Nomenclature Worksheet

3 Types Ionic Nomenclature

- main group metals with main group non-metals
- Transition metals with non-metals
- main group & Transition metals with polyatomics

+	−
Cation	Anion

$MgCl_2$ — Mg^{2+} magnesium (unmodified) — Cl^- Chloride (Chlorine ⇒ Chloride)

Transition Metals

+/+2

Cu^{+} Copper(I)
Cu^{2+} Copper(II)

Hg_2^{2+} ← Hg^{+}
Hg^{2+}

+2/+3

Fe^{2+} Iron(II)
Fe^{3+} Iron(III)

Co^{2+}
Co^{3+}
Cr^{2+}
Cr^{3+}
Mn^{2+}
Mn^{3+}

+2/+4

Pb^{2+} Lead(II)
Pb^{4+} Lead(IV)

Sn^{2+}
Sn^{4+}

New naming System for transition metal Ions

Name of metal folled by roman numeral that tells the charge state

$Tin(IV) = Sn^{4+}$

Older Naming System for transition Metal Ions

Uses a root followed by a suffix that indicates high or low charge state

-ic High Charge State

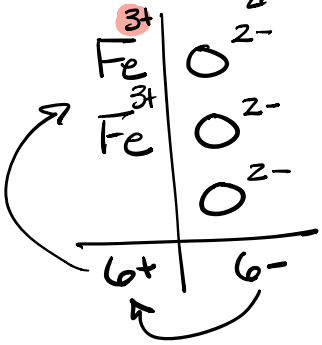
-ous Low Charge State

Root - often taken from Latin

	Root	old Name	New Name
Fe^{3+}	Ferr	Ferric	Iron(III)
Fe^{2+}	Ferr	Ferrous	Iron(II)

Fe_2O_3

always 2−



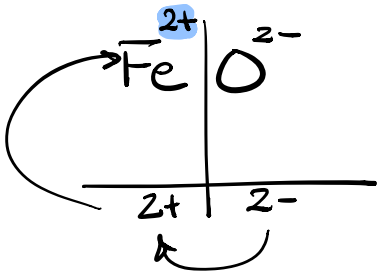
New Name

Iron(III) Oxide

Old Name

Ferric Oxide

FeO



New Name

Iron(II) Oxide

Old Name

Ferrous Oxide

Transition Metal Roots for older Naming System

+/+2

- Cu^{+} } Cuprous
- Cu^{2+} } Cupr
  Cupric

- Hg_2^{2+} } Mercurous
- Hg^{2+} } Mercur
  Mercuric

+2/+3

- Fe^{2+} } Ferrous
- Fe^{3+} } Ferr
  Ferric

- Co^{2+} } Cobaltous
- Co^{3+} } Cobalt
  Cobaltic

- Cr^{2+} } Chromous
- Cr^{3+} } Chrom
  Chromic

- Mn^{2+} } Manganous
- Mn^{3+} } Mangan
  Manganic

+2/+4

- Pb^{2+} } Plumbous
- Pb^{4+} } Plumb
  Plumbic

- Sn^{2+} } Stannous
- Sn^{4+} } Stann
  Stannic

Module 4 ⇒ Activity 9

Activity 9 - Nomenclature

Every compound has its own chemical formula and its own name. The nomenclature (naming system) for ionic and molecular compounds is different. Molecular compounds contain only nonmetals and ionic compounds contain **ions (charged particles)** comprised of metals and nonmetals.

Ionic compounds: These consist of any positive ion (**a cation**) except H^+ with any negative ion (**an anion**). If H^+ is the positive ion, it is an acid.

The **cation** may be a metal ion (e.g., Na^+) or a polyatomic ion (e.g., NH_4^+).

The **anion** may be a nonmetal ion (e.g., Cl^-) or a polyatomic ion (e.g., SO_4^{2-}).

A. Representative Metal + Nonmetal Compounds

Examples: KBr potassium bromide

$AlCl_3$ aluminum chloride

- The metal cation is always first (the name of the element is unchanged).
- The nonmetal anion is second (the element name is given an *–ide* ending).
- The compound is electrically neutral without any charges in the formula.

B. Transition Metal + Nonmetal Compounds

In general (but not in every instance), the cations formed by the transition metals can have two different charges. **Memorize** those ions assigned by your instructor (flash cards can help you).

- If the transition metal forms only one ion, name the compound as in Case 1.

Examples: $ZnCl_2$ zinc chloride

Ag_2S silver sulfide

- If the metal can form more than one type of ion, name the compounds according to one or both of the possible naming systems (each has two names!).

Examples: FeO ferrous oxide (old system) or iron (II) oxide (new system)
formed from Fe^{2+} and O^{2-}

Fe_2O_3 ferric oxide (old system) or iron (III) oxide (new system)
formed from Fe^{3+} and O^{2-}

Lead and **tin** form 2+ and 4+ ions. Even though they are **not** transition metals, they are named as such.

Archaic (old) system:

The **–ous** ending refers to the ion with the lower charge state (e.g., Fe^{2+} or Cu^+, cupr**ous**).

The **–ic** ending refers to the ion with the higher charge state (e.g., Fe^{3+} or Cu^{2+}, cupr**ic**).

Modern (new, IUPAC) system:

The modern names for Cu^+ and Cu^{2+} would be copper (I) ion and copper (II) ion.

Cases 1 and 2 involve ionic compounds that consist of only a metal cation and a nonmetal anion – two elements only. They are called **binary compounds** and consist of two monatomic ions. Ionic compounds can also be formed from more complex ions (polyatomic ions).

C. Ionic Compounds with Polyatomic Ions

The list of polyatomic ions (names and formulas) to be memorized is assigned by your instructor (again, index cards can be helpful). Don't worry – you will become more comfortable with these as you gain more experience. For all ionic compounds, the cation is named first, followed by the anion.

Examples:	$(NH_4)_2SO_4$	ammonium sulfate
	K_3PO_4	potassium phosphate
	$Fe_2(SO_4)_3$	iron(III) sulfate or ferric sulfate

Parentheses, ( ), are used only when **two or more** polyatomic ions comprise the positive portion or the negative portion (or both) of the compound. As examples, in ammonium sulfate two ammonium ions are required to balance the 2- charge on the sulfate ion to form $(NH_4)_2SO_4$, whereas in iron (III) sulfate, three 2- sulfate ions are required to balance the charge of two 3+ iron (III) ions to form $Fe_2(SO_4)_3$. An example of no need for parentheses is potassium phosphate (K_3PO_4).

D. Molecular compounds

These are compounds formed when two nonmetal atoms share electrons with other nonmetal atoms. Binary molecular compounds consist of two different atoms and should be named according to the rules below. Like ionic compounds, the more positive "ion" is first and the more negative "ion" is second, with the negative ion's name including an **–ide** ending. To determine which of the elements is the most positive (or negative), compare their relative electronegativities.

Unlike ionic compounds, **the number of each type of atom is specified with a prefix.**

1: mono	3: tri	5: penta	7: hepta	9: nona
2: di	4: tetra	6: hexa	8: octa	10: deca

If there is only one atom of the leading element, the mono prefix is not used.

Examples:	NO	nitrogen monoxide	N_2O	dinitrogen monoxide
	NO_2	nitrogen dioxide	IF_7	iodine heptafluoride
	O_2	oxygen	N_2	nitrogen

E. Acids:

Acids (from the Latin word *acidus*, meaning "sour") are an important class of compounds. One way to define these compounds is as a substance whose molecules each yield one or more hydrogen ions (H^+) when dissolved in water.

The formula for an acid is formed by adding a sufficient number of H to balance the charge on the anion. The name of the acid is related to the name of the anion and includes the label **acid**.

- Binary acids are an important class of acids. These follow the general formula HX. The anions whose names end in **–ide** have associated acids that have the **hydro–** prefix and an **–ic** ending (according to the old nomenclature system).

Example: anion = Cl^- corresponding acid = HCl (**hydro**chlor**ic acid,** or hydrogen chloride)

- Many of the most important acids are derived from oxyanions (polyatomic ions which contain oxygen). Oxyanions whose names end in **–ite** (sulfite, nitrite, chlorite, etc.) have associated acids whose names end in **–ous**.

Examples:	SO_3^{2-}	sulfite	H_2SO_3	sulfur**ous acid**
	ClO_2^-	chlorite	$HClO_2$	chlor**ous acid**

- Oxyanions whose names end in **–ate** (sulfate, phosphate, nitrate, chlorate, etc.) have corresponding acids whose names are given an **–ic** ending.

Examples:	SO_4^{2-}	sulfate	H_2SO_4	sulfuri**c acid**
	ClO_3^-	chlorate	$HClO_3$	chlor**ic acid**

- *Note that the sulfur containing acids use the root name of "sulfur-" rather than the shorter version "sulf-" used in the anions*. This is an exception and must be memorized. Phosphoric acid has three hydrogens attached to a phosphate ion and is like sulfur in that two syllables of the element name are used to name this acid.

- Table 1. Common Ions

Positive Ions (Cations)	Negative Ions (Anions)
+1 Charge	***-1 Charge***
Group 1A cations	Group 7A anions
Ammonium (NH_4^+) Polyatomic Cation	Acetate ($C_2H_3O_2^-$)
Copper (I) or cuprous (Cu^+)	Cyanide CN^-
Hydrogen (H^+) "proton"	Dihydrogen phosphate ($H_2PO_4^-$)
Silver (Ag^+)	Hydrogen carbonate or bicarbonate (HCO_3^-)
Hydronium ion (H_3O^+)	Hydrogen sulfate of bisulfate (HSO_4^-)
	Hydroxide (OH^-)
	Nitrate (NO_3^-), nitrite (NO_2^-)
	Perchlorate (ClO_4^-), chlorate (ClO_3^-), Chlorite (ClO_2^-), hypochlorite (ClO^-)
	Permanganate (MnO_4^-)
	Thiocyanate (SCN^-)
+2 Charge	***-2 Charge***
Group 2A cations	Group 6A anions
Cadmium (Cd^{2+})	Carbonate (CO_3^{2-})
Chromium (II) or chromous (Cr^{2+})	Chromate (CrO_4^{2-}), dichromate($Cr_2O_7^{2-}$)
Cobalt(II) or cobaltous (Co^{2+})	Hydrogen phosphate (HPO_4^{2-})
Copper(II) or cupric (Cu^{2+})	Oxalate ($C_2O_4^{2-}$)
Iron(II) or ferrous (Fe^{2+})	Peroxide (O_2^{2-})
Lead(II) or plumbous (Pb^{2+})	Sulfate (SO_4^{2-}), sulfite (SO_3^{2-})
Manganese(II) or manganous (Mn^{2+})	
Mercury(I) or mercurous (Hg_2^{2+})	
Mercury(II) or mercuric (Hg^{2+})	
Nickel (Ni^{2+})	
Tin(II) or stannous (Sn^{2+})	
Zinc (Zn^{2+})	
+3 Charge	***-3 Charge***
Aluminum (Al^{3+})	Group 5A anions
Chromium(III) or chromic (Cr^{3+})	Phosphate (PO_4^{3-}), phosphite (PO_3^{3-})
Iron(III) or ferric (Fe^{3+})	Phosphide (P^{3-})
Titanium (III) (Ti^{3+})	
+4 Charge	
Lead(IV) or plumbic (Pb^{4+})	
Tin(IV) or stannic (Sn^{4+})	

Summary of metal cations with more than one possible charge state:
Cu^+, Cu^{2+}; Hg_2^{2+}, Hg^{2+}; Co^{2+}, Co^{3+}; Cr^{2+}, Cr^{3+}; Fe^{2+}, Fe^{3+}; Mn^{2+}, Mn^{3+}; Pb^{2+}, Pb^{4+}; Sn^{2+}, Sn^{4+}

Activity 9 - Nomenclature

Name_____

Section_____ **Date**_____

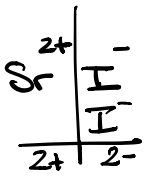
Exercise A. Representative Metal + Nonmetal Compounds

1. Name the following:

NaF Sodium Fluoride CaS _____

SrI_2 Strontium Iodide K_2O _____

Al_2O_3_____ AlN _____



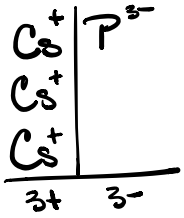
2. Give the formulas for the following (refer to the periodic table only):

Cesium phosphide Cs_3P Calcium iodide_____

Barium fluoride _____ Magnesium nitride_____

Lithium oxide _____ Potassium sulfide_____

Chloride ion_____ Aluminum ion _____



Exercise B. Transition Metal + Nonmetal Compounds

1. Name the following using both naming systems:

Pb^{2+} Lead (II) Plumbous Sn^{4+} _____ _____ Fe^{2+} _____ _____ Cu^{2+} _____ _____

Like main group with only 1 charge state

2. Name the following:

AgCl Silver Chloride $FeBr_3$_____ Cu_3N_____

3. Referring to question 2 above, what is the charge on the Ag? +1 Fe? _____Cu? _____

4. Give formulas for the following:

Chromium (III) oxide _____ Stannous fluoride _____ Ferrous iodide_____

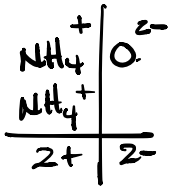
Ferric oxide _____ Cuprous sulfide_____ Plumbic chloride _____

Exercise C. Ionic Compounds with Polyatomic Ions

1. Name the following:

$(NH_4)_2O$ Ammonium Oxide $CuC_2H_3O_2$_____ Na_2SO_3_____

$Fe(NO_3)_2$ _____ LiSCN_____ $NaHCO_3$ _____



1. Give the formulas for the following:

Cupric nitrate_____ Zinc phosphate _____ Silver carbonate _____

Titanium (III) nitride_____ Mercury (II) cyanide_____ Lead(IV) acetate_____

Potassium dichromate _____ Barium permanganate_____ Cadmium sulfate _____

Sodium chlorate_____ Cobalt (II) nitrite_____ Ammonium Phosphide_____

Exercise D. Molecular compounds * see page following worksheet in notes

2. Name the following:

SO_3 Sulfur trioxide _____ N_2O_5 _____

N_2O_4 _____ CO _____

CO_2 _____ Cl_2O _____

P_2O_5 _____ N_2 _____

3. Give the formulas:

Bromine trichloride $BrCl_3$ _____ Gallium nitride _____

Oxygen difluoride _____ Carbon tetrachloride _____

Sulfur hexafluoride _____ Silicon dioxide _____

Iodine pentabromide _____ Chlorine trifluoride _____

Hydrogen _____ Dibromine monoxide _____

4. Circle any of the common names that require memorization. The compounds marked in bold are those most commonly memorized, ask your instructor to specify the ones you will be tested on.

Methane, CH_4	**Water, H_2O**	**baking soda (Sodium bicarbonate), $NaHCO_3$**
Ethane, C_2H_6	**Ammonia, NH_3**	lye (Sodium hydroxide), NaOH
Propane, C_3H_8	Acetylene, C_2H_2	table salt (Sodium chloride), NaCl
Butane, C_4H_{10}	**Hydrogen peroxide, H_2O_2**	**Methanol (wood alcohol), CH_3OH**
Benzene, C_6H_6	**Ethanol (grain alcohol), C_2H_5OH**	

molecular elements: P_4, S_8, H_2, O_2, F_2, Br_2, I_2, N_2, Cl_2

Exercise E. Acids

5. Give the formula and name for the corresponding acids of the following anions.

Anion	Formula of anion	# of H^+ required to neutralize charge	Formula of Acid	Name of acid
Sulfide				
Carbonate				
Oxalate				
Phosphate				
Acetate				
Nitrite				

6. List of common acids (*ask your instructor to specify the ones you will be tested on*). Acids in boldface are STRONG acids/STRONG electrolytes.

HCl(aq)	**Hydrochloric acid**	HF(aq)	Hydrofluoric acid	H_3PO_4	Phosphoric acid
HBr(aq)	**Hydrobromic acid**	**HNO_3**	**Nitric acid**	H_2SO_3	Sulfurous acid
HI(aq)	**Hydroiodic acid**	**H_2SO_4**	**Sulfuric acid**	$HC_2H_3O_2$	Acetic acid

Binary Covalent Nomenclature
Molecular nomenclature

X_nY_m where X & Y are both nonmetals

* No Charges ⇒ no ions
* Name must reflect the number of each atom.

both non-metals ⇒ Molecular Compound

SO_3

Rules

First element listed by name
- if more than 1 a prefix is used to tell how many

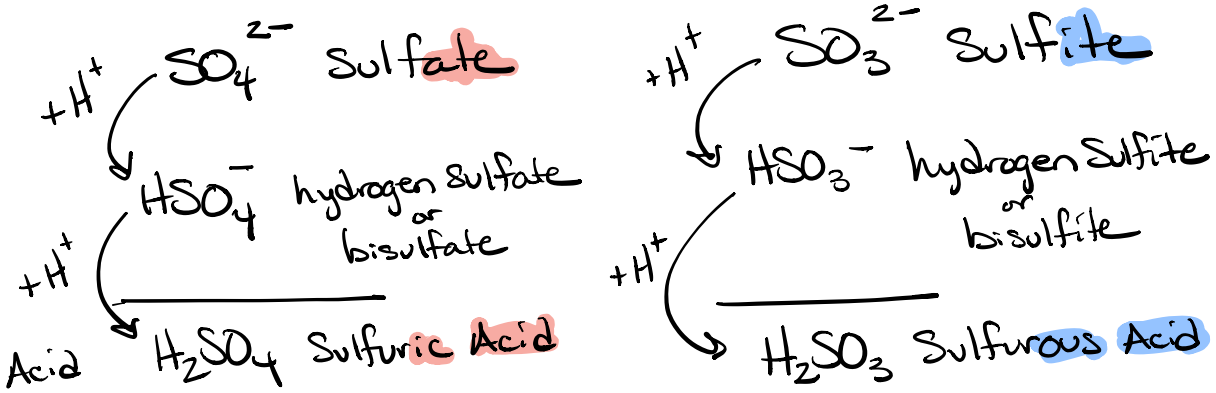
- mon 1	- hexa 6
- di 2	- hepta 7
- tri 3	- octa 8
- tetra 4	- nona 9
- penta 5	- deca 10

- Second element always preceeded by prefix followed by name of element with -ide ending

SO_3 Sulfur trioxide

Cl_2O Dichlorine monoxide

Acid Nomenclature



S^{2-} Sulfide

HS^- hydrogen Sulfide

H_2S hydrosulfic Acid

Careful

SO_3 vs SO_3^{2-}

Binary Covalent

Sulfur trioxide

Polyatomic anion

Sulfite ion