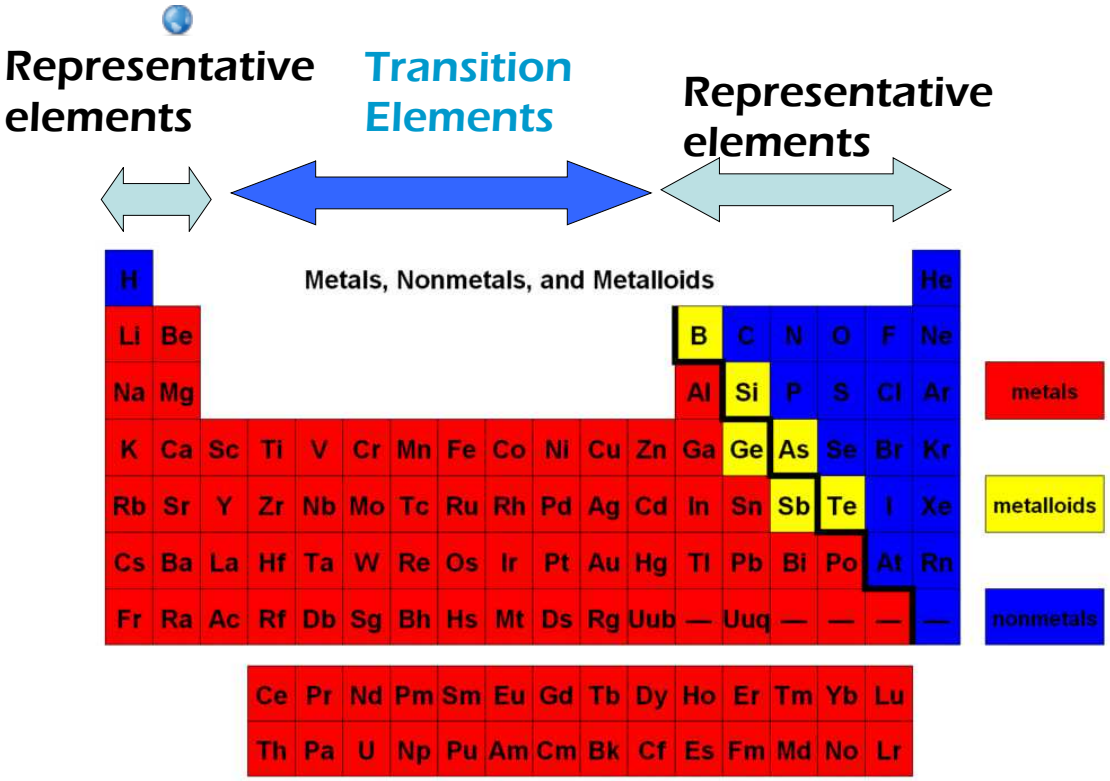
Unit 4: NOMENCLATURE

1. The Periodic Table
2. Atoms, Ions, & Isotopes
3. Ion Formation
4. Ionic Formulas & Nomenclature
5. Hydrates & Acids
6. Covalent Formulas & Nomenclature

1. The Periodic Table

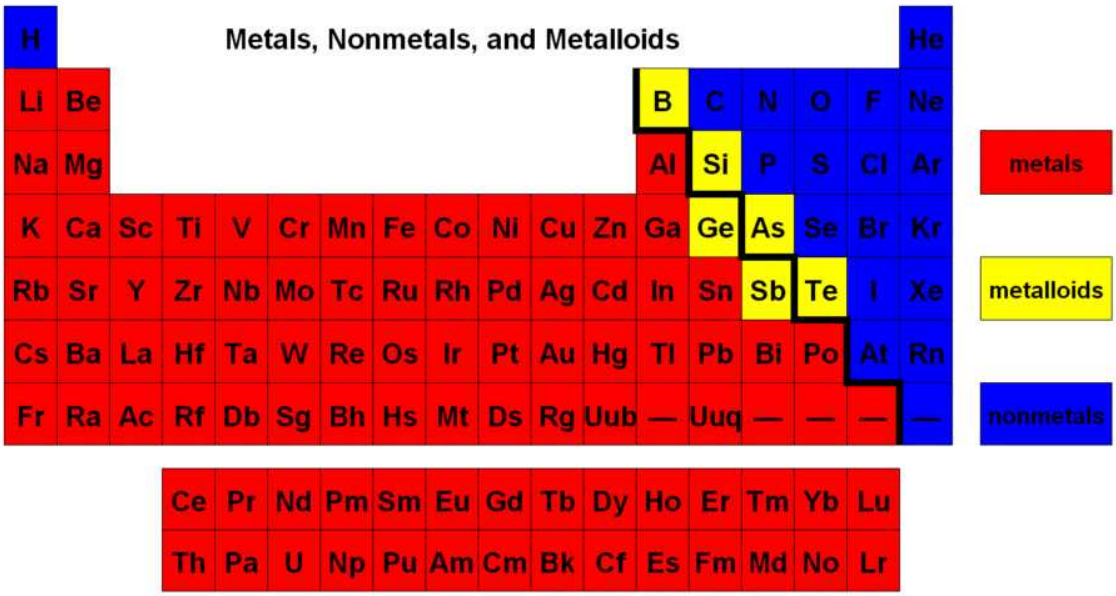


http://www.periodicvideos.com/

Semiconductors
B, Si, Ge As, Se,
Sb, Te

Metals

Nonmetals



Where is the dividing point between metals and non-metals?
THE STAIRCASE!

Keep in mind: Hydrogen is a nonmetal also!

- **METALS**
- good conductors of electricity and heat
- lustrous (shiny), malleable (able to hammer flat) and ductile (can form into wire)
- Solids at room temperature, except Mercury (Hg) which is a liquid
- Form compounds with nonmetals

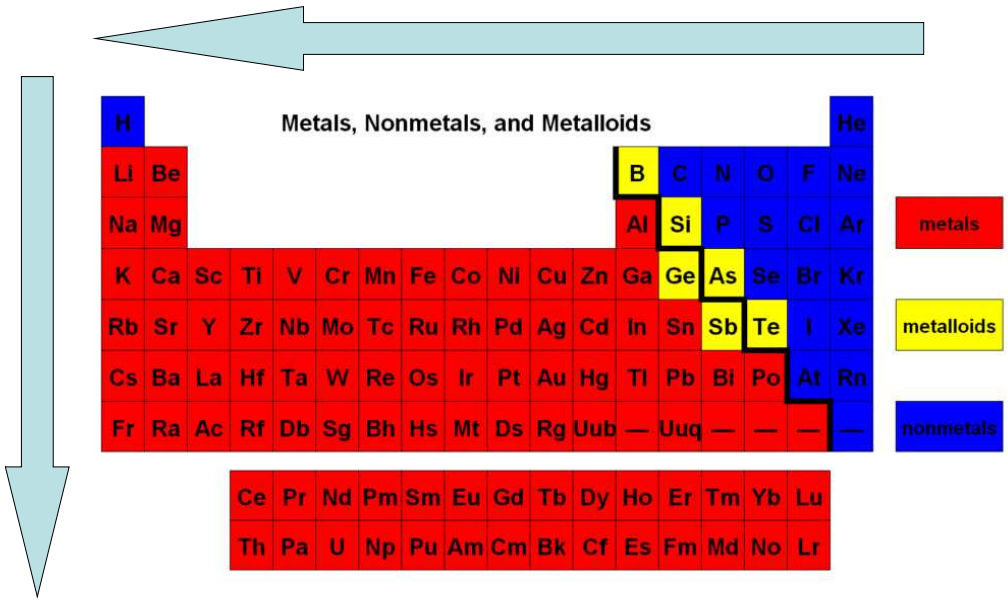
- **NONMETALS**
- moderate to poor conductors of heat and electricity
- dull and brittle if solid
- can be solid, liquid, or gas at room temperature depending on the element
- form compounds with metals or other nonmetals

- **SEMICONDUCTORS**
- also called Metalloids or Semi-Metals
- display both metal and nonmetal properties
- conductivity increases as temperature increases

http://www.lookchem.com/Periodic-Table/Silicon/

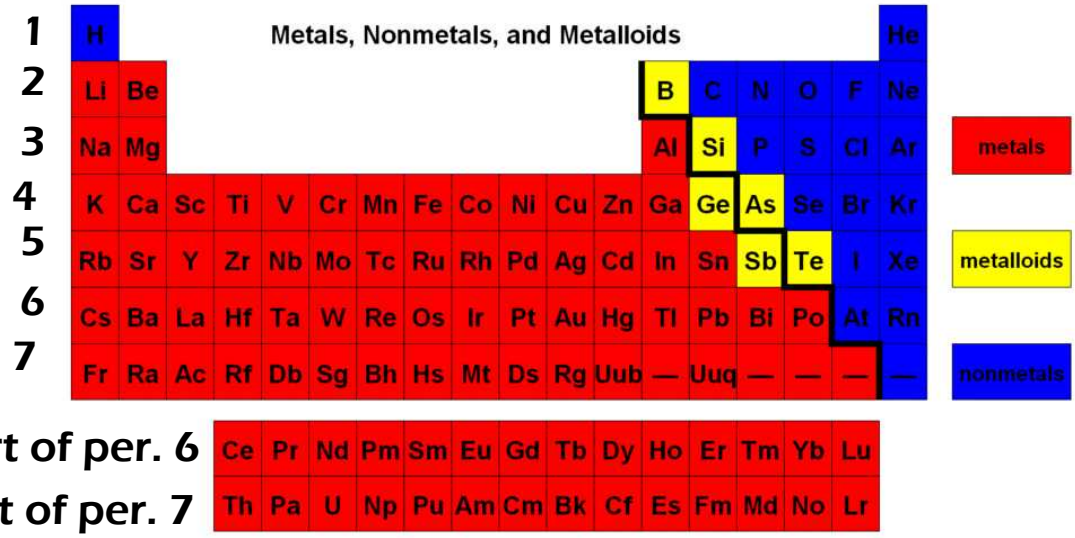
http://www.learnerstv.com/animation/animation.php?ani=184&cat=chemistry

More metallic in direction of arrows



FRANCIUM is the most metallic element!!

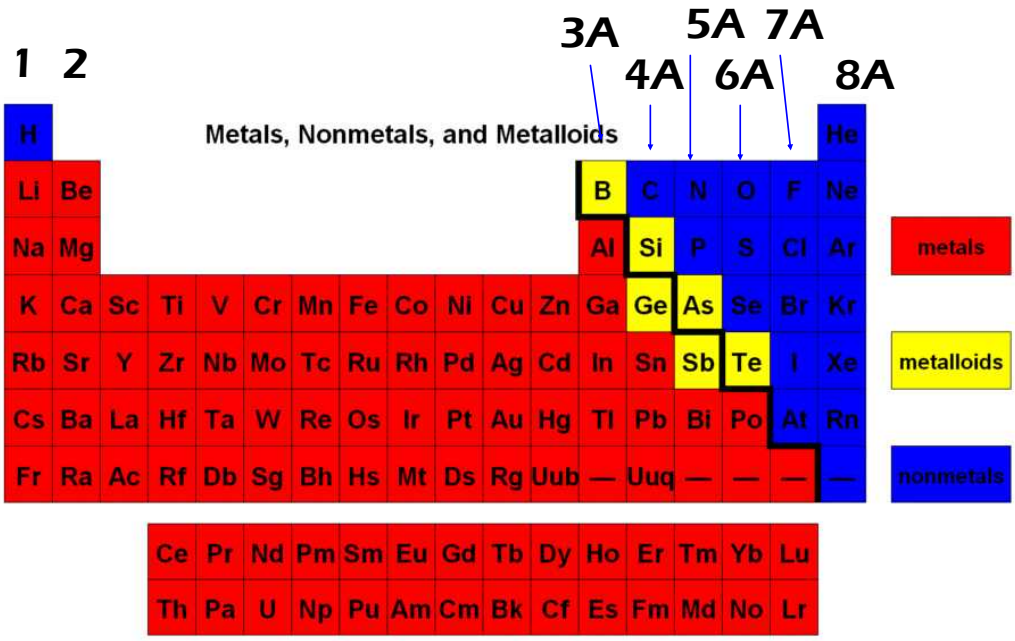
Periods
(HORIZONTAL ROWS)



Part of per. 6 Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu

Part of per. 7 Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr

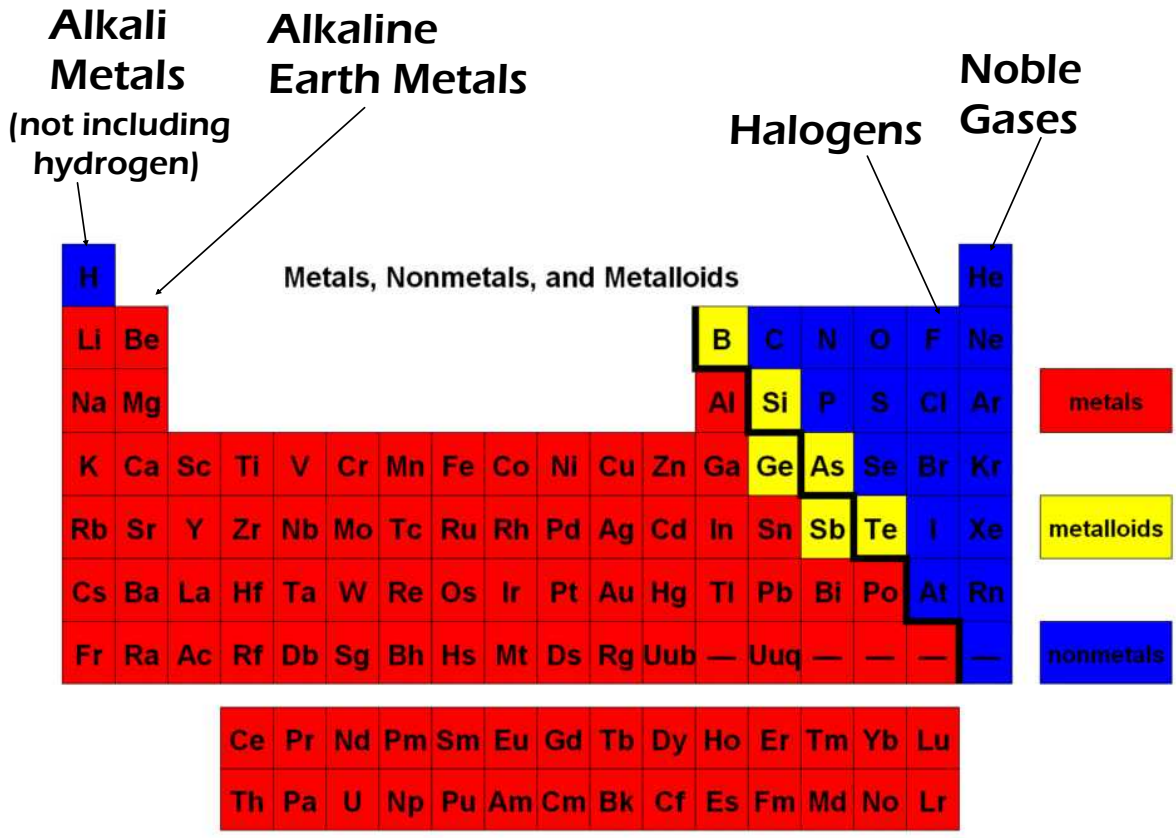
Families (VERTICAL COLUMNS)



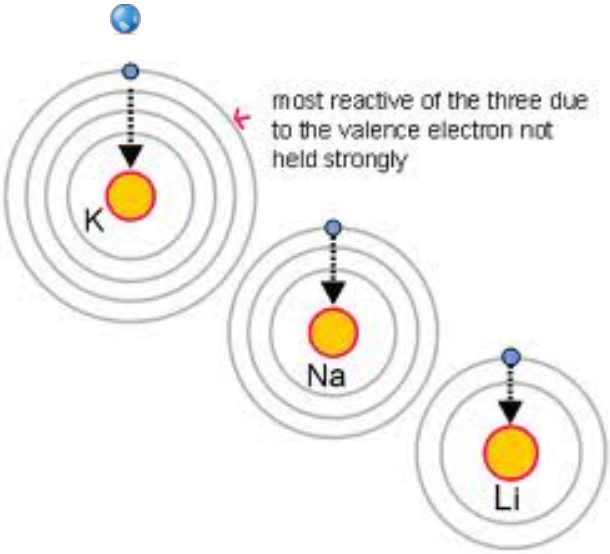
Elements in a family have similar physical and chemical properties due to electron configurations

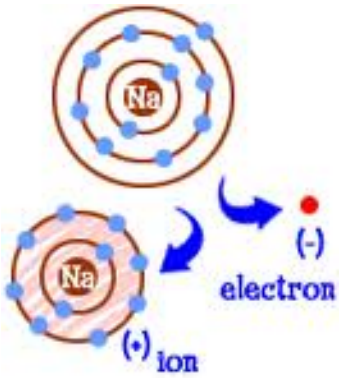
http://www.wwnorton.com/college/chemistry/gilbert2/tutorials/interface.asp?chapter=chapter_08&folder=periodic_table

Family Names



http://www.youtube.com/watch?v=DFQPnHkQlZM





Alkali metals (Group 1) all have one outer electron that they easily lose (making them very reactive) to get full shells and a +1 ion charge

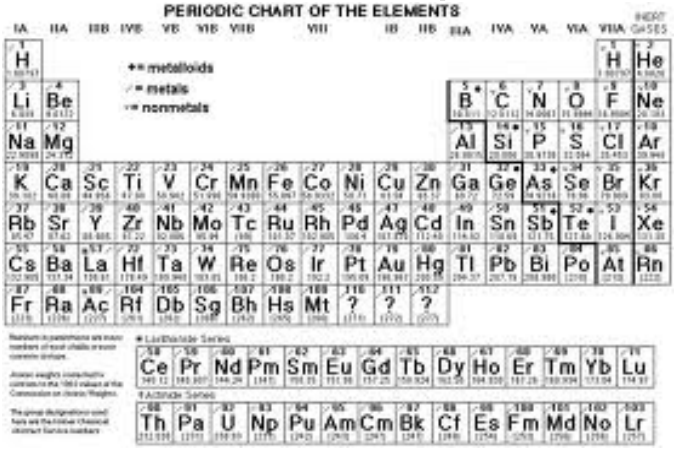
Element Symbols

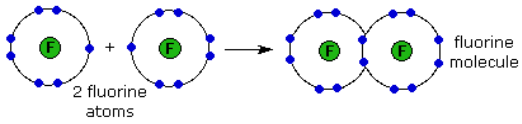
- Can be one or two letters Ex. N or Ne
- First letter is always uppercase
- Second letter is always lower case
- Symbol may be first letter of element name Ex. O
- Symbol may be first and second letter of name
  Ex. Fr
- Symbol may be first and third (or fourth or fifth etc.) letter of name Ex. Zn, Rn
- Symbol may be from letters of element's Latin or Greek name Ex. Pb K

http://en.wikipedia.org/wiki/Potassium

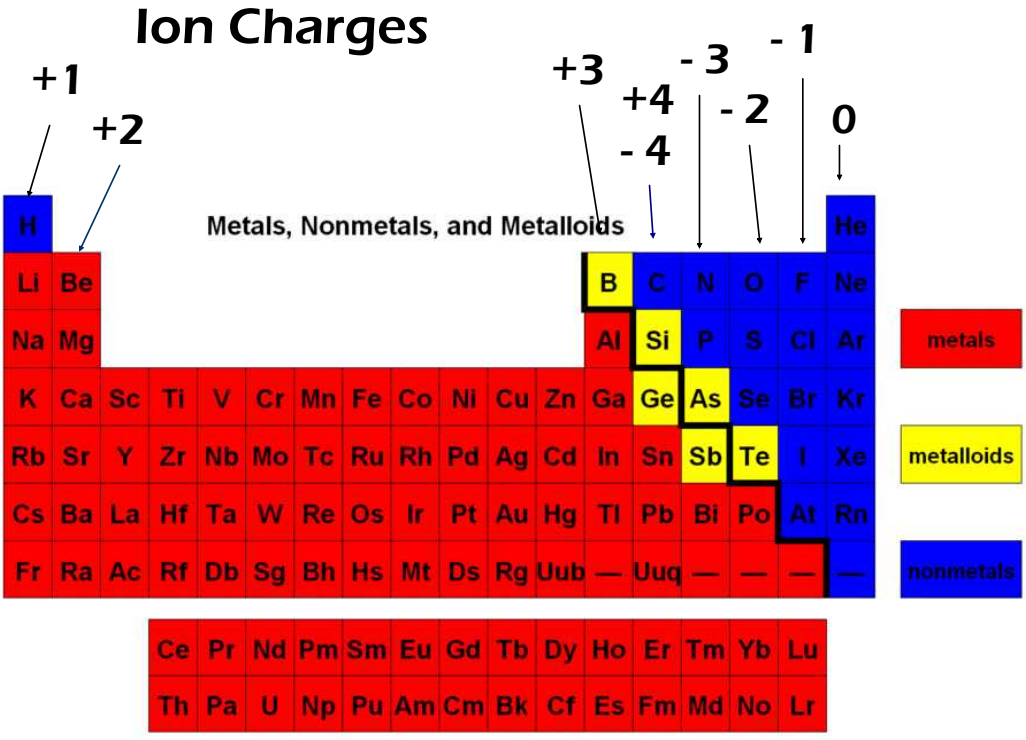
Diatomic Molecules

- Most elements naturally occur as groups of singular atoms, but seven elements occur as groups of diatomic molecules:
- H_2, N_2, O_2, F_2, Cl_2, Br_2, I_2
- All diatomic molecules except H_2 form a "seven" shape on the periodic table



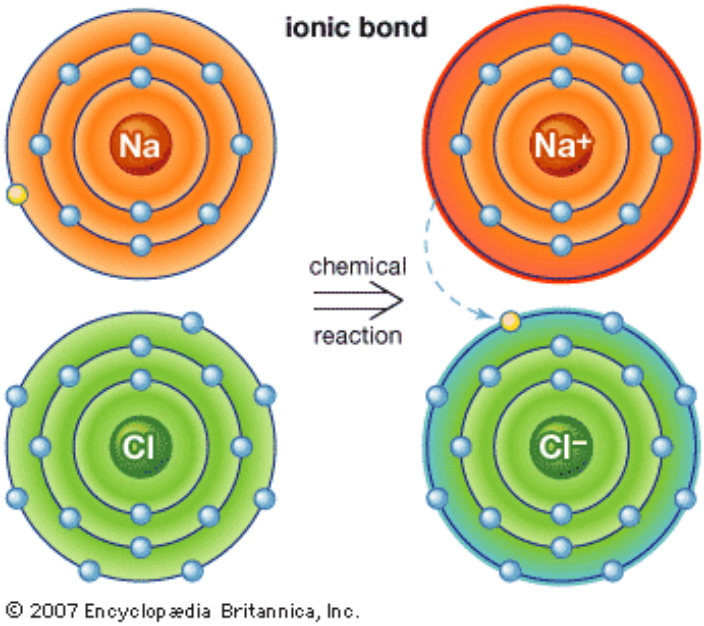


http://preparatorychemistry.com/element_properties_flash.htm


Ion Charges
+1
+2
+3
+4
- 4
- 3
- 2
- 1
0
Metals, Nonmetals, and Metalloids
H
He
Li Be
B C N O F Ne
Na Mg
Al Si P S Cl Ar
K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr
Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe
Cs Ba La Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po At Rn
Fr Ra Ac Rf Db Sg Bh Hs Mt Ds Rg Uub — Uuq — — — —
Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr
metals
metalloids
nonmetals

Ion Charges

- Metals react to make positive charge
  - they like to donate electrons to have full shells like the noble gases
- Nonmetals react to make negative charge
  - they like to gain electrons to attain full shells like the noble gases
- Transition metals can have more than one ion charge (but they are always positive)
- Ex. Fe can have charges of +2 or +3



Na gives an electron to Cl so they both have full electron orbitals. This is a chemical reaction. Na + Cl --> Na^+ + Cl^-

HOMEWORK:

Introduction to Periodic Table Worksheet

2. Atoms, Ions, and Isotopes

Atoms

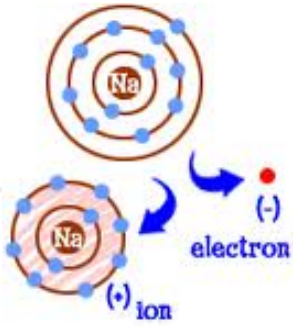
- An atom is composed of electrons orbiting around a central nucleus, which contains protons and neutrons.
- An atom has the same amount of electrons as it does protons

Sub-Atomic Particles
(smaller than atoms)

- Atoms are made up of three main type of particles:
- **Protons**
-
- Found in nucleus
- Positive charge (+1)
- Mass: 1 atomic mass unit (a.m.u.)
- What happens if an atom gains or loses a proton?
- it becomes an atom of a different element
- E.g. If N lost a proton, it would become C - this doesn`t happen naturally
- This process involves vast amounts of energy and doesn`t occur in a `normal`setting - it is NUCLEAR science (fusion, fission, nuclear reactors etc)

http://www.youtube.com/watch?v=fSr3V498A3I

Electrons



- Negative charge (-1)
- Very small mass compared to protons
  (Mass approx 1/1800 a.m.u.)
- exist outside the nucleus in orbitals
- If an atom gains or loses one or more electrons,
  it becomes an ion
- an ion has an imbalance of protons and electrons
- reactions involve the transfer of electrons from one particle to another as particles want to have full electron orbitals (like noble gases)

Neutrons

- Found in nucleus of atom
- Neutral (no charge)
- Made up of a proton fused with an electron
- Mass 1 a.m.u. (actually slightly greater)
- Each element has atoms with different amounts of neutrons – the different atoms are called isotopes

http://education.jlab.org/atomtour/fact1.html

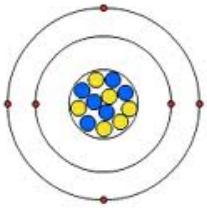
QUICK SUMMARY

- If an atom gains or loses protons, it becomes a different element altogether - VERY RARE
- If an atom gains or loses electrons, it becomes an ION - happens all the time (chemical reactions)
- If two atoms have the same amount of protons, but different amount of neutrons, they are the same element, but are ISOTOPES of one another

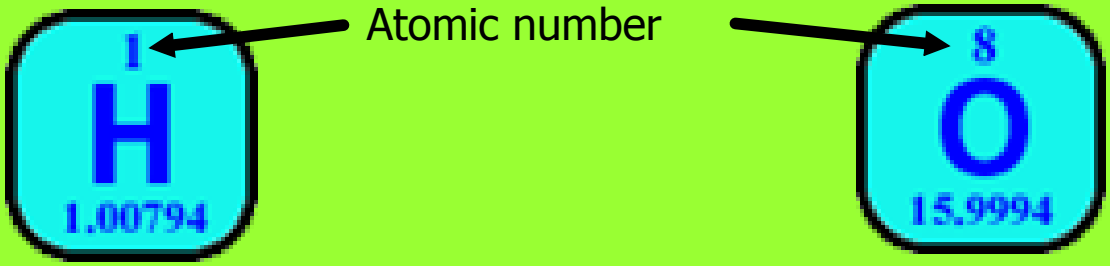
Atomic Number

- Number of protons in the atom
- Each atomic number is unique and defines each different element
- E.g. Oxygen has an atomic number of 8 because it has 8 protons whereas carbons has 6 protons thus an atomic number of 6 etc.
- Easily recognized on the periodic table for each element (see next slide)
- In chemical symbol notation, the atomic number is written on the bottom left

e.g. $_{6}C$



- The atomic number is found at the top of each square on the periodic table.



If you have a periodic table you can instantly find the number of protons as it always matches the atomic number.

Mass Number

- Total number of all protons and neutrons in a specific isotope of an element (always a whole number) [units are in a.m.u.]
- Note - electrons are too small to effect total mass (1/1800 of mass of proton)
- In chemical symbol notation, the mass number is written on the top left
- Ex. $^{35}_{17}Cl$

Mass Number

- To find mass number from a periodic table, look under the symbol (or name)
- It will be explained later why decimal values are given on the periodic table

Number of Electrons

- In any atom the number of protons is always equal to the number of electrons.
- Therefore, for an atom:
- Number of electrons = atomic number.
- If there are 8 protons, there will be 8 electrons.
- For an ION, there are less electrons if the charge is +, and more electrons if -

Number of Neutrons

- Can be determined because…
- mass number = protons + neutrons,
- therefore:
- # Neutrons = mass number – # protons

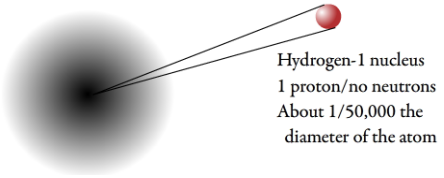
Calculating Protons, Neutrons and Electrons

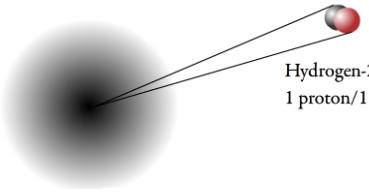
- Find number of protons, neutrons and electrons and write chemical symbol notation for each of the following atoms

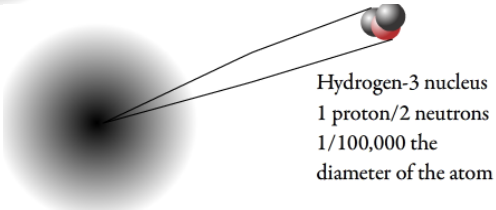
- Carbon-13 6p, 7n, 6e
-
- Sodium-23 11p, 12n, 11e
-
- Uranium-235 92p, 143n, 92e

- Isotopes are atoms of the same element that have different masses due to different amounts of neutrons

- Hydrogen has three isotopes
-
- Ordinary hydrogen
- (protium) $^{1}_{1}H$
-
- Heavy hydrogen
- (deuterium) $^{2}_{1}H$
-
- Radioactive hydrogen
- (tritium) $^{3}_{1}H$







http://www.media.pearson.com.au/schools/cw/au_sch_derry_ibcsl_1/int/isotopes/0203.html

http://www.dlt.ncssm.edu/core/c3.htm
tennis ball video

Atomic Mass

- The atomic mass reported on the periodic table is actually a weighted average of the masses of all the isotopes of an element.
- Most hydrogen is Hydrogen – 1, therefore the average mass is very close to 1 (1.0079).

http://en.wikipedia.org/wiki/Isotopes_of_hydrogen

- For most atoms, one isotope is much more common than the other(s).

http://www.sisweb.com/referenc/source/exactmas.htm

Ions

- Atoms which have either gained or lost electrons by a chemical reaction
- Positive ions (lost electrons) are called CATIONS
- Negative ions (gained electrons) are called ANIONS

Ions

- In chemical symbol notation, the ionic charge is written in the top right if there is a charge

e.g. $^{32}_{16}S^{2-}$

How many protons, electrons, and neutrons?

16p, 16n, 18e

- Write chemical symbol notation for an element with 19 protons, 21 neutrons, and 18 electrons

$^{40}_{19}K^{+}$

- Write chemical symbol notation for an element with 15 protons, 17 neutrons, and 18 electrons

$^{32}_{15}P^{3-}$

- How many protons, electrons, and neutrons?

$^{206}_{82}Pb^{4+}$ 82p, 124n, 78e

Fun Facts

- Carbon has three isotopes…C-12 (most abundant), C-13 (used in medical imaging), and C-14 (radiocarbon dating or fossils)
- Tin (Sn) has the most isotopes at 10
- http://www.tracesciences.com/sn.htm
- Many isotopes are radioactive - unstable nucleus that eventually breaks apart giving off large amounts of energy - fission). The higher the atomic number, the greater the frequency of radioactive isotopes.
- Any isotope with an atomic number greater than 82 is radioactive

http://www.ndt-ed.org/EducationResources/HighSchool/Radiography/halflife2.htm

http://www.iem-inc.com/toolhalf.html

HOMEWORK:

Atomic Structure Worksheet

http://education.jlab.org/elementmath/index.html

3. Ion Formation - The Quest for Happiness

- Helium and the other noble gases are non-reactive because they have full outer electron orbitals.
- The goal for any atom is to interact with other particles in order to attain a full outer electron orbital, just like a noble gas!

- Alkali metals want to lose one electron to have a full shell.
- Halogens want to gain one electron to have a full shell

- The **combining capacity** *(potential ion charge)* of an element tells us the number of electrons the element needs to lose (positive cc) or gain (negative cc) in order to attain a full outer electron shell.

- The charged particles formed by gaining and losing electrons are called IONS

- The elements on the left side of the periodic table all react by losing electron(s) to make positive ion charges and are . . .
- . . . METALS!

- The elements on the right side of the periodic table all react to gain electron(s) to make negative ion charges and are . . .
- . . . NONMETALS!

- Sodium can be found in elemental form as a metal atom (Na) or as an ion due to the loss of an electron (Na^+)

- In ionic form, there is a +1 charge because sodium now has 11 protons but only 10 electrons
- Whether sodium is an atom (Na) or an ion (Na+), it is still called SODIUM and still has a COMBINING CAPACITY (potential ion charge) of +1
- However, Na and Na^+ have completely different physical and chemical properties

Sodium atom (Na)	Sodium ion (Na^+)
soft silver-white metal	ion dissolved in water or paired with an anion (table salt)
11 protons, 11 electrons, 1 valence electron - very reactive	11 protons, 10 electrons, 0 valence electrons - non-reactive

- Chlorine can be found in elemental form as a neutral diatomic molecule (Cl_2), or as an ion due to the gain of an electron (Cl^-)

Elemental Chlorine (Cl_2)	**Chloride Ion (Cl^-)**
green gas - very toxic	ion dissolved in water or paired with a cation (table salt)
each Cl has 17p, 17e	17 protons, 18 electrons

- Whether chlorine is a neutral molecule (Cl_2) or an ion (Cl^-), it still has a combining capacity of –1.

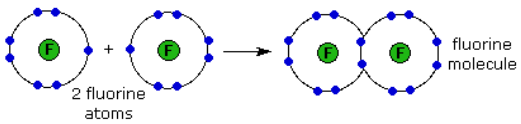
- However, neutral chlorine is called CHLORINE, while the ion (Cl^-) is called CHLORIDE

4. Ionic Formulas & Nomenclature

What are the two different types of compounds?

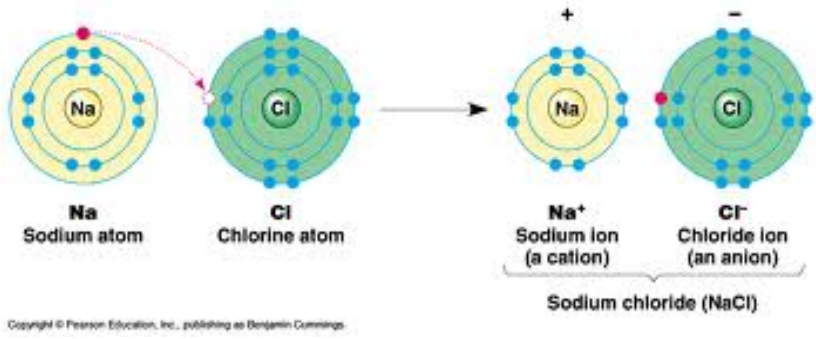
1. Ionic Compounds: compounds that involve a TRANSFER of electrons. Also called 'salts'

2. Covalent Compounds: compounds that involve SHARING of electrons



Formulas for Ionic Compounds

- What is an ionic compound?
- A compound made up of a metal cation and a non-metal anion



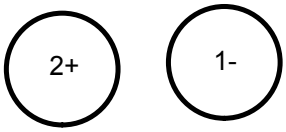
Writing a Formula

Problem: Write the formula for the ionic compound that will form between sodium and chlorine.

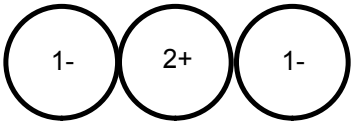
- **Write the symbol for sodium first (because it's the metal) along with its combining capacity.**
- **Then write the symbol for chlorine with its combining capacity.**
- **Na^{+} Cl^{-}**
- **How do you know which is the metal?**
- **It has a positive charge, and it's further left on the periodic table**

- **The goal is to balance the positive and negative charges to make a neutral compound**
- **Na^+ Cl^-**
- are the charges balanced?
-
- **So the formula is…**
- **NaCl**

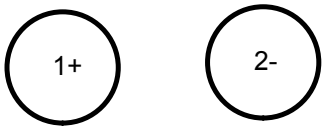
- **What is the ionic formula for a compound of barium and bromine?**
- **Ba^{+2} Br^{-}**
- **Br^{-}**



- **Thus, the formula is…**
- **$BaBr_2$**

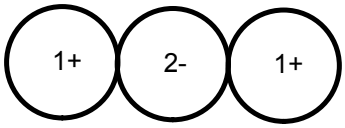


- **Write the formula for lithium with oxygen.**

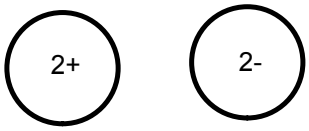


- Li^{+} O^{-2}
  Li^{+}

= **Li_2O**

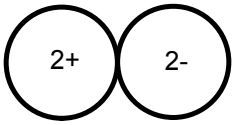


Write the formula for magnesium with oxygen.



- Mg^{+2} O^{-2}

= **MgO**



Learning Check

Write the correct formula for the compounds containing the following ions:

1. Na^{+}, S^{2-}

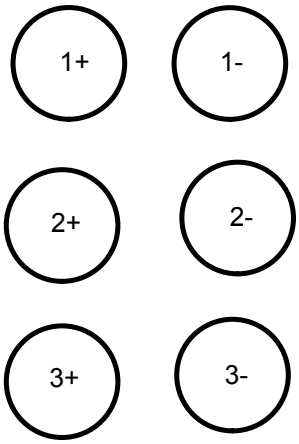
   A) NaS B) Na_2S C) NaS_2

2. Al^{3+}, Cl^{-}

   A) $AlCl_3$ B) AlCl C) Al_3Cl

3. Mg^{2+}, N^{3-}

   A) MgN B) Mg_2N_3 C) Mg_3N_2



Naming Binary Ionic Compounds

- **Contain 2 different elements**
- **Name the metal first with its regular name, then the nonmetal with an *–ide* ending.**

Examples:

- **NaCl** sodium chloride
- **ZnI_2** zinc iodide
- **Al_2O_3** aluminum oxide

Learning Check

Complete the names of the following binary compounds:

Na_3N	sodium	_nitride_____
KBr	potassium	_bromide_____
Al_2S_3	aluminum	_sulphide_____
MgF_2	magnesium fluoride	

Learning Check

1. The formula for the ionic compound of Na^+ and O^{2-} is

   A) NaO B) Na_2O C) NaO_2

   What is the name of the compound?

   sodium oxide

2. The formula of a compound of aluminum and bromine is

   A) Al_3Br B) $AlBr_2$ C) $AlBr_3$

   What is the name of the compound?

   aluminum bromide

- **Try writing formulas and names for the first 14 questions on your Ionic Formula Writing / Naming Worksheet**

Metals with more than one Ion Charge

- Some transition metals have more than one ion charge, e.g.
-
- Copper can be Cu^{+1} or Cu^{+2}
- Iron can be Fe^{+2} or Fe^{+3}
- Lead can be Pb^{+2} or Pb^{+4}
-
- There are others as well…see the periodic table

How do you name compounds containing these metals?

Use a ROMAN NUMERAL in brackets after the name of a metal that indicates the ion charge in that compound, therefore, deconstruct the compound to find the original combining capacity.

$FeCl_3$	(Fe^{3+})	iron (III) chloride
$CuCl$	(Cu^{+})	copper (I) chloride
SnF_4	(Sn^{4+})	tin (IV) fluoride
$PbCl_2$	(Pb^{2+})	lead (II) chloride
Fe_2S_3	(Fe^{3+})	iron (III) sulfide

Learning Check

Complete the names of the following binary compounds with variable metal ions:

$FeBr_2$	iron (II) bromide
Cu_2O	copper (I) oxide
SnO_2	tin (IV) oxide
$FeCl_3$	iron (III) chloride
HgS	mercury (II) sulphide

Learning Check

Name the following compounds:

1. **CaO** - hint: does Ca have only one charge, or multiple charge? Do you need a roman numeral??

   A) calcium oxide B) calcium(I) oxide

   C) calcium (II) oxide

2. **$SnCl_4$**

   A) tin tetrachloride B) tin(II) chloride

   C) tin(IV) chloride

3. **Fe_2O_3**

   A) iron oxide B) iron (III) oxide

   C) iron trioxide

- **Try finding formulas and names for the rest of the questions on the front of the Ionic Formula Writing / Naming Worksheet**

Polyatomic Ions

- **There are groups of atoms that tend to stay together and carry an overall charge**

- **These groups are called polyatomic ions**

- **There is a list of polyatomic ions in the back of your Hebden text (p. 341) and on the back of your periodic table**

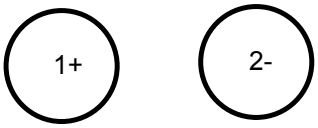
Table E
Selected Polyatomic Ions

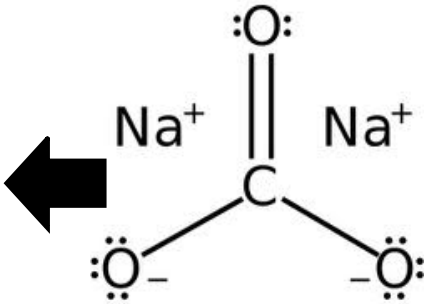
H_3O^+	hydronium	CrO_4^{2-}	chromate
Hg_2^{2+}	dimercury (I)	$Cr_2O_7^{2-}$	dichromate
NH_4^+	ammonium	MnO_4^-	permanganate
$C_2H_3O_2^-$ / CH_3COO^-	acetate	NO_2^-	nitrite
CN^-	cyanide	NO_3^-	nitrate
CO_3^{2-}	carbonate	O_2^{2-}	peroxide
HCO_3^-	hydrogen carbonate	OH^-	hydroxide
$C_2O_4^{2-}$	oxalate	PO_4^{3-}	phosphate
ClO^-	hypochlorite	SCN^-	thiocyanate
ClO_2^-	chlorite	SO_3^{2-}	sulfite
ClO_3^-	chlorate	SO_4^{2-}	sulfate
ClO_4^-	perchlorate	HSO_4^-	hydrogen sulfate
		$S_2O_3^{2-}$	thiosulfate

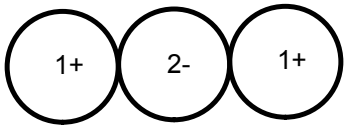
- **All common polyatomic ions except ammonium NH_4^+ have negative charges and act as nonmetal anions**
Notice that many have an *–ate* or *–ite* ending…this is characteristic of a polyatomic ion (although some end in *-ide*)

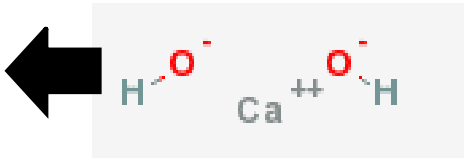
- **<u>ACTIVITY:</u> Complete the Polyatomic Ions Worksheet**

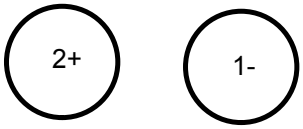
- **The charges on the polyatomic ions are also their combining capacity.**
- **Write the formula for the compound made with sodium and carbonate:**
- **Na^{+} CO_3^{-2}**
- **Na^{+}**
-
- **the formula is…**
- **Na_2CO_3**



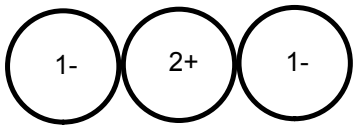




- **If you end up with two or more polyatomic ions in your formula, you need brackets!!**
- **Find the formula for the compound that has calcium and hydroxide**
- **Ca^{2+} OH^-**
- **OH^-**
-
- **The formula is…**
- 



$Ca(OH)_2$



Try strontium phosphate:

Sr^{2+} PO_4^{3-}

Sr^{2+} PO_4^{3-}

Sr^{2+}

$Sr_3(PO_4)_2$

- Complete the formula column on the back of your worksheet

Naming Compounds with Polyatomic Ions

- **Name like you would any other ionic compound but DON'T change the ending of the polyatomic ion**
- **$Ca(OH)_2$ Does Ca have more than one combining capacity? NO so no roman numerals**
- **calcium hydroxide**
-
- **$FeCO_3$ Does Fe have more than one cc?**
- **Deconstruct: CO_3^{2-} and 1:1 so Fe^{2+}**
- **iron (II) carbonate**

HOMEWORK:

- **Complete the remainder of the Ionic Formula Writing / Naming Worksheet**

- **There will be an Ionic Name & Formula QUIZ _____**

5. Hydrates & Acids

Hydrates

- Some ionic compounds have water molecules attached. These are called HYDRATES
- *Because the structure of hydrates are sometimes complex or even unknown, a dot is used in the formula of a hydrate to specify the composition without indicating how the water(s) is/are bound.*
- *Chem 12 – sometimes, the water can be bound solely to the metal ion – generally +2 or +3 ions.*
- Anhydrous: an ionic compound that does not have water molecules attached (may have had them removed)
- $CuSO_4 \bullet 5H_2O$ copper II sulfate pentahydrate

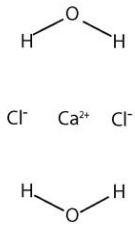
Naming Hydrates

- Name the ionic compound of a hydrate using the ionic naming rules we've already learned
- The hydrate part of the compound is named using a prefix naming system that can tell us the number of water molecules attached to the compound

Table 2.6 Numerical Prefixes for Hydrates and Binary Covalent Compounds

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

- Name the following:
- $LiOH \cdot H_2O$
- lithium hydroxide monohydrate
- $NiSO_4 \cdot 7H_2O$
- nickel (II) sulfate heptahydrate
- $CaCl_2 \cdot 2H_2O$
- calcium chloride dihydrate



Writing Formulas for Hydrates

- Write the ionic formula using the rules learned earlier in the chapter
- Use a “DOT” following the formula, then write the number of water molecules attached to the hydrate

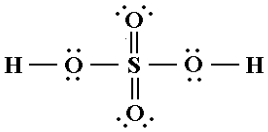
Finding the formula of a hydrate

- iron III oxide tetrahydrate
- $Fe_2O_3 \bullet 4H_2O$
- magnesium fluoride hexahydrate
- $MgF_2 \bullet 6H_2O$

Naming Acids

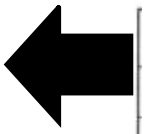
- all acids contain 1 or more hydrogen atoms
- Binary Acids: acids made up of hydroger and one other type of atom
- HCl - hydrochloric acid
- HBr - hydrobromic acid
- HF - hydrofluoric acid
- HI - hydroiodic acid

- Oxyacids: acids that contain an oxygen (as part of a Polyatomic Ion)
- Ending of ACID name depends on RADICAL
- If the polyatomic ion ends in **–ATE**, the acid name ends in **–IC**



- H_2SO_4 - sulfuric acid
- HNO_3 - nitric acid
- CH_3COOH - acetic acid
- $HClO_3$ - chloric acid

- If the polyatomic ion ends in **–ITE**, the acid name ends in **–OUS**
- H_2SO_3 - sulfurous acid
- HNO_2 - nitrous acid
- $HClO_2$ - chlorous acid



SEE PAGE 74 FOR ALL ACIDS YOU NEED TO KNOW (except H_2CO_3)
SOME ARE ALSO ON THE BACK OF YOUR PERIODIC TABLE

Formulas

- Phosphoric Acid
- H_3PO_4
-
- Nitrous Acid
- HNO_2
-
- Carbonic Acid
- H_2CO_3

HOMEWORK:

- Complete the Naming Hydrates & Acids Worksheet

6. Covalent Formulas & Nomenclature

- Compounds made up of a metal and nonmetal

are *ionic* compounds (transfer of electrons) – we have already learned how to write formulas and name these

- Compounds which contain only nonmetals

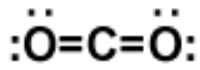
(such as water or CO_2) are called *covalent* compounds (sharing of electrons)

- Covalent compounds use a completely

different naming system than ionic compounds

Naming Covalent Compounds

- The prefix naming system is used for covalent compounds (remember the prefixes for hydrates?)
- CO_2



- carbon dioxide (one carbon, two oxygens)
- SO_3
- sulfur trioxide

Examples

- N_2O_4
- dinitrogen tetroxide
- CO
- carbon monoxide
- If there is only one of the first atom in the compound, you do not need to use ***mono***…but if there is only one of the second type of atom, you do need to use ***mono*** (see last example)

More Examples

- NO
- nitrogen monoxide
- PCl_5
- phosphorus pentachloride
- H_2O
- dihydrogen monoxide

Writing Formulas from Names

- Simply use the prefixes from the name to build the formula
- Carbon tetrachloride
- CCl_4
- Dinitrogen pentoxide
- N_2O_5
- Diarsenic trisulphide
- As_2S_3

- Don't allow the Ionic Naming World and the Covalent Naming World to COLLIDE!
- How are you going to know which system to use?
- Look at the first atom in the compound. If it's a metal (left of staircase), use the ionic naming system. If it's a nonmetal, use the covalent naming system!
- Exceptions – any ammonium compound (starts with NH_4) is IONIC!
- --ACIDS are also ionic (H^+ with an anion or polyatomic)

- Complete the Covalent Formula Writing / Naming Worksheet
- Quiz on Hydrates, Acids and Covalent Compounds
