Unit 8: Stoichiometry

-- involves finding amts. of reactants & products in a reaction

What can we do with stoichiometry?

For generic equation: \( R_A + R_B \rightarrow P_1 + P_2 \)

<table>
<thead>
<tr>
<th>Given the…</th>
<th>…one can find the…</th>
</tr>
</thead>
<tbody>
<tr>
<td>amount of ( R_A ) (or ( R_B ))</td>
<td>amount of ( R_B ) (or ( R_A )) that is needed to react with it</td>
</tr>
<tr>
<td>amount of ( R_A ) or ( R_B )</td>
<td>amount of ( P_1 ) or ( P_2 ) that will be produced</td>
</tr>
<tr>
<td>amount of ( P_1 ) or ( P_2 ) you need to produce</td>
<td>amount of ( R_A ) and/or ( R_B ) you must use</td>
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</table>

Governing Equation: \( 2 \) patties + \( 3 \) bread \( \rightarrow \) 1 Big Mac®

\( 4 \) patties + ?

excess + 18 bread \( \rightarrow \) ?

? + ? \( \rightarrow \) 25 Big Macs®

Stoichiometry Island Diagram

1 mol = molar mass (in g)
1 mol = 22.4 L
1 mol = 22.4 dm³
1 mol = 6.02 x 10²³ particles

Use coefficients from balanced equation
EX. \( \text{__TiO}_2 + \text{__Cl}_2 + \text{__C} \rightarrow \text{__TiCl}_4 + \text{__CO}_2 + \text{__CO} \)

How many mol chlorine will react with 4.55 mol carbon?

What mass titanium (IV) oxide will react with 4.55 mol carbon?

How many molecules titanium (IV) chloride can be made from 115 g titanium (IV) oxide?

**Island Diagram helpful reminders:**

1. Use coefficients from the equation only when crossing the middle bridge. The other six bridges always have “1 mol” before a substance’s formula.

2. The middle bridge conversion factor is the only one that has two different substances in it. The conversion factors for the other six bridges have the same substance in both the numerator and denominator.

3. The units on the islands at each end of the bridge being crossed appear in the conversion factor for that bridge.
EX. \[ 2 \text{Ir} + \text{Ni}_3\text{P}_2 \rightarrow 3 \text{Ni} + 2 \text{IrP} \]

If \(5.33 \times 10^{28}\) m’cules nickel (II) phosphide react with excess iridium, what mass iridium (III) phosphide is produced?

How many grams iridium will react with 465 grams nickel (II) phosphide?

How many moles of nickel are produced if \(8.7 \times 10^{25}\) atoms of iridium are consumed?

EX. What volume hydrogen gas is liberated (at STP) if 50 g zinc react with excess hydrochloric acid (HCl)?

EX. At STP, how many m’cules oxygen react with 632 dm\(^3\) butane (C\(_4\)H\(_{10}\))? 
Energy and Stoichiometry \[ \text{CH}_4(g) + 2 \text{O}_2(g) \rightarrow \text{CO}_2(g) + 2 \text{H}_2\text{O}(g) + 891 \text{ kJ} \]

How many kJ of energy are released when 54 g methane are burned?

At STP, what volume oxygen is consumed in producing 5430 kJ of energy?

What mass of water is made if 10,540 kJ are released?

The Limiting Reactant

A balanced equation for making a Big Mac® might be: \[ 3 \text{ B} + 2 \text{ M} + \text{ EE} \rightarrow \text{B}_3\text{M}_2\text{EE} \]

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<th>With…</th>
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<td>30 M</td>
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A balanced equation for making a tricycle might be: \[ 3 \text{ W} + 2 \text{ P} + \text{ S} + \text{ H} + \text{ F} \rightarrow \text{W}_3\text{P}_2\text{SHF} \]

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<td>50 P</td>
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</table>
Solid aluminum reacts with chlorine gas to yield solid aluminum chloride.

\[ 2 \text{Al(s)} + 3 \text{Cl}_2(g) \rightarrow 2 \text{AlCl}_3(s) \]

If 125 g aluminum react with excess chlorine, how many g aluminum chloride are made?

If 125 g chlorine react with excess aluminum, how many g aluminum chloride are made?

If 125 g aluminum react with 125 g chlorine, how many g aluminum chloride are made?

**limiting reactant** (LR): the reactant that runs out first.

Any reactant you don’t run out of is an **excess reactant** (ER).

<table>
<thead>
<tr>
<th>From Examples Above…</th>
<th>Limiting Reactant</th>
<th>Excess Reactant(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big Macs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>tricycles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Al / Cl₂ / AlCl₃</td>
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**How to Find the Limiting Reactant**

For the generic reaction \( R_A + R_B \rightarrow P \), assume that the amounts of \( R_A \) and \( R_B \) are given. Should you use \( R_A \) or \( R_B \) in your calculations?

1. Calc. # of mol of \( R_A \) and \( R_B \) you have.
2. Divide by the respective coefficients in balanced equation.
3. Reactant having the smaller result is the LR.
For the Al / Cl₂ / AlCl₃ example:

EX. \[ \text{2 Fe(s) + 3 Cl}_2(g) \rightarrow \text{2 FeCl}_3(s) \]

\[ 223 \text{ g Fe } \quad 179 \text{ L Cl}_2 \]

Which is the limiting reactant: Fe or Cl₂?

How many g FeCl₃ are produced?

EX. \[ \text{2 H}_2(g) + \text{O}_2(g) \rightarrow \text{2 H}_2\text{O}(g) \]

\[ 13 \text{ g H}_2 \quad 80 \text{ g O}_2 \]

Which is LR: H₂ or O₂?

How many g H₂O are formed?

How many g O₂ are left over?

How many g H₂ are left over?
EX. \[2 \text{ Fe(g)} + 3 \text{ Br}_2(\text{l}) \rightarrow 2 \text{ FeBr}_3(\text{s})\]

181 g Fe \quad 96.5 \text{ L} \text{ Br}_2

Find LR.

How many g FeBr$_3$ are formed?

How many g of the ER are left over?

<table>
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<th>Percent Yield</th>
<th>molten + solid $\rightarrow$ molten + solid</th>
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| sodium        | aluminum oxide
| aluminum oxide| sodium oxide

EX. Find mass of aluminum produced if you start $\frac{w}{575}$ g sodium and 357 g aluminum oxide.

This amount of product is the theoretical yield.

Now suppose that we perform this reaction and get only 172 grams of aluminum. Why?
8

% yield = \( \frac{\text{actual yield}}{\text{theoretical yield}} \times 100 \)

---

EX. Find % yield for previous problem.

EX. Reaction that powers space shuttle is:

\[
2 \text{H}_2(g) + \text{O}_2(g) \rightarrow 2 \text{H}_2\text{O}(g) + 572 \text{kJ}
\]

From 100 g hydrogen and 640 g oxygen, what amount of energy is possible?

What mass of excess reactant is left over?

EX. On NASA spacecraft, lithium hydroxide “scrubbers” remove toxic CO\(_2\) from cabin.

\[
\text{CO}_2(g) + 2 \text{LiOH}(s) \rightarrow \text{Li}_2\text{CO}_3(s) + \text{H}_2\text{O}(l)
\]

For a seven-day mission, each of four individuals exhales 880 g CO\(_2\) daily. If reaction is 75% efficient, how many g LiOH should be brought along?
EX. Automobile air bags inflate with nitrogen via the decomposition of sodium azide:

\[ 2 \text{NaN}_3(s) \rightarrow 3 \text{N}_2(g) + 2 \text{Na}(s) \]

At STP and a % yield of 85%, what mass sodium azide is needed to yield 74 L nitrogen?

EX.

\[ \text{B}_2\text{H}_6 + 3 \text{O}_2 \rightarrow \text{B}_2\text{O}_3 + 3 \text{H}_2\text{O} \]

10 g 30 g X g

EX.

\[ \underline{\text{ } \text{C}_3\text{H}_8 + \underline{\text{ } \text{O}_2 \rightarrow \underline{\text{ } \text{CO}_2 + \underline{\text{ } \text{H}_2\text{O} + \text{energy}}} \]

200 g 200 g X kJ

Strategy:

1. 

2. 
EX. \( \text{ZnS} + \text{O}_2 \rightarrow \text{ZnO} + \text{SO}_2 \)

\[
\begin{array}{ccc}
100 \text{ g} & 100 \text{ g} & X \text{ g (assuming 81% yield)}
\end{array}
\]

Strategy:
1.
2.
3.

EX. \( \text{Al} + \text{Fe}_2\text{O}_3 \rightarrow \text{Fe} + \text{Al}_2\text{O}_3 \)

\[
\begin{array}{ccc}
X \text{ g} & X \text{ g} & 800 \text{ g needed} \quad \text{**Rxn. has an 80% yield.**}
\end{array}
\]