Chemical Calculations

- Moles and Molecules
- Moles and Chemical Reactions
- Moles, Chemical Reactions, and Molarity

- All done as UNIT CONVERSIONS!!!

- ...and practice, practice, practice
How many molecules of aspirin (C₉H₈O₄) in a dose of 1000 mg?

Find MM of aspirin:

$$MM = 9 \times 12 + 8 \times 1 + 4 \times 16 = 180 \text{ g/mole}$$

First find moles:

$$\text{moles} = \frac{1000 \text{ mg} \times 1 \text{ g/1000 mg}}{180 \text{ g/mole}} = 0.0055 \text{ moles}$$

Now find molecules:

$$\text{molecules} = 0.0055 \text{ moles} \times \frac{6.02 \times 10^{23} \text{ molecules/mole}}{1 \text{ mole}} = 3.3 \times 10^{21} \text{ molecules}$$

How many atoms of carbon?

$$\text{atoms C} = \frac{9 \text{ atoms/molecule}}{3.3 \times 10^{21} \text{ molecules}} = 3.0 \times 10^{22} \text{ atoms}$$

Conversion factors in boxes

For 12.6g NaHCO₃, how many moles do you have?

$$\text{Mass of substance A} \rightarrow \frac{\text{MM}}{\text{Moles of substance A}}$$

How many CO₂ molecules in 0.17 moles CO₂?

$$\text{Moles of substance A} \rightarrow \frac{6.02 \times 10^{23}}{\text{Molecules of substance A}}$$
Another way to find moles...

For a solution (homogeneous mixture), there are two components: **solute** (substance being dissolved) and **solvent** (dissolving medium, usually water)

A unit of concentration – amount solute per amount solution or solvent

\[
\text{Molarity} = \frac{\text{moles of solute}}{\text{volume of solution in liters}} \ (\text{moles/L})
\]

Rearranging the definition of molarity:

\[
\text{moles} = M \times V_L
\]

Another way to find moles!

---

How many moles NaCl in 50 mL of 0.28 M NaCl?

\[
50 \text{ mL} \times \frac{1 L}{1000 \text{ mL}} \times 0.28 \text{ mole/L} = 0.014 \text{ mole NaCl}
\]

---

What is the molarity if 35 g KCl are dissolved to make 350 mL of solution?

---

**Moles of substance A** \[\rightarrow\] **Molarity** \[\rightarrow\] **Volume of substance A**

How many moles are in 300 mL of a 0.23 M NaOH solution?
The ratio of moles in a reaction

\[ 2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O \]

<table>
<thead>
<tr>
<th>Mole ratios</th>
<th>2</th>
<th>13</th>
<th>8</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
<td>26</td>
<td>16</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>130</td>
<td>80</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>6.5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td></td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>32</td>
<td></td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>1.37</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Click for answers

Mole-to-mole conversions

This comes from the balanced chemical reaction! ...and it relates substances in the reaction!

\[ 2HCl + CaCO_3 \rightarrow CaCl_2 + H_2O \]

How many moles of HCl react with a mole of CaCO_3?

1 mole CaCO_3 × 2 mole HCl/1 mole CaCO_3 = 2 mole HCl

mole ratio
How many grams of \( \text{O}_2 \) are required to react with 10g \( \text{C}_3\text{H}_8 \)?

\[
\text{C}_3\text{H}_8 + 5\text{O}_2 \rightarrow 3\text{CO}_2 + 4\text{H}_2\text{O}
\]

\[
10\text{g} \text{C}_3\text{H}_8 \times \frac{1\text{ mole}}{44\text{g}} = 0.23 \text{ moles} \text{ C}_3\text{H}_8
\]

\[
0.23 \text{ moles} \text{ C}_3\text{H}_8 \times 5 \text{ moles} \text{ O}_2/\text{1 mole} \text{ C}_3\text{H}_8 = 1.15 \text{ moles} \text{ O}_2
\]

\[
1.15 \text{ moles} \text{ O}_2 \times 32.0\text{g/mole} = 37 \text{ g} \text{ O}_2
\]

This is a classic stoichiometry problem!
How many grams of O₂ are required to reaction with 10g C₃H₈?

Another view of solving

\[ \text{C}_3\text{H}_8 + 5\text{O}_2 \rightarrow 3\text{CO}_2 + 4\text{H}_2\text{O} \]

**Step 1**  
10g C₃H₈ x \(\frac{1 \text{ mole}}{44 \text{g}}\) = 0.23 moles C₃H₈

**Step 2**  
0.23 moles C₃H₈ x 5 moles O₂/1mole C₃H₈ = 1.15 moles O₂

**Step 3**  
1.15 moles O₂ x \(\frac{32.0 \text{g}}{\text{mole}}\) = 37 g O₂

If 74g O₂ react, how many grams of CO₂ will be produced?

\[ \text{C}_3\text{H}_8 + 5\text{O}_2 \rightarrow 3\text{CO}_2 + 4\text{H}_2\text{O} \]
What volume of stomach acid, 0.16 M HCl, reacts with 1.0 g CaCO₃?

\[
2\text{HCl} + \text{CaCO}_3 \rightarrow \text{CaCl}_2 + \text{H}_2\text{O}
\]

1.0 g CaCO₃ \times \frac{1 \text{ mole}}{100 \text{ g}} = 0.010 \text{ mole CaCO₃}

0.010 \text{ mole CaCO₃} \times \frac{2 \text{ mole HCl}}{1 \text{ mole CaCO₃}} = 0.020 \text{ mole HCl}

0.020 \text{ mole HCl} \times 1 \text{L/0.16 moles} = 0.13 \text{ L} = 130 \text{ mL stomach acid}

What volume of 0.25 M CH₃COOH will react with 25.0 mL of 0.37M NaOH?

\[
\text{CH}_3\text{COOH} + \text{NaOH} \rightarrow \text{CH}_3\text{COONa} + \text{H}_2\text{O}
\]

25.0 mL \times \frac{1 \text{ L}}{1000 \text{ mL}} \times 0.37 \text{ mole/L} = 0.0093 \text{ moles NaOH}

0.0093 \text{ moles NaOH} \times \frac{1 \text{ mole CH}_3\text{COOH}}{1 \text{ mole NaOH}} = 0.0093 \text{ mole CH}_3\text{COOH}

0.0093 \text{ mole} \times \frac{1 \text{L/0.25 moles}}{0.037 \text{ L} = 37 \text{ mL CH}_3\text{COOH}}

This is a classic titration problem!
Could you find one of the conversion factors?

Suppose 2.0g \( \text{CaCO}_3 \) reacted with 25.0 mL of \( \text{HCl} \). What is the molarity of the \( \text{HCl} \)?

\[
2\text{HCl} + \text{CaCO}_3 \rightarrow \text{CaCl}_2 + \text{H}_2\text{O}
\]

- 2.0 g \( \text{CaCO}_3 \times \frac{1 \text{ mole}}{100 \text{ g}} = 0.020 \text{ mole \text{CaCO}_3} \)
- 0.020 \( \text{mole \text{CaCO}_3} \times 2 \text{ mole \text{HCl}}/1 \text{ mole \text{CaCO}_3} = 0.040 \text{ mole \text{HCl}} \)

\[
\text{Molarity} = \frac{\text{moles}}{V_\text{l}} = \frac{0.040 \text{ mole \text{HCl}}}{(25.0 \text{ mL} \times 1 \text{L}/1000 \text{mL})} = 1.6 \text{ M \text{HCl}}
\]

How many grams of \( \text{Al(OH)}_3 \) will react with 100 mL of 0.15 M \( \text{HCl} \)?

\[
\text{Al(OH)}_3 + 3\text{HCl} \rightarrow \text{AlCl}_3 + 3\text{H}_2\text{O}
\]
For a 1.0 kg of Al₂O₃, how much aluminum metal, in grams, can be produced?

\[2\text{Al}_2\text{O}_3 (\ell) + 3\text{C} (\text{s}) \rightarrow 4\text{Al} (\ell) + 3\text{CO}_2 (\text{g})\]

How many atoms of carbon are consumed for the problem above?

How many grams of CH₃COOH are needed to react with 27.3 mL of 0.21 M NaOH?

\[\text{CH}_3\text{COOH} + \text{NaOH} \rightarrow \text{CH}_3\text{COONa} + \text{H}_2\text{O}\]

If 0.121g HX react with 26.2 mL of 0.229 M NaOH, what is the molar mass of HX?

\[\text{HX} + \text{NaOH} \rightarrow \text{NaX} + \text{H}_2\text{O}\]

What is element X?
What if two reagents are added, how much product do you get?

Suppose 10 g Na and 10 g Cl₂ are mixed together. How much NaCl can be produced?

\[2\text{Na} + \text{Cl}_2 \rightarrow 2\text{NaCl}\]

First find the moles of each reactant:

<table>
<thead>
<tr>
<th>Reactant</th>
<th>Moles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na</td>
<td>0.43</td>
</tr>
<tr>
<td>Cl₂</td>
<td>0.14</td>
</tr>
</tbody>
</table>

Find the moles of NaCl produced for each reactant:

<table>
<thead>
<tr>
<th>Reactant</th>
<th>Moles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cl₂</td>
<td>0.28</td>
</tr>
</tbody>
</table>

This is what can be produced! Cl₂ is limiting reagent.

A chemical analysis problem

A chemist decides to check the molarity of H₂SO₄ in her car battery. A 10.0 mL sample is reacted with 31.03 mL of 2.73M NaOH. What is the molarity of H₂SO₄?

\[\text{H}_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}\]
20. 4.2 M H₂SO₄
18. 0.346 CH₃COONH₄; Mₙ = 20.2 & mole; x = F
17. 5.3 x 10⁻³ & 8.9 x 10⁻⁴ & atoms C
16. 0.396 Al(OH)₃
12. 6.1 g CO₂
6. 1.3 M KCl; 0.069 mole NaOH
4. 0.15 mole NH₄Cl; 1.0 x 10²⁷ molecules CO₂

Answers to problems by slide number: