

Chapter 3

Formulas, Equations, and Moles: I



Chemical Reactions and Equations

- What is a chemical reaction?
- A chemical equation uses symbols to represent what happens at the atomic level.
- What happens when you boil water? What happens during the electrolysis of water?
- Chemical equations follow the Law of Conservation of Mass
 - ♦ Conservation of atoms, not conservation of molecules (molecular structures can change)

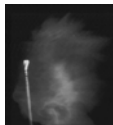
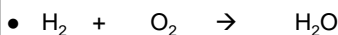
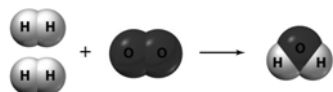


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Balancing Equations

- Adjust coefficients, not subscripts, to balance an equation
- Coefficients are whole-number integers in the **lowest** ratio

- Reactants → Products



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Balancing Equations

Coefficients vs. Subscripts

Chemical symbol	Meaning	Composition
H_2O	One molecule of water:	Two H atoms and one O atom
$2\text{H}_2\text{O}$	Two molecules of water:	Four H atoms and two O atoms
H_2O_2	One molecule of hydrogen peroxide:	Two H atoms and two O atoms

Balancing Equations

- Draw each substance in the equations below. Add more substances as needed to balance the equations. (Hint: Think about what subscripts mean in a formula!)
- $\text{H}_2(\text{g}) + \text{Br}_2(\text{l}) \rightarrow \text{HBr}(\text{g})$
- $\text{CO}(\text{g}) + \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g})$
- $\text{Al}(\text{s}) + \text{Cl}_2(\text{g}) \rightarrow \text{AlCl}_3(\text{g})$
- $\text{N}_2(\text{g}) + \text{H}_2(\text{g}) \rightarrow \text{NH}_3(\text{g})$

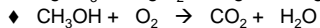
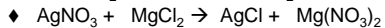
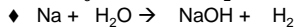
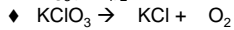
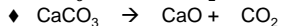
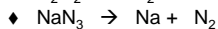
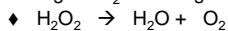
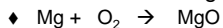
Guidelines to Balancing Equations

- Write correct formulas for reactants and products.
- Begin balancing with the most complex formula.
- Balance polyatomic ions as a single unit.
- Check each reactant and product to verify the coefficients.
- $\text{Mg}(\text{NO}_3)_2 + \text{Cr}(\text{OH})_3 \rightarrow \text{Mg}(\text{OH})_2 + \text{Cr}(\text{NO}_3)_3$

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Practice Balancing Equations

- Balance the following equations:



- Worked Ex. 3.1 - 3.3; Problems 3.1 - 3.3



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Avogadro's Number and the Mole

- We need to be able to determine amounts of chemicals to use so they react in the exact ratio needed.
- For example, we need 2 molecules of H_2 and 1 molecule of O_2 to make 2 molecules of H_2O .
- Do you want to count individual atoms and molecules?



Avogadro's Number

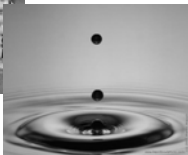
- Who wants to count:



Grains of rice?



Peppers?



Water Molecules?

The Mole



- We can measure the mass of a pure sample but how do we know how many atoms or molecules are in that sample?
- Mole: amount of a substance that contains a specific number of particles.
- A mole (mol) is a quantity that tells us two things:
 - ◆ the number of particles in a substance
 - ◆ the mass of that substance (containing a specific number of particles)

Avogadro's Number and the Mole

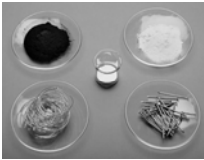
- 1 ^{12}C atom weighs 12 amu, 1 mole of ^{12}C atoms weighs 12 grams.
- 1 dozen = 12 objects; 1 mole = 6.022×10^{23} objects. This is Avogadro's number.
- The moral: 1 mole of carbon-12 weighs 12 grams and contains 6.022×10^{23} atoms.

Avogadro's Number and the Mole

- How big **IS** Avogadro's number?
 - ◆ An Avogadro's number of standard soft drink cans would cover the surface of the earth to a depth of over 200 miles.
 - ◆ If you had Avogadro's number of unpopcorned popcorn kernels, and spread them across the US, the country would be covered in popcorn to a depth of over 9 miles.
 - ◆ If we were able to count atoms at the rate of 10 million per second, it would take about 2 billion years to count the atoms in one mole.

Avogadro's Number and the Mole

- Demo: 1 mole of different substances
- What do these substances have in common?
- Atoms measured in amu, moles measured in grams
- amu and g are the same value, different units
 - ♦ 1 atom ^{12}C = 12 amu; 1 mol ^{12}C atoms = 12 g
 - ♦ 1 atom ^4He = 4 amu; 1 mol ^4He atoms = 4 g



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Avogadro's Number and the Mole

- 1 mole contains 6.0221415×10^{23} particles
 - ♦ Particles can be atoms, ions, molecules, or formula units
- Determine what type of particle Avogadro's number will describe for the following:
 - ♦ Kr
 - ♦ $\text{C}_6\text{H}_{12}\text{O}_6$
 - ♦ MgCO_3
 - ♦ SF_6
 - ♦ CaBr_2
 - ♦ P

Avogadro's Number and the Mole

- 1 O atom = 16.00 amu
 - ♦ 1 mol of O atoms = 16.00 g = 6.022×10^{23} atoms
- 1 O_2 molecule = 32.00 amu
 - ♦ 1 mol of O_2 molecules = 32.00 g = 6.022×10^{23} **molecules**
- 1 CO_2 molecule = 44.00 amu
 - ♦ 1 mol of CO_2 molecules = 44.00 g = 6.02×10^{23} **molecules**
- 1 NaCl formula unit = 58.44 amu
 - ♦ 1 mol of NaCl f. units = 58.44 g = 58.44 f. units
- 1 mol of substance has 6.022×10^{23} particles

Molar Masses

- Atomic, molecular, and formula masses are not practical in lab. We can scale up to calculate the mass of a mole of substances.
- Molar mass is the same value as atomic mass, just with different units. Molar mass (g/mol: (mass per 1 mole of substance)
- What is molar mass of C_6H_6 ?
- What is molar mass of $\text{Mg}(\text{OH})_2$?
- Molar masses have 6.022×10^{23} particles in the substance.
- Worked Ex. 3.4; Problems 3.4 - 3.6

Calculate Molar Masses of the following:

- Al
- CO_2
- Cl_2
- SO_2
- CaCl_2
- H_2SO_4
- AlCl_3
- $\text{Mg}_3(\text{PO}_4)_2$
- Na_2CO_3

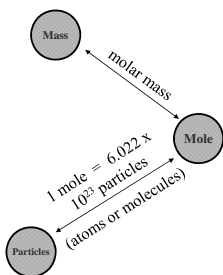
Avogadro's Number and the Mole

- Conversions:
 - ♦ If we know the mass of a substance, how can we calculate number of moles?
 - mass \rightarrow moles (use molar mass)
 - ♦ If we know how many moles of a substance, how can we calculate number of particles?
 - moles \rightarrow number of particles (use Avogadro's number)

$$\frac{1 \text{ mol}}{\text{molar mass (in g)}}$$

$$\frac{1 \text{ mol}}{6.02 \times 10^{23} \text{ particles}}$$

Mole Diagram



Courtesy: www.unit5.org/christijs/Stoichiometry/Mole%20Stand%20Diagram.ppt

Practice – Group Work

1. How many moles are in a 2.67 g sample of Ag?
2. How many grams are in a 0.45 mol sample of $\text{Mg}_3(\text{PO}_4)_2$?
3. How many atoms are in a 16.3 g sample of S?
4. How many formula units are in 0.81 g of MgCl_2 ?
5. How many **ions** are in 0.81 g of MgCl_2 ? (Hint: How many ions are in 1 formula unit of MgCl_2 ?)
6. How many **C atoms** are in 3.64 g of $\text{C}_6\text{H}_{12}\text{O}_6$?
7. How many **O atoms** are in 0.0765 g of CO_2 ?

Practice – Group Work

- Calculate the number of atoms that are in a 6.00 g sample of carbon.
- Calculate the number of moles in 12.04×10^{23} atoms of uranium.
- Calculate the mass of 12.04×10^{23} atoms of uranium.
- If you have 1 g samples of NaCl, CO_2 , and H_2O , which sample will contain the fewest particles?