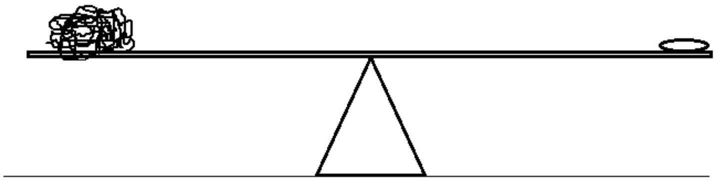
To study

Iron is a metal.
Iron wool is made up of thin strands of iron loosely bundled together.

Your teacher has attached a piece of iron wool to a see-saw balance. At the other end of the see-saw is a piece of Plasticine.



Iron wool can combust. Your teacher is going to make the iron wool combust by heating it.

If there is a change in mass, the see-saw will either tip to the left or to the right.

To discuss or to answer

1 What do you think will happen?

....

2 Why do you think this will happen?

....

....

3 What do you see happen when it is demonstrated?

....

4 Was your prediction correct?

....

To study

When iron is heated in air it reacts with oxygen to form the compound iron oxide.

Iron is a solid and oxygen is a gas.

To answer

5 Draw diagrams to show how the atoms are arranged in iron, oxygen and iron oxide in the circles below their names. Use different colours for the iron atoms and the oxygen atoms.

iron	+	oxygen	→	iron oxide
(a solid)		(a gas)		(another solid)

6 Use words and diagrams to explain why the iron wool increased in mass when it was heated and reacted.

Use the words solid, gas, atom and compound in your answer.

....

....

....

7 Explain how the particle models you have drawn help to explain the change in the mass of iron wool when it combusts.

....

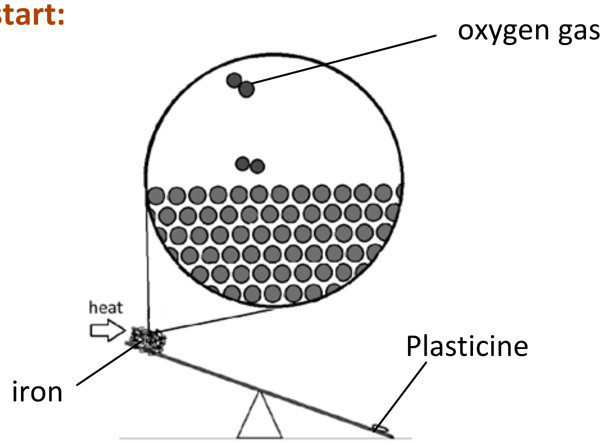
....

Writing frame

Use the words from the box to complete the sentences and the diagrams.
Each word can be used once, more than once, or not at all.

iron	iron oxide	reacted	oxygen	closely	apart
more	move	gas	not	solid	

At the start:



Key

Atom of ___________

Atom of ___________

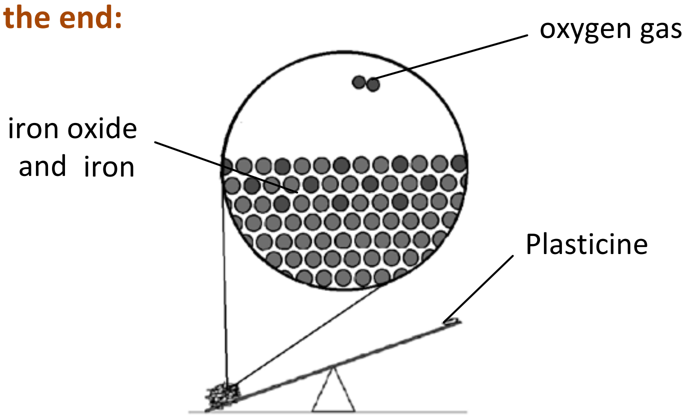
The iron is a _________. The particles are packed ____________ together.

They can vibrate but ___________ move about.

The oxygen is a _________. The particles are far _____________.

They can __________ about very quickly.

At the end:



The iron and oxygen have _____________ together to form

__________ __________ which is a solid.

It contains atoms of both __________ and ____________.

The iron and iron oxide together weigh _________ than the ___________ on its own so the balance tips to the side of the iron.

Combustion of iron wool – Assessing learning

To study

Many different substances react in air.

Combustion is a reaction with oxygen.

Some substances react with oxygen and form a solid product, while others react with oxygen and form a product which is a gas.

Here are some examples of combustion reactions:

magnesium(solid) + oxygen(gas) → magnesium oxide(solid)

sulfur(solid) + oxygen(gas) → sulfur dioxide(gas)

carbon(solid) + oxygen(gas) → carbon dioxide(gas)

copper(solid) + oxygen(gas) → copper oxide(solid)

To do

a Draw a diagram to represent the particles in magnesium.

b Draw a diagram to represent the particles in carbon dioxide.

To answer or to discuss

1 Predict which of the four starting materials (magnesium, sulfur, carbon and copper) will **gain** mass when they burn.

2 Predict which of the four starting materials (magnesium, sulfur, carbon and copper) will **lose** mass when they burn.

3 Use the particle model to explain why some things gain mass but others lose mass when they burn.

Learning structure of the lesson

The big picture

This lesson is designed to exemplify a model-based inquiry approach to practical work.

Iron wool is placed on a simple balance and set alight. Will it gain or lose mass? Students use their own ideas (mental models) to make predictions about the outcome of the experiment. They compare their predictions with their observations, and then use the consensus model to develop an explanation. In this case the consensus model is made up of the equation for the reaction and particle theory.

Age range: 13–15

Timing: 50 minutes

Learning episodes	Learning outcomes
Learning episode 1 (teacher-led) 5 mins Demonstrate that there is a decrease in mass when a candle burns. Show a piece of iron wool and ask students to recall what they already know about iron. Demonstrate the combustion of iron wool (not on a balance). Students observe that it catches light and reacts.	Students will be able to:
Learning episode 2 (teacher-led) 15 mins Introduce the equipment set-up for the main demonstration. Students work in pairs then fours to predict whether there will be an increase or decrease in mass or whether the mass will stay the same. They must identify their reasoning. Feedback into class discussion. Carry out the demonstration. Students record their observations and evaluate their prediction.	
Learning episode 3 (student-led) 20 mins Introduce the particle model and diagrammatic representations of solids and gases. Students work in pairs to use their particle diagrams to explain the change in mass. Some pairs share their ideas with the class. Encourage others to refine or extend the explanations.	• use a scientific model to explain the change in mass during the combustion of iron wool
Learning episode 4 (teacher-led) 10 mins Use the interactive to show what happens to the particles during the reaction. Students write a few sentences of explanation. They then apply their learning to explain the change in mass when other substances burn or combust.	

Equipment and materials

Teacher guidance

Practical guidance

Slide presentation

Interactive

Student sheet

Eye protection
Birthday candle
Iron or steel wool, about 8 g
Small heatproof dish
Bunsen burner
Heat-resistant mat
Aluminium cooking foil, about 10 cm x 10 cm
Plasticine, a few grams
Wooden metre rule (not plastic)
Retort stand, boss and clamp
Triangular block or something similar
Balance, 2 d.p.

Refer to the health and safety advice and practical guidance

Key words

Solid, gas, chemical reaction, particle, particle theory, mass, model

Prior knowledge

It is assumed that students know the following.

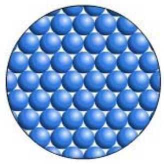
- In solids the particles are arranged closely together and stay in one place. This can be represented in a diagram.
- In gases the particles are far apart and can move freely. This can be represented in a diagram.
- Atoms and molecules (particles) have mass.

Students will have seen a burning candle and will have observed how it gets smaller (loses mass). They may have made close observations of burning candles in science lessons. They may also have learnt about the products of the reaction when a hydrocarbon is burnt.

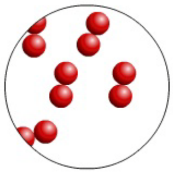
Background information

The particle or kinetic theory model is the consensus model used in this lesson to explain why there is an increase in mass during the combustion of iron.

In solids, the particles are close together and only vibrate on the spot. Solids have mass. They do not move about. The particles can be drawn like this:



In gases, the particles are far apart and move about quickly in all directions. Gases also have mass. The particles can be drawn like this:



Unless students have learnt that oxygen is O_2, they may well draw the oxygen as single atoms/circles. This does not matter for the purposes of this model and will not affect their explanations.

In the demonstration, a chemical reaction takes place. In a chemical reaction matter is conserved. Overall there is the same number of particles (atoms) at the end as there were at the start.

While the oxygen atoms are in the air (as a gas) they do not contribute to the mass on the end of the metre rule. In the reaction, they combine with the iron atoms in the iron wool (a solid) to form iron oxide (also a solid).

The number of atoms in the solid product is greater than in the iron at the start. This is because it is now made up of all the iron atoms and some added oxygen atoms. There are more atoms, so the mass has increased.

Students may want to know why iron wool combusts, but bigger bits of iron such as iron nails will not. The explanation for this goes beyond what is required at Key Stage 3 but it is summarised below.

One reason is the greater surface area. The iron wool has a much larger surface area in contact with the air than a nail. This means that more iron is available to combine with the oxygen in the air.

The other reason is the easier build-up of heat. In a lump of iron, the heat from a reaction is conducted away quickly into the lump. Not enough heat builds up in one place to sustain a reaction. In thin strands, the heat can't dissipate so easily; as it is conducted along the strand it just sets off further reactions due to the availability of oxygen there.

The iron wool stops reacting when iron oxide builds up enough to stop oxygen getting to any more of the iron. There may well be some unreacted iron inside each coated strand, but it cannot react because no oxygen can get to it there.

Terminology

The terms which students need to understand and use in this lesson are:

solid – in a solid the particles are arranged in a regular pattern, touching each other. The particles don't move around but just vibrate on the spot.

gas – in a gas the particles are far apart. The particles move quickly in all directions.

chemical reaction – chemical reactions create new substances. The substances you end up with are different from the ones you started with.

particle – everything is made up of particles. These particles might be atoms, molecules (or ions).

particle theory – particle theory is a scientific model which explains the behaviour of solids, liquids and gases in terms of particles.

mass – how much matter is in an object. The mass of an object can be found by placing it on a balance.

model – a mentally visualisable way of linking theory with experiment. They enable predictions to be formulated and tested by experiment.

Differentiation

This video shows another way in which the increase in mass can be demonstrated; members of the public are asked to make predictions.
www.bbc.co.uk/learningzone/clips/burning-steel/10877.html

The key to making an accurate prediction in this reaction is the idea that the oxygen and the iron react together to form a product which is a *solid,* and which contains atoms of both iron and oxygen.

The assessment questions ask students to predict and explain changes in mass when sulfur, carbon, magnesium and copper are burnt. This *should not be carried out* in the same way as the iron wool. For older and more able students this can link to chemical behaviour of metals and non-metals: metals form solid oxides whereas many non-metal oxides are gases.

Another possible thought experiment is to ask students what would happen to the mass if the iron and oxygen were in a sealed container. If they react together, what happens to the mass?

The answer in this case is that there would be no change in mass, as the same number of atoms would still be in the sealed container. How they are arranged does not affect their mass.

Taking it further

- Further work on the idea of conservation of mass. For example, the practical activities ‘Change in mass when magnesium burns’, or ‘Copper envelope’. (See links below to activities on Practical Chemistry). Explain the results using the ideas of particles in a similar way to the combustion of iron practical.
- Use the particle model to explain other observations such as diffusion in liquids or gases.

Related practical activities on Practical Chemistry

There are detailed instructions for the activity in this lesson on Practical Chemistry:
www.nuffieldfoundation.org/practical-chemistry/combustion-iron-wool

Change in mass when magnesium burns:
www.nuffieldfoundation.org/practical-chemistry/change-mass-when-magnesium-burns

Copper envelope:
www.nuffieldfoundation.org/practical-chemistry/copper-envelope

Diffusion in liquids:
www.nuffieldfoundation.org/practical-chemistry/diffusion-liquids

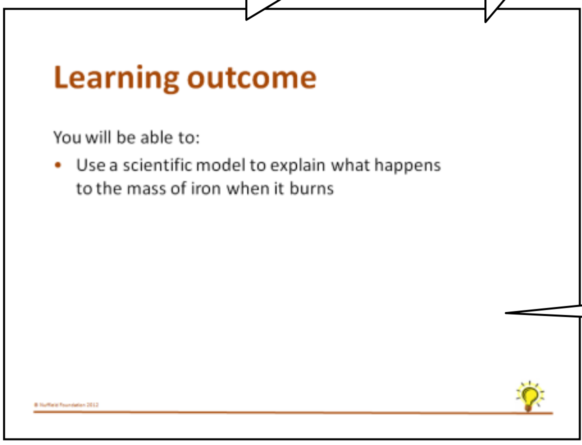
Diffusion in gases:
www.nuffieldfoundation.org/practical-chemistry/diffusion-gases-ammonia-and-hydrogen-chloride

Lesson details

Task: Prior to the lesson weigh a birthday cake candle. As students arrive light the candle at the front of the class and leave it to burn. After a few minutes extinguish the candle and weigh it again. Show that the mass has decreased.

Demonstration

Slide 2



Task: Show students a piece of iron wool, and ask them what they know about iron.

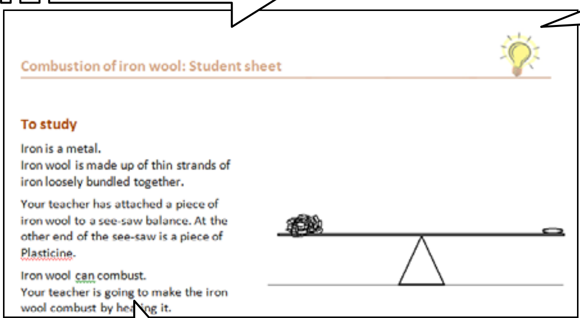
Students may be able to recall properties of iron such as; it is a metal, an element, conducts electricity, and is silver grey in colour.

Task: Carry out the teacher demonstration part 1. (see **Practical guidance**).

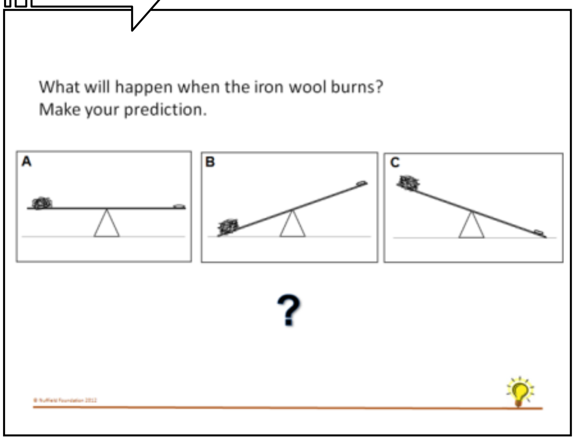
Explain: Present the learning outcome for the lesson using **slide 2**.

Task: Show students iron wool and the equipment for the teacher demonstration part 2 (see **Practical guidance**). Do not carry out the demonstration yet.

Student sheet



Slide 3



Task: Give out page 1 of **Student sheet** and get students to work in pairs to answer questions 1 and 2 using scientific terms if they can. **Slide 3** shows three possible outcomes.

Differentiation: Less able students may need to relate to what they have seen burn previously. More able students can be encouraged to think in terms of the iron atoms, and may be able to use diagrams to represent their ideas.

Task: Pairs get into fours to compare their predictions and explanations. They can amend their answers if they wish.

Task: Ask for a brief show of hands (and write the numbers on the board) of who thinks there will be an increase in mass, who thinks there will be a decrease in mass, and who thinks it will stay the same. Ask a few students to explain their predictions.

Push them to **identify their reasoning** as clearly as possible. Encourage other students to say whether they agree, and if not, why not.

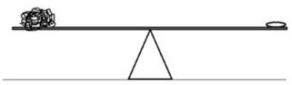
Demonstration → **Student sheet**

Combustion of iron wool: Student sheet

To study

Iron is a metal.
Iron wool is made up of thin strands of iron loosely bundled together.

Your teacher has attached a piece of iron wool to a see-saw balance. At the other end of the see-saw is a piece of Plasticine.



Iron wool can combust.
Your teacher is going to make the iron wool combust by heating it.

If the mass of the iron stays the same, the see-saw will remain balanced.
If the mass of the iron changes, the see-saw will either tip to the left or to the right.

To discuss or to answer

1 What do you think will happen?

……………………………………………………………

2 Why do you think this will happen?

……………………………………………………………

……………………………………………………………

3 What do you see happen when it is demonstrated?

……………………………………………………………

4 Was your prediction correct?

……………………………………………………………

Task: Set up the balance so that the Plasticine is only *just* weighting the balance down on the side away from the iron wool.
Carry out the teacher demonstration part 2. (see **Practical guidance**).

After about 1 minute of strong heating, the balance will tip showing that the iron wool has gained mass – even though some may have fallen off the ruler.

Task: Students complete questions 3 and 4 on **student sheet**.

If students predicted incorrectly, explain that the model used in their reasoning may be incorrect. They need a better 'model' to explain what happened. If they predicted correctly, challenge their models and their reasoning. Question any possible flaws.

Differentiation: If any student got their prediction and explanation correct, then extend them by asking them to think about: What information would you need to be able to predict how much heavier a piece of iron wool would get? (The mass of iron, and the mass of oxygen that reacts with each gram of iron – or the number of atoms of oxygen which react with each iron atom, and the masses of the atoms.)

Student sheet

To study

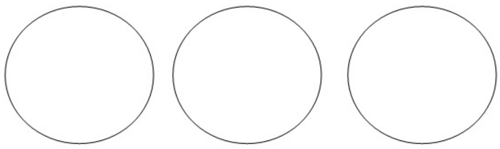
When iron is heated in air it reacts with oxygen to form the compound iron oxide.

Iron is a solid, and oxygen is a gas.

To answer

5 Draw diagrams to show how the atoms are arranged in iron, oxygen and iron oxide in the circles below their names. Use different colours for the iron atoms and the oxygen atoms.

iron (a solid) + oxygen (a gas) → iron oxide (another solid)



6 Use words and diagrams to explain why the iron wool increased in mass when it was heated and reacted.

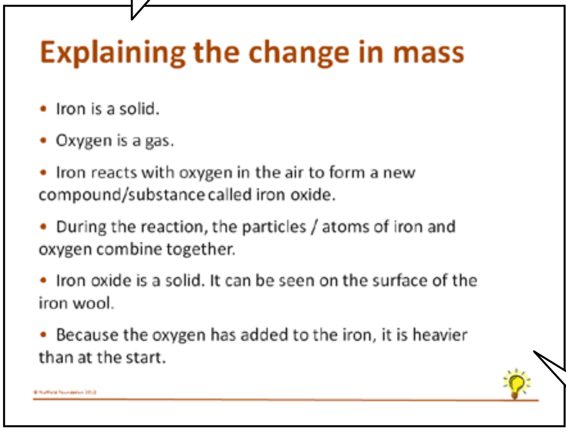
Use the words solid, gas, atom and compound in your answer.

Task: Give out **Student sheet** page 2 and get students to complete question 5 about iron, oxygen, and iron oxide.

They should carefully think about their observations before deciding what to draw for iron oxide.
Ensure that all students have an accurate idea of how the particles are arranged in a solid and in a gas, and understand what is meant by the term 'particle'.

The **interactive** includes diagrams representing solids and gases. Use these if students are having difficulty recalling these representations. Showing a physical model such as polystyrene balls arranged as a solid and a gas is also a possibility.

Slide 6



Task: Ask students prompting questions to help them use the particle model.

Example questions
- Do solids have mass?
- Do gases have mass?
- What is iron oxide made up of?
- Is iron oxide a solid, liquid or gas?

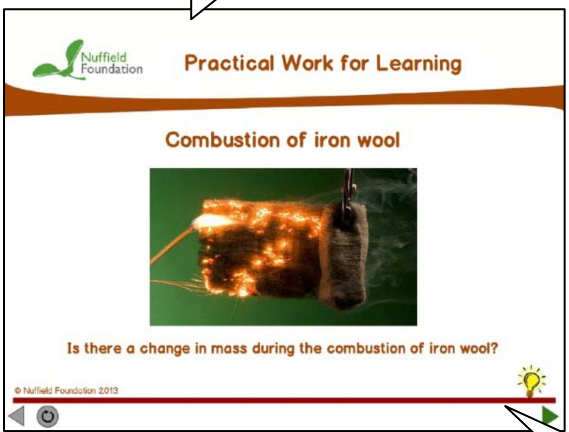
Explain: In a chemical reaction matter is conserved. There is the same number of particles at the end as there were at the start. Iron (a solid) reacts with oxygen (a gas) to form iron oxide (another solid).

Task: Students work in pairs to discuss why there was an increase in mass in the reaction.
Ask some of their pairs to share their ideas with the class. Encourage others to add to or extend the explanations if needed. **Slide 6** identifies some key points.

Students should use their particle diagrams to help them. Encourage them to use scientific terms in their explanations.

Differentiation: A writing frame is available on the **Student sheet** for students who need

Interactive



Task: Ask students prompting questions to help them develop their explanation.

Example questions
- What happened to the atoms of the iron?
- What happened to the atoms of the oxygen?
- What is the product called?
- What atoms does the product contain?
- Why is the product heavier than the iron wool was at the start?
- Does the model that we are using (the particle model) help us to explain what is going on during the reaction?

Task: Use the first part of the **interactive** to show what happens to the particles during the reaction. When you are happy that the students understand what is going on, ask them to individually write a few sentences (and draw a diagram) to describe, in terms of particles, what was going on in the reaction and why the there was an increase in mass. Students check each others' answers.

Student sheet

Combustion of iron wool - Assessing learning

To study

Many different substances react in air.

Combustion is a reaction with oxygen.

Some substances react with oxygen and form a solid product, while others react with oxygen and form a product which is a gas.

Here are some examples of combustion reactions:

magnesium(solid) + oxygen(gas) → magnesium oxide(solid)

sulfur(solid) + oxygen(gas) → sulfur dioxide(gas)

carbon(solid) + oxygen(gas) → carbon dioxide(gas)

copper(solid) + oxygen(gas) → copper oxide(solid)

To do

a Draw a diagram to represent the particles in magnesium.

b Draw a diagram to represent the particles in carbon dioxide.

To answer or to discuss

1 Predict which of the four starting materials (magnesium, sulfur, carbon and copper) will **gain** mass when they burn?

2 Predict which of the four starting materials (magnesium, sulfur, carbon and copper) will **lose** mass when they burn.

3 Use the particle model to explain why some things gain mass but others lose mass when they burn.

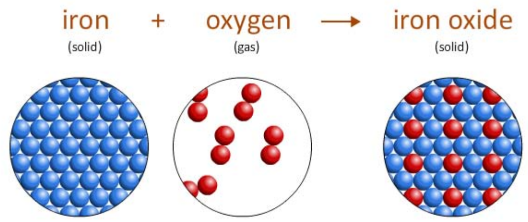
Task: Remind students of the candle burning at the start of the lesson, and ask:
- What happens to the mass of a candle when it burns?
- Can the model we are using explain why some things gain mass but others lose mass during combustion?

Scaffold students to suggest 'rules'. For example, if the product of combustion is a solid then the starting material will gain mass, but if the product is a gas then the starting material will lose mass.

Task: The assessment questions on the **Student sheet** and in the second part of the **interactive** ask students to transfer their understanding to other combustion reactions. They are asked about how the model can be used to predict and explain changes in mass for these reactions.

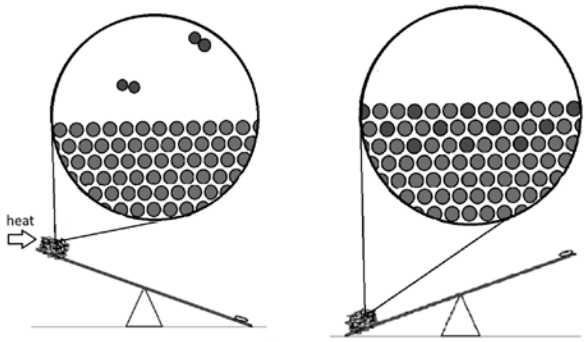
Student sheet: Answers

5



6 Iron wool is a solid. Oxygen is a gas. When iron wool combusts, it reacts with oxygen from the air to form iron oxide. Iron oxide is a solid, so the oxygen atoms from the air add to the mass on the balance. The balance tips as the iron wool reacts with the oxygen to form solid iron oxide.

Possible diagram:



7 The particle model helped to explain where the additional mass came from. The additional mass was due to the oxygen atoms which added to the iron atoms when the product iron oxide was formed.

Writing frame: Answers

At the start:

Key

● Atom of oxygen

● Atom of iron

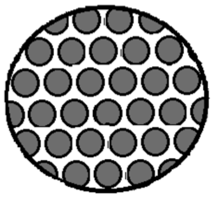
The iron is a **solid**. The particles are packed **closely** together. They can vibrate but **not** move about.
The oxygen is a **gas**. The particles are far **apart**. They can **move** about very quickly.

At the end:

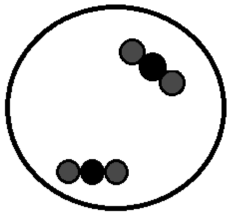
The iron and oxygen have **reacted** together to form **iron oxide** which is a solid. It contains atoms of both **iron** and **oxygen**.
The iron and iron oxide together weigh **more** than the **iron** on its own so the balance tips to the side of the iron.

Assessing learning: Answers

a



b



Students are not expected to know how to draw molecules of carbon dioxide. The important thing is for them to recognise it is a gas. For this question it is acceptable for them to use single circles to represent the carbon dioxide molecules.

1 Magnesium and copper will gain mass when they burn.

2 Sulfur and carbon will lose mass when they burn.

3 If the product of the reaction is a solid, the substance will gain mass when it burns. This is because the oxygen atoms from the air add to the starting material in the reaction. There are more atoms in the solid product than there were in the solid starting material, so it is heavier.

If the product of the reaction is a gas, the substance will lose mass when it burns. This is because the oxygen atoms from the air combine with the atoms in the starting material and form a gas. The gas escapes into the air, taking atoms from the starting material with it, so what is left is lighter.

Combustion of iron wool – Practical guidance

In **part 1** the flammability of iron wool is demonstrated.

In **part 2** iron wool is heated in air on a simple 'see-saw' balance.
The increase in mass is seen clearly.

Equipment and materials

Eye protection

Part 1 The combustion of iron wool

For one demonstration
Iron or steel wool, about 4 g (see note 1)
Small heatproof dish, such as Pyrex oven dish (see note 2)
Bunsen burner
Heat-resistant mat

Part 2 The combustion of iron wool to observe the change in mass

For one demonstration
Iron or steel wool, about 4 g (see note 1)
Aluminium cooking foil, about 10 cm x 10 cm
Plasticine, a few grams
Bunsen burner
Heat-resistant mat
Wooden metre rule (not plastic) (see note 3)
Retort stand, boss and clamp
Triangular block or something similar
Balance, 2 d.p.

Health and Safety and technical notes

Before carrying out this practical, users are reminded that it is their responsibility to carry out a risk assessment in accordance with their employer's requirements, making use of up-to-date information.

Read our standard health & safety guidance.

1 Tease out the pieces of iron wool in order to allow air to get around it easily. Do this in advance of the lesson.

2 The small heatproof dish should be large enough to comfortably hold one piece of the iron wool.

3 A shallow groove cut across the width of the ruler at the 50 cm mark will help when balancing it on the triangular block. Cover the end of the metre ruler with foil to protect it from the Bunsen burner.

There are detailed instructions for this demonstration on Practical Chemistry:
www.nuffieldfoundation.org/practical-chemistry/combustion-iron-wool

Procedure

Part 1 The combustion of iron wool

1 Place one piece of iron wool in the heatproof dish on a heat-resistant mat.

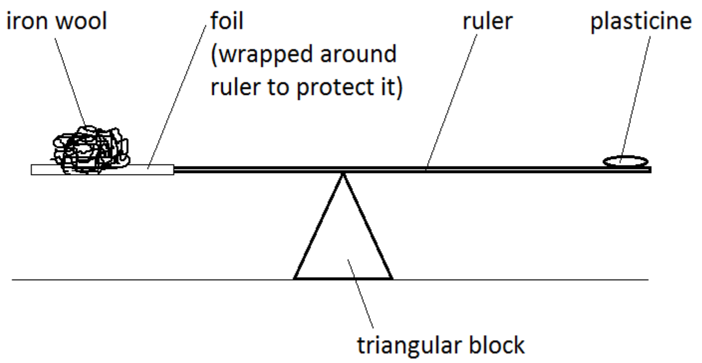
2 Wear eye protection. Light the Bunsen burner and heat the iron wool from the top with a roaring flame. When the iron has been set alight, remove the Bunsen burner. Students observe that the iron wool catches light and reacts. You may need to relight the iron wool as it sometimes goes out sooner than you would like.

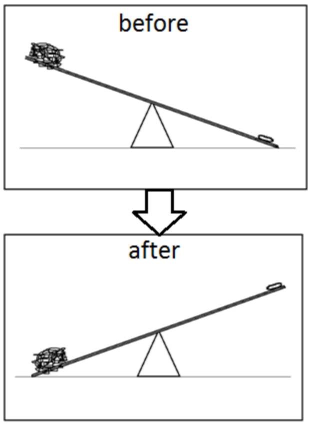
3 Once the fire is out, allow the iron wool and bowl to cool down.

Part 2 The combustion iron wool to observe the change in mass

1 Cover one end of the metre ruler with foil to protect it from the Bunsen burner. Take about 4 g of iron wool and use a few of the strands to attach it to the end of the ruler.

2 Balance the ruler on a triangular block at the 50 cm mark. Weight the opposite end with Plasticine until this end is only **just** down (see the 'before' diagram). This part is critical.





3 Place a heat-resistant mat underneath the iron wool.

4 Wear eye protection. Light the Bunsen burner and heat the iron wool from the top with a roaring flame. It will glow and some pieces of reacting wool may drop onto the heat-resistant mat. Take care to direct the flame at the iron wool rather than the foil protecting the ruler. Heat for about a minute, by which time the metre ruler will have over-balanced and the iron wool side will be down (see the 'after' diagram).

NOTE: Students may complain that you are 'pushing down the iron wool with the flame'. If this is the case, repeat the demonstration taking care to heat it from the side. If they complain that it isn't 'fair' because they thought the balance would tip the other way and you started with the Plasticine side down, you can repeat the demonstration showing that if you start with the iron wool side down it doesn't go up.