CHAPTER 2

RULES OF INORGANIC NOMENCLATURE

8. INTRODUCTION

a. This chapter discusses how to name a compound from its formula. The interrelationship of names and formulas is very important to you. You will be required to recognize both, in interpreting, preparing, and using these chemicals.

b. This chapter is in the format of programmed instruction. Each frame presents some material, and then asks some questions in which you apply the material presented. The correct answers follow so that you can check your answers for accuracy. It is important that you use a piece of paper to cover the answers as you work the program. You should fill in the answers as you work each frame and then check your answers. If you answered any questions incorrectly, go back and review the frame so that you understand the correct answer.

9. GENERAL TERMS

There are several general terms we use that give us information about inorganic compounds. To describe the number of different elements in a compound we use the terms binary, ternary, and quaternary. A *binary* compound contains *two* different elements, such as NaCl. A *ternary* compound contains *three* different elements, such as H_2SO_4. A *quaternary* compound contains *four* different elements such as $NaHCO_3$.

a. Questions.

(1) CO_2 is a _____ compound because it contains _____ different elements.

(2) $Al(OH)_2Cl$ is a _____ compound because it contains _____ different elements.

(3) KNO_3 is a _____ compound because it contains _____ different elements.

b. Answers.

(1) binary, two (C,O)

(2) quaternary, four (Al,O,H,Cl)

(3) ternary, three (K,N,O)

10. NUMBER PREFIXES

We often use prefixes to denote the number of atoms of an element in a compound. For example, CO contains one oxygen atom and is named carbon *mon*oxide. *Mon* or *mono* indicates one atom. Here is a list of the commonly used number prefixes:

		Examples	
Mono, mon	= one	CO	Carbon *mon*oxide
Di	= two	CO_2	Carbon *di*oxide
Tri	= three	SO_3	Sulfur *tri*oxide
Tetra	= four		
Penta	= five		
Hexa	= six		
Hepta	= seven		
Octa	= eight		
Nona	= nine		
Deca	= ten		

a. Questions.

(1) NCl_3 is named nitrogen_____chloride.

(2) SO_2 is named sulfur_____oxide.

(3) CF_4 is named carbon_____flouride.

b. Answers.

(1) tri

(2) di

(3) tetra

11. NAMING METALLIC CATIONS

Many metallic elements have only one possible valence. The names for the cations formed by these metals are given the name of the element. For example, Na^{+1} is called sodium ion; Ca^{+2} is called calcium ion. Other metallic elements, however, may have more than one valence. Since valence is a measure of combining power, these elements may form more than one compound with the same anion. Therefore we must have some way to differentiate between the varying valences when we name them. There are two common methods for doing this.

a. The first method uses a root word from the name of the element (or the Latin name for the element) with a suffix to indicate the valence state. The suffix *–ous* indicates the *lower* valence; the suffix *–ic* indicates the *higher* valence. For example, Hg^{+1} is called mercurous ion, but Hg^{+2} is called mercuric ion.

(1) *Questions.* (You may wish to refer to table 3.)

(a) Al^{+3} is called _____ion.

(b) Fe^{+2} is called ferr– _____ion.

(c) Fe^{+3} is called ferr– _____ion.

(d) K^{+1} is called _____ion.

(e) Cu^{+1} is called cupr– _____ion.

(f) Cu^{+2} is called cupr– _____ion.

(g) Ba^{+2} is called _____ion.

(2) *Answers.*

(a) aluminum

(b) –ous

(c) -ic

(d) potassium

(e) –ous

(f) –ic

(g) barium

b. The second method for naming metallic cations uses the name of the element followed by a roman numeral in parentheses to indicate the valence. For example, Cu^{+1} is written as copper (I) and Cu^{+2} is written as copper (II). Remember these methods for specifying valence need be used only when there is more than one valence possible.

(1) *Questions.*

(a) Fe^{+2} is written _____ion.

(b) Fe^{+3} is written _____ ion.

(c) Mg^{+2} is written _____ ion.

(d) Hg^{+1} is written _____ ion.

(e) Ag^{+1} is written _____ ion.

(f) Pb^{+4} is written _____ ion.

(2) *Answers.*

(a) iron (II) (ferrous)

(b) iron (III) (ferric)

(c) *magnesium*

(d) mercury (I) (mercurous)

(e) silver

(f) lead (IV) (plumbic)

12. NAMING ANIONS

There are generally two types of anions. Many anions are elemental; that is they are made of only one atom of one element. Others are composed of groups of atoms of one or more elements that pass through a reaction unchanged in most cases. This latter group of anions is called radicals. We will concern ourselves first with the naming of elemental or monatomic anions.

a. The names of the elemental anions are made by adding the *–ide* suffix to the root of the elements name. Thus anions formed by chlorine (Cl^{-1}) are called chloride ion, anions formed by oxygen (O^{-2}) are called oxide ion.

(1) *Questions.*

(a) Br^{-1} is called _____ ion.

(b) S^{-2} is called _____ ion.

(c) H^{-1} is called _____ ion.

(d) N^{-3} is called _____ ion.

(2) *Answers.*

(a) bromide

(b) sulfide

(c) hydride

(d) nitride

b. The most common type of anionic radicals consists of a central atom covalently bonded to a number of atoms of oxygen. Monovalent anionic radicals (valence = −1) normally contain three oxygen atoms; radicals with negative valences greater than one normally contain four oxygen atoms. The names for these normal types of radicals are formed from the root for the name of the central atom plus the suffix *–ate*. Thus, ClO_3^{-1} is named chlorate and SO_4^{-2} is named sulfate. It is important to note that these generalizations have exceptions. The best way to remember the names and formulas for the radicals is to memorize the common ones. Most of these are listed in this study guide.

Sometimes a central atom may be bonded to a different number of oxygen atoms than normal; in other words, a series of radicals may be formed with the same central atom. Different suffixes and prefixes are used to name these different radicals. When there is one less oxygen atom than normal, the suffix *–ite* is used. The name for ClO_2^{-1} is chlorite; SO_3^{-2} is called sulfite.

Occasionally there are other radicals in a series. This is especially true of the halides (fluoride, chloride, bromide, and iodide ions). If there are two less oxygen atoms than usual, the *–ite* suffix is used with the prefix *hypo–*. For example, ClO^{-1} is called hypochlorite. If there is one more oxygen atom than normal, the *–ate* suffix is used in combination with the prefix *per–*, so ClO_4^{-1} is named perchlorate.

A chart summarizing the use of the prefixes and suffixes with the series of radicals formed by chlorine as examples follows:

PREFIX	SUFFIX	NAME OF ION	RADICAL
hypo–	–ite	hypochlorite	ClO^{-1}
	–ite	chlorite	ClO_2^{-1}
	–ate	chlorate	ClO_3^{-1}
per–	–ate	perchlorate	ClO_4^{-1}

(1) *Questions.*

(a) IO_3^{-1} is called _____ion.

(b) IO_2^{-1} is called _____ion.

(c) IO_4^{-1} is called _____ ion.

(d) PO_4^{-3} is called _____ ion.

(e) PO_3^{-3} is called _____ ion.

(f) NO_3^{-1} is called _____ ion.

(g) CO_3^{-2} is called _____ ion.

(2) *Answers.*

(a) iodate

(b) iodite

(c) periodate

(d) phosphate

(e) phosphite

(f) nitrate

(g) carbonate (Be sure to learn the exceptions!)

c. There are several significant exceptions to the rules for the naming of anionic radicals. The most important is the previously mentioned carbonate radical (CO_3^{-2}). Several others bear mentioning because you are likely to see them in medicine.

(1) Certain radicals contain ionizable hydrogens. Those which contain one ionizable hydrogen are commonly named by using the prefix *bi–* with the name of the radical. For example, HCO_3^{-1} is called bicarbonate and HSO_4^{-1} is called bisulfate. Those which have more than one ionizable hydrogen are named by using a number prefix to denote the number of hydrogens followed by the word "hydrogen". Thus, $H_2PO_4^{-1}$ is called dihydrogen phosphate.

(2) Several radicals do not follow any of the above rules. Their names and formulas must be learned by rote. Some of the most common are hydroxide (OH^{-1}); peroxide (O_2^{-2}), and thiosulfate ($S_2O_3^{-2}$).

(3) Occasionally metals with valences higher than +1 will form salts which contain oxide or hydroxide ion. When these occur in the middle of the formula, they are referred to as either *oxy-* or *hydroxy-*, respectively. Number prefixes are used to denote the number of them.

NO RESPONSE REQUIRED

13. NAMING SALTS

A salt is an ionic compound containing some cation other than hydrogen and some anion other than hydroxide and oxide. Since the compound must be electrically neutral, the total positive valence (from all of the cations) must equal the total negative valence (from all the anions). This gives us a method for determining the valence of any particular ion in the formula. The names for salts are made by writing the name of the cation followed by the name of the anion. For example, $CaCl_2$ has calcium as the cation and chloride as the anion, so the compound is called calcium chloride. $FeSO_4$ has sulfate as the anion, but we need to know whether the ion is ferrous ion or ferric ion. This is easy for us to do: since we know the total negative valence (from sulfate) is −2, the total positive valence (for iron) must be +2; therefore it is ferrous ion. The compound is ferrous sulfate.

a. **Questions.**

(1) KBr is _____.

(2) $Mg(NO_3)_2$ is _____.

(3) $BaSO_4$ is _____.

(4) BiOCl is _____.

(5) $HgCl_2$ is _____.

(6) $CuSO_4$ is _____.

(7) $Al(OH)_2Cl$ is _____.

(8) $NaHCO_3$ is _____.

(9) $PbSO_4$ is _____.

(10) $KBrO_3$ is _____.

b. **Answers.**

(1) potassium bromide

(2) magnesium nitrate

(3) barium sulfate

(4) bismuth oxychloride

(5) mercuric chloride (mercury (II) chloride)

(6) cupric sulfate (copper (II) sulfate)

(7) aluminum dihydroxychloride

(8) sodium bicarbonate (sodium hydrogen carbonate)

(9) plumbous sulfate (lead (II) sulfate)

(10) potassium bromate

14. NAMING BINARY ACIDS

All acids have hydrogen as the only cation. Binary acids are those acids which are composed of only two elements; that is, they consist of hydrogen in combination with some elemental anion. Usually the anion is a halide (F, Cl, Br, I), but binary acids with other anions also occur.

The names for the binary acids are formed by using the prefix *hydro—*, the root name for the anion, and the suffix *—ic*, followed by the word "acid". For example, HCl is called hydrochloric acid.

An exception to this rule is hydrocyanic acid which has the formula HCN. Although this is a ternary acid, the cyanide radical (CN^{-1}) is usually treated like a halide ion when naming its compounds.

The binary acids are really covalent compounds which act as acids only when they are in solution, especially in water. When you know that one of the binary acids is by itself, you can properly name it in a similar manner to the salts; thus, HCl as a pure gas would be called hydrogen chloride.

a. Questions.

(1) HBr is called _____.

(2) HI is called _____.

(3) H_2S is called _____.

(4) HF gas is called _____.

b. Answers.

(1) hydrobromic acid

(2) hydriodic acid

(3) hydrosulfuric acid

(4) hydrogen fluoride

15. NAMING TERNARY ACIDS

The ternary acids generally are made of hydrogen ion combined with one of the radicals which contain oxygen. For this reason they are often referred to as "oxyacids."

When naming the ternary acids, the suffixes on the names of the radicals are changed and followed by the word "acid" to show the presence of the hydrogen. Radicals ending in *–ate* change their suffix to *–ic;* radicals ending in *–ite* change their suffix to *–ous*. The prefixes, if there are any, are not changed. Occasionally an extra syllable is added in the middle of the name for pronounciation purposes—these do not follow any pattern and must be learned. Here are some examples of naming ternary acids from the radicals:

RADICAL	NAME OF RADICAL	ACID	NAME OF ACID
SO_4^{-2}	Sulfate	H_2SO_4	Sulfuric acid
SO_3^{-2}	Sulfite	H_2SO_3	Sulfurous acid
ClO^{-1}	Hypochlorite	HClO	Hypochlorous acid

a. Questions.

(1) HNO_3 is called _____.

(2) HNO_2 is called _____.

(3) $HClO_4$ is called _____.

(4) H_2CO_3 is called _____.

(5) H_3PO_3 is called _____.

(6) H_3PO_4 is called _____.

b. Answers.

(1) nitric acid

(2) nitrous acid

(3) perchloric acid

(4) carbonic acid

(5) phosphorous acid

(6) phosphoric acid

16. NAMING BASES

The most common bases are those included by the Classical Theory of Acids and Bases; that is, they are hydroxyl ion (OH^{-1}) donors. Thus most of the bases are composed of the hydroxyl radical combined with a metallic cation.

The names for these bases are made by writing the name of the cation followed by "hydroxide." It is not normally necessary to use number prefixes because the valence of the cation tells us the number of hydroxyl radicals in each molecule. You can see that this method of naming bases is very similar to the method used for naming salts, except that the anion is always hydroxide. For example, NaOH is called sodium hydroxide and $Ca(OH)_2$ is called calcium hydroxide.

a. Questions.

(1) KOH is called _____.

(2) $Mg(OH)_2$ is called _____.

(3) $Fe(OH)_2$ is called _____.

(4) $Al(OH)_3$ is called _____.

(5) $Fe(OH)_3$ is called _____.

b. Answers.

(1) potassium hydroxide

(2) magnesium hydroxide

(3) ferrous hydroxide

(4) aluminum hydroxide

(5) ferric hydroxide

17. NAMING COVALENT INORGANIC COMPOUNDS

There are a number of inorganic compounds which are bonded into molecules by covalent bonds. Most of these are the oxides, sulfides, and halides of the nonmetallic elements.

Generally these compounds are named by writing the name of the central atom (usually the first one in the formula) followed by the name of the *anion* formed by the other element. Number prefixes are used when necessary to avoid confusion between different compounds formed by the same elements. Here are some examples:

COMPOUND	NAME OF COMPOUND
H_2S gas (see para 14a(3))	Hydrogen sulfide
CO	Carbon monoxide
CO_2	Carbon dioxide

There are two very important exceptions to this which you have probably already seen. These are *water* (H_2O) and *ammonia* (NH_3). Both of these have common names which are firmly established in the nomenclature. A property of these two compounds which makes them different from almost all others is the ability to readily accept a proton (co-ordinate covalent bond with a hydrogen cation) to form cations. Thus water becomes *hydronium ion* (H_3O^{+1}); ammonia becomes *ammonium ion* (NH_4^{+1}) very easily in the right conditions.

a. **Questions.**

(1) SO_2 is called _____.

(2) SO_3 is called _____.

(3) CCl_4 is called _____.

(4) NI_3 is called _____.

(5) CS_2 is called _____.

(6) NH_3 is called _____.

(7) NH_4^{+1} is called _____ ion.

(8) NH_4Cl is called _____.

b. **Answers.**

(1) sulfur dioxide

(2) sulfur trioxide

(3) carbon tetrachloride

(4) nitrogen triiodide

(5) carbon disulfide

(6) ammonia

(7) ammonium

(8) ammonium chloride

18. WATERS OF HYDRATION

Many times when a substance crystallizes into a solid, molecules of water are included in the crystal. These molecules of water combine with the substance in a fixed ratio, similar to the fixed ratios between the atoms in a molecule. Whenever weighing or doing calculations based on compounds which have waters of hydration, the amount of water in the crystals must be taken into consideration.

When writing formulas for these compounds, the waters of hydration are shown by placing a dot (or dash) after the formula for the compound, followed by the formula for water with a coefficient to indicate the number of waters of hydration. For example, cupric sulfate forms crystals which contain five molecules of water for each molecule of cupric sulfate—its formula is written $CuSO_4 \cdot 5H_2O$.

Compounds which contain waters of hydration are called *hydrates.* (If all the water has been removed by drying, they are called *anhydrous.)* When writing the names for these compounds, the number of waters of hydration is indicated by using number prefixes. Thus the name for $CuSO_4 \cdot 5H_2O$ is cupric sulfate pentahydrate. Another number prefix seen occasionally in the names of hydrates is *hemi–*, which means one-half (1/2).

a. **Questions.**

(1) $AlCl_3 \cdot 6H_2O$ is called _____.

(2) $Mg_3(PO_4)_2 \cdot 5H_2O$ is called _____.

(3) $Na_2HPO_4 \cdot 7H_2O$ is called _____

(4) $FeSO_4 \cdot 7H_2O$ is called _____.

(5) $Na_2CO_3 \cdot 10H_2O$ is called _____.

(6) $CaSO_4 \cdot 1/2H_2O$ is called _____.

b. **Answers.**

(1) aluminum chloride hexahydrate

(2) magnesium phosphate pentahydrate

(3) disodium hydrogen phosphate heptahydrate

(4) ferrous sulfate heptahydrate

(5) sodium carbonate decahydrate

(6) calcium sulfate hemihydrate (two molecules of calcium sulfate for each molecule of water)