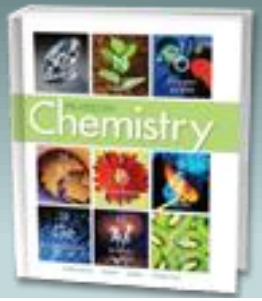
Chapter 9

Chemical Names and Formulas

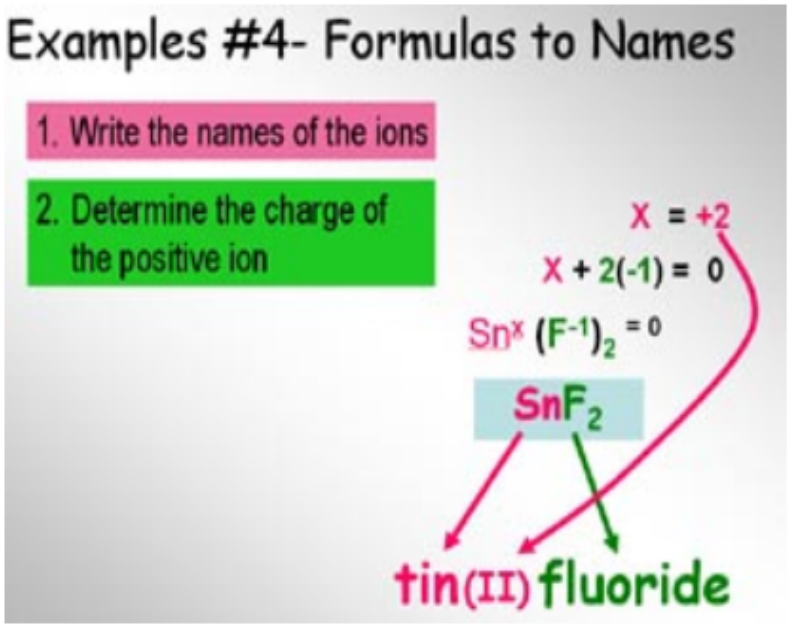
Naming and Writing Formulas for

- Ionic Compounds
- Molecular Compounds
- Acids and Bases

The Laws Governing How Compounds Form



FORMULAS CHAPTER 9A



Topics:

1. Chemical Names and Formulas

Objectives:

1. Explain how to determine the charges of monatomic ions.
2. Apply the rules for naming and writing formulas for compounds with polyatomic ions.
3. Determine the names and formulas of ionic and covalent compounds, of acids and bases.
4. Understand Law of Definite Proportions

Inquiry: Use Your Knowledge of Algebra in Chemistry

WARM-UP

Ionic compounds can be made from a m_____ ion and a ___metallic ion. Metallic ions are p_____ (c_____). Nonmetallic ions are n_____ (a_____). Find the net charge when the following atoms combine (use octet rule):

Alkali metal + halogen

Alkaline earth metal + Group VIA

Group IA and Group VIA

Group IIIA and Group VIIA

Group IIA and Group VA

M(+1) + (–2) = 0 Groups?
What does M have to be? ____

(+2) + N(–1) = 0 Groups?
What does N have to be? ____

M(+2) + N(–3) = 0 Groups?
What do M and N have to be?

M(+3) + N(–3) = 0 Groups?
What do M and N have to be?

_____

(+3) + N(–1) = 0 Groups?
What does N have to be? ____

Inquiry: Use Your Knowledge of Algebra in Chemistry

WARM-UP

Ionic compounds can be made from a metallic ion and a nonmetallic ion.
Metallic ions are positive (cations).
Nonmetallic ions are negative (anions).
Find the net charge when the following atoms combine (use octet rule):

Alkali metal + halogen

(+1) + (–1) = 0

Alkaline earth metal + Group VIA

(+2) + (–2) = 0

Group IA and Group VIA

2(+1) + (–2) = 0

Group IIIA and Group VIIA

(+3) + 3(–1) = 0

Bonding requires:
- *Electrical neutrality*
- *Full valence*

Group IIA and Group VA

3(+2) + 2(–3) = 0

M(+1) + (–2) = 0 Group IA + VIA
What does M have to be? 2

(+2) + N(–1) = 0 Group IIA + VIIA
What does N have to be? 2

M(+2) + N(–3) = 0 Group IIA + VA
What do M and N have to be?

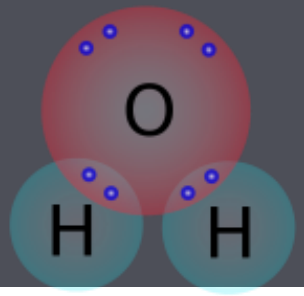
M = 3 and N = 2

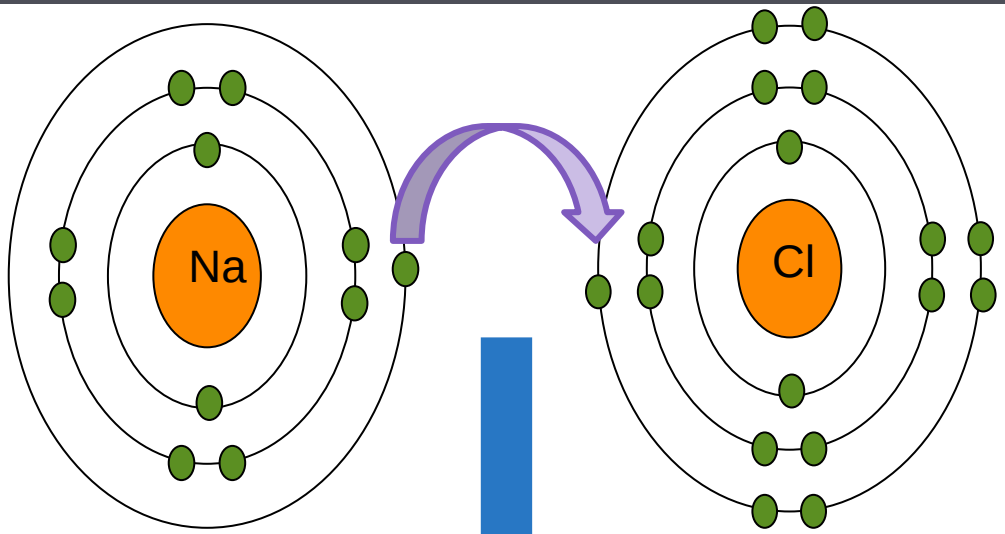
M(+3) + N(–3) = 0 Group IIIA + VA
What do M and N have to be?

M = 1 and N = 1

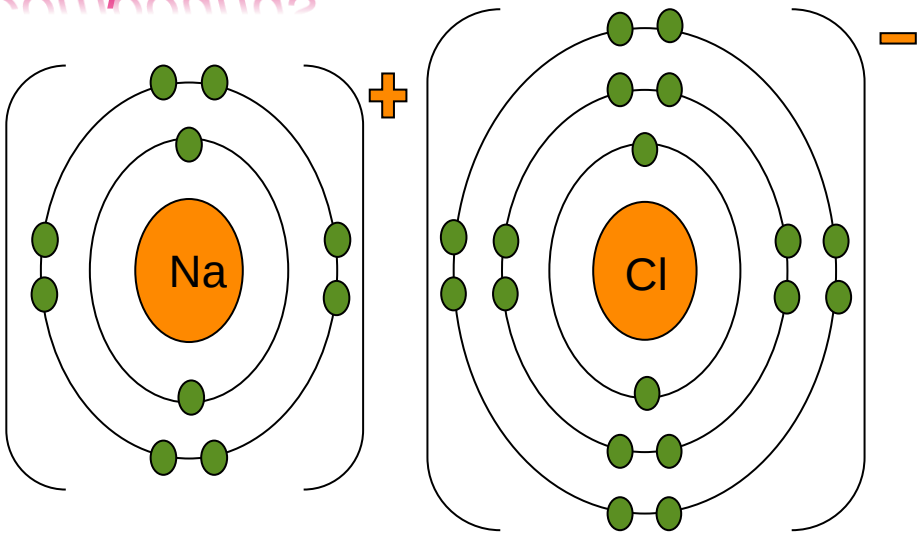
(+3) + N(–1) = 0 Group IIIA + VIIA
What does N have to be? 3

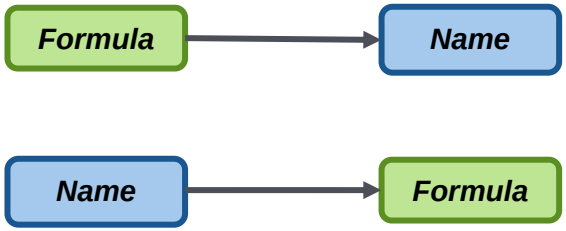
What are the Basics of Naming Compounds and Molecules?

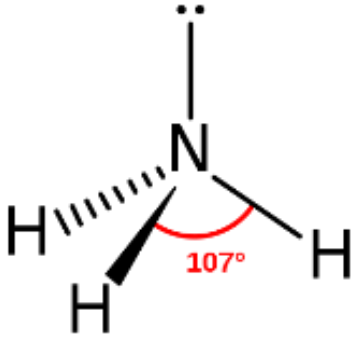




Ionic Compounds







Ammonia

Covalent Molecules

Chemical Symbols

Chemical Symbols on the Periodic Table are a Shorthand for the elements **— Symbols are either ONE or TWO letters**

- *The first letter is ALWAYS capitalized, while the second letter is small case* *Na (for sodium)*

Letters for the symbols are derived in various ways:

Use the first letter of the Chemical Element

Use the first and second letter of the Chemical Element.

Use the first and third letter of the Chemical Element.

Some symbols are derived from the Latin origin of the element.

Chemical Symbols

Chemical Symbols on the Periodic Table are a Shorthand for the elements **— Symbols are either ONE or TWO letters**

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Letters for the symbols are derived in various ways:

Use the first letter of the Chemical Element

Carbon, Nitrogen, Boron, Hydrogen

Use the first and second letter of the Chemical Element.

Beryllium (Be), Helium (He), Neon (Ne), Calcium (Ca), Lithium (Li)

Use the first and third letter of the Chemical Element.

Cesium (Cs), Chlorine (Cl), Magnesium (Mg)

Some symbols are derived from the Latin origin of the element.

e.g. Mercury (Hg), Sodium (Na), Tin (Sn), Silver (Ag), Gold (Au), Iron (Fe), Potassium (K), Tungsten (W), etc.

Chemical Formulas

Chemical Formulas are used to represent the composition of elements in a compound or molecule.

Subscripts

Indicate the number of atoms within ONE compound or molecule

$$Ca(ClO_3)_2 \rightarrow CaCl_2 + \_\_ O_2\,(g)$$

Chemical Formulas

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Subscripts

Indicate the number of atoms within ONE compound or molecule

$$Ca(ClO_3)_2 \rightarrow CaCl_2 + \_\_\ O_2\ (g)$$

$$ClO_3 + ClO_3 = 2\ Cl + 6\ O$$

Notice, that there are 6 oxygen atoms on the left (reactants) but only 2 on the right (products) …

Chemical Formulas

Coefficients are used to balance chemical equations:

Coefficients

Indicate the number of compounds or molecules (“moles”) and are used to balance Chemical Equations or reactants & products

$$Ca(ClO_3)_2 \rightarrow CaCl_2 + 3\ O_{2\ (g)}$$

$$Ca(ClO_3)_2 \rightarrow CaCl_2 + O_{2\ (g)} + O_{2\ (g)} + O_{2\ (g)}$$

There are the same number of each element on each side of the equation.

1 Ca, 2 Cl, 6 O → 1 Ca, 2 Cl, 6 O

Typical Patterns of Ions

Metals:

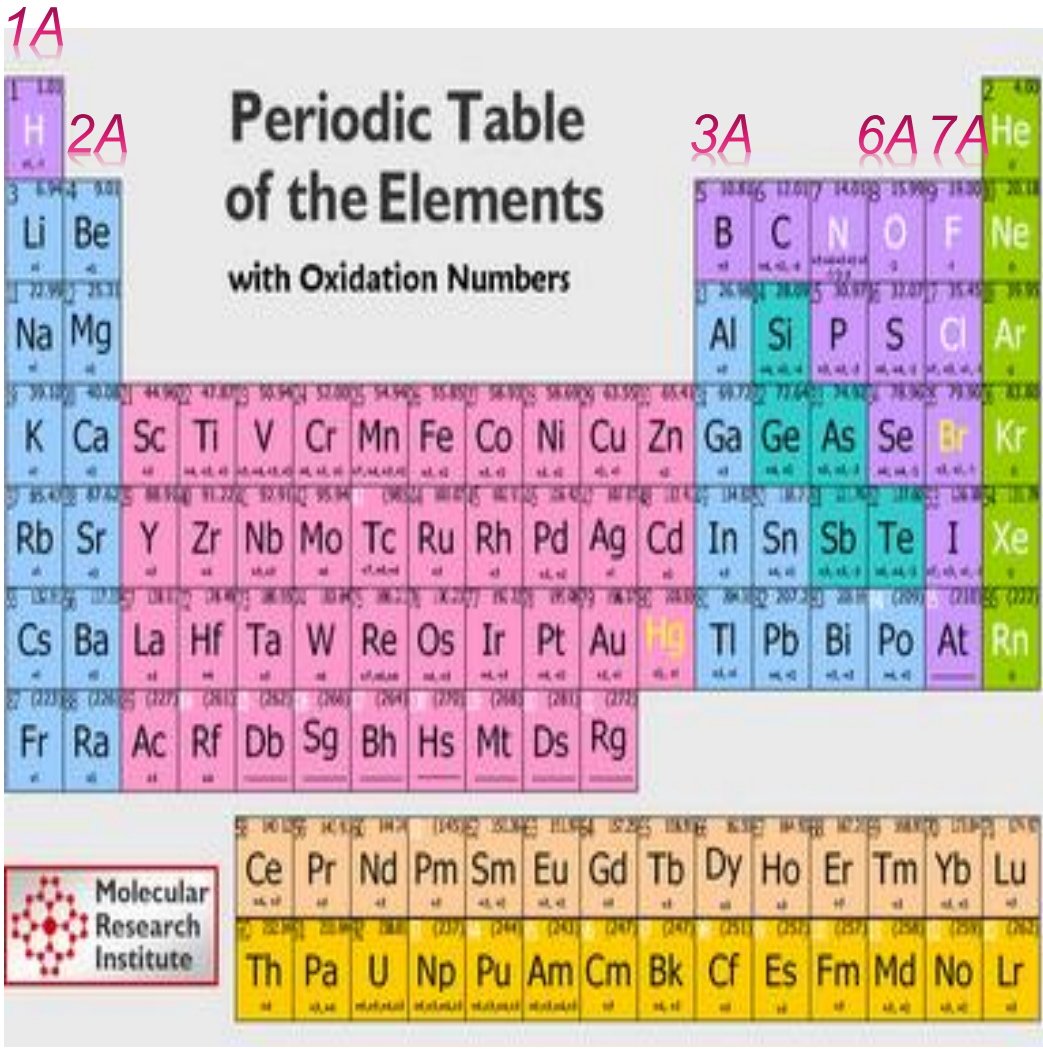
form cations (positive charge)

- Group IA: +1
- Group IIA: +2
- Group IIIA: +3

Nonmetals:

form anions (negative charge)

- Group 16 (VIA): –2
- Group 17 (VIIA): –1



STRATEGY Naming Ionic Compounds

Nomenclature: "rules" for "naming" compounds

- Name the cation(s) first, then anion(s)
- Metal cations: name of metal ("as is")
- Nonmetal anions: replace ending with *-ide*

Example

- KBr
  - K^{+1} = potassium cation
  - Br^{1-} = bromide anion

Name: potassium bromide

Write the Chemical Name from the formula (Identify the cations & anions using the Octet rule)

QUICK CHECK

LiBr

$CaCl_2$

MgS

Na_3N

Al_2O_3

BF_3

Write the Chemical Name from the formula (Identify the cations & anions using the Octet rule)

QUICK CHECK

$LiBr$

Li^+ = lithium cation

Br^- = Bromide anion

Name → lithium bromide

MgS

Mg^{2+} = magnesium cation

S^{-2} = sulfide anion

Name → magnesium sulfide

Al_2O_3

Al^{+3} = aluminum cation

O^{-2} = oxide anion

Name → aluminum oxide

$CaCl_2$

Ca^{2+} = calcium cation

Cl^- = chloride anion

Name → calcium chloride

Na_3N

Na^+ = sodium cation

N^{3-} = nitride anion

Name → sodium nitride

BF_3

B^{+3} = boron cation

F^- = fluoride anion

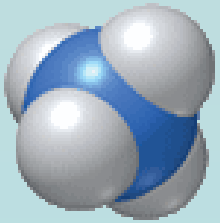
Name → boron fluoride

Note: for IONIC compounds, the number of atoms does NOT matter in the naming.

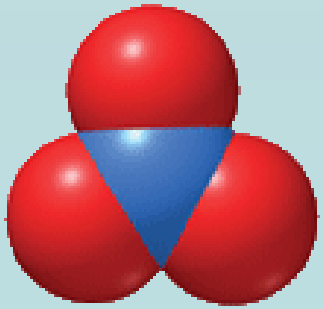
Polyatomic Ions

Polyatomic ions are covalently bonded atoms (composed of more than one atom), which behave as ONE unit and carries a charge.

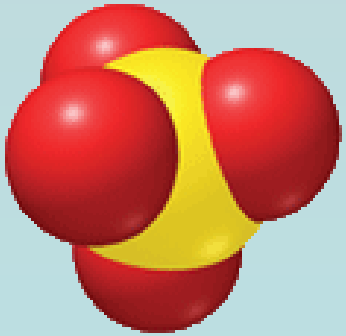
The sulfate anion (SO_4^{2-}) consists of one sulfur atom and four oxygen atoms, but chemically acts as ONE molecule. These five atoms together comprise a single anion with an overall 2– charge.



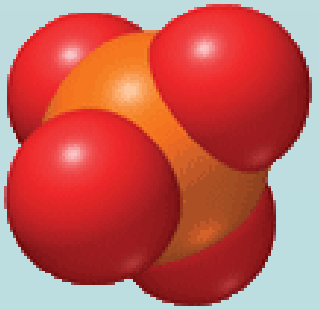
Ammonium ion
(NH_4^+)



Nitrate ion
(NO_3^-)



Sulfate ion
(SO_4^{2-})



Phosphate ion
(PO_4^{3-})

The atoms are held together by polar covalent bonds, but the overall polyatomic ion bonds IONICally.

Naming Polyatomic Ions

You may use a reference table when naming polyatomic ions (download from Course Resources).

Common Polyatomic Ions		
Charge	**Formula**	**Name**
1–	**HSO_4^-**	**Hydrogen sulfate**
	NO_2^-	**Nitrite**
	ClO^-	**Hypochlorite**
2–	**SO_3^{2-}**	**Sulfite**
	SO_4^{2-}	**Sulfate**
	CO_3^{2-}	**Carbonate**
3–	**PO_4^{3-}**	**Phosphate**
1+	**NH_4^+**	**Ammonium**

Name a polyatomic ion "as is" whether it is a cation or an anion.

Polyatomic ions may be listed first (cations) or last (anions).

e.g. $(NH_4^+)(PO_4^{3-})$
Ammonium phosphate

Using parenthesis helps.

Name the compounds & determine the # of atoms:

Ion Name	Formula
ammonium (uh moh' nee uhm)	NH_4^+
hydroxide (hye drox' ide)	OH^-
chlorate (klor' ate)	ClO_3^-
chlorite (klor' ite)	ClO_2^-
nitrate (nye' trate)	NO_3^-
nitrite (nye' trite)	NO_2^-
acetate (as' uh tate)	$C_2H_3O_2^-$

Ion Name	Formula
cyanide (sigh' uh nide)	CN^-
carbonate (kar' bun ate)	CO_3^{2-}
chromate (krohm' ate)	CrO_4^{2-}
dichromate (dye krohm' ate)	$Cr_2O_7^{2-}$
sulfate (suhl' fate)	SO_4^{2-}
sulfite (suhl' fite)	SO_3^{2-}
phosphate (fahs' fate)	PO_4^{3-}

$Na_3^+(PO_4^{3-})$

$(NH_4^+)_2(CO_3^{2-})$

$Mg^{+2}(ClO_3^-)_2$

$Al_2^{+3}(SO_4^{2-})_3$

Name the compounds & determine the # of atoms:

QUICK CHECK

Ion Name	Formula
ammonium (uh moh' nee uhm)	NH_4^+
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nitrite (nye' trite)	NO_2^-
acetate (as' uh tate)	$C_2H_3O_2^-$

Ion Name	Formula
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carbonate (kar' bun ate)	CO_3^{2-}
chromate (krohm' ate)	CrO_4^{2-}
dichromate (dye krohm' ate)	$Cr_2O_7^{2-}$
sulfate (suhl' fate)	SO_4^{2-}
sulfite (suhl' fite)	SO_3^{2-}
phosphate (fahs' fate)	PO_4^{3-}

$Na_3^+(PO_4^{3-})$ … 3 + 1 + 4 = 8 atoms

sodium phosphate

$(NH_4^+)_2(CO_3^{2-})$… 2 + 8 + 1 + 3 = 14 atoms

ammonium carbonate

$Mg^{+2}(ClO_3^-)_2$ … 1 + 2 + 6 = 9 atoms

magnesium chlorate

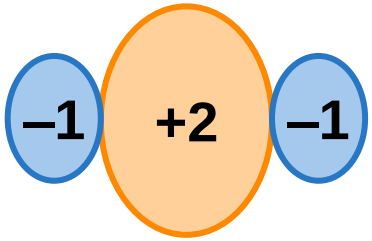
$Al_2^{+3}(SO_4^{2-})_3$ … 2 + 3+ 12 = 17 atoms

aluminum sulfate

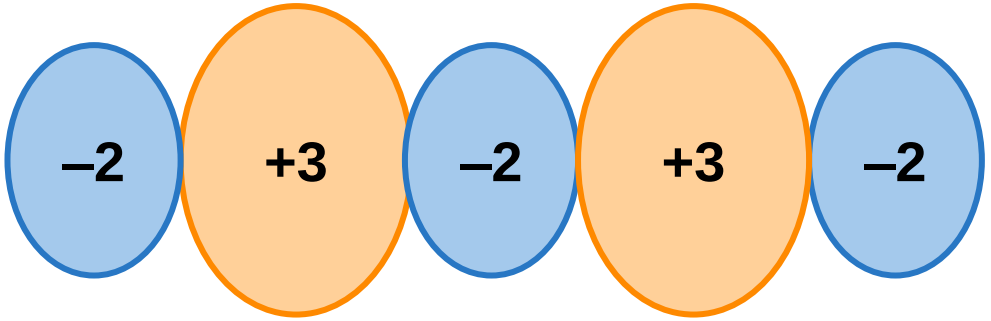
EXAMPLE

Balancing Charges

How many –1 ions would bond with a +2 ion?



What is the ratio of +3 ions to –2 ions in a neutral compound?



EXAMPLE

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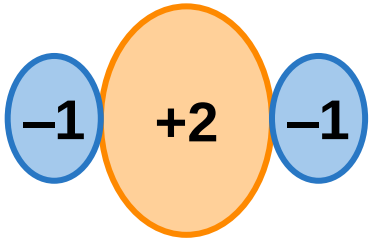
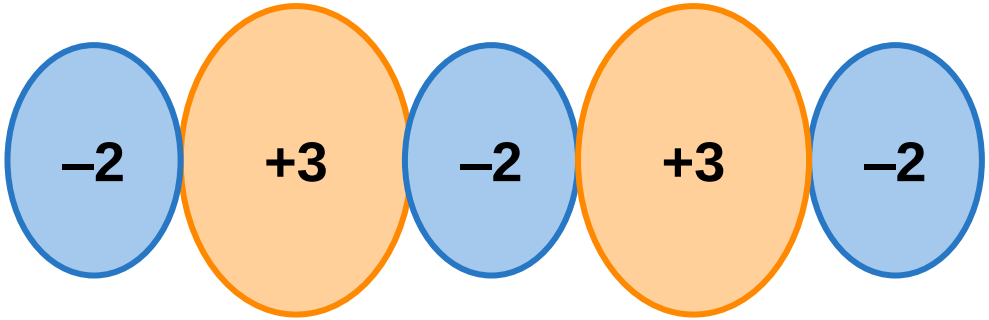


(+2) + N(–1) = 0

two -1 atoms balance the one +2 atom

What is the ratio of +3 ions to –2 ions in a neutral compound?



M(+3) + N(–2) = 0

Three -2 atoms balance two +3 atoms

Writing Chemical Formulas from the Name

Write the metallic "ion" (cation) first and the non-metallic "ion" (anion) last

- Metals lose electrons … therefore, become positively charged (cations)
- Non-metals gain electrons … become negatively charged (anions)

e.g. sodium chloride:

$Na^{+1}Cl^{-1}$

NOT $Cl^{-1}Na^{+1}$

Write the Chemical Formulas from the Name

sodium phosphate

ammonium carbonate

TRY IT

Write the Chemical Formulas from the Name

sodium phosphate

Sodium: Na^+ Phosphate: PO_4^{3-}

(3)(+1) + (–3) = 0

$Na_3^+(PO_4)^{3-}$

$Na^+(PO_4)^{3-}$

ammonium carbonate

Ammonium: NH_4^+ Carbonate: CO_3^{2-}

(2)(+1) + (–2) = 0

$(NH_4)_2^+(CO_3)^{-2}$

$NH_4^+(CO_3)^{2-}$

Writing Chemical Formulas using the Criss-Cross Method

The numerical value of the charge of each ion (oxidation state) is crossed over and becomes the subscript for the other ion.

Notice that the signs of the charges are dropped.

The formula is correct because the overall charge of the formula is zero, and the subscripts are expressed in the lowest whole-number ratio.

Write the chemical formula for Iron III Oxide

Writing Chemical Formulas using the Criss-Cross Method

The numerical value of the charge of each ion (oxidation state) is crossed over and becomes the subscript for the other ion.

Notice that the signs of the charges are dropped.

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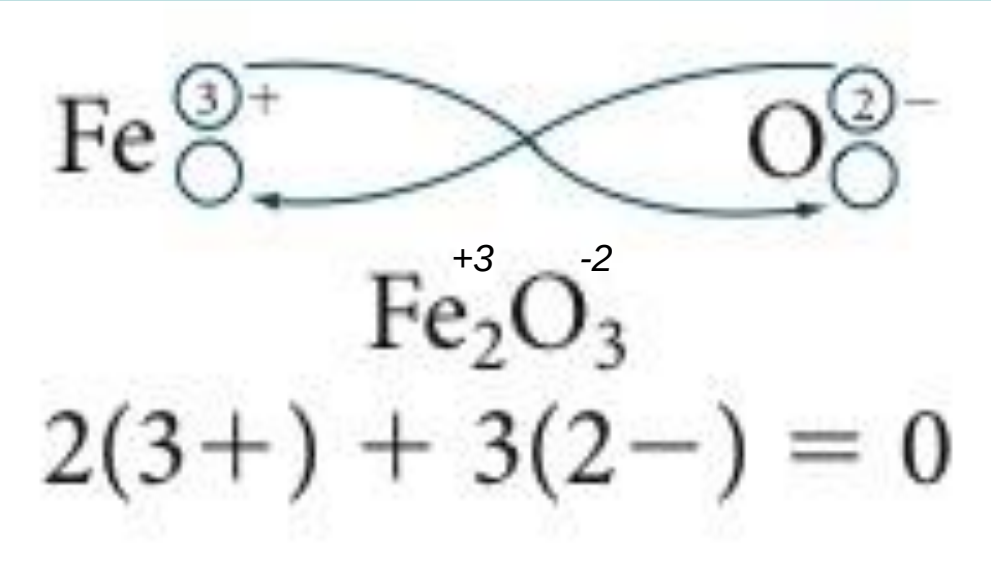


"Hey! Don't take the 'rejuvenescence' serum! I wrote the formula backwards!"
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Naming Covalent Molecules

Covalently bonded molecules usually involve non-metals bonding with non-metals.

Generally, the MORE electronegative element is listed SECOND because it draws the electrons more and becomes the "anion".

e.g. Carbon dioxide → carbon is named first because it is the less electronegative, more "metallic", than oxygen.

260 C 2.6	336 N 3.1	314 O 3.5	402 F 4.0
188 Si 1.9	242 P 2.2	239 S 2.6	300 Cl 3.2
182 Ge 1.9	226 As 2.0	225 Se 2.5	273 Br 2.9

Fluorine is always listed second (highest electronegativity).

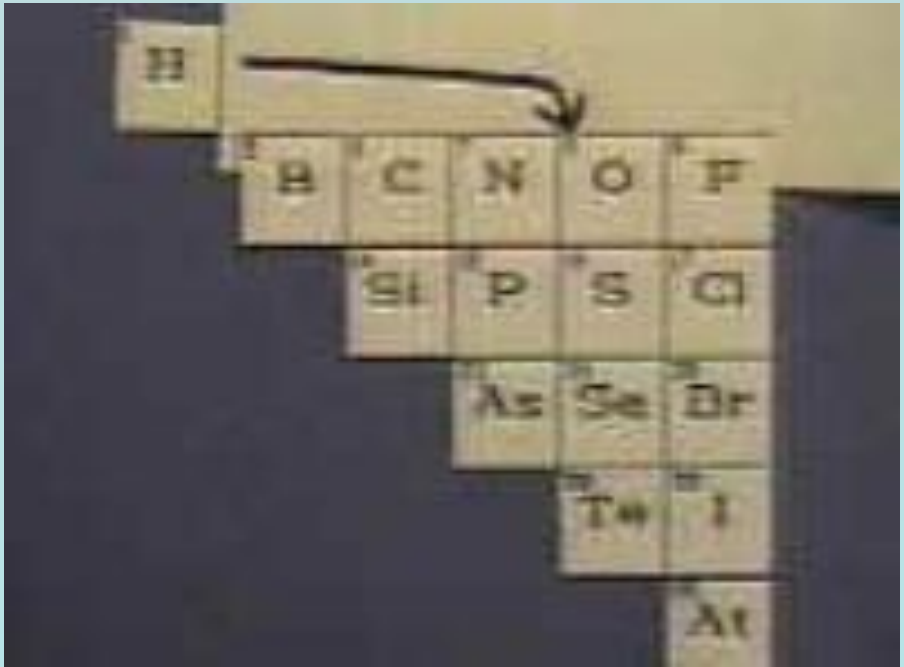
e.g. Chlorate ion $(ClO_3)^{-1}$ → Chlorine is listed first (less electronegative)

Naming Covalent Molecules

Generally, one names the non-metals from left-to-right order as found on the periodic table, EXCEPT that you would have to squeeze hydrogen in between nitrogen and oxygen.

Nitrogen trihydride (NH_3) → (ammonia) nitrogen is named first, then hydrogen

Dihydrogen monoxide (H_2O) → (water) Hydrogen is named first.



Naming Covalent Molecules

*Name the **NONMETAL** farthest to the left on the periodic table first. It is the most metallic element.*

CO_2 = carbon dioxide, not oxygen carbide

The second element is given an –ide ending.

CO_2 = carbon dioxide, not carbon dioxygen

Prefixes are used to indicate how many atoms of each element are present in the compound.

Mono = one, ONLY used for the second element in compound; e.g. carbon monoxide, CO*

Di = two; e.g. sulfur dioxide, SO_2

Tri = three; e.g. phosphorus trihydride, PH_3

Tetra = four; e.g. carbon tetrachloride, CCl_4

Exceptions: Common Names & Hydrogen

Some common compounds that contain hydrogen have non-IUPAC names that do not indicate the number of hydrogen atoms (related to acids).

Examples:

- Hydrogen sulfide (H_2S)
- Hydrogen fluoride (HF)
- Hydrogen chloride (HCl)
- Hydrogen sulfate (H_2SO_4)

Some common (traditional) names are still used.

Formula	Common Name	IUPAC Name
H_2O	Water	dihydrogen monoxide
NH_3	Ammonia	nitrogen trihydride
NO	Nitric oxide	nitrogen monoxide
NO_2	Nitrous oxide	nitrogen dioxide
PH_3	Phosphine	phosphorus trihydride

Name the Covalent Molecules

NH_3

PCl_3

XeF_6

SiO_2

N_2O_4

P_4O_6

CBr_4

H_2O

Name the Covalent Molecules

NH_3

Ammonia, nitrogen trihydride

PCl_3

phosphorus trichloride

If there is only ONE of the 1st element, do not use "mono"

XeF_6

xenon hexafluoride

SiO_2

silicon dioxide

N_2O_4

dinitrogen tetroxide

P_4O_6

tetraphosphorus hexaoxide

CBr_4

carbon tetrabromide

H_2O

Water, dihydrogen monoxide

Expected Oxidation States of Atoms

Oxidation States

*The number representing **the charge of an atom** when its valence is complete in the formation of a compound or molecule (octet rule).*

Group	IA	IIA	IIIA	IVA	VA	VIA	VIIA
Valence	1	2	3	4	5	6	7
Expected Charge	+1	+2	+3	+/- 4	-3	-2	-1
	Lose 1 e-	Lose 2 e-	Lose 3 e-	Lose or gain 4 e-	Gain 3 e-	Gain 2 e-	Gain 1 e-

Naming Compounds with expected Oxidation States

Use the naming method we have been using: cation first, anion second with suffix of "-ide".

e.g. $K_3^{+}P^{-3}$ → *potassium phosphide*

Expected Oxidation States of Atoms

Free Elements

The oxidation number is zero for all unbonded free elements → this includes all the elements on the Periodic Table EXCEPT:

- These diatomic elements are considered free elements as well:

"H O F Br I N Cl" → H_2 O_2 F_2 Br_2 I_2 N_2 Cl_2

"Charged" Atoms or Ions

- Whenever a chemical reaction takes place, a free element must take on an "ionic" form as a cation or an anion
- The oxidation number of the "ion" produced in a chemical reaction is determined the same way as the oxidation state of an atom filling its valence (octet rule)

Oxygen

oxidation number = -2 **exception**: *peroxides* (e.g. H_2O_2) … -1

Hydrogen

oxidation number = +1 **exception**: *hydrides* (e.g. NaH, CaH_2) … -1

Multiple Oxidation States of Atoms

Many elements have multiple oxidation states that do not match the expected oxidation state based on valence.

If the charge of the atom does not match the expected charge, assume a multiple oxidation state

N is in Group V (gains 3 e-)… expected oxidation of N^{-3}

N^{+5} N^{+4} N^{+3} N^{+2} N^{-1} N^{-2} N^{-3}

In order to distinguish between molecules containing an atom whose oxidation is not expected (like N), one needs a different name. E.g. imagine having triplets … they each need their own name.

Determining NON-expected Oxidation States of Atoms

For a compound or molecule (electrically neutral overall), the sum of the oxidation numbers of all the elements must total ZERO.

Carbon dioxide CO_2 →

Carbon monoxide CO →

Hydrogen Phosphate $H_3(PO_4)$

Determining NON-expected Oxidation States of Atoms

For a compound or molecule (electrically neutral overall), the sum of the oxidation numbers of all the elements must total ZERO.

Carbon dioxide CO_2 → *Use "oxygen" as the standard for oxid. #*

$C^{+4} + 2O^{-2} = 1(+4) + 2(-2) = 0$

The total charge around oxygen is 2(-2) = -4

Therefore, C must have an oxidation of +4 when bonded

Carbon monoxide CO → *Use "oxygen" as the standard for oxid. #*

$C^{+2} + O^{-2} = 1(+2) + (-2) = 0$

The total charge around oxygen is 1(-2) = -2

Therefore, C must have an oxidation of +2 when bonded

Hydrogen Phosphate $H_3(PO_4)$

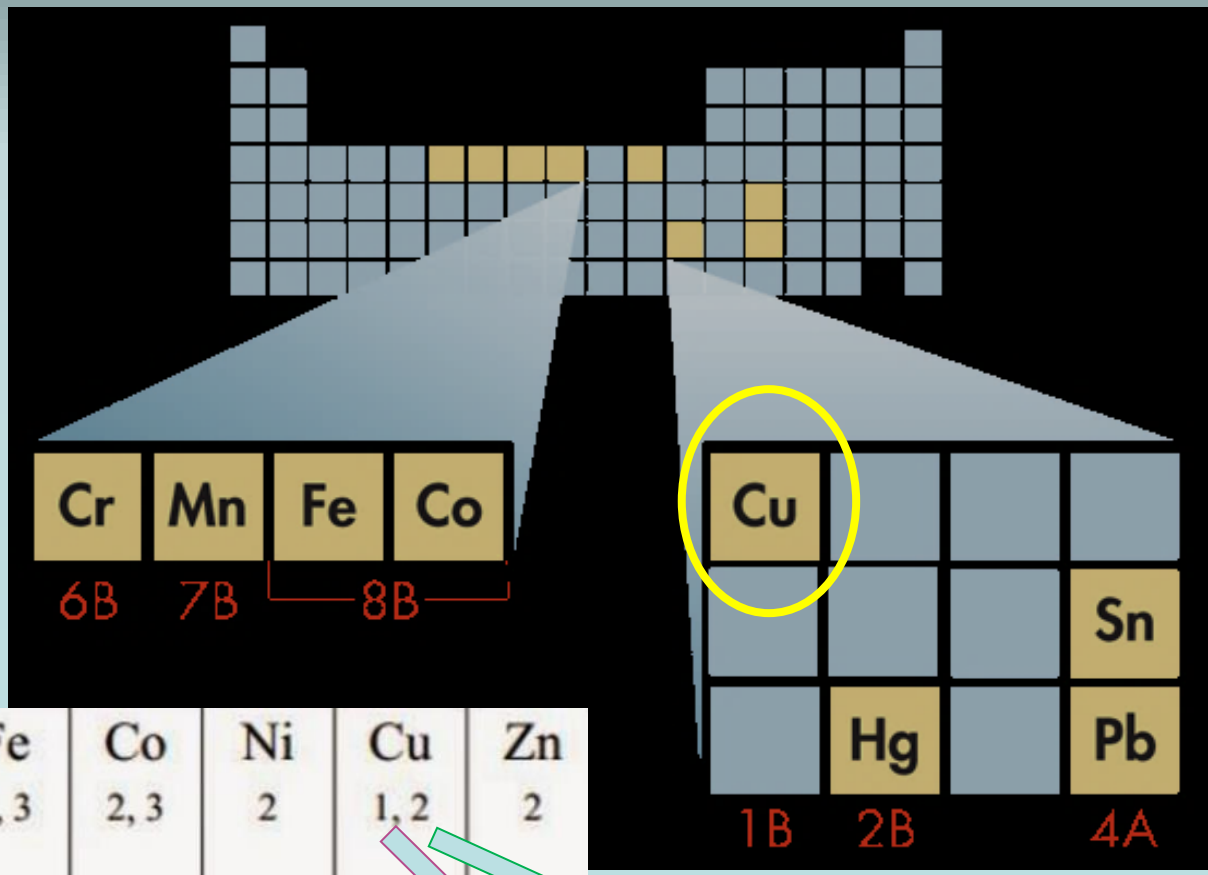
Use "hydrogen" and "oxygen" as the standard for oxid. #

$3H^{+1} + 1P^{+5} + 4O^{-2} = 3(+1) + 1(+5) + 4(-2) = 0$

The P atom must have an oxidation of +5 when bonded

Multiple Oxidation States of Atoms

<u>Transition metals</u> (Groups 1B–8B) typically form more than one cation with different ionic charges.



Sc 3	Ti 3,4	V 2, 3, 4, 5	Cr 2, 3, 4, 6	Mn 2, 3, 4, 6, 7	Fe 2, 3	Co 2, 3	Ni 2	Cu 1, 2	Zn 2
Y 3	Zr 4	Nb 3,4, 5	Mo 2,3,4, 5, 6	Tc 2,3,4, 5,6,7	Ru 2,3,4, 5,6,7, 8	Rh 1, 3	Pd 2, 4	Ag 1	Cd 2
La 3	Hf 4	Ta 3, 4, 5	W 2,3,4, 5, 6	Re 2,3,4, 5,6,7	Os 3,4,5, 6,7,8	Ir 1, 3	Pt 2, 4	Au 1, 3	Hg 1, 2

$Cu^{+2}Cl_2^-$

$Cu^{+}Cl^{-}$

Naming Molecules containing atoms with Multiple Oxidation States

Binary Molecules

Covalently bonded molecules usually have multiple oxidation states

- *Commonly found with N, S, and P*

OPTION 1 → IUPAC naming system

*Use a **Roman Numeral** to indicate the oxidation of the most metallic element which has the multiple oxidation state ("Stock" system)*

$N_2^{+1}O^{-2}$	
$N_2^{+3}O_3^{-2}$	
$N_2^{+5}O_5^{-2}$	

The expected oxidation for N = -3

Naming Molecules containing atoms with Multiple Oxidation States

Binary Molecules

Covalently bonded molecules usually have multiple oxidation states

- *Commonly found with N, S, and P*

OPTION 1 → IUPAC naming system

*Use a **Roman Numeral** to indicate the oxidation of the most metallic element which has the multiple oxidation state ("Stock" system)*

$N_2^{+1}O^{-2}$	Nitrogen I Oxide
$N_2^{+3}O_3^{-2}$	Nitrogen III Oxide
$N_2^{+5}O_5^{-2}$	Nitrogen V Oxide

The expected oxidation for N = -3

Naming Compounds containing atoms with Multiple Oxidation States

Binary Compounds

- *Transition Elements* *usually exhibit multiple oxidation due to the filling of "d" and "f" sublevel orbitals*

OPTION 1 → IUPAC naming system

*Use a **Roman Numeral** to indicate the oxidation of the most metallic element which has the multiple oxidation state ("Stock" system)*

Containing Transition Metals

Cu^{+1}	CuCl	
Cu^{+2}	$CuCl_2$	

Naming Compounds containing atoms with Multiple Oxidation States

Binary Compounds

- *Transition Elements* *usually exhibit multiple oxidation due to the filling of "d" and "f" sublevel orbitals*

OPTION 1 → IUPAC naming system

*Use a **Roman Numeral** to indicate the oxidation of the metallic element which has the multiple oxidation state ("Stock" system)*

Containing Transition Metals

Cu^{+1}	CuCl	Copper(I) Chloride
Cu^{+2}	$CuCl_2$	Copper(II) Chloride

Naming Molecules containing atoms with Multiple Oxidation States

Binary Molecules

OPTION 2 → Greek prefixes

Add a prefix to EACH element, indicating the number of atoms of a particular element within the compound or molecule

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

Covalent Molecules

$N_2^{+1}O^{-2}$	
$N_2^{+3}O_3^{-2}$	
$N_2^{+5}O_5^{-2}$	

Naming Molecules containing atoms with Multiple Oxidation States

Binary Molecules

OPTION 2 → Greek prefixes

Add a prefix to EACH element, indicating the number of atoms of a particular element within the compound or molecule

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

Covalent Molecules

$N_2^{+1}O^{-2}$	diNitrogen monOxide
$N_2^{+3}O_3^{-2}$	diNitrogen triOxide
$N_2^{+5}O_5^{-2}$	diNitrogen pentOxide

Naming Compounds containing atoms with Multiple Oxidation States

OPTION 3 → Transition Elements

Transition elements are characterized by their multiple oxidations

"-OUS" and "-IC" ("Classical" Naming)

- *Use "-ous" for the first oxidation number listed*
- *Use "-ic" for the second oxidation number listed*

Ion	Formula	Option 3	Option 1
Cu^{+1}	$CuCl$	Cuprous Chloride	Copper I Chloride
Cu^{+2}	$CuCl_2$	Cupric Chloride	Copper II Chloride
Hg^{+1}	Hg_2Cl_2	Mercurous Chloride	Mercury I Chloride
Hg^{+2}	$HgCl_2$	Mercuric Chloride	Mercury II Chloride
Fe^{+2}	$FeCl_2$	Ferrous Chloride	Iron II Chloride
Fe^{+3}	$FeCl_3$	Ferric Chloride	Iron III Chloride
Co^{+2}	$CoCl_2$	Cobaltous Chloride	Cobalt II Chloride
Co^{+3}	$CoCl_3$	Cobaltic Chloride	Cobalt III Chloride
Pb^{+2}	$PbCl_2$	Plumbous Chloride	Lead II Chloride
Pb^{+4}	$PbCl_4$	Plumbic Chloride	Lead IV Chloride
Sn^{+2}	$SnCl_2$	Stannous Chloride	Tin II Chloride
Sn^{+4}	$SnCl_4$	Stannic Chloride	Tin IV Chloride

Naming Compounds containing atoms with Multiple Oxidation States

A few transition metals have only ONE ionic charge. The names of these cations do NOT have a Roman numeral.

These metals include the silver 1+ cation (Ag^+) [Ag_2O → silver oxide], & cadmium & zinc with 2+ cations (Cd^{2+} & Zn^{2+}).

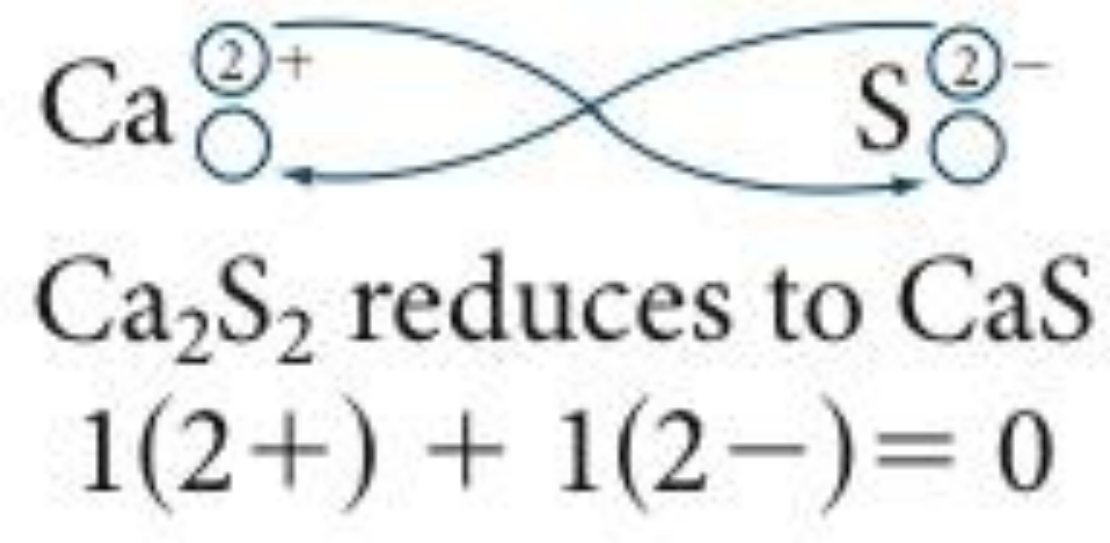
The "classical" naming system does not indicate oxidation states:

Symbols and Names of Common Metal Ions With More Than One Ionic Charge		
Symbol	**Stock Name**	**Classical Name**
Cu^+	**Copper(I) ion**	**Cuprous ion**
Cu^{2+}	**Copper(II) ion**	**Cupric ion**
Pb^{2+}	**Lead(II) ion**	**Plumbous ion**
Pb^{4+}	**Lead(IV) ion**	**Plumbic ion**

Empirical Formulas

For ionic compounds and many covalent molecules, formulas should be written with the LOWEST whole number ratio of atoms.

Calcium sulfide (Ca^{2+} and S^{2-}) → Ca_2S_2.



The 2:2 ratio can be reduced to CaS.

This is called an empirical formula.

Review

The remainder of the slides are for review.

QUICK CHECK

Bonding Elements	Name of Compound
Sodium + Sulfur	
Calcium + Fluorine	
Oxygen + Silver	
Chlorine + Magnesium	
Lithium + Nitrogen	
Strontium + Sulfur	
Barium + Bromine	
Oxygen + Potassium	
Copper (+2) + Sulfur	
Copper (+1) + Sulfur	
Iron (+2) + Oxygen	
Iron (+3) + Oxygen	

QUICK CHECK

Bonding Elements	Name of Compound
Sodium + Sulfur	Sodium sulfide
Calcium + Fluorine	Calcium fluoride
Oxygen + Silver	Silver oxide (*Ag only has 1 oxid. #)*
Chlorine + Magnesium	Magnesium chloride
Lithium + Nitrogen	Lithium nitride
Strontium + Sulfur	Strontium sulfide
Barium + Bromine	Barium bromide
Oxygen + Potassium	Potassium oxide
Copper (+2) + Sulfur	Copper(II) sulfide, cupric sulfide
Copper (+1) + Sulfur	Copper(I) sulfide, cuprous sulfide
Iron (+2) + Oxygen	Iron(II) oxide, Ferrous Oxide
Iron (+3) + Oxygen	Iron(III) oxide, Ferric Oxide

Write the Chemical Formulas (Use Criss Cross Method, showing cations/anions)

Sodium oxide

Barium phosphide

Potassium chloride

Lithium sulfide

Copper(I) nitrate

Manganese(IV) sulfate

Ammonium phosphate

Cobalt(II) chloride

Write the Chemical Formulas (Use Criss Cross Method, showing cations/anions)

Sodium oxide

$Na_2^{+}O^{-2} \rightarrow Na_2O$

Barium phosphide

$Ba_3^{+2}P_2^{-3} \rightarrow Ba_3P_2$

Potassium chloride

$K^{+}Cl^{-} \rightarrow KCl$

Lithium sulfide

$Li_2^{+}S^{-2} \rightarrow Li_2S$

Copper(I) nitrate

$Cu^{+}(NO_3)^{-} \rightarrow Cu(NO_3)$

Manganese(IV) sulfate

$Mn_2^{+4}(SO_4)_4^{-2} \rightarrow Mn(SO_4)_2$

Ammonium phosphate

$(NH_4)_3^{+}(PO_4)^{-3} \rightarrow (NH_4)_3(PO_4)$

Cobalt(II) chloride

$Co^{+2}Cl_2^{-2} \rightarrow CoCl_2$

Ionic compounds do not need special naming, but transition elements do.

Name the Following Ionic Compounds

$MgCl_2$

B_2O_3

CsF

BaS

Na_3N

$Fe_2(SO_4)_3$

$Mn(NO_3)_2$

Cu_2CO_3

NH_4I

Na_3PO_4

Name the Following Ionic Compounds

$MgCl_2$

magnesium chloride

B_2O_3

boron oxide

CsF

cesium fluoride

BaS

barium sulfide

Na_3N

sodium nitride

$Fe_2^{+3}(SO_4)_3$

iron(III) sulfate, Ferric sulfate

$Mn^{+2}(NO_3)_2$

manganese(II) nitrate

$Cu_2^{+1}CO_3$

copper(I) carbonate,
cuprous carbonate

NH_4I

ammonium iodide

Na_3PO_4

sodium phosphate

Ionic compounds do not need special naming, but transition elements do.

Compounds With Polyatomic Ions

TRY IT

Determine the formula: use the criss-cross method with polyatomic ions, treating the polyatomic ion as ONE unit:

Calcium nitrate

Lithium Carbonate

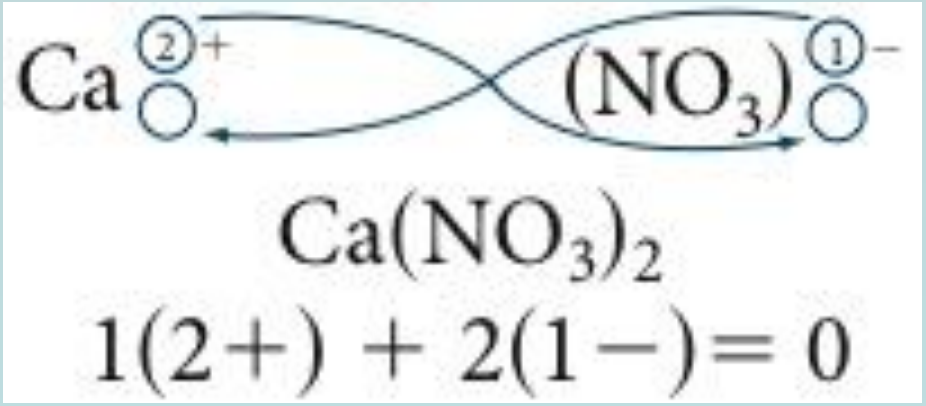
Magnesium Hydroxide

Compounds With Polyatomic Ions

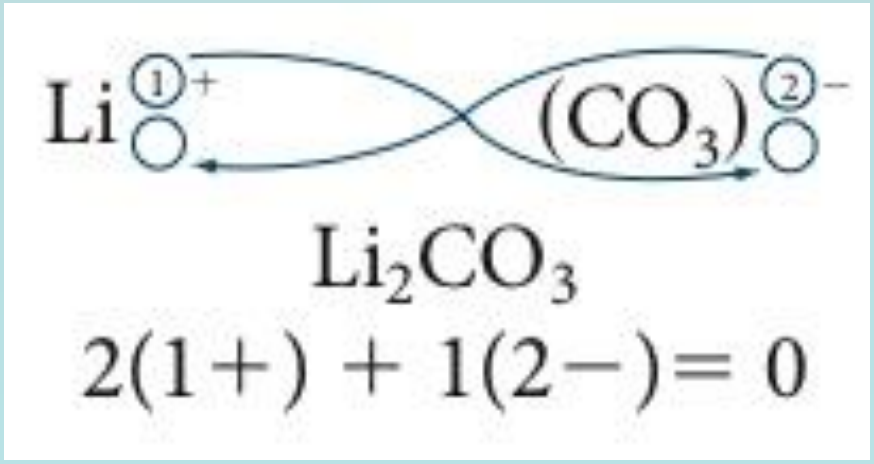
TRY IT

Determine the formula: use the criss-cross method with polyatomic ions, treating the polyatomic ion as ONE unit:

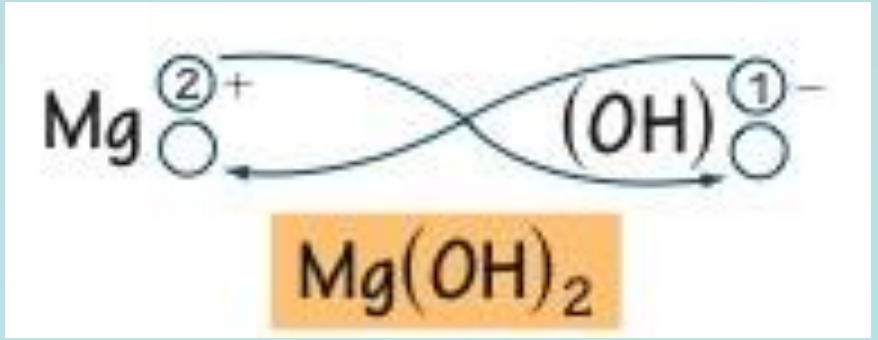
Calcium nitrate



Lithium Carbonate



Magnesium Hydroxide



1(2+) + 2(1-) = 0

Oxidation State of Elements in Polyatomic Ions

TRY IT

Determine the oxidation state of the elements in a polyatomic ion:

Nitrate $(NO_3)^{-1}$ …

Carbonate $(CO_3)^{-2}$ …

Chlorite $(ClO_2)^{-1}$ …

Perphosphate $(PO_5)^{-3}$ …

Oxidation State of Elements in Polyatomic Ions

TRY IT

The sum of the oxidation states of elements in a polyatomic ion equals the charge given:

Oxygen's oxidation is -2 in each case.

Nitrate $(NO_3)^{-1}$ … N + 3(-2) = -1 … therefore, N^{+5}

Carbonate $(CO_3)^{-2}$ … C + 3(-2) = -2 … therefore, C^{+4}

Chlorite $(ClO_2)^{-1}$ … C + 2(-2) = -1 … therefore, Cl^{+3}

Perphosphate $(PO_5)^{-3}$ … P + 5(-2) = -3 … P^{+7}

Name the Covalent Compounds or Give the Formula

NI_3

N_4O

SulfurVI Fluoride

CS_2

Dinitrogen tetroxide

Diphosphorous pentoxide

CarbonII Oxide

H_2O

Name the Covalent Compounds or Give the Formula

NI_3

Nitrogen tri-iodide

N_4O

Tetranitrogen monoxide

SulfurVI Fluoride

$S^{+6}F_6^{-1}$

CS_2

Carbon disulfide

Dinitrogen tetroxide

N_2O_4

Diphosphorous pentoxide

P_2O_5

CarbonII Oxide

$C^{+2}O^{-2}$ (carbon monoxide)

H_2O

Dihydrogen monoxide

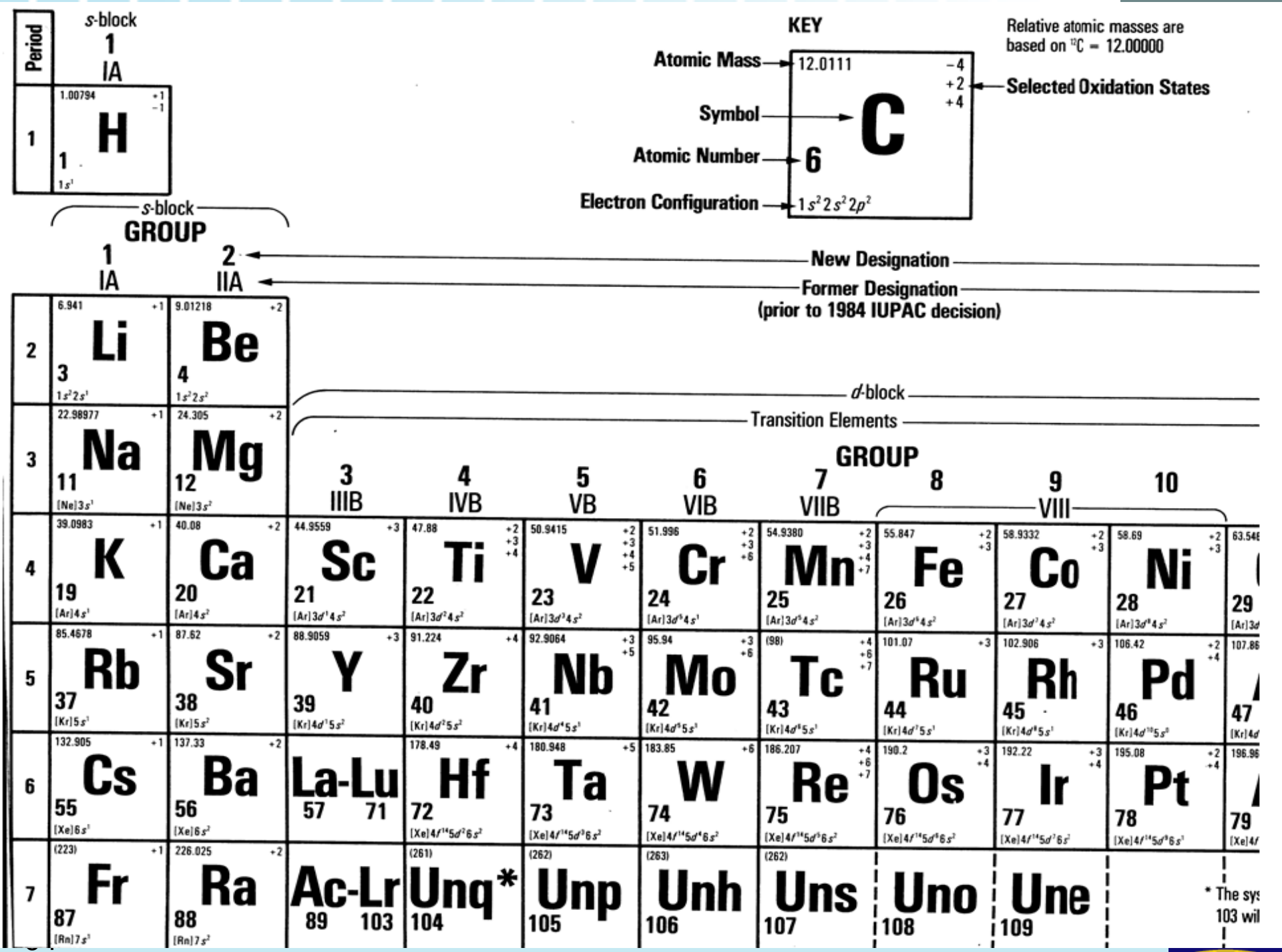
Elements	Formula	Name of Compound
Sodium, Sulfur		
Calcium, Fluorine		
Silver, Oxygen		
Magnesium, Chlorine		
Lithium, Nitrogen		
Strontium, Sulfur		
Barium, Bromine		
Potassium, Oxygen		
Copper (+2), Sulfur		
Copper (+1), Sulfur		
Iron (+2), Oxygen		
Iron (+3) Oxygen		
Aluminum, Chlorine		
Aluminum, Sulfur		
Ammonium, Sulfur		
Copper (+2), Nitrate		
Calcium, Phosphate		
Potassium, Chlorine		
Hydrogen, Oxygen		
Lead (+2), Oxygen		
Sodium, Hydroxide		
Ammonium, Sulfate		
Zinc, Acetate		
Barium, Chlorate		

Elements	Formula	Name of Compound
Sodium, Sulfur	$Na_2^{+1}S^{-2}$	Sodium sulfide
Calcium, Fluorine	$Ca^{+2}F_2^{-1}$	Calcium fluoride
Silver, Oxygen	$Ag_2^{+1}O^{-2}$	Silver oxide
Magnesium, Chlorine	$Mg^{+2}Cl_2^{-1}$	Magnesium chloride
Lithium, Nitrogen	$Li_3^{+1}N^{-3}$	Lithium nitride
Strontium, Sulfur	$Sr^{+2}S^{-2}$	Strontium sulfide
Barium, Bromine	$Ba^{+2}Br_2^{-1}$	Barium bromide
Potassium, Oxygen	$K_2^{+1}O^{-2}$	Potassium oxide
Copper (+2), Sulfur	$Cu^{+2}S^{-2}$	Copper(II) sulfide, cupric sulfide
Copper (+1), Sulfur	$Cu_2^{+1}S^{-2}$	Copper(I) sulfide, cuprous sulfide
Iron (+2), Oxygen	$Fe^{+2}O^{-2}$	Iron(II) oxide, Ferrous Oxide
Iron (+3) Oxygen	$Fe_2^{+3}O_3^{-2}$	Iron(III) oxide, Ferric Oxide
Aluminum, Chlorine	$Al^{+3}Cl_3^{-1}$	Aluminum chloride
Aluminum, Sulfur	$Al_2^{+3}S_3^{-2}$	Aluminum sulfide
Ammonium, Sulfur	$(NH_4)_2^{+1}S^{-2}$	Ammonium sulfide
Copper (+2), Nitrate	$Cu^{+2}(NO_3)_2^{-1}$	Copper(II) nitrate, cupric nitrate
Calcium, Phosphate	$Ca_3^{+2}(PO_4)_2^{-3}$	Calcium phosphate
Potassium, Chlorine	$K^{+1}Cl^{-1}$	Potassium chloride
Hydrogen, Oxygen	$H_2^{+1}O^{-2}$	diHydrogen monoxide, water
Lead (+2), Oxygen	$Pb^{+2}O^{-2}$	Plumbous oxide
Sodium, Hydroxide	$Na^{+1}(OH)^{-1}$	Sodium hydroxide
Ammonium, Sulfate	$(NH_4)_2^{+1}(SO_4)^{-2}$	Ammonium sulfate
Zinc, Acetate	$Zn^{+1}(C_2H_3O_2)_2^{-1}$	Zinc acetate
Barium, Chlorate	$Ba^{+2}(ClO_3)_2^{-1}$	Barium chlorate

TRY IT

General guidelines for writing the name and formula of a chemical compound:

1. Follow the rules for naming acids when **H** is the first element in the formula and it is aqueous (dissolved in water).
2. If the compound is binary, generally the non-metal name ends with the suffix *-ide*.
3. If the compound is a molecular (covalently bonded) binary compound, use prefixes to indicate the number of atoms.
4. When a polyatomic ion that includes oxygen is in the formula, the compound name generally ends in *-ite* or *-ate*.
5. If the compound contains a metallic cation that can have different ionic charges (transition, group B metals), use a Roman numeral to indicate the numerical value of the ionic charge in the compound.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IA
1
1.00794
+1
−1
H
1
1s¹
KEY
Atomic Mass
12.0111
−4
+2
+4
Selected Oxidation States
Symbol
C
Atomic Number
6
Electron Configuration
1s²2s²2p²
Relative atomic masses are based on ¹²C = 12.00000
s-block
GROUP
1
IA
2
IIA
New Designation
Former Designation
(prior to 1984 IUPAC decision)
d-block
Transition Elements
GROUP
3
IIIB
4
IVB
5
VB
6
VIB
7
VIIB
8
9
10
VIII
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Zr
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Mo
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+6
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Ru
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Rh
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Pd
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+2
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Hf
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+5
Ta
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+6
W
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+7
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+4
Os
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+2
Ra
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[Rn]7s²
Ac-Lr
89
103
(261)
Unq*
104
(262)
Unp
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(263)
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(262)
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p-block

GROUP

10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 0
								4.00260 0 **He** 2 $1s^2$
			10.81 +3 **B** 5 $1s^2 2s^2 2p^1$	12.0111 −4 +2 +4 **C** 6 $1s^2 2s^2 2p^2$	14.0067 −3 −2 −1 +1 +2 +3 +4 +5 **N** 7 $1s^2 2s^2 2p^3$	15.9994 −2 **O** 8 $1s^2 2s^2 2p^4$	18.998403 −1 **F** 9 $1s^2 2s^2 2p^5$	20.179 0 **Ne** 10 $1s^2 2s^2 2p^6$
			26.98154 +3 **Al** 13 [Ne]$3s^2 3p^1$	28.0855 −4 +2 +4 **Si** 14 [Ne]$3s^2 3p^2$	30.97376 −3 +3 +5 **P** 15 [Ne]$3s^2 3p^3$	32.06 −2 +4 +6 **S** 16 [Ne]$3s^2 3p^4$	35.453 −1 +1 +3 +5 +7 **Cl** 17 [Ne]$3s^2 3p^5$	39.948 0 **Ar** 18 [Ne]$3s^2 3p^6$
58.69 +2 +3 **Ni** 28 [Ar]$3d^8 4s^2$	63.546 +1 +2 **Cu** 29 [Ar]$3d^{10} 4s^1$	65.39 +2 **Zn** 30 [Ar]$3d^{10} 4s^2$	69.72 +3 **Ga** 31 [Ar]$3d^{10} 4s^2 4p^1$	72.59 −4 +2 +4 **Ge** 32 [Ar]$3d^{10} 4s^2 4p^2$	74.9216 −3 +3 +5 **As** 33 [Ar]$3d^{10} 4s^2 4p^3$	78.96 −2 +4 +6 **Se** 34 [Ar]$3d^{10} 4s^2 4p^4$	79.904 −1 +1 +5 **Br** 35 [Ar]$3d^{10} 4s^2 4p^5$	83.80 0 +2 **Kr** 36 [Ar]$3d^{10} 4s^2 4p^6$
106.42 +2 +4 **Pd** 46 [Kr]$4d^{10} 5s^0$	107.868 +1 **Ag** 47 [Kr]$4d^{10} 5s^1$	112.41 +2 **Cd** 48 [Kr]$4d^{10} 5s^2$	114.82 +3 **In** 49 [Kr]$4d^{10} 5s^2 5p^1$	118.71 +2 +4 **Sn** 50 [Kr]$4d^{10} 5s^2 5p^2$	121.75 −3 +3 +5 **Sb** 51 [Kr]$4d^{10} 5s^2 5p^3$	127.60 −2 +4 +6 **Te** 52 [Kr]$4d^{10} 5s^2 5p^4$	126.905 −1 +1 +5 +7 **I** 53 [Kr]$4d^{10} 5s^2 5p^5$	131.29 0 +2 +4 +6 **Xe** 54 [Kr]$4d^{10} 5s^2 5p^6$
195.08 +2 +4 **Pt** 78 [Xe]$4f^{14} 5d^9 6s^1$	196.967 +1 +3 **Au** 79 [Xe]$4f^{14} 5d^{10} 6s^1$	200.59 +1 +2 **Hg** 80 [Xe]$4f^{14} 5d^{10} 6s^2$	204.383 +1 +3 **Tl** 81 [Xe]$4f^{14} 5d^{10} 6s^2 6p^1$	207.2 +2 +4 **Pb** 82 [Xe]$4f^{14} 5d^{10} 6s^2 6p^2$	208.980 +3 +5 **Bi** 83 [Xe]$4f^{14} 5d^{10} 6s^2 6p^3$	(209) +2 +4 **Po** 84 [Xe]$4f^{14} 5d^{10} 6s^2 6p^4$	(210) **At** 85 [Xe]$4f^{14} 5d^{10} 6s^2 6p^5$	(222) 0 **Rn** 86 [Xe]$4f^{14} 5d^{10} 6s^2 6p^6$

Polyatomic Ions

Name	Formula	Name	Formula
perPhosphate	$(PO_5)^{-3}$	perCarbonate	$(CO_4)^{-2}$
Phosphate	$(PO_4)^{-3}$	**Carbonate**	$(CO_3)^{-2}$
Phosphite	$(PO_3)^{-3}$	Carbonite	$(CO_2)^{-2}$
hypoPhosphite	$(PO_2)^{-3}$	hypocarbonite	$(CO)^{-2}$
perChlorate	$(ClO_4)^{-1}$	perNitrate	$(NO_4)^{-}$
Chlorate	$(ClO_3)^{-1}$	**Nitrate**	$(NO_3)^{-}$
Chlorite	$(ClO_2)^{-1}$	Nitrite	$(NO_2)^{-}$
hypoChlorite	$(ClO)^{-1}$	Hyponitrite	$(NO)^{-}$
perSulfate	$(SO_5)^{-2}$	perChromate	$(CrO_5)^{-2}$
Sulfate	$(SO_4)^{-2}$	**Chromate**	$(CrO_4)^{-2}$
Sulfite	$(SO_3)^{-2}$	Chromite	$(CrO_3)^{-2}$
hyposulfite	$(SO_2)^{-2}$	Hypochromite	$(CrO_2)^{-2}$
Acetate	$(C_2H_3O_2)^{-1}$	**Cyanide**	$(CN)^{-1}$
Hydroxide	$(OH)^{-1}$	**Manganate**	$(MnO_4)^{-2}$

Ammonium $(NH_4)^{+1}$

IONIZATION ENERGIES AND ELECTRONEGATIVITIES

1	2	13	14	15	16	17	18
H 313 / 2.2							He 567
Li 125 / 1.0	Be 215 / 1.5	B 191 / 2.0	C 260 / 2.6	N 336 / 3.1	O 314 / 3.5	F 402 / 4.0	Ne 497
Na 119 / 0.9	Mg 176 / 1.2	Al 138 / 1.5	Si 188 / 1.9	P 242 / 2.2	S 239 / 2.6	Cl 300 / 3.2	Ar 363
K 100 / 0.8	Ca 141 / 1.0	Ga 138 / 1.6	Ge 182 / 1.9	As 226 / 2.0	Se 225 / 2.5	Br 273 / 2.9	Kr 323
Rb 96 / 0.8	Sr 131 / 1.0	In 133 / 1.7	Sn 169 / 1.8	Sb 199 / 2.1	Te 208 / 2.3	I 241 / 2.7	Xe 280
Cs 90 / 0.7	Ba 120 / 0.9	Tl 141 / 1.8	Pb 171 / 1.8	Bi 168 / 1.9	Po 194 / 2.0	At / 2.2	Rn 248
Fr / 0.7	Ra 122 / 0.9						

First Ionization Energy (kcal/mol of atoms)

Electronegativity*

* Arbitrary scale based on fluorine = 4.0