Limiting reactants

4.3.2.4 · Quantitative chemistry · revision notes

When two substances react, one is often added in excess so that all of the other is used up. The reactant that is completely used up is the limiting reactant: it decides how much product forms. This subtopic is Higher tier only; you need to identify the limiting reactant from masses or moles and explain its effect on the amount of product.

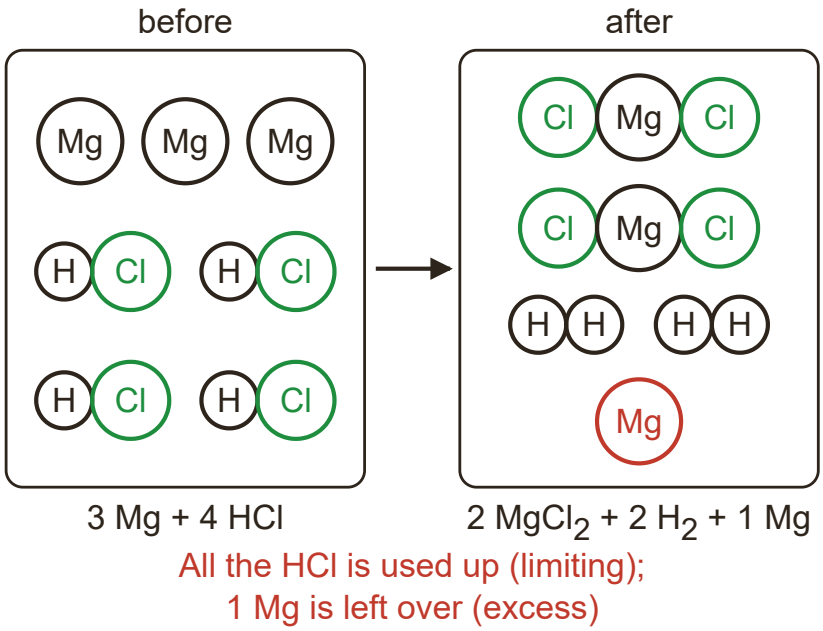
Key facts

- Limiting reactant: completely used up; it limits the amount of product
- To find the limiting reactant: moles ÷ balancing number; the smallest value is limiting
- Calculate the product from the limiting reactant only
- Excess reactant: some is left over at the end
- Amount of product is proportional to the amount of limiting reactant
- Excess left over = moles at start − moles reacted

Notes

Limiting and excess reactants

- In a reaction with two reactants, it is common to use an **excess** of one of them so that all of the other reactant is used up.
- The reactant that is completely used up is the **limiting reactant**, because it limits the amount of product that can form.
- The reaction stops when the limiting reactant runs out. Some of the excess reactant is left over.



$Mg + 2HCl \rightarrow MgCl_2 + H_2$: four HCl can only react with two Mg, so the HCl runs out first.

- Doubling the amount of limiting reactant doubles the amount of product (if the other reactant is still in excess). Adding more of the excess reactant makes no more product.
- In a practical, if excess magnesium is added to acid, fizzing stops while some magnesium is still left: the acid was the limiting reactant.

Finding the limiting reactant

- Step 1: moles of each reactant = mass ÷ M_r.
- Step 2: divide each by its balancing number in the equation.
- Step 3: the reactant with the smallest answer is the limiting reactant.
- Worked example: 4.8 g of Mg is added to 0.30 mol of HCl. $Mg + 2HCl \rightarrow MgCl_2 + H_2$. Mg: 4.8 ÷ 24 = 0.20 mol, and 0.20 ÷ 1 = 0.20. HCl: 0.30 ÷ 2 = 0.15. HCl gives the smaller value, so HCl is limiting and magnesium is in excess.

Working out the product and the leftover

- Always use the limiting reactant to calculate the amount of product.
- From the example: 0.30 mol of HCl makes 0.15 mol of H_2 (ratio 2 : 1), which is 0.15 × 2 = 0.30 g of hydrogen.
- Magnesium used = 0.15 mol, so 0.20 − 0.15 = 0.05 mol of Mg is left over. That is 0.05 × 24 = 1.2 g.

Grade 9+ only

How to answer each type of question

Explain why a reactant is used in excess

1 to 2 marks | Grade 6

1. Say that it makes sure all of the other reactant is used up.
2. If it fits the context, say how the leftover excess is removed (e.g. by filtering).

Example. To make copper sulfate solution, a student adds copper oxide to warm sulfuric acid until no more dissolves, so that the copper oxide is in excess.
Explain why the copper oxide is added in excess. [2 marks]

Model answer. So that all of the sulfuric acid reacts / is used up (1). The unreacted copper oxide can then be removed by filtering, leaving only copper sulfate solution (1).

Explain the effect of changing the amount of a reactant

2 marks | Grade 6

1. Identify which reactant is limiting.
2. Say that the amount of product is proportional to the amount of limiting reactant.

Example. A student reacts excess marble chips with 50 cm^3 of hydrochloric acid and collects the carbon dioxide. She repeats the experiment with 100 cm^3 of the same acid. The marble chips are still in excess.
Explain the effect on the total volume of carbon dioxide produced. [2 marks]

Model answer. The acid is the limiting reactant (1). Doubling the amount of acid doubles the amount of carbon dioxide, so the volume doubles (1).

Identify the limiting reactant

3 marks | Grade 7

1. Work out the moles of each reactant.
2. Compare them using the balancing numbers in the equation.
3. State clearly which reactant is limiting and which is in excess.

Example. Zinc reacts with copper sulfate solution.
$Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$

A student added 1.30 g of zinc to a solution containing 0.0250 mol of copper sulfate.
Show which reactant is the limiting reactant.
A_r: Zn = 65 [3 marks]

Model answer.

moles of Zn = 1.30 ÷ 65 = 0.0200 mol	(1)
the ratio is 1 : 1, and 0.0200 mol is less than 0.0250 mol	(1)
so zinc is the limiting reactant (copper sulfate is in excess)	(1)

Calculate the mass of product from the limiting reactant

4 marks | Grade 8

1. Work out the moles of both reactants.
2. Use the equation to decide which is limiting.
3. Use the limiting reactant's moles and the ratio to find the moles of product.
4. Convert to a mass.

Example. Hydrogen reacts with chlorine.
$H_2 + Cl_2 \rightarrow 2HCl$

1.0 g of hydrogen is mixed with 14.2 g of chlorine.
Calculate the maximum mass of hydrogen chloride that can form.
A_r: H = 1; Cl = 35.5 [4 marks]

Model answer.

moles of H_2 = 1.0 ÷ 2 = 0.50; moles of Cl_2 = 14.2 ÷ 71 = 0.20	(1)
the ratio is 1 : 1, so chlorine is limiting	(1)
moles of HCl = 2 × 0.20 = 0.40 mol	(1)
mass of HCl = 0.40 × 36.5 = 14.6 g	(1)

Don’t lose marks

- Choosing the reactant with the smaller mass as limiting. You must compare moles, using the ratio.
- Forgetting the balancing numbers when comparing moles.
- Calculating the amount of product from the excess reactant.
- Saying the excess reactant 'does not react'. Some of it reacts; only the leftover part is in excess.

More tips

Memory tricks

- Divide by the balancing number: moles ÷ balancing number, and the smallest value is limiting.
- Think of sandwiches: 10 slices of bread and 3 slices of cheese make only 3 sandwiches (2 bread + 1 cheese each). The cheese is limiting and the bread is in excess.
- In a practical, the reactant you can still see at the end (solid left over, colour remaining) is the one in excess.
- More limiting reactant = more product. More excess reactant = no more product.

Exam technique

- Show the moles of both reactants and state clearly which one is limiting.
- Use the phrases 'completely used up' and 'in excess' in explanations.
- When a question says one reactant is in excess, the other one is limiting: base your calculation on it.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 5 — **Define limiting reactant and excess**
The limiting reactant is completely used up; the reactant in excess is partly left over.

Grade 6 — **Explain why a reactant is used in excess**
To make sure that all of the other reactant is used up.

Grade 6 — **Predict how the limiting reactant affects product**
The amount of product is proportional to the amount of limiting reactant; extra excess reactant makes no more product.

Grade 7 — **Identify the limiting reactant using moles**
Divide the moles of each reactant by its balancing number; the smallest value is limiting.

Grade 8 — **Calculate product mass from the limiting reactant**
Use only the moles of the limiting reactant in the reacting-mass method.

Grade 9 — **Calculate the mass of excess reactant left**
Moles left over = moles at the start − moles that reacted; then convert to a mass.

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