Naming Compounds Handout

IONIC COMPOUNDS versus MOLECULAR COMPOUNDS

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: consist of **nonmetal atoms** bonded together by shared electrons (covalent bonding)
- **acid:** a molecular compound that releases hydrogen ions (H^+) when dissolved 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 IIIA elements 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}
   - Group IIIA elements form +3 ions: Al^{+3}
   - silver ion = Ag^+; zinc ion = Zn^{+2}; cadmium ion = Cd^{+2}

When a Group IA–IIIA element, silver, zinc, or cadmium forms an ion, it is named:

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 and other metals that form more than one ion:

- iron (Fe) forms two ions: Fe^{+2} and Fe^{+3}
- lead (Pb) forms two ions: Pb^{+2} and Pb^{+4}

When a a metal can form more than one ion, each ion is named:

element name (charge in Roman numerals) + ion

e.g. Fe^{+2} = iron (II) ion Pb^{+2} = lead (II) ion Cu^{+} = copper (I) ion
Fe^{+3} = iron (III) ion Pb^{+4} = lead (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^{+2} = _____ 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 ⇒ O^{-2} = **ox**ide ion

N = **nitr**ogen atom ⇒ N^{-3} = **nitr**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

NH_4^+= ammonium ion

Polyatomic Ions

OH^- = hydroxide ion	NO_2^- = nitrite ion	$C_2H_3O_2^-$ = acetate ion
CN^- = cyanide ion	NO_3^- = nitrate ion	PO_4^{-3}= phosphate ion
CrO_4^{-2} = chromate ion	SO_4^{-2} = sulfate ion	MnO_4^- = permanganate ion
$Cr_2O_7^{-2}$ = dichromate ion	SO_3^{-2} = sulfite ion	CO_3^{-2} = carbonate ion

HCO_3^- = hydrogen carbonate ion or bicarbonate ion

Name each of the following polyatomic ions:

CN^- = _____ CrO_4^{-2} = _____

SO_4^{-2} = _____ NO_3^- = _____

OH^- = _____ PO_4^{-3} = _____

NH_4^+ = _____ $C_2H_3O_2^-$ = _____

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) fi **formula of the compound contains one of each ion**

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

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

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

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

$NH_4^+ + F^- \Rightarrow$ _____ $Li^+ + CN^- \Rightarrow$ _____

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

$Na^+ + C_2H_3O_2^- \Rightarrow$ _____ $K^+ + OH^- \Rightarrow$ _____

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

$Cd^{+2} + SO_4^{-2} \Rightarrow$ _____ $Co^{+3} + P^{-3} \Rightarrow$ _____

2a. If two monatomic ions have different charges

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

- superscript for cation becomes subscript for anion
- superscript for anion becomes subscript for cation
- **simplify subscripts** to get lowest ratio of atoms
  (Note: **Only the numbers cross down**, not the signs!)

Na^{+} S^{2-} → Na_2S

Ba^{2+} N^{3-} → Ba_3N_2

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!)

NH_4^{+} O^{2-} → $(NH_4)_2O$

Ca^{2+} NO_3^{-} → $Ca(NO_3)_2$

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}

Sn^{+4} SO_4^{-2}

K^{+} P^{-3}

Li^{+} CO_3^{-2}

Fe^{+3} S^{-2}

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} S^{-2}		
Ca^{+2} Br^{-}		
Al^{+3} P^{-3}		
Co^{+2} NO_2^{-}		
K^{+} CrO_4^{-2}		
Fe^{+3} O^{-2}		

GIVEN THE CHEMICAL FORMULA, NAME THE COMPOUND

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

   e.g. **NaCl** ⇒ Na = **sodium** and Cl = **chloride** ⇒ **sodium chloride**

   BaI_2 ⇒ Ba = **barium** and I = **iodide** ⇒ **barium iodide**

   $Al(OH)_3$ ⇒ Al = **aluminum** and OH = **hydroxide** ⇒ **aluminum hydroxide**

   $ZnSO_4$ ⇒ Zn = **zinc** and SO_4 = **sulfate** ⇒ **zinc sulfate**

2. If the metal can form more than one ion,
   a. Use reverse crossover to get the individual ions
      – Make the **subscript of cation** the **negative charge of anion**
      – Make the **subscript of anion** the **positive charge of cation**
   b. Check to make sure the charges on the ions are correct
   c. Name the cation and the anion, then remove "ion" from both

   e.g. **$NiBr_2$** ⇒ **Ni^{+2} = nickel (II)** ion **Br^{-} = bromide** ion
   Is bromide's charge really –1? YES!
   then ⇒ **$NiBr_2$ = nickel (II) bromide**

   d. If a polyatomic ion is involved, remember that more than one polyatomic is shown in parentheses—i.e. **DO NOT bring up the subscript of atoms in a polyatomic ion to be the charge of the metal!**

   $CuSO_4$ ⇒ There is only ONE Cu and ONE SO_4, so get the charge for the Cu based on the SO_4. The formula is **SO_4^{-2}**, and there is only ONE **SO_4^{-2}**, so **Cu**'s charge here must be **+2** for the compound to have an overall charge of zero.
   ⇒ **Cu^{+2} = copper (II)** ion **SO_4^{-2} = sulfate** ion
   then ⇒ **$CuSO_4$ = copper (II) 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** $\Rightarrow$ **barium** = Ba^{+2} **chloride =** Cl^{-}

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

aluminum sulfate $\Rightarrow$ **aluminum** = Al^{+3} **sulfate =** SO_4^{-2}

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

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: **Mono is generally omitted**, except in common names like ***CO = carbon monoxide***

P_2O_5

diphosphorus **penta**oxide

SF_6

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:

tetraphosphorus **hexa**sulfide

P_4S_6

Give the formulas for each of the following molecular compounds:

nitrogen trichloride dibromine heptaoxide 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** $\xrightarrow{\text{add \# of H's equal to negative charge}}$ $HF_{(aq)}$ = **hydro**fluor**ic acid**

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

SO_4^{-2} = sulf**ate ion** $\xrightarrow{\text{add \# of H's equal to negative charge}}$ $H_2SO_{4\,(aq)}$ = 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_2SO_4 (aq)= _____ $HC_2H_3O_2$ (aq)= _____

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

hydrofluoric 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:

$BaCl_2$ _____ $NiBr_2$ _____

HNO_3(aq)_____ SO_2 _____

AgF _____ $PbSe_2$ _____

$NiSO_3$ _____ PF_5 _____

K_2SO_4 _____ $Cr(C_2H_3O_2)_3$_____

FeP _____ $Al_2(CO_3)_3$ _____

$CuMnO_4$ _____ $Cd(OH)_2$ _____