FORMULAS AND NOMENCLATURE CHEM 151

At first thought, it may seem difficult to learn the formulas and names of the hundred or so compounds you will encounter in a first year chemistry course. Actually, it is not very difficult if you follow a few systematic rules.

I. BINARY COMPOUNDS COMPOSED OF TWO NONMETALS

Binary compounds are composed of atoms of two different elements. One type of binary compound is composed of two nonmetals and is named by using the elemental name for the first element followed by the name of the second element with its ending changed to "IDE". A prefix is added to each name to indicate the number of atoms of each element in the molecule. The mono prefix can be eliminated if it refers to the first element in the name.

Number of Atoms	Prefix
1	mono
2	di
3	tri
4	tetra
5	penta
6	hexa
7	hepta

Example: Name CO_2

Use the elemental name for the first element - carbon (a prefix is not used since we drop a mono at the beginning of the name) and then use the root of the second element name "ox" followed by ide and preceeded by di to indicate the presence of two oxygen atoms - dioxide. The correct name for CO_2 is carbon dioxide.

The following examples will illustrate some common compounds of this type:

NO_2	nitrogen dioxide	N_2O_4	dinitrogen tetroxide
CO	carbon monoxide	CS_2	carbon disulfide

Notice in the name "tetroxide" the "a" from tetra is omitted, and in the name "monoxide" the "o" from mono is omitted.

DRILL I (Note: Answers are given at the end of this handout)

I. Name the following compounds. (Correct spelling is required)

1. SO_2
2. CCl_4
3. P_2O_5
4. ClO
5. ICl
6. SF_6

II. Write the correct chemical formulas.

1. dichlorine heptoxide
2. dinitrogen pentoxide
3. oxygen difluoride
4. phosphorus pentachloride

DO NOT PROCEED TO NEXT SECTION UNTIL YOU HAVE THROUGHLY MASTERED PREVIOUS SECTION

II. BINARY COMPOUNDS OF A METAL AND A NONMETAL (Binary Salts)

A second type of binary compound is composed of a metal and a nonmetal. It is named by first naming the metal ion and then the nonmetal ion. As illustrated below, the name of a metal ion is generally the same as the name of the element. Nonmetal ions are named by changing the ending of the element's name to "IDE".

Certain metals tend to form two common ions of different charge. In this case, the charge is indicated using Roman Numerals as shown in Table I below. As an alternative, the ion with the higher charge is named using an "IC" ending and the ion with the lesser charge receives an "OUS". In this second system, the original Latin stem names are often used.

Sn^{2+} Tin (II)
Sn^{4+} Tin (IV)
Cr^{2+} Chromium (II)
Cr^{3+} Chromium (III)

TABLE I CATIONS

H^+	hydrogen		Fe^{3+} iron(III) or ferric
Li^+	Lithium		Fe^{2+} iron(II) or ferrous
		Group IA	
Na^+	sodium		Cu^{2+} copper(II) or cupric
		Alkali Metals	
K^+	potassium		Cu^{1+} copper(I) or cuprous
Rb^+	rubidium		Pb^{4+} lead(IV) or plumbic
Mg^{2+}	magnesium		Pb^{2+} lead(II) or plumbous
		Group IIA	
Ca^{2+}	calcium		Sn^{4+} tin(IV) or stannic
		Alkaline Earths	
Sr^{2+}	strontium		Sn^{2+} tin(II) or stannous
Ba^{2+}	barium		Hg^{2+} mercury(II) or mercuric
Al^{3+}	aluminum	Group IIIA	Hg_2^{2+} mercury(I) or mercurous
			Ag^+ silver

Mn^{2+} Manganese (II)
Mn^{3+} Manganese (III)
Co^{2+} Cobalt (III)
Co^{3+} Cobalt (III)

Nonmetal ions are named using the stem of the element's name and changing the ending to "IDE".

TABLE II ANIONS

F^-	fluoride	O^{2-}	oxide	N^{3-}	nitride	C^{4-}	carbide
Cl^-	chloride	S^{2-}	sulfide	P^{3-}	phosphide		
Br^-	bromide						
I^-	iodide						
H^-	hydride						

NH_4^+ ammonium
CN^- cyanide
OH^- hydroxide

A few of the polyatomic (more than one atom) ions have names that are similar to their monatomic counterparts. These are:

TABLE III Polyatomic Ions

NH_4^+ ammonium	CN^- cyanide	OH^- hydroxide

We combine the metal ion with the nonmetal ion in such a way that the sum of the positive and negative charge is zero or such that the resulting compound is neutral.

Example 1: Let us write the formula for sodium chloride by using the charges on its constituent elements. Place the element with the positive charge first followed by the element with the negative charge. The charge on the sodium ion is 1^+ and the charge on the chloride ion is 1^-.

Since the sum of +1 and -1 is zero, the correct formula for electrically neutral compund sodium chloride is NaCl.

Example 2: Write the formula for magnesium chloride.
The charge on a magnesium ion is 2^+. Therefore two chloride ions are required to make a neutral compound.

$$Mg^{2+} + 2Cl^- = MgCl_2$$
$$+2 + 2(-1) = 0$$

Example 3: Write the formula for aluminum oxide. The charge on the aluminum ion is 3^+ and the charge on the oxide ion is 2^-.

Because +3 and -2 does not equal zero, AlO is not the correct formula. By inspection, it is readily seen that 2 atoms of aluminum would give a total of 6 positive units and that three atoms of oxygen would give 6 negative units.

$$2Al^{3+} + 3O^{2-} = Al_2O_3$$
$$2(3^+) + 3(2^-) = 0$$

Since the sum of +6 and -6 is zero, the correct simplest formula for aluminum oxide is therefore Al_2O_3.

Some examples of naming binary salts are:

NaCl	sodium chlorIDE
KBr	potassium bromIDE
CaI_2	calcium iodIDE

DRILL II

I. Name the following compounds: (Correct spelling is required)

1. MgO
2. K_2S
3. $FeCl_3$
4. AgI
5. $Ca(OH)_2$
6. Ba_3P_2
7. LiH
8. Mg_3N_2
9. $SrBr_2$
10. Cu_2S

II. Write the correct chemical formulas

1. calcium nitride
2. aluminum oxide
6. rubidium phosphide
7. ammonium chloride

3. sodium cyanide
4. potassium hydroxide
5. tin(IV) or stannic bromide
8. barium hydride
9. mercuric or mercury(II) sulfide
10. iron(II) or ferrous iodide

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III. TERNARY SALTS

Ternary compounds are composed of three or more elements. Ternary salts generally are composed of a metal cation and an anion that consists of a group of nonmetals rather than just one. These negative ions are often called polyatomic ions. Examples of polyatomic ions are given in Tables IV and V shown below. In general, when the central atom of a polyatomic ion is bound to a higher number of oxygens, the ion name will end with "ATE". If the central atom is bound to fewer oxygens, the ending will be "ITE". To name ternary salts name the metal cation and then the anion.

TABLE IV Some Polyatomic Ions

MnO_4^-	permanganATE	CO_3^{2-}	carbonATE	PO_4^{3-}	phosphATE
$C_2H_3O_2^-$	acetATE	SO_4^{2-}	sulfATE	CrO_4^{2-}	chromATE
NO_3^-	nitrATE	SO_3^{2-}	sulfITE	$Cr_2O_7^{2-}$	dichromATE
NO_2^-	nitrITE	$S_2O_3^{2-}$	thiosulfATE		

TABLE V

ClO^-	HYPOchlorITE	BrO^-	HYPObromITE	IO^-	HYPOiodITE
ClO_2^-	chlorITE	BrO_2^-	bromITE	IO_2^-	iodITE
ClO_3^-	chlorATE	BrO_3^-	bromATE	IO_3^-	iodATE
ClO_4^-	PERchlorATE	BrO_4^-	PERbromATE	IO_4^-	PERiodATE

Some examples of ternary compounds are:

$+1 - 1 = 0$
$NaC_2H_3O_2$ $\qquad$ $NaC_2H_3O_2$ $\qquad$ sodium acetATE

The charge on the ion gives the combining power of the ion taken as a unit.

$2(+1) - 2 = 0$
Na_2CO_3 $\qquad$ Na_2CO_3 $\qquad$ sodium carbonATE

$+2 + 2(-1) = 0$
$Ca(ClO_2)_2$ $\qquad$ $Ca(ClO_2)_2$ $\qquad$ calcium chlorITE

Parentheses are used when a polyatomic ion is to be taken as a factor more than once to indicate that all of the atoms of the unit are to be taken as a factor.

$2Al^{+3} + 3SO_4^{-2}$
$2(+3) + 3(-2) = 0$

$Al_2(SO_4)_3$

aluminum sulfATE

DRILL III

1. Name the following compounds (Watch your endings)

1. $Ca_3(PO_4)_2$	8. $Cu(C_2H_3O_2)_2$	15. $Na_2Cr_2O_7$
2. KNO_3	9. $KMnO_4$	16. $CuNO_2$
3. $BaCO_3$	10. Rb_3PO_4	17. $Al(ClO_2)_3$
4. $LiBrO_2$	11. Na_2CrO_4	18. $Ca(IO)_2$
5. $SrSO_3$	12. $Fe(BrO)_3$	19. $Ba(BrO_4)_2$
6. $Mg(IO_4)_2$	13. $AgClO_3$	20. Li_2CO_3
7. $Na_2S_2O_3$	14. $SnSO_4$	

II. Write the correct formulas for the following compounds:

1. lithium thiosulfate	4. ammonium sulfate	7. copper(II) phosphate
2. tin(II) nitrate	5. beryllium phosphate	8. potassium dichromate
3. sodium carbonate	6. mercury(I) chloride	9. magnesium chlorate
10. lithium acetate		

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IV. **BINARY ACIDS** - the water solutions of compounds composed of hydrogen and a nonmetal

RULE: Acids composed of hydrogen and a nonmetal are named by putting the prefix HYDRO before the root of the name of the nonmetal and adding the suffix -IC followed by the word ACID.

For example: When hydrogen chloride (HCl) is dissolved in water, we get hydrochloric acid.

HF(aq)	HYDROfluorIC acid
HCl(aq)	HYDROchlorIC acid
HBr(aq)	HYDRObromIC acid
HI(aq)	HYDROiodIC acid

$H_2S(aq)$ HYDROsulfurIC acid

NOTE: The formulas of binary acids must be followed by (aq). The (aq) means aqueous or dissolved in water. Without the (aq) it would represent a gas. For instance, HBr is hydrogen bromide gas.

V. ACIDS CONTAINING OXYGEN - compounds of hydrogen and a polyatomic ion

RULES:

1. If there is only one oxygen acid, the name is that of the characteristic element followed by the suffix -IC.

2. If there are two oxygen acids, the name of the one with the larger number of oxygen atoms ends in -IC, and the name of the one with the smaller number of oxygen atoms ends in - OUS.

3. If there are four oxygen acids, like the oxyacids of the halogen family, the acid with the greatest number of oxygens is desiginated by the prefix PER- and suffix -IC, the one with the next fewer oxygens has the suffix -IC, the one with the next fewer has the suffix -OUS and the fewest oxygen acid is designated with the prefix HYPO- and the suffix -OUS.

For example:

HNO_3 is nitrIC acid	HBrO is HYPObromOUS acid
HNO_2 is nitrOUS acid	$HBrO_2$ is bromOUS acid
H_2SO_4 is sulfurIC acid	$HBrO_3$ is bromIC acid
H_2SO_3 is sulfurOUS acid	$HBrO_4$ is PERbromIC acid

NOTE: Ternary acid formulas are not usually followed by (aq). It is assumed that they are dissolved in water.

VI. ACID SALTS

When one or more hydrogens of an acid is replaced by a metal, the result is an acid salt. We have already encountered salts which result from the replacement of all of the available hydrogens in the acid. However, if the metal replaces only one or two of the available number of hydrogen ions from an acid, provision must be made to distinguish between the different salts that may be formed.

For example: H_3PO_4 is phosphorIC acid

The salts are named as: KH_2PO_4 is potassium DIhydrogen phosphATE

K_2HPO_4 is potassium MONOhydrogen phosphATE

K_3PO_4 is potassium phosphATE

If the acid contains only two hydrogens, then only two different salts are possible. The salts derived from these acids can be named by the method just described, but a common method, using the prefix bi, will probably continue in use for many years.

For example: H_2SO_4 is sulfuric acid

The salts are: $KHSO_4$ is potassium MONOhydrogen sulfATE
or
potassium BIsulfATE

K_2SO_4 is potassium sulfATE

DRILL IV

I. Name each of the following:

1. H_2S (aq)
2. K_2HPO_4
3. $HC_2H_3O_2$
4. HBrO
5. H_3PO_4
6. $NaHCO_3$
7. HIO_3
8. $HBrO_2$

II. Give the chemical formula of each of the following:

1. magnesium monohydrogen phosphate
2. potassium monohydrogen sulfite
3. perbromic acid
4. sodium monohydrogen sulfate
5. iodous acid
6. chloric acid

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VII. DIATOMIC MOLECULES

Many elements exist naturally as diatomic molecules. They are named by naming the element preceded by the word "molecular".

Examples: O_2 - molecular oxygen
H_2 - molecular hydrogen
I_2 - molecular iodine
F_2 - molecular fluorine
Cl_2 - molecular chlorine
Br_2 - molecular bromine
N_2 - molecular nitrogen

III. HYDRATES

Some ionic compounds exist with definite numbers of water molecules bonded loosely within the crystal. These compounds are called hydrates and the waters are referred to as waters of hydration. In naming a specific hydrate, first name the ionic compound then specify the number of waters with the appropriate prefix and then add the term "hydrate." For example, $CuSO_4 \cdot 5H_20$ indicates five waters of hydration per copper or sulfate ion. This compound is named copper(II) sulfate pentahydrate. (An alternate system uses a number rather than a prefix & would name this compound copper (II) sulfate 5-hydrate.)

IX. PRACTICE QUIZ

1. Give the correct name of each of the following.

   a. KCl

   b. Na_2CO_3

   c. CCl_4

   d. PBr_3

   e. $NaNO_2$

   f. $HBr(aq)$

   g. KIO_4

   h. H_2SO_4

   i. $HBrO_3$

   j. NaH_2PO_4

   k. $Na_2SO_4 \cdot 2H_20$

2. Give the chemical formula of each of the following:

   a. sodium oxide

   b. iron(II) phosphate

   c. dinitrogen monoxide

   d. potassium permanganate

   e. barium hypochorite

   f. nitric acid

   g. molecular oxygen

   h. chloric acid

   i. ammonium sulfate

   j. magnesium cyanide

   k. iron(II) sulfate tetrahydrate

POLYATOMIC ION CHARGES

ION NAME	ION FORMULA	CHARGE
Acetate ACETATE	$C_2H_3O_2$	-1
Ammonium (a cation)	NH_4	+1
Borate	BO_2	-1
Bromate	BrO_3	-1
Carbonate	CO_3	-2
Chlorate	ClO_3	-1
Chloride	Cl	-1
Chlorite	ClO_2	-1
Chromate	CrO_4	-2
Cyanate	OCN	-1
Cyanide	CN	-1
Dichromate	Cr_2O_7	-2
Dihydrogen phosphate	H_2PO_4	-1
Hydrogen carbonate (bicarbonate)	HCO_3	-1
Hydrogen sulfate	HSO_4	-1
Hydrogen sulfite	HSO_3	-1
Hydroxide HYDROXIDE	OH	-1
Hypochlorite HYPOCHLORITE	OCl	-1
Iodate	IO_3	-1
Monohydrogen phosphate	HPO_4	-2
Nitrate	NO_3	-1
Nitrite	NO_2	-1
Oxalate	C_2O_4	-2
Oxide	O	-2
Perchlorate	ClO_4	-1
Permanganate	MnO_4	-1
Peroxide	O_2	-2
Phosphate	PO_4	-3
Silicate	SiO_3	-2
Sulfate	SO_4	-2
Sulfite	SO_3	-2
Tetra borate	B_4O_7	-1
Thiocyanate THIOCYANATE	SCN	-1
Thiosulfate THIOSULFATE	S_2O_3	-2