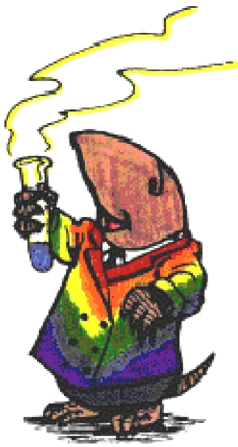


Chapter 3

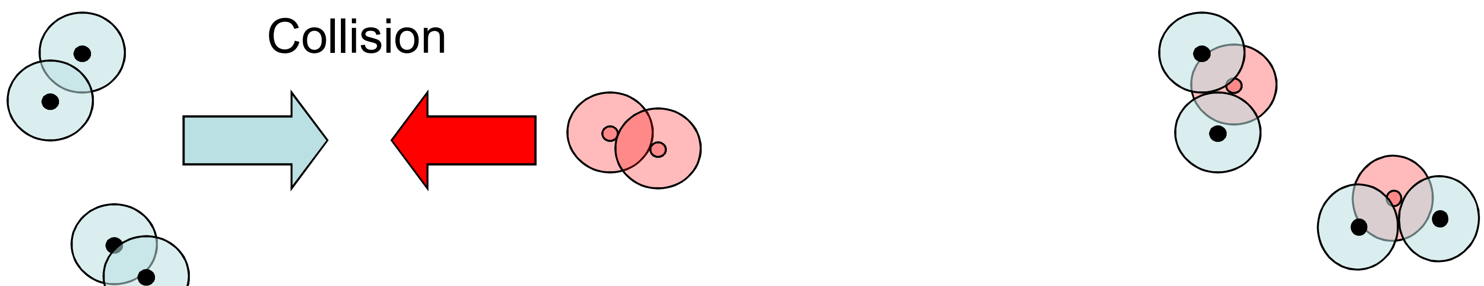
The MOLE

Chemical Reactions

- Reactions take place between individual atoms and molecules
- COLLISIONS MUST OCCUR
- Number of atoms and molecules is important
- Therefore: <u>In chemistry, we need to count particles (atoms/molecules).</u>

Reactants | Products

$$2\ H_{2(g)} \quad + \quad O_{2(g)} \quad \rightarrow \quad 2\ H_2O_{(g)}$$



2 $H_{2(g)}$ molecules | 1 $O_{2(g)}$ molecules | 2 $H_2O_{(g)}$ molecules

2 million $H_{2(g)}$ molecules | 1 million $O_{2(g)}$ molecules | 2 million $H_2O_{(g)}$ molecules

The Mole: How to count large numbers of objects.

- 1 dozen = 12 objects
- 1 gross = 144 objects
- **1 mole = 6.022×10^{23} objects**

Conversion Factor
(Avogadro's number)

We think that there are about 20 billion (that's 2.0×10^{10}) stars in our galaxy! How many *moles* of stars is this?

$$\frac{2.0 \times 10^{10} \text{ stars}}{1} \times \frac{1 \text{ mole stars}}{6.022 \times 10^{23} \text{ stars}} = 3.3 \times 10^{-14} \text{ mole stars}$$

The Mole and the Periodic Table

Atomic Number (p^+) →

18
Ar
39.948

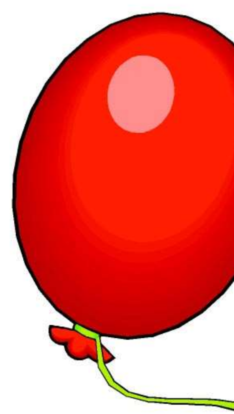
Average Atomic Mass (amu or Da) →

← Molar Mass of Ar (grams)

Conversion Factors:

1 mole Ar = 6.022 × 10^{23} Ar atoms

1 mole Ar = 39.948 grams



1 mole $Ar_{(g)}$

6.022 × 10^{23} Ar atoms

39.948 grams Ar

Molar Mass Example:

Application to molecules.

How many moles, individual molecules and hydrogen atoms are there in 100.0 grams of methanol, $CH_3OH_{(l)}$?

6	8	1
C	O	H
12.011	16.00	1.008

Molar Mass CH_3OH: 12.011 g + 16.00 g + 4 × 1.008 g = 32.042 g

$$\frac{100.0 \text{ g } CH_3OH}{1} \times \frac{1 \text{ mole } CH_3OH}{32.042 \text{ g } CH_3OH} \times \frac{6.022\times10^{23} \text{ molecules}}{1 \text{ mole}} \times \frac{4 \text{ Hydrogen atoms}}{1 CH_3OH \text{ molecule}}$$

= 3.121 moles CH_3OH

= 1.879×10^{24} CH_3OH molecules

= 7.518×10^{24} H atoms

Mass Percents:

Introduction To Empirical Formulae

Consider Glucose (monosaccharide): $C_6H_{12}O_6$

6	1	8
C	H	O
12.011	1.008	16.00

Molar Mass $C_6H_{12}O_6$: 6×12.011 g + 12×1.008 g + 6×16.00 g =

72.066 g + 12.096 g + 96.00 g = 180.162 g

Carbon Mass %

$$\frac{72.066\text{ g}}{180.162\text{ g}} \times \mathbf{100}$$

= 40.00%

Hydrogen Mass %

$$\frac{12.096\text{ g}}{180.162\text{ g}} \times \mathbf{100}$$

= 6.714%

Oxygen Mass %

$$\frac{96.00\text{ g}}{180.162\text{ g}} \times \mathbf{100}$$

= 53.28%

Mass Percents:

Introduction To Empirical Formulae

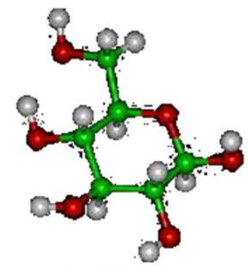
Are these mass percents *UNIQUE?*

Carbon Mass % = 40.00%

Hydrogen Mass % = 6.714%

Oxygen Mass % = 53.28%

NO!



All of the following molecules would have exactly the same elemental mass percentages:

CH_2O	×2 $C_2H_4O_2$	×3 $C_3H_6O_3$	×4 $C_4H_8O_4$	×5 $C_5H_{10}O_5$	×6 $C_6H_{12}O_6$

Simplest ratio (1:2:1)

Empirical Formula

Glucose

Molecular Formula

Mass Percents Backwards:

Determining the Empirical Formulae

A sample believed to be serotonin is analyzed and found to contain the elements and mass percentages at right. What is the empirical formula?

Carbon (C) : 68.2% **Nitrogen (N) : 15.9 %**

Hydrogen (H) : 6.86 % **Oxygen (O) : 9.08 %**

Solution:

Assume 100.00 grams of sample and convert the elemental masses into moles:

$$\frac{68.2 \text{ grams}_C}{1} \times \frac{1 \text{ mole}_C}{12.011 \text{ grams}_C} = 5.678 \text{ moles}_C \quad \div 0.5675 \quad = \sim 10$$

$$\frac{6.86 \text{ grams}_H}{1} \times \frac{1 \text{ mole}_H}{1.008 \text{ grams}_H} = 6.806 \text{ moles}_H \quad \div 0.5675 \quad = \sim 12$$

$$\frac{15.9 \text{ grams}_N}{1} \times \frac{1 \text{ mole}_N}{14.01 \text{ grams}_N} = 1.135 \text{ moles}_N \quad \div 0.5675 \quad = \sim 2$$

$$\frac{9.08 \text{ grams}_O}{1} \times \frac{1 \text{ mole}_O}{16.00 \text{ grams}_O} = 0.5675 \text{ moles}_O \quad \div 0.5675 \quad = 1$$

Smallest Value

Mass Percents Backwards:
Determining the Empirical Formulae

Empirical Formula: $C_{10}H_{12}N_2O$

Molecular Formulae Possibilities include:

$C_{10}H_{12}N_2O$	$C_{20}H_{24}N_4O_2$	$C_{30}H_{36}N_6O_3$	$C_{40}H_{48}N_8O_4$	…etc
176.21516 amu	352.43032 amu	528.64548 amu	704.86064 amu	

A mass spectrometer is used to determine the actual mass of the molecule to be ~176 amu. What is the molecular formula for serotonin? …this is additional information!!!

Molecular Formula (…and empirical formula) : $C_{10}H_{12}N_2O$