Mass changes when a reactant or product is a gas

4.3.1.3 · Quantitative chemistry · revision notes

Some reactions in open containers seem to break the law of conservation of mass. The measured mass goes up if a gas from the air reacts, and goes down if a gas is produced and escapes. You need to explain these changes using the balanced equation and the particle model.

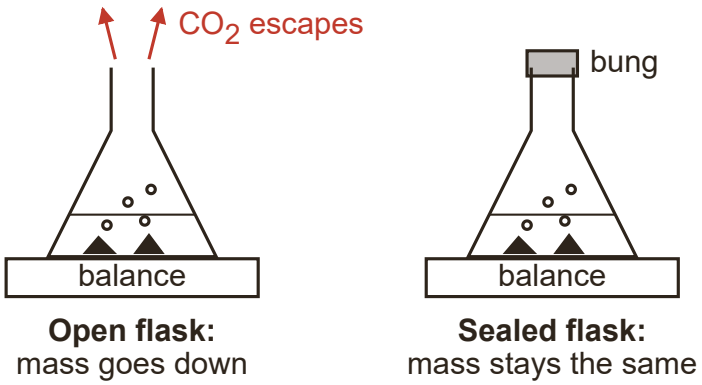
Key facts

- Non-enclosed (open) system: gases can enter or leave, so the measured mass can change
- Gas is a product (escapes) → measured mass decreases
- Metal carbonate → metal oxide + carbon dioxide (mass goes down)
- Sealed container: mass stays the same
- Gas is a reactant (from the air) → measured mass increases
- Metal + oxygen → metal oxide (mass goes up)
- Mass of gas = change in mass

Notes

Why the mass can seem to change

- Mass is always conserved. But in a **non-enclosed system** (an open container) gases can move in or out without being weighed.
- If a **reactant is a gas** from the air (usually oxygen), the measured mass goes **up**.
- If a **product is a gas** (such as carbon dioxide or hydrogen), it escapes and the measured mass goes **down**.
- In a sealed container nothing can get in or out, so the mass stays the same.



Marble chips and acid: in the open flask the gas escapes and the reading falls; with a bung nothing leaves.

Mass increases: metals reacting with oxygen

- $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$
- Oxygen atoms from the air join onto the magnesium, so the magnesium oxide has a greater mass than the magnesium you started with.
- Mass gained = mass of oxygen that reacted.

Mass decreases: gases given off

- Thermal decomposition of a metal carbonate: $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$. The carbon dioxide escapes into the air, leaving the metal oxide as the only solid product.
- Acid with a carbonate gives off carbon dioxide, acid with a metal such as magnesium gives off hydrogen, and decomposing hydrogen peroxide gives off oxygen.
- Mass lost = mass of gas that escaped.

Explaining it with particles

- Gas particles are far apart and move quickly and randomly in all directions, so a gas spreads out and escapes from an open container.
- Oxygen particles in the air collide with the surface of the hot metal and react, becoming part of the solid.
- Higher tier: you can predict the size of the change with moles. Heating 100 g (1 mol) of $CaCO_3$ releases 44 g (1 mol) of CO_2, so the solid loses 44% of its mass. Grade 8+ only

How to answer each type of question

Explain why the mass decreased 2 marks **Grade 4**

1. Name the gas produced.
2. Say that it escapes from the open container into the air, so its mass is not measured.

Example. A student added marble chips (calcium carbonate) to hydrochloric acid in an open conical flask on a balance. The mass of the flask and contents decreased during the reaction.
Explain why. [2 marks]

Model answer. Carbon dioxide gas is produced (1). The gas escapes from the flask into the air, so its mass is no longer measured (1).

Explain why the mass increased

2 to 3 marks | **Grade 5**

1. Say that the substance reacted with oxygen from the air.
2. Name the product (a metal oxide).
3. Say that the mass of the oxygen atoms is added to the solid.

Example. A student heated 1.20 g of copper powder in an open crucible. After heating, the mass of the solid was 1.50 g.
Explain why the mass increased. [3 marks]

Model answer. The copper reacted with oxygen from the air (1) to form copper oxide (1). The oxygen atoms that combined with the copper added to the mass of the solid (1).

Calculate the mass of gas given off

2 to 3 marks | **Grade 5**

1. Subtract the final mass from the starting mass (or the other way round if the mass went up).
2. Give the unit.
3. If asked, explain that heating to constant mass shows the reaction is complete.

Example. Zinc carbonate decomposes when heated.
$ZnCO_3(s) \rightarrow ZnO(s) + CO_2(g)$
A student heated 6.25 g of zinc carbonate in an open tube until the mass stopped changing. The final mass of solid was 4.05 g.
(a) Calculate the mass of carbon dioxide given off. [2 marks]
(b) Suggest why the student heated the tube until the mass stopped changing. [1 mark]

Model answer.

(a) 6.25 − 4.05 (1) = 2.20 g (1)

(b) To make sure all of the zinc carbonate had decomposed (1).

Predict the mass change from an equation 1 mark each **Grade 5**

1. Look for gases, shown by (g), in the equation.
2. Gas on the left comes from the air: mass up. Gas on the right escapes: mass down.
3. No gases at all: the mass stays the same. Give the reason each time.

Example. Each reaction is carried out in an open container. Predict whether the mass of the container and contents increases, decreases or stays the same. Give a reason for each.
(a) $4Na(s) + O_2(g) \rightarrow 2Na_2O(s)$
(b) $Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$
(c) $NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$ [3 marks]

Model answer.

(a) Increases: oxygen from the air is a reactant and becomes part of the solid (1).
(b) Decreases: hydrogen gas is produced and escapes into the air (1).
(c) Stays the same: there are no gases, so nothing enters or leaves (1).

Don't lose marks

- Saying mass is 'lost' or 'destroyed'. Mass is conserved; the gas is just not being weighed.
- Writing 'a gas is produced' without saying that it **escapes** into the air.
- Saying a heated metal gains mass because it 'absorbs heat'. Heat has no mass; oxygen atoms are added.
- Forgetting that the oxygen comes from the air when a question only mentions heating a metal.
- Subtracting the wrong way round and giving a negative mass of gas.

More tips

Memory tricks

- Gas IN (a reactant from the air) → mass UP. Gas OUT (a product) → mass DOWN.
- Scan the equation for (g). No (g) at all means the mass stays the same, even in an open container.
- Put a lid on it: in a sealed container the mass never changes.
- The change in mass is the mass of the gas. Nothing else needs working out.

Exam technique

- Use the words 'open' or 'non-enclosed', and name the gas (oxygen, carbon dioxide or hydrogen).
- When an equation is given, point to the gas and its state symbol (g) in your answer.
- A mass-change explanation needs two points: what the gas is, and whether it enters or leaves.
- In practical questions, heating to constant mass shows that the reaction has finished.

What each grade needs

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

Grade 3

State that gases can enter or leave

In an open container, gases can escape into the air or react from the air.

Grade 4

Explain a mass decrease when gas forms

The gas produced escapes into the air, so its mass is no longer measured.

Grade 5

Explain why a heated metal gains mass

Oxygen atoms from the air combine with the metal, so the metal oxide has a greater mass than the metal.

Grade 5

Use an equation to predict the mass change

Look for (g): a gas reactant means the mass goes up, a gas product means it goes down.

Grade 7

Explain mass changes using the particle model

Gas particles move quickly and randomly and spread out, so they leave an open container or reach the reactants from the air.

Grade 8

Predict the size of a mass change

Use moles, e.g. 100 g (1 mol) of $CaCO_3$ loses 44 g (1 mol) of CO_2 when heated.

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