Chemical Equations

solid(s)
liquid(ℓ)
gas(g)
aqueous(aq): dissolved in water

Balancing Chemical Equations by Inspection

\[
\text{Mg(s)} + \text{N}_2(\text{g}) \rightarrow \text{Mg}_3\text{N}_2(\text{s})
\]

\[
\text{C}_3\text{H}_8(\text{ℓ}) + \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{g})
\text{combustion}
\]

\[
\text{K(s)} + \text{H}_2\text{O}(\text{ℓ}) \rightarrow \text{KOH(aq)} + \text{H}_2(\text{g})
\]
Relative Atomic Masses

\[
\begin{array}{c}
\text{17} \\
\text{Cl} \\
\hline
\text{35.453}
\end{array}
\]

relative mass \(=\) not integer because:

1. naturally occurring isotopes
2. \(p^+, n^0\) mass not identical: \(1.0073, 1.0087\) (wrt to \(^{12}\text{C}\))
3. \(E = mc^2;\) some mass converted to \(E\)

\[^{35}\text{Cl} = 75.555\% \quad \text{relative mass} = 34.96885\]
\[^{37}\text{Cl} = 24.445\% \quad \text{relative mass} = 36.94739\]

weighted average \(=\) \(0.75555(34.96885) + 0.24445(36.94739)\)
\(= 35.453\)

Formula Weight (FW) \(= 35.453\)

Relative Atomic Masses

\[\begin{array}{c}
\text{1} \\
\text{H} \\
\hline
\text{1.008}
\end{array}
\quad \begin{array}{c}
\text{6} \\
\text{C} \\
\hline
\text{12.011}
\end{array}\]

“average” \(\text{C} \) atom \(\sim 12\times\) heavier than “average” \(\text{H} \) atom

relative mass \(1.000 \Rightarrow \) actual mass \(1.661 \times 10^{-24} \text{ g}\)
\((\frac{1}{12} \text{ mass } ^{12}\text{C} \text{ atom})\)

“average” \(\text{C} \) atom \(= 12.011 \times 1.661 \times 10^{-24} \text{ g} = 1.995 \times 10^{-23} \text{ g}\)
The Mole

# of atoms in exactly 12 g of $^{12}C$

$6.022 \times 10^{23}$

Avogadro’s Number: $N_A$

pair = 2
dozen = 12
gross = 144

Wilhelm Ostwald
German
1893

Amedeo Avogadro
Italian
1776 - 1856

Why The Mole?

1 atom Br _ x mass of 1 atom Ca
1 atom Br same mass as 1 g Br
1 g Br _ # of atoms as 1 g Ca
2 g Br same # of atoms as $80$ g Br
same # of atoms as
Unit for Formula Weight

(molar mass) \( FW = \frac{29 \text{ Cu}}{63.546 \text{ g/mole}} \)

mass, in grams, that contains 1 mole

\( FW \text{ Cu} = 63.546 \text{ g Cu per 1 mole Cu} \)

= 63.546 \text{ g Cu/1 mole Cu}

= 63.546 \text{ g/mole}

do not use amu!

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Formula Weight of Compounds

atom’s \( FW \Rightarrow \text{ compound’s } FW \) (molecular/ionic)

\[
\begin{align*}
\text{C}_6\text{H}_{12}\text{O}_6 & \quad \text{FW} = \\
11 \text{ Na} & \quad 22.990 \text{ g/mole} \\
17 \text{ Cl} & \quad 35.453 \text{ g/mole} \\
8 \text{ O} & \quad 15.999 \text{ g/mole}
\end{align*}
\]

\[
\begin{align*}
\text{NaClO}_3 & \quad \text{FW} = \\
11 \text{ Na} & \quad 22.990 \text{ g/mole} \\
17 \text{ Cl} & \quad 35.453 \text{ g/mole} \\
8 \text{ O} & \quad 15.999 \text{ g/mole}
\end{align*}
\]
Percent Composition (by Weight) from Formula

copper(II) oxide
CuO

\[
\% X = \frac{\# X x \text{FW} \times X}{\text{FW}} \times 100
\]

\[
\begin{array}{c|c|c|c}
\text{Cu} & 63.546 & \text{O} & 15.999 \\
\end{array}
\]

\[
\% \text{Cu} = \frac{1 \times 63.546 \text{ g/mole}}{79.545 \text{ g/mole}} \times 100 = 79.887\% 
\]

\[
\% \text{O} = \frac{1 \times 15.999 \text{ g/mole}}{79.545 \text{ g/mole}} \times 100 = 20.113\% 
\]

Combustion Analysis

chemical composition of organic compounds \((C_xH_yO_z)\)

\[
C_xH_yO_z + O_2 \rightarrow x \text{CO}_2 + \frac{y}{2} \text{H}_2\text{O}
\]
1. find a **balanced** equation
2. convert what you **have** (mass, concentration) to moles
3. use balanced equation to convert moles of what you **have** to moles of what you **want**: stoichiometry
4. answer question: mass, concentration, gas volume…