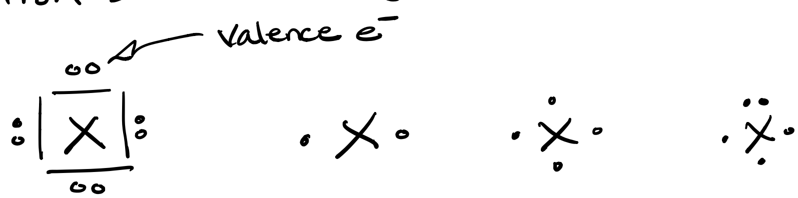
Activity 4 - Writing Formulas & Names

Electronic Configuration

Group	5A	
Element	N	N^{3-}
Electronic Config	$1s^2\ 2s^2 2p^3$	$[1s^2\ 2s^2 2p^6]^{3-}$
Electron Arrangement	2 - 5	2 - 8 ← octet
Electron dot Structure	·N̈· (5 dots)	:N̈: $^{3-}$ (8 dots)

Electron Dot Structures



Cation Example

Group #	2A	
Element	Mg	Mg^{2+}
Electron Config	$1s^2\ 2s^2\ 2p^6\ 3s^2$	$[1s^2 2s^2 2p^6\ 3s^0]^{2+}$
Electron Arrangement	2 - 8 - 2	2 - 8 - 0
Dot Structure	·Mg·	Mg^{2+}

no dots because $3s^0$

A values tell you the # of valence e^-

+ 1 1A	+2 2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	+3 13 3A	14 4A	-3 15 5A	-2 16 6A	- 17 7A	18 8A
1 H Hydrogen 1.008																	2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 16.00	9 F Fluorine 19.00	10 Ne Neon 20.18
11 Na Sodium 22.99	12 Mg Magnesium 24.30											13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.07	17 Cl Chlorine 35.45	18 Ar Argon 39.95
19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.87	23 V Vanadium 50.94	24 Cr Chromium 52.00	25 Mn Manganese 54.94	26 Fe Iron 55.84	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.39	31 Ga Gallium 69.72	32 Ge Germanium 72.61	33 As Arsenic 74.92	34 Se Selenium 78.96	35 Br Bromine 79.90	36 Kr Krypton 83.80
37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.95	43 Tc Technetium 97.91	44 Ru Ruthenium 101.1	45 Rh Rhodium 102.9	46 Pd Palladium 106.4	47 Ag Silver 107.9	48 Cd Cadmium 112.4	49 In Indium 114.8	50 Sn Tin 118.7	51 Sb Antimony 121.8	52 Te Tellurium 127.6	53 I Iodine 126.9	54 Xe Xenon 131.3
55 Cs Cesium 132.9	56 Ba Barium 137.3		72 Hf Hafnium 178.5	73 Ta Tantalum 180.9	74 W Tungsten 183.8	75 Re Rhenium 186.2	76 Os Osmium 190.2	77 Ir Iridium 192.2	78 Pt Platinum 195.1	79 Au Gold 197.0	80 Hg Mercury 200.6	81 Tl Thallium 204.4	82 Pb Lead 207.2	83 Bi Bismuth 209.0	84 Po Polonium 209	85 At Astatine 210	86 Rn Radon 222
87 Fr Francium 223	88 Ra Radium 226		104 Rf Rutherfordium 261	105 Db Dubnium 262	106 Sg Seaborgium 263	107 Bh Bohrium 262	108 Hs Hassium 265	109 Mt Meitnerium 266	110 Ds Darmstadtium 269	111 Rg Roentgenium 272	112 Cn Copernicium 277	113 Nh Nihonium	114 Fl Flerovium 289	115 Mc Moscovium	116 Lv Livermorium 289	117 Ts Tennessine	118 Og Oganesson

Lanthanides	57 La Lanthanum 138.9	58 Ce Cerium 140.1	59 Pr Praseodymium 140.9	60 Nd Neodymium 144.2	61 Pm Promethium 145	62 Sm Samarium 150.4	63 Eu Europium 152.0	64 Gd Gadolinium 157.2	65 Tb Terbium 158.9	66 Dy Dysprosium 162.5	67 Ho Holmium 164.9	68 Er Erbium 167.3	69 Tm Thulium 168.9	70 Yb Ytterbium 173.0	71 Lu Lutetium 175.0
Actinides	89 Ac Actinium 227	90 Th Thorium 232.0	91 Pa Protactinium 231.0	92 U Uranium 238.0	93 Np Neptunium 237	94 Pu Plutonium 244	95 Am Americium 243	96 Cm Curium 247	97 Bk Berkelium 247	98 Cf Californium 251	99 Es Einsteinium 252	100 Fm Fermium 257	101 Md Mendelevium 258	102 No Nobelium 259	103 Lr Lawrencium 262

Activity 4 - Writing Formulas and Names

Goals

- Write the electron dot structure for an atom.
- Predict the charge of an ion from its electron dot structure.
- Use the periodic table to determine the ionic charge of a metal or nonmetal ion.
- Write the correct formula and name of an ionic or covalent compound.
- Write the correct formula and name of a compound containing polyatomic ions.

Pre-lab Questions*(answer these on a separate sheet using complete sentences)*

1. Where are the valence electrons in an atom located?
2. How is a positive ion formed from an atom? Why is the charge positive?
3. How is a negative ion formed from an atom? Why is the charge negative?
4. How are the group numbers on the periodic table related to the number of valence electrons? To ionic charge?
5. How do subscripts represent the charge balance in polyatomic ions?
6. According to what rubric are electrons shared in covalent compounds (i.e. what does electron sharing accomplish?
7. How do the names of covalent compounds differ from the names of ionic compounds?
8. What are polyatomic ions? How are they named?

Concepts to Review

Electronic structure (energy levels)
Formation of positive and negative ions
Balancing ionic charge
Ionic and covalent compounds
Writing formulas of ionic and covalent compounds
Naming ionic and covalent compound

Introduction

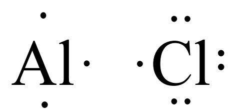
Most of the chemical reactivity of an element is determined by the **valence electrons**, which are the electrons in the highest energy level (or outermost electron shell). Usually in a compound, each atom has an **octet** of electrons (i.e. eight of these) in each of the valence shells. An octet of valence electrons provides atoms with the stable electron configuration found among the noble gases, a group of elements that are particularly stable and inert (unreactive). The first noble gas ($_2$He) does not have an octet since the second electron fills the first (n=1) valence shell, which can accommodate only two electrons.

Required Materials

A Periodic Table of the Elements.

A. Electron Dot Structures

When atoms of metals in groups 1A, 2A or 3A react with atoms of nonmetals in groups 5A, 6A and 7A, the metals lose valence shell electrons and the nonmetals gain valence shell electrons. We can predict the number of electrons lost or gained by analyzing the electron dot structures of the atoms. In an electron dot structure, the valence electrons are represented as dots around the symbol of the atom. For example, aluminum has 13 electrons, 2 in the first energy level, 8 in the second energy level and 3 in the third energy level. To describe this electronic structure we write the **electron arrangement** as 2-8-3. The last number represents the valence electrons so aluminum has three valence electrons and thus an electron dot structure with three dots. Chlorine (electron arrangement 2-8-7) has seven valence electrons and an electron dot structure with seven dots.



Main group metals (group A elements) with 1, 2 or 3 valence electrons *lose* their valence electrons to reach a stable electron configuration with a filled outer shell. For example, an aluminum atom loses its three valence electrons to reach stability and thus acquires an ionic charge of 3+. It is now an aluminum ion with a new electron arrangement of 2-8 (note the complete octet in the outer shell). Positive ions keep the same name as the element.

	Aluminum atom	Aluminum ion	
Symbol	Al	Al^{3+}	
Electron arrangement	2-8-3	2-8-0	(3 electons lost)
Number of protons	13 p^+	13 p^+	(same)
Number of electrons	13 e^-	10 e^-	(3 fewer electrons)
Net ionic charge	0	3+	

When nonmetals with 5, 6 or 7 valence electrons combine with metals, they *gain* electrons to complete their outer shells, and form stable (negatively charged) ions. For example, a chlorine atom gains one valence electron to become stable with an electron arrangement of 2-8-8. With the addition of one electron, chlorine becomes a chloride ion with an ionic charge of 1-. (When two elements combine to form a binary compound called a salt, the name of the negative ion ends in ***-ide***.)

	Chlorine atom	Chloride ion	
Symbol	Cl	Cl^-	
Electron arrangement	2-8-7	2-8-8	(electon added)
Number of protons	17 p^+	17 p^+	(same)
Number of electrons	17 e^-	18 e^-	(1 more electron)
Net ionic charge	0	1-	

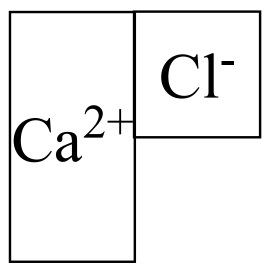
In the worksheet, *write the electron arrangements for atoms and their ions. Write the symbol, ionic charge, and name of each ion.*

B. Writing Ionic Formulas

The group number on the periodic table can be used to determine the ionic charges of elements in each family. **Nonmetals form ions only if they combine with a metal; if they combine with another non-metal, they form covalent (non-ionic) compounds.**

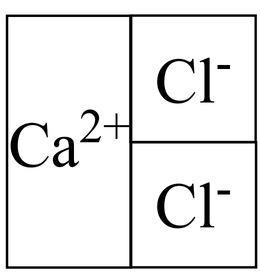
Group number	1A	2A	3A	4A	5A	6A	7A
Valence electrons	$1e^-$	$2e^-$	$3e^-$	$4e^-$	$5e^-$	$6e^-$	$7e^-$
Change	lose	lose	lose	none	gain	gain	gain
Ionic charge	1+	2+	3+	none	3-	2-	1-

In an ionic formula, the **total loss of electrons and total gain of electrons are equal.** The overall net charge is *zero.* This means that the total amount of positive charge must be made equal to the total amount of negative charge. To balance charge, we determine the smallest number of positive and negative ions that give an overall charge of *zero*. We can illustrate the process by showing the ions Ca^{2+} and Cl^- as geometric shapes that represent the amount of ionic charge:



The charge is balanced by using two Cl^- ions to match the shape of the Ca^{2+}. Charge balance occurs with one calcium ion and two chloride ions. This is shown by the subscripts in the formula $CaCl_2$. The subscript "1" for Ca is understood; it is never written. Note that *only the symbols are written in the formula, not the ionic charges.*

Balancing amount of ionic charge | Resulting formula



= $CaCl_2$

In the following worksheet, *write the symbols of the positive and negative ions using the periodic table to determine the charge. Determine the number of each ion that will give a charge balance. Write the correct formula using subscripts to indicate that two or more ions were needed. Write the names of the ionic compounds by placing the metal name first, then the nonmetal name ending in* **-ide**.

C. Ionic Charges for Transition Metals

Most of the transition metals form more than one type of positively charged ion (or cation). We will illustrate this variable valence (combining capacity) with *iron*. Iron forms two cations, one (Fe^{2+}) with a 2+ charge, and another (Fe^{3+}) with a 3+ charge. To distinguish between the two ions, a Roman numeral that gives the ionic charge of that particular ion follows the element name (see below). The Roman numeral is always included in the names of compounds with positive ions that can have variable charge (or oxidation) states. (In an older naming system, the ending -*ous* indicates the lower valence and the ending -*ic* indicates the higher one. Compound names using this system still appear on old reagent bottles and in old chemistry texts.)

Ions	Names	Formula of Compound	Name of Compound
Fe^{2+}	iron (II) ion or ferrous ion	$FeCl_2$	Iron (II) chloride or ferrous chloride
Fe^{3+}	iron (III) ion or ferric ion	$FeCl_3$	Iron (III) chloride or ferric chloride

Among the transition metals a few elements (zinc, silver and cadmium) form only a single type of ion; these have fixed ionic charges and are *not* variable, hence these *do not* use a Roman numeral in their names. Examples are: **Zn^{2+}, zinc ion; Ag^{+}, silver ion; Cd^{2+}, cadmium ion.**

D. Polyatomic Ions

When an ionic compound consists of three or more kinds of atoms, there is a generally a central atom (usually a metal), and a group of attached nonmetal atoms. Such ions are called *polyatomic ions*. A polyatomic ion is a group of covalently bonded atoms with an overall charge that is usually negative. The most common polyatomic ions consist of the nonmetals C, N, S, P, Cl or Br, combined with two to four oxygen atoms. Some examples are given below. The ions are named by replacing the ending of the nonmetal with **-ate** or **-ite**. The form for each central element's most common oxidation state takes the -*ate* ending; the -*ite* ending is for the ion with one less oxygen atom than the -*ate* ion has. Ammonium ion, NH_4^{+}, is unusual because it has a positive charge and a metal-like name.

Common polyatomic ions		One oxygen less than common ion	
HO^{-}	hydroxide ion		
NO_3^{-}	nitrate ion	NO_2^{-}	nitrite ion
CO_3^{2-}	carbonate ion		
HCO_3^{-}	hydrogen carbonate ion or bicarbonate ion		
SO_4^{2-}	sulfate ion	SO_3^{2-}	sulfite ion
HSO_4^{-}	hydrogen sulfate ion or bisulfate ion	HSO_3^{-}	hydrogen sulfite ion or bisulfite ion
PO_4^{3-}	phosphate ion	PO_3^{3-}	phosphite ion

Note that there are polyatomic ions that consist of only two different types of atoms (e.g. hydroxide ion; see above) as well as those that have multiple copies of the same atom (e.g. azide ion: N_3^-).

In the worksheet, *write the formulas of compounds that contain ions of transition metals with variable valences. Write a correct name for each compound listed. Be sure to indicate the ionic charge if the transition metal has a variable valence by using a Roman numeral.*
To write the correct formula of a compound with a polyatomic ion, determine the ions required to achieve charge balance just as earlier. When two or more polyatomic ions are needed, enclose the formula of the ion in parentheses, and write the subscript **outside** the parentheses. *No change is made in the formula of the polyatomic ion itself.*

Consider the formula of the compound formed by Ca^{2+} and NO_3^- ions. The ions are $\mathbf{Ca^{2+}}$ and $\mathbf{NO_3^-}$. Since 2 nitrate ions will be needed to balance the charge on the calcium ion, we will need to indicate two NO_3^- ions using parentheses: $\mathbf{Ca(NO_3)_2}$. Note that the formula of the nitrate ion is not changed.

In the worksheet, *determine the positive ions and negative polyatomic ions needed for charge balance. Write the formula using parentheses if necessary. Name the compounds listed using the correct names of the polyatomic ions.*

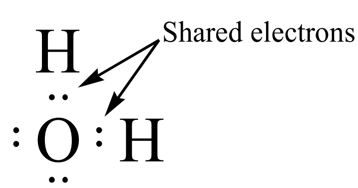
E. Covalent (Molecular) Compounds

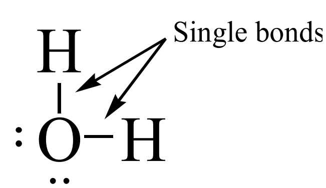
Covalent bonds form between nonmetal atoms located in Groups 4A, 5A, 6A or 7A. In a **covalent compound,** octets are achieved by sharing electrons between atoms. The sharing of one pair of electrons is referred to as a single bond. A double bond is the sharing of two pairs of electrons between atoms. In a triple bond, three pairs of electrons are shared. To write the formula of a covalent compound, determine the number of electrons needed to complete an octet. For example, nitrogen in Group 5 has five valence electrons so that it needs 3 more electrons for an octet; each nitrogen atom shares 3 electrons in covalent compounds.

Electron Dot Structures

The formulas of covalent compounds are determined by sharing valence electrons until each atom has an octet. For example, in water, oxygen shares two electrons with two hydrogen atoms. Oxygen has an octet and the hydrogen atoms are stable because they have two electrons in their outer (valence) shells. (Note that shared electron pairs are often represented as lines connecting the atoms that share them.)

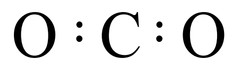
Dot Structure for H_2O



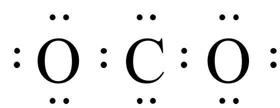


In another example, consider CO_2, a molecule that has two double bonds. In electron dot structures, carbon has 4 valence electrons and each oxygen atom has 6. Thus for CO_2, a total of 16 (4 + 6 + 6) electrons can be used in forming the octets by sharing electrons. We can use the following steps to determine the electron dot structure for CO_2:

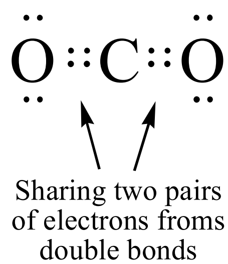
1. Connect the atoms with pairs of electrons, which uses 4 electrons:

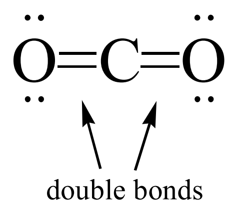


2. Add electrons to complete octets around all atoms:



3. Count the number of electrons used. We used 20. But only 16 are available. Therefore, we must economize by removing 2 pairs of electrons (4 electrons), and move 2 other pairs in between the C and the O's in order to maintain octets. This will form two double bonds:





Names of Covalent Compounds

Binary (two-element) covalent compounds are named by using*prefixes* that give the number of atoms of each element in the compound. The first nonmetal is named by the element name; the second ends in -*ide*. The prefixes are derived from Greek names: mono-, di-, tri-, tetra-, penta-, hexa-, hepta-, octa-, nona-and deca-. (Higher ones exist, but are rarely used.) Usually the prefix mono- is not shown for the first element.

Formula of Covalent Compound	Name
CO	carbon**mon**oxide
CO_2	carbon**di**oxide
PCl_3	phosphorus**tri**chloride
N_2O_4	**di**nitrogen**tetr**oxide ("a" dropped before the vowel "o" in "oxide")
SCl_6	sulfur**hexa**chloride

In the worksheet, *write the electron dot structure for each nonmetal. Then write electron dot structures for the covalent compounds. Name each of the covalent compounds, using the numerical prefixes when appropriate.*

Activity 4 - Writing Formulas and Names Worksheet

Name______________________________

Section_____________ **Date**_______

Exercise A. Electron Dot Structures

1. Using the example given, complete this table.

Element	Atomic Number	Electron arrangement of atom	Electron dot structure of atom	Loss/gain of electrons by atom	Electron arrangement of ion	Ionic charge	Symbol of ion	Name of ion
Sodium	11	2-8-1 **Or** $1s^22s^22p^63s1$	Na•	Lose 1 e^-	2-8 **Or** $1s^22s^22p^6$	1+	Na^+	Sodium ion
Oxygen	8	$1s^22s^22p^4$ 2-6	:Ö:	Gain 2ē	$[1s^22s^22p^6]^{-2}$ 2-8	2-	O^{2-}	oxide
Aluminum								
Potassium								
Chlorine								
Calcium								
Nitrogen								
Sulfur								

* 2. Review the "Name of ion" column above. What distinguishes the naming of the metal cations from the naming of nonmetals anions?

Mg^{2+} | Cl^-
| Cl^-

2+ | 2−

$MgCl_2$

Exercise B. Writing Ionic Formulas:

1. Use the periodic table to help complete the table below.

Name	Positive ion	Negative ion	Formula
Sodium oxide	Na^+	O^{2-}	Na_2O
Magnesium chloride	Mg^{2+}	Cl^-	$MgCl_2$
Potassium chloride			
Calcium oxide			
Aluminum bromide			
Lithium phosphide			
Aluminum sulfide			
Aluminum nitride			
Calcium nitride			

2. Name the following ionic compounds:

Na_2S Sodium Sulfide

MgF_2 ____________________

MgS ____________________

K_3N ____________________

Ca_3P_2 ____________________

$AlCl_3$ ____________________

3. Review the answers in problems 1 and 2 of exercise B above. What do the subscripts represent?

Exercise C. Ionic Charges for Transition Metals

1. Complete the table below.

Name	Positive ion	Negative ion	Formula
Iron (II) bromide	Fe^{2+}	Br^{-}	$FeBr_2$
Iron (II) chloride			
Iron (III) sulfide	Fe^{3+}	S^{2-}	
Copper (II) chloride			
Copper (II) sulfide			
Copper (II) nitride			
? Zinc oxide			
? Silver sulfide			

* Zn & Ag only have one charge state ⇒ Treated like main group metal Zn^{2+} Ag^{+}

2. Name the following ionic compounds:

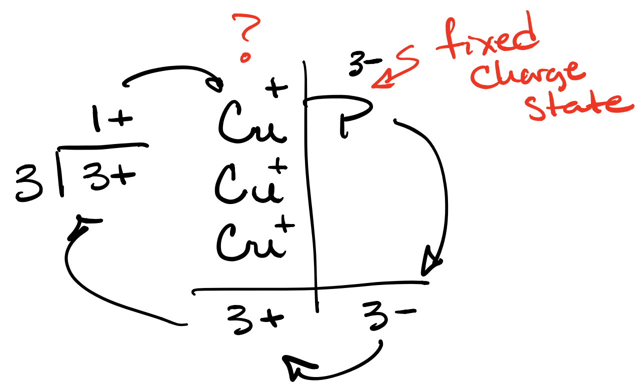
Cu_3P Copper(I) Phosphide

Fe_2O_3 __________

FeI_3 __________

$CuCl$ __________

$ZnBr_2$ __________



3. Consider your answers in problems 1 and 2 of exercise C above. What do the roman numerals in parentheses represent?

Li^{+} | CO_3^{2-}
Li^{+}
2+ | 2−

Mg^{2+} | HCO_3^- HCO_3^-
2+ | 2−

$Mg(HCO_3)_2$
magnesium Carbonate

Exercise D. Polyatomic Ions

1. Complete the table below.

Name	Positive ion	Negative ion	Formula
Sodium nitrate	Na^{+}	NO_3^{-}	$NaNO_3$
Lithium carbonate	Li^{+}	CO_3^{2-}	Li_2CO_3
Potassium sulfate			
Calcium bicarbonate			
Aluminum hydroxide			
Lithium sulfite			
Sodium phosphate			
Iron (II) phosphate			

SO_4^{2-} sulfate
SO_3^{2-} sulfite

2. Name the following ionic compounds:

Transition metals

$CaSO_4$ Calcium Sulfate

Cu_3PO_4 ________________

$Al(NO_3)_3$ ________________

Na_2CO_3 ________________

$MgSO_3$ ________________

$Fe(HCO_3)_2$ Iron (II) bicarbonate

fixed charge state

Fe^{2+} | HCO_3^- HCO_3^-
2+ | 2−

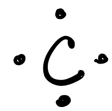
3. Consider *all* of the nomenclature exercises in exercises B, C and D. What are the rules for the correct placement of parentheses in the naming and writing chemical formulas of ionic compounds?

Iron (II) Bicarbonate $Fe(HCO_3)_2$

Exercise E. Lewis Dot Structures of Atoms and Molecules

1. ***Electron dot formulas of elements:*** Atoms are represented by symbol with valence e⁻'s represented by dots. Complete the following table. Distribute dots on all four sides before pairing.

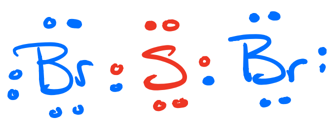
C = 4A

Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Chlorine
H·					

Examples on pg 15 of notes

2. ***Electron dot formulas of covalent compounds:*** Lewis dot structures must have the correct number of valence electrons displayed in bonded or nonbonded pairs along with the octet rule being obeyed (duet rule for H). Complete the following table for the given binary covalent compounds.

Binary Covalent Nomenclature

Compound	Electron dot structure	Name
HCl	H:Cl: (with lone pairs above and below Cl)	Hydrogen chloride
6 7 SBr_2		element name Sulfur dibromide prefix ide
PCl_3		
OF_2		
SO_3		

Questions and Problems

1. Write the correct formulas for the following ions:

sodium ion ___________	oxide ion ___________	calcium ion ___________
chloride ion __________	sulf**ate** ion __________ (← polyatomic)	iron (II) ion ___________

2. Write the correct name of the following compounds.

Ionic	CuO	____________________	Transition metal
Binary Covalent	N_2O_4	____________________	
Ionic	$Al(NO_3)_3$	____________________	main group metal
Binary Covalent	PCl_3	____________________	
	$FeCO_3$	____________________	Transition metal
	$Cu(OH)_2$	____________________	Transition metal
	Ag_2O	____________________	Like main group

3. Identify the following compounds as ionic or covalent. (circle I or C) and write the corresponding molecular formula.

metal = Ionic

no metal = Covalent

Sodium oxide	I C	__________________________
Iron (III) bromide	I C	__________________________
Sodium carbonate	I C	__________________________
Aluminum sulfite	I C	__________________________
Carbon tetrachloride	I C	__________________________
Nitrogen tribromide	I C	__________________________

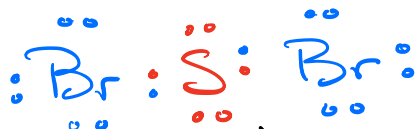
4. Your friend wants to know what the formula $FeSO_4$ on her vitamin bottle means and what the name of this ingredient is. Help her understand the meaning of the symbols and the correct name associated with this formula (i.e write a brief answer to her question).

Example of Lewis Dot Structures

SBr_2

first element is central

Lewis Dot Structure



e⁻ paired to make a covalent Bond

Lewis Structure

Sharing of $2e^-$ represented with a line = Covalent bond