

Nomenclature Worksheet

In order to succeed in chem. 1A and 1E, you will be required to learn and apply the principles of chemical nomenclature. Data shows that students that fail to master nomenclature by the 3rd week, generally 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 are 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 without 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.

<u>Group</u>	<u>Element</u>	<u>Cation</u>	<u>Ion name</u>	<u>Group</u>	<u>Element</u>	<u>Cation</u>	<u>Ion name</u>
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.

<u>Metal</u>	<u>Ion</u>	<u>Systematic name</u>	<u>Common name</u> (<i>not used on exams and quizzes</i>)
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*.

<u>Group</u>	<u>Element</u>	<u>Anion</u>	<u>Ion name</u>	<u>Group</u>	<u>Element</u>	<u>Anion</u>	<u>Ion name</u>
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 Hg₂²⁺.

Polyatomic Ions

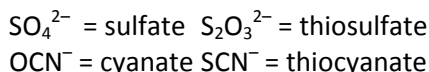
Polyatomic ions are ions that are composed of two or more atoms that are linked by covalent bonds, but that still have a net deficiency or surplus of electrons, resulting in an overall charge on the group. A metal plus a polyatomic ion yields an ionic compound.

Formulas and Names of Some Polyatomic Ions

<u>Formula</u>	<u>Name</u>	<u>Formula</u>	<u>Name</u>
NH_4^+	ammonium	CO_3^{2-}	carbonate
H_3O^+	hydronium	HCO_3^-	hydrogen carbonate (<i>bicarbonate</i>)
OH^-	hydroxide		
OCN^-	cyanate		
CN^-	cyanide	SCN^-	thiocyanate
O_2^{2-}	peroxide		
N_3^-	azide	CrO_4^{2-}	chromate
NO_2^-	nitrite	$\text{Cr}_2\text{O}_7^{2-}$	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 (<i>bisulfate</i>)
ClO_2^-	chlorite	HSO_3^-	hydrogen sulfite (<i>bisulfite</i>)
ClO^-	hypochlorite	$\text{S}_2\text{O}_3^{2-}$	thiosulfate
HS^-	hydrogen sulfide(<i>bisulfide</i>)		
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		
$\text{C}_2\text{H}_3\text{O}_2^-$	acetate (alternate ways to write acetate are CH_3CO_2^- or CH_3COO^-)		
$\text{C}_2\text{O}_4^{2-}$	oxalate		
HC_2O_4^-	hydrogen oxalate (<i>bioxalate</i>)		
$\text{C}_4\text{H}_4\text{O}_6^{2-}$	tartrate		
AsO_4^{3-}	arsenate	BO_3^{3-}	borate
SeO_4^{2-}	selenate	$\text{B}_4\text{O}_7^{2-}$	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:



- 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 $\text{Na}(\text{NO}_3)$. 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., $\text{Ca}(\text{OH})_2$, $\text{Ba}_3(\text{PO}_4)_2$, etc. Note, $\text{Ca}(\text{OH})_2 \neq \text{CaOH}_2$

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^-	$\text{Mg}(\text{NO}_3)_2$
NH_4^+	SO_4^{2-}	$(\text{NH}_4)_2\text{SO}_4$

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 ₂ O	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 ₃ P 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 ₃ PO ₄	Potassium phosphate
(NH ₄) ₂ SO ₄	Ammonium sulfate
NH ₄ F	Ammonium fluoride
CaCO ₃	Calcium carbonate
Mg(C ₂ H ₃ O 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 to 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:	<u>Anion</u>	<u>Acid Formula</u>	<u>Name</u>
	chloride (Cl^-)	HCl(aq)	Hydrochloric acid
	fluoride (F^-)	HF(aq)	Hydrofluoric acid
	sulfide (S^{2-})	$\text{H}_2\text{S(aq)}$	Hydrosulfuric 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:	<u>Anion</u>	<u>Acid Formula</u>	<u>Name</u>
	nitrate (NO_3^-)	$\text{HNO}_3(\text{aq})$	nitric acid
	acetate ($\text{C}_2\text{H}_3\text{O}_2^-$)	$\text{HC}_2\text{H}_3\text{O}_2(\text{aq})$	acetic acid
	perchlorate ClO_4^-	$\text{HClO}_4(\text{aq})$	perchloric acid

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

Examples:	<u>Anion</u>	<u>Acid Formula</u>	<u>Name</u>
	nitrite (NO_2^-)	$\text{HNO}_2(\text{aq})$	nitrous acid
	chlorite (ClO_2^-)	$\text{HClO}_2(\text{aq})$	chlorous 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 <i>or</i> 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 ₂ O ₄	dinitrogen tetraoxide
N ₂ O	dinitrogen monoxide	N ₂ O 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 C₄, the prefixes are the same as those listed above for binary covalent compounds.)

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

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

Give the names of the following compounds

1. NaCl _____
2. AgNO₃ _____
3. BaCrO₄ _____
4. KOH _____
5. ZnSO₄ _____
6. MgBr₂ _____
7. Al₂O₃ _____
8. CdCl₂ _____
9. NH₄I _____
10. Fe(OH)₃ _____
11. Ba₃(PO₄)₂ _____
12. KClO₃ _____
13. H₂CO₃(aq) _____
14. (NH₄)₂C₂O₄ _____
15. (NH₄)₂CO₃ _____
16. NiF₂ _____
17. Zn(ClO₃)₂ _____
18. Ca(OH)₂ _____
19. BaSO₃ _____
20. AlCl₃ _____
21. Cu₂CO₃ _____
22. FeO _____

23. AgC₂H₃O₂ _____
24. Cr₂O₃ _____
25. KBr _____
26. Cd(HSO₄)₂ _____
27. CO₂ _____
28. H₂O₂ _____
29. CaSO₄ _____
30. Ni₃(PO₄)₂ _____
31. AsF₃ _____
32. Co₃(AsO₄)₂ _____
33. ZnCr₂O₇ _____
34. HCN _____
35. Bi(NO₃)₃ _____
36. CaH₂ _____
37. SnS₂ _____
38. Cr₂(SO₄)₃ _____
39. Hg(BrO₃)₂ _____
40. N₂O₄ _____
41. Pb(HCO₃)₂ _____
42. Na₂Cr₂O₇ _____
43. PbO₂ _____
(2 possible names)

Give the names or formulas for the following acids