Chapter 7

Chemical Formulas and Chemical Cmpds

Chemical Names and Formulas

7.1

Objectives

- **Explain** the significance of a chemical formula.
- **Determine** the formula of an ionic compound formed between two given ions.
- **Name** an ionic compound given its formula.
- Using prefixes, **name** a binary molecular compound from its formula.
- **Write** the formula of a binary molecular compound given its name.

Molecular Chemical Formulas

- A chemical formula indicates the relative _____ of atoms of each kind in a chemical compound.
- For a _____ compound, the chemical formula reveals the number of atoms of each _____ contained in a _____ molecule of the compound.

Example: H_2O, CO_2,$C_{12}H_{22}O_{11}$

- How many H, C, or O in each molecule?

Ionic Chemical Formula

- The chemical formula for an _____ compound represents one formula unit—the _____ ratio of the compound's positive ions (cations) and its negative ions (anions)
- Examples: NaCl, $BeCl_2$, $Al_2(SO_4)_3$
- How many of each <u>atom</u> in each of the examples?

Monatomic Ions

- _____ **Ions** are a single ion
  - Ex. Mg^{+2}, Na^{+1}, F^{-1}, etc.
- Cations
  - Atom name
    - Magnesium, Sodium, …
- Anions
  - Atom name with "- _____" at end
    - Chloride, Fluoride,…

Monatomic Ions

- _____ ions have the charge we learned from earlier
  - Na, Li, K = +1
  - O, S = -2
- _____ have the charge in the name
  - Iron (II) = Fe^{+2}, Iron (III) = Fe^{+3}

Practice

- Name the following ions.

1. Na^{+1}
2. Hg^{+2}
3. O^{-2}
4. Cu^{+3}
5. N^{-3}

Formation of an Ionic Bond

- The overall charge of ionic compound will be _____
- This means that the _____ charges and the _____ charges must be _____

Ex. $Li^{+} + O^{-2} \rightarrow Li_2O$

$2 \times (+1) + (-2) = 0$

Example on Board (cross and Drop)

Examples

- Write the chemical formula for the following:
- Sodium Chloride
- Beryllium Chloride
- Aluminum Oxide
- Calcium Sulfide
- Potassium Nitride

Naming Ionic Cmpds

- When writing names and formulas for ionic compounds, the _____ appears first followed by the _____.
  - _____ and then _____
- _____ represent the number of ions of each element in an ionic compound.
- The total charge must equal _____ in an ionic compound.

Names for Ions and Ionic Compounds

- When naming _____ ionic compounds you write the name of the cation followed by the anion.
  - You change the ending of the anion to *-ide*
- Ex. Sodium chlor**ide**

  NOT Sodium chlor**ine**

Practice

- Name the following cmpds
- Na_2O
- BeS
- $BeCl_2$
- Mg_3S_2

The combo of O and Li = Lithium Oxide

1. True
2. False

Combo of Na and Br = sodium bromine

1. True
2. False

More than 1 oxidation number

- Sometime cations have _____ than 1 oxidation number (i.e. _____ metals)
- Writing chemical formula is the same
  - Iron (_____) Oxide = FeO
- Practice
  - Mercury (III) Oxide
  - Tin (IV) Sulfide
  - Cobalt (I) Nitride

More than 1 oxidation number

- Sometime cations have _____ than 1 oxidation number (i.e. _____ metals)
- Naming is slightly more difficult
  - HgCl = Mercury (I) Chloride
  - Do the box thingy!
- Example:
- On next slide

Name this cmpd…$HgCl_2$

Ion	Ion Charge		# of them		Total Charge
Hg	**+2**		1	divide	+2
Cl	-1	x	2		-2
					0

Mercury (II) Chloride

Practice

- FeO
- CoO_2
- Au_2S
- Ag_3N_4
- There is more practice on page 213

Polyatomic Ions

- Naming
  - Same as before but use polyatomic ion name
    - Na_3PO_4 = Sodium Phosphate
- Practice
- NaOH
- $Ca(NO_3)_2$
- Tricky…. $PbSO_4$

Polyatomic ions

- Chemical Formulas are the same as before but with _____ around the polyatomic ion is there are more than one of them
- Sodium chlorite = $NaClO_2$
- Calcium chlorite = $Ca(ClO_2)_2$
- Practice
- Potassium phosphate
- Iron (III) sulfate

What is the formula for sodium chlorate?

A. $NaClO_3$
B. $Na(ClO_3)$
C. NaCl
D. More than one of the above
E. None of the above

What is the formula for Lithium nitride?

A. $LiNO_3$
B. $Li_2(NO_3)$
C. $Li(NO_3)_2$
D. Li_3N
E. More than one of the above
F. None of the above

What is the formula for magnesium phosphate?

A. $MgPO_4$
B. Mg_3PO_{42}
C. $Mg_3(PO_{42})$
D. $Mg_3(PO_4)_2$
E. Mg_2P_3
F. More than one of the above
G. None of the above

Polyatomic Ions

- Many common polyatomic ions are _____— polyatomic ions that contain _____.
- Some elements can combine with _____ to form more than one type of _____.
- Example: _____(NO_3^{-1}) and _____(NO_2^{-1})

Based off of the -ate

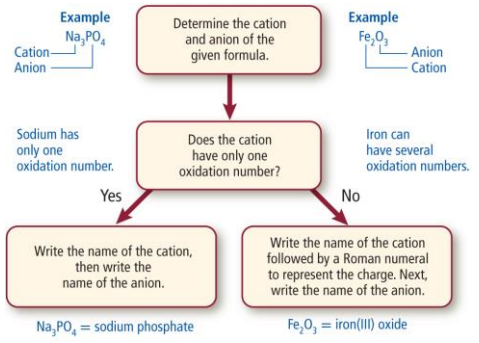
Name Change	# of oxygen's
Per-	
-ate	
-ite	
Hypo-	

Name Change	# of oxygen's
Perdogate	
Dogate	DO_3
Dogite	
Hypodogite	

Names for Ions and Ionic Compounds

- Chemical nomenclature is a systematic way of naming compounds.
  - Name the cation followed by the anion.
  - For monatomic, cations use the element name.
  - For monatomic anions, use the root element name and the suffix ***–ide***.
    - Sodium chloride
  - To distinguish between different oxidation states of the same element, the oxidation state is written in parentheses after the name of the cation.
    - Copper(III), Copper (II)
  - When the compound contains a polyatomic ion, name the cation followed by the name of the polyatomic ion.
    - Sodium hydroxide

Names for Ions and Ionic Compounds



Assignment

- 7.1 worksheet until you hit STOP

Naming Binary Molecular Compounds

- The first element is always named first using the _____ name.
  - Ex. Nitrogen, Carbon…
- The second element is named using its root and adding the suffix –_____.
  - Ex. sulfide, bromide

Naming Binary Molecular Compounds

- Prefixes are used to indicate the number of atoms of each element in a compound.

Figure 1.4			
Number	Prefix	Number	Prefix
1		6	
2		7	
3		8	
4		9	
5		10	

Naming Binary Molecular Compounds

- Many compounds were discovered and given common names long before the present naming system was developed (water, ammonia, hydrazine, nitric oxide).
- So, these names are different than expected.

Formula	Common Name	Molecular Compound Name
H_2O	water	dihydrogen monoxide
NH_3	ammonia	nitrogen trihydride
N_2H_4	hydrazine	dinitrogen tetrahydride
HCl	muriatic acid	hydrochloric acid
$C_9H_8O_4$	aspirin	2-(acetyloxy)benzoic acid

Writing formulas from names

- The prefixes in the name determine the number of atoms in the compound.

- Example
- Dinitrogen trioxide
- Di = _____ and tri = _____, so……N_2O_3

Practice??

- More Practice on board??
- Worksheet

Acids and Salts

- An *acid* is a certain type of molecular compound. Most acids used in the laboratory are either _____ acids or _____.
  - _____ *acids* are acids that consist of two elements, usually hydrogen and a halogen.
  - _____ are acids that contain hydrogen, oxygen, and a third element (usually a nonmetal).

Naming Acids

- Binary acids (_____ elements)
- The first word has the prefix _____ followed by the root of the element plus the suffix _____.
- The second word is always _____ (hydrochloric acid is HCl in water).
- Example:
  - HCl = _____
  - HF = _____

Naming Acids

- _____ are acids that contain hydrogen, oxygen, and a third element (usually a nonmetal).
- Identify the _____ present.
- The first word is the _____ of the oxyanion and the prefix *per-* or *hypo-* if it is part of the name
  - ate = _____
  - ite = _____
  - Examples on next slide

Naming Acids

- The second word is always acid.

Chem Form	Oxyion	Oxyion Name	Name
HNO_2			
HNO_3			
H_2SO_3			
H_2SO_4			

Write Acid Chemical Formulas

- Figure out the oxyanion
- Add the # of hydrogens to balance the charge

Example

- Chlorous Acid
- Oxyanion… ous→ite
  - So chlorite (ClO_2^{-1})
  - You need 1 H^{+1} to balance
    - $HClO_2$

Nona is a prefix meaning what number?

- Numeric

Hexa is a prefix meaning what number?

- Numeric

What is the chemical name for C_3O_4?

A. Carbon dioxide
B. Tetracarbon trioxide
C. Tricarbon tetraoxide
D. Tricarbon nanoxied
E. None of the above

What is the chemical name for P_5O_7?

A. Pentaphosphorus heptoxide
B. Phosphorus oxide
C. Heptaphosphorus pentoxide
D. None of the above

What is the name for HCl?

A. Hydrochloic Acid
B. Chloric Acid
C. Chlorous Acid
D. None of the above

What is the name for H_3PO_3?

- Hydrophosphic acid
- Phosphoric acid
- Phosphous acid
- Hypophosphoric acid
- None of the above

Assignment

- 7.1 Worksheet until STOP 2

Oxidation Numbers

7.2

Objectives

- **List** the rules for assigning oxidation numbers.
- **Give** the oxidation number for each element in the formula of a chemical compound.
- **Name** binary molecular compounds using oxidation numbers and the Stock system.

Oxidation Numbers

- The charges on the ions in an ionic compound reflect the electron distribution of the compound.
- In order to indicate the general distribution of electrons among the bonded atoms in a molecular compound or a polyatomic ion, **oxidation numbers** are assigned to the atoms composing the compound or ion.
- Unlike ionic charges, oxidation numbers do not have an exact physical meaning: rather, they serve as useful "bookkeeping" devices to help keep track of electrons.

Assigning Oxidation Numbers

- In general when assigning oxidation numbers, shared electrons are assumed to "belong" to the more electronegative atom in each bond.
- More-specific rules are provided by the following guidelines.
  1. The atoms in a pure element have an oxidation number of zero

Assigning Oxidation Numbers

2. The _____ element in a binary compound is assigned a negative number equal to the charge it would have as an anion. Likewise for the less-electronegative element.
3. Fluorine has an oxidation number of _____ in all of its compounds because it is the most electronegative element

Assigning Oxidation Numbers

4. Oxygen usually has an oxidation number of _____.

   Exceptions:

   - In peroxides, such as H_2O_2, oxygen's oxidation number is –1.
   - In compounds with fluorine, such as OF_2, oxygen's oxidation number is +2.

5. Hydrogen has an oxidation number of _____in all compounds containing elements that are more electronegative than it; it has an oxidation number of –1 with metals

Assigning Oxidation Numbers

6. The algebraic sum of the oxidation numbers of all atoms in an _____ compound is equal to zero.
7. The algebraic sum of the oxidation numbers of all atoms in a polyatomic ion is equal to the _____.
8. Although rules 1 through 7 apply to covalently bonded atoms, oxidation numbers can also be applied to atoms in ionic compounds similarly.

Practice

- CO_2
- O is most electronegative and have a charge of -2
- -2 x 2 (you have 2 of them) = -4
- Overall charge = 0 so C = +4

Practice

- Page 222
- 1 (d, g, i)

Stock System

- We will NOT be using this system but you should be familiar with it
  - There will be a quiz/test question(s) about it ☺
- The difference is you put in roman numerals and do not use prefixes
- Prefix System: Phosphorus trichloride
- Stock System: Phosphorus (III) Chloride

Assignment

- 7.2 Worksheet

Using Chemical Formulas

7.3

Objectives

- **Calculate** the formula mass or molar mass of any given compound.
- **Use** molar mass to convert between mass in grams and amount in moles of a chemical compound.
- **Calculate** the number of molecules, formula units, or ions in a given molar amount of a chemical compound.
- **Calculate** the percentage composition of a given chemical compound.

Formula Mass

- The _____ of any molecule, formula unit, or ion is the sum of the _____ of all atoms represented in its formula
- NaCl = 57.45
  - Na = 23.00
  - Cl = 35.45
- H_2O = _____
  - H = _____
  - O = _____

Molecular Mass

- This is the formula mass for a molecule!

Practice

- HCl
- $MgCl_2$
- Fe_2O
- $Hg_3(PO_4)_2$
- More practice on 226

Molar mass

- The _____ is the mass for 1 mole of a substance
- Luckily, the molar mass = the _____!
- The _____ are the number of moles in the cmpd
  - Example: H_2O has _____ moles H and _____ mole O
- Practice
  - Page 227 (1-2)

Percent Composition

- The percent by mass of each element in a compound is the _____ of a compound.
- Percent composition of a compound can also be determined from its chemical formula.

$$\text{percent by mass} = \frac{\text{mass of element in 1 mol of compound}}{\text{molar mass of compound}} \times 100$$

Lets Try this…

Ibuprofen, $C_{13}H_{18}O_2$, is the active ingredient in many nonprescription pain relievers. Its molar mass is 206.31 g/mol.

a. If the tablets in a bottle contain a total of 33 g of ibuprofen, how many moles of ibuprofen are in the bottle?

b. How many molecules of ibuprofen are in the bottle?

c. What is the total mass in grams of carbon in 33 g of ibuprofen?

Percent Composition

Example

You have a 126 grams of a compound and 48 grams is element A and 78 grams is element B

The percent composition for element A is:

$$\frac{48}{126} \times 100 = 38.1\%$$

Percent Composition

- Practice
- Page 232
  - 1 a

Naming Hydrates

- A _____ is a compound that has a specific number of water molecules bound to its atoms.
- The number of water molecules associated with each formula unit of the compound is written following a dot.
- Sodium carbonate decahydrate =

Common Names

Table 10.1 Formulas of Hydrates

Prefix	Molecules H_2O	Formula	Name
Mono-	1	$(NH_4)_2C_2O_4 \cdot H_2O$	ammonium oxalate monohydrate
Di-	2	$CaCl_2 \cdot 2H_2O$	calcium chloride dihydrate
Tri-	3	$NaC_2H_3O_2 \cdot 3H_2O$	sodium acetate trihydrate
Tetra-	4	$FePO_4 \cdot 4H_2O$	iron(III) phosphate tetrahydrate
Penta-	5	$CuSO_4 \cdot 5H_2O$	copper(II) sulfate pentahydrate
Hexa-	6	$CoCl_2 \cdot 6H_2O$	cobalt(II) chloride hexahydrate
Hepta-	7	$MgSO_4 \cdot 7H_2O$	magnesium sulfate heptahydrate
Octa-	8	$Ba(OH)_2 \cdot 8H_2O$	barium hydroxide octahydrate
Deca-	10	$Na_2CO_3 \cdot 10H_2O$	sodium carbonate decahydrate

Analyzing a Hydrate

- When heated, water molecules are _____ from a hydrate leaving an anhydrous compound.
  - _____ means that it does not contain any water
- To determine the formula of a hydrate, find the number of moles of _____ associated with 1 mole of hydrate.

Analyzing a Hydrate

1. Weigh hydrate.
2. Heat to drive off the water.
3. Weigh the anhydrous compound.
4. Subtract and convert the difference to moles.
5. The ratio of moles of water to moles of anhydrous compound is the coefficient for water in the hydrate.

Analyzing a Hydrate

Example:
$BaCl_2 \bullet xH_2O$

- Weight the Hydrate:
  $BaCl_2 \bullet xH_2O$ = 5 grams
- Heat to drive off the water.
  Add heat and weigh (4.26 g $BaCl_2$)

Analyzing a Hydrate

- Weigh the anhydrous compound.
  5 g of $BaCl_2 \bullet xH_2O$ – 4.26 g $BaCl_2$ = 0.74 g H_2O
- Subtract and convert the difference to moles.

$$\frac{4.26 \text{ g } BaCl_2}{} \left| \frac{1 \text{ mole } BaCl_2}{208.23 \text{ g } BaCl_2} \right. = \mathbf{0.0205 \text{ mole } BaCl_2}$$

$$\frac{0.74 \text{ g } H_2O}{} \left| \frac{1 \text{ mol } H_2O}{18.02 \text{ g } H_2O} \right. = \mathbf{0.041 \text{ mole } H_2O}$$

Analyzing a Hydrate

- The ratio of moles of water to moles of anhydrous compound is the coefficient for water in the hydrate.

$$\frac{0.041 \text{ moles } H_2O}{0.0205 \text{ moles } BaCl_2} = 2{:}1 \text{ ratio of } H_2O \text{ to } BaCl_2$$

- So… $BaCl_2 \bullet xH_2O$ is actually $BaCl_2 \bullet \mathbf{2}H_2O$

Uses for Hydrates

- Anhydrous forms of hydrates are often used to absorb water, particularly during shipment of electronic and optical equipment.
- In chemistry labs, anhydrous forms of hydrates are used to remove moisture from the air and keep other substances dry.

Assignment

- 7.3 Worksheet

Determining Chemical Formulas

7.4

Objectives

- **Define** *empirical formula,* and explain how the term applies to ionic and molecular compounds.
- **Determine** an empirical formula from either a percentage or a mass composition.
- **Explain** the relationship between the empirical formula and the molecular formula of a given compound.
- **Determine** a molecular formula from an empirical formula.

Empirical Formula

- An _____ consists of the symbols for the elements combined in a compound, with subscripts showing the smallest whole-number mole ratio of the different atoms in the compound.
- For an ionic compound, the formula unit is usually the compound's empirical formula.
- For a molecular compound, however, the empirical formula does _____ necessarily indicate the actual numbers of atoms present in each molecule
  - Diboron hexahydide = B_2H_6
  - _____ formula is BH_3

Empirical Formula

Example

- What is the empirical formula for a compound that contains 40.05% Sulfur and 59.95% of Oxygen?

- Assume there is 100 grams so now you have:
  40.05 grams of S
  59.95 grams of O

Empirical Formula

- Divide each of the elements by their molar mass

$$40.05 \text{ g S} \times \frac{1 \text{ mole S}}{32.07 \text{ g S}} = \mathbf{1.249 \text{ mol S}}$$

$$59.95 \text{ g O} \times \frac{1 \text{ mole O}}{16.00 \text{ g O}} = \mathbf{3.747 \text{ mol O}}$$

Empirical Formula

- Divide the moles by the smaller number of moles

$$\frac{1.249 \text{ mol S}}{1.249 \text{ mol S}} = 1 \text{ mol S} \qquad \frac{3.747 \text{ mol O}}{1.249 \text{ mol S}} = 3 \text{ mol O}$$

The ratio is a 1:3 ratio so you have

SO_3

Empirical Formula

- Some times the ratios do not match up, then you need to multiply them by the smallest whole number to get a whole number

Ex.

A ratio of 1 and 1.33

1 * 3 = 3

1.33 * 3 = 4

The new ratio is 3:4

More Practice

- Page 235
  - 1-2
- Page 237
  - 1 = me
  - 2 = you

Assignment

- 7.4 Worksheet