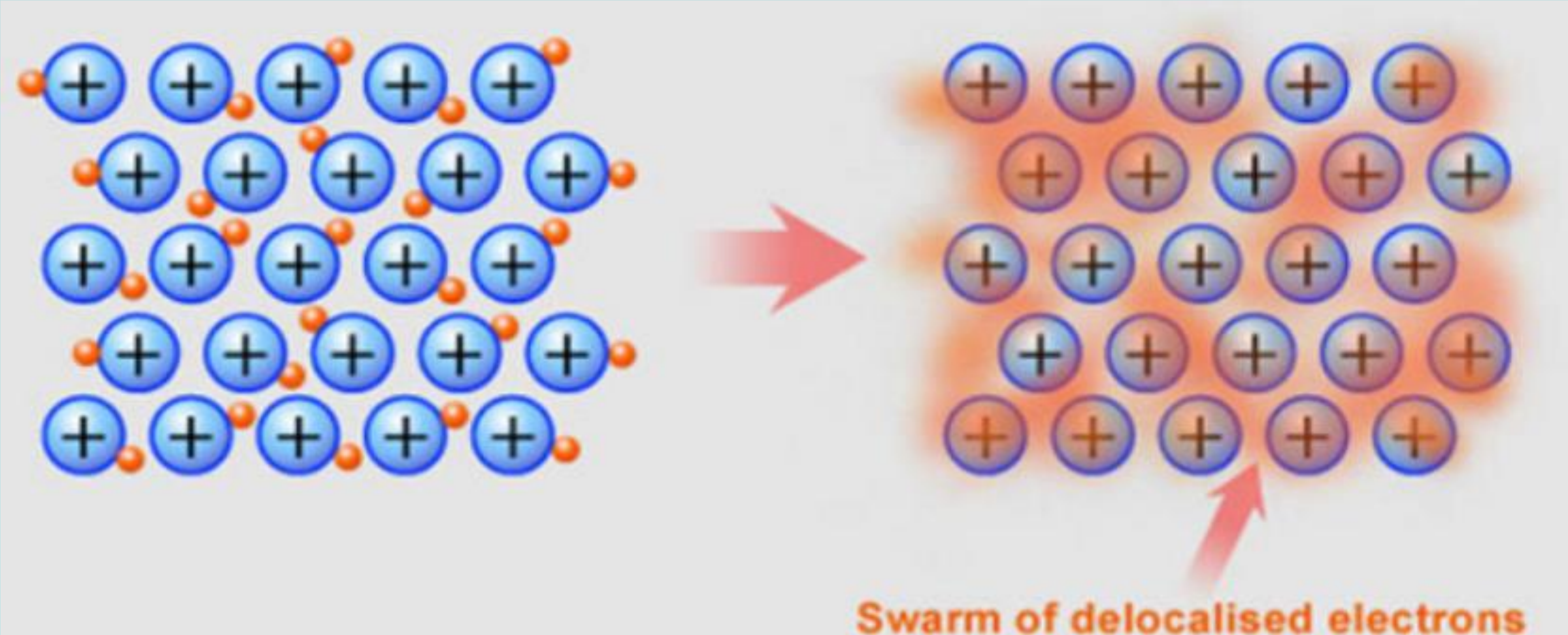
Chapter 6.3-6.4

Naming Compounds & Writing Formulas; Metallic Bonding

- Ionic Compounds
- Molecular Compounds
- Acids and Bases

The Laws Governing How Compounds Form



WARM-UP

Give the Ion Symbol for each element and the charge of each cation & anion.

Some Common Cations		
Name	**Symbol**	**Charge**
Lithium		
Aluminum		
Calcium		
Sodium		
Magnesium		
Boron		
Potassium		
Beryllium		

Some Common Anions		
Name	**Symbol**	**Charge**
Fluoride		
Phosphide		
Sulfide		
Iodide		
Oxide		
Bromide		
Nitride		
Chloride		

WARM-UP

Give the Ion Symbol for each element and the charge of each cation & anion.

Some Common Cations		
Name	**Symbol**	**Charge**
Lithium	Li^{+}	1+
Aluminum	Al^{+3}	3+
Calcium	Ca^{+2}	2+
Sodium	Na^{+}	1+
Magnesium	Mg^{+2}	2+
Boron	B^{+3}	3+
Potassium	K^{+}	1+
Beryllium	Be^{+2}	2+

Some Common Anions		
Name	**Symbol**	**Charge**
Fluoride	F^{-}	1–
Phosphide	P^{3-}	3–
Sulfide	S^{2-}	2–
Iodide	I^{-}	1–
Oxide	O^{2-}	2–
Bromide	Br^{-}	1–
Nitride	N^{3-}	3–
Chloride	Cl^{-}	1–

Identify Electrons Available for Bonding

WARM-UP

For each of the following elements, identify: (1) the “A” Group, (2) the number of valence electrons available for bonding, and (3) how the atom would behave according to the Octet Rule (gain/lose e-, how many e-?), (4) cation or anion? Use your Periodic Table.

- C
- H
- N
- Al
- Ne
- O
- P
- Cl
- Mg

Identify Electrons Available for Bonding

WARM-UP

For each of the following elements, identify: (1) the "A" Group, (2) the number of valence electrons available for bonding, and (3) how the atom would behave according to the Octet Rule (gain/lose e-, how many e-?), (4) cation or anion? Use your Periodic Table.

- C … IVA, 4 e-, gain or lose 4 e-, ±4
- H^{+} … IA, 1 e-, lose 1 e-, +1 cation
- N^{-3} … VA, 5 e-, gain 3 e-, -3 anion
- Al^{+3} … IIIA, 3 e-, lose 3 e-, +3 cation
- Ne^{0} … VIIIA, 8 e-, no bond, 0
- O^{-2} … VIA, 6 e-, gain 2 e-, -2 anion
- P^{-3} … VA, 5 e-, gain 3 e-, -3 anion
- Cl^{-1} … VIIA, 7 e-, gain 1 e-, -1 anion
- Mg^{+2} … IIA, 2 e-, lose 2 e-, +2 cation

Chemical Formulas & Metallic Bonding

Focus Points

- Explain how to determine the charges of atoms that become ions (cations, anions).
- Show how elements become ions (cations and anions) related to protons and electrons.
- Distinguish types of compounds and apply the rules for naming and writing formulas for ionic compounds, covalent molecules, and polyatomic ions.
- Describe metallic bonding and explain metallic properties.
- Define alloys and give examples.

How Do Materials Become Charged? Review

QUICK CHECK

Material A

+1 +1

+1 +1

+1 +1

Material B

+1 +1

+1 +1

Material A has 6 e- & B has 4 e-. Show the net charge of the materials?

QUICK CHECK

How Do Materials Become Charged? Review

Material A

-1 -1

-1 -1

-1 -1

+6

-6

0

Material B

-1 -1

-1 -1

+4

-4

0

Material A has 6 e- & B has 4 e-. Show the net charge of the materials?

How Do Materials Become Charged? Review

QUICK CHECK

Material A		Material B	
+1	+1	+1	+1
+1	+1	+1	+1
+1	+1		

Initially Material A has 6 e- & B has 4 e-. 2 e- transfer to Material B.
Show the overall net charge of the materials after the transfer of e-.

How Do Materials Become Charged? Review

Material A

-1 -1

-1 -1

+1 +1

+6
-4
+2

→ 2e-

Material B

-1 -1

-1 -1

-1 -1

+4
-6
-2

Initially Material A has 6 e- & B has 4 e-. 2 e- transfer to Material B.
Show the overall net charge of the materials after the transfer of e-.

How Do Materials Become Charged? Review

Material A

+1 +1

+1 +1

+1 +1

Material B

+1 +1

+1 +1

Materials A & B are initially neutral.
How can Material A gain a net charge of +4?

QUICK CHECK

How Do Materials Become Charged? Review

Material A

-1 -1

+1 +1

+1 +1

+1 +1

+6
-2
+4

→ 4e-

Material B

-1 -1

+1 +1

-1 -1

-1 -1

+1 +1

-1 -1

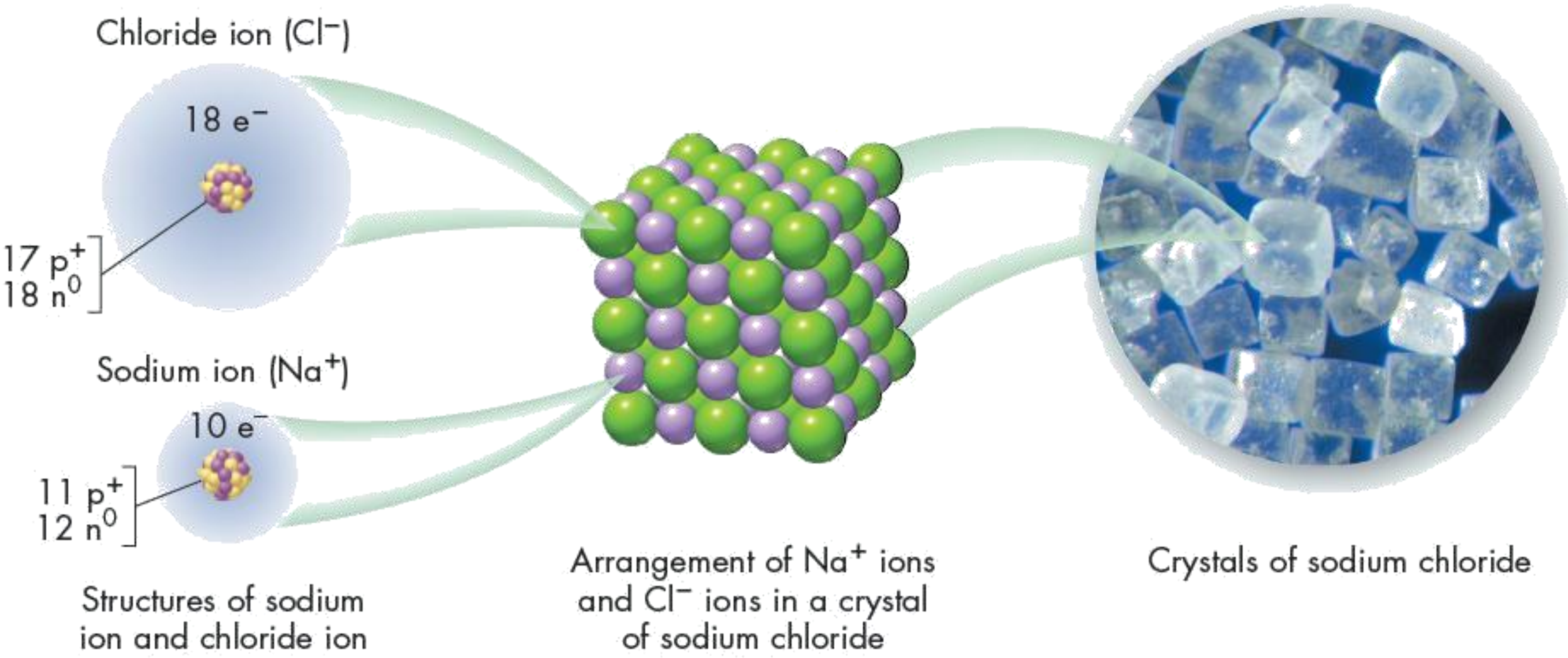
+4
-8
-4

Materials A & B are initially neutral.
How can Material A gain a net charge of +4?

Formation of Compounds

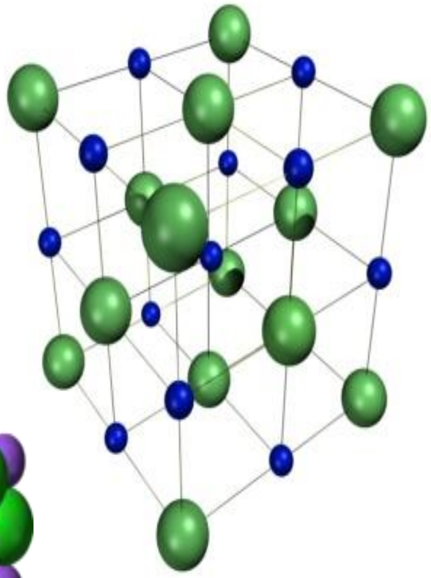
Ionic or Covalent compounds are represented by a **chemical formula** showing the number of atoms of each element in a substance.

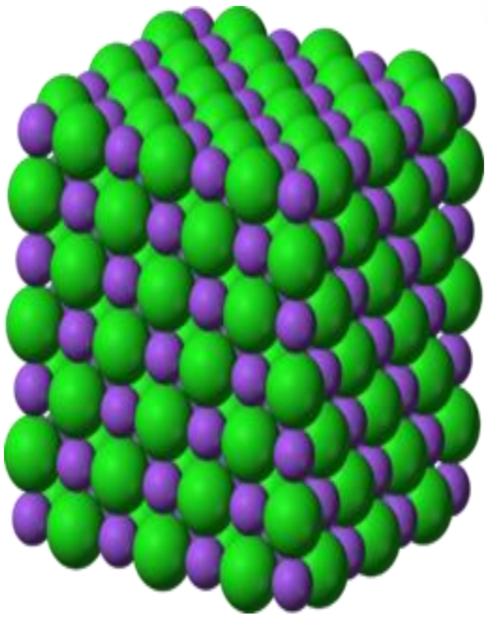
NaCl is the chemical formula for sodium chloride.



Describing Ionic Compounds

- **The name of an ionic compound must distinguish the compound from other ionic compounds containing the same elements.**
- **The formula of an ionic compound describes the ratio of the ions in the compound.**





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

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

Typical Patterns of Ions

Metals:

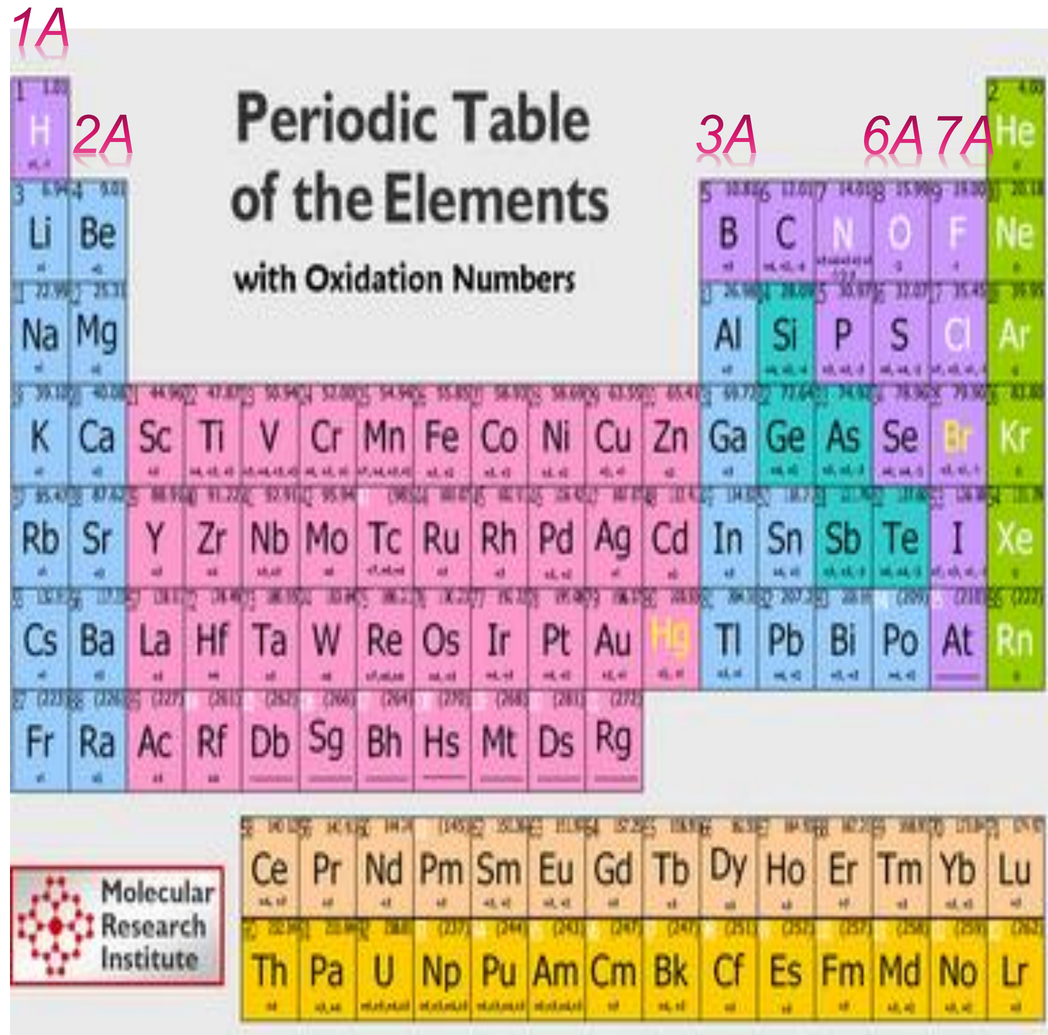
form cations (positive charge)

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

Nonmetals:

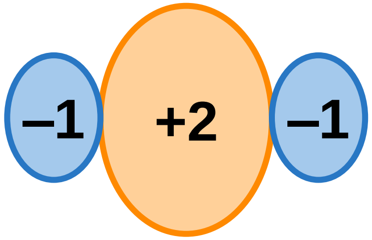
form anions (negative charge)

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

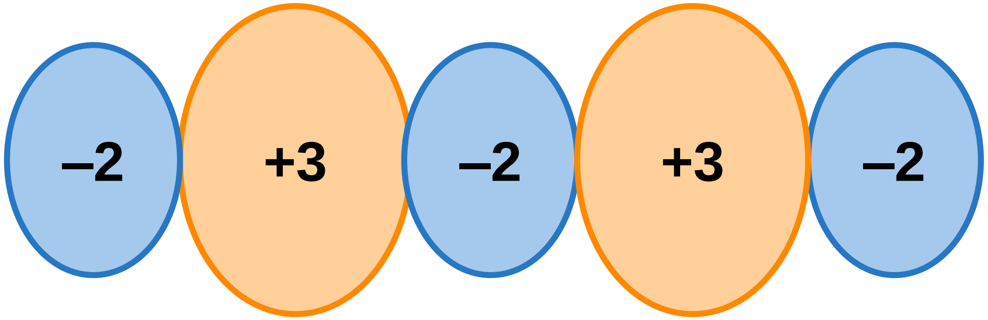


Balancing Charges

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



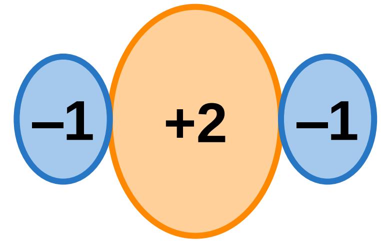
What is the ratio of +3 ions to –2 ions in a neutral compound?



EXAMPLE

Balancing Charges

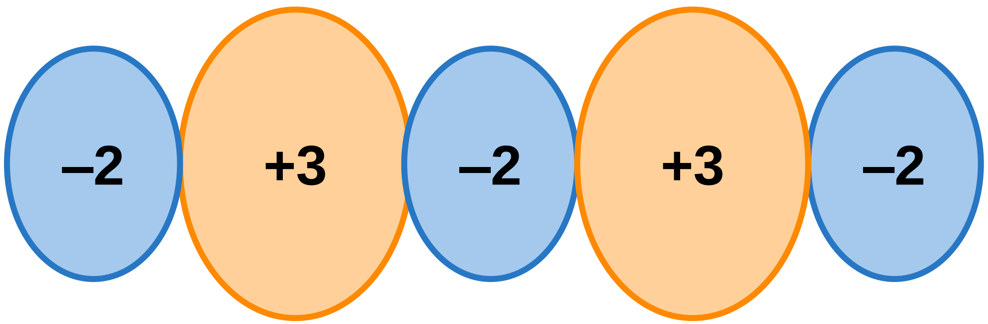
How many –1 ions would bond with a +2 ion?



(+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

Formula Units

The chemical formula of an ionic compound refers to a ratio known as a formula. A **formula** is the lowest whole-number ratio of ions in an ionic compound.

Determine the formula of the following elements when they bond ionically (show the cation, anion and correct formula):

Sodium + Fluorine

Calcium + Chlorine

Aluminum + Oxygen

Formation of Ionic Compounds

Formula Units

Sodium + Fluorine

$1\ Na^{+}\ \ 1\ F^{-} \rightarrow NaF$

Calcium + Chlorine

$1\ Ca^{2+}\ \ 2\ Cl^{-} \rightarrow CaCl_2$

Aluminum + Oxygen

$2\ Al^{3+},\ 3\ O^{2-} \rightarrow Al_2O_3$

- **Remember that non-metals form anions that end in "-ide" … Name the compounds:**

Sodium Fluoride
Calcium Chloride
Aluminum Oxide

Criss-Cross Method

Making Formulas easy:

- Place the cation 1st with its charge as a superscript
- Place the anion 2nd with its charge as a superscript
- Criss-Cross the superscripts without the + or -

$Na^{+}F^{-} \rightarrow Na_1F_1$

$Ca^{2+}Cl^{-} \rightarrow Ca_1Cl_2$

$Al^{3+}O^{2-} \rightarrow Al_2O_3$

You do NOT have to write subscripts of "1"

Predicting Formulas of Ionic Compounds

Use electron dot structures to predict the formulas of the ionic compounds formed from the following elements:

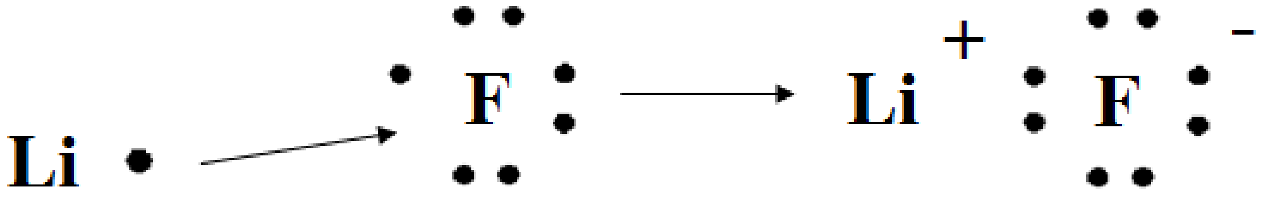
Lithium and Fluorine

Predicting Formulas of Ionic Compounds

Use electron dot structures to predict the formulas of the ionic compounds formed from the following elements:

Lithium and Fluorine

In order to have a completely filled valence shell, the fluorine atom must gain one electron. These electrons come from one lithium atoms, each of which loses one electron.



The formula of the compound formed is LiF which is electrically neutral and the atoms have full valence.

QUICK CHECK

Use electron dot diagrams to determine the formula of the ionic compound formed when potassium reacts with oxygen. Show the overall charge on the formula unit.

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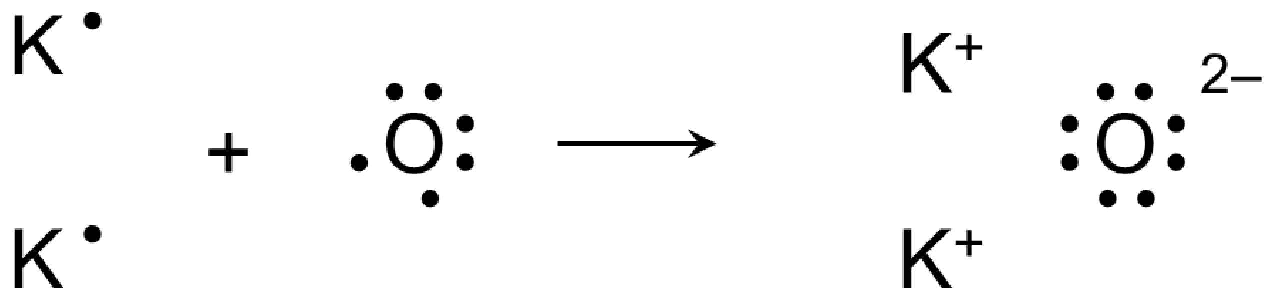
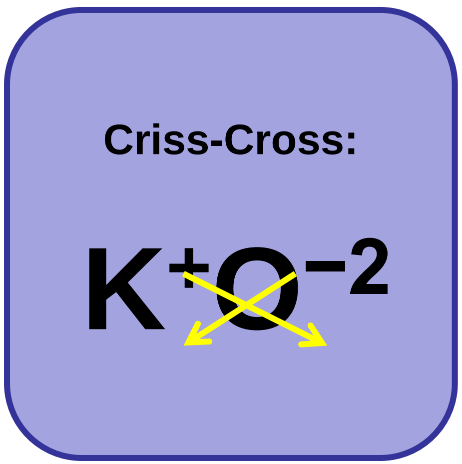
Use electron dot diagrams to determine the formula of the ionic compound formed when potassium reacts with oxygen. Show the overall charge on the formula unit





K_2O

Overall Charge = 2(+1) -2 = **0**

All the atoms have a full valence.

QUICK CHECK

Use electron dot diagrams to determine the formula of the ionic compound formed when calcium reacts with fluorine. Show the overall charge on the formula unit.

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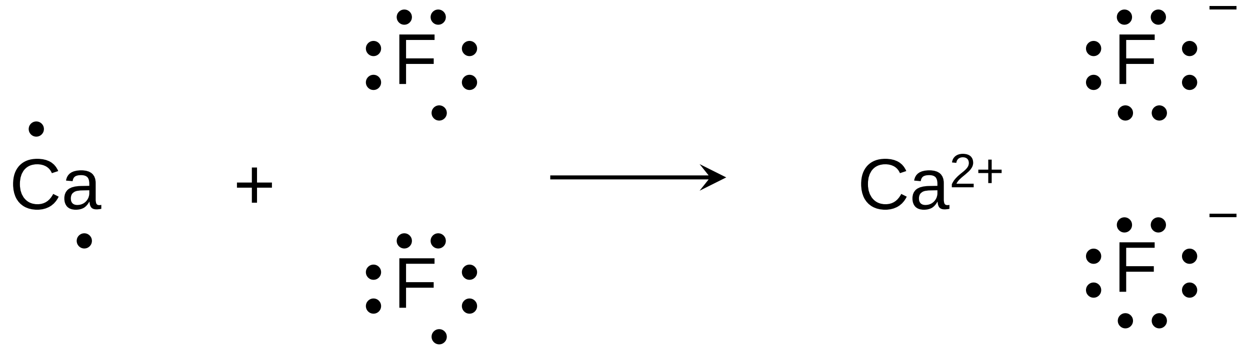
Use electron dot diagrams to determine the formula of the ionic compound formed when calcium reacts with fluorine. Show the overall charge on the formula unit.



Criss-Cross:

$Ca^{+2}F^{-}$

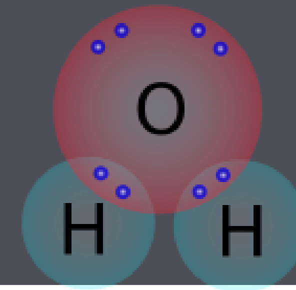
$$CaF_2$$

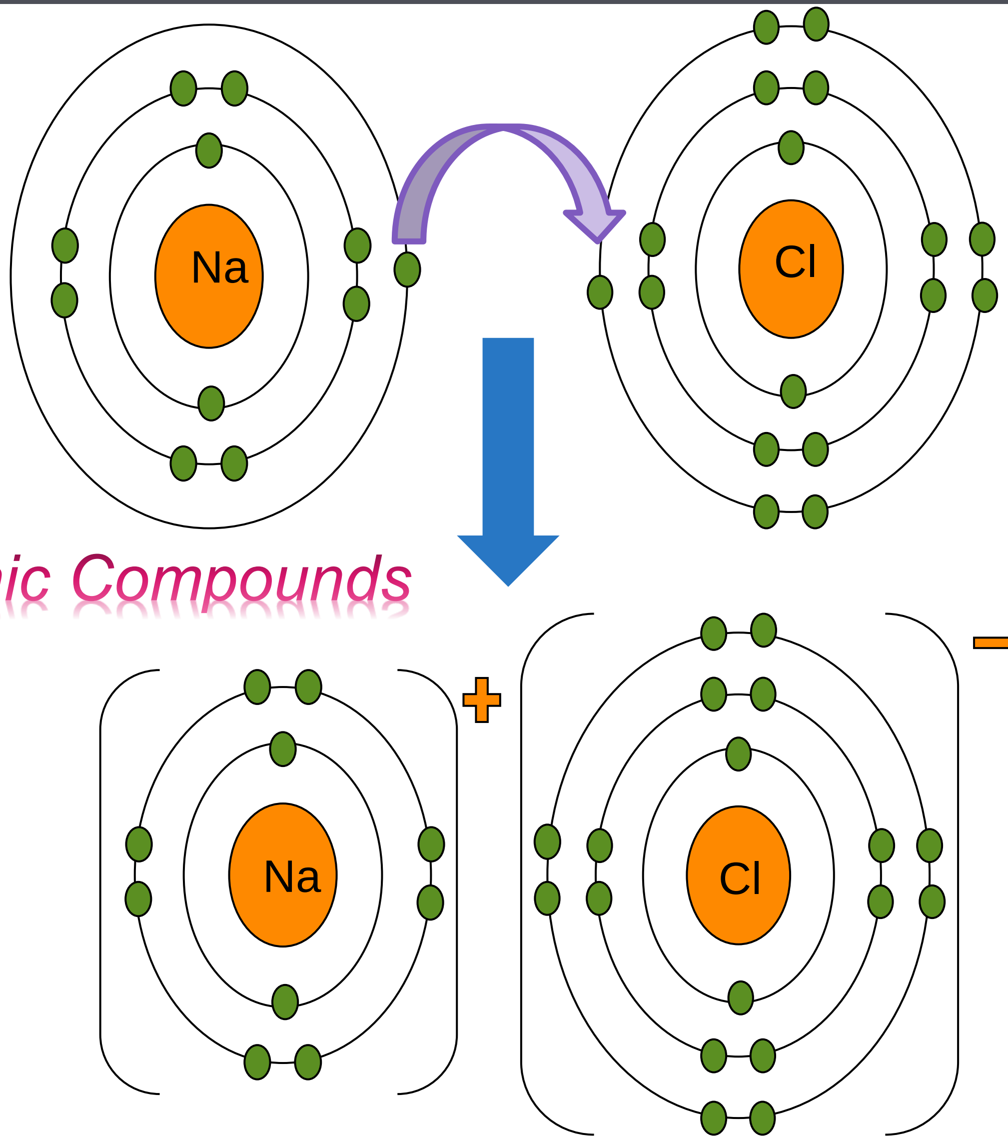
Overall Charge = $+2 + 2(-1) =$ **0**

All the atoms have a full valence.

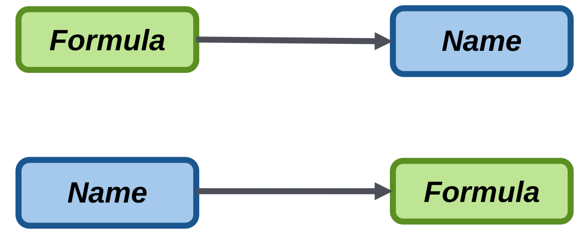
LESSON QUESTION

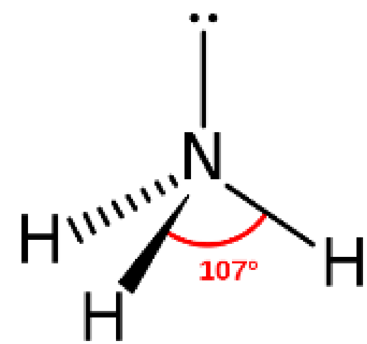
What are the Basics of Naming Compounds and Molecules?





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**

- *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

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.

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

Naming Ionic 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
  - Br^{1-} = bromine

Name: potassium bromide

QUICK CHECK

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

$LiBr$

$CaCl_2$

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
- Br^{-} = Bromine
- Name → lithium bromide

MgS
- Mg^{2+} = magnesium
- S^{-2} = sulfur
- Name → magnesium sulfide

Al_2O_3
- Al^{+3} = aluminum
- O^{-2} = oxygen
- Name → aluminum oxide

$CaCl_2$
- Ca^{2+} = calcium
- Cl^{-} = chlorine
- Name → calcium chloride

Na_3N
- Na^{+} = sodium
- N^{3-} = nitrogen
- Name → sodium nitride

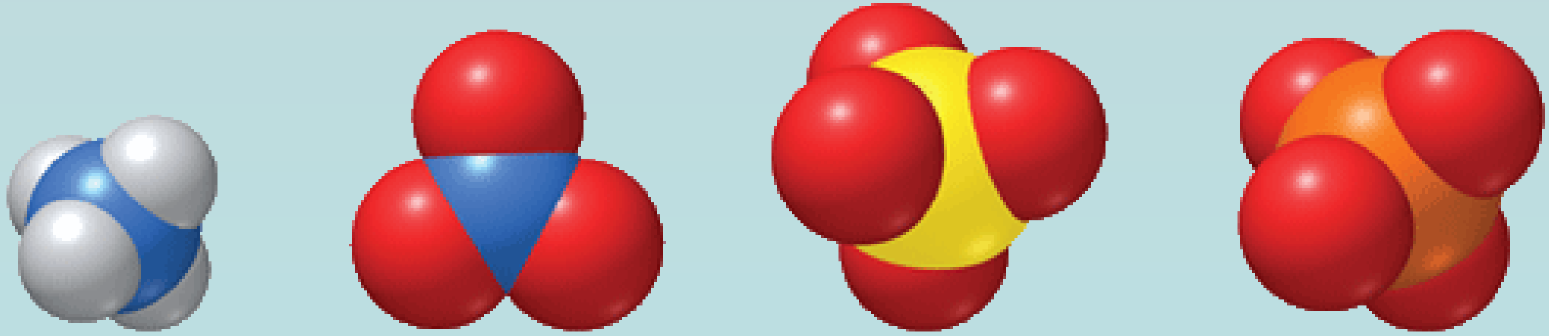
BF_3
- B^{+3} = boron
- F^{-} = fluorine
- Name → boron fluoride

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.

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

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

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

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

Chemical Formulas

ENRICHMENT

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

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

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

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

Naming Polyatomic Ions

You may use a reference table when naming polyatomic ions (download from Study Place).

Common Polyatomic Ions

Charge	Formula	Name
1–	HSO_4^- NO_2^- ClO^-	Hydrogen sulfate Nitrite Hypochlorite
2–	SO_3^{2-} SO_4^{2-} CO_3^{2-}	Sulfite Sulfate 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:

QUICK CHECK

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^+
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-}

$Na_3^{+}(PO_4^{3-})$ … 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

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:

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

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


"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 non-metallic element is listed SECOND because it draws the electrons more and becomes the “anion”.

e.g. Carbon dioxide → carbon is named <u>first</u> because it is the less non-metallic, <u>more “metallic”</u>, 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

Naming Covalent Molecules

Non-metallic character increases to the RIGHT on the Periodic Table.

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

Fluorine is always listed second (most non-metallic).

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

e.g. Cyanide ion $(CN)^{-1}$ → Carbon is listed first (most "metallic")

Naming Covalent Molecules

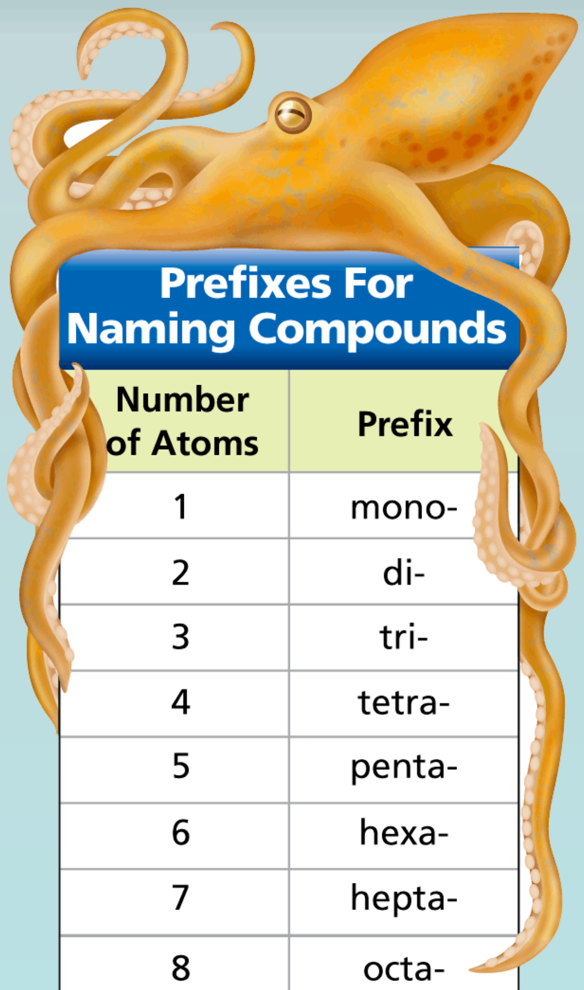
Prefixes are used to indicate how many atoms of each element are present in the compound.

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



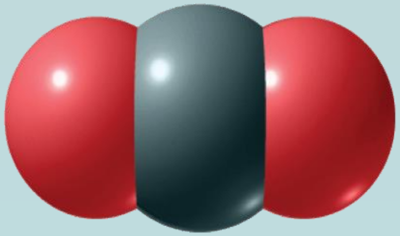
Prefixes For Naming Compounds

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

Naming Covalent Molecules

Name the NONMETAL farthest to the left on the periodic table first. It is the <u>most metallic element</u>.

CO_2 = carbon dioxide, not oxygen carbide



The second element is given an –ide ending.

CO_2 = carbon dioxide, not carbon dioxygen

The prefix mono- often is not used for the first element in the name if there is only one of that element in the formula, so a more common name is carbon dioxide.

Name the Covalent Molecules

TRY IT

NH_3

PCl_3

XeF_6

SiO_2

N_2O_4

P_4O_6

CBr_4

H_2O

Name the Covalent Molecules

TRY IT

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

Multiple Ion States of Atoms

Many elements have multiple ion states that do not match the expected charge 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 $H_3(PO_4)$

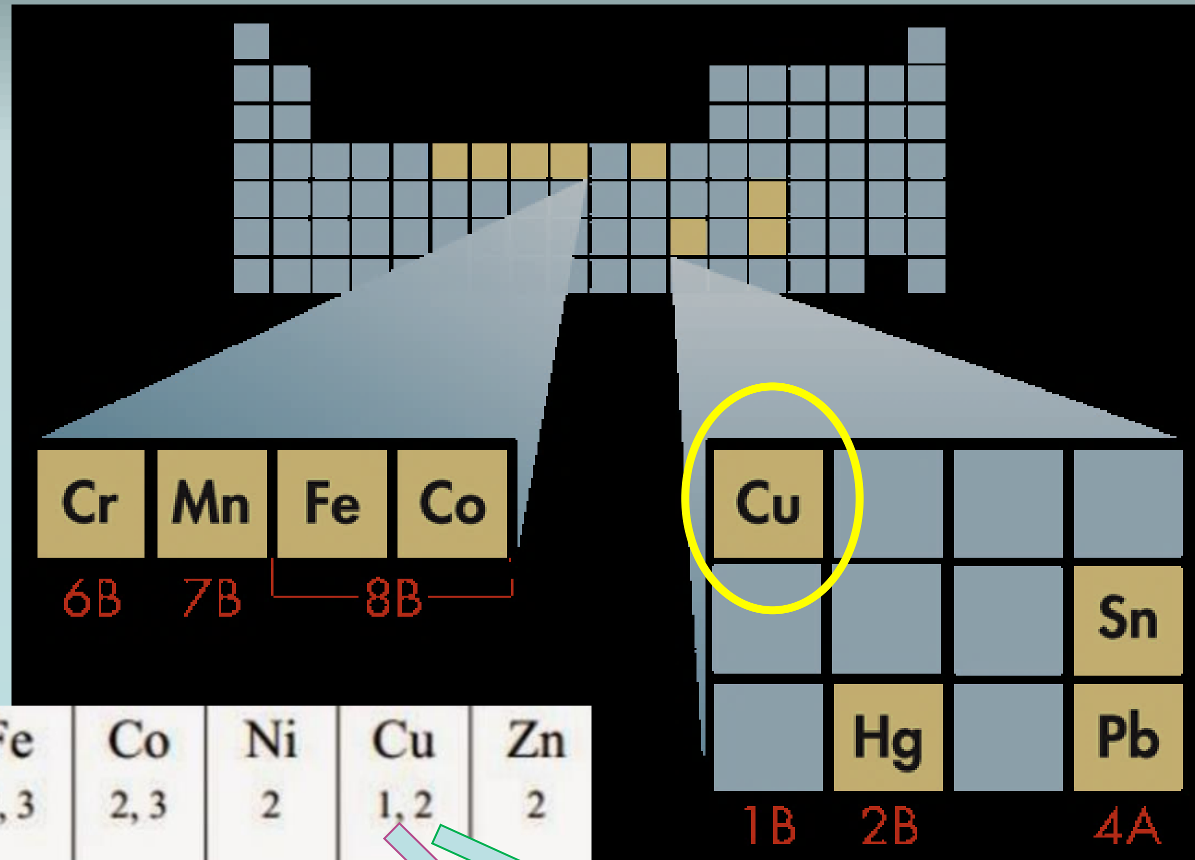
Use "hydrogen" and "oxygen" as the standard for oxid. #

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

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

Multiple Oxidation States of Atoms

Transition metals (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

Covalently bonded molecules usually have multiple oxidation states.

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

TRY IT

The expected oxidation for N = -3

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

Transition Metals usually have multiple oxidation states.

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

Use a ***Roman Numeral*** *to indicate the oxidation of the* ***most metallic element*** *which has the multiple oxidation state.*

Naming Molecules containing atoms with Multiple Oxidation States

Covalently bonded molecules usually have multiple oxidation states.

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

The expected oxidation for N = -3

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

Transition Metals usually have multiple oxidation states.

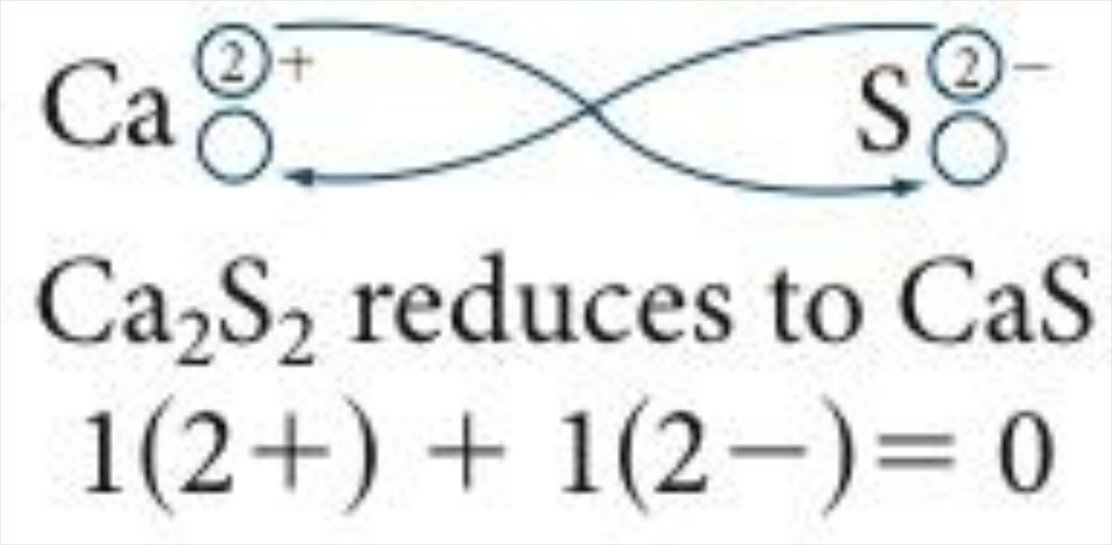
Cu^{+1}	CuCl	Copper(I) Chloride
Cu^{+2}	$CuCl_2$	Copper(II) Chloride

Use a ***Roman Numeral*** *to indicate the oxidation of the* ***most metallic element*** *which has the multiple oxidation state.*

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.

LESSON QUESTION

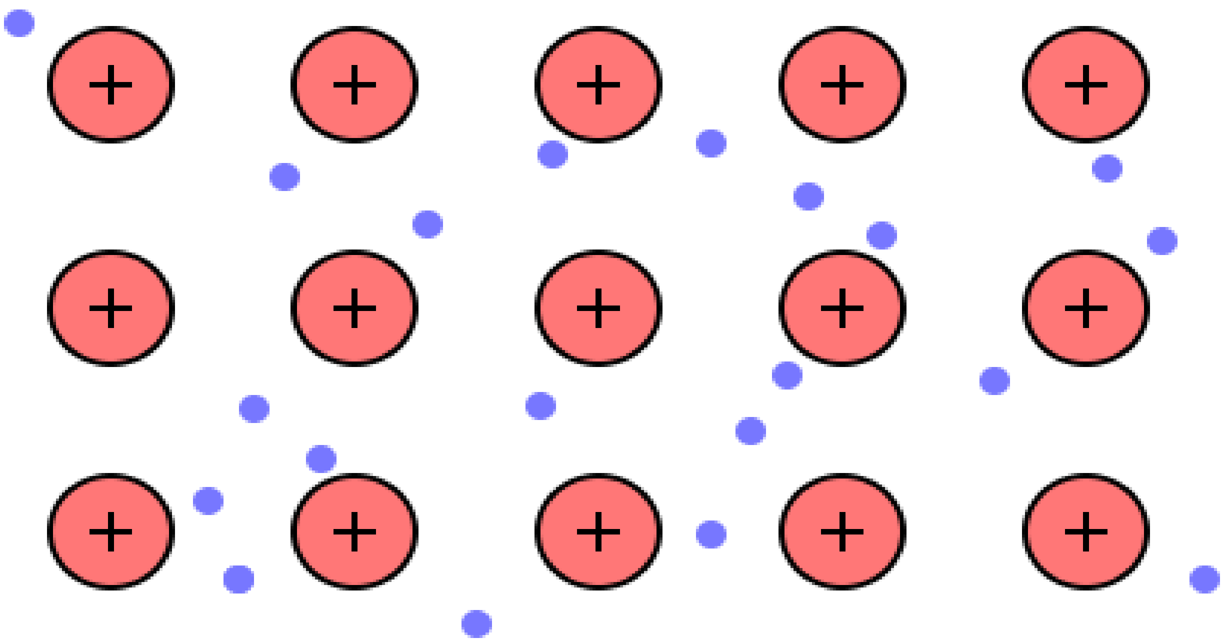
What are the properties of metals? How do metals form bonds with each other?

Metallic Bonds and Metallic Properties

Metals consist of closely packed cations and loosely held valence electrons rather than “neutral” atoms.

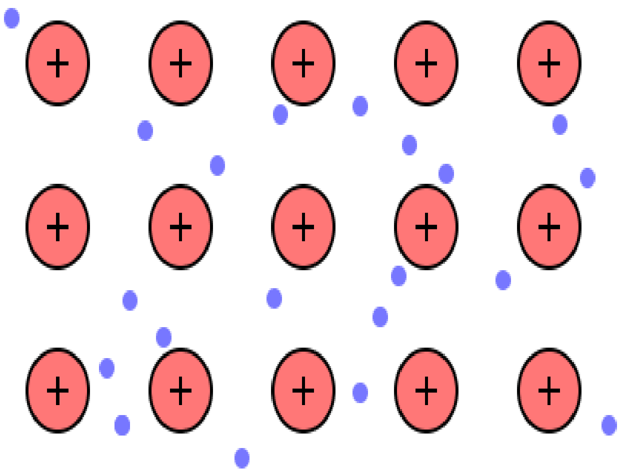
The valence electrons in metals are free to move around among the metallic atoms.

Metal atoms become cations surrounded by a pool of electrons.



The Electron in Metallic Bonds

Metallic bonds are the forces of attraction between the free-floating valence electrons and the positively charged metal ions. These bonds hold metals together.



Metallic bonding results from the sharing of valence electrons among any of the metal atoms.

The strength of the metallic bond is often determined by the number of valence electrons shared in the “pool” of cations.

Describe the Electron Sea Model

Check all the boxes that describe the electron sea model.

[ ] Metallic bonding results from the transfer of valence electrons.

[ ] Metallic bonding results from the sharing of valence electrons.

[ ] The electrons are free to move among the metallic cations.

[ ] The electrons are attracted to specific metallic cations.

[ ] The free moving electrons serve as the glue that keeps the metal atoms together.

[ ] The electrons that are attracted to specific nuclei serve as the glue that keeps the metal atoms together.

Describe the Electron Sea Model

Check all the boxes that describe the electron sea model.

[X] Metallic bonding results from the transfer of valence electrons.

[ ] Metallic bonding results from the sharing of valence electrons.

[X] The electrons are free to move among the metallic cations.

[ ] The electrons are attracted to specific metallic cations.

[X] The free moving electrons serve as the glue that keeps the metal atoms together.

[ ] The electrons that are attracted to specific nuclei serve as the glue that keeps the metal atoms together.

Metallic Bonds and Metallic Properties

Ductile — can be drawn into wires.

Malleable — hammered or pressed into shapes.

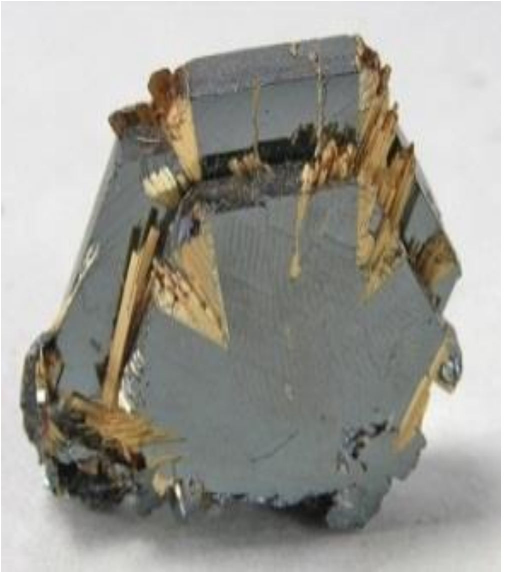
Good Conductors of heat and electricity.

When a metal is subjected to pressure, its cations easily slide past one another.

Malleability, Ductility, and Luster in Metals Explained

Metals are malleable, ductile, and exhibit luster.

- Free moving electrons allow for metals to be easily shaped.
- Easy electron movement produces “flexible” bonds.
  - Metals are malleable and ductile instead of brittle.
- Metallic luster (shines) is due to “free” electrons easily lost.



Conductivity of Metals Explained

Metals conduct heat and electricity well.

- Free moving electrons allow for easy electron movement and the moving electrons carry current or thermal energy
- As electrons enter one end of a bar of metal, an equal number of electrons leave the other end.

Describe the Consequences of Mobile Electrons

What properties of metals are explained by its mobile electrons?

[ ] strength

[ ] malleability

[ ] ductility

[ ] heat conduction

[ ] current conduction

[ ] luster

[ ] opacity (non-transparent)

Sodium (Na)

Tin (Sn)

Copper (Cu)

Silver (Ag)

Describe the Consequences of Mobile Electrons

What properties of metals are explained by its mobile electrons?

[ ] strength (not due to mobility)

[X] malleability

[X] ductility

[X] heat conduction

[X] current conduction

[X] luster (shiny)

[ ] opacity (non-transparent)

Sodium (Na)

Tin (Sn)

Copper (Cu)

Silver (Ag)

Alloys

Homogeneous mixture (solution) of two or more metals.

- Properties of an alloy are different from properties of the pure metals
- Composition can vary from sample to sample

Alloy	Component Metals
Bronze	Copper and tin or aluminum
Brass	Copper and zinc
Rose gold	Gold and copper
Steel	Iron, chromium, and nickel

Alloys

Alloys are important because their properties are often superior to those of their component elements.

Sterling silver (92.5% silver and 7.5% copper) is harder and more durable than pure silver, yet it is still soft enough to be made into jewelry and tableware.

Cast Iron can be molded into intricate shapes.

Sterling Silver
92.5% Ag
7.5% Cu

Cast Iron
96% Fe
4% C

3 Bonding in Metals

Alloys

The most important commercial alloys today are **steels**.

The principal elements in most steels, in addition to **iron** and **carbon**, are boron, chromium, manganese, molybdenum, nickel, tungsten, and vanadium.

Steels have a wide range of useful properties, such as corrosion resistance, ductility, hardness, and toughness.

Stainless Steel
80.6% Fe
18.0% Cr
0.4% C
1.0% Ni

KEY

Atomic Mass	12.0111
Selected Oxidation States	−4, +2, +4
Symbol	C
Atomic Number	6
Electron Configuration	$1s^2 2s^2 2p^2$

Relative atomic masses are based on ^{12}C = 12.00000

Period	*s*-block 1 IA
1	1.00794 +1 −1 **H** 1 $1s^1$

s-block GROUP

New Designation / Former Designation (prior to 1984 IUPAC decision)

d-block — Transition Elements

GROUP 8, 9, 10: VIII

Period	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIII	9 VIII	10 VIII	
2	6.941 +1 **Li** 3 $1s^2 2s^1$	9.01218 +2 **Be** 4 $1s^2 2s^2$									
3	22.98977 +1 **Na** 11 $[Ne]3s^1$	24.305 +2 **Mg** 12 $[Ne]3s^2$									
4	39.0983 +1 **K** 19 $[Ar]4s^1$	40.08 +2 **Ca** 20 $[Ar]4s^2$	44.9559 +3 **Sc** 21 $[Ar]3d^1 4s^2$	47.88 +2 +3 +4 **Ti** 22 $[Ar]3d^2 4s^2$	50.9415 +2 +3 +4 +5 **V** 23 $[Ar]3d^3 4s^2$	51.996 +2 +3 +6 **Cr** 24 $[Ar]3d^5 4s^1$	54.9380 +2 +3 +4 +7 **Mn** 25 $[Ar]3d^5 4s^2$	55.847 +2 +3 **Fe** 26 $[Ar]3d^6 4s^2$	58.9332 +2 +3 **Co** 27 $[Ar]3d^7 4s^2$	58.69 +2 +3 **Ni** 28 $[Ar]3d^8 4s^2$	63.546 29 [Ar]3d
5	85.4678 +1 **Rb** 37 $[Kr]5s^1$	87.62 +2 **Sr** 38 $[Kr]5s^2$	88.9059 +3 **Y** 39 $[Kr]4d^1 5s^2$	91.224 +4 **Zr** 40 $[Kr]4d^2 5s^2$	92.9064 +3 +5 **Nb** 41 $[Kr]4d^4 5s^1$	95.94 +3 +6 **Mo** 42 $[Kr]4d^5 5s^1$	(98) +4 +6 +7 **Tc** 43 $[Kr]4d^6 5s^1$	101.07 +3 **Ru** 44 $[Kr]4d^7 5s^1$	102.906 +3 **Rh** 45 $[Kr]4d^8 5s^1$	106.42 +2 +4 **Pd** 46 $[Kr]4d^{10} 5s^0$	107.868 47 [Kr]4d
6	132.905 +1 **Cs** 55 $[Xe]6s^1$	137.33 +2 **Ba** 56 $[Xe]6s^2$	**La-Lu** 57 71	178.49 +4 **Hf** 72 $[Xe]4f^{14}5d^2 6s^2$	180.948 +5 **Ta** 73 $[Xe]4f^{14}5d^3 6s^2$	183.85 +6 **W** 74 $[Xe]4f^{14}5d^4 6s^2$	186.207 +4 +6 +7 **Re** 75 $[Xe]4f^{14}5d^5 6s^2$	190.2 +3 +4 **Os** 76 $[Xe]4f^{14}5d^6 6s^2$	192.22 +3 +4 **Ir** 77 $[Xe]4f^{14}5d^7 6s^2$	195.08 +2 +4 **Pt** 78 $[Xe]4f^{14}5d^9 6s^1$	196.96 79 [Xe]4f
7	(223) +1 **Fr** 87 $[Rn]7s^1$	226.025 +2 **Ra** 88 $[Rn]7s^2$	**Ac-Lr** 89 103	(261) **Unq*** 104	(262) **Unp** 105	(263) **Unh** 106	(262) **Uns** 107	**Uno** 108	**Une** 109		

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lation States

s-block

p-block

GROUP

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

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
$(NH_4)^{+1}$