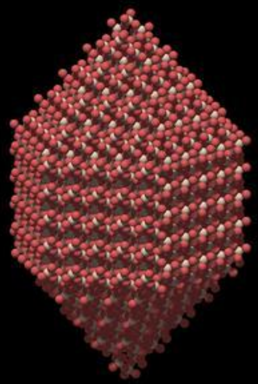
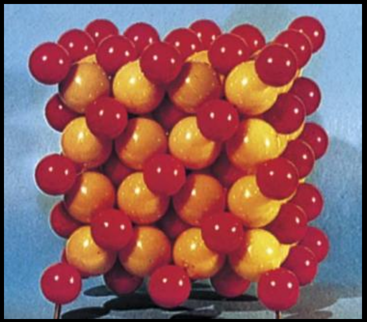
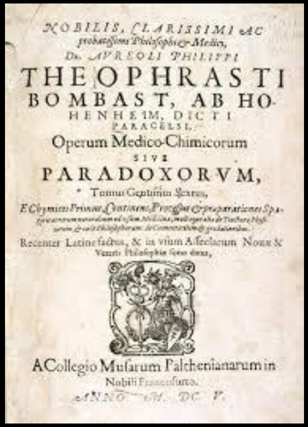
Formulas & Nomenclature







NOBILIS, CLARISSIMI AC
probatissimi Philosophi & Medici,
Dn. AVREOLI PHILIPPI
THEOPHRASTI
BOMBAST, AB HO-
HENHEIM, DICTI
PARACELSI.
Operum Medico-Chimicorum
SIVE
PARADOXORVM,
Recenter Latine facti, & in vsum Asseclarum Novae &
Veteris Philosophiae

A Collegio Musarum Paltheniarum in
Nobili Francofurto.
ANNO M. DC. V.

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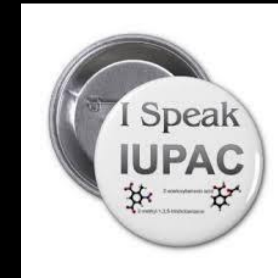
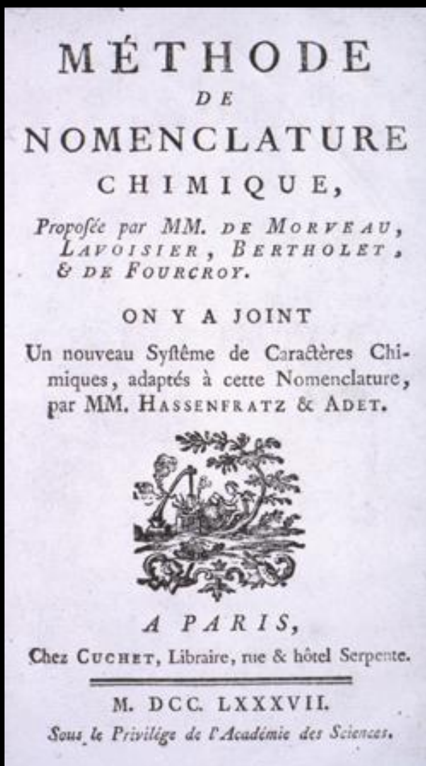
Nomenclature



Latin for “calling by name”

Precise system of naming chemical compounds



MÉTHODE
DE
NOMENCLATURE
CHIMIQUE,
Propoſée par MM. de Morveau, Lavoisier, Bertholet, & de Fourcroy.
ON Y A JOINT
Un nouveau Syſtême de Caractères Chimiques, adaptés à cette Nomenclature, par MM. Hassenfratz & Adet.
A PARIS,
Chez Cuchet, Libraire, rue & hôtel Serpente.
M. DCC. LXXXVII.
Sous le Privilège de l'Académie des Sciences.

(1787)

Memorize:

- Diatomic elements
- Polyatomic ions
  - -ic oxyacids and their -ate anions
  - -ous oxyacids and their -ite anions
- Greek prefixes for naming molecular compounds

(Flashcards on the web site in Course Documents)

(Lists in Unit 0 on the web site)

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Elements

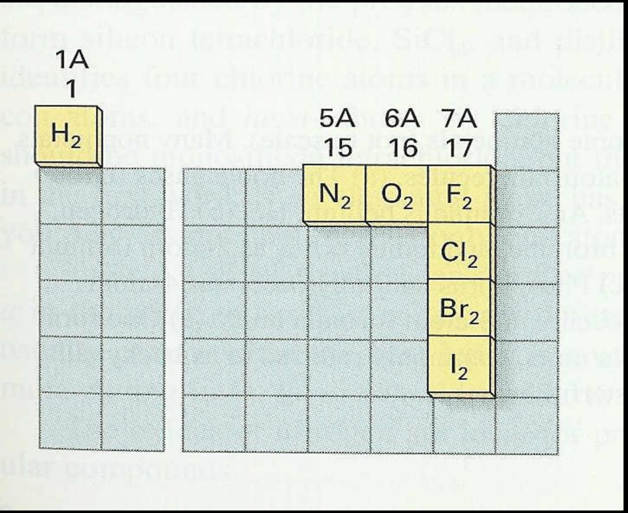
Elements contain only one type of atom

Mono-atomic (Monatomic) – single atoms

Examples: Cu Al C P

Di-atomic – two atoms (Must Know)

Examples: H_2 N_2 O_2 F_2 Cl_2 Br_2 I_2



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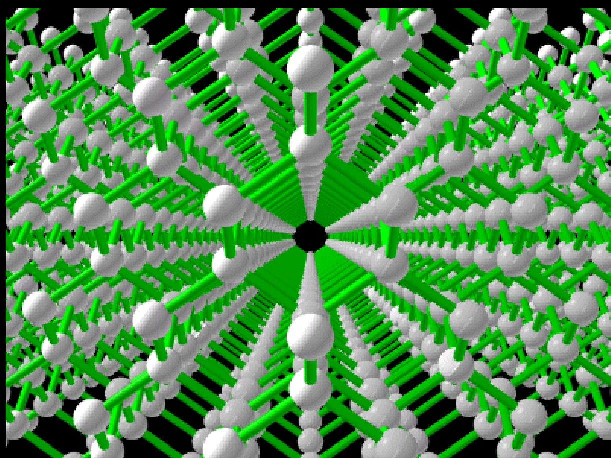
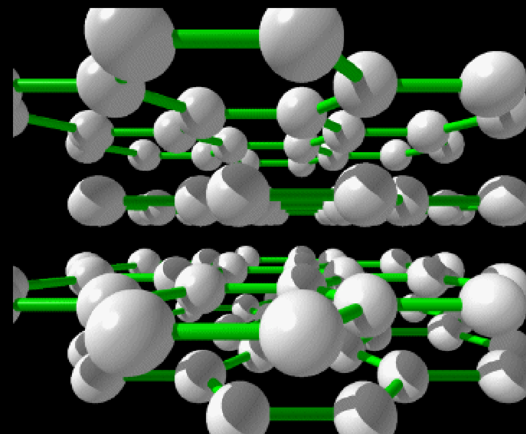
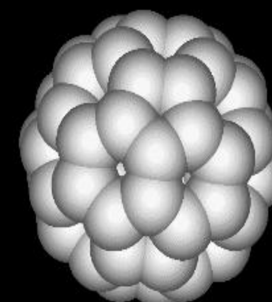
Elements

Poly-atomic – multiple atoms

Examples: O_3 P_4 S_8 C_{60}







Diamond

Graphite

Fullerene
"Bucky Ball"

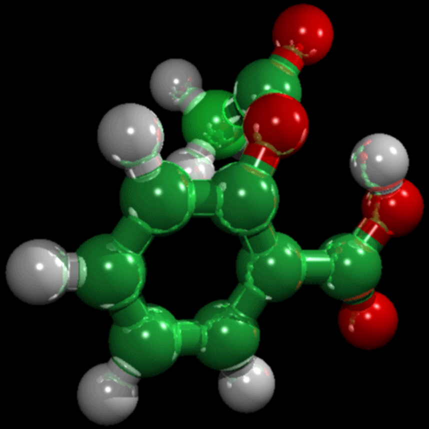
"Nano-tech"

Allotrope: only one element; different forms

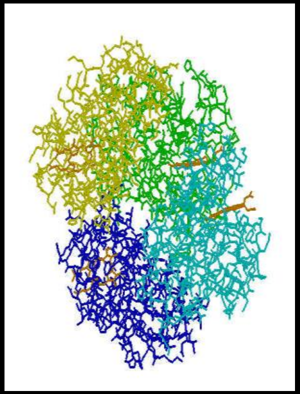
Molecules

Two or more atoms joined together chemically in a neutral unit

Water



Aspirin



Hemoglobin

Molecules can contain thousands of atoms

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Binary Compounds

Binary = 2; but 5 different schemes

$NaCl$ | **PCl_5** | **HBr** | **H_2O** | **Fe_2O_3**

Sodium Chloride
Ionic

Phosphorus Pentachloride
Molecular

Hydrobromic Acid
Acid

Dihydrogen Monoxide
Water
Common

Iron (III) Oxide
Ferric Oxide
Transition

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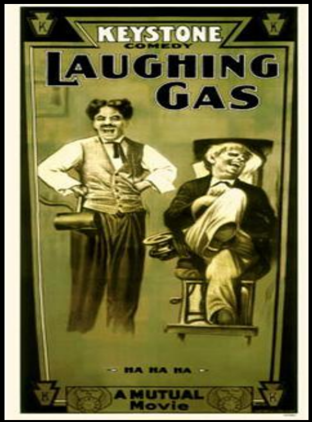
Nitrogen Oxide?

N_2O	Dinitrogen Monoxide	Laughing Gas, Auto Fuel Additive
NO_2	Nitrogen Dioxide	Rocket Fuel, Liquid Explosive
NO_3^-	Nitrate Anion	Fertilizer, Explosive
$NO\cdot$	Nitrogen Monoxide (Nitrous Oxide)	Excitatory Neurotransmitter



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Binary Molecular Compounds
Two Non-Metals or Metalloid + Non-Metal

First Word

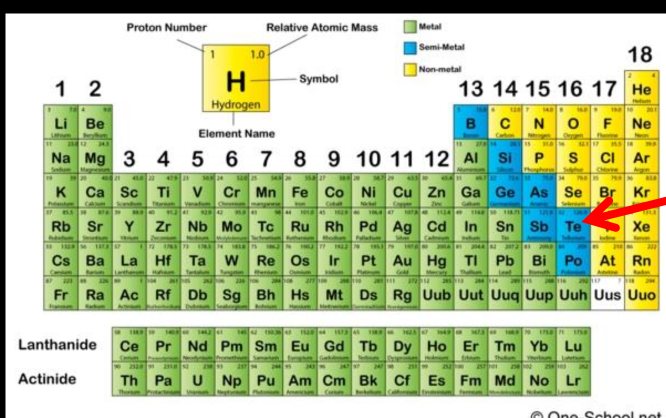
Name of the element appearing first in the formula

Include a prefix to indicate # atoms

Second Word

Name of the element appearing second in the formula,
changed to end in –ide

Include prefix to indicate # atoms



Metalloid + Non-Metal

Two Non-metals

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Greek prefixes indicating numbers of atoms

1	mono– (omitted for first–named element)
2	di–
3	tri–
4	tetra–
5	penta–
6	hexa–
7	hepta–
8	octa–
9	nona–
10	deca–

final "a" & "o" of prefix omitted with oxides

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Examples

N_2O_4	Dinitrogen Tetroxide
N_2O_5	Dinitrogen Pentoxide
Si_2Cl_6	Disilicon Hexachloride
CO	Carbon Monoxide
CO_2	Carbon Dioxide
P_2O_5	Diphosphorus Pentoxide

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Noble Gases

Chemically inert under most circumstances

Xenon reacts with fluorine at temperature and pressure extremes

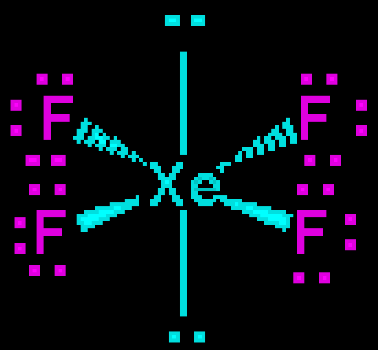
These are molecular compounds

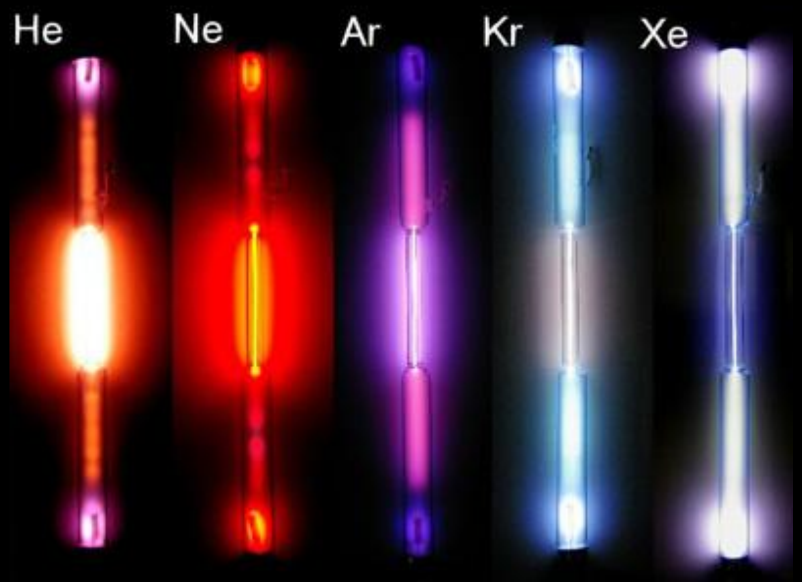
Name as Non-Metals:

XeF_2 xenon difluoride

XeF_4 xenon tetrafluoride

XeF_6 xenon hexafluoride





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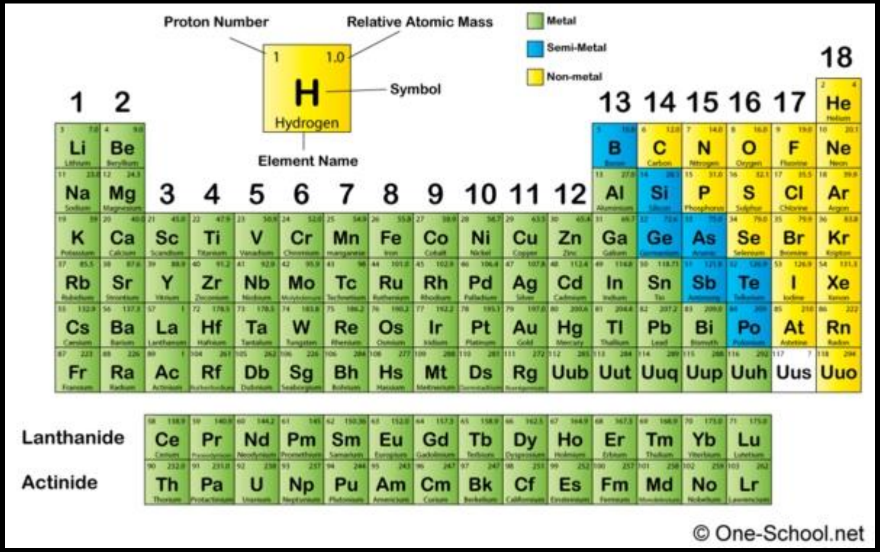
Name the following compounds:

Cl_2O_7	dichlorine heptoxide
P_4O_{10}	tetraphosphorus decoxide
SO_3	sulfur trioxide
NO	nitrogen monoxide
IF_5	iodine pentafluoride



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Name to Formula: Both Elements Non-Metal

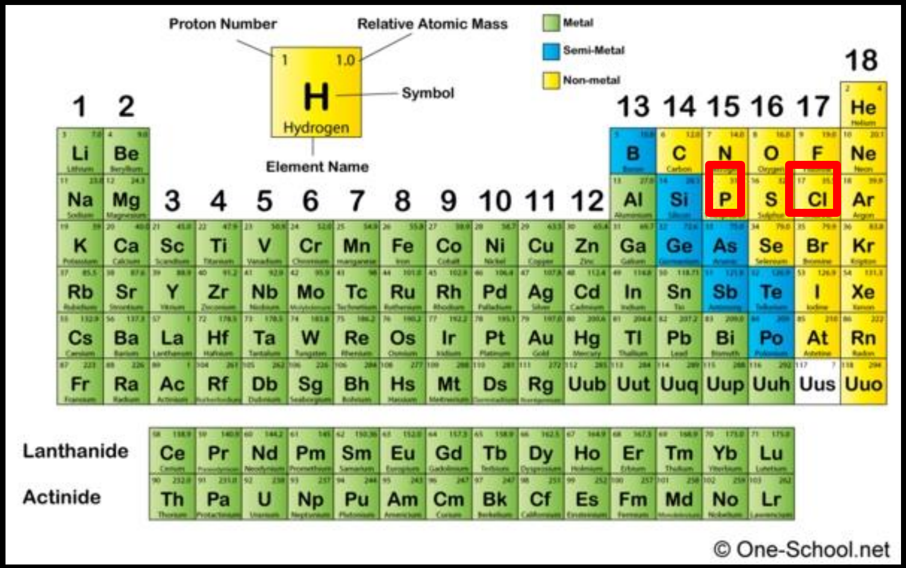
Diphosphorus Pentachloride

1. Write Symbols for Elements in order of name

   P Cl

2. Add subscripts based on Greek numbers in name

   P_2Cl_5



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Name To Formula: "Staircase" Cation & Non-Metal Anion

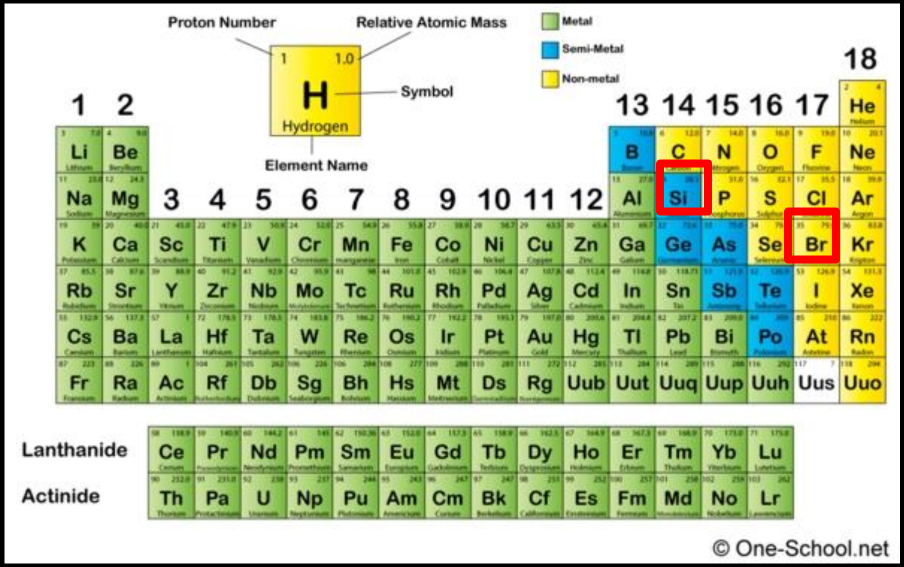
Silicon Heptabromide

1. Write Symbols for Elements in order of name

   Si Br

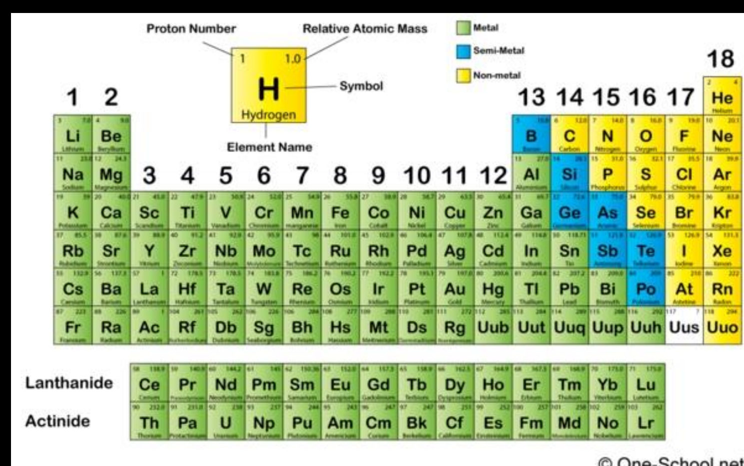
2. Add subscripts based on Greek numbers in name

   $SiBr_7$



Write the proper formula for:

carbon monoxide	CO
phosphorus pentachloride	PCl_5
dinitrogen pentoxide	N_2O_5
silicon dioxide	SiO_2
sulfur tetrafluoride	SF_4



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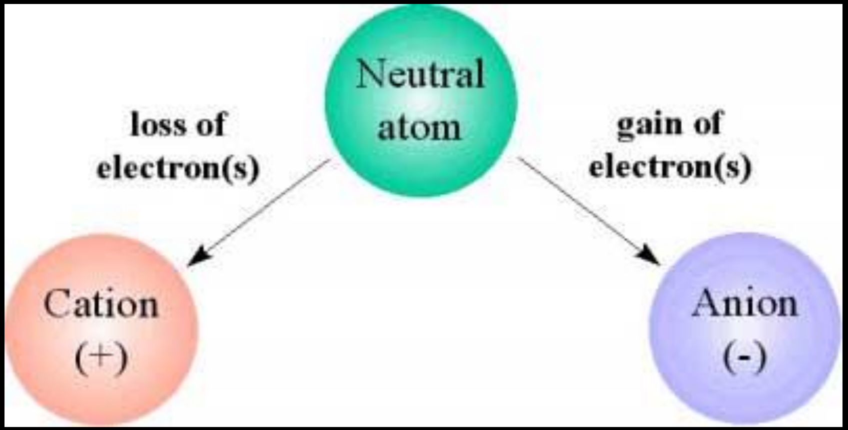
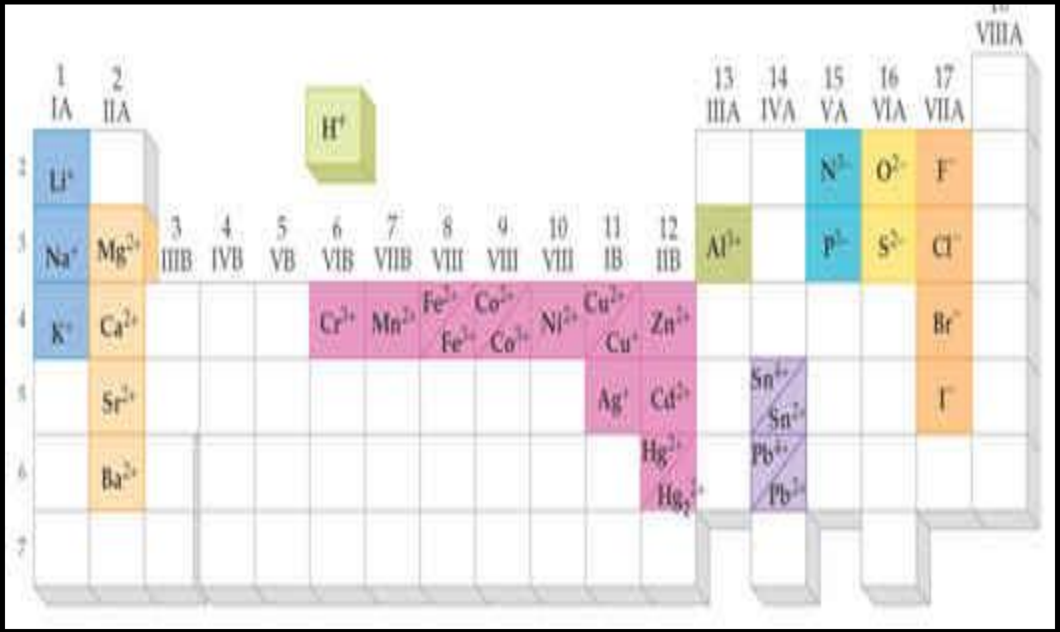
Ions



Metals lose electrons
Non-metals gain electrons



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Ions

Symbol size of charge, sign of charge

Examples:

Na^{+} Ca^{2+} Fe^{+3} F^{-} S^{2-} N^{-3}

(1 is not shown, but understood)

Oxidation Number = charge on a monatomic ion

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Cations

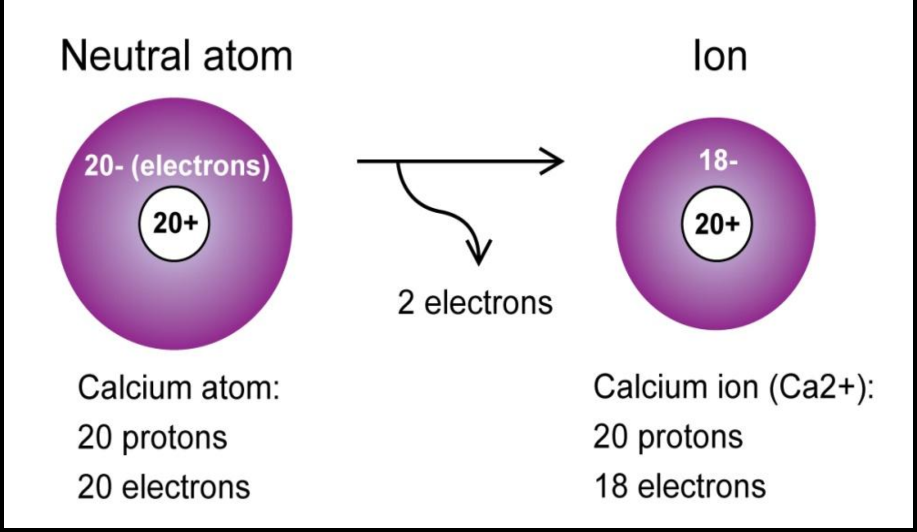
Positive ions

Loss of e^- creates positive species

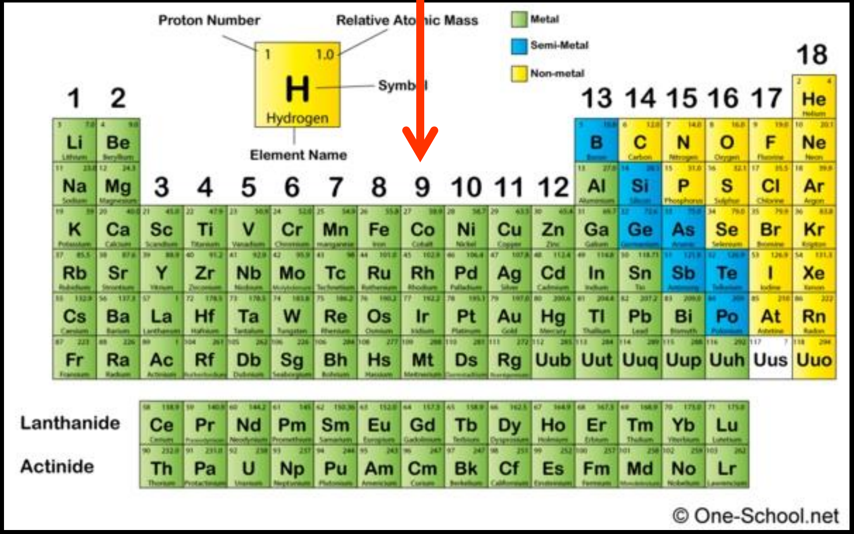
$\#p^+ > \#e^-$

Metals form cations

Name: Base metal element plus “ion”



Metals



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Metal Cation Nomenclature

For Representative Metals (the "A's" Group 1-3): name the element and add the word ion

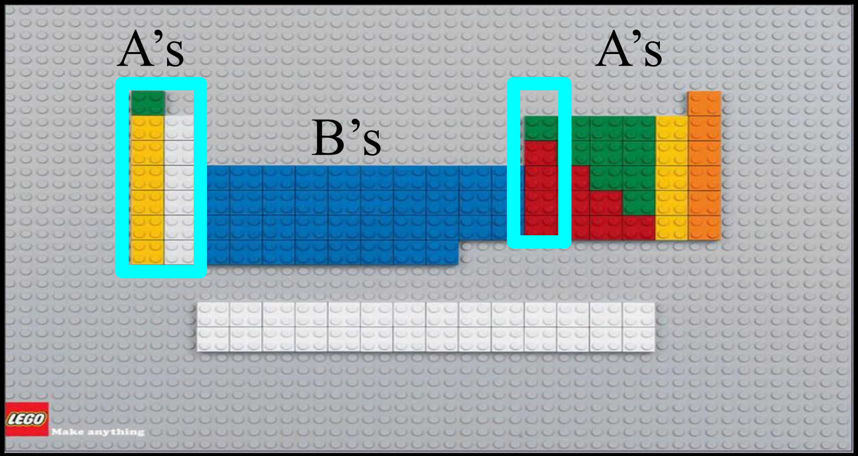
Na^{+} Sodium Ion

K^{+} Potassium Ion

Ca^{2+} Calcium Ion

Mg^{2+} Magnesium Ion

Al^{3+} Aluminum Ion



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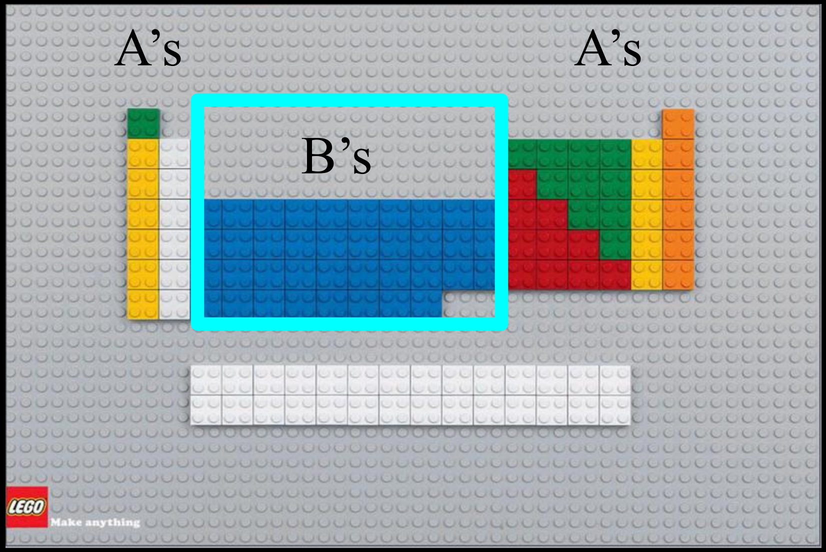
Metal Cation Nomenclature

Transition Metals (the "B's") - several charges possible

Name element, charge (in roman numerals), then "ion"

Fe^{3+}	iron (III) ion	(ferric)
Fe^{2+}	iron (II) ion	(ferrous)
Cu^{2+}	copper (II) ion	(cupric)
Cu^{+}	copper (I) ion	(cuprous)



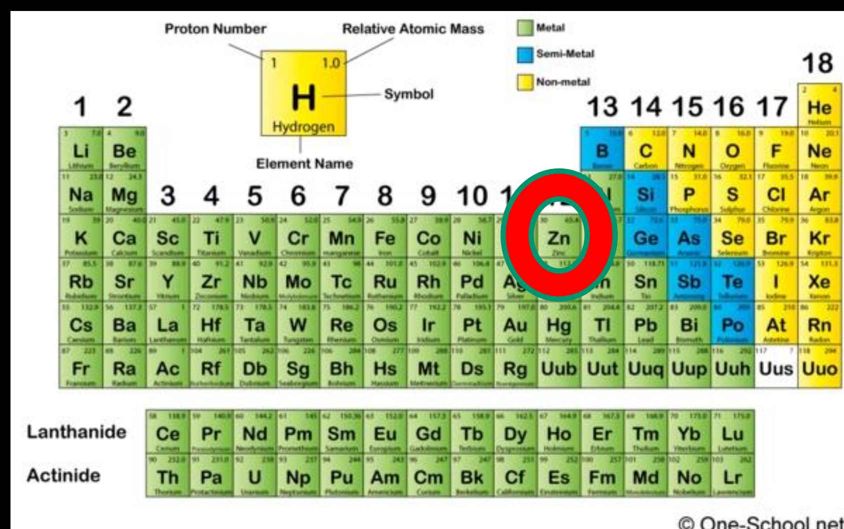
Metal Cation Nomenclature: Zinc

Always plus 2

Zn^{2+}

No Roman Numeral needed

Zinc Sulfate: $ZnSO_4$



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Anions

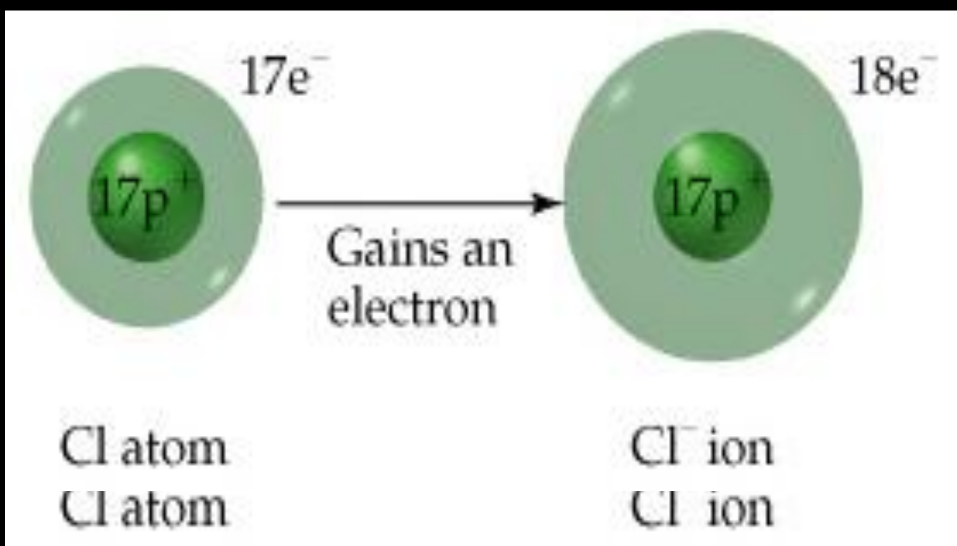
Negative ions

Gain of e^- creates negative species

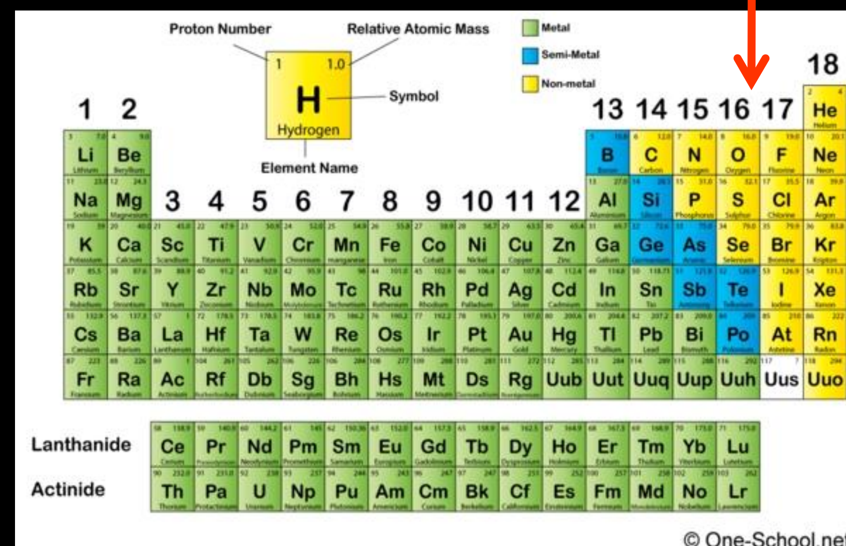
$\#p^+ < \#e^-$

Nonmetals form anions

Name: Base element ending in –ide + Ion



Non-Metals



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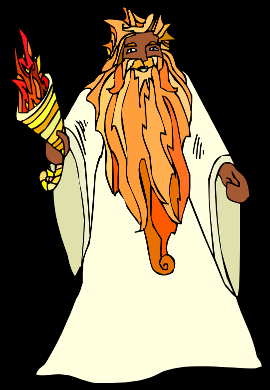
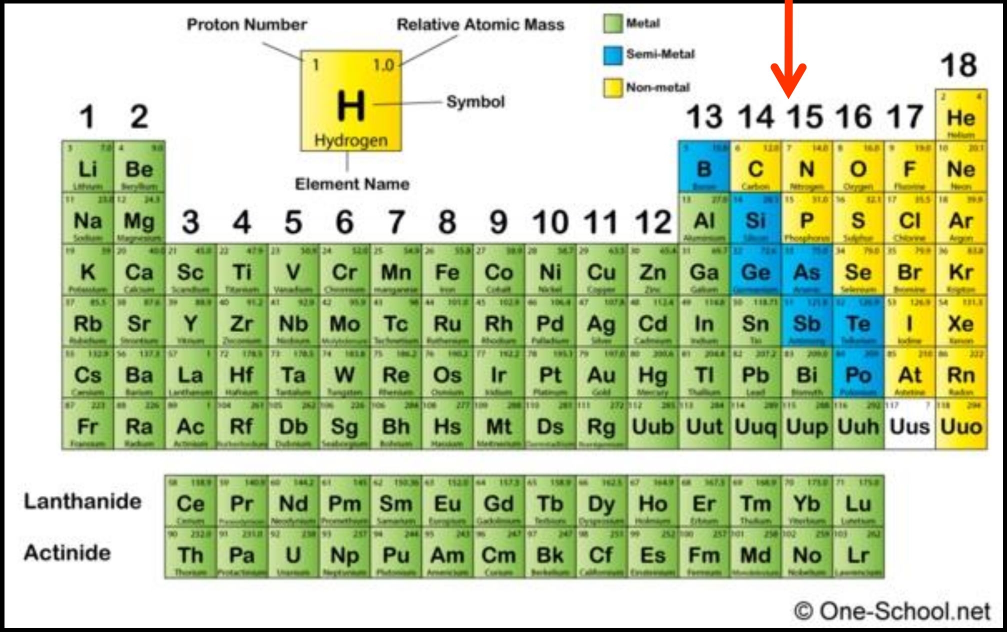
Anion Nomenclature

Name: Base element ending in –ide + Ion



H^-	hydride ion
F^-	fluoride ion
Cl^-	chloride ion
Br^-	bromide ion
O^{2-}	oxide ion
S^{2-}	sulfide ion
N^{3-}	nitride ion
P^{3-}	phosphide ion

Non-Metals



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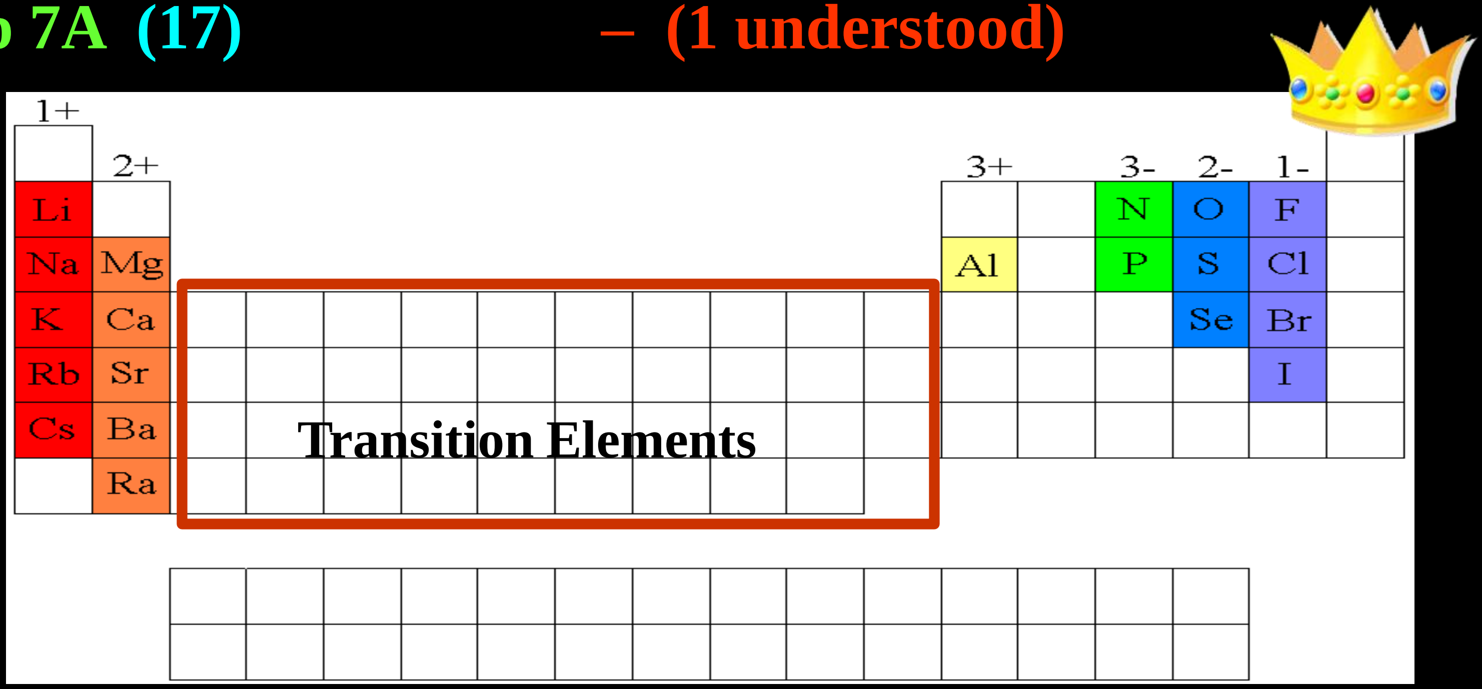
Predicting Charge

Group 1A (1)	+ (1 understood)
Group 2A (2)	2+
Group 3A (13)	3+
Transition (3-12)	form cations with various charges
Group 5A (15)	3–
Group 6A (16)	2–
Group 7A (17)	– (1 understood)



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Common Mono-Atomic Ions

The Roman numeral in the formula gives the oxidation state

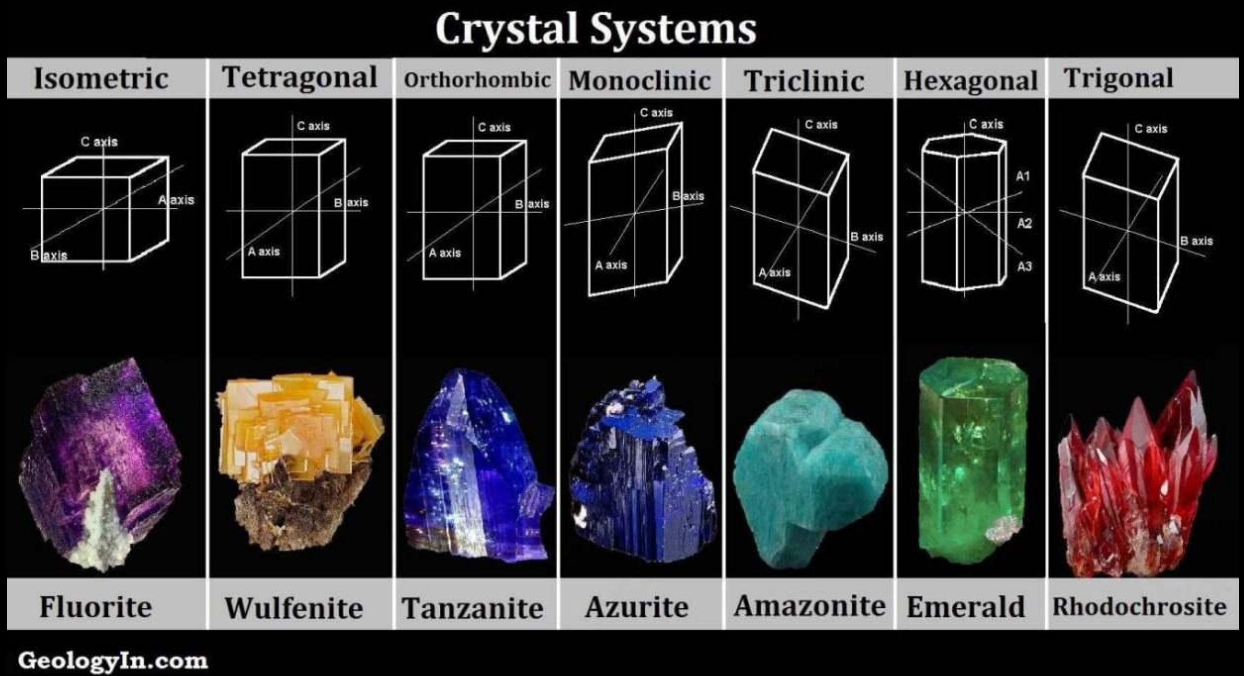
Iron (III) Oxide	Fe_2O_3
Lead (IV) Chloride	$PbCl_4$
Copper (I) Sulfate	Cu_2SO_4
Copper (II) Sulfate	$CuSO_4$
Mercury (II) Phosphate	$Hg_3(PO_4)_2$

1+	2+											3+		3–	2–	1–	
H^+																H^-	
Li^+	Be^{2+}													N^{3-}	O^{2-} O_2^{2-}	F^-	
Na^+	Mg^{2+}											Al^{3+}		P^{3-}	S^{2-}	Cl^-	
K^+	Ca^{2+}				Cr^{2+} Cr^{3+}	Mn^{2+} Mn^{3+}	Fe^{2+} Fe^{3+}	Co^{2+} Co^{3+}	Ni^{2+}	Cu^+ Cu^{2+}	Zn^{2+}					Br^-	
										Ag^+			Sn^{2+} Sn^{4+}			I^-	
	Ba^{2+}										Hg_2^{2+} Hg^{2+}		Pb^{2+} Pb^{4+}				

Ionic Compounds

Contain charged particles, ions

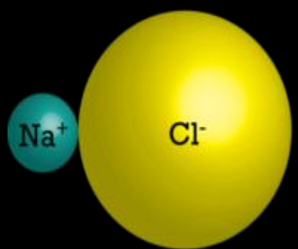
Compound is neutral (+ and – charges equal)
Not discrete "Molecule"; 3–d arrays of (+) and (–) ions



Typically: metal + (non-metal or polyatomic ion)

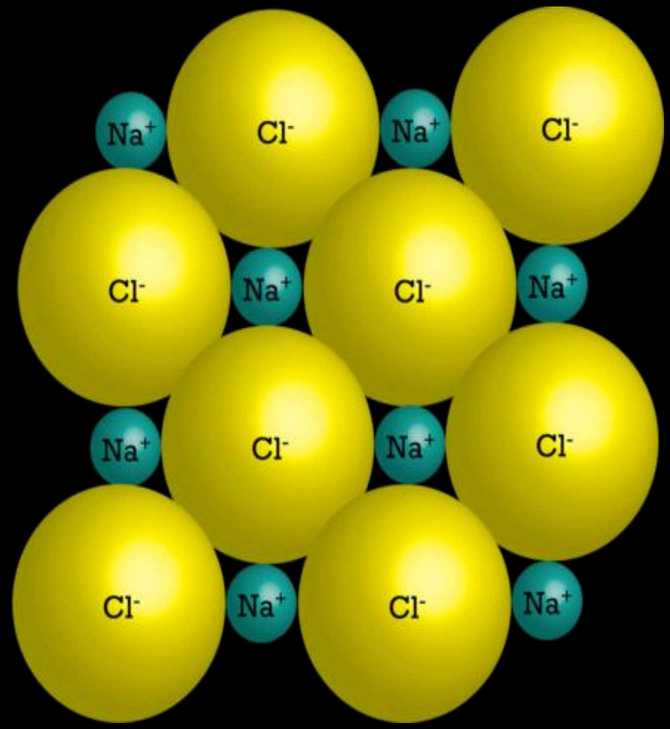
Observed Crystal Reflects Atomic Level Geometry

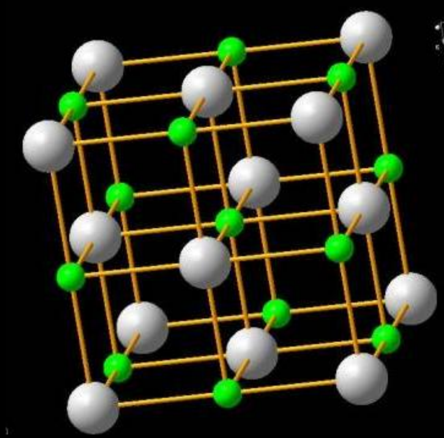
Formula Unit



Simplest Ratio
Cannot Isolate

Ionic Crystal

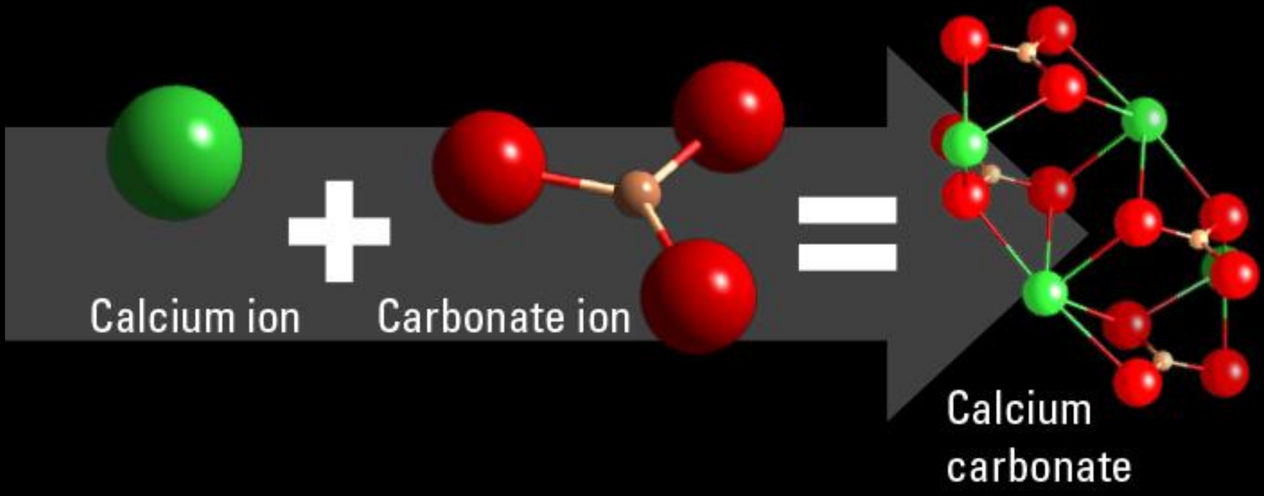


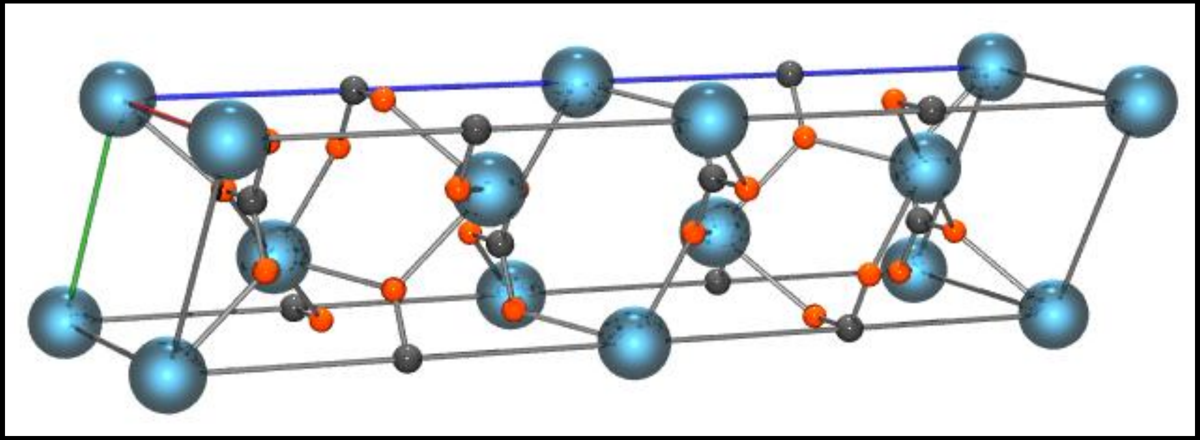


Cubic Array
Of Ions

Observed Crystal Reflects Atomic Level Geometry

Calcite





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Ionic compounds formed between:

Na^+	and	Cl^-	$NaCl$
K^+	and	Br^-	KBr
Ca^{2+}	and	F^-	CaF_2
Ba^{2+}	and	S^{2-}	BaS
Li^+	and	S^{2-}	Li_2S
Al^{3+}	and	O^{2-}	Al_2O_3
Mg^{2+}	and	N^{3-}	Mg_3N_2

Total + charge = total – charge

and

Keep simplest ratio of atoms

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Subscript Trick

Quick way to balance charges

Cation +Charge   Anion –charge

Cation   Anion

Ca^{2+} NO_3^{-}

Ca^{2+} NO_3^{-}

$Ca(NO_3)_2$

Al^{3+} Cl^{-}

Al^{3+} Cl

$AlCl_3$

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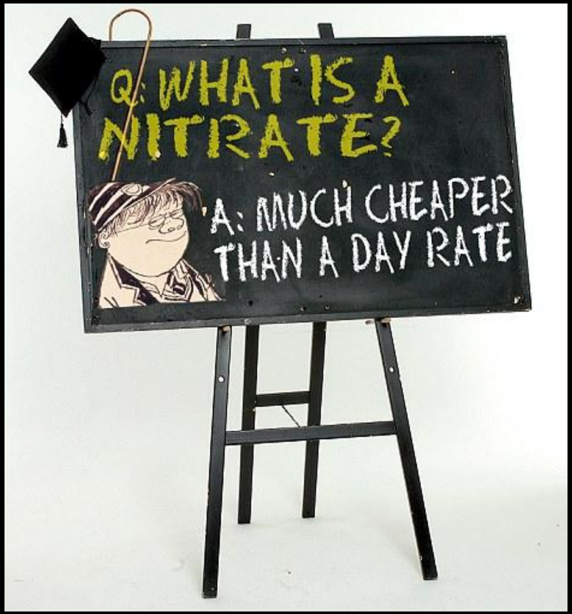
Memorized Polyatomic Ions

Ammonium	$(NH_4)^+$
Acetate	$(C_2H_3O_2)^-$ or $(CH_3COO)^-$
Hydroxide	$(OH)^-$
Chlorate	$(ClO_3)^-$
Chlorite	$(ClO_2)^-$
Nitrate	$(NO_3)^-$
Nitrite	$(NO_2)^-$
Sulfate	$(SO_4)^{2-}$
Hydrogen sulfate	$(HSO_4)^-$
Sulfite	$(SO_3)^{2-}$
Carbonate	$(CO_3)^{2-}$
Hydrogen carbonate	$(HCO_3)^-$
Phosphate	$(PO_4)^{3-}$



Cannot predict charge from periodic table

Compounds Containing Polyatomic Ions

Charged species containing more than one atom

Treat as single entity : (+) and (–) charges must balance

More than one polyatomic ion, use ( ) and subscript

NH_4^{+} and SO_4^{2-} = $(NH_4)_2SO_4$

Ca^{2+} and OH^{-} = $Ca(OH)_2$

Mg^{2+} and PO_4^{3-} = $Mg_3(PO_4)_2$

Total + charge = total - charge

LPT

Naming Ionic Compounds

name the cation, then the anion as -ide

BaF_2	barium fluoride	
CaF_2	calcium fluoride	
$NaBr$	sodium bromide	
Mg_3N_2	magnesium nitride	
Al_2O_3	aluminum oxide	(alumina)
Li_3P	lithium phosphide	
AlN	aluminum nitride	
$CuCl_2$	copper (II) chloride	(cupric chloride)
$CuCl$	copper (I) chloride	(cuprous chloride)
FeN	iron (III) nitride	(ferric nitride)
Fe_3N_2	iron (II) nitride	(ferrous nitride)
$SnCl_4$	tin (IV) chloride	(stannic chloride)
$SnCl_2$	tin (II) chloride	(stannous chloride)

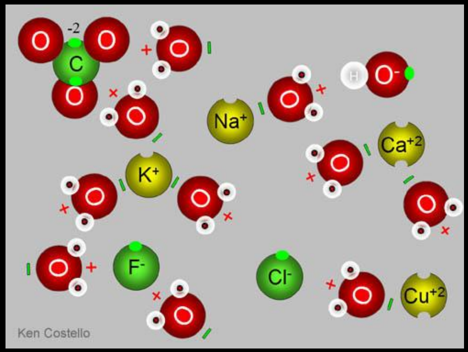
Naming Compounds Containing Polyatomic Ions

Name cation

(not "representative" ➔ charge in parenthesis)

Name anion

$(NH_4)_2SO_4$	Ammonium Sulfate
$Co(NO_3)_3$	Cobalt (III) Nitrate
$PbCO_3$	Lead (II) Carbonate
$Pb(CO_3)_2$	Lead (IV) Carbonate
$Mg_3(PO_4)_2$	Magnesium Phosphate
Cu_2SO_4	Copper (I) Sulfate
$CuSO_4$	Copper (II) Sulfate
$NaClO_3$	Sodium Chlorate



Roman Numeral is the charge, not the subscript

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Name to Formula: Representative Cation & Anion

Magnesium Oxide

1. Write Symbols for Cation and Anion

   Mg O

2. Add Charges (from periodic table)

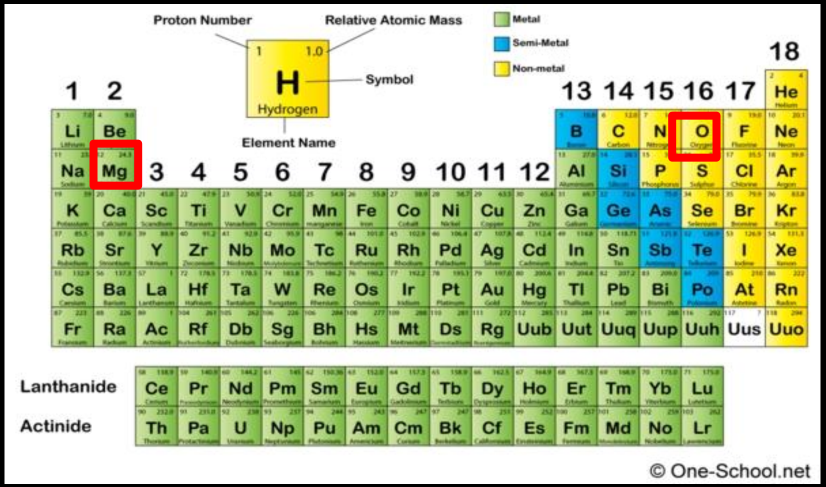
   Mg^{2+} O^{2-}

3. Use Subscript trick to generate element subscripts

   Mg_2O_2

4. Divide all subscripts by common number (if possible)

   MgO



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Name to Formula: Representative Cation & Polyatomic Anion

Sodium Sulfate | **Calcium Phosphate**

1. **Write Symbols for Cation and Anion**

   $Na\ \ SO_4$ | $Ca\ \ PO_4$

2. **Add Charges (from periodic table & memory)**

   $Na^{+}\ \ SO_4^{2-}$ | $Ca^{2+}\ \ PO_4^{3-}$

3. **Use Subscript trick to generate element subscripts**

   Na_2SO_4 | $Ca_3(PO_4)_2$

4. **Divide all subscripts by common number (if possible)**

   Na_2SO_4 | $Ca_3(PO_4)_2$

( ) used to indicate polyatomic group as a unit
Formula unit contains 3 Ca^{2+} and 2 PO_4^{3-} ions

Name to Formula: Transition Metal Cation & Anion

Iron (III) Oxide (Roman Numeral is cation charge)

1. Write Symbols for Cation and Anion

   Fe O

2. Add Charges (from Roman Numeral & Periodic Table)

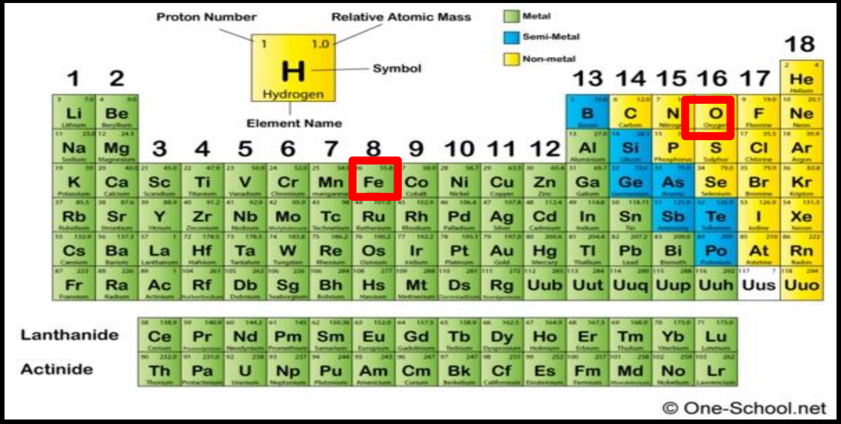
   Fe^{3+} O^{2-}

3. Use Subscript trick to generate element subscripts

   Fe_2O_3

4. Divide all subscripts by common number (if possible)

   Fe_2O_3



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Name to Formula: Transition Metal Cation & Polyatomic Anion

Copper (II) Sulfate (Roman Numeral is cation charge)

1. **Write Symbols for Cation and Anion**

   Cu SO_4

2. **Add Charges (from Roman Numeral & Memory)**

   Cu^{2+} SO_4^{2-}

3. **Use Subscript trick to generate element subscripts**

   $Cu_2 (SO_4)_2$

4. **Divide all subscripts by common number (if possible)**

   $CuSO_4$

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Acids

Molecular Compounds that produce H^+ in solution

Binary Acids = Hydrogen + nonmetal

HYDRO + ROOT + IC ACID

H_2S	hydrosulfuric acid (hydrogen sulfide)
HCl	hydrochloric acid (muriatic)
HBr	hydrobromic acid
HI	hydroiodic acid
HF	hydrofluoric acid

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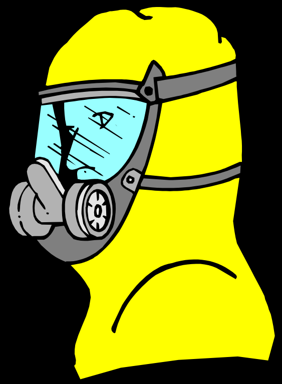
Oxy Acids

H + nonmetal + Oxygen   H + polyatomic ion

–ate ions   root+ic acid

–ite ions   root+ous acid

$HClO_3$	chloric acid
$HClO_2$	chlorous acid
H_2SO_4	sulfuric acid
H_2SO_3	sulfurous acid
HNO_3	nitric acid
HNO_2	nitrous acid



-ic acid: 1 more oxygen in the anion than –ous acid

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Hint: For "ates" and "ites"

Where X = N or Halide

Species	Acid	Salt
XO_4	per X ic	per X ate (more than –ate)
XO_3	X ic	X ate
XO_2	X ous	X ite
XO	hypo X ous	hypo X ite (less than ite)

For X = Chlorine

Acid	Anion
$HClO_4$ = perchloric	ClO_4^- = perchlorate
$HClO_3$ = chloric	ClO_3^- = chlorate
$HClO_2$ = chlorous	ClO_2^- = chlorite
$HClO$ = hypochlorous	ClO^- = hypochlorite

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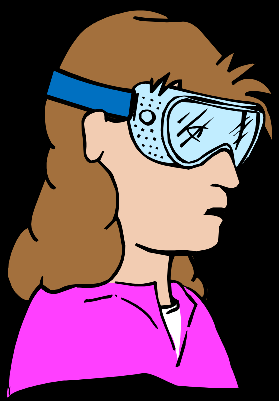
Formula for:

phosphoric acid	H_3PO_4
carbonic acid	H_2CO_3
acetic acid	$H(C_2H_3O_2)$ (HOAc)
hydrofluoric acid	HF
hydrosulfuric acid	H_2S



Most missed name in CEM 101

cation formula	anion formula	anion name	acid name	acid formula
H^+		sulfate		
H^+				HBr
H^+	NO_3^-			
H^+		phosphate		
H^+			sulfurous	
H^+	ClO_2^-			
H^+			hydroiodic	
H^+	CO_3^{2-}			

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cation formula	anion formula	anion name	acid name	acid formula
H^+	$SO_4{}^{2-}$	sulfate	sulfuric	H_2SO_4
H^+	Br^-	bromide	hydrobromic	HBr
H^+	NO_3^-	nitrate	nitric	HNO_3
H^+	$PO_4{}^{3-}$	phosphate	phosphoric	H_3PO_4
H^+	$SO_3{}^{2-}$	sulfite	sulfurous	H_2SO_3
H^+	ClO_2^-	chlorite	chlorous	$HClO_2$
H^+	I^-	iodide	hydroiodic	HI
H^+	CO_3^{2-}	carbonate	carbonic	H_2CO_3

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cation formula	anion formula	anion name	acid name	acid formula
H^+			acetic	
H^+	Cl^-			
H^+			hydrosulfuric	
H^+		chlorate		
H^+				HNO_2

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cation formula	anion formula	anion name	acid name	acid formula
H^+	$(C_2H_3O_2)^-$	acetate	acetic	$H(C_2H_3O_2)$
H^+	Cl^-	chloride	hydrochloric	HCl
H^+	S^{-2}	sulfide (sulphide)	hydrosulfuric	H_2S
H^+	$ClO_3^{\ -}$	chlorate	chloric	$HClO_3$
H^+	$NO_2^{\ -}$	nitrite	nitrous	HNO_2

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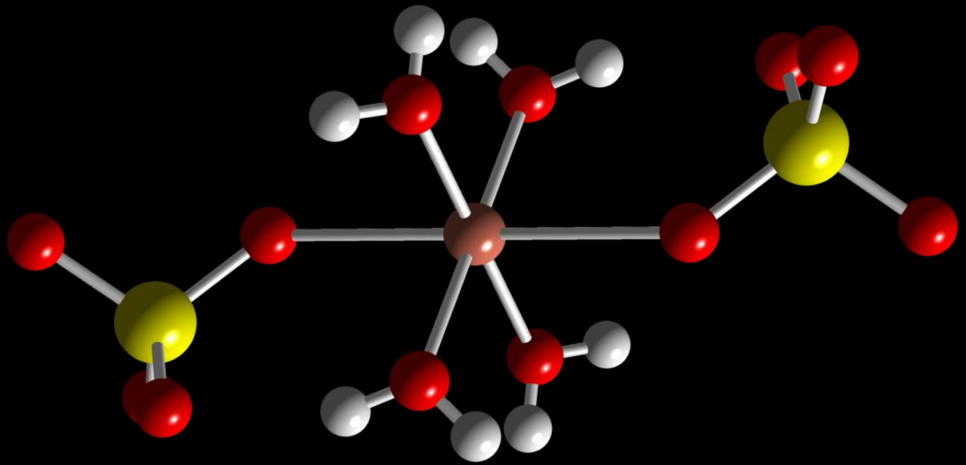
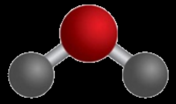
Hydrates

Absorb water from atmosphere

Water becomes associated with structure





Adding Water to Dry (anhydrous) $CuSO_4$

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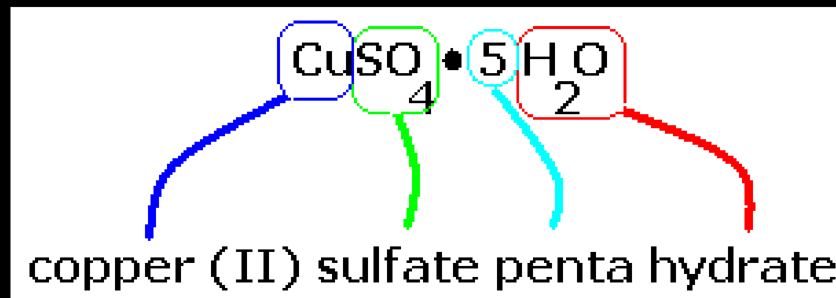
Naming Hydrates

Anhydrous (without water) name "• n H_2O's"



$CuSO_4 \bullet 5\ H_2O$
copper (II) sulfate pentahydrate

$Na_2CO_3 \bullet 10\ H_2O$
sodium carbonate decahydrate

$CaSO_4 \bullet 2\ H_2O$
calcium sulfate dihydrate

- Indicates distinct chemical entities held together

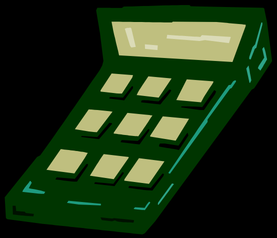
Composition Calculations

Find the percent water present in the hydrate $CuSO_4 \cdot 5\ H_2O$

Cu = 63.55	
S = 32.07	10 H = 10.08
4 O = 64.00	5 O = 80.00
Total = 159.62	Total = 90.08

$$\% \text{ Water} = \frac{90.08}{159.62 + 90.08} \times 100 = 36.08$$

(249.70)



36.08 % = 0.3608

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Desiccants

Compounds that absorb water to form hydrates

Used to protect variety of commercial products

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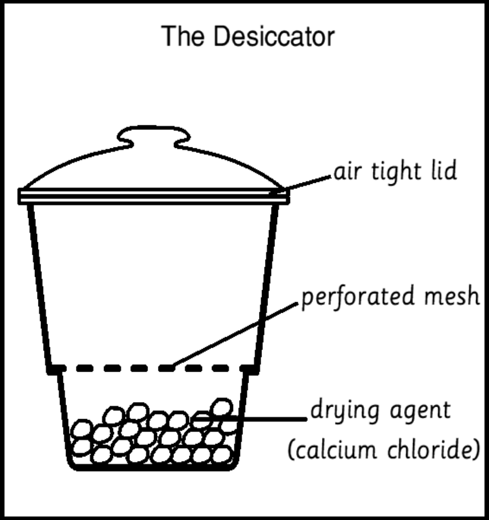
Lab Desiccators

Used to Keep Sensitive Chemicals Dry

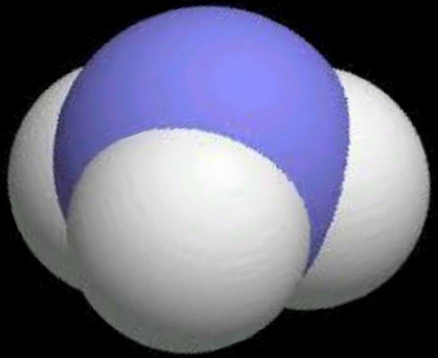


Two common names you need to know

H_2O water

Dihydrogen Monoxide

NH_3 ammonia



Nitrogen Trihydride

These are molecular compounds

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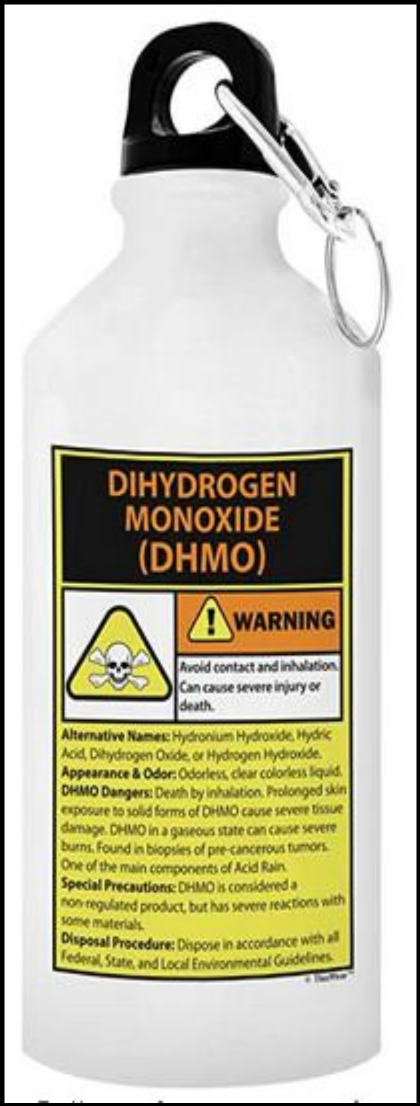
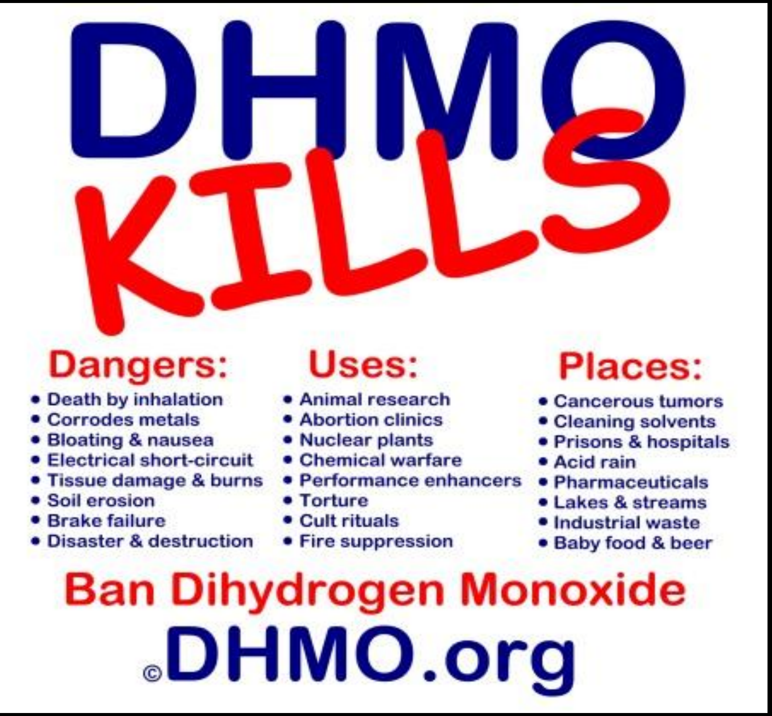
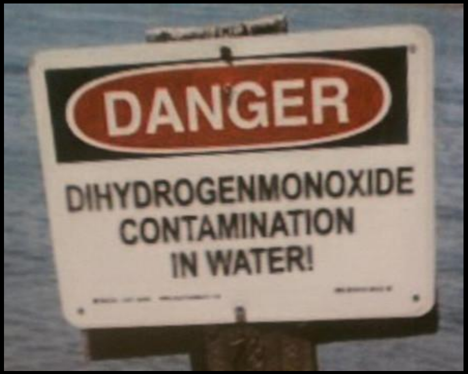
Dihydrogen Monoxide (DHMO)







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Common Names

Alumina	aluminum oxide	Al_2O_3
Baking Soda	sodium hydrogen carbonate	$NaHCO_3$
Baking Soda	sodium bicarbonate	$NaHCO_3$
Cream of Tarter	potassium hydrogen tartrate	$KHC_2H_4O_6$
Epsom Salt	magnesium sulfate heptahydrate	$MgSO_4 \cdot 7\ H_2O$
Grain Alcohol	ethanol	C_2H_5OH
Lye	sodium hydroxide	$NaOH$
Potash	potassium carbonate	K_2CO_3
Quicksilver	mercury	Hg
Washing Soda	sodium carbonate decahydrate	$Na_2CO_3 \cdot 10\ H_2O$
Wood Alcohol	methanol	CH_3OH

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Table 6.9 Summary of Nomenclature System

Substance	Name	Formula
Element	Name of element	Symbol of element; exceptions: H_2, N_2, O_2, F_2, Cl_2, Br_2, I_2
Compounds made up of two nonmetals	First element in formula followed by second, changed to end in *-ide,* each element preceded by prefix to show the number of atoms in the molecule	Symbol of first element in name followed by symbol of second element, with subscripts to show number of atoms in molecule
Acid	Most common: middle element changed to end in *-ic* One more oxygen than *-ic* acid: add prefix *per-* to name of *-ic* acid One fewer oxygen than *-ic* acid: change ending of *-ic* acid to *-ous* Two fewer oxygens than *-ic* acid: add prefix *hypo-* to name of *-ous* acid No oxygen: Prefix *hydro-* followed by name of second element changed to end in *-ic*	H followed by symbol of nonmetal followed by O (if necessary), each with appropriate subscript. *Memorize the following:* Chloric acid $HClO_3$ Nitric acid HNO_3 Sulfuric acid H_2SO_4 Carbonic acid H_2CO_3 Phosphoric acid H_3PO_4
Monatomic cation	Name of element followed by ion; if element forms more than one monatomic cation, elemental name is followed by ion charge in Roman numerals and in parentheses	Symbol of element followed by superscript to indicate charge
Monatomic anion	Name of element changed to end in *-ide*	Symbol of element followed by superscript to indicate charge
Polyatomic anion from total ionization of oxyacid	Replace *-ic* in acid name with *-ate,* or replace *-ous* in acid name with *-ite,* followed by ion	Acid formula without hydrogen plus superscript showing negative charge equal to number of hydrogens removed from acid formula
Polyatomic anion from step-by-step ionization of oxyacid	Hydrogen followed by name of ion from total ionization of acid (dihydrogen in the case of $H_2PO_4^-$)	Acid formula minus one (or two for H_3PO_4) hydrogen(s), plus superscript showing negative charge equal to number of hydrogen removed from acid formula
Other polyatomic ions	Ammonium ion Hydroxide ion	NH_4^+ OH^-
Ionic compound	Name of cation followed by name of anion	Formula of cation followed by formula of anion, each taken as many times as necessary to yield a net charge of zero (polyatomic ion formulas enclosed in parentheses if taken more than once)
Hydrate	Name of anhydrous compound followed by (number prefix)hydrate, where (number prefix) indicates the number of water molecules associated with one formula unit of anhydrous compound	Formula of anhydrous compound followed by "· n H_2O" where n is number of water molecules associated with one formula unit of anhydrous compound

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Which of these are ionic compounds?

Na_2O **I** — Sodium Oxide

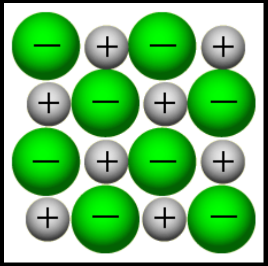
H_2S **M** — Hydrosulfuric Acid

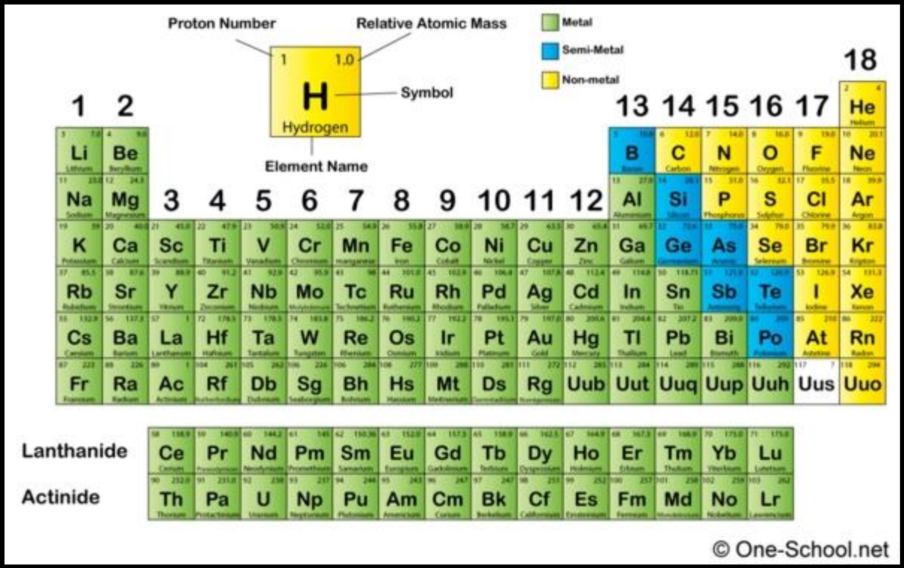
$CaBr_2$ **I** — Calcium Bromide

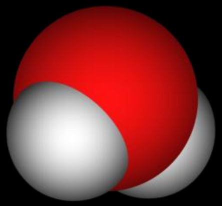
PCl_3 **M** — Phosphorus Trichloride

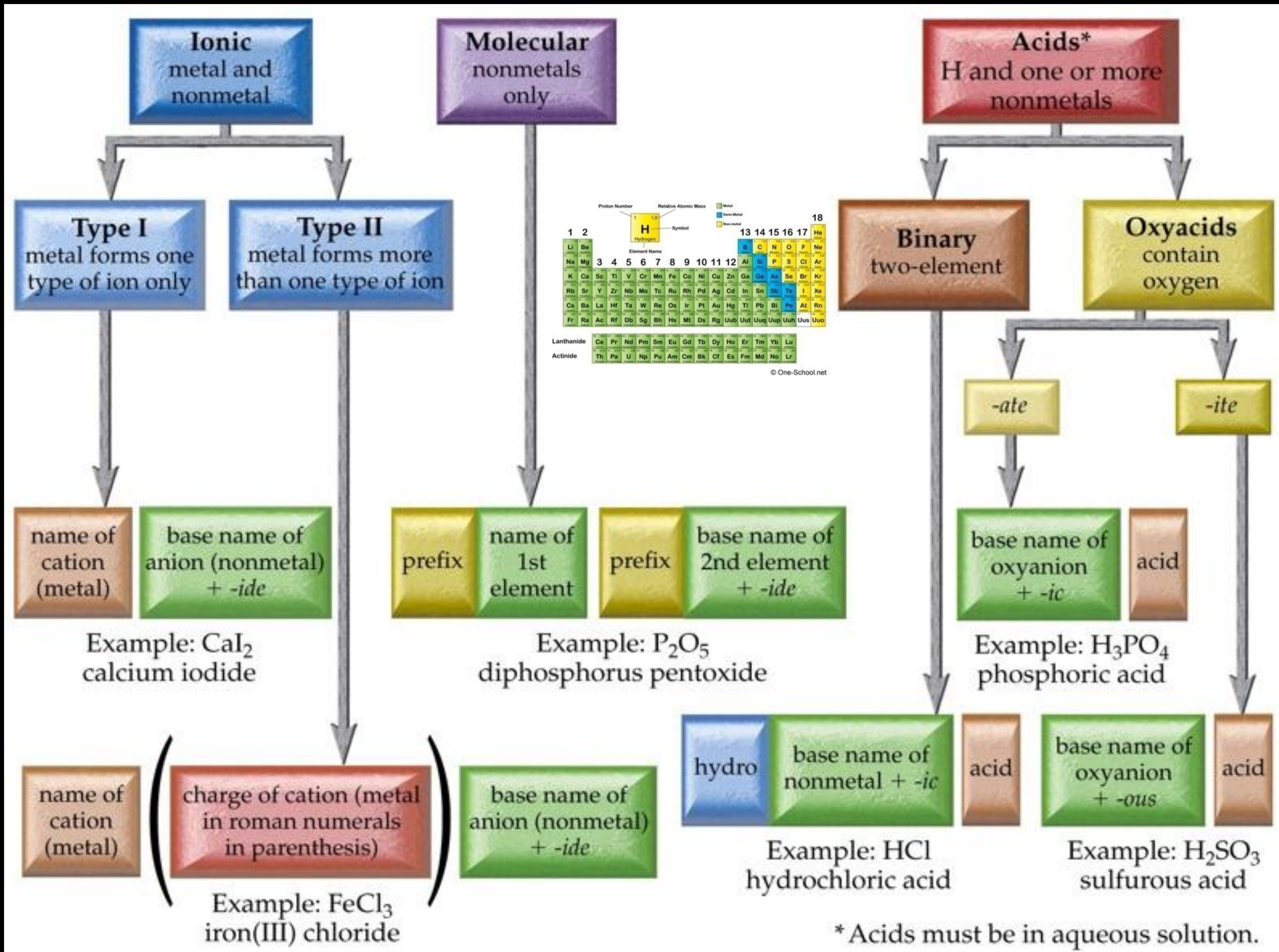
AgI **I** — Silver Iodide

Fe_2S_3 **I** — Iron (III) Sulfide








Ionic
metal and nonmetal
Molecular
nonmetals only
Acids*
H and one or more nonmetals
Type I
metal forms one type of ion only
Type II
metal forms more than one type of ion
Binary
two-element
Oxyacids
contain oxygen
-ate
-ite
name of cation (metal)
base name of anion (nonmetal) + -ide
Example: CaI_2
calcium iodide
prefix
name of 1st element
prefix
base name of 2nd element + -ide
Example: P_2O_5
diphosphorus pentoxide
base name of oxyanion + -ic
acid
Example: H_3PO_4
phosphoric acid
name of cation (metal)
charge of cation (metal in roman numerals in parenthesis)
base name of anion (nonmetal) + -ide
Example: $FeCl_3$
iron(III) chloride
hydro
base name of nonmetal + -ic
acid
Example: HCl
hydrochloric acid
base name of oxyanion + -ous
acid
Example: H_2SO_3
sulfurous acid
* Acids must be in aqueous solution.
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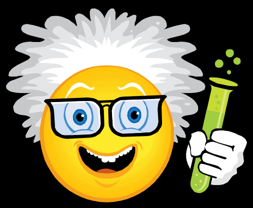


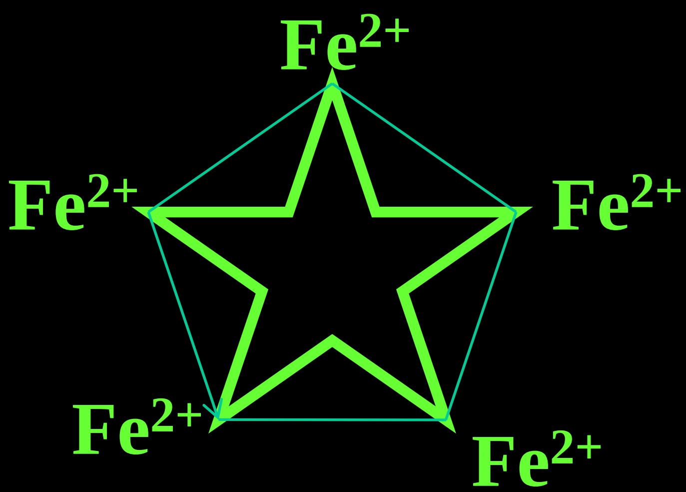
These Will Not Be On The Test

HIOAg = Hi O Silver

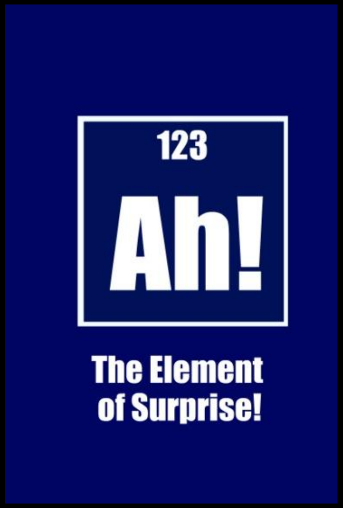
CH_2O = Sea Water

$BaNa_2$ = Banana

HIJKLMNO = Water (H to O)



Ferrous Wheel



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