Naming Compounds Handout

IONIC COMPOUNDS versus MOLECULAR COMPOUNDS (or **MOLECULES**)

ionic compound: consist of **cations** (positive ions) and **anions** (negative ions) held together by electrostatic attraction
- usually **metal + nonmetal(s)**
- made of monatomic ions, polyatomic ions, and/or both
  - **monatomic ions:** consist of a single atom
  - **polyatomic ions:** consist of more than one atom

molecular compound: (or **molecule**) consist of **nonmetal atoms** held together by covalent bonds
- **acid:** a molecule that releases H^+ ions in water

NAMING MONATOMIC CATIONS:

Metal atoms lose valence electrons to form positively charged ions, called **cations**.

An ion formed from an individual atom is a **monatomic** (or monoatomic) **cation**.

I. Groups IA to IIA elements, aluminum (Al), silver (Ag), zinc (Zn) and cadmium (Cd) form only one type of ion each:
- Group IA elements form +1 ions: Li^+, Na^+, K^+, Rb^+, Cs^+
- Group IIA elements form +2 ions: Be^{+2}, Mg^{+2}, Ca^{+2}, Sr^{+2}, Ba^{+2}
- aluminum ion = Al^{+3}; silver ion = Ag^+; zinc ion = Zn^{+2}; cadmium ion = Cd^{+2}

These ions are named as follows: **element name + ion**

e.g. Na^+ = sodium ion Sr^{+2} = strontium ion Zn^{+2} = zinc ion

II. The **Stock system** is used to name transition metals, Sn, and Pb that each form more than one ion:

element name(charge in Roman numerals) + ion

e.g. Fe^{+2} = iron (II) ion Pb^{+2} = tin (II) ion Cu^+ = copper (I) ion
Fe^{+3} = iron (III) ion Pb^{+4} = tin (IV) ion Cu^{+2} = copper (II) ion

Name each of the following monatomic cations:

Li^{+} = _____ Cd^{+2} = _____

Ag^{+} = _____ Cu^{+2} = _____

Al^{+3} = _____ Mg^{+2} = _____

Mn^{+2} = _____ Sn^{+4} = _____

H^{+} = _____ Co^{+3} = _____

Fe^{+3} = _____ Na^{+} = _____

K^{+} = _____ Ti^{+4} = _____

Ca^{+} = _____ Ni^{+2} = _____

NAMING MONATOMIC ANIONS:

Nonmetal atoms gain valence electrons to form ***negatively charged ions*** called **anions**.

When a nonmetal forms an ion, it is named:

element stem name + "ide" + ion

e.g. O = **ox**ygen atom $\rightarrow$ O^{-2} = **ox**ide ion

N = **nitr**ogen atom $\rightarrow$ N^{-3} = **nitr**ide ion

P = **phosph**orus atom $\rightarrow$ P^{-3} = **phosh**ide ion

Name each of the following monatomic anions:

F^{-} = _____ Cl^{-} = _____

Br^{-} = _____ S^{-2} = _____

I^{-} = _____ P^{-3} = _____

NAMING POLYATOMIC IONS:

Ions made up of more than one atom are **polyatomic ions**:

– only one polyatomic cation: **NH_4^+ = ammonium ion**
– many polyatomic anions: see table below

Common Polyatomic Ions

NH_4^+	ammonium ion	SO_4^{-2}	sulfate ion	NO_3^-	nitrate ion
		SO_3^{-2}	sulfite ion	NO_2^-	nitrite ion
PO_4^{-3}	phosphate ion				
CrO_4^{-2}	chromate ion	CN^-	cyanide ion	CO_3^{-2}	carbonate ion
$C_2H_3O_2^-$	acetate ion	OH^-	hydroxide ion	HCO_3^-	hydrogen carbonate ion (or bicarbonate ion)
MnO_4^-	permanganate ion				

Be able to use the table above to name and determine the formula of compounds with polyatomic ions.

WRITING CHEMICAL FORMULAS GIVEN INDIVIDUAL IONS

Compounds must be neutral → total +ve charge = total –ve charge

1. If the two ions have exactly opposite charges (+1 and –1, +2 and –2, +3 and –3)
   → **formula of the compound contains one of each ion**

e.g. $Na^+ + Cl^- \rightarrow NaCl$ $\quad$ $K^+ + NO_3^- \rightarrow KNO_3$

$Ca^{+2} + S^{-2} \rightarrow CaS$ $\quad$ $Ba^{+2} + SO_4^{-2} \rightarrow BaSO_4$

$Al^{+3} + N^{-3} \rightarrow AlN$ $\quad$ $Fe^{+3} + PO_4^{-3} \rightarrow FePO_4$

Combine each pair of ions to get the formula of the compound they form:

$NH_4^+ + F^- \rightarrow$ _____ $\quad$ $Li^+ + CN^- \rightarrow$ _____

$Sr^{+2} + CO_3^{-2} \rightarrow$ _____ $\quad$ $Al^{+3} + PO_4^{-3} \rightarrow$ _____

$Na^+ + C_2H_3O_2^- \rightarrow$ _____ $\quad$ $K^+ + OH^- \rightarrow$ _____

$Ni^{+2} + CrO_4^{-2} \rightarrow$ _____ $\quad$ $Fe^{+3} + N^{-3} \rightarrow$ _____

2a. If two monatomic ions have different charges

→ **use the crossover method to get the formula of the compound**

- The superscript for the cation becomes the subscript for the anion.
- The superscript for the anion becomes the subscript for the cation.
- Finally, **simplify subscripts** to get the lowest ratio of ions.
  (Note: **Only the *NUMBERS* cross down**, not the signs!)

e.g. $Na^{+}\ S^{-2}$ → Na_2S $\quad Ba^{+2}\ N^{-3}$ → Ba_3N_2 $\quad Ti^{+4}\ O^{-2}$ → TiO_2

Ti_2O_4 is simplified!

b. If two ions have different charges and at least polyatomic ion is involved

→ **use crossover rule to get formula of the compound**

- if more than one of polyatomic ion in formula, use parentheses
- **simplify subscripts** to get lowest ratio of atoms
  (Note: Again **only the numbers cross down**, not the signs!)

e.g. $NH_4^{+}\ O^{-2}$ → $(NH_4)_2O$ $\quad Ca^{+2}\ NO_3^{-}$ → $Ca(NO_3)_2$ $\quad Pb^{+4}\ CO_3^{-2}$ → $Pb(CO_3)_2$

$Pb_2(CO_3)_4$ is simplified!

Combine each pair of ions to get the formula of the compound they form:

$Cu^{+}\ O^{-2}$ $\qquad Sn^{+4}\ SO_4^{-2}$ $\qquad K^{+}\ P^{-3}$

$Li^{+}\ CO_3^{-2}$ $\qquad Fe^{+3}\ S^{-2}$ $\qquad Ni^{+2}\ PO_4^{-3}$

CHEMICAL FORMULAS AND NAMES FROM INDIVIDUAL IONS

Compounds are named from the individual ions they come from.

Name the cation and the anion, then remove "ion" from each name:

e.g. Na^{+} → **sodium** ion
Cl^{-} → **chloride** ion → **NaCl = sodium chloride**

K^{+} → **potassium** ion
CO_3^{-2} → **carbonate** ion → **K_2CO_3 = potassium carbonate**

Fe^{+3} → **iron (III)** ion
NO_3^{-} → **nitrate** ion → **$Fe(NO_3)_3$ = iron (III) nitrate**

Ag^{+} → **silver** ion
S^{-2} → **sulfide** ion → **Ag_2S = silver sulfide**

Combine each pair of ions to get the chemical formula, then name the compound:

Individual ions	Compound Formula	Compound Name
Mg^{+2} F^{-}	MgF_2	magnesium fluoride
Ni^{+2} Se^{-2}		
Ca^{+2} Br^{-}		
Cu^{+2} P^{-3}		
Co^{+2} NO_2^{-}		
K^{+} CrO_4^{-2}		
Al^{+3} O^{-2}		

GIVEN THE CHEMICAL FORMULA, NAME THE COMPOUND

WHEN THE METAL CATION FORMS ONLY ONE CHARGE:

1. If the metal is in Groups IA–IIA, aluminum, silver, cadmium, or zinc, then just name the metal cation and the anion:

e.g. **NaCl** → Na^+ → **sodium** and Cl^- → **chloride** → **NaCl = sodium chloride**

BaI_2 → Ba^{2+} → **barium** and I^- → **iodide** → **BaI_2 = barium iodide**

$Al(OH)_3$ → Al^{3+} → **aluminum**, OH^- → **hydroxide** → **$Al(OH)_3$ = aluminum hydroxide**

$ZnSO_4$ → Zn^{2+} → **zinc** and SO_4^{-2} → **sulfate** → **$ZnSO_4$ = zinc sulfate**

WHEN THE METAL CATION FORMS MULTIPLE CHARGES:

2. If the metal can form more than one ion,
   a. Use the charge on the anion to determine the overall negative charge.
   b. Since an ionic compound is neutral (overall charge is zero), the overall positive charge must equal the overall negative charge.
   c. If there is more than one of the cation present, divide the overall positive charge by the number of cations present to get the charge for each cation.
   d. Name the cation and the anion, then remove "ion" from both

e.g. **$NiBr_2$** → Br has a -1 charge → so **2 Br^- = -2**
→ overall positive charge = +2 → **Ni^{+2}**
→ **Ni^{+2} = nickel (II)** ion **Br^- = bromide** ion
→ **$NiBr_2$ = nickel (II) bromide**

If a polyatomic ion is involved, remember that more than one polyatomic is shown in parentheses—i.e. **DO NOT confuse the subscripts of the ATOMS in a polyatomic ion with the number of polyatomic ions present!**

e.g. **$Fe_2(SO_4)_3$** → SO_4 has a -2 charge → so **3 SO_4^{-2} = -6**
→ overall positive charge = +6 → **2 Fe = +6**
→ each Fe must be +3 → **Fe^{+3}**
→ **Fe^{+3} = iron (III)** ion **SO_4^{-2} = sulfate** ion
→ **$Fe_2(SO_4)_3$= iron(III) sulfate**

Give the name for each compound given its chemical formula:

Formula	Individual Ions	Name of Compound
$MgCl_2$	Mg^{+2} Cl^-	magnesium chloride
LiOH		
$ZnCO_3$		
K_2S		
$FePO_4$		
SnO_2		
$CuBr_2$		
Ag_3N		
$Mn(CN)_2$		
$AgC_2H_3O_2$		

WRITING CHEMICAL FORMULAS GIVEN THE COMPOUND NAME

Get the individual ions from the name, then combine them using the crossover rule:

e.g. **barium chloride** → **barium** = Ba^{+2} **chloride =** Cl^-

$$Ba^{+2} \quad Cl^- \rightarrow BaCl_2$$

aluminum sulfate → **aluminum** = Al^{+3} **sulfate =** SO_4^{-2}

$$Al^{+3} \quad SO_4^{-2} \rightarrow Al_2(SO_4)_3$$

Give the name for each compound given its chemical formula:

Name of Compound	individual ions	Formula
lithium cyanide	Li^+ CN^-	LiCN
iron(III) sulfate		
calcium iodide		
tin(IV) dichromate		
cadmium nitrite		
copper(II) acetate		
zinc carbonate		
lead(II) phosphide		
potassium sulfite		
cobalt(II) nitride		
nickel(II) permanganate		

NAMING MOLECULAR COMPOUNDS

Indicate number of atoms of each element with **Greek prefix** before element name:

# of atoms	Greek Prefix	# of atoms	Greek Prefix
1	mono (usually omitted)	**6**	hexa
2	di	**7**	hepta
3	tri	**8**	octa
4	tetra	**9**	nona
5	penta	**10**	deca

For the **first element:** **Greek prefix + element name**

For the **second element:** **Greek prefix + element name stem + "-ide"**

Note: 1. **mono is generally omitted**, except in common names like **CO = carbon monoxide**

2. Whenever a Greek prefix ends with "**a**" and the second element starts with **a vowel**, the "**a**" is removed (e.g. instead of tetr**a**oxide, use tetroxide)

P_2O_5 SF_6

diphosphorus **penta**oxide sulfur **hexa**fluoride

Name the following molecular compounds:

SO_3 = _____ $SiBr_4$ = _____

XeF_6 = _____ ClF_3 = _____

N_2O_4 = _____ Cl_2O_7= _____

PCl_5 = _____ P_4O_{10} = _____

DETERMINING FORMULAS OF MOLECULAR COMPOUNDS

Use Greek prefix(es) to determine number of atoms of each element in formula.

Get **elements** and **number of atoms** of each from name:

dichlorine **penta**oxide **tetra**phosphorus **hexa**sulfide

Cl_2O_5 P_4S_6

Give the formulas for each of the following molecular compounds:

nitrogen trichloride dibromine heptoxide dinitrogen pentasulfide

DETERMINING FORMULAS AND NAMES OF ACIDS FROM IONS

Given an ion,

we can get formula of acid by: adding **H atoms** equal to negative charge on ion

we can name for acid: depending on suffix of ion name

F^- = fluor**ide ion** —(add # of H's equal to negative charge)→ $HF_{(aq)}$ = **hydro**fluor**ic acid**

NO_2^- = nitr**ite ion** —(add # of H's equal to negative charge)→ $HNO_{2(aq)}$ = nitr**ous acid**

SO_4^{-2} = sulf**ate ion** —(add # of H's equal to negative charge)→ $H_2SO_{4(aq)}$ = sulfur**ic acid**

Name each of the following ions, and determine the formula and name of the corresponding acid that forms from the ion.

	Name of Ion	**Formula of Acid**	**Name of Acid**
Cl^- =	chloride ion	→ HCl(aq) =	hydrochloric acid
CO_3^{-2} =	_____	→ _____(aq) =	_____
SO_3^{-2} =	_____	→ _____(aq) =	_____
PO_4^{-3} =	_____	→ _____(aq) =	_____
NO_3^- =	_____	→ _____(aq) =	_____

Name each of the following acids:

$HBr(aq)$= _____ $H_2CrO_4(aq)$= _____

$H_2S(aq)$= _____ $HC_2H_3O_2(aq)$= _____

$HCN(aq)$= _____ $H_2SO_4(aq)$= _____

Give the formula for each of the following acids: [Don't forget to indicate(aq)!]

perchloric acid = _____ nitrous acid = _____

phosphoric acid = _____ chromic acid = _____

hydroiodic acid = _____ carbonic acid = _____

sulfurous acid = _____ nitric acid = _____

PUTTING IT ALL TOGETHER:

Name each of the following compounds:

$BaCl_2$ _____ $CoBr_2$ _____

$HNO_3(aq)$_____ SO_2 _____

AgF _____ $PbSe_2$ _____

$CuNO_3$ _____ PF_5 _____

K_2SO_3 _____ $Bi(C_2H_3O_2)_3$ _____

FeP _____ $Al_2(CO_3)_3$ _____

$NiSO_3$ _____ $Cd(OH)_2$ _____