Chemistry Nomenclature

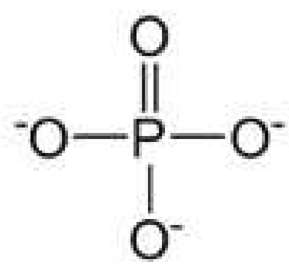
What to call ionic compounds and binary compounds

Nomenclature

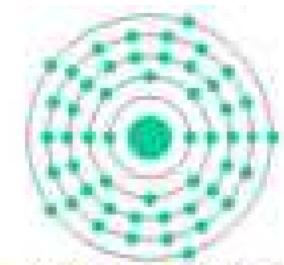
- Nomenclature can be defined as the terminology of chemical compounds.
- It represents the basic "language of chemistry" and, just as the student who is studying French or Spanish must learn the terminology of those languages, so must the chemistry student learn the basic terminology of the discipline.
- Purpose: chemistry students are to be able to read the formulas on the bottles of stock solutions correctly when they have only the names of these substances on their lab sheet or vice versa.

Important tasks to master

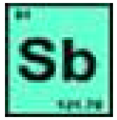
- Naming compounds
- Writing chemical formulas
- Converting from name to formula and formula to name
- Example: $SbPO_4$ or antimony 3+ phosphate (IUPAC)
  - Prior alternate name antimony orthophosphate



Phosphate Ion



Antimony (Sb) Bohr Model



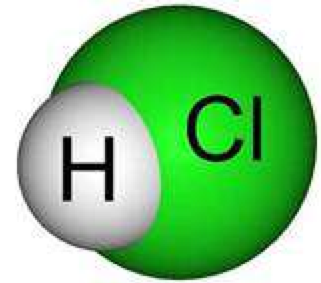
Ions to know

- Learn the correct symbols for the elements. (This is similar to reciting the alphabet…a, b, c… , as well as identifying the symbols we use for each letter.)
- **Learn the names and formulas of seven (7) acids and ammonia. The acids and their formulas, along with ammonia and its formula are:**

hydrochloric acid	**HCl**
nitric acid	**HNO_3**
acetic acid	**$HC_2H_3O_2$**
perchloric acid	**$HClO_4$**
carbonic acid	**H_2CO_3**
sulfuric acid	**H_2SO_4**
phosphoric acid	**H_3PO_4**
ammonia	**NH_3**

Hydrochloric acid

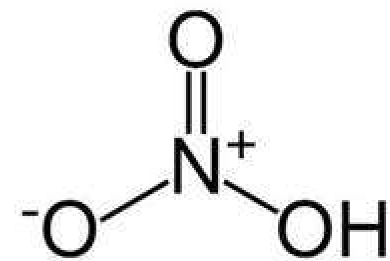
- Concentrated HCl is corrosive.

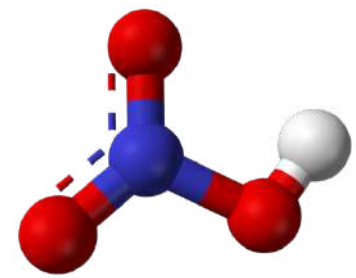


- Stomach acid: pH 1.5 to 3.0

Nitric acid

- Nitric acid is also called aqua fortis or spirit of nitre in the past.
- Majority of nitric acid is used in fertilizers





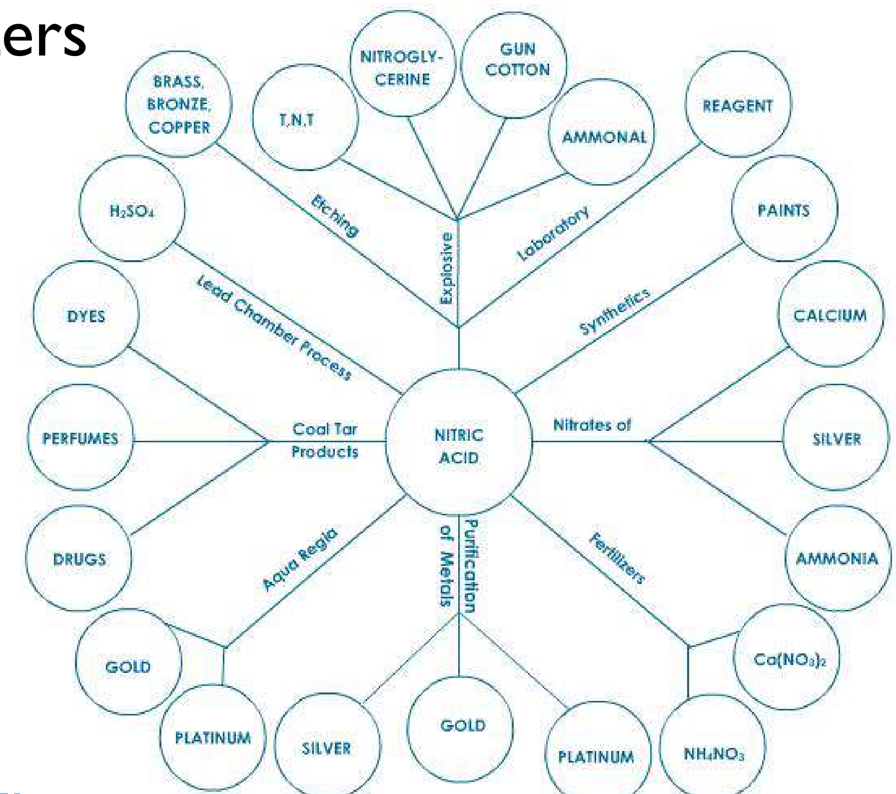
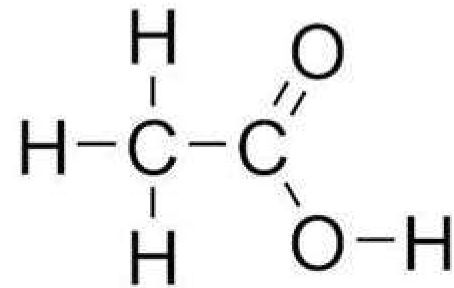
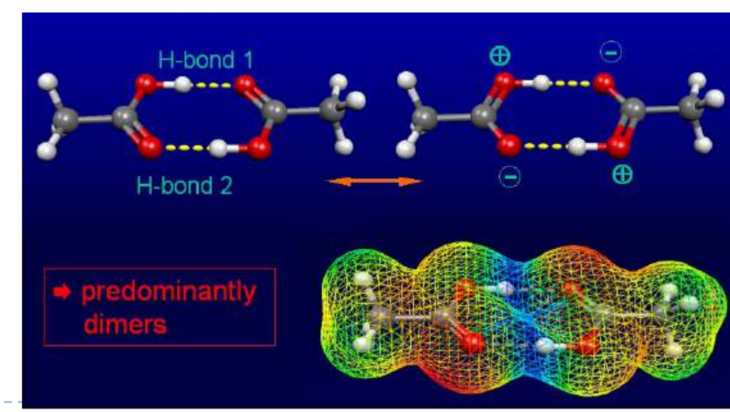


Fig. 6.18 Summary of uses of nitric acid

Acetic acid

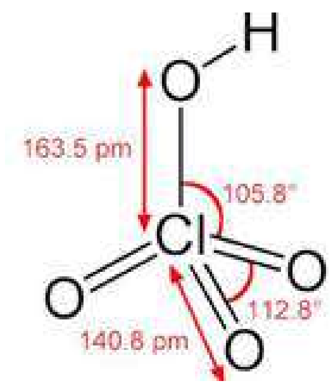
- Most commonly known as vinegar, an organic acid.
- Used in pickling, food preservation, and cleaning

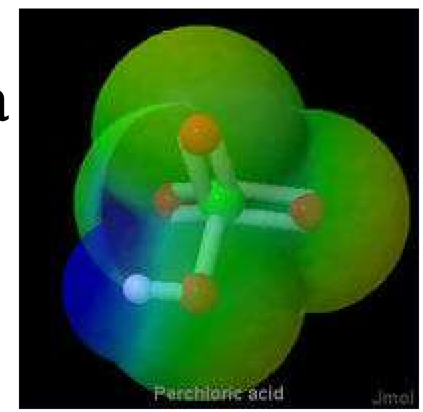




Perchloric acid

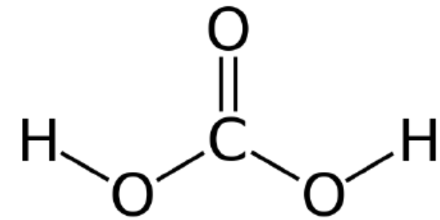
- A clear, colorless, odorless liquid
- Perchloric acid is a strong oxidizer and under certain circumstances potentially explosive. This acid is not itself at risk of combustion. Organic substances are susceptible to spontaneous combustion if mixed with this acid.
- Skin contact or contact with vapors are a health hazard that can result in serious burns.
- Perchloric acid is used to prepare ammonium perchlorate, important in rocket fuel.

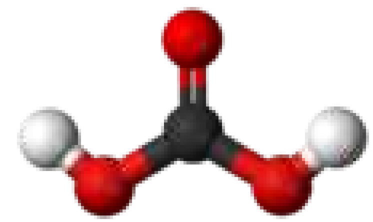




Carbonic acid

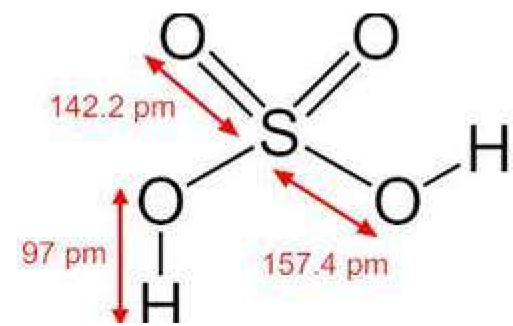
- This exists only in solution, appearing whitish in a water solution.
- Carbonic acid is a weak acid that forms two kinds of compounds: carbonates and bicarbonates.
- Carbonic acid is an intermediate form in the transport of CO_2 in the blood. Carbonic acid-bicarbonate system buffers the blood pH.
- The absorption of CO_2 by the oceans contributes to acidification as carbonic acid is formed.

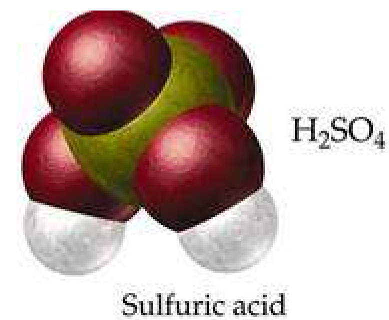




Sulfuric acid

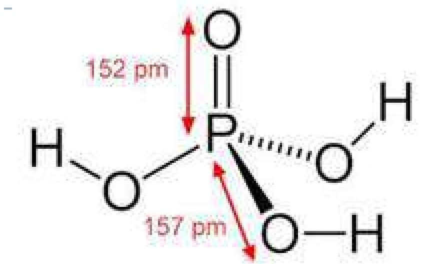
- Sulfuric acid is a highly corrosive strong mineral acid. It is colorless to slightly yellow viscous liquid soluble in water at all concentrations.
- It is an important industrial acid, about 40 million tons are produced annually.
- It is used in drain cleaner, lead-acid batteries, mineral processing, fertilizer, oil refining, waste water processing.

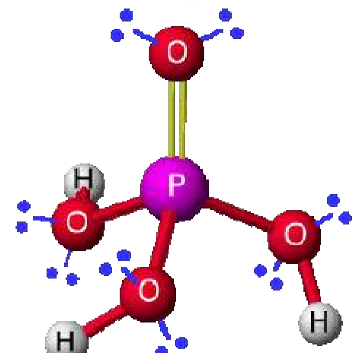




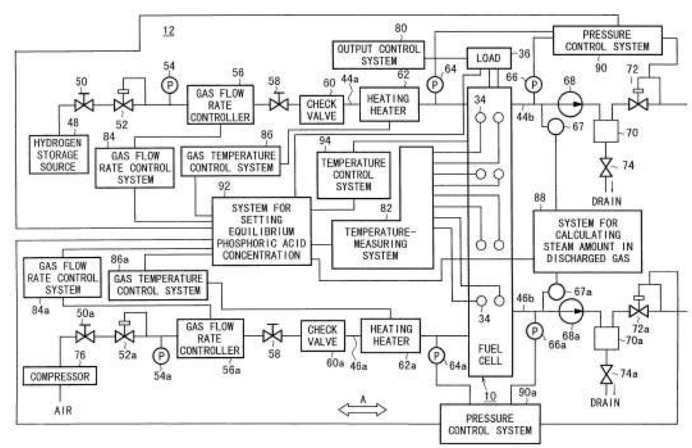
Phosphoric acid

- Pure anhydrous phosphoric acid is a white solid that melts at 42.35 °C to form a colorless, viscous liquid.
- It may form polymers, polyphosphoric acids.
- The oxidation state of phosphorus in these compounds is +5.
- It has three hydrogens to potentially dissociate. It has a wide pH range, useful in buffering, generally nontoxic.
- Important in biochemistry, ATP.



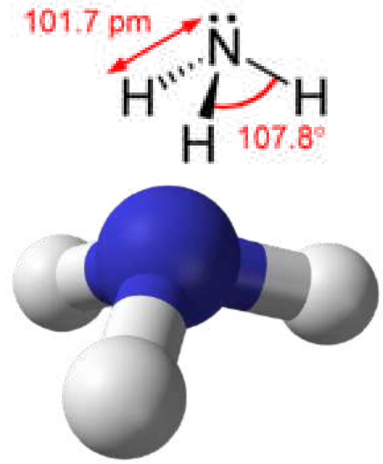


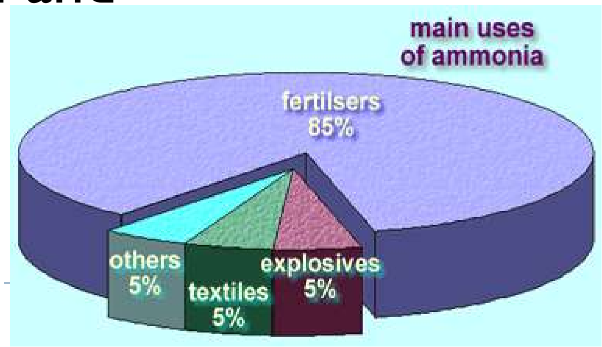
Phosphoric Acid - H_3PO_4



Ammonia

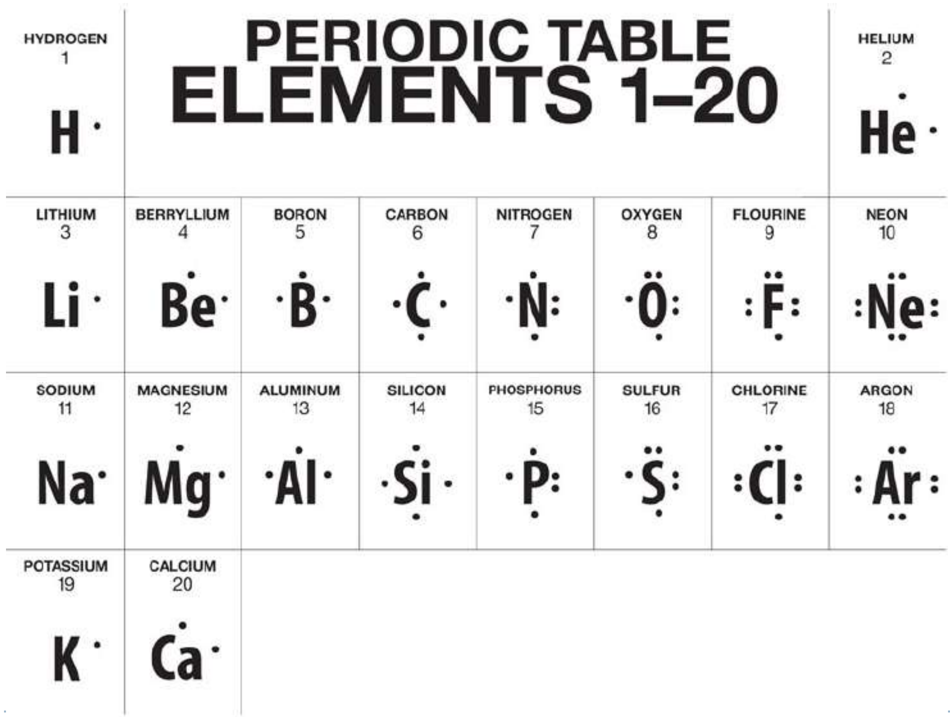
- Ammonia is a colorless gas with a characteristic pungent (almost painful) smell. It is lighter than air.
- It contributes significantly to nutritional needs of producer organisms as a precursor to food and fertilizer.
- It is released into the atmosphere by putrefaction (small percentage of air composition).
- Industrial production annually exceeds 100 million metric tonnes.
- Combustion of ammonia to yield nitrogen and water is highly exothermic.
- Main uses are in fertilizer, cleaners, and production of nitrogenous compounds.

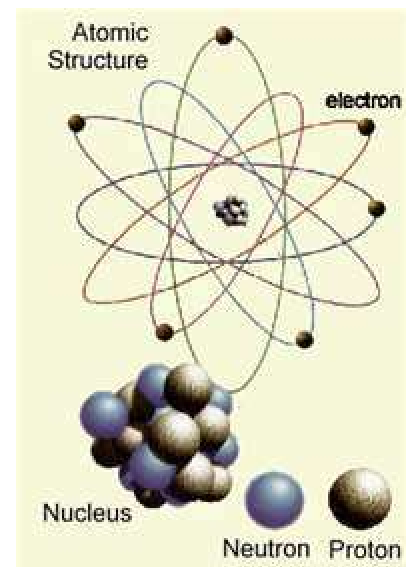




Atomic Structure

- Atoms have neutrons, protons, and electrons.
- The number of electrons effect the chemical properties of an element.





Predicting Valences with the Periodic Table

- Valence is typically, the number of electrons needed to fill the outermost shell of an atom.

- Or, due to exceptions: valence is the number of electrons with which a given atom generally bonds or number of bonds an atom forms.

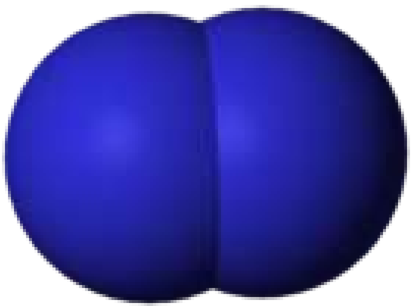
Octet Rule

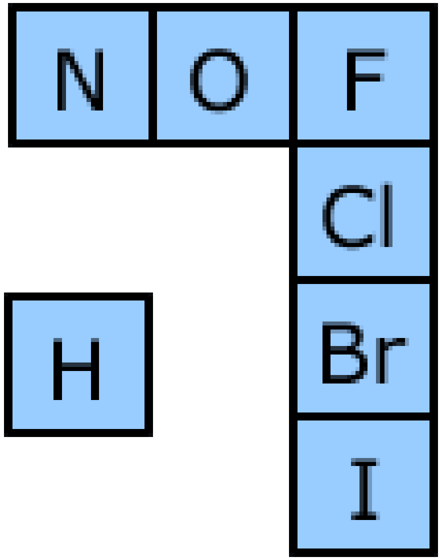
- Atoms tend to form bonds with other atoms to achieve a shell of eight e-, either in unbonded pairs or in bonds with other atom(s)
- For second row elements, eight electrons are required to fill the 2*s* and 2*p* orbitals.
- *s* orbitals hold up to 2 e-.
- The three *p* orbitals each hold 2 e- for a total of six e-.

BrINClHOF

- The diatomic gases occur naturally in bonded pairs.
  - Bromine Br_2
  - Iodine I_2
  - Nitrogen N_2
  - Chlorine Cl_2
  - Hydrogen H_2
  - Oxygen O_2
  - Fluorine F_2

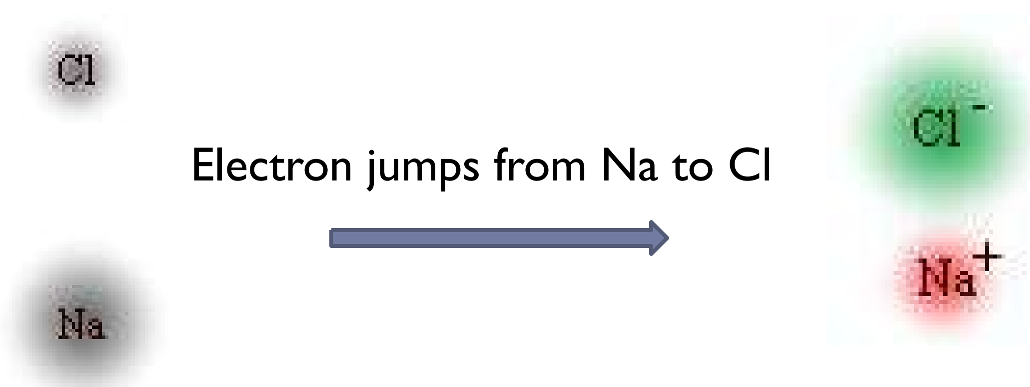
  Pronounced Brinklehoff





Ionic compounds

- Electron transfer creates anions & cations, which attract because of their opposite charges
- Ionic compounds are made up of metal cations and non-metal anions.
- Metals are good electron donors, and nonmetals are good electron acceptors.

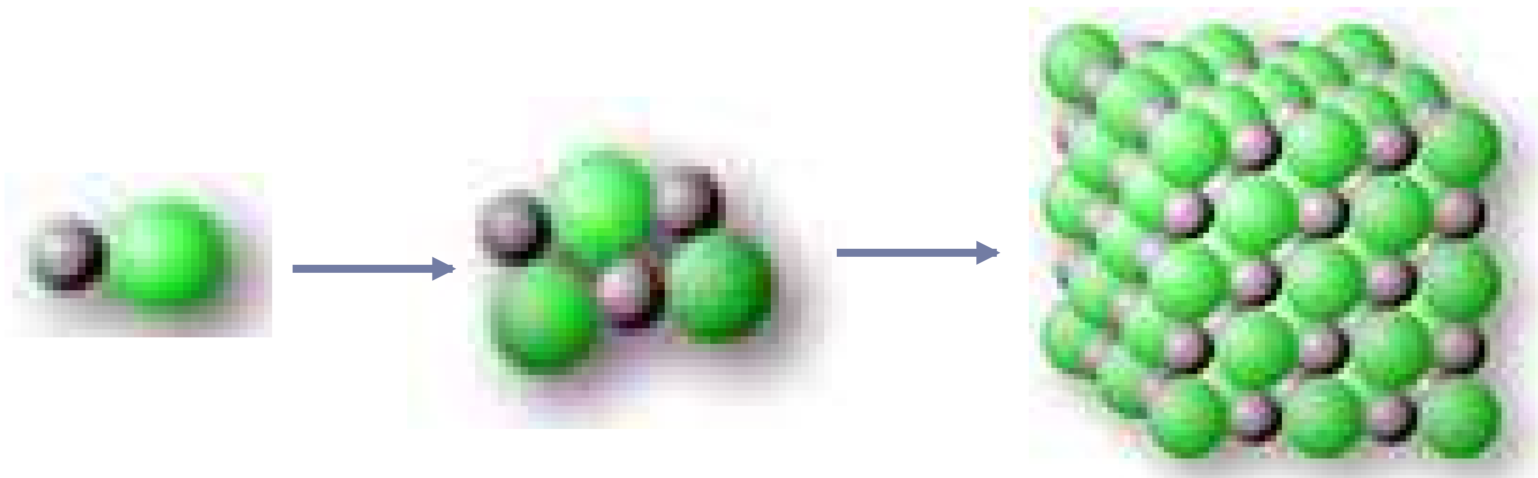


electron acceptor (Cl)
meets
electron donor (Na)

ions attract
to form
neutral pair

Ionic compounds

- **structure:** smallest building blocks are ions- *not molecules!*
  - large numbers of ions can attract to form clusters and eventually crystals



An ion pair — an ion cluster — an ion crystal

  - ions can separate when compound is dissolved, melted, or vaporized

Ionic compounds

- There are two groups:
  - **Type I**: the metal only forms one type of cation.
    - Group 1 metal cations are always 1+.
    - Group 2 metal cations are always 2+.
    - Group 13 metals such as aluminum, gallium, and indium are always 3+.
    - Silver is always 1+.
  - **Type 2**: the metal present can for two (or more) cations that have different charges.
    - The different charges are noted with a Roman numeral after the element symbol. Tin(II) for Sn^{2+} or Tin (IV) for Sn^{4+}
    - Romans are found in the transition metals.

Anions with one charge

- The following elements can only form one monatomic anion:

  - Group 17, the halogens, all can form anions with a single negative charge.
    - F^-, Cl^-, Br^-, I^-

  - Group 16 nonmetals form anions with two negative charges.
    - O^{2-}, S^{2-}, Se^{2-}, Te^{2-}

Type I Binary Ionic Compounds

- Writing the formulas:
  - Cation 1st, then the anion 2nd.
  - **+** charge * number of cations = **-** charge * number of anions
    - KNOW the charges for the different ions.
  - Adjust the number of ions until there is no net charge.
    - This is changing the subscripts: Mg^{++} + Cl^{-} needs 2Cl^{-} to balance the 2 positive charges from the magnesium. Formula: $MgCl_2$.
  - Use the simplest form: Na_2Cl_2 in simplest form is NaCl.
  - Do NOT alter the charges of the ions to obtain balanced charges. Sodium can not become ++.

Write the formula for the Type I compound

- Lithium chloride
- Magnesium bromide
- Cesium fluoride
- Aluminum sulfide
- Beryllium oxide
- MgI_2
- $NaBr$
- $AgCl$
- SrO
- Li_2O

Type II Binary Ionic Compounds

- Writing the formulas:
  - Cation 1st, then the anion 2nd.
  - + charge * number of cations = - charge * number of anions
    - KNOW the charges for the different ions.
  - Adjust the number of ions until there is no net charge.
    - This is changing the subscripts: Sn^{++} + Cl^{-} needs 2Cl^{-} to balance the 2 positive charges from the tin. Formula: $SnCl_2$.
  - Use the simplest form: Ru_2Cl_4 in simplest form is $RuCl_2$.
  - Do NOT alter the charges of the ions to obtain balanced charges. Sodium can not become ++.
  - **Systematic name uses roman numerals for the charge**.
  - Name of higher charge ion ends in –ic. Old system
  - Name of lower charge ion ends in –ous. Old system
  - Same process as Type I. **KNOW** the charges for the ions.

Type II Cations, the Transition Metals

- Iron (II)
  - Fe^{2+},ferrous
- Iron (III)
  - Fe^{3+}, ferric
- Copper (I)
  - Cu^{+}, cuprous
- Copper (II)
  - Cu^{2+}, cupric
- Cobalt (II)
  - Co^{2+}, cobaltous
- Cobalt (III)
  - Co^{3+}, cobaltic
- Tin (II)
  - Sn^{2+}, stannous
- Tin (IV)
  - Sn^{4+}, stannic
- Lead (II)
  - Pb^{2+}, plumbous
- Lead (IV)
  - Pb^{3+}, plumbic
- Mercury (I)
  - Hg^{+}, mercurous
- Mercury (II) exception: forms Hg_2^{2+}
  - Hg^{2+}, mercuric
- Chromium (II)
  - Cr^{2+}, chromous
- Chromium (III)
  - Cr^{3+}, chromic
- Manganese (II)
  - Mn^{2+}, manganous
- Manganese(IV)
  - Mn^{3+}, manganic
- Nickel (II)
  - Ni^{2+}, nickelous
- Nickel (III)
  - Ni^{3+}, nickelic

Write the formula for the Type II compound

- Iron (III) oxide
- Tin (II) sulfide
- Mercury (II) bromide
- http://www.youtube.com/watch?v=PNaZqnFwIIQ
- Vanadium(V) nitride
- Chromium(VI) oxide
- Nickel(III) selenide
- Tin(IV) chloride
- Antimony(V) bromide
- zinc selenide*

Write the formula

- copper(II) iodide
- copper(I) oxide
- iron(II) sulfide
- manganese(IV) oxide
- gallium(III) chloride
- gold(I) sulfide
- silver bromide

- CuI_2
- Cu_2O
- FeS
- MnO_2
- $GaCl_3$
- Au_2S
- AgBr

Write the name

- $FeCl_3$
- Au_2O
- $FeCl_2$
- AuI_3
- V_2O_5
- PbO
- MnO_2
- PbS_2
- NiF_3
- Hg_2F_2
- CuS

- Iron (III) chloride
- Gold (I) oxide
- Iron (II) chloride
- Gold (III) iodide
- Vanadium (V) oxide
- Lead (II) oxide
- Manganese (IV) oxide
- Lead (IV) sulfide
- Nickel (III) fluoride
- Mercury (I) fluoride
- Copper (II) sulfide

- HgI_2
- $CuBr$
- $CdSe$
- Fe_2O_3
- $ZnBr_2$
- SnF_4
- $ScCl_3$
- Ga_2S
- $MnCl_2$
- AgI
- $NiCl_2$

- Mercury (II) iodide
- Copper (I) bromide
- Cadmium (II) selenide
- Iron (III) oxide
- Zinc (II) bromide
- Tin (IV) fluoride
- Scandium (III) chloride
- Gallium (I) sulfide
- Manganese (II) chloride
- Silver iodide
- Nickel (II) chloride

Polyatomic ions—building blocks

- Learning the names, charges, and formulas of the most common polyatomic ions is absolutely essential before many other skills can be mastered. Those skills include:
  - writing down empirical formulas for ionic compounds
  - naming ionic compounds
  - reading and correctly interpreting labels on reagent bottles
  - naming inorganic acids
  - predicting the solubility of an ionic compound
  - predicting the products of a reaction between aqueous ionic compounds
  - predicting the products of neutralization reactions
  - writing and balancing ionic equations
  - writing and balancing redox equations
  - understanding environmental chemistry (e. g. mechanisms in acid rain formation and water quality assessment)
  - understanding geochemistry (e. g. composition and formation of minerals)
  - understanding clinical and biological chemistry (e. g. electrolyte balance and buffering in blood)

Polyatomic Oxyanions

prefix + **Root** + **suffix**

per-

-or-

hypo

-ate

-or-

-ite

Root: identifies the element other than O (or H

-ite: contains 1 fewer O atoms than does the -ate ion

Prefixes and suffixes

- -ate: common form of the oxyanion.
  - chlorate, ClO_3^-
    nitrate, NO_3^-
    sulfate, SO_4^{2-}
- -ite: form that contains one less oxygen than the -ate form.
  - chlorite, ClO_2^-
    sulfite, SO_3^{2-}
    nitrite, NO_2^-
- Per- the ion contains one more O than the –ate form.
  - perchlorate, ClO_4^-
    perbromate, BrO_4^-
- Hypo- the ion contains one less O than the –ite form.
  - hypochlorite, ClO^-
  - hypobromite, BrO^-

More

- Hydrogen or bi- : anion has (1) captured H^+ ion.
  - Examples: hydrogen carbonate: HCO_3^-
    hydrogen sulfate: HSO_4^-
- Dihydrogen: anion has (2) captured H^+ ions.
  - Examples: dihydrogen phosphate: $H_2PO_4^-$
- Thio- : replace an O with an S.
  - Examples: thiosulfate, $S_2O_3^{2-}$
    thiosulfite, $S_2O_2^{2-}$

Oxoacids

- These acids contain oxygen, hydrogen, and another element.
- When hydrogen is the cation, the resulting ionic compound is an acid.
- Naming acids use the oxoanion and replace the suffix.
  - -ate becomes –ic
  - -ite becomes -ous
- Acids with more than one H are polyprotic acids able to dissociate more than once.
  - When dissolved in water, an oxoacid yields one or more H^+ ions.

+1 CHARGE		-1 CHARGE		-2 CHARGE		-3 CHARGE		-4 CHARGE	
ion	**name**	**ion**	**name**	**ion**	**name**	**ion**	**name**	**ion**	**name**
NH_4^+	**ammonium**	$H_2PO_3^-$	dihydrogen phosphite	HPO_3^{2-}	hydrogen phosphite	PO_3^{3-}	**phosphite**	$P_2O_7^{4-}$	pyrophosphate
H_3O^+	hydronium	$H_2PO_4^-$	dihydrogen phosphate	HPO_4^{2-}	hydrogen phosphate	PO_4^{3-}	**phosphate**		
Hg_2^{2+}	**mercury(I)**	HCO_3^-	hydrogen carbonate	CO_3^{2-}	carbonate	PO_2^{3-}	**hypophosphite**		
		HSO_3^-	hydrogen sulfite	SO_3^{2-}	**sulfite**	AsO_3^{3-}	arsenite		
		HSO_4^-	hydrogen sulfate	SO_4^{2-}	**sulfate**	AsO_4^{3-}	arsenate		
		NO_2^-	**nitrite**	$S_2O_3^{2-}$	thiosulfate				
		NO_3^-	**nitrate**	SiO_3^{2-}	silicate				
		OH^-	**hydroxide**	C_2^{2-}	carbide				
		CH_3COO^-	**acetate**	$C_2O_4^{2-}$	**oxalate**				
		CrO_2^-	chromite	CrO_4^{2-}	**chromate**				
		CN^-	**cyanide**	$Cr_2O_7^{2-}$	**dichromate**				
		CNO^-	cyanate	MoO_4^{2-}	molybdate				
		CNS^-	thiocyanate	S_2^{2-}	disulfide				
		MnO_4^-	**permanganate**						
		ClO^-	**hypochlorite**						
		ClO_2^-	**chlorite**						
		ClO_3^-	**chlorate**						
		ClO_4^-	**perchlorate**						
		BrO^-	**hypobromite**						
		BrO_2^-	**bromite**						
		BrO_3^-	**bromate**						
		BrO_4^-	**perbromate**						
		IO^-	**hypoiodite**						
		IO_2^-	**iodite**						
		IO_3^-	**iodate**						
		IO_4^-	**periodate**						

Covalent molecules

- Nonmetal to nonmetal (few exceptions)
- Atoms bond by sharing electrons.
- Molecules have no net charge.
- Nonmetals often combine in a variety of different proportions to form different compounds.
  - Numerical prefixes are used in naming binary molecules to specify the number of each atom present.

Prefix	Meaning
mono-	1
di-	2
tri-	3
tetra-	4
penta-	5
hexa-	6
hepta-	7
octa-	8

Covalent molecules

Table: Comparing molecular and ionic compounds.

	Molecular compounds	**Ionic compounds**
smallest particles	molecules	cations and anions
origin of bonding	electron sharing	electron transfer
forces between particles	strong bonds between atoms	strong attractions between anions and cations (*opposite* charge)
	weak attractions between molecules	strong repulsions between ions of *like* charge
elements present	close on the periodic table	widely separated on the periodic table
metallic elements present	rarely	usually
electrical conductivity	poor	good, when melted or dissolved
state at room temperature	solid, liquid, or gas	solid
melting and boiling points	lower	higher
other names	covalent compounds	salts

Common covalent compounds

Name	Formula	Name	Formula
ammonia	NH_3	methane	CH_4
carbon dioxide	CO_2	nitrous oxide	N_2O
carbon monoxide	CO	nitric oxide	NO
hydrazine	N_2H_4	sulfur dioxide	SO_2
hydrogen peroxide	H_2O_2	water	H_2O
hydrogen sulfide	H_2S		

Write the formula or name

hydrogen bromide (g)	HBr
hydrogen sulfide (g)	H_2S
ammonia (g)	NH_3
carbon tetrachloride	CCl_4
CO_2 (g)	Carbon dioxide
hydrosulfuric acid	H_2SO_4
dinitrogen pentoxide	N_2O_5
H_2Se (aq)	Hydrogen selenide
P_2O_3	Diphosphorous trioxide
NO_2 (g)	Nitrogen dioxide

Try these

- HF(aq)
- N_2O
- H_2S
- PCl_5
- HCl(aq)
- CS_2
- CO(g)
- CO_2 (s)
- NO (g)
- HF (g)

- Hydrofluoric acid
- Nitrous oxide
- Hydrogen sulfide
- Phosphorus pentachloride
- Hydrochloric acid
- Carbon disulfide
- Carbon monoxide
- Carbon dioxide
- Nitrogen monoxide
- Hydrogen fluoride

Bond types

- Covalent bonds share atoms.
- http://www.youtube.com/watch?v=QqjcCvzWwww&safety_mode=true&persist_safety_mode=1&safe=active animation ionic bond
- http://www.youtube.com/watch?v=yjge1WdCFPs&feature=related&safety_mode=true&persist_safety_mode=1&safe=active Ionic and covalent

Reactions

- Single replacement (A + BX B + AX)
  - Ag +
- Double replacement (ZA + BX BA + ZX)
- Synthesis (A + B C)
- Decomposition
- Combustion

Resources

- http://www.files.chem.vt.edu/RVGS/ACT/notes/Nomenclature.html
- Nomenclature of Inorganic Chemistry *(IUPAC)* Primary source for formulas and names in the field guide section (International Union of Pure and Applied Chemistry, Nomenclature of Inorganic Chemistry, 2nd Edition, Butterworths, London, 1979)
- Inorganic Chemical Nomenclature *(IUPAC)* Bibliography of IUPAC publications on inorganic nomenclature.