Ch03

Compounds

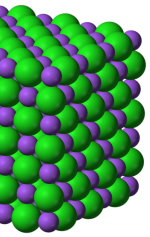
Building with atoms.

Ionic and molecular compounds.

version 1.5

Ch03

Compounds



- What are compounds?
  - *Compounds are not mixtures.*
  - Chemical Bonding
    - covalent vs ionic bonds
    - molecular vs ionic compounds
- Representing Compounds
  - Combining Symbols
  - Types of chemical formula
  - Nomenclature / Naming
- Elements and Ions
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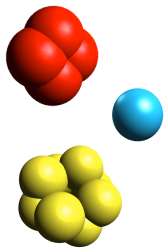
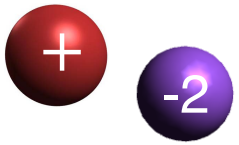
N_2

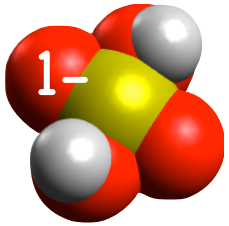
N^{3-}

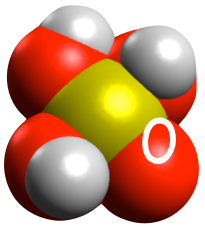
NaCl

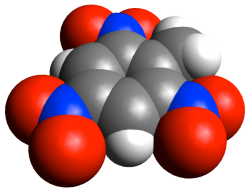




- Binary Compounds
  - Non-metal and metal
    - Non-metal and transition metal
  - Two non-metals
- Polyatomic Ions
  - Oxy-Ions
    - (oxygen + one other element)
  - Compounds of Oxy-Ions
- Acids
  - Binary Acids
  - Oxy-ions
    - Hydrogen Oxy-ions
    - Oxy-acids



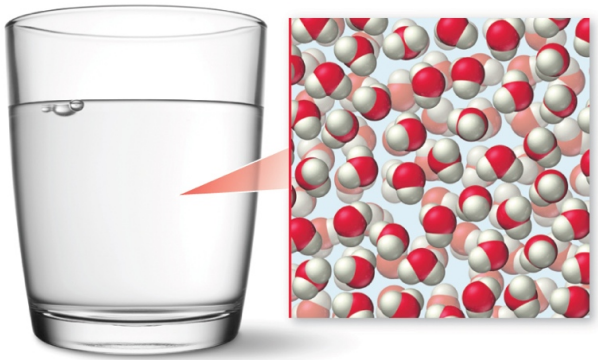


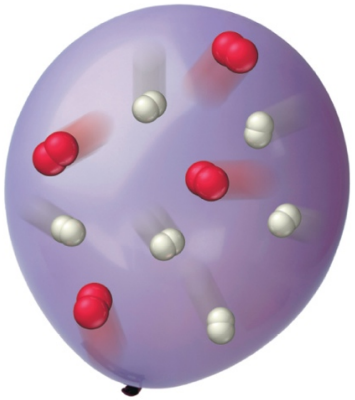


$C_6H_2(NO_2)_3CH_3$

Chemical Bonding

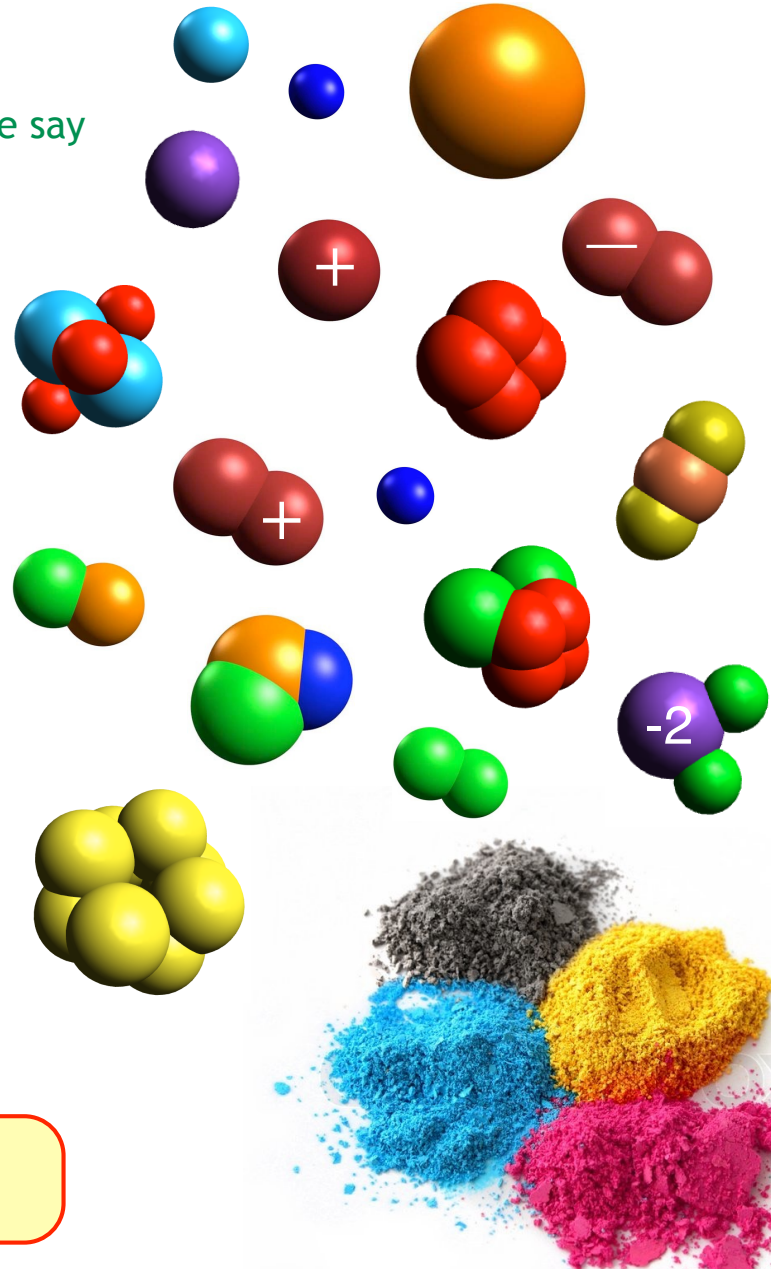
- Bringing elements together to form new compounds.
- Not a mixture, but bonding the elements at the atomic level.
- When you mix hydrogen and oxygen, you don't have a new substance — no new properties are observed.
  - Mixtures are useful, but it's not a reaction.
  - It's just stirring up the particles.
- When you react hydrogen and oxygen, you have a new substance — you see new properties.
  - Water is a compound
    - won't burn
    - liquid at room temperature
    - causes sodium to burn
- The compound forms because the atoms bond to each other.
- All chemical bonding uses electrons to glue atoms to each other
- There are different types of bonding.
    - metallic
    - ionic
    - covalent





An Overview of Atom Size Particles

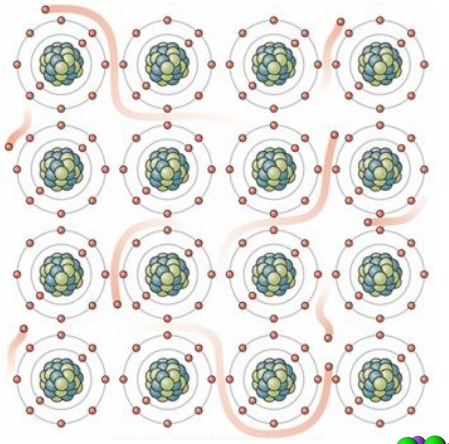
- Matter is made up of particles.
  - Particle is a generic term for small pieces of matter. We say particle when we want to be vague or comprehensive.
- Matter is made up of either ions or molecules.
  - Ions are charged particles (+ or -).
  - Molecules are neutral particles (no charge).
- Ions and molecules are made up of atoms.
  - Monatomic particles are just a single atom.
  - Diatomic particles are particles made of two atoms.
  - Polyatomic particles are made of more than two atoms.
- Atoms come in 118 flavors (elements).
  - If a sample of matter contains only one flavor atom, we say that sample is an element.
    - Yes, we use the word element two ways!
  - If a sample of matter contains two elements we say it is a binary compound or just a compound.
  - If a sample of matter contains more than two elements we say that sample of matter is a compound.

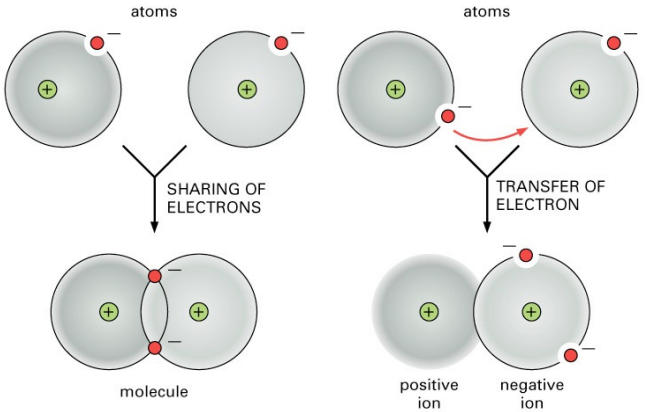


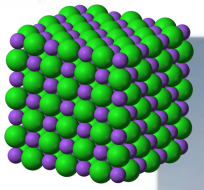
This slide will reappear a lot.
in upcoming lectures.

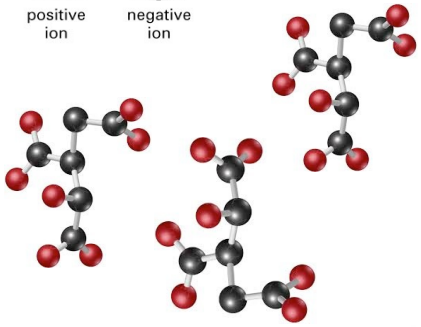
Combining (Bonding) Atoms

- Metallic Bonding (only metals)
  - In pure metals (Fe, Au, Co) or alloys (mixtures of metals) electrons break off and float between the atoms.
  - These free flowing electrons make metals extremely good conductors of electricity.
  - Metal atoms pull on the electrons flowing between them causing the mass to stick together.
  - Metallic bonding does not form compounds.
- Ionic Bonding (metal with non-metal)
  - When you mix metals and non-metals electrons break off from metals and are captured by non-metals.
  - This creates positively and negatively charged particles.
  - The particles attract each other, this is an ionic bond.
  - Ionic bonds are extremely strong.
  - These ions clump together in simple, large complexes.
  - Compounds made from ionic bonds are ionic compounds.
- Covalent Bonding (only non-metals)
  - Nonmetals pull on each others electrons.
  - If neither non-metal pulls hard enough to remove the electron from the other, the two end up sharing a pair of electrons.
  - The shared electrons are localized between two atoms, creating a bond between just those two atoms.
  - This produces discrete microscopic structures built of atoms.
  - Particles made of covalent bonds are molecules.
  - Compounds made from covalent bonds are molecular compounds.









Bonding in Compounds

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  - Nonmetals pull on each others electrons.
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  - Covalent bonding produces discrete microscopic structures built of atoms.
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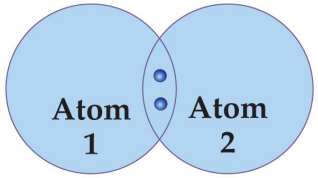
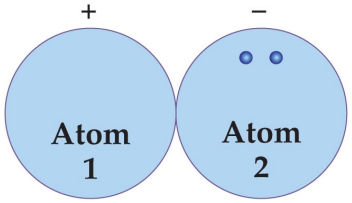


Covalent bond:
electrons shared equally



Ionic bond:
electron transferred

- Ionic Bonding (metal with non-metal)
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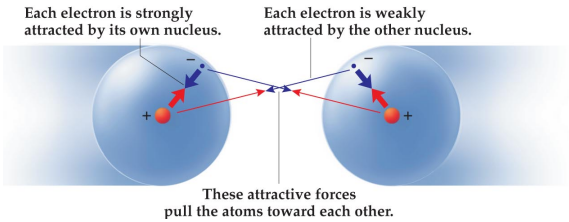

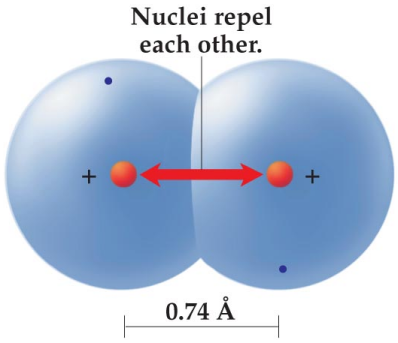

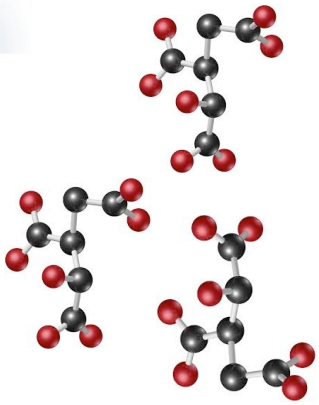

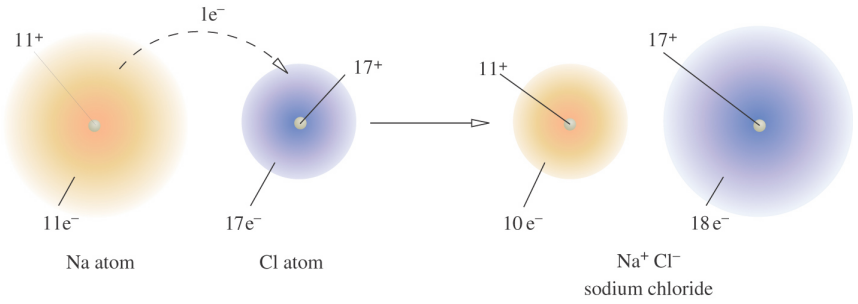

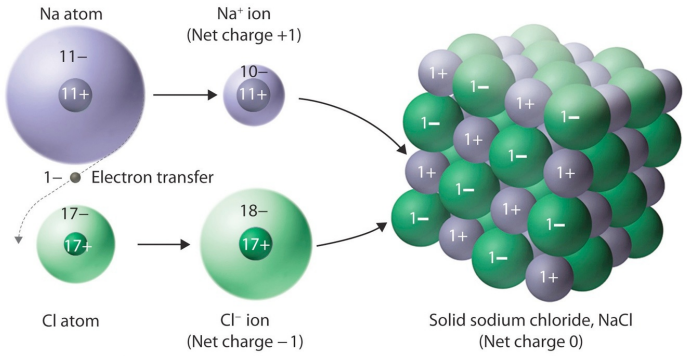

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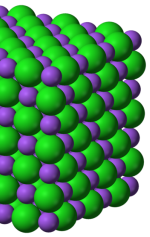
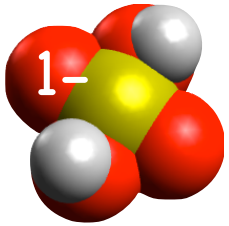
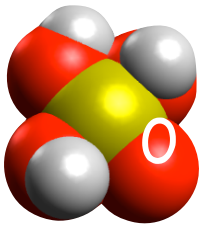


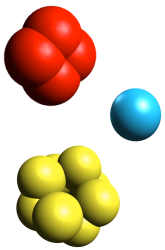


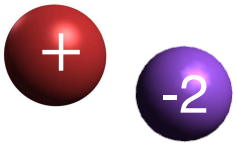


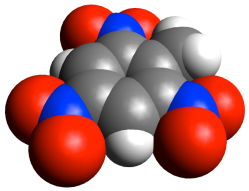
N_2

N^{3-}

NaCl







$C_6H_2(NO_2)_3CH_3$

Chemical Formulas

- We use symbols to represent elements and also to represent atoms of that element.
  - You must memorize the symbols of the first 18 elements! (this is easier than it sounds)
- The order of elements goes from the most metal-like element to the least. Na before C before H before F, etc (we'll talk more about this later)
- We use subscripts to indicate the number of atoms of that element.
  - Subscripts of 1 are omitted.
  - Omitted subscripts mean 1.
- We use superscripts to indicate the net charge (if any) on the entire particle.
  - Superscripts of 0 (charge 0) are omitted.
  - Omitted superscripts are assumed to mean 0 (no charge).

Au

$AlBr_3$

CH_4

Cl^-

Na^+

HF

Br_2

Al^{3+}

NO_2^-

Sn

$C_6H_8NO_4$

PO_4^{2-}

H_2O

SO_4^{2-}

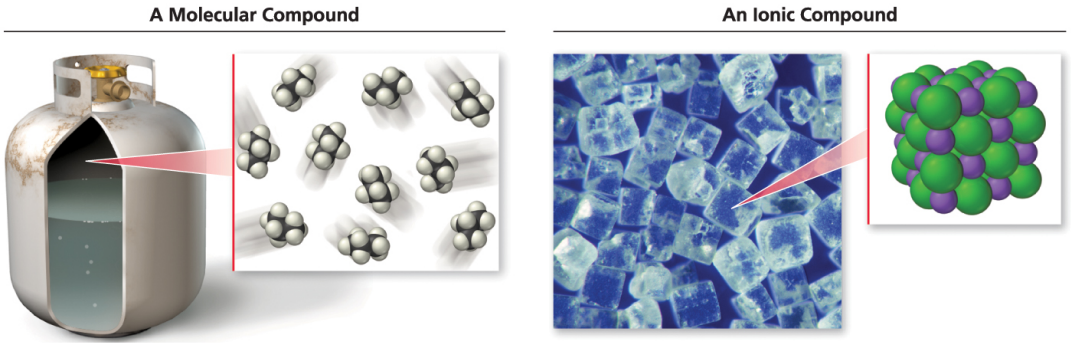
Charge

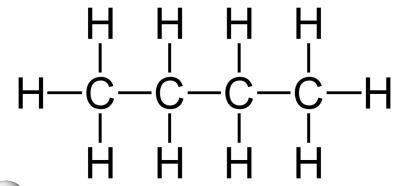
Atom Count

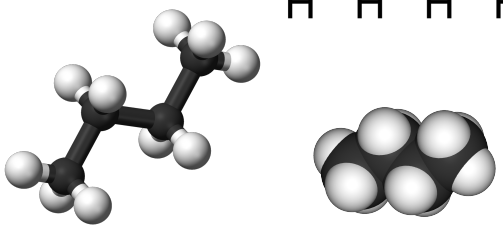
Water is a binary compound, it is a polyatomic molecule composed of 2 hydrogen atoms and 1 oxygen atom. It has a charge of zero.

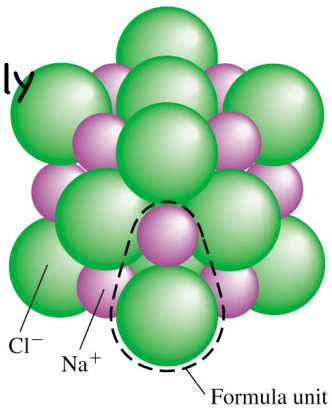
Sulfate is a binary ion, it is a polyatomic ion composed of 1 sulfur atom and 4 oxygen atoms. It has a charge of minus two.

Chemical Formula



	Butane	Salt
Empirical	C_2H_5	NaCl
Molecular	C_4H_{10}	does not apply
Structural		does not apply





- We use chemical formulas to describe both types of compound.
- There are three kinds of chemical formulas.
- Empirical formulas describe the ratio of elements in the compound.
  - Empirical formulas can describe either molecular or ionic compounds.
  - The smallest whole number ratio of elements is also called a formula unit.
- Molecular formulas describe the number of atoms in each molecule.
  - Molecular formulas can only be used to describe molecular compounds.
- Structural formulas graphically describe the connectivity between atoms.
  - Structural formals can only be used to describe molecular compounds.
  - We will talk more about these shortly.

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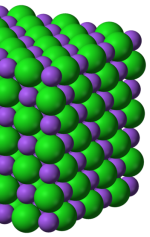
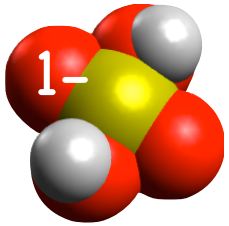
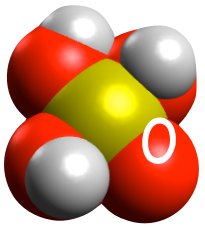
N_2

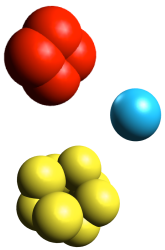
N^{3-}

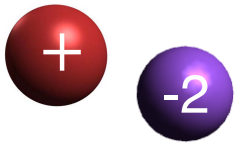
NaCl

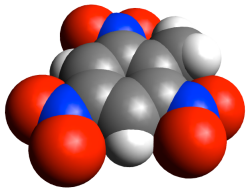












$C_6H_2(NO_2)_3CH_3$

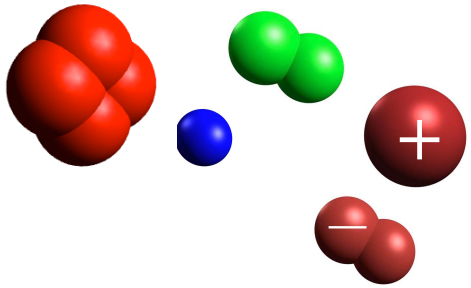
Nomenclature / Naming

OVERVIEW

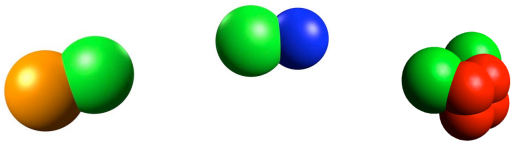
- Stuff made of 1 element:
  - Elements (atoms or molecules)
  - Ions (charged atoms—monatomic ions)
    - Ions with more than one possible charge:
      - Classical System (historical)
      - Stock System (you'll like this one better)

N_2

N^{3-}

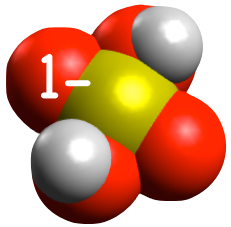


- Stuff made of 2 elements:
  - When it's a non-metal and a metal
  - When it's a non-metal and a metal w/ more than one possible charge
  - When both elements are non-metals



NaCl

- Some Stuff made of more than 2 elements:
  - Some Oxy-Ions (oxygen + one other element)
  - Some other Ions (some stuff that you'll run into a lot)
  - Use them just like monatomic ions



- Hydrogen is a wild card (Acids):
  - Binary compounds with Hydrogen & Binary Acids
  - Some Oxy-ions with Hydrogen
  - Some Oxy-Ion Acids

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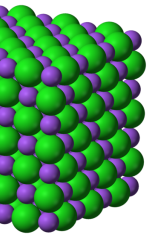
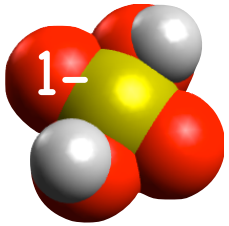
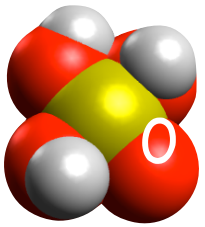
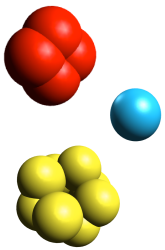
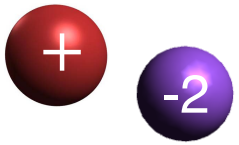
NaCl

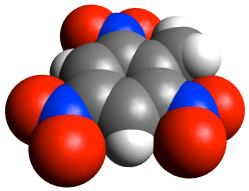










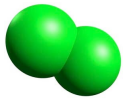


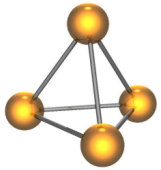
$C_6H_2(NO_2)_3CH_3$

Naming Elements

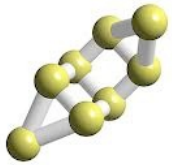
The name for any substance that contains atoms of only one element, is just the name of that element. The formula is also easy:

- Most elements are monatomic.
- Seven elements are diatomic.
- Two elements are polyatomic.

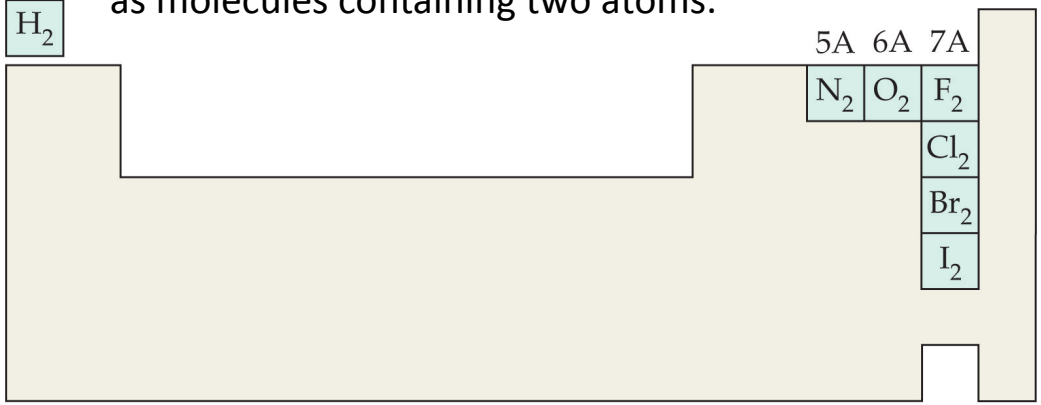




Sulfur, S_8 and Phosphorous, P_4



These seven elements occur naturally as molecules containing two atoms.



Everything else is monatomic and the formula is just the symbol of the element: Au, C, Na, Ne, etc

Don’t Confuse Elements vs Ions

Elements	Atoms	Ions	Compounds
Cl_2	Cl	Cl^{1-}	$FeCl_2$
Fe	Fe	Fe^{2+}	

Substances are elements and compounds.

Substances are large groups of molecules and ions.

Molecules are built from atoms and ions.

Naming Monatomic Ions

Most Monatomic Ions are easy to name.

- Positively charged atoms are cations. (CA+ION)
- Negatively charged atoms are anions.

- Cations—just add "ion" to the element name:

  Na^+ is sodium ion

  Mg^{2+} is magnesium ion

- Anions—just add "-ide ion" to the stem of the element:

  (The stem is usually the first syllable of the element name)

  Cl^- is chloride ion

  N^{3-} is nitride ion

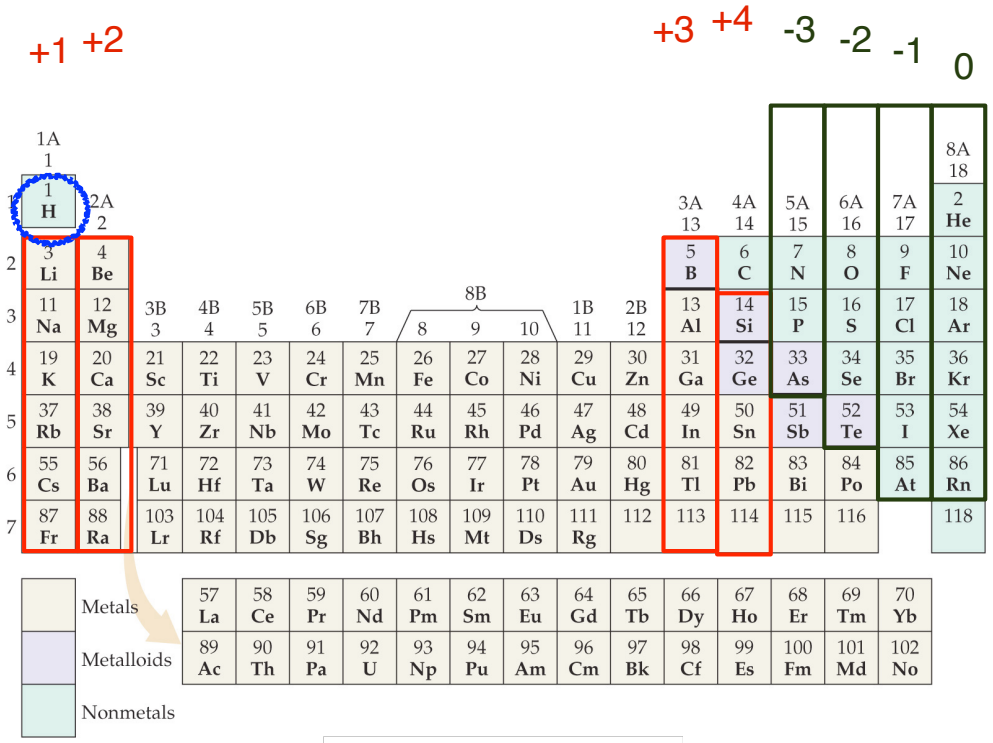
  C^{4-} is carbide ion

S^{2-} Ca^+ K^+ F^- Li^+ P^{3-} Br^- Al^{3+} O^{2-} H^- H^+ Fe^{2+} Fe^{3+}

Use the Periodic Table to predict ion charges

- Cations can be predicted reliably with only the transition metals causing exceptions.
- Hydrogen can be either +1 or -1
  — it's a wild card.
- Carbon can be either +4 or -4
  (there's much more to the story of carbon)
- Non-metals can only be predicted reliably <u>when teamed up with a metal</u>.

  DO NOT RELY ON THIS TRICK IF THE COMPOUND HAS MORE THAN ONE NON-METAL!



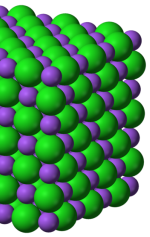
Cr Fe Co +2/+3

Cu Hg +1/+2

Sn Pb Mn +2/+4

Ch03

Compounds

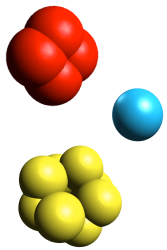


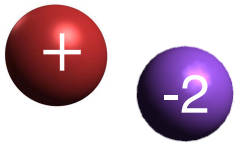
- What are compounds?
  - *Compounds are not mixtures.*
  - Chemical Bonding
    - covalent vs ionic bonds
    - molecular vs ionic compounds
- Representing Compounds
  - Combining Symbols
  - Types of chemical formula
  - Nomenclature / Naming

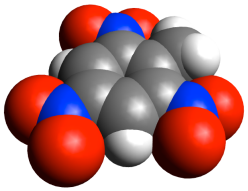
N_2 N^{3-} NaCl

- Elements and Ions
  - Elements (atoms or molecules)
  - Ions (charged atoms)

    - Ions can have more than one possible charge:
      - Classical System (historical)
      - Stock System (you'll like this one better)

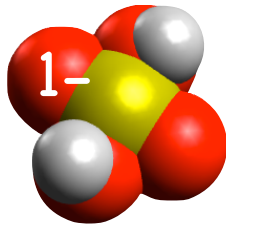


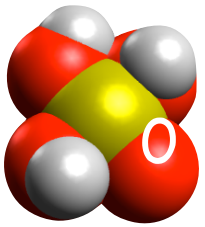




$C_6H_2(NO_2)_3CH_3$

- Binary Compounds
  - Non-metal and metal
    - Non-metal and transition metal
  - Two non-metals
- Polyatomic Ions
  - Oxy-Ions
    - (oxygen + one other element)
  - Compounds of Oxy-Ions
- Acids
  - Binary Acids
  - Oxy-ions
    - Hydrogen Oxy-ions
    - Oxy-acids

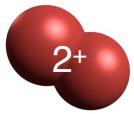




Some Metals have more than one cation.

- Chromium (Cr^{2+},Cr^{3+})
- Iron (Fe^{2+}, Fe^{3+})
- Cobalt (Co^{2+}, Co^{3+})
- Copper (Cu^{+}, Cu^{2+})
- Mercury (Hg_2^{2+}, Hg^{2+})
- Tin (Sn^{2+}, Sn^{4+})
- Lead (Pb^{2+}, Pb^{4+})
- Manganese (Mn^{2+}, Mn^{4+})

(better table on next slide)



Hg_2^{2+}
mercury (I) ion

Hg^{2+}
mercury (II) ion

- For these you need to do something extra, to show which ion you're talking about.
- These are all cations. They are all transition metals.
- You are only responsible for these 8, but be aware there are others.
- There are two methods (you need to know both):
- **Classical System**
  - —name the ion "classic stem+**ous**" for smaller ion
    ex: ferr**ous** ion (Fe^{2+}), cupr**ous** ion (Cu^{+})
  - —name the ion "classic stem+**ic**" for the larger ion
    ex: ferr**ic** ion (Fe^{3+}), cupr**ic** ion (Cu^{2+})

  remember: think of a third wheel on a date:

  2 < 3 two's company "us"; three's a crowd "ick"
- **Stock System**
  - —name the ion "element name (charge) ion"
    ex: iron (II) ion (Fe^{2+}), copper (I) ion (Cu^{+})
    ex: iron (III) ion (Fe^{3+}), copper (II) ion (Cu^{2+})

Ref: The origin and adoption of the Stock system, George B. Kauffman and Christian Klixbüll Jørgensen J. Chem. Educ., 1985, 62 (3), p 243; DOI: 10.1021/ed062p243

Classic Stems for Ancient Metals

- For most elements the stem is simply the first syllable of the elements name.
- Example:
  - Chromium produces the Chrom**ous** and Chrom**ic** ions.
  - Manganese produces Mangan**ous** and Mangan**ic** ions.
  - Mercury produces the Mercur**ous** and Mercur**ic** ions.
  - Cobalt produces the Cobalt**ous** and Cobalt**ic** ions.

- For 11 metal elements the symbol and (in 4 cases) the stem is also based on the latin name (when using the classic system).
  - Copper produces the Cupr**ic** and Cupr**ous** ions.
  - Tin produces the Stann**ic** and Stann**ous** ions.
  - Iron produces the Ferr**ic** and Ferr**ous** ions.
  - Lead produces the Plumb**ic** and Plumb**ous** ions.

- On the next slide you'll see the ions of the eight elements whose classical names you are responsible for.

Element	Symbol	Latin Name
Antimony	Sb	Stibium
Copper	Cu	Cuprum
Gold	Au	Aurum
Iron	Fe	Ferrum
Lead	Pb	Plumbum
Mercury	Hg	Hydragyrum
Potassium	K	Kalium
Silver	Ag	Argentum
Sodium	Na	Natrium
Tin	Sn	Stannum
Tungsten	W	Wolfram

Metals that form more than one cation.

	Element	Ion	Classical Name	Stock Name
Cr Fe Co +2/+3	Chromium	Cr^{2+}	Chromous ion	Chromium (II) ion
		Cr^{3+}	Chromic ion	Chromium (III) ion
	Iron	Fe^{2+}	Ferrous ion	Iron (II) Ion
		Fe^{3+}	Ferric ion	Iron (III) Ion
	Cobalt	Co^{2+}	Cobaltous ion	Cobalt (II) ion
		Co^{3+}	Cobaltic ion	Cobalt (III) ion
Cu Hg +1/+2	Copper	Cu^{+}	Cuprous ion	Copper (I) Ion
		Cu^{2+}	Cupric ion	Copper (II) Ion
	Mercury	Hg_2^{2+}	Mercurous ion	Mercury (I) Ion
		Hg^{2+}	Mercuric ion	Mercury (II) Ion
Sn Pb Mn +2/+4	Tin	Sn^{2+}	Stannous ion	Tin (II) ion
		Sn^{4+}	Stannic ion	Tin (IV) ion
	Lead	Pb^{2+}	Plumbous ion	Lead (II) ion
		Pb^{4+}	Plumbic ion	Lead (IV) ion
	Manganese	Mn^{2+}	Manganous ion	Manganese (II) Ion
		Mn^{4+}	Manganic ion	Manganese (IV) Ion

Name or provide the formula for...

- Sulfur
- S_8
- Bromine
- Br_2
- Bromide Ion
- Br^-
- Iron (II)
- Fe^{2+}
- Aluminum Ion
- Al^{3+}
- Cuprous Ion
- Cu^+
- Stannic Ion
- Sn^{4+}

Name or provide the formula for...

- Ca^{2+}
- F^-
- Fe^{3+}
- Sn^{4+}
- Mn^{2+}

- Calcium Ion
- Fluoride Ion
- Iron (III) Ion or Ferric Ion
- Stannic Ion or Tin (IV) Ion
- Manganous Ion or Manganese (II) Ion

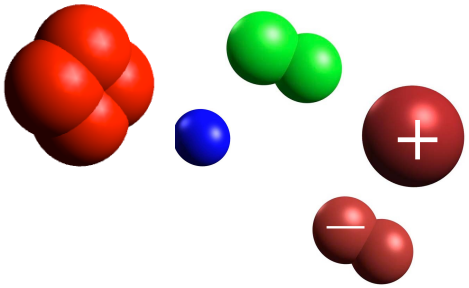
Nomenclature / Naming

OVERVIEW

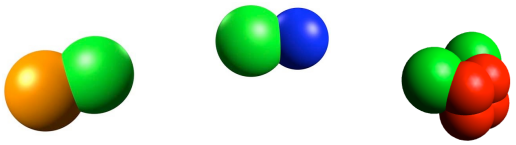
- Stuff made of 1 element:
  - Elements (atoms or molecules)
  - Ions (charged atoms—monatomic ions)
    - Ions with more than one possible charge:
      - Classical System (historical)
      - Stock System (you'll like this one better)

N_2

N^{3-}

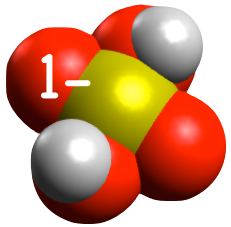


- Stuff made of 2 elements:
  - When it's a non-metal and a metal
  - When it's a non-metal and a metal w/ more than one possible charge
  - When both elements are non-metals



NaCl

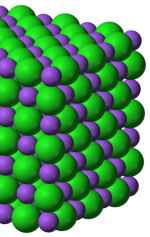
- Some Stuff made of more than 2 elements:
  - Some Oxy-Ions (oxygen + one other element)
  - Some other Ions (some stuff that you'll run into a lot)
  - Use them just like monatomic ions



- Hydrogen is a wild card (Acids):
  - Binary compounds with Hydrogen & Binary Acids
  - Some Oxy-ions with Hydrogen
  - Some Oxy-Ion Acids

Ch03

Compounds



- What are compounds?
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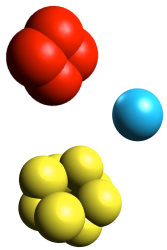
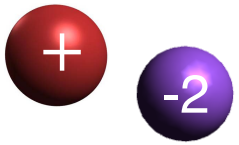
N_2

N^{3-}

NaCl





- Binary Compounds
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    - Non-metal and transition metal
  - Two non-metals
- Polyatomic Ions
  - Oxy-Ions
    - (oxygen + one other element)
  - Compounds of Oxy-Ions
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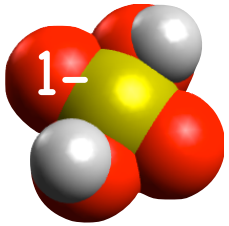
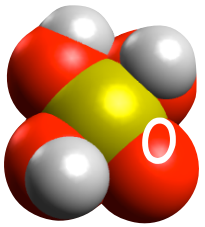
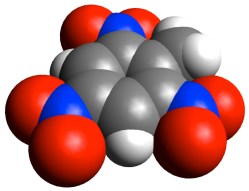


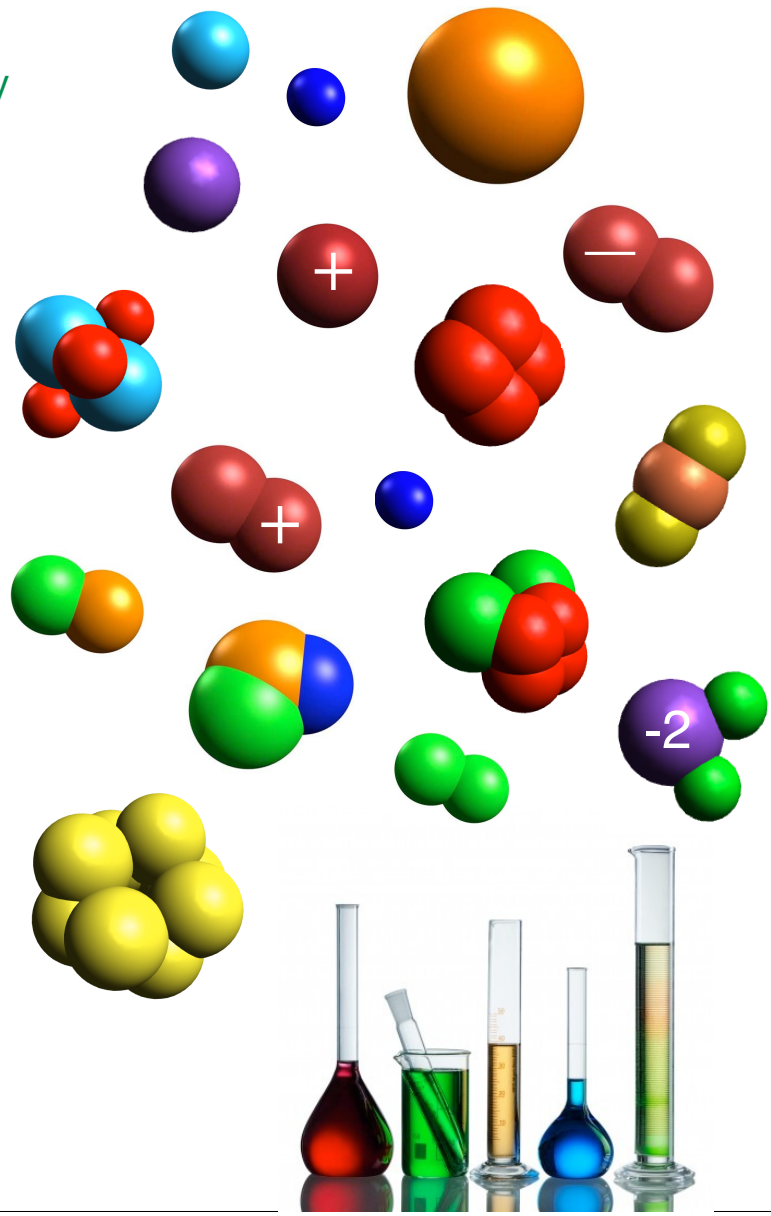




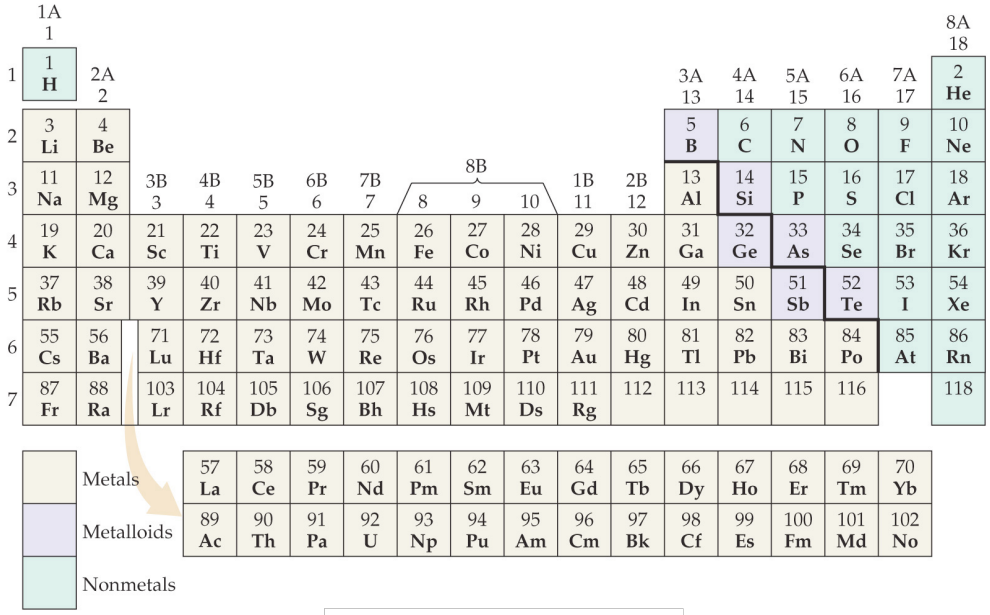
$C_6H_2(NO_2)_3CH_3$

An Overview of Atomic Particles

- Matter is made up of particles.
  - Particle is a generic term for small pieces of matter. We say particle when we want to be vague or comprehensive.
- Matter is made up of either ions or molecules.
  - Ions are charged particles (+ or -).
  - Molecules are neutral particles (no charge).
- Ions and molecules are made up of atoms.
  - Monatomic particles are just a single atom.
  - Diatomic particles are particles made of two atoms.
  - Polyatomic particles are made of more than two atoms.
- Atoms come in 118 flavors (elements).
  - If a sample of matter contains only one flavor atom, we say that sample is an element.
    - Yes, we use the word element two ways!
  - If a sample of matter contains two elements we say it is a binary compound or just a compound.
  - If a sample of matter contains more than two elements we say that sample of matter is a compound.



Metals, Non-metals, and Metaloids

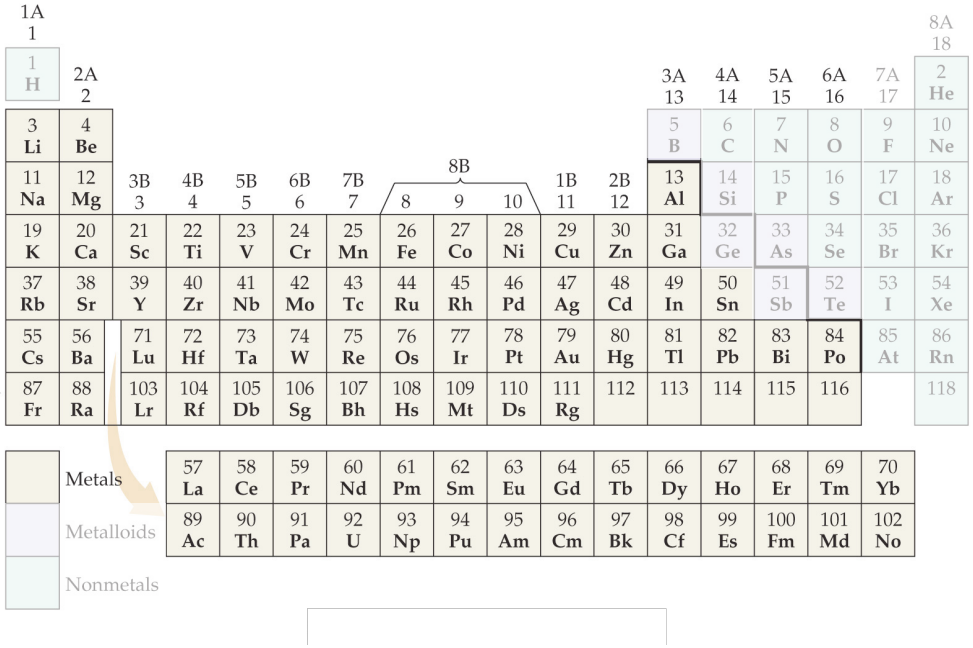


All elements are either metals, non-metals, or metaloids.

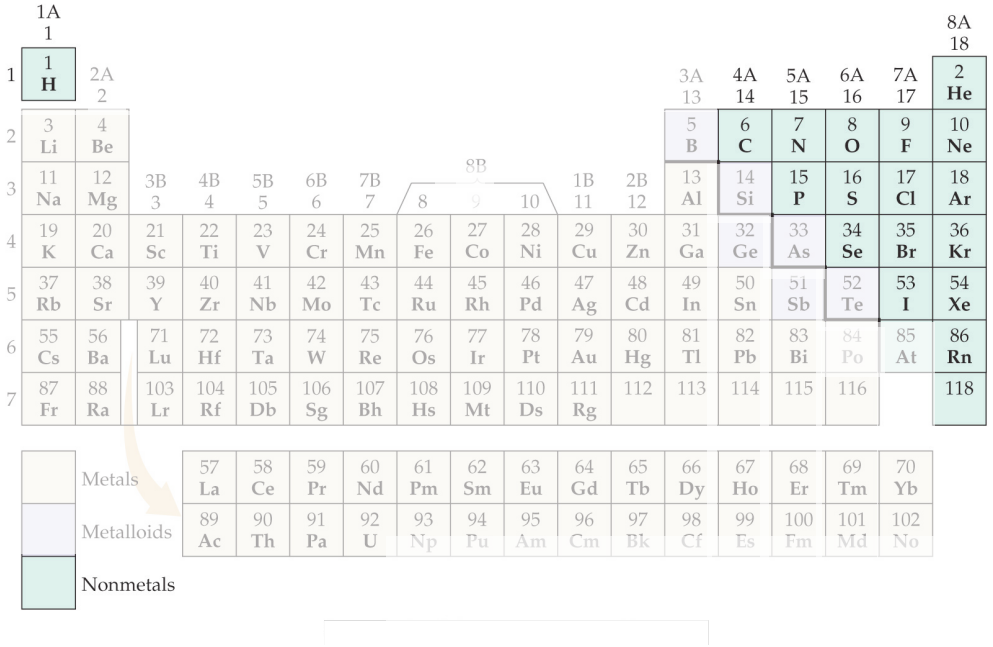
For naming we just worry whether something is a metal or not a metal.

Metals, Non-metals, and Metaloids

Metals are on the left side of the periodic table.

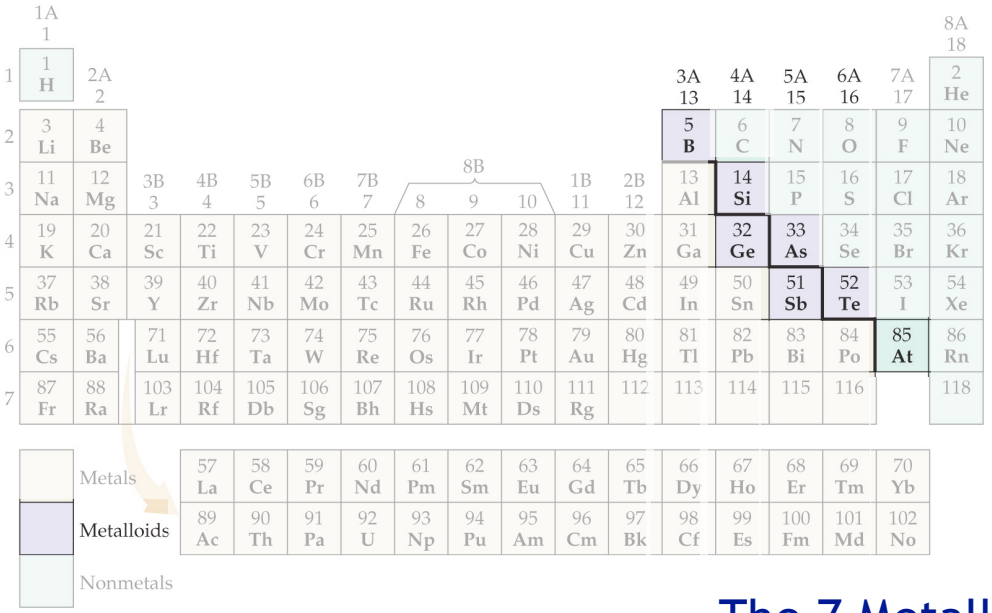


Metals, Non-metals, and Metaloids



Nonmetals are on the right side of the periodic table (with the exception of H).

Metals, Non-metals, and Metaloids



Metalloids are not metals. We don't distinguish between metalloids and non-metals in naming!

The 7 Metalloids:

B, Si, Ge, As, Sb, Te & At

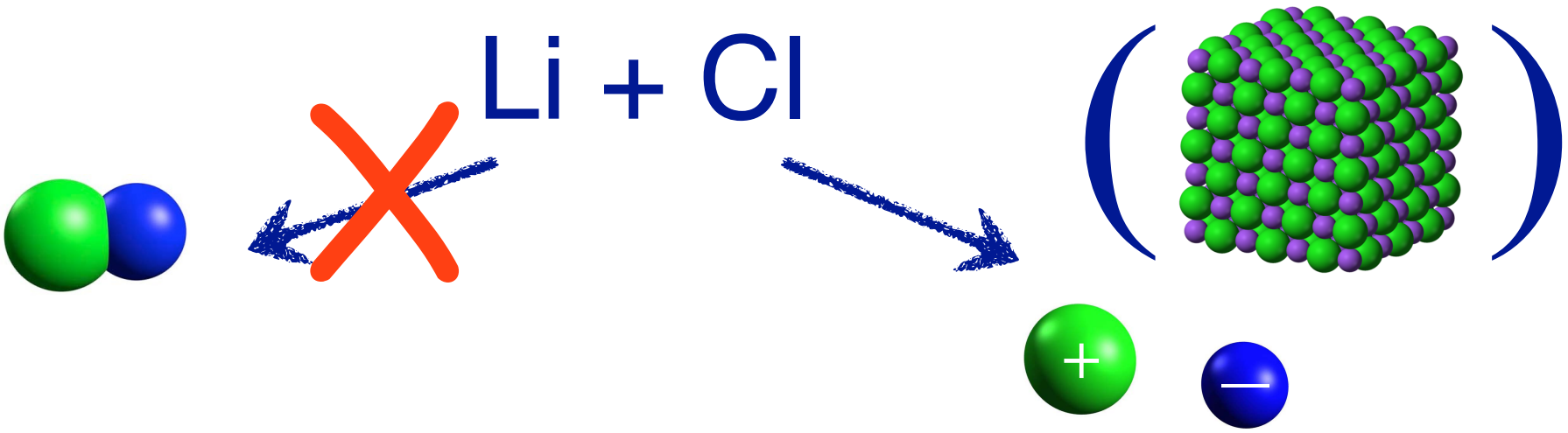
border the stair-step line

(Al is <u>not</u> a metalloid)

Metals, Nonmetals, and Metalloids

- Metals
  - With the exception of mercury, all metals are solids at room temperature.
  - Metals have high luster and are good conductors of electricity and heat.
  - Metals are malleable (can be rolled or hammered into sheets) and are ductile (can be drawn into wires).
  - Most metals have a high melting point and a high density.
  - Metals tend to form cations.
  - Often form ions with easily predictable charges (exception is transition metals).
- Nonmetals
  - Not lustrous.
  - Have low melting pts. and densities.
  - Poor conductors of heat and electricity.
  - Are brittle.
  - Have lower boiling point, melting point, and density.
  - Nonmetals tend to form anions.
- Metalloids
  - Have properties that are intermediate between those of metals and those of non-metals.
  - For naming we don't distinguish between metalloids and non-metals.

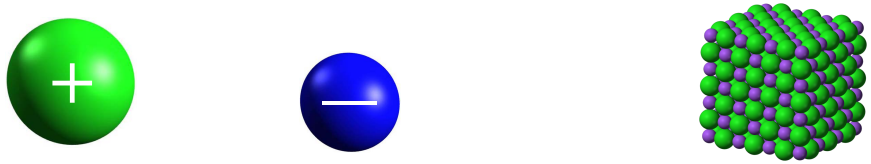
Metal + NonMetal Binary Compounds



- A binary compound of a metal and a non-metal forms ions — not a molecule.
- The ions collect into a huge ionic mass.
- We still write the formula as the ratio of the two ions in the compound
  (e.g. LiCl, $MgCl_2$, Li_3N, etc)
- We name binary compounds by just writing the names of the two ions:

Lithium ion + chloride ion = lithium chloride

The cation always goes first!



Name or provide the formula for…

- $NaBr$ — Sodium Bromide
- $MgCl_2$ — Magnesium Chloride
- K_2S — Potassium Sulfide
- AlF_3 — Aluminum Fluoride
- Be_3N_2 — Beryllium Nitride
- HCl — Hydrogen Chloride
- LiH — Lithium Hydride (hydrogen is a wild card)
- Cs_3P — Cesium Phosphide
- Na_4C — Sodium Carbide
- K_2O — Potassium Oxide

Metal + NonMetal Binary Compounds

- Some cations can have more than one charge.
- Iron, Cobalt, Mercury, Tin, Copper, etc.
- You can use known charge on the anion, to read the charge of the cation from a formula.
- If the cation has a variable charge, you must indicate that charge in it's name.
- When you have a choice, use the stock system.

$FeCl_3$

Ferrous Chloride ?

Ferric Chloride ?

	Total Charge
$FeCl_3$	0
Chloride Ion	-1
3x Chloride Ion	-3
Fe must be	+3

Ferrous Ion is +2 Ferric Ion is +3

$FeCl_3$ is Ferric Chloride
also called Iron (III) Chloride

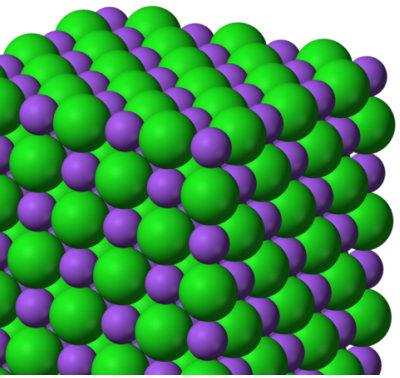
0

Name or provide the formula for…

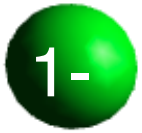
- $FeCl_3$ — Ferric Chloride or Iron (III) Chloride
- SnS — Stannous Sulfide or Tin (II) Sulfide
- CrN — Chromic Nitride or Chromium (III) Nitride
- $CuBr$ — Cuprous Bromide or Copper (I) Bromide
- Hg_2F_2 — Mercurous Fluoride or Mercury (I) Fluoride
- HgF_2 — Mercuric Fluoride or Mercury (II) Fluoride
- CoS — Cobaltous Sulfide or Cobalt (II) Sulfide
- $MgCl_2$ — Magnesium Chloride (Mg has only one charge!)
- SnS_2 — Stannic Sulfide or Tin (IV) Sulfide
- FeO — Ferrous Oxide or Iron (II) Oxide

Metal + NonMetal Binary Compounds

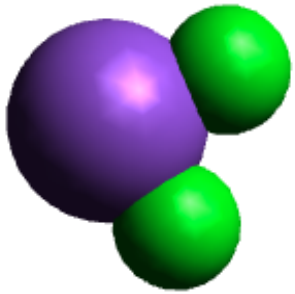
- To write the formula, you need to know the ratio of atoms. – It's not always one to one.
- Molecules always have a net charge of zero.
- Use the known charge of the atoms to figure out the smallest whole number ratio of atoms.



Mg^{2+} Cl^-



	Total Charge
Magnesium Chloride	0
$2+$	+2
$2\times 1-$	-2
$MgCl_2$	0



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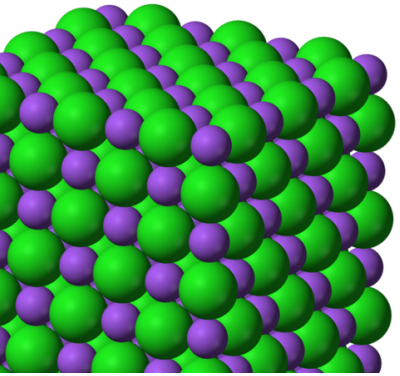
- Molecules always have a net charge of zero.
- Use the known charge of the atoms to figure out the smallest whole number ratio of atoms.

Ba^{2+} P^{3-}

Barium Phosphide

Total Charge

3x 2+	+6
2x 3-	-6
Ba_3P_2	0



Metal + NonMetal Binary Compounds

- To write the formula, you need to know the ratio of atoms. – It's not always one to one.
- Molecules always have a net charge of zero.
- Use the known charge of the atoms to figure out the smallest whole number ratio of atoms.

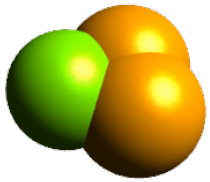
Sn^{4+} S^{2-}

Total Charge

Tin (IV) Sulfide 0

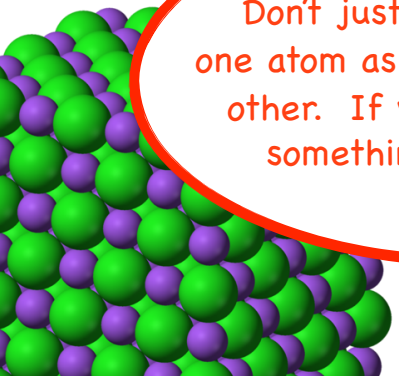
4+ +4

2x 2- -4



SnS_2 0

Don't just use the charge of one atom as the subscript for the other. If you do, you may get something silly like: Sn_2S_4

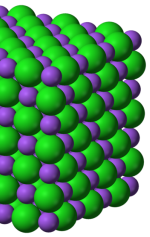


Name or provide the formula for...

- Beryllium Sulfide — BeS
- Calcium Chloride — $CaCl_2$
- Potassium Sulfide — K_2S
- Aluminum Fluoride — AlF_3
- Magnesium Nitride — Mg_3N_2
- Hydrogen Chloride — HCl
- Cesium Phosphide — Cs_3P
- Calcium Carbide — Ca_2C
- Aluminum Oxide — Al_2O_3
- Calcium Hydride — CaH_2

Ch03

Compounds



- What are compounds?
  - *Compounds are not mixtures.*
  - Chemical Bonding
    - covalent vs ionic bonds
    - molecular vs ionic compounds
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  - Combining Symbols
  - Types of chemical formula
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  - Elements (atoms or molecules)
  - Ions (charged atoms)
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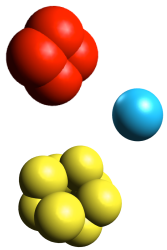
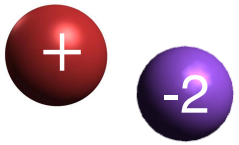
N_2

N^{3-}

NaCl





- Binary Compounds
  - Non-metal and metal
    - Non-metal and transition metal
  - Two non-metals
- Polyatomic Ions
  - Oxy-Ions
    - (oxygen + one other element)
  - Compounds of Oxy-Ions
- Acids
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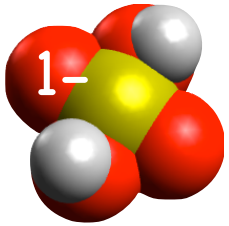
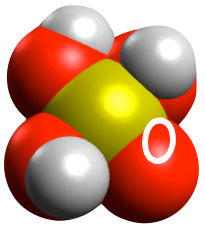
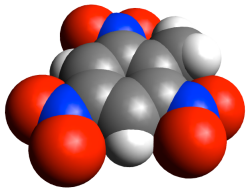
    - Hydrogen Oxy-ions
    - Oxy-acids

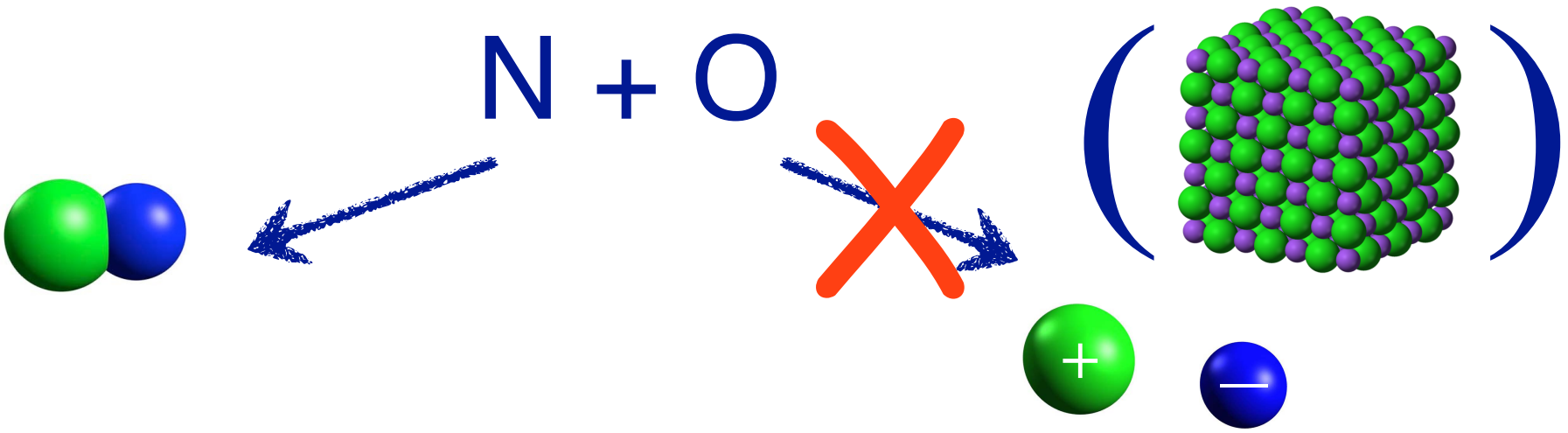






$C_6H_2(NO_2)_3CH_3$

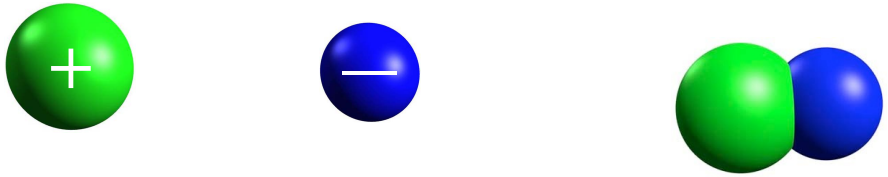
Two NonMetal Binary Compounds



- A binary compound of two non-metals form a molecule — not ions.
- To name it though, we treat the binary compound as if it were two ions.
- We choose the most anion-like thing and call it the anion. Oxide ion.
- We choose the most cation-like thing and call it the cation. Nitrogen ion.
- We name it by just writing the names of the two *imaginary* ions:

Nitrogen ion + oxide ion = nitrogen oxide

The cation always goes first!



Two NonMetal Binary Compounds

Which one is “anion”-like?

- F is the king.
- As you get farther away from F, on the PT you get less “anion”-like.

N or O

— oxygen forms the anion

Nitrogen Oxide

O or F

— fluorine forms the anion

Oxygen Fluoride

C or Br

— bromine forms the anion

Carbon Bromide

Si or Cl

— chlorine forms the anion

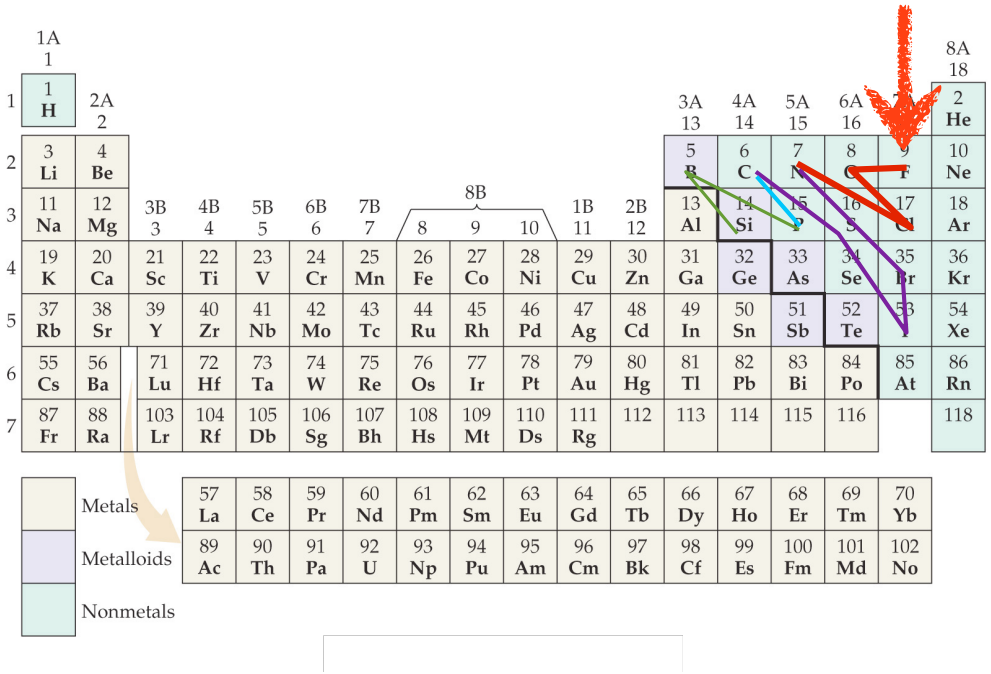
Silicon Chloride

P or S

— sulfur forms the anion

Phosphorus Sulfide

F is the king.



F
O
Cl
N
Br
I
S
C
P
B
Si

We’re not done...

the ions don’t really exist, so you can’t use charge to figure out how many atoms are in the formula!

Summary: Naming Binary Compounds

- Lithium + Chlorine forms LiCl
  - always (this is a metal and nonmetal)
- Iron + Chlorine forms $FeCl_2$ or $FeCl_3$
  - so we have to differentiate (multiple charge metal and nonmetal)
- Phosphorus + Chlorine forms PCl_2, PCl_3, PCl_5, P_2Cl_7...
  - so we *really* have to differentiate (this is two nonmetals)

Prefix to indicate number of atoms of each element

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

*mono is omitted for the cation, but is required for the anion
example: CO is carbon monoxide

Lithium Chloride

Iron (II) Chloride
or
Iron (III) Chloride

Phosphorus Dichloride
or
Phosphorus Trichloride
or
Phosphorus Pentachloride
or
Diphosphorus Heptachloride

Name or provide the formula for…

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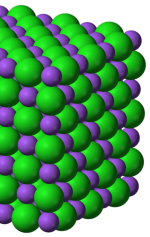
- NO — Nitrogen Monoxide
- OF — Oxygen Monofluoride
- NO_3 — Nitrogen Trioxide
- N_2O_5 — Dinitrogen Pentoxide
- B_3Cl_6 — Triboron Hexachloride
- P_4 — Phosphorus (what's the other polyatomic element?)
- P_4O_{10} — Tetraphosphorus Decoxide
- B_2P_3 — Diboron Triphosphide
- Cl_2O — Dichlorine monoxide
- Cl_2 — Chlorine (what are the 7 diatomic elements?)

Name or provide the formula for...

- Carbon Tetrachloride — CCl_4 (common solvent)
- Dioxygen Monofluoride — O_2F
- Nitrogen Dioxide — NO_2
- Diphosphorus Nonachloride — P_2Cl_9
- Hexabromine Dinitride — Br_6N_2
- Disufur Tetrabromide — S_2Br_4
- Silicon Dioxide — SiO_2 (sand)
- Dinitrogen Pentoxide — N_2O_5
- Nitrogen Trioxide — NO_3
- Nitrogen Oxide — NO (should be nitrogen monoxide!)

Ch03

Compounds



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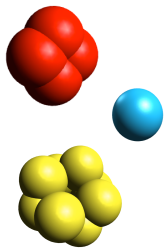
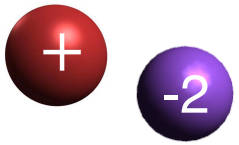
N_2

N^{3-}

$NaCl$





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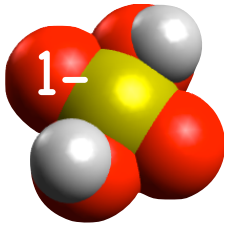
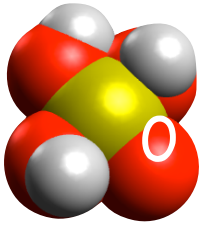
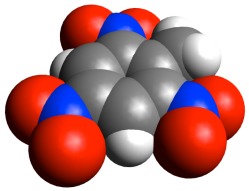


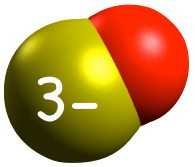


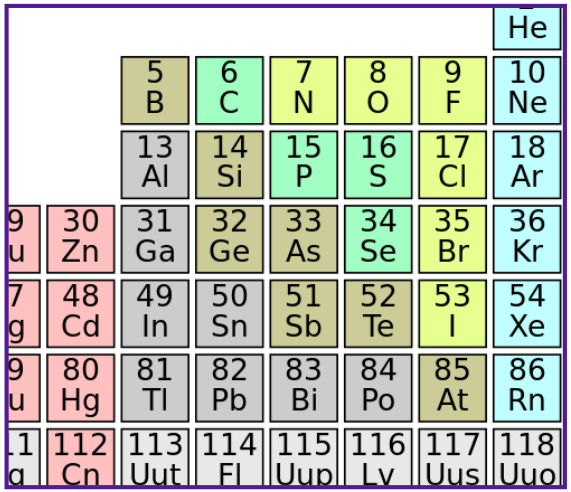


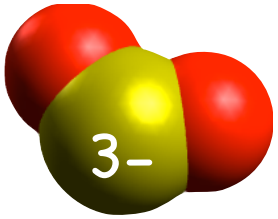
$C_6H_2(NO_2)_3CH_3$

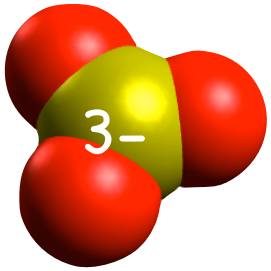
Oxy-ions are Polyatomic Ions

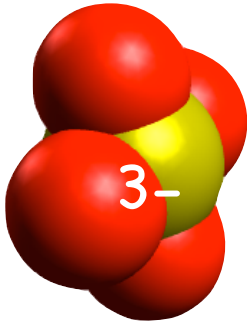
- Most of the polyatomic ions you will be responsible for are oxy-ions.
- Oxy-ions are elements with some number of oxygen atoms clustered around them with a charge on the whole package.
- Basically a dog pile on one atom, with oxygen pulling at it's electrons.
  - C, N, P, S, and the halogens Cl, Br, and I form oxy-ions.
    - Fluorine is the king, he's never on the bottom of the dog pile!
- Oxy-ions will vary by:
  - The element of the central atom.
  - The number of oxygen atoms.
  - The charge on the central atom.
- There are other polyatomic ions you will be responsible for, but most will be oxy-ions.



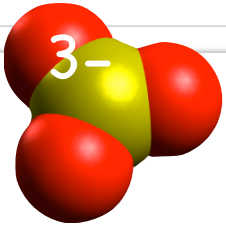


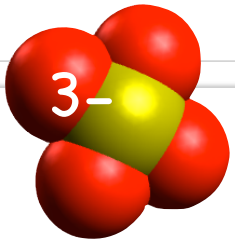






Naming Oxy-ions





	The Element at the center of the ion	Chg the element prefers	Chg of the ion			
3/4 ions	P	-3	-3	4 oxygens	PO_4^{3-}	Phosphate ion
				3 oxygens	PO_3^{3-}	Phosphite ion
	S	-2	-2	4 oxygens	SO_4^{2-}	Sulfate ion
				3 oxygens	SO_3^{2-}	Sulfite ion
2/3 ions	C	-4/+4	-2	3 oxygens	CO_3^{2-}	Carbonate ion
				2 oxygens	CO_2^{2-}	Carbonite ion
	N	-3	-1	3 oxygens	NO_3^{1-}	Nitrate ion
				2 oxygens	NO_2^{1-}	Nitrite ion
	Cl, Br, I	-1	-1	4 oxygens	BrO_4^{1-}	*Per*bromate ion
				3 oxygens	BrO_3^{1-}	Bromate ion
				2 oxygens	BrO_2^{1-}	Bromite ion
				1 oxygen	BrO_1^{1-}	*Hypo*bromite ion

Think of a party, and remember: I "ate more". The ate ion has more oxygens.

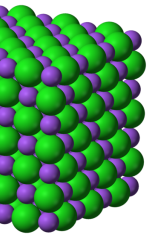
NH_4^{1+}	Ammonium ion
OH^{1-}	Hydroxide ion
OAc^{1-} ($CH_3CO_2^{1-}$)	Acetate Ion
CN^{1-}	Cyanide Ion

- All 20 oxy-ions have the same charge as their central atom normally prefers — except carbon and nitrogen
- P and S oxy-ions have 3 or 4 oxygens.
- C,N,Cl,Br, and I oxy-ions have 2 or 3 oxygens.
- The "ite" ion is always the one with less oxygens.
- The "ate" ion is always the one with more oxygens.
- The 3 halogens can super size: 4 oxygens = perchlorate ion
- The 3 halogens can also have a really small ion: 1 oxygen = hypochlorite ion
- There are four misc polyatomic ions you should also know:

  NH_4^{1+}, OH^{1-}, OAc^{1-}, and CN^{1-}.

Ch03

Compounds



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N^{3-}

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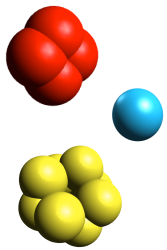

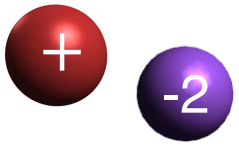

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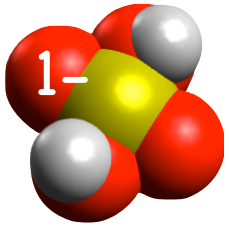
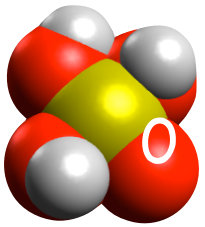
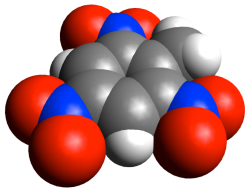






$C_6H_2(NO_2)_3CH_3$

Using Polyatomic Ions

- Lithium + Chlorine forms $LiCl$
  - always (this is a metal and nonmetal)

Lithium Chloride

- Iron + Chlorine forms $FeCl_2$ or $FeCl_3$
  - so we have to differentiate (multiple charge metal and nonmetal)

Iron (II) Chloride
or
Iron (III) Chloride

Use polyatomic ions like you used monoatomic ions:

- Lithium + Nitrate Ion (NO_3^{1-}) forms $LiNO_3$
  - polyatomic anions are just like monoatomic anions.

Lithium Nitrate

- Iron + Nitrate Ion (NO_3^{1-}) forms $Fe(NO_3)_2$ or $Fe(NO_3)_3$
  - if the metal can have more than one charge, specify the charge.
  - use parenthesis for multiple polyatomic ions in a compound.

Iron (II) Nitrate
or
Iron (III) Nitrate

- Ammonium Ion (NH_4^{1+}) + Chlorine forms NH_4Cl
  - polyatomic cations are just like monoatomic cations.

Ammonium Chloride

Name or provide the formula for…

- CO_3^{2-} — Carbonate Ion
- SO_3^{2-} — Sulfite Ion
- NO_3^- — Nitrate Ion
- $LiNO_3$ — Lithium Nitrate
- $MgCO_2$ — Magnesium Carbonite
- $Mg(NO_2)_2$ — Magnesium Nitrite
- $Ca(CN)_2$ — Calcium Cyanide
- $KBrO_3$ — Potassium Bromate
- $KBrO_4$ — Potassium *Per*bromate
- $(NH_4)_3PO_4$ — Ammonium Phosphate

P	-3	4	PO_4^{3-}
		3	PO_3^{3-}
S	-2	4	SO_4^{2-}
		3	SO_3^{2-}
C	-2	3	CO_3^{2-}
		2	CO_2^{2-}
N	-1	3	NO_3^{1-}
		2	NO_2^{1-}
Cl,Br, I	-1	4	ClO_4^{1-}
		3	ClO_3^{1-}
		2	ClO_2^{1-}
		1	ClO^{1-}

NH_4^+
OH^-
O_2^{2-}
CN^-

Name or provide the formula for...

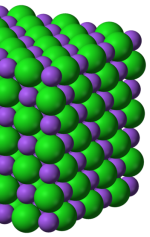
- Calcium Sulfate — $CaSO_4$
- Lithium Sulfite — Li_2SO_3
- Potassium Nitrate — KNO_3
- Magnesium Nitrite — $Mg(NO_2)_2$
- Iron (II) Carbonate — $FeCO_3$
- Iron (III) Carbonate — $Fe_2(CO_3)_3$
- Cupric Bromate — $Cu(BrO_3)_2$
- Calcium Hydroxide — $Ca(OH)_2$
- Tin (II) Phosphite — $Sn_3(PO_3)_2$
- Ammonium Carbonite — $(NH_4)_2CO_2$

P	-3	4	PO_4^{3-}
		3	PO_3^{3-}
S	-2	4	SO_4^{2-}
		3	SO_3^{2-}
C	-2	3	CO_3^{2-}
		2	CO_2^{2-}
N	-1	3	NO_3^{1-}
		2	NO_2^{1-}
Cl,Br, I	-1	4	ClO_4^{1-}
		3	ClO_3^{1-}
		2	ClO_2^{1-}
		1	ClO^{1-}

NH_4^+
OH^-
O_2^{2-}
CN^-

Ch03

Compounds



- What are compounds?
  - *Compounds are not mixtures.*
  - Chemical Bonding
    - covalent vs ionic bonds
    - molecular vs ionic compounds
- Representing Compounds
  - Combining Symbols
  - Types of chemical formula
  - Nomenclature / Naming
- Elements and Ions
  - Elements (atoms or molecules)
  - Ions (charged atoms)
    - Ions can have more than one possible charge:
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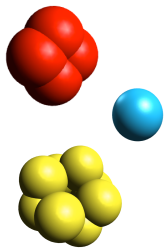
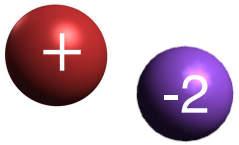
N_2

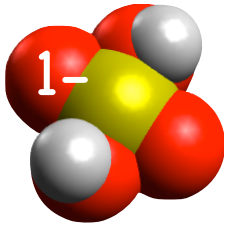
N^{3-}

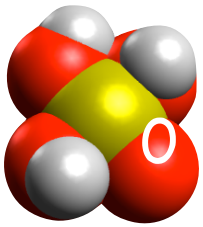
NaCl →

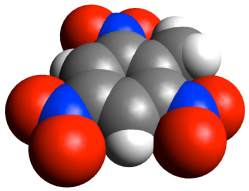




- Binary Compounds
  - Non-metal and metal
    - Non-metal and transition metal
  - Two non-metals
- Polyatomic Ions
  - Oxy-Ions
    - (oxygen + one other element)
  - Compounds of Oxy-Ions
- Acids
  - Binary Acids
  - Oxy-ions
    - Hydrogen Oxy-ions
    - Oxy-acids



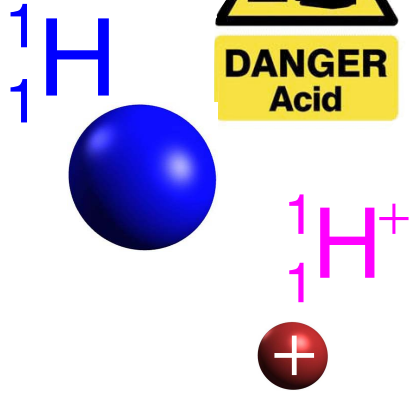




$C_6H_2(NO_2)_3CH_3$

Acids

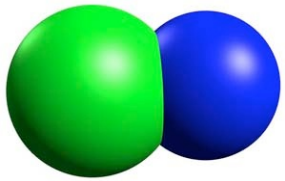
- Acids are compounds which release hydrogen ions (H^+)
  - Hydrogen ions are simply free protons.
  - They are the most concentrated source of a positive charge chemists know of – acids can be dangerous.
- Binary compounds where one of the two non-metals is hydrogen are not acids. But some become acids when they're dissolved in water.
  - Binary compounds only release protons into water.
- The binary compounds that become acids are: HF, HCl, HBr, and HI
- We indicate something is dissolved in water by putting "(aq)" after it's formula. Aqueous is Latin for "with water."
- To name a binary acid add "-ic acid" to the anion and prefix the name with "hydro".

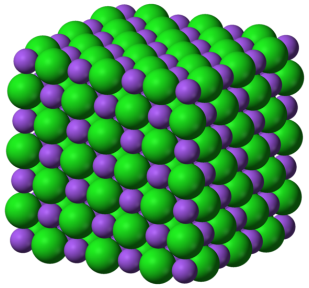


HBr is hydrogen bromide. It's not an acid.

HBr (aq) is hydrobromic acid.

HCl (aq) is hydrochloric acid, a very powerful acid.





What's the name or formula?	Answer:
Hydrogen Bromide	HBr
Hydrobromic Acid	HBr (aq)
Hydroiodic Acid	HI (aq)
HF	Hydrogen Fluoride
HCl (aq)	Hydrochloric Acid

Ch03

Compounds

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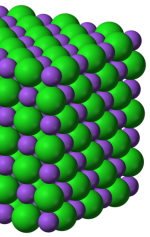
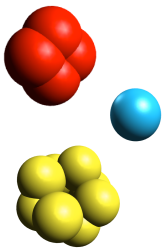
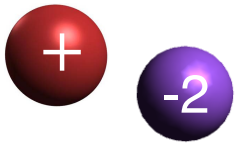
N^{3-}

NaCl







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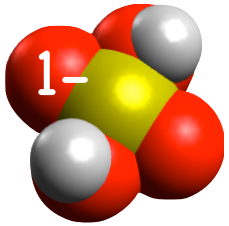
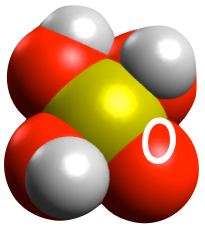
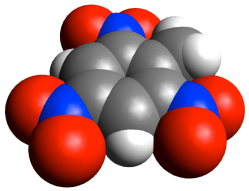






$C_6H_2(NO_2)_3CH_3$

Naming Oxy-ions

	The Element at the center of the ion	Chg the element prefers	Chg of the ion			
3/4 ions	P	-3	-3	4 oxygens	PO_4^{3-}	Phosphate ion
				3 oxygens	PO_3^{3-}	Phosphite ion
	S	-2	-2	4 oxygens	SO_4^{2-}	Sulfate ion
				3 oxygens	SO_3^{2-}	Sulfite ion
2/3 ions	C	-4/+4	-2	3 oxygens	CO_3^{2-}	Carbonate ion
				2 oxygens	CO_2^{2-}	Carbonite ion
	N	-3	-1	3 oxygens	NO_3^{1-}	Nitrate ion
				2 oxygens	NO_2^{1-}	Nitrite ion
	Cl, Br, I	-1	-1	4 oxygens	BrO_4^{1-}	*Per*bromate ion
				3 oxygens	BrO_3^{1-}	Bromate ion
				2 oxygens	BrO_2^{1-}	Bromite ion
				1 oxygen	BrO_1^{1-}	*Hypo*bromite ion

Think of a party, and remember: I "ate more". The ate ion has more oxygens.

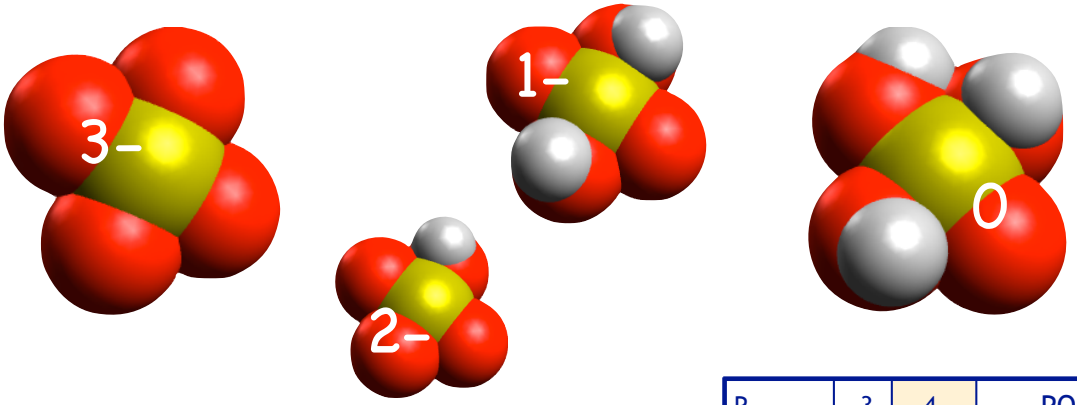
NH_4^{1+}	Ammonium ion
OH^{1-}	Hydroxide ion
OAc^{1-} $(CH_3CO_2^{1-})$	Acetate Ion
CN^{1-}	Cyanide Ion

- All 20 oxy-ions have the same charge as their central atom normally prefers – except carbon and nitrogen
- P and S oxy-ions have 3 or 4 oxygens.
- C,N,Cl,Br, and I oxy-ions have 2 or 3 oxygens.
- The "ite" ion is always the one with less oxygens.
- The "ate" ion is always the one with more oxygens.
- The 3 halogens can super size: 4 oxygens = perchlorate ion
- The 3 halogens can also have a really small ion: 1 oxygen = hypochlorite ion
- There are four misc polyatomic ions you should also know:

  NH_4^{1+}, OH^{1-}, OAc^{1-}, and CN^{1-}.

Hydrogen with Polyatomic Ions

- Hydrogen ion is a wild card, it changes a lot of things.
- Some polyatomic ions have extra hydrogen ions attached to them, but are still ions. That changes their names slightly.
- An acid is a compound that releases hydrogen ions.
  (we'll talk more about acids next chapter)
- Polyatomic ions with enough hydrogens on them to neutralize their charge are acids.
- Monatomic ions with a hydrogen ion attached to them are not acids — but some become acids in water.



SO_4^{2-} is sulfate ion
HSO_4^- is hydrogen sulfate ion
H_2SO_4 is not an ion — it's an acid.

PO_4^{3-} is phosphate ion
HPO_4^{-2} is hydrogen phosphate ion
$H_2PO_4^-$ is dihydrogen phosphate ion
H_3PO_4 is not an ion — it's an acid.

HNO_3 is an acid.

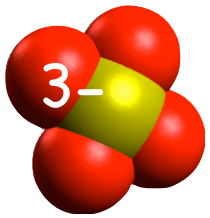
$HCIO_4$ is an acid.

... the acids name is derived from the name of the ion.

P	-3	4	PO_4^{3-}
		3	PO_3^{3-}
S	-2	4	SO_4^{2-}
		3	SO_3^{2-}
C	-2	3	CO_3^{2-}
		2	CO_2^{2-}
N	-1	3	NO_3^{1-}
		2	NO_2^{1-}
Cl, Br, I	-1	4	ClO_4^{1-}
		3	ClO_3^{1-}
		2	ClO_2^{1-}
		1	ClO^{1-}

Hydrogen with Polyatomic Ions

- Polyatomic ions with a charge larger than 1- can add a hydrogen and still be an ion.
- We name them by just adding "hydrogen" or "dihydrogen" to the name of the oxy-ion.
- Then we treat them as any other ion in naming compounds that contain them.
- Ions of sulfur and carbon have a common name (nick name). Because we need twice as much of the -1 ion to do the work of a -2 ion, we call them "bi"carbonate.



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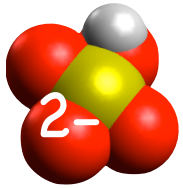
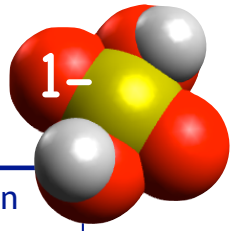
P	PO_4^{3-}	
	PO_3^{3-}	
S	SO_4^{2-}	
	SO_3^{2-}	
C	CO_3^{2-}	
	CO_2^{2-}	





			Add 1H		Add 2H	
P	PO_4^{3-}	Phosphate ion	HPO_4^{2-}	Hydrogen Phosphate ion	$H_2PO_4^{1-}$	Dihydrogen Phosphate ion
	PO_3^{3-}	Phosphite ion	HPO_3^{2-}	Hydrogen Phosphite ion	$H_2PO_3^{1-}$	Dihydrogen Phosphite ion

			Add 1H		Nick Name
S	SO_4^{2-}	Sulfate ion	HSO_4^{1-}	Hydrogen Sulfate ion	Bisulfate ion
	SO_3^{2-}	Sulfite ion	HSO_3^{1-}	Hydrogen Sulfite ion	Bisulfite ion
C	CO_3^{2-}	Carbonate Ion	HCO_3^{1-}	Hydrogen Carbonate Ion	Bicarbonate ion
	CO_2^{2-}	Carbonite Ion	HCO_2^{1-}	Hydrogen Carbonite Ion	Bicarbonite ion

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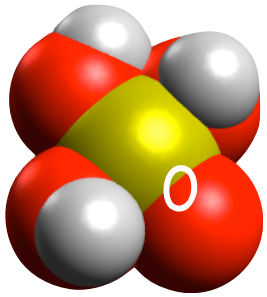
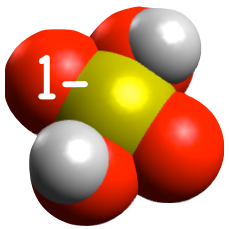
	CO_2^{2-}

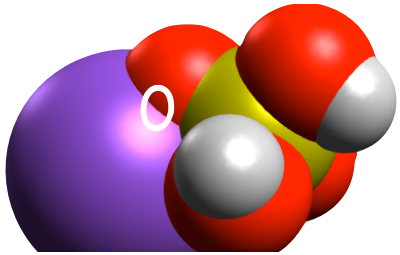


What's the name or formula?

Hydrogen Sulfate Ion
HPO_4^{2-}
HPO_3^{2-}
HCO_3^{1-}



Potassium Hydrogen Sulfate
Lithium Dihydrogen Phosphite
$MgHPO_4$
NaH_2PO_4
$LiHSO_3$
$NaHCO_3$



Answer:

HSO_4^{1-}
Hydrogen Phosphate Ion
Hydrogen Phosphite Ion
Hydrogen Carbonate Ion (aka "Bicarbonate Ion")

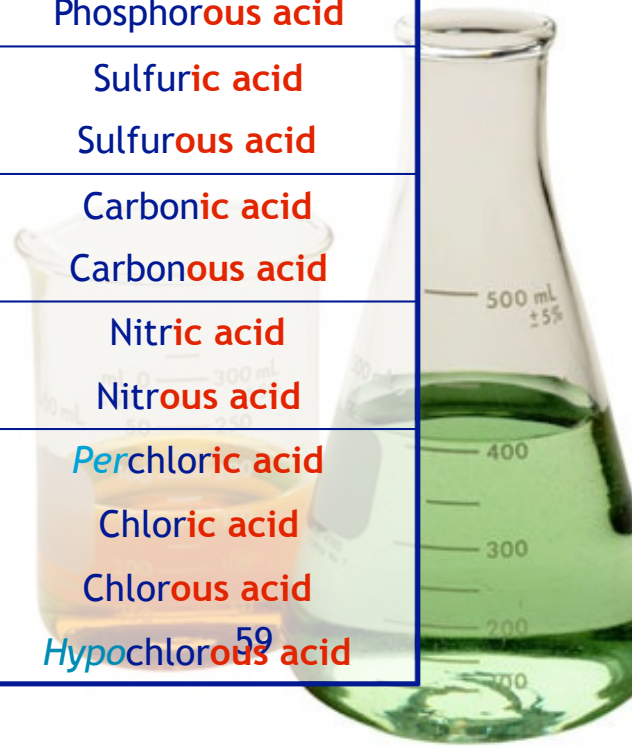
$KHSO_4$
LiH_2PO_3
Magnesium Hydrogen Phosphate
Sodium Dihydrogen Phosphate
Lithium Hydrogen Sulfite ("Lithium Bisulfite")
Sodium Hydrogen Carbonate ("Sodium Bicarbonate")

Polyatomic Ions form Oxy-Acids

- Polyatomic ions with enough hydrogens on them to neutralize their charge become acids.
- Oxy acids do not need to be in water to be acids, they are acids with or without (aq).

- To name acids of oxy-ions, replace
  - the "-ate ion" with "-ic acid"
  - the "-ite ion" with "-ous acid"

P	PO_4^{3-}	Phosphate ion	H_3PO_4	Phosphoric acid
	PO_3^{3-}	Phosphite ion	H_3PO_3	Phosphorous acid
S	SO_4^{2-}	Sulfate ion	H_2SO_4	Sulfuric acid
	SO_3^{2-}	Sulfite ion	H_2SO_3	Sulfurous acid
C	CO_3^{2-}	Carbonate Ion	H_2CO_3	Carbonic acid
	CO_2^{2-}	Carbonite Ion	H_2CO_2	Carbonous acid
N	NO_3^{1-}	Nitrate Ion	HNO_3	Nitric acid
	NO_2^{1-}	Nitrite Ion	HNO_2	Nitrous acid
Cl,Br, I	ClO_4^{1-}	*Per*chlorate Ion	$HClO_4$	*Per*chloric acid
	ClO_3^{1-}	Chlorate Ion	$HClO_3$	Chloric acid
	ClO_2^{1-}	Chlorite Ion	$HClO_2$	Chlorous acid
	ClO^{1-}	*Hypo*chlorite Ion	$HClO$	*Hypo*chlorous acid



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		2	CO_2^{2-}
N	-1	3	NO_3^{1-}
		2	NO_2^{1-}
Cl,Br, I	-1	4	ClO_4^{1-}
		3	ClO_3^{1-}
		2	ClO_2^{1-}
		1	ClO^{1-}

- Write the name or formula for these oxy-acids:
  - H_3PO_4 — Phosphoric Acid
  - H_2SO_3 — Sulfurous Acid
  - $HClO_3$ — Chloric Acid
  - $HClO_4$ — Perchloric Acid

  - Nitric Acid — HNO_3
  - Carbonous Acid — H_2CO_2
  - Sulfuric Acid — H_2SO_4
  - Bromic Acid — $HBrO_3$

Ch03

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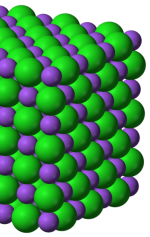

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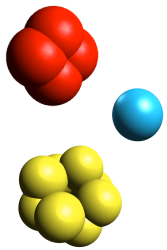
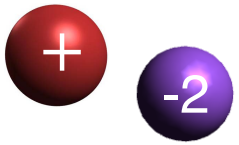
N_2

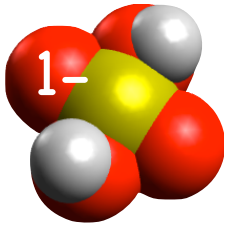
N^{3-}

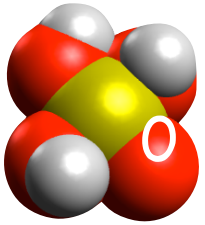
NaCl

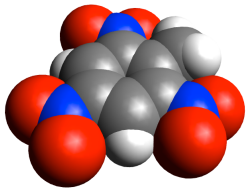




- Binary Compounds
  - Non-metal and metal
    - Non-metal and transition metal
  - Two non-metals
- Polyatomic Ions
  - Oxy-Ions
    - (oxygen + one other element)
  - Compounds of Oxy-Ions
- Acids
  - Binary Acids
  - Oxy-ions
    - Hydrogen Oxy-ions
    - Oxy-acids







$C_6H_2(NO_2)_3CH_3$

Questions?