Chemical Names and Formulas

CHAPTER 9

Big Idea: Chemical bonding occurs as a result of attractive forces between particles.

Pa Stds: 3.4.10.A.5, 3.4.10.A.6, 3.4.12.A.1 3.4.12.A.5

9.1 Naming Ions

Connecting to Your World

In the play *Romeo and Juliet*, William Shakespeare wrote, "What's in a name? That which we call a rose/By any other name would smell as sweet." A rose is *rosa* in Spanish, *warda* in Arabic, and *julab* in Hindi. To truly understand another culture, you must first learn the language used in that culture. Similarly, to understand chemistry, you must learn its language. Part of learning the language of chemistry involves understanding how to name ionic compounds. For this you need to know how to name ions.

9-1 Naming ions

- **Monatomic ions-**
  - consist of a single atom with a positive or negative charge resulting from the loss or gain of one or more valence electrons.

Review:

- When the metals in Groups 1A-3A lose electrons they form cations with **"+" Charges equal to their group number.**

- The charge of any ion in Group A nonmetals is determined by subtracting 8 from the group number.

9-1 Naming ions

Table 9.1

Ionic Charges of Representative Elements

1A	2A	3A	4A	5A	6A	7A	8A
Li^+	Be^{2+}			N^{3-}	O^{2-}	F^-	
Na^+	Mg^{2+}	Al^{3+}		P^{3-}	S^{2-}	Cl^-	
K^+	Ca^{2+}			As^{3-}	Se^{2-}	Br^-	
Rb^+	Sr^{2+}					I^-	
Cs^+	Ba^{2+}						

9-1 Naming ions

- Groups 1B-8B, transition metals and Group 4A;
  - form more than one cation with different ionic charges.
  - The charges of the cations of many transition metal ions must be determined from the number of electrons lost.

    - Ex:
      - Fe^{3+} 3 electrons lost
      - Fe^{2+} 2 electrons lost

      - Cu^{+} 1 electron lost
      - Cu^{+2} 2 electrons lost

  - **Exceptions**: Ag^{+}, Zn^{+2}, Cd^{+2}

9-1 Naming ions

Naming methods for ions with multiple charges:

- **1. Stock system**-
  - a Roman number in parentheses is placed after the name of the element to indicate the numerical value of the charge.

- **2**. Older, classical name of the element is used to form the root with different suffixes at the end of the word.
  - *ous*- is used to name the cation with lower charge.
  - *Ic* – used to name the ion with the higher of the two charges.

Table 9.2

Symbols and Names of Common Metal Ions with More than One Ionic Charge

Symbol	Stock name	Classical name
Cu^{+}	Copper(I) ion	
Cu^{2+}	Copper(II) ion	
Fe^{2+}	Iron(II) ion	
Fe^{3+}	Iron(III) ion	
$^{*}Hg_2^{2+}$	Mercury(I) ion	
Hg^{2+}	Mercury(II) ion	
Pb^{2+}	Lead(II) ion	
Pb^{4+}	Lead(IV) ion	
Sn^{2+}	Tin(II) ion	
Sn^{4+}	Tin(IV) ion	
Cr^{2+}	Chromium(II) ion	
Cr^{3+}	Chromium(III) ion	
Mn^{2+}	Manganese(II) ion	
Mn^{3+}	Manganese(III) ion	
Co^{2+}	Cobalt(II) ion	
Co^{3+}	Cobalt(III) ion	

*A diatomic elemental ion.

9-1 Naming ions

- How to remember “ous” and “ic”:
  - The “high” one is the “i” one, and
  - The “low” one is the “o” one.

- Fe^{+2} = Ferr[redacted]

- Fe^{+3} = Ferr[redacted]

9-1 Naming ions

- **Polyatomic ion**s-
  - ions composed of more than one atom.
  - The names of most end in *ite* or *ate*
    - *meaning it contains O as well as another non-metal (usually)*

- *Ite*- indicates one less O atom than the *ate* ending.

Big Idea: Chemical bonding occurs as a result of attractive forces between particles.
Pa Stds: 3.4.10.A.5, 3.4.10.A.6

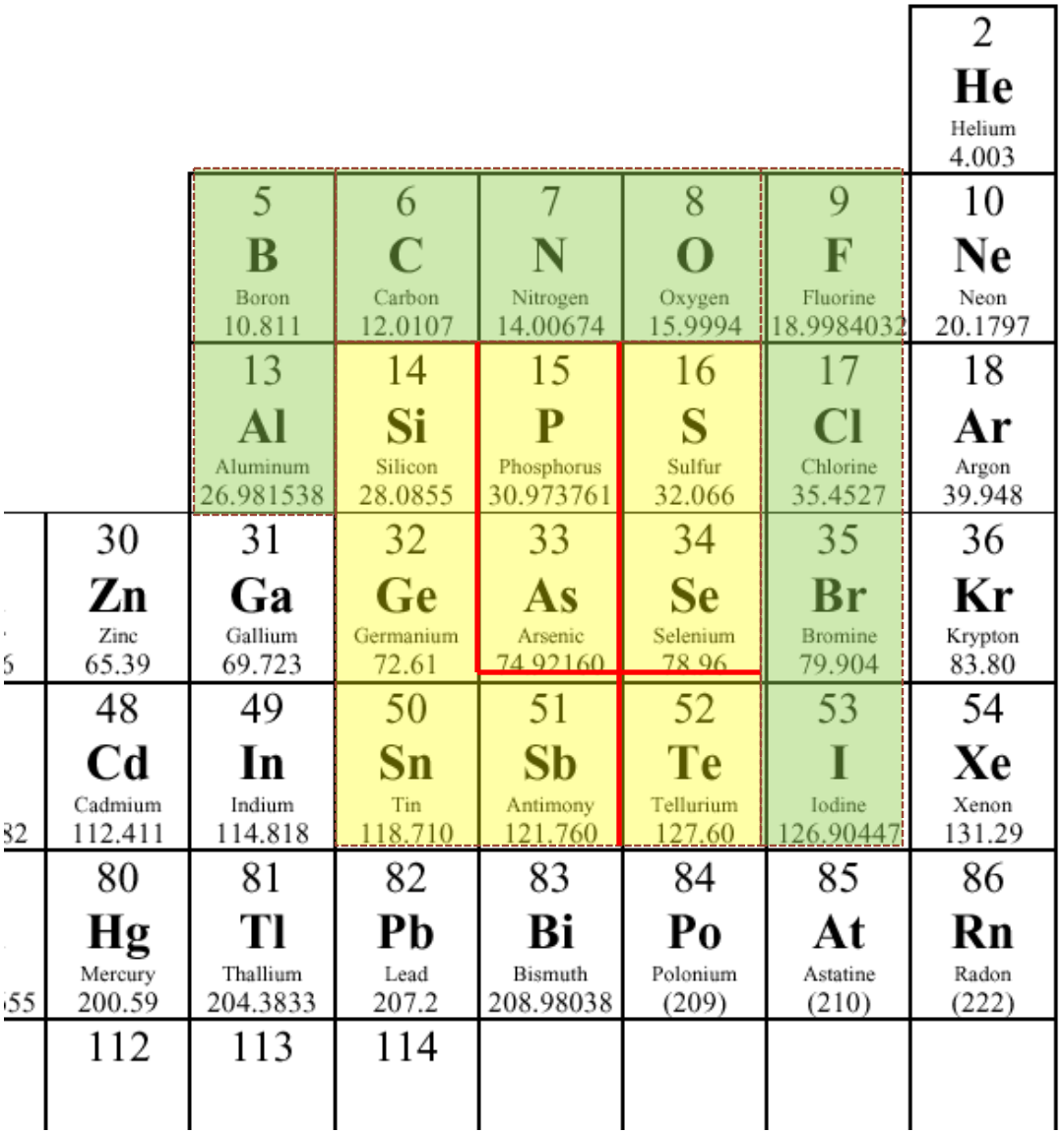
Table 9.3

Common Polyatomic Ions

Formula	Name
Charge = 1−	
$H_2PO_4^-$	Dihydrogen phosphate
$C_2H_3O_2^-$	Acetate
HSO_3^-	Hydrogen sulfite
HSO_4^-	Hydrogen sulfate
HCO_3^-	Hydrogen carbonate
NO_2^-	Nitrite
NO_3^-	Nitrate
CN^-	Cyanide
OH^-	Hydroxide
MnO_4^-	Permanganate
ClO^-	Hypochlorite
ClO_2^-	Chlorite
ClO_3^-	Chlorate
ClO_4^-	Perchlorate
Charge = 2−	
HPO_4^{2-}	Hydrogen phosphate
$C_2O_4^{2-}$	Oxalate
SO_3^{2-}	Sulfite
SO_4^{2-}	Sulfate
CO_3^{2-}	Carbonate
CrO_4^{2-}	Chromate
$Cr_2O_7^{2-}$	Dichromate
SiO_3^{2-}	Silicate
Charge = 3−	
PO_3^{3-}	Phosphite
PO_4^{3-}	Phosphate
Charge = 1+	
NH_4^+	Ammonium

"ate" is our baseline 4 or 3

- " ate & ite" means it contains O
- " ate" can mean 3 or 4 O's
- How can we tell?
  - If it's in the square-
    - "ate"=4 O's
  - If it's in the 7-
    - "ate" =3 O's (think 7-4)



							2 He Helium 4.003
		5 B Boron 10.811	6 C Carbon 12.0107	7 N Nitrogen 14.00674	8 O Oxygen 15.9994	9 F Fluorine 18.9984032	10 Ne Neon 20.1797
		13 Al Aluminum 26.981538	14 Si Silicon 28.0855	15 P Phosphorus 30.973761	16 S Sulfur 32.066	17 Cl Chlorine 35.4527	18 Ar Argon 39.948
	30 Zn Zinc 65.39	31 Ga Gallium 69.723	32 Ge Germanium 72.61	33 As Arsenic 74.92160	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80
	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.90447	54 Xe Xenon 131.29
	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98038	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
	112	113	114				

Big Idea: Chemi

Pa Stds: 3.4.10.A.5, 3.4.10.A.6, 3.4.12.A.1 3.4.12.A.5

9-1 Naming ions

- Polyatomic suffixes
  - "ate"-base
  - "ite"=1 less O than "ate"
- Polyatomic <u>prefixes</u>
  - "Per"=1 <u>more</u> O than "ate"
  - "Hypo"=2 less O than "ate"
  - "Bi" = H is included

- ClO_4^- percholorate
- ClO_3^- Chlorate
- ClO_2^- Chlorite
- ClO^- Hypochlorite

- CO_3^{-2} Carbonate
- HCO_3^- Bicarbonate or Hydrogen Carbonate

Big Idea: Chemical bonding occurs as a result of attractive forces between particles.

Pa Stds: 3.4.10.A.5, 3.4.10.A.6, 3.4.12.A.1 3.4.12.A.5

Table 9.3

Common Polyatomic Ions

Formula	Name
Charge = 1−	
$H_2PO_4^-$	Dihydrogen phosphate
$C_2H_3O_2^-$	Acetate
HSO_3^-	Hydrogen sulfite
HSO_4^-	Hydrogen sulfate
HCO_3^-	Hydrogen carbonate
NO_2^-	Nitrite
NO_3^-	Nitrate
CN^-	Cyanide
OH^-	Hydroxide
MnO_4^-	Permanganate
ClO^-	Hypochlorite
ClO_2^-	Chlorite
ClO_3^-	Chlorate
ClO_4^-	Perchlorate
Charge = 2−	
HPO_4^{2-}	Hydrogen phosphate
$C_2O_4^{2-}$	Oxalate
SO_3^{2-}	Sulfite
SO_4^{2-}	Sulfate
CO_3^{2-}	Carbonate
CrO_4^{2-}	Chromate
$Cr_2O_7^{2-}$	Dichromate
SiO_3^{2-}	Silicate
Charge = 3−	
PO_3^{3-}	Phosphite
PO_4^{3-}	Phosphate
Charge = 1+	
NH_4^+	Ammonium

Naming and Writing Formulas for Ionic Compounds

SECTION 9.2

Pa Stds: 3.4.10.A.5, 3.4.10.A.6, 3.4.12.A.1 3.4.12.A.5

9.2 Naming and Writing Formulas for Ionic Compounds

Connecting to Your World At festivals throughout the summer, contestants compete for blue ribbons for the best barbecue. Some cooks say the recipe for their barbecue sauce is the key to winning and they may hint at a secret ingredient. The recipe is the formula for the sauce—a complete list of ingredients and their proportions. With the recipe, anyone could reproduce a sauce, so a cook is likely to keep a prize-winning recipe a closely guarded secret. Chemistry also uses formulas, but without any secrets. Once you know the rules, you can write the formula for any chemical compound. In this section, you will learn how to write the formulas for ionic compounds.

9.2 Naming and Writing Formulas for Ionic Compounds

- **Early compounds named as the discoverer pleased:**
  - **Ex.**
    - **Potash, Plaster of paris, gypsum, lye, baking soda**

- **Antoine Lavoisier** 1743-1794
  - French chemist &Father of modern day chemistry,
  - recognized the importance of a method for naming compounds.

- **Binary compound**-
  - is composed of two elements
  - can be either ionic or molecular.

Big Idea: Chemical bonding occurs as a result of attractive forces between particles.

Pa Stds: 3.4.10.A.5, 3.4.10.A.6, 3.4.12.A.1 3.4.12.A.5

9.2 Naming and Writing Formulas for Ionic Compounds

- To name any binary ionic compound,
  - place the cation name first, followed by the anion name.

Compound	Name
$MgCl_2$	
NaBr	
SrF_2	

  - Note: Binary compounds usually end in **"ide"**

9.2 Naming and Writing Formulas for Ionic Compounds

- Naming a compound containing an ion w/ more than 1 possible charge
  - Ex.
    - CuO
      - Cu is in B group,
        - either Cu (I) or Cu (II)
      - Need to work backwards
        - Oxygen is O^{2-} and
        - it is a 1 to 1 ratio with Cu
        - Meaning charges must be equal and opposite
      - so must be Cu $^{2+}$,
      - use naming method: Copper(II) oxide

9.2 Naming and Writing Formulas for Ionic Compounds

Writing formulas for binary ionic compounds.

1. Write the symbol for Cation first followed by anion
2. Write charges for cation & anion as superscript
3. Add subscripts to balance charges
   - Use crisscross method
   - Drop +/- signs
4. Remove/erase charges

- Write the formula for Iron(III) Oxide

1. Fe O
2. $Fe^{+3}O^{-2}$
3. $Fe^{+3}O^{-2}$ 
4. Fe_2O_3

Big Idea: Chemical bonding occurs as a result of attractive forces between particles.

Pa Stds: 3.4.10.A.5, 3.4.10.A.6, 3.4.12.A.1 3.4.12.A.5

CONCEPTUAL PROBLEM 9.2

Writing Formulas for Binary Ionic Compounds

Write formulas for these binary ionic compounds.

a. copper(II) sulfide, shown in the photo

b. potassium nitride

Practice Problems

10. Write formulas for compounds formed from these pairs of ions.

a. Ba^{2+}, S^{2-} **b.** Li^{+}, O^{2-}

c. Ca^{2+}, N^{3-} **d.** Cu^{2+}, I^{-}

11. Write formulas for these compounds.

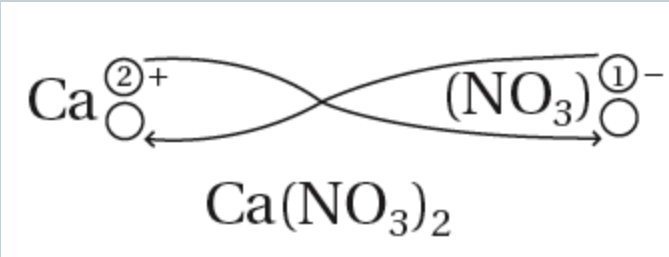
a. sodium iodide **b.** stannous chloride

c. potassium sulfide **d.** calcium iodide

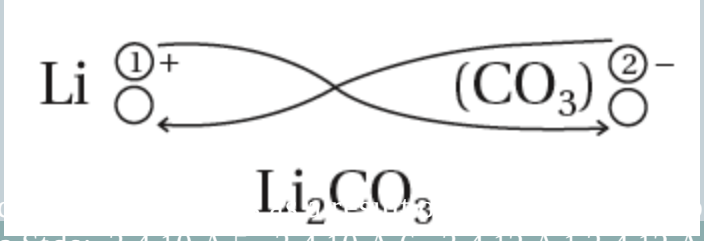
9.2 Naming and Writing Formulas for Ionic Compounds

Writing Formulas for compounds with polyatomic ions-

- use crisscross method and parentheses.
  - Ex Calcium Nitrate



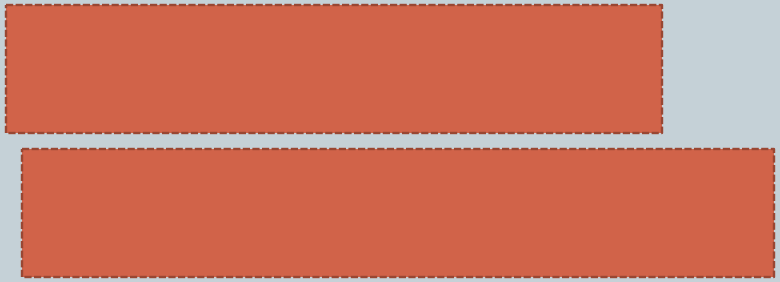
  - Lithium Carbonate



9.2 Naming and Writing Formulas for Ionic Compounds

Naming compounds with polyatomic ions,

- state the cation first then the anion. (Turn to p.257)
  - Ex.
    - LiCN
    - $(NH_4)_2C_2O_4$



learning check

9.2 Naming and Writing Formulas for Ionic Compounds

CONCEPTUAL PROBLEM 9.3

Writing Formulas for Compounds with Polyatomic Ions

Practice Problems

Naming and writing formulas for molecular compounds

SECTION 9.3

Chemical bonding occurs as a result of attractive forces between particles.

Pa Stds: 3.4.10.A.5, 3.4.10.A.6, 3.4.12.A.1 3.4.12.A.5

9.3 Naming and Writing Formulas for Molecular Compounds

Connecting to Your World Gold was one of the first metals to attract human attention. When gold was discovered in California in the late 1840s, people from all over the world came to find it and make their fortune. Today, gold is still greatly prized and valued. Whereas one milligram of gold is worth only about one cent, one kilogram of gold is worth approximately $12,500. In this case, using the correct prefix (*milli-* or *kilo-*) makes quite a difference! Prefixes are important in chemistry, too. In this section, you will learn how prefixes in the name of a binary molecular compound tell you its composition.

9.3 Naming and writing formulas for molecular compounds

- The prefix in the name of a binary molecular compound tells-
  - how many atoms of each element are present in each molecule of the compound.
- Remember: "molecular" compounds composed of 2 nonmetals
- Unlike ionic compounds, molecular compounds require prefixes to indicate number of atoms present.

9.3 Naming and writing formulas for molecular compounds

Table 9.4

Prefixes Used in Naming Binary Molecular Compounds

Prefix	Mono-	Di-	Tri-	Tetra-	Penta-	Hexa-	Hepta-	Octa-	Nona-	Deca-
Number	1	2	3	4	5	6	7	8	9	10

- N_2O
- Cl_2O_8
- CO_2
- CO

note: not necessary to write mono before the first atom

9.3 Naming and writing formulas for molecular compounds

Writing formulas for Binary molecualr compounds

- Work backwards!
  - Use the prefixes in the name to tell you the subscript of each element in the formula.
  - Then write the correct symbols for the two elements with the appropriate subscripts.
    - Ex.
      - Silicon Carbide
      - Dinitrogen tetraoxide

9.3 Naming and writing formulas for molecular compounds

- Write the names for these molecular compounds.
  1. NCl_3
  2. BCl_3
  3. NI_3
  4. SO_3
  5. N_2H_4
  6. N_2O_3

9.3 Naming and writing formulas for molecular compounds

Write the formulas or names for these molecular compounds.

1. CS_2
2. carbon tetrabromide
3. Cl_2O_7
4. diphosphorus trioxide

9.3 Naming and writing formulas for molecular compounds

Write the formulas for these binary molecular compounds.

1. phosphorus pentachloride
2. iodine heptafluoride
3. chlorine trifluoride
4. iodine dioxide

Naming and Writing Formulas for Acids and Bases

SECTION 9.4

9.4 Naming and Writing Formulas for Acids and Bases

Connecting to Your World Some ants can give painful stings when threatened or disturbed. Certain ant species called formicines have poison glands that produce venom containing formic acid. Formicines protect themselves by spraying this venom on their predators. Formic acid can stun or even kill the ants' most common enemies. A formicine attack on a human, however, is much less severe. The contact of formic acid with the skin usually results only in blistering. In this section, you will learn the names and formulas of some important acids such as formic acid.

9-4 Naming and Writing Formulas for Acids and Bases

- Acid-
  - is a compound that contains one or more hydrogen atoms
  - produces Hydrogen ions (H+) when dissolved in water.

- Generic symbol---H_nX
  - **Acid formulas begin w/ "H"**
  - **X** can be a monatomic or polyatomic anion

9-4 Naming and Writing Formulas for Acids and Bases

3 Rules to Naming Acids

- naming system depends on the name of the anion.
- rules deals with an anion with suffixes: -ide, -ite, and –ate.

When the name of the anion (X) ends in:

1. -ide, (Binary)
   - the acid name begins "**hydro-**."
   - The stem of the anion has the suffix -ic
   - followed by the word "acid.
     - Ex
       - HCl
       - HBr
       - HI

9-4 Naming and Writing Formulas for Acids and Bases

When the name of the anion (X) ends in:

2. -ite, (polyatomic $XO_{3 \text{ or } 2}$)
   - the acid name is the stem of the anion with the suffix -ous,
   - followed by the word acid.
     - H_2SO_3
     - HNO_2

3. -ate, (polyatomic $XO_{3 \text{ or } 4}$)
   - the acid name is the stem of the anion with the suffix -ic
   - followed by the word acid
     - H_2SO_4
     - HNO_3

9-4 Naming and Writing Formulas for Acids and Bases

Table 9.5

Naming Common Acids

Anion ending	Example	Acid name	Example
-ide	chlor*ide*, Cl^-	*hydro*-(stem)-*ic acid*	*hydro*chlor*ic acid*
-ite	sulf*ite*, SO_3^{2-}	(stem)-*ous acid*	sulfur*ous acid*
-ate	nitr*ate*, NO_3^-	(stem)-*ic acid*	nitr*ic acid*

9-4 Naming and Writing Formulas for Acids and Bases

Table 9.6

Common Acids

Name	Formula
Hydrochloric acid	HCl
Sulfuric acid	H_2SO_4
Nitric acid	HNO_3
Acetic acid	CH_3COOH
Phosphoric acid	H_3PO_4
Carbonic acid	H_2CO_3

9-4 Naming and Writing Formulas for Acids and Bases

Give the names of these acids. (look @ table p. 257)

- HNO_2
- $HMnO_4$
- HCN
- H_2S

9-4 Naming and Writing Formulas for Acids and Bases

Names and Formulas for bases.

- **Base**-
  - is an ionic compound that
  - produces hydroxide ions when dissolved in water.
  - **USUALLY ENDS IN "OH".**

- Bases are named in the same way other ionic compounds
  - the name of the cation followed by the anion.
    - Ex:
      - NaOH sodium hydroxide
      - $Al(OH)_3$ Aluminum hydroxide
      - KOH Potasium hydroxide

9-4 Naming and Writing Formulas for Acids and Bases

Write the names of these bases.

- LiOH
- $Pb(OH)_2$
- $Mg(OH)_2$
- $Al(OH)_3$

9-4 Naming and Writing Formulas for Acids and Bases

Assignment:

- P 273
  - 31 & 32

- Read section 9.5

The Laws Governing Formulas and Names

SECTION 9.5

9.5 The Laws Governing Formulas and Names

Connecting to Your World A birthday cake for a four-year-old has four candles. The ratio of candles to birthday cake is 4:1. A sixteen-year-old's birthday cake has 16 candles. The ratio of candles to cake is also a whole number ratio, 16:1. Is there a whole number ratio between the numbers of candles on one cake at two different birthdays? For the sixteenth and fourth birthdays, the ratio is 16:4 or 4:1. In chemistry, similar relationships exist among the masses of elements as they combine in compounds.

9.5 The Laws Governing Formulas and Names

- **Law of definite proportions**-
  - states that in samples of any chemical compound, the masses of the elements are always in the same proportions.

- What is the ratio of Mg:S in MgS?
  - Atomic mass Mg=24.31g
  - Atomic mass S = 32.07g
  - Divide each by the latter value (32.07)

$$24.31/32.07 \; : \; 32.07/32.07$$
$$0.758 \; : \; 1$$

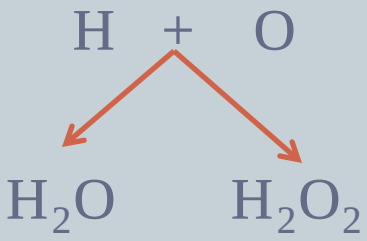
- This mass ratio does not change no matter how the MgS is formed or the size of the sample.

- Their proportions by mass must always be the same.

9.5 The Laws Governing Formulas and Names

Law of multiple proportions-

- stated by John Dalton,
- whenever the same two elements form more than one compound,
  - the different masses of one element that combine with the same mass of the other element are in the ratio of small whole numbers.



9.5 The Laws Governing Formulas and Names

- What is the mass ratio of O:H in H_2O_2?
  - 32g:2g or 16:1
- What is the mass ratio of O:H in H_2O?
  - 16g:2g or 8:1
- What is the O ratio in H2O2:H2O?
  - 16:8 or 2:1

Definite proportions

Multiple proportions

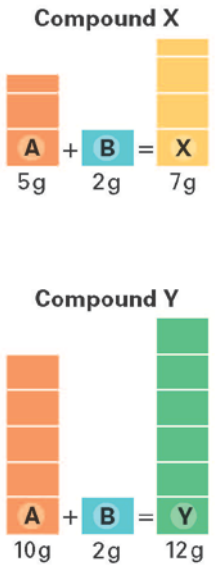
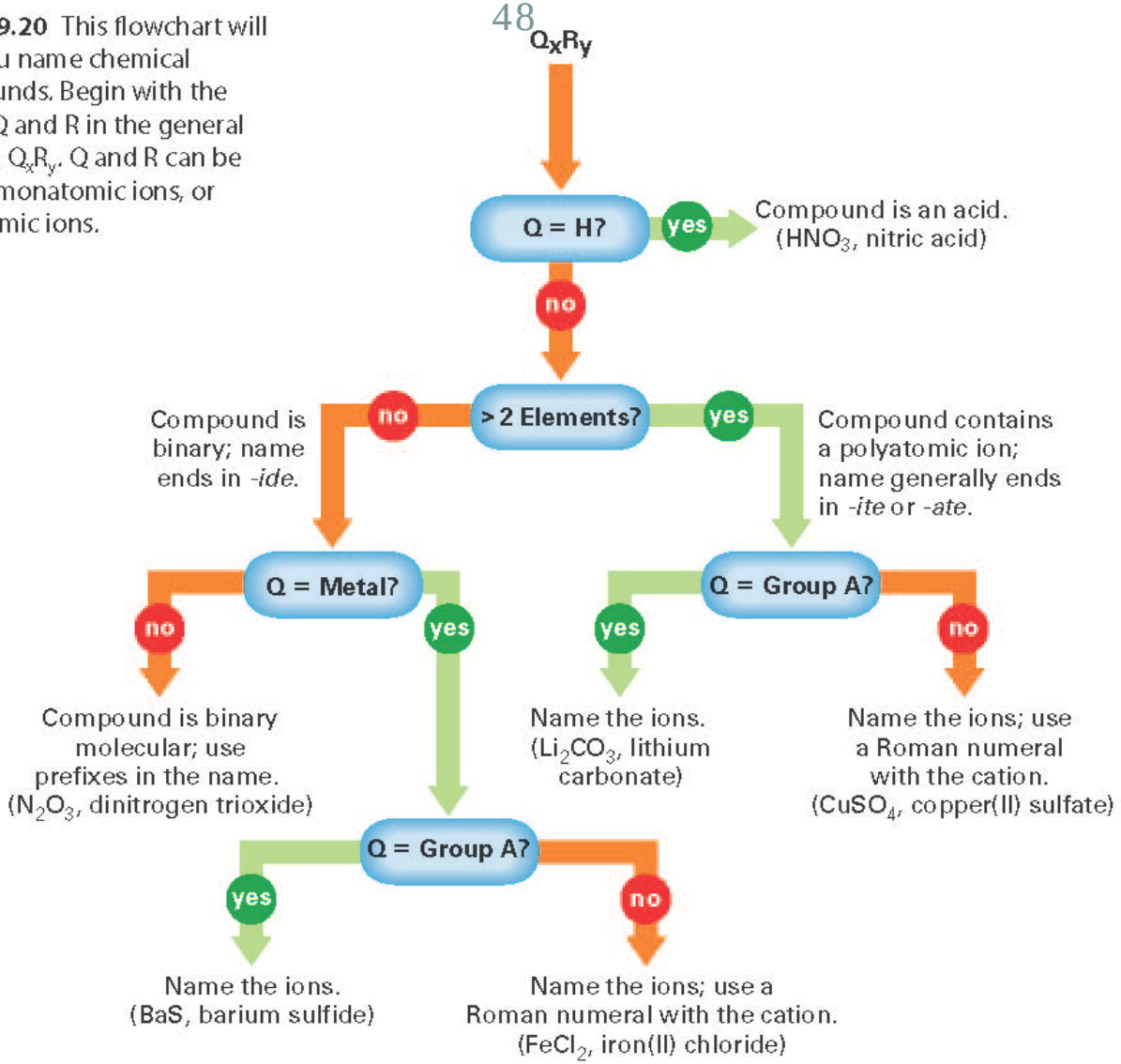


Figure 9.17 The diagram illustrates the law of multiple proportions. Two compounds, X and Y, contain equal masses of element B. The ratio of the masses of A in these compounds is 5:10 or 1:2 (a small whole number ratio). **Applying Concepts** ***Would the ratio be different if samples of X and Y contained 3 g of B?***

Naming Chemical Compounds

Figure 9.20 This flowchart will help you name chemical compounds. Begin with the letters Q and R in the general formula Q_xR_y. Q and R can be atoms, monatomic ions, or polyatomic ions.



9.5 The Laws Governing Formulas and Names

Writing chemical formulas:

- 1. An *ide* ending generally indicates a binary compound.
- 2. An ite or *ate* ending indicates a polyatomic ion that includes O is in the formula.
- 3. Prefixes in a name generally indicate that the compound is molecular.
- 4. A Roman Numeral after the name of a cation shows the ionic charge of the cation.

Writing Chemical Formulas

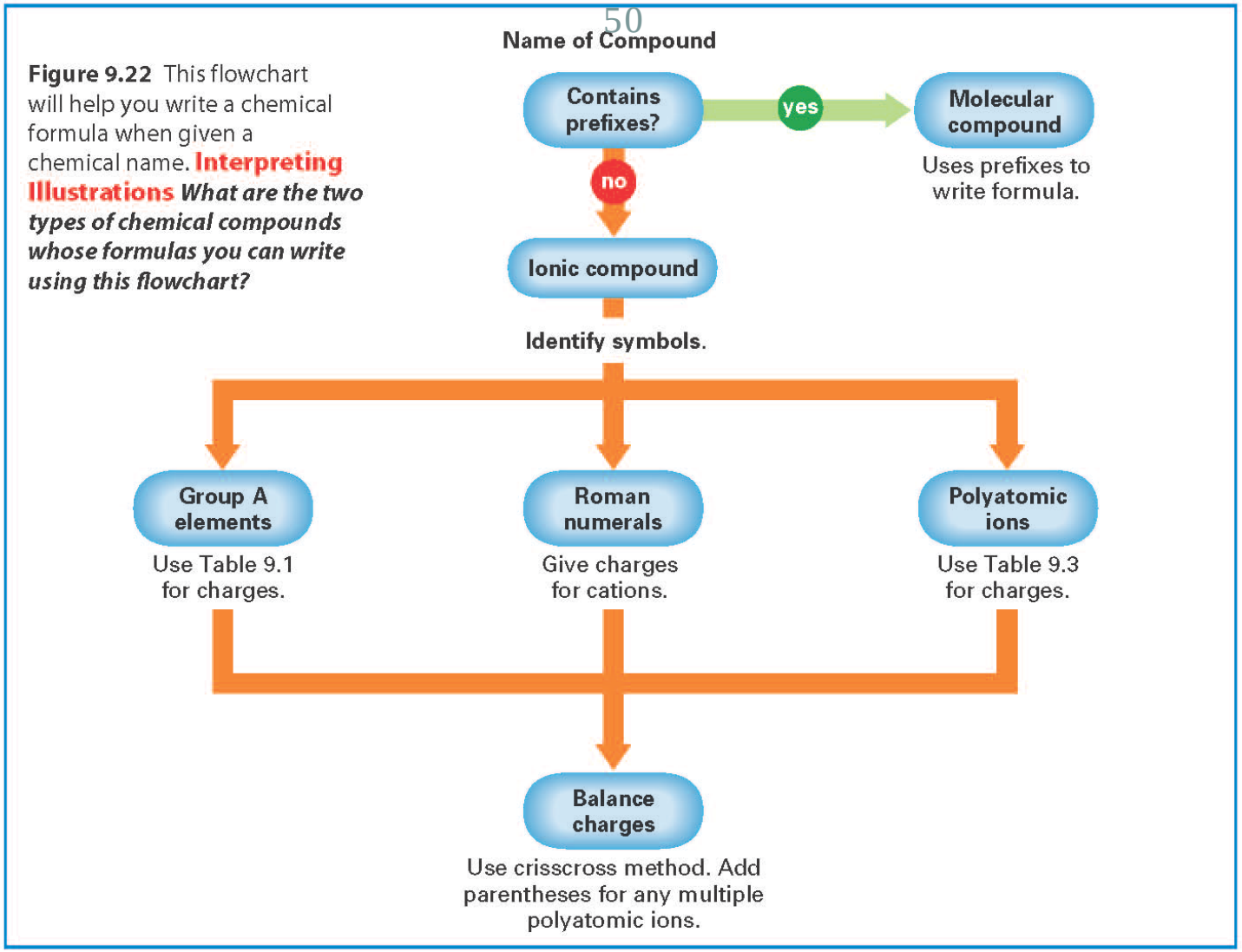


Figure 9.22 This flowchart will help you write a chemical formula when given a chemical name. **Interpreting Illustrations** ***What are the two types of chemical compounds whose formulas you can write using this flowchart?***