WRITING CHEMICAL FORMULAS & NAMING COMPOUNDS

PART A: THE BUILDING BLOCKS

Chemical formulas provide 2 pieces of information:

- elements that make up the compound.
- number of atoms of each element that are present in a compound.

COVALENT COMPOUNDS

- chemical formula represents how many of each type of atom are in each molecule.
- Eg. C_2H_6 ; H_2O

IONIC COMPOUNDS

- chemical formula represents the ratio in which ions are present in the compound.
- Eg. MgO ; $Al_2(SO_4)_3$

Using Valence Numbers to Describe Bonding Capacity

As a general rule, based on the octet rule, if 2 atoms form...

- ***an ionic bond***, valence indicates **charges** on the ions formed.
- ***a covalent bond***, valence indicates how many electrons each atom contributes to the covalent bond.

Eg. Sodium is a Group 1A element and has 1 electron in its valence shell. Na has a valence of 1+ and forms an ionic bond with a non-metal.

Eg. Sulfur is a Group VIA element and has 6 valence electrons.
Its bonding capacity is 6, which means that it will either form an ionic charge of 2- with a metal, or it will share 2 of its valence electrons in a covalent bond with a non-metal.

METALS WITH SINGLE & MULTI-VALENCES -- (the cation)

- ***Group A*** elements that form cations have valences that correspond with their group number, without exception. These metals have a ***single*** valence. For instance, Calcium is in group IIA, so its valence is 2+.

- ***Group B*** elements: many elements belonging to transition metals or post-transition metals form cations with different valences. For instance, Iron is a transition metal and it can form 2 different valences, 2+ and 3+. Elements with ***multi-valences*** can form compounds with different chemical formulas having different physical and chemical properties.

- when naming an ionic compound containing a multi-valence metal, the valence of the metal must be stated.

- there are 2 systems of naming compounds with multi-valences: the Stock System & the Classical System.

STOCK SYSTEM

- naming a compound with a metal having more than one valence, include the valence in parentheses, written in ***Roman numerals***.

Eg. Fe^{2+} is written as iron (II) Cu^{1+} is written as copper (I)

Fe^{3+} is written as iron (III) Cu^{2+} is written as copper (II)

CLASSICAL SYSTEM

- pre-dates the Stock System
- uses the Latin name of the metal
- metal with ***smaller valence ends in -ous***
- metal with ***larger valence ends in -ic***

Common Type II Cations

Ion	Stock System	Traditional System
Fe^{3+}	iron (III)	ferric
Fe^{2+}	iron (II)	ferrous
Cu^{2+}	copper (II)	cupric
Cu^{1+}	copper (I)	cuprous
Co^{3+}	cobalt (III)	cobaltic
Co^{2+}	cobalt (II)	cobaltous
Sn^{4+}	tin (IV)	stannic
Sn^{2+}	tin (II)	stannous
Pb^{4+}	lead (IV)	plumbic
Pb^{2+}	lead (II)	plumbous
Hg^{2+}	mercury (II)	mercuric
Hg_2^{2+}	mercury (I)	mercurous

*Mercury (I) ions are always bound together in pairs to form Hg_2^{2+}

ELECTRONEGATIVITY & ORDER -- (what about the anion?)

- generally, the element with the lower electronegativity (EN) is written first, followed by the element with the greater EN.
- ionic compounds -- metals have lower EN than non-metals.

METAL + NON-METAL

- covalent compounds -- order is determined by consulting the periodic table.

NON-METAL + NON-METAL
(lower EN) (higher EN)

GIVEN THE NAME or WHEN NAMING the compound...

- in most cases, there are 2 parts to the name
- ionic compounds: name of cation is followed by name of anion
- covalent compounds: name of 2 non-metals

Specifically in terms of ***ionic*** compounds,

FIRST PART	SECOND PART
• name of element in periodic table • if metal is multivalent, include Roman numeral valence or use Classical system	• if monoatomic (1 type of atom) ending of name changes to -ide * there are exceptions • if polyatomic (more than 1 type of atom, then consult next page)

POLYATOMIC IONS

PO_4^{3-} phosphate ion = group of 1 P and 4 O's with an overall charge of 3-

- a group of atoms that contain a single charge.
- atoms in the ion are covalently bonded to one another
- behave as a single unit and treated as a single ion
- often remain unchanged in simple chemical reactions due to strong bonds holding component atoms together

Valence = –1			
Ion	**Name**	**Ion**	**Name**
CN^-	cyanide	$H_2PO_3^-$	dihydrogen phosphite
CH_3COO^-	acetate	$H_2PO_4^-$	dihydrogen phosphate
ClO^-	hypochlorite	MnO_4^-	permanganate
ClO_2^-	chlorite	NO_2^-	nitrite
ClO_3^-	chlorate	NO_3^-	nitrate
ClO_4^-	perchlorate	OCN^-	cyanate
HCO_3^-	hydrogen carbonate	HS^-	hydrogen sulfide
HSO_3^-	hydrogen sulfite	OH^-	hydroxide
HSO_4^-	hydrogen sulfate	SCN^-	thiocyanate

Valence = –2			
Ion	**Name**	**Ion**	**Name**
CO_3^{2-}	carbonate	O_2^{2-}	peroxide
$C_2O_4^{2-}$	oxalate	SiO_3^{2-}	silicate
CrO_4^{2-}	chromate	SO_3^{2-}	sulfite
$Cr_2O_7^{2-}$	dichromate	SO_4^{2-}	sulfate
HPO_3^{2-}	hydrogen phosphite	$S_2O_3^{2-}$	thiosulfate
HPO_4^{2-}	hydrogen phosphate		

Valence = –3			
Ion	**Name**	**Ion**	**Name**
AsO_3^{3-}	arsenite	PO_3^{3-}	phosphite
AsO_4^{3-}	arsenate	PO_4^{3-}	phosphate

COMPOUNDS WITH POLYATOMIC IONS

- Use patterns such as T41 and T43

PATTERNS in the names of polyatomic ions:

- know the base ions ending in **-ate**, then the other ions follow...

# of O-atoms	**prefix and suffix**
x - 2	*hypo _____ ite*
x - 1	*_____ ite*
x	***_____ ate***
x + 1	*per _____ ate*

Eg. If BrO_3^{1-} is the bromate ion, then...

BrO^{1-} is hypobromite ion
BrO_2^{1-} is bromite ion
BrO_3^{1-} is bromate ion
BrO_4^{1-} is perbromate ion

Eg. If HPO_4^{2-} is the hydrogen phosphate ion, then...

HPO_2^{2-} is hydrogen hypophosphite ion
HPO_3^{2-} is hydrogen phosphite ion
HPO_4^{2-} is hydrogen phosphate ion
HPO_5^{2-} is hydrogen perphosphate ion

Notice the ***valence*** of the polyatomic ions is the same; as the number of O-atoms changes, the prefix and suffix changes. These changes are consistent with all groups of polyatomic ions. Not all polyatomic ions contain the 4 names.

PART B: WRITING CHEMICAL FORMULAS

1. IONIC COMPOUNDS

- Write symbols for the ions. Place brackets around polyatomic ions that are present. *Remember:* ***metal + non-metal***.
- Write the valence above each ion or polyatomic ion.
- Criss-cross the valences to indicate the number of each ion as a subscript.
- Tidy up the formula. Reduce the NEW subscripts (from the criss-cross) to lowest terms. Remove "1"s on monoatomic ions and brackets only when polyatomic ion has subscript of "1".

Eg. Write the formula for ammonium carbonate.

1. $(NH_4)^{1+}$ $(CO_3)^{2-}$
2. $(NH_4)_2$ $(CO_3)_1$
3. $(NH_4)_2(CO_3)_1$
4. $(NH_4)_2CO_3$ ammonium carbonate

Exercise: Write the chemical formula for each compound.

1. sodium phosphate
2. magnesium chlorate
3. copper (II) nitride
4. iron (III) permanganate
5. stannic chlorite
6. aurous sulfide

2. COVALENT COMPOUNDS

- add prefix to each non-metal to indicate the number of atoms of each element in one molecule of compound
- if prefix is left out on the first element, there is only 1 atom of the element

Exercise: Write the chemical formula for each compound.

1. dinitrogen pentoxide
2. nitrogen trichloride

PART C: NAMING CHEMICAL COMPOUNDS

1. IONIC COMPOUNDS

A) METAL (group A) + (NON-METAL or polyatomic ion)

- **BINARY** ionic compounds -- METAL + NON-METAL

  METAL CATION
  -- use name of metal from periodic table

  NON-METAL ANION
  -- change ending to **-ide**

  Eg. sulfur → sulfide
  phosphorus → phosphide
  oxygen → oxide

- **TERNARY** ionic compounds -- METAL + polyatomic ion

  -- consists of 3 or more types of elements

  METAL CATION
  -- use name of metal from periodic table

  POLYATOMIC ANION
  -- see Page 98 Table 3.4 and patterns in naming these ions
  -- most ions end in -ate or -ite, with few exceptions

Eg. Name K_3N

Potassium has valence 1+
Therefore, potassium nitride.

Eg. Name $Ca_3(PO_3)_2$

Calcium has valence of 2+,
Therefore, calcium phosphite.

Name the following compounds.

1. Na_2S
2. Al_2O_3
3. $Ba(ClO_3)_2$
4. K_3HPO_3
5. KCH_3CO_2
6. $(NH_4)_2SO_3$

B) METAL (group B) + (NON-METAL or polyatomic ion)

- rules of naming are similar to those in part A (group A metals)

GROUP B metals have multi-valences; therefore, there is a required step to determine the valence of the group B metal.

- use TOTAL negative charges to determine the TOTAL positive charges
- (TOTAL Positive Charge) + (TOTAL Negative Charge) = 0
- to determine the appropriate ***valence*** on the GROUP B metal, divide the TOTAL positive charges by the number of atoms making up the cation.

Eg. Name Au_3P

Gold has 2 valences -- 1+, 3+

Phosphorus has valence 3-

TOTAL negative charge = 3-
TOTAL positive charge = 3+

valence of Au = 1+
(3 atoms of Au share the total 3+)

NAME: gold (I) phosphide
aurous phosphide

Eg. Name $Sn(SO_4)_2$

Tin has 2 valences -- 2+, 4+

Sulfate ion has valence 2-

TOTAL negative charge = 4-
TOTAL positive charge = 4+

valence of Sn = 4+
(1 atom of Sn accepts total charge)

NAME: tin (IV) sulfate
stannic sulfate

Name the following compounds.

1. Cr_2Se_3

2. $Pb(NO_2)_2$

3. MnO_2

4. $Fe_2(HPO_3)_3$

5. Cu_2CO_3

6. $Re(OH)_4$

2. COVALENT COMPOUNDS

- prefix is added to each non-metal - indicates the number of atoms of each element in one molecule of compound

- mono- is left out if there is only 1 atom of the first element

- if a prefix is added AND -a or -o is followed by an "o", drop the -a / -o.

Eg. P_2O_5 H_2O

CBr_4 OCl_2

PRACTICE:

1. State the formula of each of the following ionic compounds. Watch out! There is a mix of binary compounds and polyatomic compounds. Do you remember how to tell the difference?

eg. sodium nitrite $NaNO_2$ eg. sodium nitride Na_3N

(a) calcium sulfate ____________ (b) sodium sulfide ____________

(c) lead (II) phosphate ____________ (d) aluminum chloride ____________

(e) mercury (I) nitrate ____________ (f) lithium nitride ____________

(g) copper (II) phosphide ____________ (h) magnesium oxide ____________

(i) tin (IV) phosphate ____________ (j) potassium dichromate____________

(o) ammonium sulphate ____________ (p) potassium sulfate ____________

(q) sodium cyanide ____________ (r) lead (II) chromate ____________

(s) iron (III) hydroxide ____________ (t) ammonium nitrate ____________

(u) sodium chlorate ____________ (v) ammonium phosphate____________

(w) zinc perchlorate ____________ (x) iron (II) sulfite ____________

(y) magnesium hypochlorite____________ (z) ammonium sulfate ____________

(A) barium acetate ____________ (B) sodium dichromate ____________

(C) tin (IV) nitrate ____________ (D) potassium permanganate__________

(E) sodium perchlorate ____________ (F) silver sulfide ____________

(G) tin (II) hypochlorite ____________ (H) iron (III) perchlorate ____________

2. Write the formula for each of the following:

(a) oxygen difluoride __________ (b) dinitrogen tetroxide __________

(c) silicon dioxide __________ (d) silicon tetrafluoride __________

(e) diiodine pentoxide __________ (f) dihydrogen monoxide __________

(g) phosphorus trichloride__________

3. Name the following compounds. Use both the Stock and classical method if possible.

eg. $Fe_2(Cr_2O_7)_3$ iron (III) dichromate *or* ferric dichromate

(a)	$NaNO_3$	________________	(b)	$Ca(NO_2)_2$	________________
(c)	NH_4Br	________________	(d)	Rb_2SO_4	________________
(e)	$CaSO_4$	________________	(f)	$Pb(NO_3)_2$	________________
(g)	$Cu(CH_3CO_2)_2$	________________	(h)	Na_3PO_4	________________
(i)	$Al(OH)_3$	________________	(j)	$ZnSO_3$	________________
(k)	NH_4ClO_4	________________	(l)	$LiClO$	________________
(m)	$Mg(NO_3)_2$	________________	(n)	$Mg(NO_2)_2$	________________
(o)	Li_2CO_3	________________	(p)	$Fe_2(SO_4)_3$	________________
(q)	$(NH_4)_2S$	________________	(r)	$Sn_3(PO_4)_2$	________________

4. Write an IUPAC name for each of the following compounds:

(a)	CO_2	________________________	(b)	Cl_2O_7	________________________
(c)	SO_2	________________________	(d)	P_2O_5	________________________
(e)	NO	________________________	(f)	SCl_2	________________________
(g)	PCl_3	________________________	(h)	CF_4	________________________
(i)	$SbCl_3$	________________________	(j)	CBr_4	________________________