

# Formulas, Equations, and Amounts

## Objectives

- Provide the names and formulas of commonplace ionic compounds.
- Interpret molecular formulas.
- Interpret chemical reaction equations.
- Employ the mole as a unit of quantity.
- Relate quantities, concentrations, and volumes.
- Quantitatively apply reaction equations to determine equivalent amounts and theoretical yields.

## Overview

Matter is not continuous. Every substance on Earth is made of molecules, which in turn are made of atoms interacting in specific ways. Atoms combine to make molecules in specific numbers and proportions. Molecules interact with each other, exchanging and splitting off specific parts to make definite new molecules.

The tendency of substances to react with each other in specific amounts was recognized as a general rule after numerous workers studied countless reactions. This **law of definite proportions** was key evidence that matter is composed of atoms, and allowed chemists to begin to understand the transformations of molecules far too small to see.

To understand and describe the transformations of molecules—**chemical reactions**—chemists use a number of specialized concepts and terms. These allow them to think of the properties of molecules, too small to see or manipulate, in terms of quantities familiar to our ordinary experience. With these tools, chemists rapidly and precisely specify chemical substances, “count” molecules they can’t even see, and determine exactly what amount of one substance reacts with another to create how much of something else. You will too.

Chemical names and formulas tell what a substance is, and how much of which elements it contains. Reaction equations tell the definite proportions of the substances that react and are created. Moles and molar masses convert numbers and proportions of invisible molecules into proportions and amounts that we can measure and manipulate.

Concentrations allow us to determine how much of a substance exists in a known volume of a solution. These concepts will help you make sense of the chemical transformations you study.

## Commonly-Encountered Ions

### Monatomic Anions (negative charge): named with “-ide” suffix

*Halides (column under F): -1 charge*

$F^-$  = fluoride;  $Cl^-$  = chloride;  $Br^-$  = bromide;  $I^-$  = iodide

*Chalcides (column under O): -2 charge*

$O^{2-}$  = oxide;  $S^{2-}$  = sulfide;  $Se^{2-}$  = selenide

*Hydride:  $H^-$  (uncommon, water-reactive)*

### Monatomic Cations (positive charge): named as elements

*Alkali metals (first column): +1 charge*

$(H^+)$ ,  $Li^+$ ,  $Na^+$ ,  $K^+$ ,  $Rb^+$ ,  $Cs^+$

*Alkaline earth metals (second column): +2 charge*

$Be^{+2}$ ,  $Mg^{+2}$ ,  $Ca^{+2}$ ,  $Sr^{+2}$ ,  $Ba^{+2}$

*Group 3 (third main-group column): +3 charge*

$B^{+3}$ ,  $Al^{+3}$ ,  $Ga^{+3}$

*Metals with more possibilities: Specify charge as “Element(roman numeral charge)”*

$Fe^{+2}$  = Iron(II);  $Fe^{+3}$  = Iron(III);  $Pb^{+2}$  = Lead(II);  $Pb^{+4}$  = Lead(IV)

### Polyatomic Ions

*Cations*

$NH_4^+$  = ammonium

*Anions*

$ClO^-$  = hypochlorite;  $ClO_2^-$  = chlorite;  $ClO_3^-$  = chlorate;  $ClO_4^-$  = perchlorate

$BrO^-$  = hypobromite;  $BrO_2^-$  = bromite;  $BrO_3^-$  = bromate;  $BrO_4^-$  = perbromate

$IO^-$  = hypoiodite;  $IO_2^-$  = iodite;  $IO_3^-$  = iodate;  $IO_4^-$  = periodate

$SO_3^{2-}$  = sulfite;  $SO_4^{2-}$  = sulfate;  $SeO_4^{2-}$  = selenate

$NO_3^-$  = nitrate;  $PO_4^{3-}$  = phosphate

$CO_3^{2-}$  = carbonate;  $HCO_3^-$  = hydrogen carbonate or “bicarbonate”

$OH^-$  = hydroxide;  $SH^-$  = hydrosulfide

## Formulas

### I. Counting atoms and naming

1. Identify and count the atoms in each formula unit.
2. Identify the ions in each formula unit, and name the ionic compound.

Formula	Atoms	Ions	Compound name
NaCl			
BaO			
CuCl <sub>2</sub>			
H <sub>2</sub> SO <sub>4</sub>			
MgSO <sub>4</sub>			
AgNO <sub>3</sub>			
Al(NO <sub>3</sub> ) <sub>3</sub>			
Al <sub>2</sub> O <sub>3</sub>			
KH <sub>2</sub> PO <sub>4</sub>			
Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>			

### II. Balancing charges

1. Label each ion with its charge.
2. Determine the smallest number of each ion to balance the charges and write the complete formula with subscripts.
3. Name the ionic compound.

Cation	Anion	Formula	Compound name
Ba	HCO <sub>3</sub>		
Al	NO <sub>3</sub>		
Ca	ClO		
K	Br		
Ca	PO <sub>4</sub>		

### III. Names to formulas

Find the charge of each ion, determine the number of each ion, and write the complete structural formula.

Compound name	Formula	Compound name	Formula
Copper(I) sulfide		Calcium bicarbonate	
Aluminum hydroxide		Chromium(VI) oxide	

## Equations

### IV. Is it balanced?

- Determine the number of atoms of each element in the reactant and product sides of each chemical reaction equation below.
- Decide if the reaction equations are balanced.

Equation	Reactants	Products	Bal?
$\text{NaHCO}_3 + \text{HCl} \rightarrow \text{NaCl} + \text{CO}_2 + \text{H}_2\text{O}$			Y N
$2 \text{NaHCO}_3 \rightarrow \text{Na}_2\text{CO}_3 + \text{CO}_2 + \text{H}_2\text{O}$			Y N
$\text{Cl}_2 + \text{NaOH} \rightarrow \text{NaCl} + \text{NaOCl}$			Y N
$\text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2$			Y N

### V. Balance it!

Balance the equations below by entering the correct coefficients.

- \_\_\_\_\_  $\text{H}_2$  + \_\_\_\_\_  $\text{O}_2 \rightarrow$  \_\_\_\_\_  $\text{H}_2\text{O}$
- \_\_\_\_\_  $\text{AlCl}_3$  + \_\_\_\_\_  $\text{H}_2\text{O} \rightarrow$  \_\_\_\_\_  $\text{Al(OH)}_3$  + \_\_\_\_\_  $\text{HCl}$
- \_\_\_\_\_  $\text{KClO}_3 \rightarrow$  \_\_\_\_\_  $\text{KCl}$  + \_\_\_\_\_  $\text{O}_2$
- \_\_\_\_\_  $\text{CH}_4$  + \_\_\_\_\_  $\text{O}_2 \rightarrow$  \_\_\_\_\_  $\text{CO}_2$  + \_\_\_\_\_  $\text{H}_2\text{O}$
- \_\_\_\_\_  $\text{FeCl}_3$  + \_\_\_\_\_  $\text{NaOH} \rightarrow$  \_\_\_\_\_  $\text{Fe(OH)}_3$  + \_\_\_\_\_  $\text{NaCl}$
- \_\_\_\_\_  $\text{H}_2$  + \_\_\_\_\_  $\text{N}_2 \rightarrow$  \_\_\_\_\_  $\text{NH}_3$
- \_\_\_\_\_  $(\text{NH}_4)_2\text{CO}_3 \rightarrow$  \_\_\_\_\_  $\text{CO(NH}_2)_2$  + \_\_\_\_\_  $\text{H}_2\text{O}$
- \_\_\_\_\_  $\text{NaH} +$  \_\_\_\_\_  $\text{NH}_3 \rightarrow$  \_\_\_\_\_  $\text{NaNH}_2$  + \_\_\_\_\_  $\text{H}_2$
- \_\_\_\_\_  $\text{Fe}_2\text{O}_3$  + \_\_\_\_\_  $\text{C} \rightarrow$  \_\_\_\_\_  $\text{Fe}$  + \_\_\_\_\_  $\text{CO}$
- \_\_\_\_\_  $\text{FeSO}_4$  + \_\_\_\_\_  $\text{H}_2\text{O}_2$  + \_\_\_\_\_  $\text{H}_2\text{O} \rightarrow$  \_\_\_\_\_  $\text{Fe(OH)}_3$  + \_\_\_\_\_  $\text{H}_2\text{SO}_4$

### VI. Names to equations

Below are chemical equations in words. Convert to formulas and balance.

- strontium chloride + ammonium sulfate  $\rightarrow$  strontium sulfate + ammonium chloride
- iron + oxygen  $\rightarrow$  iron(III) oxide
- lead + lead(IV) oxide + hydrogen sulfate  $\rightarrow$  lead (II) sulfate + water

## Moles

### VII. Atomic masses

What is the mass in grams of:

1. 1 mol of sulfur (S)?
2. 1 mol of lithium (Li)?
3. 1 mol of xenon (Xe)?
4. 1 mol of molybdenum (Mo)?
5. 1 mol of calcium (Ca)?

### VIII. Moles to masses (of elements)

What is the mass in grams of:

1. 0.5 mol of carbon (C)?
2. 2.0 mol of sodium (Na)?
3. 5.5 mol of cobalt (Co)?

### IX. Masses to moles (of elements)

How many moles of each element are in:

1. 2.0 g aluminum (Al)?
2. 250 g selenium (Se)?
3. 1 tonne (= 1000 kg) carbon (C)?

### X. Formula masses

What is the mass in grams of:

1. 1 mol  $\text{Na}_2\text{S}$ ?
2. 1 mol  $\text{H}_2\text{SO}_4$ ?
3. 1 mol  $\text{CO}_2$ ?

### XI. Masses to moles (of compounds)

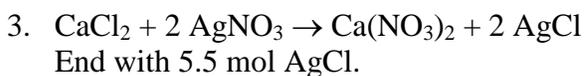
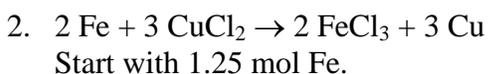
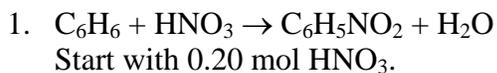
How many moles of each compound are in:

1. 454 g  $\text{C}_{12}\text{H}_{22}\text{O}_{11}$ ?
2. 1 kg  $\text{H}_2\text{O}$ ?
3. 3.67 tonnes  $\text{CO}_2$ ?

## Moles

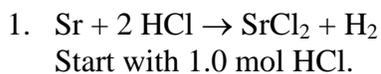
### *XII. Equivalent Molar Amounts*

Given the reaction and number of moles of one species, find the equivalent numbers of moles of the other species.



### *XIII. Equivalent Molar Amounts and Masses*

Given the reaction and the number of moles of one species, find the equivalent numbers of moles of the other species and the equivalent masses of all species.

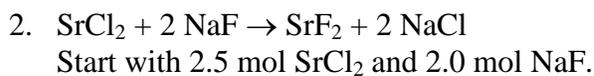
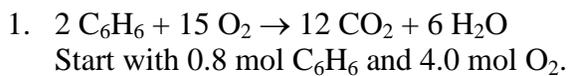




## Moles

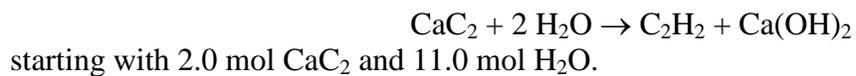
### XV. Limiting Reagent

Find the limiting reagents of the following reactions.



### XVI. Limiting Molar Amounts

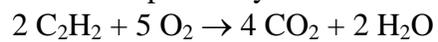
Find the limiting reagent and determine the masses of all components consumed or produced in the reaction



Moles

*XVII. Limiting Reagent Mass*

Find the limiting reagent and calculate the product yields for the reaction



starting with 500 g  $\text{C}_2\text{H}_2$  and 1000 g  $\text{O}_2$ .