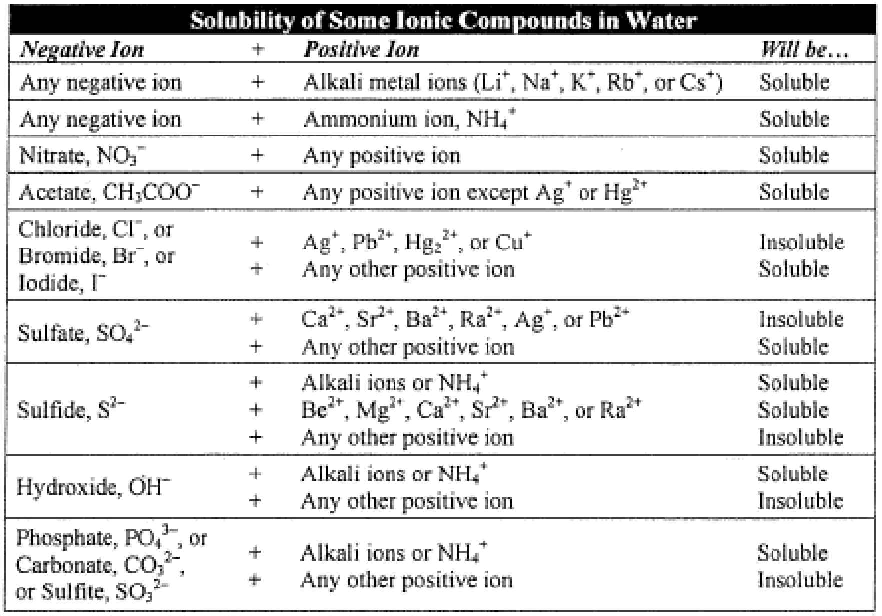
$CH_4 + O_2 \rightarrow$

Practice Problem:

Can you predict the products for the following reactions:

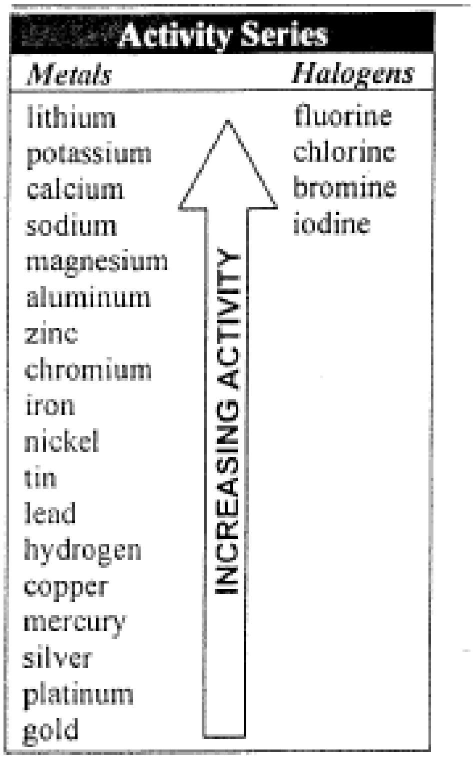
(a) $Na_2SO_4 + BaCl_2 \rightarrow$ (b) $Al + Cl_2 \rightarrow$ (c) $PbS + O_2 \rightarrow$

Double displacement reactions only occur when an INSOLUBLE solid is formed in the products. (Use the solubility chart below). Single displacement reactions only occur if the FREE element in the reactants is MORE ACTIVE than the free element in the products. (Use the Activity Series below).



Solubility of Some Ionic Compounds in Water

Negative Ion	+	*Positive Ion*	*Will be…*
Any negative ion	+	Alkali metal ions (Li^+, Na^+, K^+, Rb^+, or Cs^+)	Soluble
Any negative ion	+	Ammonium ion, NH_4^+	Soluble
Nitrate, NO_3^-	+	Any positive ion	Soluble
Acetate, CH_3COO^-	+	Any positive ion except Ag^+ or Hg^{2+}	Soluble
Chloride, Cl^-, or Bromide, Br^-, or Iodide, I^-	+	Ag^+, Pb^{2+}, Hg_2^{2+}, or Cu^+	Insoluble
	+	Any other positive ion	Soluble
Sulfate, SO_4^{2-}	+	Ca^{2+}, Sr^{2+}, Ba^{2+}, Ra^{2+}, Ag^+, or Pb^{2+}	Insoluble
	+	Any other positive ion	Soluble
Sulfide, S^{2-}	+	Alkali ions or NH_4^+	Soluble
	+	Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, or Ra^{2+}	Soluble
	+	Any other positive ion	Insoluble
Hydroxide, OH^-	+	Alkali ions or NH_4^+	Soluble
	+	Any other positive ion	Insoluble
Phosphate, PO_4^{3-}, or Carbonate, CO_3^{2-}, or Sulfite, SO_3^{2-}	+	Alkali ions or NH_4^+	Soluble
	+	Any other positive ion	Insoluble



Activity Series

Metals	*Halogens*
lithium	fluorine
potassium	chlorine
calcium	bromine
sodium	iodine
magnesium	
aluminum	
zinc	
chromium	
iron	
nickel	
tin	
lead	
hydrogen	
copper	
mercury	
silver	
platinum	
gold	

Practice Problem:

Let's revisit the last few practice problems. Will the following reactions occur?

$2Al + 3CuCl_2 \rightarrow 2AlCl_3 + 3Cu$

$3CuCl_2 + 2Al(OH)_3 \rightarrow 2AlCl_3 + 3Cu(OH)_2$

$Na_2SO_4 + BaCl_2 \rightarrow 2NaCl + BaSO_4$

$Cl_2 + MgBr_2 \rightarrow MgCl_2 + Br_2$

Foundations of Chemistry

Lesson 1

- Metric Prefixes
- Scientific Notation
- Density
- Dimensional Analysis
- Significant Figures

In Chemistry, measurements are made using the metric system.

Common Unit	Abbreviation	Conversion Factor
Milliliter	mL	1L = 1000 mL
Milligram	mg	1g = 1000 mg
Micromolar	μM	1M = 1×10^6 μM
Nanometer	nm	1m = 1×10^9 nm

Most of our lab measurements are teeny-tiny!

- We use **scientific notation** in order to express them. Change into scientific notation:
- 24500 = 2.45×10^4
- 356 = 3.56×10^2
- 0.000985 = 9.85×10^{-4}
- 0.222 = 2.22×10^{-1}
- 12200 = 1.22×10^4

Can you convert OUT of scientific notation?

- 4.2×10^3 = 4200
- 2.15×10^{-4} = 0.000215
- 3.14×10^{-6} = 0.00000314
- 9.22×10^5 = 922000
- 9.57×10^2 = 957

Density

- Density is a measure of how closely packed atoms/molecules are in a substance. Write the equation for density: $D = \frac{m}{v}$
- The two possible units for density are:

g/mL   g/cm^3

Practice Problem:

- What is the volume of a chunk of lead with a mass of 255g and a density of 11.34g/cm^3?

$$D = \frac{m}{v}$$

$$11.34 = \frac{255}{v}$$

$$v = 22.5\ cm^3$$

Dimensional Analysis

Dimensional analysis is a way of lining up numbers so that units cancel. This allows you to know when to multiply and when to divide so that you can get the right answer. Here's dimensional analysis for the density problem:

$$255\cancel{g} \times \frac{1\ cm^3}{11.34\ \cancel{g}} = 22.5\ cm^3$$

$$\begin{array}{c|c} 255\cancel{g} & 1\ cm^3 \\ \hline & 11.34\ \cancel{g} \end{array} = 22.5\ cm^3$$

Practice Problem:

- What is the volume (in µL) of ethanol if the mass is 54.0 ounces? (The density of ethanol is 789 mg/mL; 28.35 g = 1oz). Give your answer with in scientific notation with 2 places past the decimal and show your work using dimensional analysis.

$$\begin{array}{c|c|c|c|c|c} 54.0\ \cancel{oz} & 28.35\ \cancel{g} & 1000\ \cancel{mg} & 1\ \cancel{mL} & 1\ \cancel{L} & 1 \times 10^6\ \mu L \\ \hline & 1\ \cancel{oz} & 1\ \cancel{g} & 789\ \cancel{mg} & 1000\ \cancel{mL} & 1\ \cancel{L} \end{array}$$

$$= 1940304.183\ \mu L \longrightarrow 1.94 \times 10^6\ \mu L$$

Types of Zeros in a Number

- Leading zeros

  $\underline{0.00}25$
- Captive zeros

  $2{,}5\underline{0}5$
- Trailing zeros

  $2{,}5\underline{00}$

  $2{,}5\underline{00.0}$

Practice Problem:

- Circle the LEADING zero(s):

  0.005 0.30 0.020190
- Circle the CAPTIVE zero(s):

  0.005 0.30 0.020190
- Circle the TRAILING zero(s):

  0.005 0.30 0.020190

Some Zeros are Significant

- All non-zeros are significant.
- Leading zeros are **NEVER** significant

  $\underline{0.00}25$ TWO sig figs
- Captive zeros are **ALWAYS** significant

  $2{,}5\underline{0}5$ FOUR sig figs
- Trailing zeros are only significant if there's a **DECIMAL** present ANYWHERE in the number.

  $2{,}5\underline{00}$ TWO sig figs

  $2{,}5\underline{00.0}$ FIVE sig figs

Practice Problem:

How many sig figs are in the following measurements:

5.010	**5.010 = 4 sig figs**
0.25050	**0.25050 = 5 sig figs**
0.039010	**0.039010 = 5 sig figs**
2500	**2500 = 2 sig figs**

Rules for Calculating with Sig Figs

► Multiply/Divide –

Count sig figs in each value in the problem.

The value with fewest sig figs = # of sig figs in answer.

(13.91)(23.3) = 324.103

4 SF **3 SF** ↓ **3 SF**

324

Rules for Calculating with Sig Figs

► Add/Subtract–

The value with least precision matches the "places past the decimal" or the place of the last sig fig in the answer.

```
  3.75            224
+ 4.1           + 130
  7.85 → 7.9      354 → 350
```

Practice Problem:

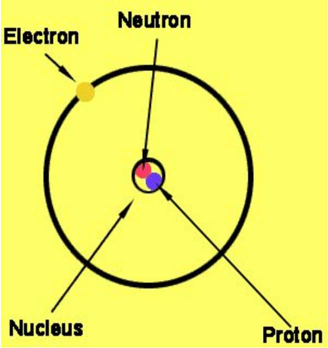
Solve the following problems with the correct number of sig figs in your answer.

11 – 3.92 =	7
2550.0 – 31 =	2519
25.1 x 30.11 =	756
10.2 x 2.1 =	21

Lesson 2

- Atomic Structure
- Isotopes
  - Mass Spectrometry
  - Average Atomic Mass
- The Mole and Molar Mass
- Organization of the Periodic Table

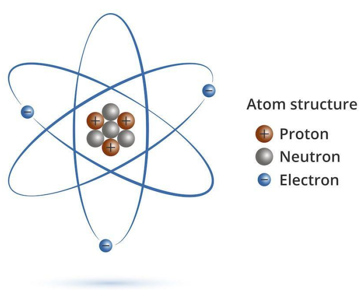
Subatomic Particles



The atom contains:

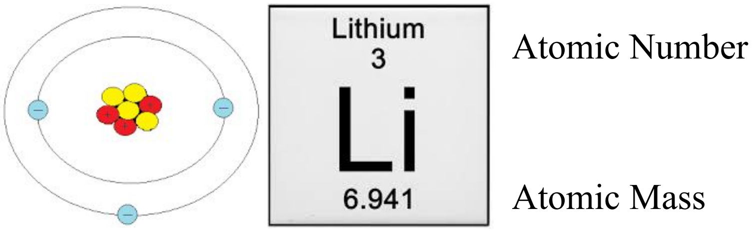
- **Protons**
  - **in the nucleus**
- **Neutrons**
  - **in the nucleus**
- **Electrons**
  - **in shells around the nucleus**

Subatomic Particles are Charged



- Protons
  - (positively-charged particles)
- Neutrons
  - (neutral particles)
- Electrons
  - (negatively-charged particles)

The Periodic Table tells the Atomic Structure of each Element!



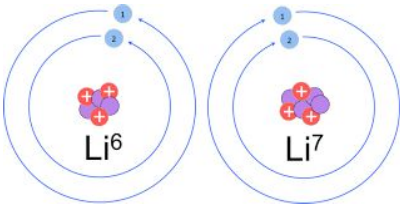
Atomic Number = # protons = # electrons

Atomic Mass = sum of protons & neutrons

The Periodic Table of the Elements

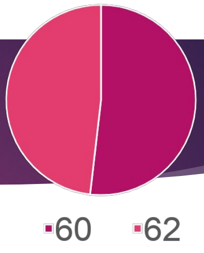
1 **H** Hydrogen 1.00794																	2 **He** Helium 4.003
3 **Li** Lithium 6.941	4 **Be** Beryllium 9.012182											5 **B** Boron 10.811	6 **C** Carbon 12.0107	7 **N** Nitrogen 14.00674	8 **O** Oxygen 15.9994	9 **F** Fluorine 18.9984032	10 **Ne** Neon 20.1797
11 **Na** Sodium 22.989770	12 **Mg** Magnesium 24.3050											13 **Al** Aluminum 26.981538	14 **Si** Silicon 28.0855	15 **P** Phosphorus 30.973761	16 **S** Sulfur 32.066	17 **Cl** Chlorine 35.4527	18 **Ar** Argon 39.948
19 **K** Potassium 39.0983	20 **Ca** Calcium 40.078	21 **Sc** Scandium 44.955910	22 **Ti** Titanium 47.867	23 **V** Vanadium 50.9415	24 **Cr** Chromium 51.9961	25 **Mn** Manganese 54.938049	26 **Fe** Iron 55.845	27 **Co** Cobalt 58.933200	28 **Ni** Nickel 58.6934	29 **Cu** Copper 63.546	30 **Zn** Zinc 65.39	31 **Ga** Gallium 69.723	32 **Ge** Germanium 72.61	33 **As** Arsenic 74.92160	34 **Se** Selenium 78.96	35 **Br** Bromine 79.904	36 **Kr** Krypton 83.80
37 **Rb** Rubidium 85.4678	38 **Sr** Strontium 87.62	39 **Y** Yttrium 88.90585	40 **Zr** Zirconium 91.224	41 **Nb** Niobium 92.90638	42 **Mo** Molybdenum 95.94	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.07	45 **Rh** Rhodium 102.90550	46 **Pd** Palladium 106.42	47 **Ag** Silver 107.8682	48 **Cd** Cadmium 112.411	49 **In** Indium 114.818	50 **Sn** Tin 118.710	51 **Sb** Antimony 121.760	52 **Te** Tellurium 127.60	53 **I** Iodine 126.90447	54 **Xe** Xenon 131.29
55 **Cs** Cesium 132.90545	56 **Ba** Barium 137.327	57 **La** Lanthanum 138.9055	72 **Hf** Hafnium 178.49	73 **Ta** Tantalum 180.9479	74 **W** Tungsten 183.84	75 **Re** Rhenium 186.207	76 **Os** Osmium 190.23	77 **Ir** Iridium 192.217	78 **Pt** Platinum 195.078	79 **Au** Gold 196.96655	80 **Hg** Mercury 200.59	81 **Tl** Thallium 204.3833	82 **Pb** Lead 207.2	83 **Bi** Bismuth 208.98038	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
87 **Fr** Francium (223)	88 **Ra** Radium (226)	89 **Ac** Actinium (227)	104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (263)	107 **Bh** Bohrium (262)	108 **Hs** Hassium (265)	109 **Mt** Meitnerium (266)	110 (269)	111 (272)	112 (277)	113	114				
				58 **Ce** Cerium 140.116	59 **Pr** Praseodymium 140.90765	60 **Nd** Neodymium 144.24	61 **Pm** Promethium (145)	62 **Sm** Samarium 150.36	63 **Eu** Europium 151.964	64 **Gd** Gadolinium 157.25	65 **Tb** Terbium 158.92534	66 **Dy** Dysprosium 162.50	67 **Ho** Holmium 164.93032	68 **Er** Erbium 167.26	69 **Tm** Thulium 168.93421	70 **Yb** Ytterbium 173.04	71 **Lu** Lutetium 174.967
				90 **Th** Thorium 232.0381	91 **Pa** Protactinium 231.03588	92 **U** Uranium 238.0289	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)	95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (262)

Isotopes

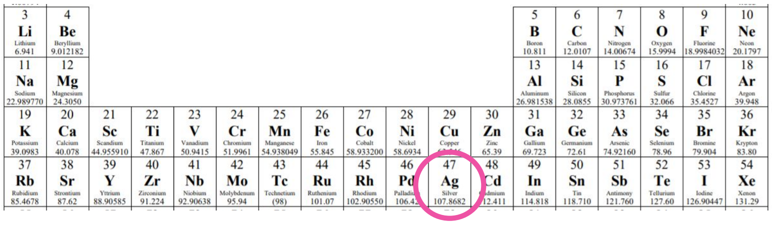


Atoms with the same atomic number but different atomic masses are called **isotopes**.

Example of Isotopes



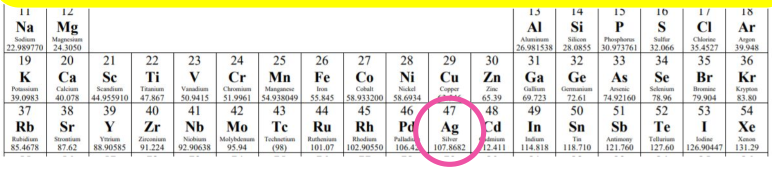
- A sample of Silver (#47) has two isotopes.
- 51.839% of silver atoms have 60 neutrons.
- 48.161% of silver atoms have 62 neutrons.



Calculating the Atomic Masses

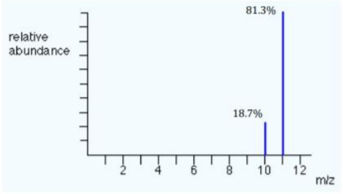
- 51.839% of silver atoms have 60 neutrons.
- 48.161% of silver atoms have 62 neutrons.

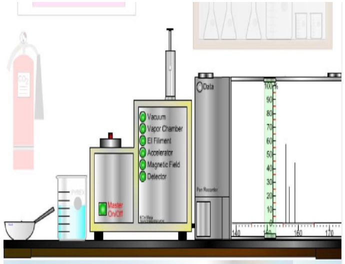
$$\text{Avg. Atomic Mass} = \frac{(107)\ (51.839)\ +\ (109)\ (48.161)}{100} = 107.96322$$



Mass Spectrometer

- This machine generates a graph for you.

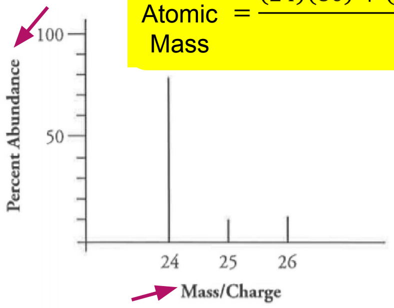




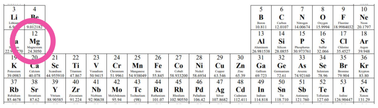
Practice Problem:

- Calculate the average atomic mass and identify the element graphed below.

$$\text{Avg. Atomic Mass} = \frac{(24)(80) + (25)(10) + (26)(10)}{100} = 24.30 \text{ amu}$$



Magnesium!



What is the Mole?

- Just like 1 dozen equals 12,

1 mole equals 6.02 x 10^{23}

- It's called Avogadro's number.
- 1 mole is abbreviated as **1 mol.**

Amadeo Avogadro

Why do we use moles to count in Chemistry?

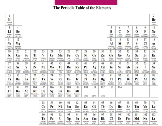
- A tablespoon of water contains about 4.94 x 10^{23} water molecules.
- That's about 0.8 moles.
- Since there are a LOT of molecules in a small amount of chemical, we count in terms of moles.

But we don't physically count at all…

How many pennies are in a 50.0 lb bag?

- Instead of counting them, weigh the bag and weigh a single penny.
- Then, you can use MATH to figure out the number of pennies in the bag!

Atomic Mass = Mass of 1 mole!



- How much does 1 mole of **carbon** weigh?

  12.01 grams

- How much does 1 mole of **calcium** weigh?

  40.08 grams

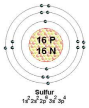
- In 6.91 g of Lithium, how many moles are there?

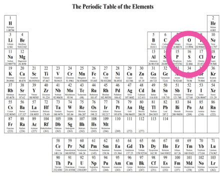
  1 mol Li (That's 6.02 x 10^{23} atoms of Li).

Atomic Mass = Molar Mass

- Atomic mass tells both the…
  - mass of 1 atom (in amu)
  - mass of 1 mole (in grams)

Sulfur





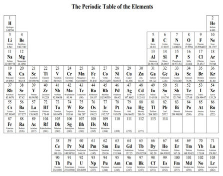
1 atom of S = 32.06 amu

6.02×10^{23} atoms of S = 32.06 g

Practice Problems:

What's the molar mass of these elements:

- magnesium 24.31 g/mol
- fluorine 19.00 g/mol
- sodium 22.99 g/mol

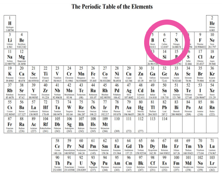


Use Dimensional Analysis & Sig Figs!

- How many moles of carbon are in 46 g of carbon?

$$\frac{46\ \cancel{g}\ C}{} \cdot \frac{1\ mol\ C}{12.01\ \cancel{g}\ C} = \mathbf{3.8304\ldots\ mol\ C}$$

= 3.8304… mol C → **3.8 mol C**

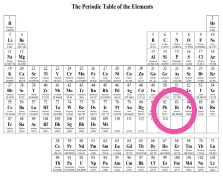


Use Dimensional Analysis & Sig Figs!

- What mass of lead, in grams, is equivalent to 2.50 moles of lead?

$$\frac{2.50\ \cancel{mol}\ Pb}{} \cdot \frac{207.2\ g\ Pb}{1\ \cancel{mol}\ Pb} = \mathbf{518\ g\ Pb}$$

= 518 mol Pb → **518 g Pb**

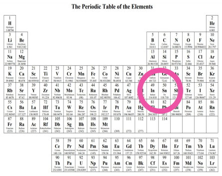


Use Dimensional Analysis & Sig Figs!

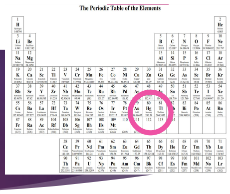
- What amount of tin, in moles, is represented by 36.5 g of tin?

$$\frac{36.5\ \cancel{g}\ Sn}{} \cdot \frac{1\ mol\ Sn}{118.71\cancel{g}\ Sn} = \mathbf{0.3074\ldots\ mol\ Sn}$$

= 0.3074… mol Sn → **0.307 mol Sn**



Practice Problem:



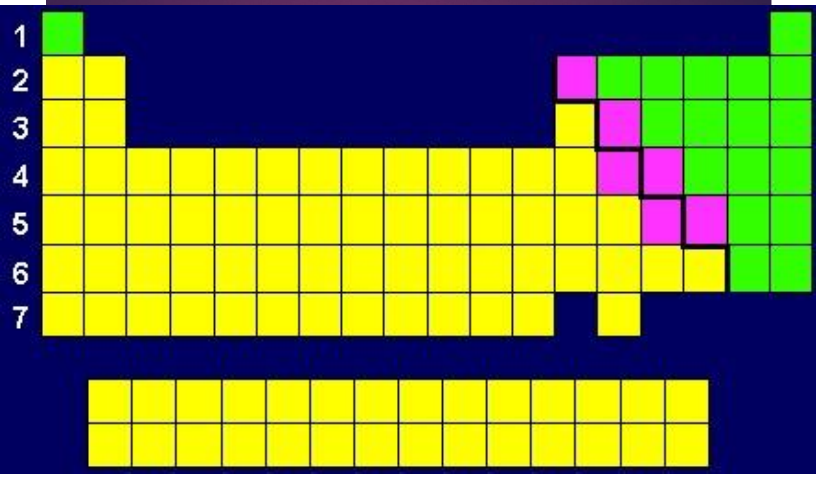
- A graduated cylinder contains 32.0 cm^3 of mercury. If the density of mercury at 25°C is 13.534 g/cm^3, what amount of mercury, in atoms, is in the cylinder?

$$\frac{32.0\ \cancel{cm^3}}{} \cdot \frac{13.534\cancel{g}}{1\ \cancel{cm^3}} \cdot \frac{1\ \cancel{mol}\ Hg}{200.59\ \cancel{g}} \cdot \frac{6.02 \times 10^{23}\ atoms}{1\ \cancel{mol}}$$

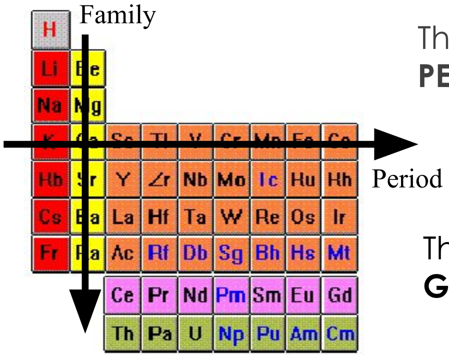
$= 1.2994 \times 10^{24}$ ➡ **1.30×10^{24} atoms**

The Periodic Table is Divided

🟨 **Metals** 🟩 **Nonmetals** 🟪 **Metalloids**



The Periodic Table has rows and columns!

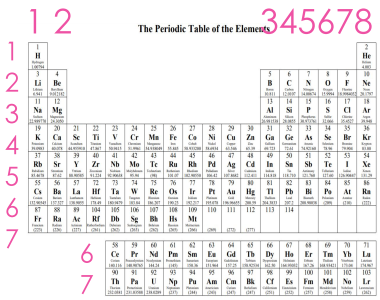


The rows are called **PERIODS.**

The columns are called **GROUPS** or **FAMILIES.**

Periods and Families are Numbered!

- What element is found in Group 2, Period 3?
- Magnesium



Alkali Metals

Alkaline Earth Metals

Transition Metals

Chalcogens

Halogens

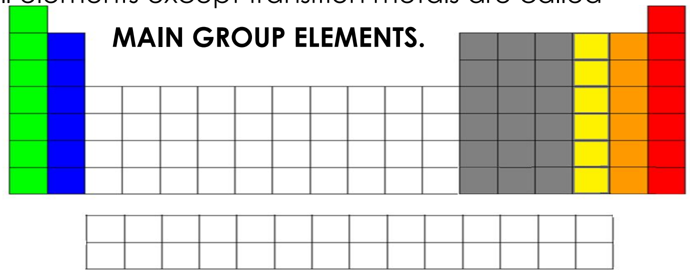
Noble Gases

*The bottom two rows are called the **Lanthanide & Actinide Series**.

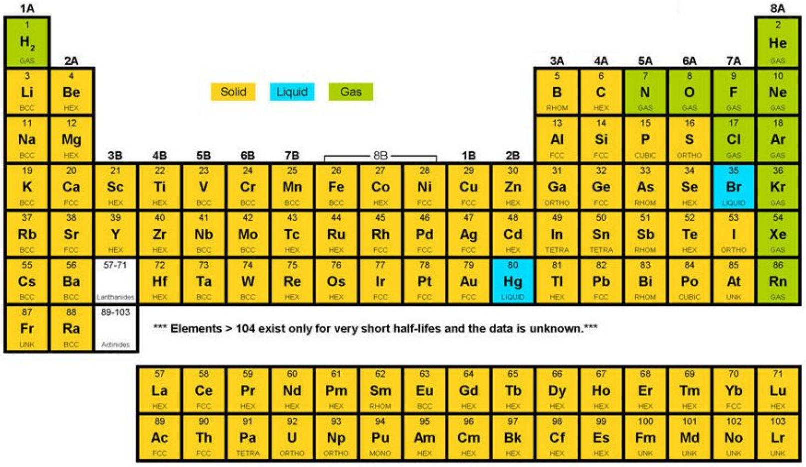
*Groups 13-15 do not have names.

*All elements except transition metals are called

MAIN GROUP ELEMENTS.



States of Matter at Room Temperature



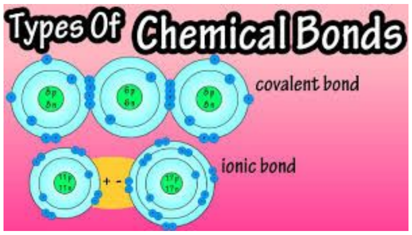
*** Elements > 104 exist only for very short half-lifes and the data is unknown.***

Lesson 3

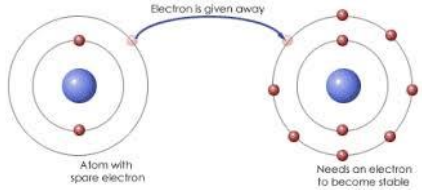
- Chemical Bonding
- Naming compounds
- Molar Mass
- Percent composition

Chemical Bonding

- Two elements can combine to become **stable** **(lower potential energy)**.
- They do this by chemical bonding.
- There are two types of chemical bonds that can form:
  - **Ionic** bonds
  - **Covalent** bonds

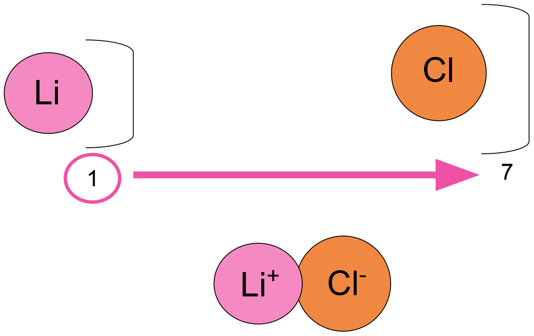


Ionic Bonds



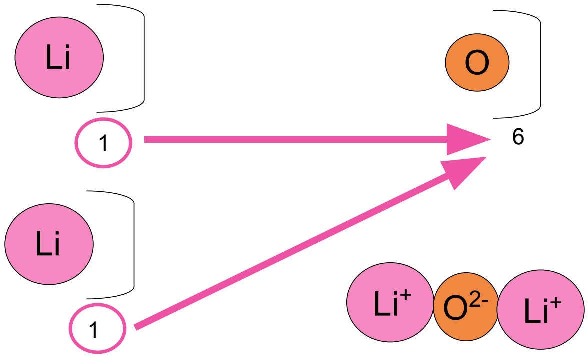
- Usually form between a **metal** and a **nonmetal**.
- This happens because metals give up electrons and nonmetals take those electrons.
- This causes the two atoms to become charged instead of being neutral, because their electrons and protons are now unequal.
- They are called **ions**.

How can Li & Cl become stable?

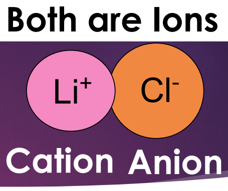


Each atom is now stable, with a lower potential energy.

How can Li & O become stable?



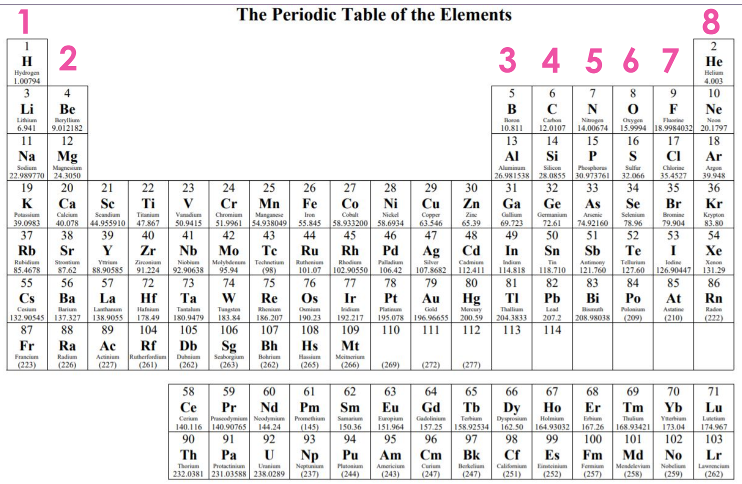
Vocabulary



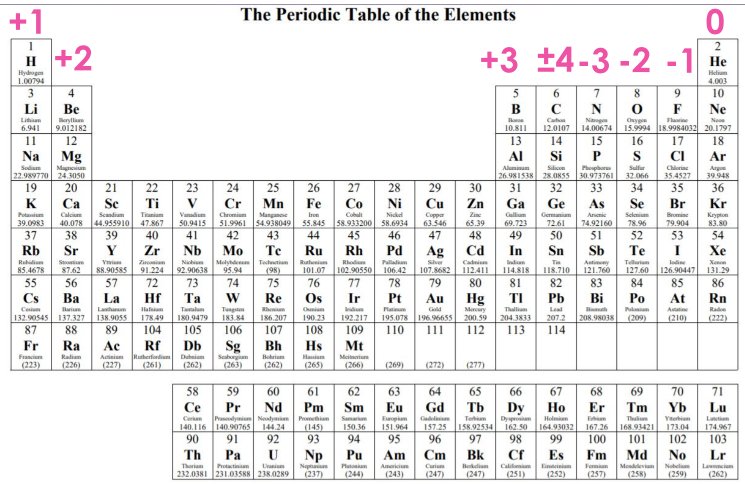
- The atom that becomes POSITIVE is called a **cation**.
- The atom that becomes NEGATIVE is called an **anion**.
- It is the OPPOSITE charges that cause the force of attraction that holds these atoms together in a bond.

How do you know *how many* electrons will be taken/given away?

- Electrons move around the atom in shells.
- The outer shell of electrons needs to be completely filled with electrons in order for the atom to be stable.
- This usually requires 8 electrons.
- This is called the **Octet** Rule.
- There is a pattern of valence electrons for the atoms of elements on the Periodic Table.



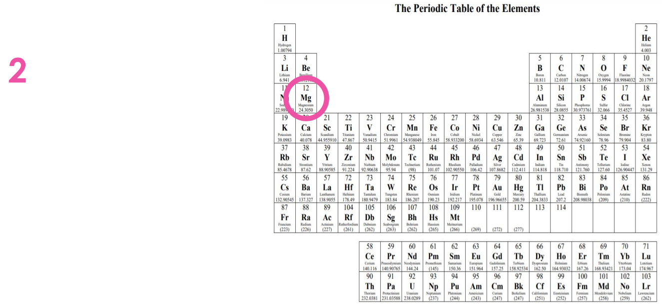
- Exception: Helium has 2 valence electrons.
- Also, the valence electrons of transition metals can vary.



- Ag^{+1}, Zn^{+2} must be memorized.

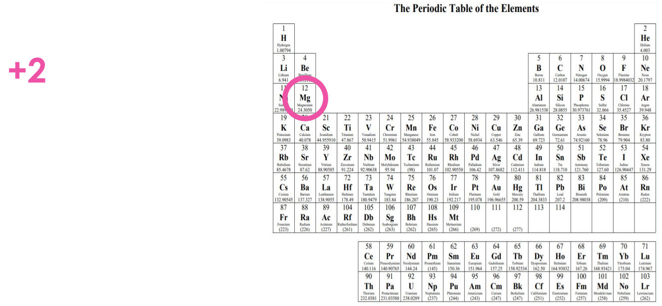
Practice Problem:

- How many valence electrons can be found in an atom of Magnesium?

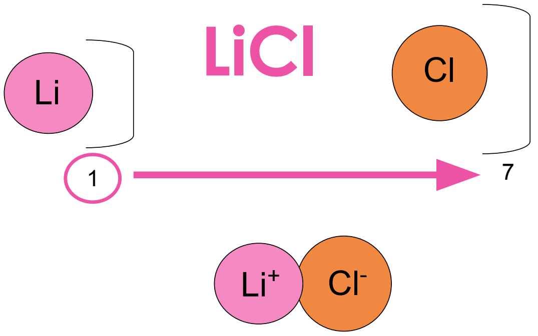


Practice Problem:

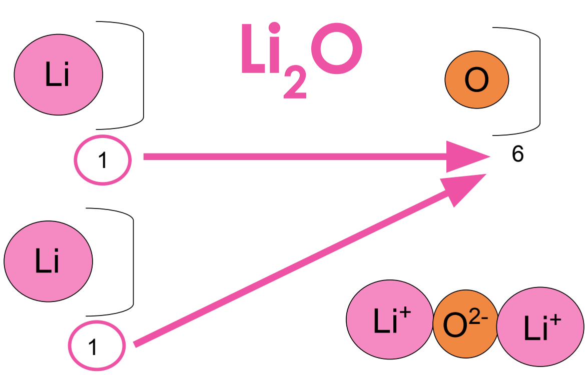
- What is the charge of Magnesium during chemical bonding?



We can use these charges to predict the FORMULA of an ionic compound.



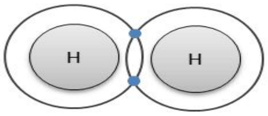
What's the FORMULA for this compound?



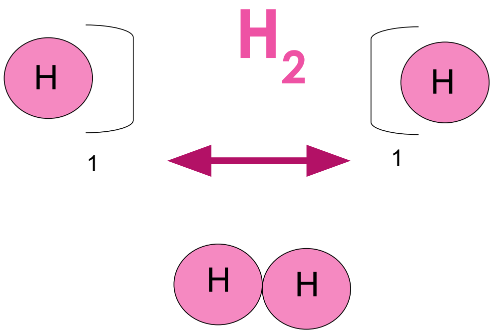
Covalent Bonds

- Usually form between two **nonmetals**.
- In this type of bond, electrons are not taken/given away, but they are **shared**.
- The atoms do NOT become charged. They remain neutral.

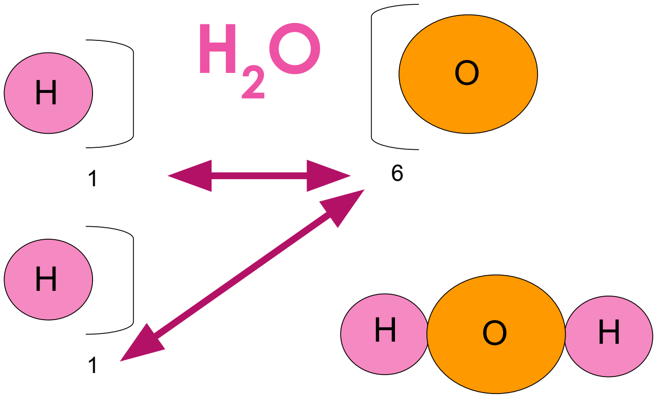
Covalent bond – H2



Example



Example



Formulas can be written for covalent bonds, too,…

- …but this does NOT require balancing positive/negative charges.
- The attractive force that holds this bond together comes from the need for these atoms to share electrons in order to be stable, so they must remain close to each other in order to share their electrons.

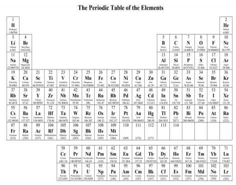
Polyatomic Ions

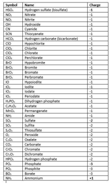
- Sometimes several nonmetals can form covalent bonds but end up with a charge.
- There are quite a few of these that we must memorize!

Symbol	Name	Charge
HSO_4	Hydrogen sulfate (bisulfate)	-1
NO_3	Nitrate	-1
NO_2	Nitrite	-1
OH	Hydroxide	-1
CN	Cyanide	-1
SCN	Thiocyanate	-1
HCO_3	Hydrogen carbonate (bicarbonate)	-1
ClO	Hypochlorite	-1
ClO_2	Chlorite	-1
ClO_3	Chlorate	-1
ClO_4	Perchlorate	-1
BrO	Hypobromite	-1
BrO_2	Bromite	-1
BrO_3	Bromate	-1
BrO_4	Perbromate	-1
IO	Hypoiodite	-1
IO_2	Iodite	-1
IO_3	Iodate	-1
IO_4	Periodate	-1
H_2PO_4	Dihydrogen phosphate	-1
$C_2H_3O_2$	Acetate	-1
MnO_4	Permanganate	-1
NH_2	Amide	-1
SO_4	Sulfate	-2
SO_3	Sulfite	-2
S_2O_3	Thiosulfate	-2
O_2	Peroxide	-2
C_2O_4	Oxalate	-2
CO_3	Carbonate	-2
CrO_4	Chromate	-2
Cr_2O_7	Dichromate	-2
HPO_4	Hydrogen phosphate	-2
PO_4	Phosphate	-3
PO_3	Phosphite	-3
BO_3	Borate	-3
NH_4	Ammonium	+1

Polyatomic ions can combine with other cations and anions to form compounds.

- Ammonium + chlorine NH_4^{+1} Cl^- → NH_4Cl
- Ammonium + oxygen NH_4^{+1} O^{2-} → $(NH_4)_2O$
- Calcium + acetate Ca^{2+} $C_2H_3O_2^-$ → $Ca(C_2H_3O_2)_2$
- Lithium + oxalate Li^+ $C_2O_4^{2-}$ → $Li_2C_2O_4$
- Ammonium sulfate NH_4^{+1} SO_4^{2-} → $(NH_4)_2SO_4$

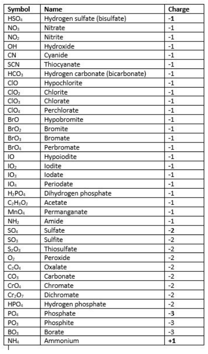




Practice Problem:

- Write the formula for ammonium hydroxide.

NH_4^{+1} OH^- $\longrightarrow$ NH_4OH



Symbol	Name	Charge
HSO_4	Hydrogen sulfate (bisulfate)	**-1**
NO_3	Nitrate	-1
NO_2	Nitrite	-1
OH	Hydroxide	-1
CN	Cyanide	-1
SCN	Thiocyanate	-1
HCO_3	Hydrogen carbonate (bicarbonate)	-1
ClO	Hypochlorite	-1
ClO_2	Chlorite	-1
ClO_3	Chlorate	-1
ClO_4	Perchlorate	-1
BrO	Hypobromite	-1
BrO_2	Bromite	-1
BrO_3	Bromate	-1
BrO_4	Perbromate	-1
IO	Hypoiodite	-1
IO_2	Iodite	-1
IO_3	Iodate	-1
IO_4	Periodate	-1
H_2PO_4	Dihydrogen phosphate	-1
$C_2H_3O_2$	Acetate	-1
MnO_4	Permanganate	-1
NH_2	Amide	-1
SO_4	Sulfate	**-2**
SO_3	Sulfite	-2
S_2O_3	Thiosulfate	-2
O_2	Peroxide	-2
C_2O_4	Oxalate	-2
CO_3	Carbonate	-2
CrO_4	Chromate	-2
Cr_2O_7	Dichromate	-2
HPO_4	Hydrogen phosphate	-2
PO_4	Phosphate	**-3**
PO_3	Phosphite	-3
BO_3	Borate	-3
NH_4	Ammonium	**+1**

Rules for Naming Compounds

- Ionic and covalent compounds can be named following a set of rules.
- Example 1: NaCl **Sodium Chloride**
- Example 2: CO_2 **Carbon Dioxide**
- Example 3: $NH_4C_2H_3O_2$ **Ammonium Acetate**

Rules

- For both types of compounds, change the **ending** of the **second** part of the formula to –ide, except in the case of polyatomic ions.
- For **covalent** compounds ONLY, use prefixes in the name to express the number of atoms of each element. (This is necessary because there are no positive/negative charges in covalent bonding to help us figure out the number of atoms that are needed).

Possible Prefixes & Examples

Prefix	**Meaning**
Mono-	**1**
Di-	**2**
Tri-	**3**
Tetra-	**4**
Penta-	**5**
Hexa-	**6**
Hepta-	**7**
Octa-	**8**
Nona-	**9**
Deca-	**10**

- Example 1: N_2O_5 **dinitrogen pentoxide**
- Example 2: NO_2 **nitrogen dioxide**
- Example 3: CO **carbon monoxide**
- Example 4: SF_6 **sulfur hexafluoride**

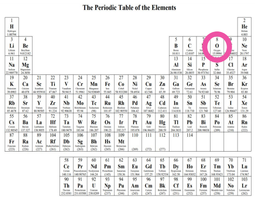
Some ionic compounds contain transition metals.

- Since they are metals, they will **lose** electrons and be **positively** charged, but we do not know what their exact charge will be without more information. (Remember there is no pattern for charges of the transition metals).
- Their charges are often given as roman numerals. Fe^{+2} will be Iron (II) and Fe^{+3} will be Iron (III).

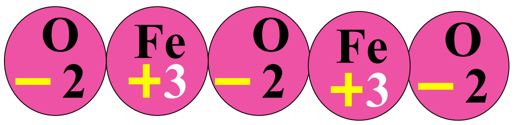
Practice Problem:

- What is the formula for Iron III oxide?

Fe^{3+} O^{2-} $\longrightarrow$ Fe_2O_3



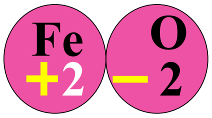
The Periodic Table of the Elements

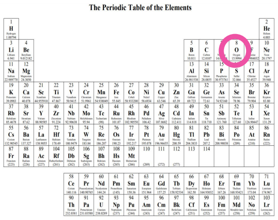


Practice Problem:

- What is the name for FeO?

Fe^{2+} O^{2-} ⟶ Iron(II) oxide





Properties are Based on Bonds

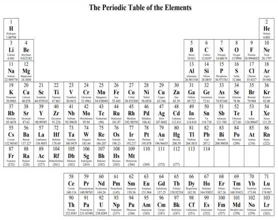
Property	Ionic	Covalent
Melts at….	High temps	Low temps
Dissolves in water?	Yes	No
Conducts electricity?	Yes	No
Hard/Soft?	Hard	Soft
Odor?	No	Yes

- Why is it necessary to distinguish between ionic and covalent bonding? Their **properties** are important.

Practice Problem:

- What properties would you expect for the chemical $C_6H_{12}O_6$?

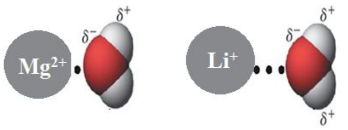
- **Melts at low temps.**
- **Doesn't dissolve in water.**
- **Doesn't conduct electricity.**
- **Soft**
- **Odorous**



Coulomb's Law

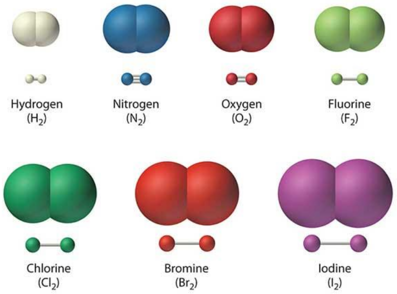
- Does it make sense that ionic compounds are hard while covalent compounds are soft? Why?

Ionic compounds are held together by +/- charges, which are strong attractive forces.



HIGHER Charge results in a shorter, **STRONGER attraction!**

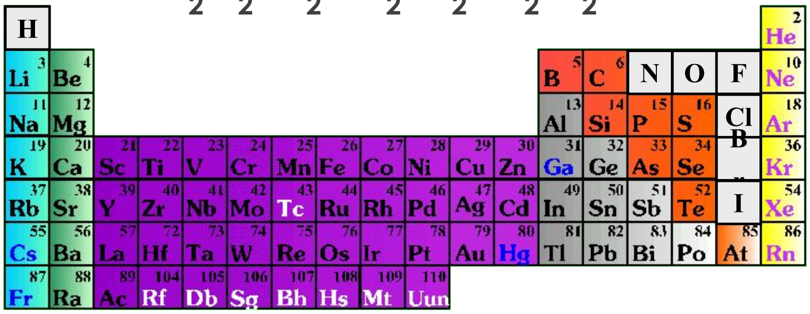
Diatomic Elements



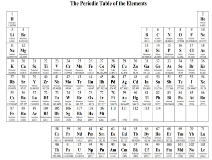
- Some elements do NOT exist as a single atom. Those elements exist as a PAIR of atoms. They are called **diatomic**.

The SEVEN diatomic elements

Br_2 I_2 N_2 Cl_2 H_2 O_2 F_2



Molar Mass of Compounds



- If you add up the atomic mass of EVERY atom in a compound, you will have the mass of 1 MOLE of that compound.
- That's the mass of 6.02 x 10^{23} molecules of that compound!
- $C_9H_8O_4$
- molar mass = (9 x 12.01) + (8 x 1..01) + (4 x 16.00)

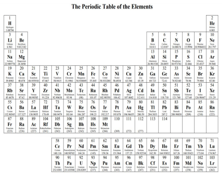
  = 180.20 g/mol
- (Give this value with 2 places past the decimal).

More Examples

- calcium hydroxide
  - $Ca(OH)_2$
  - 40.08 + 2(16.00) + 2(1.01)

    = 74.1 g/mol → **74.10 g/mol**
- ammonium sulfide
  - $(NH_4)_2S$
  - 2(14.01) + 8(1.01) +32.06

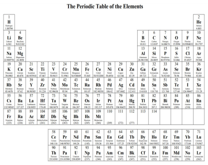
    = **68.16 g/mol**



More Examples

What's the molar mass of these compounds:

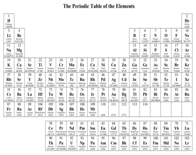
- water
  - H_2O
  - 2(1.01) + 16.00 = **18.02 g/mol**
- sodium chloride
  - NaCl
  - 22.99 + 35.45 = **58.44 g/mol**



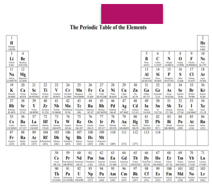
Then, the molar mass can be used in calculations along with Avogadro's number.

- The compound $C_9H_8O_4$ is aspirin. If I have an aspirin tablet that weighs 0.325g, how many molecules of aspirin are in the tablet?

$$\frac{0.325\ \cancel{g}}{} \left| \frac{1\ \cancel{mol}}{180.20\ \cancel{g}} \right| \frac{6.02 \times 10^{23}\ \text{molec.}}{1\ \cancel{mol}} = 1.09 \times 10^{21}\ \text{molec.}$$



Another Example



- You have 16.5 g of oxalic acid, $H_2C_2O_4$. How many moles of acid do you have? How many molecules are in this sample?

$$\frac{16.5\ \cancel{g}}{} \left| \frac{1\ \text{mol}}{90.04\ \cancel{g}} \right. = 0.183\ \text{mol}$$

$$\frac{0.183\ \cancel{mol}}{} \left| \frac{6.02 \times 10^{23}\ \text{molec.}}{1\ \cancel{mol}} \right. = 1.10 \times 10^{23}\ \text{molecules}$$

Percentage by Mass

- Since the molar mass is a **constant** we can figure out the percentage that each element makes up of the molar mass of a compound.
- $C_90H_80_4$....molar mass = 180.2 g/mol
- The carbon represents 108.09 grams of this compound (9 x 12.01). This is 59.98%
- (108.09/180.20) x 100 = 59.98%

Percent Composition

- We call these percents the **percent composition**.

Molar Mass of $KMnO_4$ = 158 g

$$\% K \quad \frac{39.1\text{ g K}}{158\text{ g}} \times 100 = \mathbf{24.7\ \%}$$

$$\% Mn \quad \frac{54.9\text{ g Mn}}{158\text{ g}} \times 100 = \mathbf{34.8\ \%}$$

$$\% O \quad \frac{64.0\text{ g O}}{158\text{ g}} \times 100 = \mathbf{40.5\ \%}$$

Practice Problem:

- What is the percent composition for aspirin ($C_9H_8O_4$)?

$$\%C = \frac{9(12.01)\text{ g C}}{[9(12.01) + 8(1.01) + 4(16.00)]} \times 100 = 60.00\%\text{ C}$$

$$\%H = \frac{8(1.01)\text{ g H}}{[9(12.01) + 8(1.01) + 4(16.00)]} \times 100 = 4.48\%\text{ H}$$

$$\%O = \frac{4(16.00)\text{ g O}}{[9(12.01) + 8(1.01) + 4(16.00)]} \times 100 = 35.52\%\text{ O}$$

Usefulness of these Percents

- If I have 3.25 g of aspirin, ($C_9H_8O_4$), how much carbon (in grams) do I have in my sample? How much oxygen? How much hydrogen?

60.00% C	0.60 x 3.25 = 1.95 g C
4.48% H	0.0448 x 3.25 = 0.0145 g H
35.52% O	0.3552 x 3.25 = 1.15 g O

Practice Problem:

- Imagine that I dig up a rock that is made of FeO (iron ore). If the rock weighs 2500 grams, how much iron can I pull out of the rock (in grams)?

$$\%Fe = \frac{55.85\text{ g Fe}}{[55.85 + 16.00]} \times 100 = 77.73\%\text{ Fe}$$

0.7773 x 2500 = 1943 ► 1900 g Fe

Types of Formulas

- The formula $H_2C_2O_4$ represents the TRUE formula of the chemical. This is called the **molecular** formula.
- If we divide each element by 2, we can simplify or reduce the formula to HCO_2. This is called the **empirical** formula.

$$H_2C_2O_4 \rightarrow HCO_2$$

Empirical Formula

- The formula subscripts represent a **MOLE RATIO** of the elements.

$$CH_3 \qquad \frac{\text{1 mol Carbon}}{\text{3 mol Hydrogen}} \qquad \frac{\text{3 mol Hydrogen}}{\text{1 mol Carbon}}$$

Practice Problem:

- What is the formula of Ga_xO_y if 1.25 g of Ga react with oxygen to form 1.68 g of Ga_xO_y? Is this an empirical formula?

1.68 g – 1.25 g = 0.43 g O

$Ga_{0.0179}O_{0.0269}$

$0.43\ \cancel{\text{g O}} \times \frac{1\ \text{mol}}{16.00\ \cancel{\text{g}}}$ = 0.0269 mol O

$1.25\ \cancel{\text{g Ga}} \times \frac{1\ \text{mol}}{69.72\ \cancel{\text{g}}}$ = 0.0179 mol Ga

These aren't whole numbers!

Practice Problem:

Divide both numbers by the *smallest*.

- What is the formula of Ga_xO_y if 1.25 g of Ga react with oxygen to form 1.68 g of Ga_xO_y? Is this an empirical formula?

1.68 g – 1.25 g = 0.43 g O

$Ga_1O_{1.5}$

$0.43\ \cancel{\text{g O}} \times \frac{1\ \text{mol}}{16.00\ \cancel{\text{g}}}$ = $\frac{0.0269\ \text{mol O}}{0.0179\ \text{mol}}$

$1.68\ \cancel{\text{g Ga}} \times \frac{1\ \text{mol}}{69.72\ \cancel{\text{g}}}$ = $\frac{0.0179\ \text{mol Ga}}{0.0179\ \text{mol}}$ = 1 Ga

These *still* aren't whole numbers!

$Ga_1O_{1.5}$ needs to be a whole number ratio!

View subscripts as fractions

$Ga_1O_{1½}$

⇒ Now you can see to multiply by 2 to make this a whole number ratio!

Ga_2O_3

Practice Problem:

Find the empirical formula for a sample of 57.54% C, 3.45% H, and 39.01% F.

*Assume you have a 100-gram sample of the substance.

$57.54\ \cancel{\text{g}}\ \text{C} \times \frac{1\ \text{mol}}{12.01\ \cancel{\text{g}}}$ = $\frac{4.79\ \text{mol C}}{2.05\ \text{mol}}$ = 2.33 C

$3.45\ \cancel{\text{g}}\ \text{H} \times \frac{1\ \text{mol}}{1.01\ \cancel{\text{g}}}$ = $\frac{3.42\ \text{mol H}}{2.05\ \text{mol}}$ = 1.67 H

$39.01\ \cancel{\text{g}}\ \text{F} \times \frac{1\ \text{mol}}{19.00\ \cancel{\text{g}}}$ = $\frac{2.05\ \text{mol F}}{2.05\ \text{mol}}$ = 1 F

$C_{2⅓}H_{1⅔}F_1$

↓

x3

$C_7H_5F_3$

Hydrates

- A **hydrate** compound is one that has water attached to it.
- $CuCl_2 \cdot H_2O$ is copper II chloride and it has 1 mole of water attached to it.
- What is the molar mass of this compound?
- The SUM of all the elements AND ONE water molecule (152.47 g/mol)

Practice Problem: $CuSO_4 \cdot 5H_2O$

- Copper (II) sulfate is a hydrate, but we don't know how many waters are attached to it. Suppose you measured out 1.023g of this substance ($CuSO_4 \cdot xH_2O$) and we heat it thoroughly so that all of the waters are removed and evaporated. It now weighs 0.654 grams. What is the formula of this hydrate?

1.023g – 0.654g = 0.369g H_2O

$0.369\ \cancel{\text{g}\ H_2O} \times \frac{1\ \text{mol}}{18.02\ \cancel{\text{g}}}$ = $\frac{0.0205\ \text{mol}\ H_2O}{0.00410\ \text{mol}}$ = 5 mol H_2O

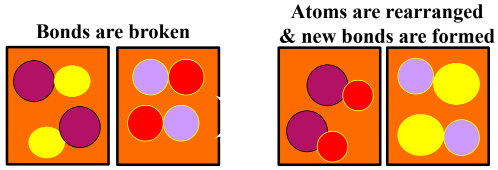
$0.654\ \cancel{\text{g}\ CuSO_4} \times \frac{1\ \text{mol}}{159.61\ \cancel{\text{g}}}$ = $\frac{0.00410\ \text{mol}\ CuSO_4}{0.00410\ \text{mol}}$ = 1 mol $CuSO_4$

Lesson 4

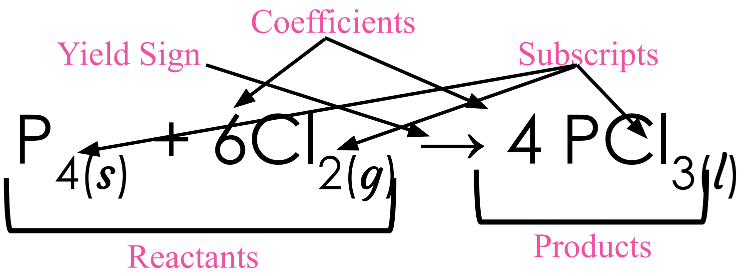
- Balancing Chemical Equations
- Stoichiometry
- Limiting Reactants
- Types of Reactions

Chemical Reactions

When two or more chemical combine together and react, the **bonds break** and atoms **rearrange**. This is a chemical reaction.



Chemical Equation



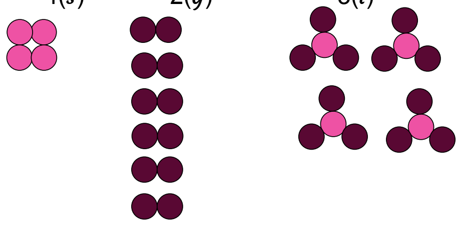
$$P_{4(s)} + 6Cl_{2(g)} \rightarrow 4\ PCl_{3(l)}$$

(aq) = aqueous (solid dissolved in

Balancing Equations

In a balanced equation, the number of atoms on the left side (reactants) is equal to the number of atoms on the right side (products).

$$P_{4(s)} + 6\,Cl_{2(g)} \rightarrow 4\,PCl_{3(l)}$$



Practice Problem:

$$4\ FeO_{(s)} + O_{2(g)} \rightarrow 2\,Fe_2O_{3(s)}$$

$4\ \cancel{2}\ \cancel{1}$	Fe	$\cancel{2}\ 4$
$6\ \cancel{4}\ \cancel{3}$	O	$\cancel{3}\ 6$

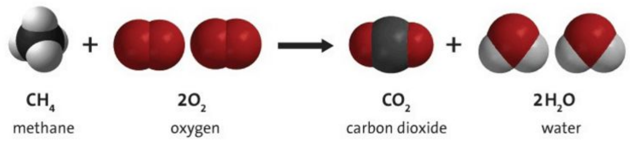
Practice Problem:

$$4\ NH_{3(g)} + \overset{(2.5)}{5}\ O_{2(g)} \rightarrow 4\ NO_{(g)} + 6\,H_2O_{(l)}$$

$4\ \cancel{2}\ \cancel{1}$	N	$\cancel{1}\ \cancel{2}\ 4$
$10\ \cancel{2}$	O	$\cancel{2}\ \cancel{3}\ \cancel{5}\ 10$
$12\ \cancel{6}\ \cancel{3}$	H	$\cancel{2}\ \cancel{6}\ 12$

Law of Conservation of Mass

Atoms cannot be created or destroyed.



16 g 2*32 g 44 g 2*18 g

Mole Ratio

- The coefficients can provide a ratio for chemicals in an equation.
- This ratio is called the **mole ratio**.

$N_2 + 3H_2 \rightarrow 2NH_3$

$$\frac{1 \text{ mol } N_2}{3 \text{ mol } H_2} \quad or \quad \frac{3 \text{ mol } H_2}{1 \text{ mol } N_2}$$

$$\frac{1 \text{ mol } N_2}{2 \text{ mol } NH_3} \quad or \quad \frac{2 \text{ mol } NH_3}{1 \text{ mol } N_2}$$

$$\frac{3 \text{ mol } H_2}{2 \text{ mol } NH_3} \quad or \quad \frac{2 \text{ mol } NH_3}{3 \text{ mol } H_2}$$

Practice Problem:

$P_{4(s)} + 6Cl_{2(g)} \rightarrow 4\ PCl_{3(l)}$

- What is the mole ratio for P_4 and PCl_3?

$$\frac{1 \text{ mol } P_4}{4 \text{ mol } PCl_3} \qquad \frac{4 \text{ mol } PCl_3}{1 \text{ mol } P_4}$$

Practice Problem:

$P_{4(s)} + 6Cl_{2(g)} \rightarrow 4\ PCl_{3(l)}$

- If we know the mass or moles of one chemical, we can use the mole ratio to figure out the mass or moles of another chemical.

$$8\ \cancel{\text{mol } PCl_3} \times \frac{1 \text{ mol } P_4}{4\ \cancel{\text{mol } PCl_3}} = 2 \text{ mol } P_4$$

This is called STOICHIOMETRY.

Practice Problem:

- What mass of oxygen (in grams) is required for a complete reaction of 25.0 g of glucose, $C_6H_{12}O_6$? The balanced equation is shown below.

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

25.0 g ? g

$$\frac{25.0\ \cancel{g\ C_6H_{12}O_6}}{} \times \frac{1\ \cancel{mol\ C_6H_{12}O_6}}{180.18\ \cancel{g\ C_6H_{12}O_6}} \times \frac{6\ \cancel{mol\ O_2}}{1\ \cancel{mol\ C_6H_{12}O_6}} \times \frac{32.00\ g\ O_2}{1\ \cancel{mol\ O_2}} = 26.6\ g\ O_2$$

Practice Problem:

- How many moles of oxygen is required for a complete reaction of 25.0 g of glucose, $C_6H_{12}O_6$? The balanced equation is shown below.

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

25.0 g ? mol

$$\frac{25.0\ \cancel{g\ C_6H_{12}O_6}}{} \times \frac{1\ \cancel{mol\ C_6H_{12}O_6}}{180.18\ \cancel{g\ C_6H_{12}O_6}} \times \frac{6\ mol\ O_2}{1\ \cancel{mol\ C_6H_{12}O_6}} = 0.832\ mol\ O_2$$

Practice Problem:

- What mass of glucose, $C_6H_{12}O_6$, is required to form 3 moles of H_2O? The balanced equation is shown below.

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

? g 3 mol

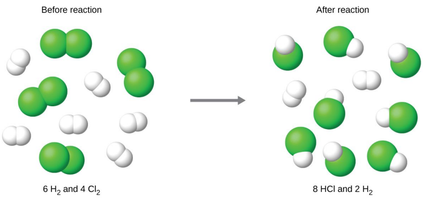
$$\frac{3\ \cancel{\text{mol}\ H_2O}}{} \times \frac{1\ \cancel{\text{mol}\ C_6H_{12}O_6}}{6\ \cancel{\text{mol}\ H_2O}} \times \frac{180.18\ \text{g}\ C_6H_{12}O_6}{1\ \cancel{\text{mol}\ C_6H_{12}O_6}} = \mathbf{90.09\ g\ C_6H_{12}O_6}$$

Limiting & Excess Reactants

- When two chemical are mixed together in a reaction, you might have some chemical left over and another chemical used up.
- We call the leftover chemical **excess** reactant. The used up chemical is called the **limiting** reactant.
- You can use stoichiometry to figure out limiting and excess reactant.
- The one that makes LESS product will be all used up (limiting). The one that is capable of making MORE product will be leftover (excess).

$H_2 + Cl_2 \rightarrow 2HCl$

- **Available Ingredients**
  - 6 H_2
  - 4 Cl_2



Limiting Reactant
- Cl_2

Excess Reactant
- H_2

Example with Explanation

- 79.1 g of zinc react with 82.03 g of HCl. Identify the limiting and excess reactants. How many moles of Zinc chloride will be formed in this reaction?

$$Zn + 2HCl \rightarrow ZnCl_2 + H_2$$

79.1 g 82.03 g ? mol

Do TWO separate problems…one for each reactant.

$Zn + 2HCl \rightarrow ZnCl_2 + H_2$

79.1 g 82.03 g ? mol

- **First problem beginning with 1st reactant (Zn)**
- **Change into moles of ANY product**

$$\frac{79.1\ \cancel{\text{g}\ Zn}}{} \times \frac{1\ \cancel{\text{mol}\ Zn}}{65.39\ \cancel{\text{g}\ Zn}} \times \frac{1\ \text{mol}\ ZnCl_2}{1\ \cancel{\text{mol}\ Zn}} = \mathbf{1.21\ mol\ ZnCl_2}$$

$Zn + 2HCl \rightarrow ZnCl_2 + H_2$

79.1 g 82.03 g ? mol

- **Second problem beginning with 2nd reactant (HCl)**
- **Change into moles of SAME product**

$$\frac{82.03\ \cancel{\text{g}\ HCl}}{} \times \frac{1\ \cancel{\text{mol}\ HCl}}{35.45\ \cancel{\text{g}\ HCl}} \times \frac{1\ \text{mol}\ ZnCl_2}{2\ \cancel{\text{mol}\ HCl}} = \mathbf{1.12\ mol\ ZnCl_2}$$

Now, compare the 2 answers. Find the smallest.

79.1 ~~g Zn~~	1 ~~mol Zn~~	1 mol $ZnCl_2$
	65.39 ~~g Zn~~	1 ~~mol Zn~~

= 1.21 mol $ZnCl_2$

82.03 ~~g HCl~~	1 ~~mol HCl~~	1 mol $ZnCl_2$
	35.45 ~~g HCl~~	2 ~~mol HCl~~

= 1.12 mol $ZnCl_2$

Since LESS product was made from the HCl, the Limiting Reactant is HCl.

79.1 ~~g Zn~~	1 ~~mol Zn~~	1 mol $ZnCl_2$
	65.39 ~~g Zn~~	1 ~~mol Zn~~

= 1.21 mol $ZnCl_2$

82.03 ~~g HCl~~	1 ~~mol HCl~~	1 mol $ZnCl_2$
	35.45 ~~g HCl~~	2 ~~mol HCl~~

= 1.12 mol $ZnCl_2$

Limiting Reactant
- HCl

Excess Reactant
- Zn

1.12 mol $ZnCl_2$ is expected to be produced.

$Zn + 2HCl \rightarrow ZnCl_2 + H_2$

79.1 g 82.03 g ? mol

- **Let's see if you truly understand.**
- **Change one reactant into the other.**

79.1 ~~g Zn~~	1 ~~mol Zn~~	2 ~~mol HCl~~	35.45 g HCl
	65.39 ~~g Zn~~	1 ~~mol Zn~~	1 ~~mol HCl~~

Limiting Reactant
- HCl

Excess Reactant
- Zn

= 85.77 g HCl

- **79.1g Zn requires 85.77g HCl to completely react.**
- **Since we only have 82.03g HCl, we will run out of HCl.**

Practice Problem:

- Methanol, CH_3OH, can be used as a fuel. It is made by reacting carbon monoxide and hydrogen gas. Write an equation for this reaction. Balance the equation.

$CO + 2H_2 \rightarrow CH_3OH$

Pra

~~356g CO~~	1 ~~mol CO~~	1 ~~mol CH_3OH~~	32.05g CH_3OH
	28.01g ~~CO~~	1 ~~mol CO~~	1 ~~mol CH_3OH~~

= 407g CH_3OH

- Suppose 356 g of CO and 65.0 g of H_2 are mixed to make the methanol. Identify the limiting and excess reactant. How much methanol will actually be made (in grams)?

$CO + 2H_2 \rightarrow CH_3OH$

356g 65.0g

356g ~~CO~~	1 ~~mol CO~~	2 ~~mol H_2~~	2.02g H_2
	28.01g ~~CO~~	1 ~~mol CO~~	1 ~~mol H_2~~

Limiting Reactant
- CO

Excess Reactant
- H_2

= 51.4 g H_2

Pra

50.0g ~~Fe_2O_3~~	1 ~~mol Fe_2O_3~~	2 ~~mol Fe~~	55.85g Fe
	159.7g ~~Fe_2O_3~~	1 ~~mol Fe_2O_3~~	1 ~~mol Fe~~

= 35.0g Fe

- Suppose 50.0 g of reactants are mixed. Identify the limiting and excess reactant. How much iron will actually be made (in grams)?

$Fe_2O_3 + 2Al \rightarrow 2Fe + Al_2O_3$

50.0g 50.0g

50.0g ~~Fe_2O_3~~	1 ~~mol Fe_2O_3~~	2 ~~mol Al~~	26.98g Al
	159.7g ~~Fe_2O_3~~	1 ~~mol Fe_2O_3~~	1 ~~mol Al~~

Limiting Reactant
- Fe_2O_3

Excess Reactant
- Al

= 16.9g Al

Percent Yield

- So now that we can calculate how much of a product *should* be made (called the **theoretical** yield), we can compare that to the amount that we actually make (called the **actual yield**).

Practice Problem:

- If 400.0 grams of CH_3OH are actually made, what is the percent yield?

356g $\cancel{CO}$	$\cancel{1\ mol}$ $\cancel{CO}$	$\cancel{1\ mol}$ $\cancel{CH_3OH}$	32.05g CH_3OH	**= 407g CH_3OH**
	28.01g $\cancel{CO}$	$\cancel{1\ mol}$ $\cancel{CO}$	$\cancel{1\ mol}$ $\cancel{CH_3OH}$	

$$\frac{400.0}{407} \text{ X } 100 = 98.3\%$$

Practice Problem:

- If 30.0 grams of Fe are actually made, what is the percent yield?

50.0g $\cancel{Fe_2O_3}$	$\cancel{1\ mol}$ $\cancel{Fe_2O_3}$	$\cancel{2\ mol}$ $\cancel{Fe}$	55.85g Fe	**= 35.0g Fe**
	159.7g $\cancel{Fe_2O_3}$	1 mol $\cancel{Fe_2O_3}$	$\cancel{1\ mol}$ Fe	

$$\frac{30.0}{35.0} \text{ X } 100 = 85.7\%$$

FIVE Types of Reactions

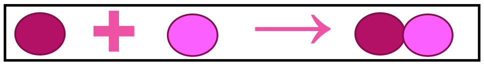
- There are 5 categories in the Animal Kingdom (mammal, amphibian, reptile, fish, and bird).
- How would you classify a rat? Why? Just like we can classify a rat as a mammal and not an amphibian, we can classify chemical equations.
- There are 5 categories of chemical equations.

Synthesis
Decomposition
Single Displacement
Double Displacement
Combustion

Synthesis

- 2 or more substances combine to form a compound
- only one product

$$A + B \rightarrow AB$$

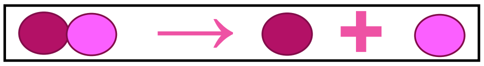


Example: $H_2 + O_2 \rightarrow H_2O$

Decomposition

- a compound breaks down into 2 or more simpler substances
- only one reactant

$$AB \rightarrow A + B$$

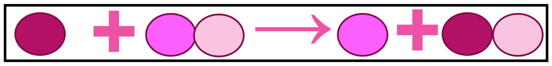


Example: $H_2O \rightarrow H_2 + O_2$

Single Displacement

- one FREE ELEMENT displaces an element in a COMPOUND

$$A + BC \rightarrow B + AC$$

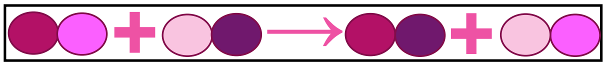


Example: $Al + CuCl_2 \rightarrow AlCl_3 + Cu$

Double Displacement

- ions in two compounds “change partners”

$$AB + CD \rightarrow AD + CB$$



Example: $CuCl_2 + Al(OH)_3 \rightarrow Cu(OH)_2 + AlCl_3$

Combustion

- the burning of any substance in O_2

$$A + O_2 \rightarrow B$$

Example: $CH_4 + O_2 \rightarrow CO_2 + H_2O$

Practice Problem:

- Identify these types of reactions:
- (a) $2Mg + O_2 \rightarrow 2MgO$

  Synthesis (or combustion)
- (b) $CH_3CO_2H + NaOH \rightarrow CH_3CO_2Na + H_2O$

  Double Displacement
- (c) $Ni + 2HNO_3 \rightarrow Ni(NO_3)_2 + H_2$

  Single Displacement

Predicting Products

- Can you identify the type of reaction without the products?

  $Li + O_2 \rightarrow$

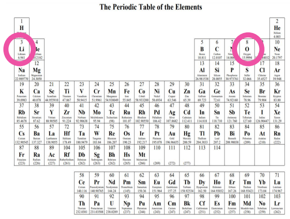
- **We know bonds will break and the atoms will rearrange.**
- **The atoms must combine.**
- **SYNTHESIS**

Predicting Products

- What will the product be?

+1 -2

$4\,Li + O_2 \rightarrow \mathbf{2\,Li_2O}$



Since they combine, they form an ionic bond (between a metal & nonmetal).

Predicting Products

- Predicting the products of a chemical reaction is an important part of Chemistry.
- We predict the products by "balancing" the charges of the elements in the reaction.

Predicting Products

+1 -2

$2H_2 + O_2 \rightarrow 2H_2O$

$2H_2O \rightarrow 2H_2 + O_2$ **H & O are *diatomic*!**

+3 +2 -1

$2Al + 3CuCl_2 \rightarrow 2AlCl_3 + 3Cu$

+2 -1 +3 -1

$3CuCl_2 + 2Al(OH)_3 \rightarrow 2AlCl_3 + 3Cu(OH)_2$

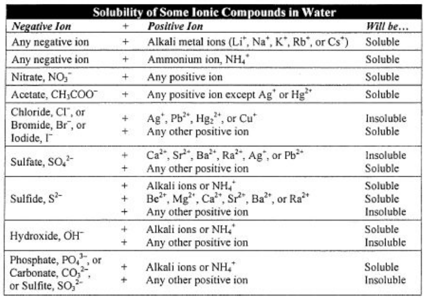
$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

Practice Problem:

- Can you predict the products for the following reactions:
- (a) $Na_2SO_4 + BaCl_2 \rightarrow 2NaCl + BaSO_4$
- (b) $2Al + 3Cl_2 \rightarrow 2AlCl_3$
- (c) $2PbS + O_2 \rightarrow 2PbO + 2S$

What are the states of matter of the products?

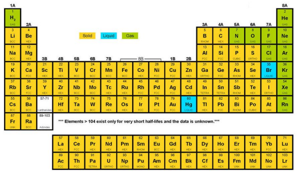
COMPOUNDS: Use this chart!



Solubility of Some Ionic Compounds in Water

Negative Ion	+	*Positive Ion*	*Will be…*
Any negative ion	+	Alkali metal ions (Li^+, Na^+, K^+, Rb^+, or Cs^+)	Soluble
Any negative ion	+	Ammonium ion, NH_4^+	Soluble
Nitrate, NO_3^-	+	Any positive ion	Soluble
Acetate, CH_3COO^-	+	Any positive ion except Ag^+ or Hg^{2+}	Soluble
Chloride, Cl^-, or Bromide, Br^-, or Iodide, I^-	+	Ag^+, Pb^{2+}, Hg_2^{2+}, or Cu^+	Insoluble
	+	Any other positive ion	Soluble
Sulfate, SO_4^{2-}	+	Ca^{2+}, Sr^{2+}, Ba^{2+}, Ra^{2+}, Ag^+, or Pb^{2+}	Insoluble
	+	Any other positive ion	Soluble
Sulfide, S^{2-}	+	Alkali ions or NH_4^+	Soluble
	+	Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, or Ra^{2+}	Soluble
	+	Any other positive ion	Insoluble
Hydroxide, OH^-	+	Alkali ions or NH_4^+	Soluble
	+	Any other positive ion	Insoluble
Phosphate, PO_4^{3-}, or Carbonate, CO_3^{2-}, or Sulfite, SO_3^{2-}	+	Alkali ions or NH_4^+	Soluble
	+	Any other positive ion	Insoluble

ELEMENTS: Solids, liquids, or gases!

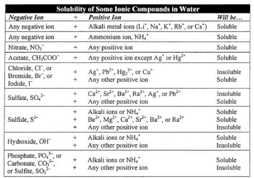


Soluble = (aq)
Insoluble = (s)

Practice Problems:

- Predict the state of matter for the products below.

$2AlCl_3(s) \rightarrow 2Al(s) + 3Cl_2(g)$



Solubility of Some Ionic Compounds in Water

Negative Ion	+	*Positive Ion*	*Will be…*
Any negative ion	+	Alkali metal ions (Li^+, Na^+, K^+, Rb^+, or Cs^+)	Soluble
Any negative ion	+	Ammonium ion, NH_4^+	Soluble
Nitrate, NO_3^-	+	Any positive ion	Soluble
Acetate, CH_3COO^-	+	Any positive ion except Ag^+ or Hg^{2+}	Soluble
Chloride, Cl^-, or Bromide, Br^-, or Iodide, I^-	+	Ag^+, Pb^{2+}, Hg_2^{2+}, or Cu^+	Insoluble
	+	Any other positive ion	Soluble
Sulfate, SO_4^{2-}	+	Ca^{2+}, Sr^{2+}, Ba^{2+}, Ra^{2+}, Ag^+, or Pb^{2+}	Insoluble
	+	Any other positive ion	Soluble
Sulfide, S^{2-}	+	Alkali ions or NH_4^+	Soluble
	+	Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, or Ra^{2+}	Soluble
	+	Any other positive ion	Insoluble
Hydroxide, OH^-	+	Alkali ions or NH_4^+	Soluble
	+	Any other positive ion	Insoluble
Phosphate, PO_4^{3-}, or Carbonate, CO_3^{2-}, or Sulfite, SO_3^{2-}	+	Alkali ions or NH_4^+	Soluble
	+	Any other positive ion	Insoluble

$2KBr(l) \rightarrow 2K(s) + Br_2(l)$

$Ca(s) + FeSO_4(aq) \rightarrow CaSO_4(s) + Fe(s)$

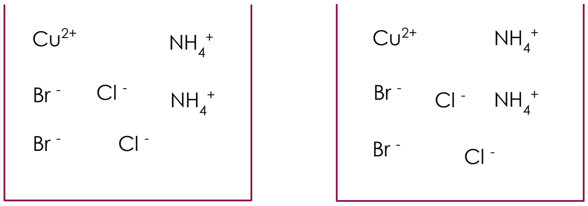
$Br_2(l) + CaCl_2(aq) \rightarrow CaBr_2(aq) + Cl_2(g)$

Just because we can predict products doesn't mean they'll actually form.

Nothing really changed.

This REACTION didn't take place.

$CuBr_{2(aq)} + 2NH_4Cl_{(aq)} \rightarrow 2NH_4Br_{(aq)} + CuCl_{2(aq)}$

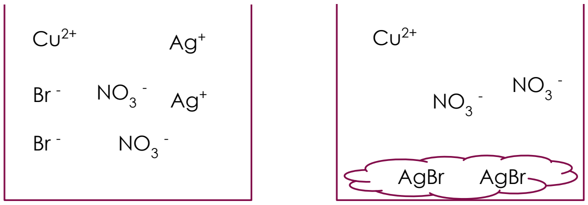


Will this reaction happen?

A solid was formed!

There WAS A REACTION!

$CuBr_{2(aq)} + 2AgNO_{3(aq)} \rightarrow 2AgBr_{(s)} + Cu(NO_3)_{2(aq)}$



Let's Consider this…

- What's happening here?

$LiCl_{(aq)} + Na_{(s)} \rightarrow NaCl_{(aq)} + Li_{(s)}$

Isn't Na "kicking out" Li?

Doesn't Na have to be "stronger" than Li to do this?

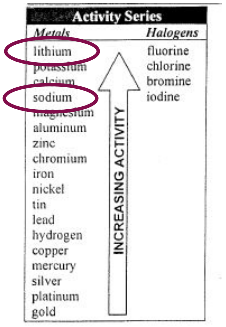
The Activity Series (Strength of Certain Elements)

- Metals on left
- Nonmetals on right
- Stronger elements are at the top

$LiCl_{(aq)} + Na_{(s)} \rightarrow NaCl_{(aq)} + Li_{(s)}$

Is Na stronger than Li? **No!**

So NO REACTION!



Activity Series

Metals	*Halogens*
lithium	fluorine
potassium	chlorine
calcium	bromine
sodium	iodine
magnesium	
aluminum	
zinc	
chromium	
iron	
nickel	
tin	
lead	
hydrogen	
copper	
mercury	
silver	
platinum	
gold	

INCREASING ACTIVITY

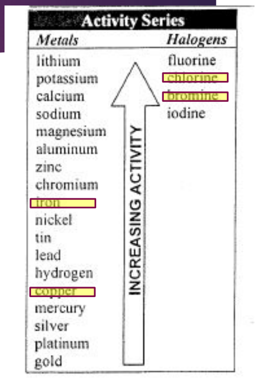
Examples:

$Fe(s) + CuSO_4(aq) \rightarrow Cu(s) + FeSO_4(aq)$

Reaction

$Br_2(l) + NaCl(aq) \rightarrow NaBr(aq) + Cl_2(g)$

No Reaction

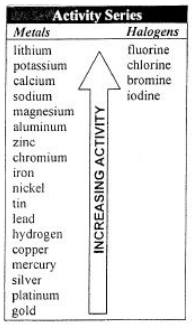


Activity Series

Metals	*Halogens*
lithium	fluorine
potassium	chlorine
calcium	bromine
sodium	iodine
magnesium	
aluminum	
zinc	
chromium	
iron	
nickel	
tin	
lead	
hydrogen	
copper	
mercury	
silver	
platinum	
gold	

INCREASING ACTIVITY

Practice Problem:



Activity Series

Metals	*Halogens*
lithium	fluorine
potassium	chlorine
calcium	bromine
sodium	iodine
magnesium	
aluminum	
zinc	
chromium	
iron	
nickel	
tin	
lead	
hydrogen	
copper	
mercury	
silver	
platinum	
gold	

INCREASING ACTIVITY

- Will the following reactions occur?
- $2Al + 3CuCl_2 \rightarrow 2AlCl_3 + 3Cu$

Yes, b/c Al is "stronger" than Cu

- $3CuCl_2 + 2Al(OH)_3 \rightarrow 2AlCl_3 + 3Cu(OH)_2$

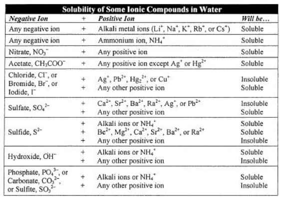
Yes, b/c $Cu(OH)_2$ is an insoluble solid.

- $Na_2SO_4 + BaCl_2 \rightarrow 2NaCl + BaSO_4$

Yes, b/c $BaSO_4$ is an insoluble solid.

- $Cl_2 + MgBr_2 \rightarrow MgCl_2 + Br_2$

Yes, b/c Cl is "stronger" than Br.



Solubility of Some Ionic Compounds in Water

Negative Ion	+	*Positive Ion*	*Will be…*
Any negative ion	+	Alkali metal ions (Li^+, Na^+, K^+, Rb^+, or Cs^+)	Soluble
Any negative ion	+	Ammonium ion, NH_4^+	Soluble
Nitrate, NO_3^-	+	Any positive ion	Soluble
Acetate, CH_3COO^-	+	Any positive ion except Ag^+ or Hg^{2+}	Soluble
Chloride, Cl^-, or Bromide, Br^-, or Iodide, I^-	+ +	Ag^+, Pb^{2+}, Hg_2^{2+}, or Cu^+ Any other positive ion	Insoluble Soluble
Sulfate, SO_4^{2-}	+ +	Ca^{2+}, Sr^{2+}, Ba^{2+}, Ra^{2+}, Ag^+, or Pb^{2+} Any other positive ion	Insoluble Soluble
Sulfide, S^{2-}	+ + +	Alkali ions or NH_4^+ Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, or Ra^{2+} Any other positive ion	Soluble Soluble Insoluble
Hydroxide, OH^-	+ +	Alkali ions or NH_4^+ Any other positive ion	Soluble Insoluble
Phosphate, PO_4^{3-}, or Carbonate, CO_3^{2-}, or Sulfite, SO_3^{2-}	+ +	Alkali ions or NH_4^+ Any other positive ion	Soluble Insoluble