Chemical Nomenclature

INTRODUCTION

Writing chemical formulas will open your eyes to the chemical world. There are four naming systems you will need to master in order to correctly write chemical formulas and names. The trick lies in recognizing *which* naming system to use! Use the following guidelines when making your decisions about how to name compounds.

- If the chemical formula for the compound starts with a metal it is most likely ionic. Use the Ionic Compounds rules.
- If the chemical formula for the compound starts with a nonmetal other than H or C, use the Binary Covalent (Molecular) Compounds rules.
- If the chemical formula for the compound starts with H, it is an acid. Use the Acids rules.
- If the chemical formula for the compound starts with C and contains quite a few H's and perhaps some O's, it is organic. Use the Organic Compounds rules.

IONIC COMPOUNDS

IONIC NAMING

How do I know it is ionic? If only two elements are present, and they are from opposite sides of the periodic table, like KCl, it is ionic. The chemical formula will begin with the metal cation (+ ion) and end with the nonmetal anion (- ion).

In an ionic compound, the charges of the metal cations (+ ions) formed in Group IA alkali metals, Group IIA alkaline earth metals, aluminum (Al), silver (Ag), cadmium (Cd) and zinc (Zn) are constant. Group IA metals are always +1, Group IIA metals are always +2, Al is always +3, Ag is always +1, and Cd and Zn are always +2 in ionic compounds. Other metals, however, often form more than one type of positive ion so Roman numerals follow the ion's name in parentheses. For example, Cu^{1+} is the copper (I) ion while Cu^{2+} is the copper (II) ion. Notice how the Roman numeral follows the name in parentheses and matches the charge of the ion that is formed. Remember the elements that do not require Roman numerals — Group IA, Group IIA, Al, Ag, Cd, Zn.

In an ionic compound, the charges of the nonmetal ions (- ions) formed from the halogens, or VIIA family, are most commonly –1, the VIA family is –2, and the VA family is –3.

Use of the following periodic table will come in handy. Notice the simple patterns for determining the most common charge of a metal or nonmetal based on their group's position on the periodic table. Also notice the metals that form more than one ion. This periodic table lists the most common metals and nonmetals that you will encounter in this class; however, you should be familiar with these patterns and how to use the Roman numeral system for any metal that can form multiple ions.

IA	IIA											IIIA	IVA	VA	VIA	VIIA	VIIIA
Li^{+}														N^{3-}	O^{2-}	F^{-}	
Na^{+}	Mg^{2+}											Al^{3+}			S^{2-}	Cl^{-}	
K^{+}	Ca^{2+}				Cr^{2+} Cr^{3+}	Mn^{2+} Mn^{3+}	Fe^{2+} Fe^{3+}	Co^{2+} Co^{3+}		Cu^{+} Cu^{2+}	Zn^{2+}					Br^{-}	
Rb^{+}	Sr^{2+}									Ag^{+}	Cd^{2+}		Sn^{2+} Sn^{4+}			I^{-}	
Cs^{+}	Ba^{2+}										Hg_2^{2+} Hg^{2+}		Pb^{2+} Pb^{4+}				

It is *essential* that you memorize the common polyatomic ions. Polyatomic ions are groups of atoms that behave as a unit and possess an overall charge. *If more than one copy of a polyatomic ion is needed to create a chemical formula, the ion must be enclosed in parentheses before adding the subscripts***.** You need to know their names, formulas and charges. When you memorize the list of polyatomic ions, you will find that chemical nomenclature becomes a very easy topic. PRACTICE, PRACTICE, PRACTICE!

The polyatomic ions that end with *–ate* and with charges less than negative one, meaning ions with charges of –2, –3, etc., can have an H added to them to form new polyatomic ions. For each H added the charge is increased by a +1. For instance, CO_3^{2-}, the carbonate ion, can have an H added and become HCO_3^{1-}, the hydrogen carbonate ion. Since the phosphate polyatomic ion, PO_4^{3-} has a –3 charge, you can add one hydrogen to from the hydrogen phosphate ion, HPO_4^{2-}, or two hydrogen ions to create the dihydrogen phosphate ion, $H_2PO_4^{1-}$. If you continue adding hydrogen ions until your reach neutral, you've made an acid! That means you will need to see the Naming Acids rules.

In order to name ionic compounds, first name the ions.

Naming positive ions: Metals commonly form cations.

- Monatomic positive ions in Group A are named by simply writing the name of the metal from which it is derived.
  Examples: Al^{3+} is the aluminum ion, Li^{1+} is the lithium ion.
- Metals often form more than one type of positive ion so Roman numerals (in parentheses) follow the ion's name.
  Examples: Cu^{1+} is the copper (I) ion, Cu^{2+} is the copper (II) ion. Remember the exceptions — Group IA, Group IIA, Al, Ag, Cd, Zn.
- NH_4^{1+} is the ammonium ion. It is the most common positive polyatomic ion that you will encounter.

Naming negative ions: Nonmetals commonly form anions (– ions). Most of the polyatomic ions are also negatively-charged.

- Monatomic negative ions are named by adding the suffix -ide to the stem of the nonmetal's name. Group VII A, the Halogens are called the halides.
  Examples: Cl^{1-} is the chlor**ide** ion, O^{2-} is the ox**ide** ion.
- Polyatomic anions are given the names of the polyatomic ion. You must memorize these as instructed.
  Examples: NO_2^{-1} is the nitrite ion

Naming the Compound: The + ion (cation) name is given *first* followed by the name of the negative ion (anion). Remember, to include the Roman numeral that indicates a metal's charge for the many metals that have more than one oxidation state. **No prefixes are used in naming ionic compounds**.

Examples: NaCl is named sodium chloride, $(NH_4)_2SO_4$ is named ammonium sulfate.

IONIC FORMULA WRITING

Naming is the trickiest part! Once you have been given the name, the formula writing is easy *as long as you have memorized the formulas and charges of the polyatomic ions*. Roman numerals are your friend; they tell you the charge of the metal ions that can have more than one oxidation state and thus form positive ions with different charges. Remember that Group IA, Group IIA, Al, Ag, Cd, & Zn are usually not written with a Roman numeral; you must know their charges. The most important thing to remember is that, the sum of the charges must add up to zero in order to form a neutral compound. The *crisscross method* is very useful—the charge on one ion becomes the subscript on the other. *If you use this method, you must always check to see that the* subscripts *are in their lowest whole number ratio!* Here are some examples:

potassium oxide $K^{1+}\ O^{2-} \rightarrow K^{1}\ O^{2} \rightarrow K_2O$

iron (III) chlorate $Fe^{3+}\ ClO_3^{1-} \rightarrow Fe^{3}\ ClO_3^{1} \rightarrow Fe(ClO_3)_3$

tin (IV) sulfite $Sn^{4+}\ SO_3^{2-} \rightarrow Sn^{4}\ SO_3^{2} \rightarrow Sn_2(SO_3)_4 \rightarrow Sn(SO_3)_2$

zinc acetate $Zn^{2+}\ C_2H_3O_2^{1-} \rightarrow Zn^{2}\ C_2H_3O_2^{1} \rightarrow Zn(C_2H_3O_2)_2$

BINARY COVALENT (MOLECULAR) COMPOUNDS

BINARY COVALENT (MOLECULAR) NAMING

How will I know it is a covalent (molecular) compound? ("Covalent" and "molecular" are used interchangeably). The chemical formula will contain a combination of nonmetals, both lying near each other on the periodic table. No polyatomic ions will be present. Use the following set of prefixes when naming covalent (molecular) compounds.

Subscript	Prefix
1	Mono- [usually used only on the second element; such as carbon monoxide or nitrogen monoxide]
2	di-
3	tri-
4	tetra-
5	penta-
6	hexa-
7	hepta-
8	octa-
9	nona-
10	deca-

Naming the Compound: Use prefixes to indicate the number of atoms of each element. Don't forget the -ide ending. If the second element's name begins with a vowel, then the "a" at the end of the prefix is usually dropped. N_2O_5 is dinitrogen pentoxide not dinitrogen pentaoxide. PCl_5 is phosphorous pentachloride not phosphorous pentchloride.

BINARY COVALENT (MOLECULAR) FORMULA WRITING

The prefixes of a molecular compound make it really easy to write the formula since the prefix tells you how many atoms are present for each element. Here are some examples:

carbon monoxide CO (No prefix on first element means one, mono- means one)

carbon dioxide CO_2 (No prefix on the first element means one, di- means two)

dinitrogen tetroxide N_2O_4 (di- means two, tetra- means four)*note the removal of the "a" from tetra-

ACIDS

ACID NAMING

How do I know it is an acid? The compound's formula begins with a hydrogen, H, and water doesn't count. Naming acids is extremely easy, if you know your polyatomic ions. There are three rules to follow:

• H + *element*: If the acid has only one element following the H, then use the prefix hydro- followed by the element's root name and an -ic ending.

Example: HCl is hydrochloric acid. HF is hydrofluoric acid. H_2S is hydrosulfuric acid. When you see an acid name beginning with "hydro", think "Caution, element approaching*!" (HCN is an exception since it is a polyatomic ion without oxygen, and it is named hydrocyanic acid).*

• H + *-ate polyatomic ion*: If the acid has an "-ate" polyatomic ion after the H, then it makes an "-ic" acid.

Example: $H_2SO_4$is sulfuric acid.

• H + *-ite polyatomic ion*: If the acid has an "-ite" polyatomic ion after the H, then it makes an "-ous" acid.

Example: H_2SO_3 is sulfurous acid.

ACID FORMULA WRITING

When writing formulas for acids you must have enough H^+ added to the anion to make the compound neutral. Also note that *-ate* and *-ite* polyatomic ions contain oxygen so, their acids are often referred to as *oxyacids*. See above examples.

NAMING ORGANIC COMPOUNDS

How do I know it is organic? The chemical formula will start with a C followed by hydrogens and may even contain some oxygen. Most of the organic carbons you will encounter will be either hydrocarbons or alcohols. These are the simplest of all to name. Memorize the list of prefixes in table found below. The prefixes correspond to the number of carbons present in the compound and will be the stem for each organic compound. Notice that the prefixes are standard geometric prefixes once you pass the first four carbons. This silly statement will help you remember the order of the first four prefixes since they are not ones you are familiar with: "Me Eat Peanut Butter." This corresponds to meth-, eth-, prop-, and but- which correspond to 1, 2, 3, and 4 carbons, respectively. Now that we have a stem, we need an ending. There are three common hydrocarbon endings that you will need to know as well as the ending for alcohols. The ending changes depending on the structure of the molecule.

- **-ane** - alkane (all single bonds & saturated) C_nH_{2n+2}; The alkanes are referred to as saturated hydrocarbons because they contain only single bonds and thus, the maximum number of hydrogen atoms.
- **-ene** = alkene (contains one double bond & unsaturated) C_nH_{2n}; The alkenes are referred to as unsaturated hydrocarbons because a pair of hydrogens have been removed to create the double bond.
- **-yne** ≡ alkyne (contains one triple bond & unsaturated) C_nH_{2n-2}; The alkynes are also referred to as unsaturated, because two pairs of hydrogens have been removed to create the triple bond. The term polyunsaturated means that the compound contains more than one double or triple bond.
- **-ol** - alcohol (one H is replaced with a hydroxyl group, -OH group, to form an alcohol) $C_nH_{2n+1}OH$; Do not be fooled—this looks like a hydroxide ion, but is not! It does not make this hydrocarbon an alkaline or basic compound. Do not name these as a hydroxide! C_2H_6 is ethane while C_2H_5OH is ethanol.

Table: Organic Nomenclature

# of carbon atoms = n	prefix or stem	-ane C_nH_{2n+2}	-ene C_nH_{2n}	-yne C_nH_{2n-2}	-anol $C_nH_{2n+1}OH$
1	meth-		None here because you must have at least 2 carbons for multiple bonding		CH_3OH
2	eth-				
3	prop-		C_3H_6		
4	but-				
5	pent-	C_5H_{12}			
6	hex-				
7	hept-				$C_7H_{15}OH$
8	oct-			C_8H_{14}	
9	non-				
10	dec-				

Ionic Nomenclature
Common Monatomic Ions

Use the periodic table and list below to help you practice for your nomenclature quizzes. Remember that although you will be unable to use this periodic table and reference list, you will get to use a clean, regular periodic table for all quizzes and exams.

IA	IIA											IIIA	IVA	VA	VIA	VIIA	VIIIA
Li^{+}														N^{3-}	O^{2-}	F^{-}	
Na^{+}	Mg^{2+}											Al^{3+}			S^{2-}	Cl^{-}	
K^{+}	Ca^{2+}				Cr^{2+} Cr^{3+}	Mn^{2+} Mn^{3+}	Fe^{2+} Fe^{3+}	Co^{2+} Co^{3+}		Cu^{+} Cu^{2+}	Zn^{2+}					Br^{-}	
Rb^{+}	Sr^{2+}									Ag^{+}	Cd^{2+}		Sn^{2+} Sn^{4+}			I^{-}	
Cs^{+}	Ba^{2+}										Hg_2^{2+} Hg^{2+}		Pb^{2+} Pb^{4+}				

Common Metals that form MORE THAN ONE Monatomic Cation

Formula	Name		Name (OLD)
Cr^{2+}	chromium(II)	or	chromous
Cr^{3+}	chromium(III)	or	chromic
Co^{2+}	cobalt(II)	or	cobaltous
Co^{3+}	cobalt(III)	or	cobaltic
Cu^{1+}	copper(I)	or	cuprous
Cu^{2+}	copper(II)	or	cupric
Fe^{2+}	iron(II)	or	ferrous
Fe^{3+}	iron(III)	or	ferric
Pb^{2+}	lead(II)	or	plumbous
Pb^{4+}	lead(IV)	or	plumbic
Mn^{2+}	manganese(II)	or	manganous
Mn^{3+}	manganese(III)	or	manganic
Mn^{4+}	manganese(IV)		
Hg_2^{2+}	mercury(I)*	or	mercurous
Hg^{2+}	mercury(II)	or	mercuric
Sn^{2+}	tin(II)	or	stannous
Sn^{4+}	tin(IV)	or	stannic

Common Metals that form only ONE Monatomic Cation

Formula	Name
H^{1+}	hydrogen ion
Li^{1+}	lithium ion
Na^{1+}	sodium ion
K^{1+}	potassium ion
Rb^{1+}	rubidium ion
Cs^{1+}	cesium ion
Ag^{1+}	silver ion
Mg^{2+}	magnesium ion
Ca^{2+}	calcium ion
Sr^{2+}	strontium ion
Ba^{2+}	barium ion
Zn^{2+}	zinc ion
Cd^{2+}	cadmium ion
Al^{3+}	aluminum ion

Common Nonmetals that form only ONE Monatomic Anion

Formula	Name
H^{1-}	hydride ion
F^{1-}	fluoride ion
Cl^{1-}	chloride ion
Br^{1-}	bromide ion
I^{1-}	iodide ion
O^{2-}	oxide ion
S^{2-}	sulfide ion
N^{3-}	nitride ion
P^{3-}	phosphide ion

Common Polyatomic Ions

+1 CHARGE		-1 CHARGE		-2 CHARGE		-3 CHARGE		-4 CHARGE	
ION	NAME	ION	NAME	ION	NAME	ION	NAME	ION	NAME
NH_4^{1+}	ammonium*	$H_2PO_3^{1-}$	dihydrogen phosphite	HPO_3^{2-}	hydrogen phosphite	PO_3^{3-}	phosphite	$P_2O_7^{4-}$	pyrophosphate
H_3O^{1+}	hydronium	$H_2PO_4^{1-}$	dihydrogen phosphate	HPO_4^{2-}	hydrogen phosphate	PO_4^{3-}	phosphate*		
Hg_2^{2+}	mercury (I)	HCO_3^{1-}	hydrogen carbonate*	CO_3^{2-}	carbonate*	PO_2^{3-}	hypophosphite		
		HSO_3^{1-}	hydrogen sulfite	SO_3^{2-}	sulfite*	AsO_3^{3-}	arsenite		
		HSO_4^{1-}	hydrogen sulfate	SO_4^{2-}	sulfate*	AsO_4^{3-}	arsenate		
		NO_2^{1-}	nitrite*	$S_2O_3^{2-}$	thiosulfate				
		NO_3^{1-}	nitrate*	SiO_3^{2-}	silicate				
		OH^{1-}	hydroxide*	C_2^{2-}	carbide				
		$C_2H_3O_2^{1-}$ CH_3COO^{1-}	acetate*	$C_2O_4^{2-}$	oxalate				
		CrO_2^{1-}	chromite	CrO_4^{2-}	chromate*				
		CN^{1-}	cyanide*	$Cr_2O_7^{2-}$	dichromate*				
		CNO^{1-}	cyanate	$C_4H_4O_6^{2-}$	tartrate				
		CNS^{1-}	thiocyanate	MoO_4^{2-}	molybdate				
		O_2^{1-}	superoxide	O_2^{2-}	peroxide				
		MnO_4^{1-}	permanganate*	S_2^{2-}	disulfide				
		ClO^{1-}	hypochlorite*						
		ClO_2^{1-}	chlorite*						
		ClO_3^{1-}	chlorate*						
		ClO_4^{1-}	perchlorate*						
		BrO^{1-}	hypobromite						
		BrO_2^{1-}	bromite						
		BrO_3^{1-}	bromate						
		BrO_4^{1-}	perbromate						
		IO^{1-}	hypoiodite						
		IO_2^{1-}	iodite						
		IO_3^{1-}	iodate						
		IO_4^{1-}	periodate						
		AlO_2^{1-}	aluminate						
		N_3^{1-}	azide						

***Ions that appear on the STAAR Chemistry Reference Chart.**

Vocabulary

Ion- an atom or group of atoms that has gained or lost electrons
Monatomic ion- a single atom that has gained or lost electrons and has a charge
Polyatomic ion- a group of covalently bound atoms that has an overall charge
Anion- a negatively charged ion
Cation- a positively charged ion
Oxidation number- hypothetical charge a covalently bound atom would have IF its bonds were ionic
Acid- a compound that donates H^{1+} ions during a reaction
Ionic Compound- a compound made of positively and negatively charged ions
Covalent (Molecular) Compound- a compound held together by shared pairs of electrons
Hydrocarbon- a compound composed of carbon and hydrogen