Nomenclature Worksheet

In order to succeed in chem. 1A and 1E, you will be required the learn and apply the principles of chemical nomenclature. Data shows that students that fail to master nomenclature by the 3rd week, general do not pass the course.

Introduction:

Every discipline or field of study has its own terminology. The vocabulary of chemistry uses words that you may or may not have heard before such as *electrolysis*, *effusion*, *hybridization*, *resonance*, and *stoichiometry*. Chemists also use words that have a different meaning than the common definition, such as the words *mole* or *degenerate*. As you study your text in preparation for lecture, it is important that you take the time to learn the new words and terms you encounter. You will find that each chapter of your text summarizes the "*Key Terms*" introduced in a section prior to the exercises and problems. There also helpful appendices that cover the requisite math skills needed for this course at the end of the text.

As a student in Chem. 1A/E, you must learn chemical nomenclature in order to understand your labs and lectures. Learning the vocabulary of chemistry prior to lecture allows you to better comprehend the material covered. This means you'll get more out of your lectures and lab discussions, which in turn will likely increase your performance on exams and quizzes. Performance on quizzes and exams requires that you communicate using proper terms and symbols that are specific to chemistry. One most certainly would not attempt a course like German or French with out learning the language and so it is the case with chemistry. It is imperative that you have a solid grasp of the language of chemistry, as it is critical to your success in this course. Mastery of the vocabulary of chemistry can't be put off. The more you procrastinate, the further you'll get behind and the lower your grade will become.

The communication of the "make-up" of matter in chemistry follows a set of conventions or rules that we call "*Nomenclature.*" Through nomenclature, one can define the elemental composition and relative proportions of elements in a substance. This has grave importance, as there are multitudes of chemical combinations.

How do you learn chemical nomenclature? You practice and practice and practice. Some of you may find that flash cards will help. Others may feel that exercises like this are sufficient. Regardless of your preference of learning nomenclature, you must work hard to incorporate it into your working knowledge.

The following pages contain notes that have been prepared as an aid in your preparation for the nomenclature workshop in lab. Please read these over carefully prior to the laboratory. You will also need to consult your text (sections 3.3-3.4) for additional help and reference. You may also consult the CD that accompanies your text. Don't forget the library is full of general chemistry texts and study guides.

STATISTICS SHOW THAT FAILURE TO LEARN CHEMICAL NOMENCLATURE WILL GRAVELY IMPACT YOUR PERFORMANCE IN THIS COURSE.

I. IONIC COMPOUNDS

Main-Group Metals (Groups IA, IIA, and IIIA) These metals tend to form *cations* by losing all of their outermost (valence) electrons. *The charge on the cation is the same as the group number.* The cation is given the same name as the neutral metal atom.

Group	Element	Cation	Ion name	Group	Element	Cation	Ion name
IA	H	H^+	hydrogen ion	**IIA**	Mg	Mg^{2+}	magnesium ion
	Li	Li^+	lithium ion		Ca	Ca^{2+}	calcium ion
	Na	Na^+	sodium ion		Sr	Sr^{2+}	strontium ion
	K	K^+	potassium ion		Ba	Ba^{2+}	barium ion
	Cs	Cs^+	cesium ion	**IIIA**	Al	Al^{3+}	aluminum ion

Transition (B-group) and Post-Transition (Group IVA and VA) Metals

The charges of the transition metals must be memorized (in chem. 1B you will learn why the charges are so…).

Many of these ions have common or older names (*-ic* endings go with the higher charge, *-ous* endings go with the lower charge). The systematic names (also known as the *Stock system*)[1] for these ions are derived by naming the metal first, followed in parentheses by the charge written in Roman numerals.

Metal	Ion	Systematic name	Common name *(not used on exams an quizzes)*
Cadmium	Cd^{2+}	cadmium ion	
Chromium	Cr^{2+}	chromium (II) ion	chromous ion
	Cr^{3+}	chromium (III) ion	chromic ion
Cobalt	Co^{2+}	cobalt (II) ion	cobaltous ion
	Co^{3+}	cobalt (III) ion	cobaltic ion
Copper	Cu^{+}	copper (I) ion	cuprous ion
	Cu^{2+}	copper (II) ion	cupric ion
Gold	Au^{3+}	gold (III) ion	
Iron	Fe^{2+}	iron (II) ion	ferrous ion
	Fe^{3+}	iron (III) ion	ferric ion
Manganese	Mn^{2+}	manganese (II) ion	manganous ion
	Mn^{3+}	manganese (III) ion	manganic ion
Mercury[2]	Hg_2^{2+}	mercury (I) ion	mercurous ion
	Hg^{2+}	mercury (II) ion	mercuric ion
Nickel	Ni^{2+}	nickel (II) ion	
Silver	Ag^{+}	silver ion	
Zinc	Zn^{2+}	zinc ion	
Tin	Sn^{2+}	tin (II) ion	stannous ion
	Sn^{4+}	tin (IV) ion	stannic ion
Lead	Pb^{2+}	lead (II) ion	plumbous ion
	Pb^{4+}	lead (IV) ion	plumbic ion
Bismuth	Bi^{3+}	bismuth (III) ion	
	Bi^{5+}	bismuth (V) ion	

Anions

Main-Group Nonmetals (Groups IVA, VA, VIA, and VIIA): The nonmetal elements tend to form *anions* by gaining enough electrons to fill their valence shell with eight electrons. The anion is named by taking the element stem name and adding the ending *-ide*.

Group	Element	Anion	Ion name	Group	Element	Anion	Ion name
IVA	C	C^{4-}	carbide ion	**VIA**	Se	Se^{2-}	selenide ion
	Si	Si^{4-}	silicide ion		Te	Te^{2-}	telluride ion
VA	N	N^{3-}	nitride ion	**VIIA**	F	F^{-}	fluoride ion
	P	P^{3-}	phosphide ion		Cl	Cl^{-}	chloride ion
	As	As^{3-}	arsenide ion		Br	Br^{-}	bromide ion
VIA	O	O^{2-}	oxide ion		I	I^{-}	iodide ion
	S	S^{2-}	sulfide ion	**IA**	H	H^{-}	hydride ion

[1] In this course, all exams and quizzes will use the "stock" form for nomenclature; you will however see examples of the common names in your text and the homework.

[2] The mercury (I) cation is a special case; it consists of two Hg^{+} ions joined together, and so is always found as Hg_2^{2+}.

Polyatomic Ions

Polyatomic ions are ions that are composed of two or more atoms that are linked by covalent bonds, but that still have a net deficiency or surplus of electrons, resulting in an overall charge on the group. A metal plus a polyatomic ion yields an ionic compound.

Formulas and Names of Some Polyatomic Ions

Formula	Name	Formula	Name
NH_4^+	ammonium	CO_3^{2-}	carbonate
H_3O^+	hydronium	HCO_3^-	hydrogen carbonate (*bicarbonate*)
OH^-	hydroxide		
OCN^-	cyanate		
CN^-	cyanide	SCN^-	thiocyanate
O_2^{2-}	peroxide		
N_3^-	azide	CrO_4^{2-}	chromate
NO_2^-	nitrite	$Cr_2O_7^{2-}$	dichromate
NO_3^-	nitrate	MnO_4^-	permanganate
NH_2^-	amide		
SO_4^{2-}	sulfate		
ClO_4^-	perchlorate	SO_3^{2-}	sulfite
ClO_3^-	chlorate	HSO_4^-	hydrogen sulfate (*bisulfate*)
ClO_2^-	chlorite	HSO_3^-	hydrogen sulfite (*bisulfite*)
ClO^-	hypochlorite	$S_2O_3^{2-}$	thiosulfate
HS^-	hydrogen sulfide(*bisulfide*)		
IO_4^-	periodate		
IO_3^-	iodate	PO_4^{3-}	phosphate
IO_2^-	iodite	PO_3^{3-}	phosphite
IO^-	hypoiodite	HPO_4^{2-}	hydrogen phosphate
	$H_2PO_4^-$ dihydrogen phosphate		
BrO_3^-	bromate		
BrO^-	hypobromite		

$C_2H_3O_2^-$	acetate (alternate ways to write acetate are $CH_3CO_2^-$ or CH_3COO^-)
$C_2O_4^{2-}$	oxalate
$HC_2O_4^-$	hydrogen oxalate (*bioxalate*)
$C_4H_4O_6^{2-}$	tartrate

AsO_4^{3-}	arsenate	BO_3^{3-}	borate
SeO_4^{2-}	selenate	$B_4O_7^{2-}$	tetraborate
SiO_3^{2-}	silicate	SiF_6^{2-}	hexafluorosilicate

There is some regularity in the names of these polyatomic ions.

a. *Thio-* implies replacing oxygen with sulfur:

SO_4^{2-} = sulfate $S_2O_3^{2-}$ = thiosulfate
OCN^- = cyanate SCN^- = thiocyanate

b. Replacing the first element with another element from the same group gives a polyatomic ion with the same charge, and a similar name:

Group VIIA		**Group VIA**		**Group VA**		**Group IVA**	
ClO_3^-	chlorate	SO_4^{2-}	sulfate	PO_4^{3-}	phosphate	CO_3^{2-}	carbonate
BrO_3^-	bromate	SeO_4^{2-}	selenate	AsO_4^{3-}	arsenate	SiO_3^{2-}	silicate
IO_3^-	iodate	TeO_4^{2-}	tellurate				

c. Some nonmetals form a series of polyatomic ions with oxygen (all having the same charge): ClO^-, hypochlorite; ClO_2^-, chlorite; ClO_3^-, chlorate; ClO_4^-, perchlorate. The general rule for such series is:

XO_n^{y-}	*stem + -ate*	SO_4^{2-}	sulfate	
XO_{n-1}^{y-}	*stem + -ite*	SO_3^{2-}	sulfite	
XO_{n-2}^{y-}	*hypo- + stem + -ite*	SO_2^{2-}	hyposulfite	
XO_{n+1}^{y-}	*per- + stem + -ate*	SO_5^{2-}	persulfate	
X^{y-}	*stem + -ide*	S^{2-}	sulfide	(the monatomic ion)

Note that in some cases, the *-ate* form has three oxygen atoms, and in some cases four oxygen atoms.

C. Naming Ionic Compounds

Writing Formulas of Ionic Compounds

1. The positive ion is given first, followed by the monatomic or polyatomic anion.
2. The subscripts in the formula must produce an electrically neutral formula unit. (That is, the total positive charge must equal the total negative charge.)
3. The subscripts should be the smallest set of whole numbers possible.
4. If there is only one of a polyatomic ion in the formula, do not place parentheses around it; e.g., $NaNO_3$, not $Na(NO_3)$. If there is more than one of a polyatomic ion in the formula, put the ion in parentheses, and place the subscript after the parentheses; e.g., $Ca(OH)_2$, $Ba_3(PO_4)_2$, etc. Note, $Ca(OH)_2 \neq CaOH_2$

Na^+	Cl^-	$NaCl$
Ca^{2+}	Br^-	$CaBr_2$
Na^+	S^{2-}	Na_2S
Mg^{2+}	O^{2-}	MgO
Fe^{3+}	O^{2-}	Fe_2O_3
Na^+	SO_4^{2-}	Na_2SO_4
Mg	NO_3^-	$Mg(NO_3)_2$
NH_4^+	SO_4^{2-}	$(NH_4)_2SO_4$

Nomenclature of Ionic and Covalent Compounds

1. **Binary Ionic Compounds Containing a Metal and a Nonmetal.** A *binary compound* is a compound formed from *two different elements*. There may or may not be more than one of each element. A *diatomic compound* (or diatomic molecule) contains two atoms, which may or may not be the same.

Cl_2	Not binary (only one type of atom), but diatomic (two atoms).
BrCl	Binary and diatomic. (Two atoms, and they're different elements.)
H_2O	Binary, since there are only two types of atoms.
CH_4	Binary, since there are only two types of atoms.
$CHCl_3$	Not binary or diatomic.

Metals combine with nonmetals to give ionic compounds. When naming binary ionic compounds, name the cation first (specifying the charge, if necessary), then the nonmetal anion (element stem + *-ide*). Do NOT use prefixes to indicate how many of each element is present; this information is implied in the name of the compound.

NaCl	Sodium chloride
$AlBr_3$	Aluminum bromide
Ca_3P_2	Calcium phosphide
SrI_2	Strontium iodide
$FeCl_2$	Iron(II) chloride or ferrous chloride

2. **Ionic Compounds Containing a Metal and a Polyatomic Ion.** Metals combine with polyatomic ions to give ionic compounds. Name the cation first (specifying the charge, if necessary), then the polyatomic ion as listed in the table above. Do NOT use prefixes to indicate how many of each element is present; this information is implied in the name of the compound.

NaOH	Sodium hydroxide
$Ca(NO_3)_2$	Calcium nitrate
K_3PO_4	Potassium phosphate
$(NH_4)_2SO_4$	Ammonium sulfate
NH_4F	Ammonium fluoride
$CaCO_3$	Calcium carbonate
$Mg(C_2H_3O_2)$	Magnesium acetate
$Fe(OH)_3$	Iron(III) hydroxide
$Cr_3(PO_4)_2$	Chromium(II) phosphate
$CrPO_4$	Chromium(III) phosphate
$NaHCO_3$	Sodium hydrogen carbonate *or* sodium bicarbonate

3. **Acids:** In their simplest form, acids are compounds that produce $H^+(aq)$ in solution. There are other definitions of acids that you will be introduced to later in your chemistry coursework, but for now let's consider those compounds that dissociate to form H^+ in solution.

Acids are always written in the (aq) form do differentiate them from molecular compounds:

Example: HCl (g) is *"hydrogen chloride"* whereas HCl(aq) is *"hydrochloric acid"*

Simple Anion Acids: These are the acid forms of "ide" anions. They take on the forms "hydro" _____ "ic" acid where the blank space is the root name of the anion:

Examples:	Anion	Acid Formula	Name
	chloride (Cl^-)	HCl(aq)	Hydro*chloric* acid
	fluoride (F^-)	HF(aq)	Hydro*fluoric* acid
	sulfide (S^{2-})	H_2S(aq)	Hydro*sulfuric* acid

Oxy Anion Acids: These are the acid forms of the oxygen containing anions like nitrate, nitrite, acetate and so on.

"–ate" anions become *"_____ –ic"* acids where the blank space corresponds to the root name of the "ate" anion.

Examples:	Anion	Acid Formula	Name
	nitrate (NO_3^-)	HNO_3(aq)	nitr*ic* acid
	acetate ($C_2H_3O_2^-$)	$HC_2H_3O_2$(aq)	acet*ic* acid
	perchlorate ClO_4^-	$HClO_4$(aq)	perchlor*ic* acid

"–ite" anions become *"_____ –ous"* acids where the blank space corresponds to the root name of the "ite" anion.

Examples:	Anion	Acid Formula	Name
	nitrite (NO_2^-)	HNO_2(aq)	nitr*ous* acid
	chlorite (ClO_2^-)	$HClO_2$(aq)	chlor*ous* acid

Acid salts are ionic compounds that still contain an acidic hydrogen, such as $NaHSO_4$. In naming these salts, specify the number of acidic hydrogen atoms still in the salt. For instance:

$NaHSO_4$	sodium hydrogen sulfate (***not*** sodium monohydrogen sulfate)
$NaHCO_3$	sodium hydrogen carbonate *or* sodium bicarbonate
Na_2HPO_4	sodium hydrogen phosphate (since there is only H, it is assumed)
NaH_2PO_4	sodium dihydrogen phosphate

The prefix *bi-* implies an acidic hydrogen: $NaHCO_3$, sodium bicarbonate (or sodium hydrogen carbonate); $NaHSO_3$, sodium bisulfite (or sodium hydrogen sulfite), etc.

4. **Binary Compounds composed of Two Nonmetals.** Two nonmetals combine to form a *covalent* or *molecular compound* (i.e., one that is held together by covalent bonds, not ionic bonds). In many cases, two elements can combine in several different ways to make completely different compounds. (This cannot happen with ionic compounds.) For instance, carbon can share electrons with one oxygen, to make CO (carbon monoxide), or with two oxygen atoms to make CO_2 (carbon dioxide). For this reason, it is necessary to specify how many of each element is present within the compound.

The more electropositive element (the one further to the left on the periodic table) is placed first, then the more electronegative element (the one further to the right on the periodic table). [*Important exception:* when the compound contains oxygen and a halogen, the halogen is placed first. If both elements are in the same group, the one with the higher period number is named first.] The first element in the formula is given the neutral element name, and the second one is named by replacing the ending of the neutral element name with *-ide*. A prefix is used in front of each element name to indicate how many of that element is present:

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

If there is only one of the first element in the formula, the *mono-* prefix is dropped.

SO_2	sulfur dioxide	NO_2	nitrogen dioxide
SO_3	sulfur trioxide	N_2O_4	dinitrogen tetraoxide
N_2O	dinitrogen monoxide	N_2O_5	dinitrogen pentaoxide
NO	nitrogen monoxide		

5. Hydrocarbons. *Hydrocarbons* contain only carbon and hydrogen, and are the simplest type of organic compound. *Alkanes* contain only carbon-carbon single bonds, and are the simplest of the hydrocarbons. The simplest of the alkanes are the straight-chain alkanes, in which all of the carbon atoms are linked together in a line, with no branches. (They don't get simpler than that!) Alkanes have the general formula C_nH_{2n+2}, and are the constituents of several important fuels, such as natural gas and gasoline.

Organic chemistry has a completely different set of rules for nomenclature; straight-chain alkanes are named using a prefix plus the suffix *–ane*. (Notice that after C_4, the prefixes are the same as those listed above for binary covalent compounds.)

CH_4	methane	C_6H_{14}	hexane
C_2H_6	ethane	C_7H_{16}	heptane
C_3H_8	propane	C_8H_{18}	octane
C_4H_{10}	butane	C_9H_{20}	nonane
C_5H_{12}	pentane	$C_{10}H_{22}$	decane

Chemical Formula Nomenclature Practice:
Complete these in lab and on your own time for practice. You should complete this by the end of the first week of class. Use the stock form for the transition metals.

Give the formula for the following:

1. sulfur dioxide _____
2. sodium thiosulfate _____
3. ammonium phosphate _____
4. potassium chlorate _____
5. lithium hydroxide _____
6. zinc nitrite _____
7. sodium sulfate _____
8. cobalt (IV) bisulfite _____
9. cadmium nitrate _____
10. nitric oxide _____
11. hydrogen peroxide _____
12. carbon monoxide _____
13. silicon dioxide _____
14. copper (I) bromide _____
15. iron (II) chromate _____
16. mercury (I) fluoride _____
17. carbon tetrachloride _____
18. carbon dioxide _____
19. cobalt (II) chloride _____
20. aluminum carbonate _____
21. diphosphorus pentaoxide _____
22. cesium oxalate _____
23. nickel (II) sulfite _____
24. barium hypochlorite _____
25. phosphorus pentachloride _____
26. methane _____
27. copper (II) sulfate _____
28. nitrogen dioxide _____
29. mercury (II) chloride _____
30. tin (II) bromide _____
31. silver iodide _____
32. magnesium bisulfite _____
33. carbon disulfide _____
34. beryllium periodate _____
35. platinum (IV) cyanide _____
36. ammonia _____
37. dinitrogen oxide _____
38. ferric oxide _____
39. gold (III) chloride _____
40. strontium sulfide _____
41. uranium (VI) fluoride _____
42. lead (II) bicarbonate _____
43. stannic fluoride _____
44. sodium dichromate _____
45. water _____
46. lead (II) peroxide _____
47. calcium carbide _____
48. rubidium chromate _____
49. nickel (II) chlorate _____
50. magnesium nitride _____

51. ammonium sulfide _____
52. aluminum phosphide _____
53. zinc dichromate _____
54. aluminum hydride _____
55. strontium phosphate _____
56. tin (II) phosphate _____
57. chromium (III) nitrate _____
58. cobalt (II) chlorate _____
59. cesium cyanide _____
60. bismuth (III) bisulfate _____
61. magnesium chlorite _____
62. arsenic trichloride _____
63. tin (II) oxide _____
64. lead (II) perchlorate _____
65. iron (II) bromide _____
66. silver sulfite _____
67. potassium permanganate _____
68. tin (IV) sulfate _____
69. cobalt (IV) fluoride _____
70. cesium bromate _____
71. iron (III) dichromate _____
72. beryllium iodide _____
73. copper (I) carbonate _____
74. mercury (I) acetate _____
75. calcium bisulfate _____
76. lithium hydride _____
77. lithium chlorate _____
78. cupric perchlorate _____
79. gold (III) perchlorate _____
80. aluminum bisulfite _____
81. iron (II) phosphate _____
82. copper (II) chloride _____
83. diphosphorus pentaoxide _____
84. ammonium nitrate _____
85. mercury (I) sulfate _____
86. cesium nitrite _____
87. sodium bisulfate _____
88. hydrochloric acid _____
89. sulfuric acid _____
90. phosphoric acid _____
91. perchloric acid _____
92. hydrobromic acid _____
93. tin (IV) permanganate _____
94. hydroiodic acid _____
95. nitric acid _____
96. magnesium dichromate _____

Give the names of the following compounds

1. $NaCl$ _____
2. $AgNO_3$ _____
3. $BaCrO_4$ _____
4. KOH _____
5. $ZnSO_4$ _____
6. $MgBr_2$ _____
7. Al_2O_3 _____
8. $CdCl_2$ _____
9. NH_4I _____
10. $Fe(OH)_3$ _____
11. $Ba_3(PO_4)_2$ _____
12. $KClO_3$ _____
13. $H_2CO_3(aq)$ _____
14. $(NH_4)_2C_2O_4$ _____
15. $(NH_4)_2CO_3$ _____
16. NiF_2 _____
17. $Zn(ClO_3)_2$ _____
18. $Ca(OH)_2$ _____
19. $BaSO_3$ _____
20. $AlCl_3$ _____
21. Cu_2CO_3 _____
22. FeO _____
23. $AgC_2H_3O_2$ _____
24. Cr_2O_3 _____
25. KBr _____
26. $Cd(HSO_4)_2$ _____
27. CO_2 _____
28. H_2O_2 _____
29. $CaSO_4$ _____
30. $Ni_3(PO_4)_2$ _____
31. AsF_3 _____
32. $Co_3(AsO_4)_2$ _____
33. $ZnCr_2O_7$ _____
34. HCN _____
35. $Bi(NO_3)_3$ _____
36. CaH_2 _____
37. SnS_2 _____
38. $Cr_2(SO_4)_3$ _____
39. $Hg(BrO_3)_2$ _____
40. N_2O_4 _____
41. $Pb(HCO_3)_2$ _____
42. $Na_2Cr_2O_7$ _____
43. PbO_2 _____
    (2 possible names)
    _____

Give the names or formulas for the following acids