Burning magnesium in carbon dioxide – what will happen?

Either the magnesium will go out or it will continue to burn. Which will it be?

You will use the evidence cards to help you make a prediction.

All the statements on the evidence cards are true.

To do

1 Divide the cards into:

a) evidence suggesting that the magnesium will continue to burn

b) evidence suggesting that the magnesium will go out

c) cards supporting neither argument.

2 Using the evidence on the cards, and any additional knowledge you have, decide what you think is going to happen.

3 Select two or three cards which provide the strongest argument for your prediction. Explain why you think they support your prediction.

4 Select two or three cards which provide the strongest evidence for the opposing prediction.

5 For each piece of evidence selected in 4, try to explain how your prediction can still be valid.

6 Write down your prediction and be prepared to share your arguments with the class.

Remember – the best arguments are based on the strongest evidence and can explain why opposing arguments are incorrect.

Evidence to suggest the magnesium will keep burning	Evidence to suggest the magnesium will go out	Evidence that suggests neither

Explanation

When burning magnesium is placed into a gas jar of carbon dioxide it continues to burn.

When writing an argument you can use **Point, Evidence and Explanation (PEE)** to frame your paragraphs.

For example:

Point: Magnesium reacts with oxygen.

Evidence: When magnesium is placed in a Bunsen burner flame in air it burns with a bright, white flame. The product is a white powdery solid.

Explanation: At high temperatures the magnesium atoms in the metal combine with the oxygen atoms in the air. A chemical reaction produces magnesium oxide. This is the powdery white solid.

Point: The magnesium continues to burn because it reacts with the carbon dioxide.

(Use evidence from your observations)

Evidence: _____

_____

Equation for the reaction:

carbon dioxide + magnesium → _____ + _____ _____

Point: Some people thought that the magnesium would go out.

(Use evidence from the evidence cards)

Evidence: _____

_____

Point: However, the magnesium continued to burn because of its position in the reactivity series.

Explanation:_____

_____

Magnesium and carbon dioxide – Teacher guidance

Learning structure of the lesson

The big picture

This lesson is designed to exemplify an argumentation approach to practical work, using a 'predict, observe, explain' framework.

When burning magnesium is placed into a gas jar of carbon dioxide it is not extinguished but burns more brightly. This is due to the relative positions of magnesium and carbon in the reactivity series. The result surprises many students who know that carbon dioxide puts out fires and that it is in many fire extinguishers. This lesson allows students to argue about what they think will happen in the reaction and to draw up competing theories. They then observe the reaction and write an explanation for what they have seen.

Age range: 14–16 (Could be adapted for able 11–14s or as a re-introduction to the reactivity series for 16–18s who have not seen the reaction before)

Timing: 50 minutes

Learning episode 1 (teacher-led) 5 mins

Remind students that carbon dioxide can be used to extinguish fires.

Introduce learning outcomes.

Learning episode 2 (student-led) 15 mins

Students predict what will happen when magnesium ribbon is placed in a Bunsen flame then held in the air. They observe a teacher demonstration and use their prior knowledge to explain their observations.

Introduce the main practical. Students work in pairs (or small groups) and use evidence cards to help them decide what will happen *and why*. A few groups share their arguments with the class along with the evidence cards they have selected. They review their predictions and revise them if they wish.

Learning episode 3 (teacher-led) 15 mins

Demonstrate the reaction. Students make their observations. Class discussion of results and development of an explanation.

Students suggest further pieces of evidence from the results of the experiment, to add to the evidence cards.

Agree on a scientific explanation.

Learning episode 4 (student-led) 15 mins

Students choose evidence cards which best support the scientific explanation and use these to develop a good written argument.

They then work in pairs to answer a question applying the same principles to a new context.

Learning outcomes

Students will be able to:

- use knowledge of the reactivity series and the fire triangle to make predictions about the outcome of reactions
- consider and evaluate other peoples' arguments
- give an explanation for what happens when burning magnesium is added to carbon dioxide
- consider and evaluate other peoples' arguments

Equipment and materials

Teacher guidance
Practical guidance
Slide presentation
Student sheet
Evidence cards (cut out in advance of lesson)

Eye protection
Magnesium ribbon
Limewater
CO_2 cylinder with regulator *or* CO_2 generator
Candles or tea lights, 2
Gas jars and lids
Beakers (100 cm^3), 2
Test tube
Pipette
Bunsen burners
Heat resistant mats
Tongs
Wooden splints
Matches or lighter

Optional
Flexicam
Polaroid or blue filters

Refer to the health and safety advice and practical guidance

Key words

Chemical reaction, reactivity series, fire triangle.

Prior knowledge

This lesson is best used soon after the students have covered the reactivity series.

It is assumed that students know the following.

- Metals can be placed into a reactivity series and carbon can also be placed into this series.
- A more reactive metal (or carbon) can remove or displace oxygen from the oxide of a less reactive metal (or carbon).
- The fire triangle model shows the ingredients needed for fire; fuel, oxygen and heat.
- Carbon dioxide is used in fire extinguishers.

Background information

Carbon dioxide puts out fires so it is used in fire extinguishers. It is heavier than air so covers the fire, smothering it so that oxygen cannot get to it. Without oxygen, the fire triangle is broken and the fire will go out.

Magnesium is above carbon in the reactivity series and so can remove oxygen from carbon dioxide and continue to burn. Black specs of carbon can be seen to be ejected during the reaction.

Terminology

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

chemical reaction – the rearrangement of atoms to form new compounds

reactivity series – a list of metals (and carbon) ranked in order of decreasing reactivity

fire triangle – a diagram showing that fuel, oxygen and heat are needed for a fire to burn

Differentiation

The fire triangle says that oxygen has to be present for a fire to burn. Is this true? You could demonstrate the reaction of sodium with chlorine as another example of a combustion reaction which does not need oxygen gas. See link below.

Related practical activities on Practical Chemistry

Carbon and the reactivity series:
www.nuffieldfoundation.org/practical-chemistry/where-does-carbon-come-reactivity-series (Experiment 2 only)

Carbon dioxide and a candle:
www.nuffieldfoundation.org/practical-chemistry/density-carbon-dioxide

Practical activities to illustrate the reactivity series:
www.nuffieldfoundation.org/practical-chemistry/metals-and-reactivity-series

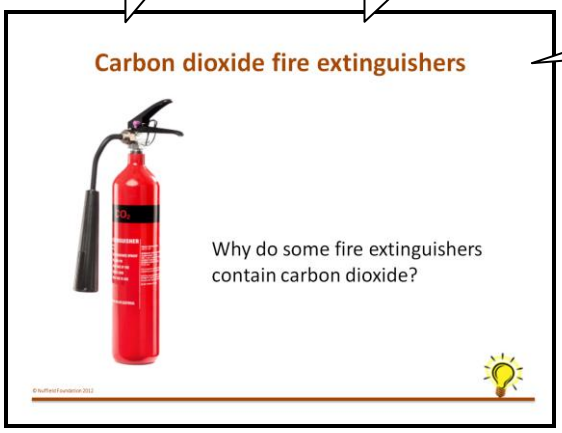
The real reactivity of aluminium is another reaction which can surprise students:
www.nuffieldfoundation.org/practical-chemistry/real-reactivity-aluminium

An alternative method for showing the reactivity of aluminium:
www.rsc.org/learn-chemistry/resource/res00000439/classic-chemistry-experiments-investigating-the-reactivity-of-aluminium

Heating sodium in chlorine:
www.nuffieldfoundation.org/practical-chemistry/heating-group-1-metals-air-and-chlorine

Lesson details

Slide 2 **Practical**



Task: Show **Slide 2**, or an actual carbon dioxide fire extinguisher if available, and ask 'Why do some fire extinguishers contain carbon dioxide?'

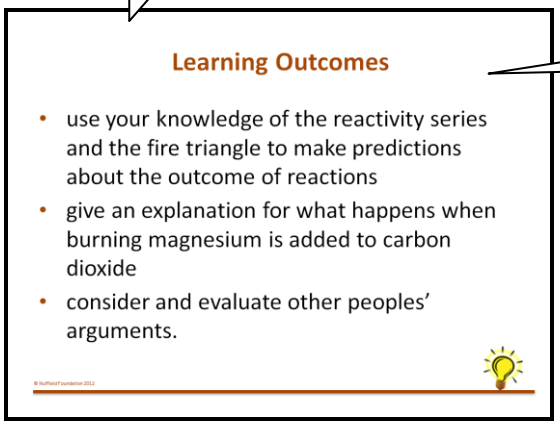
Task: Remind students that carbon dioxide can be used to extinguish fires by pouring a gas jar of carbon dioxide over a small, lit candle in a small beaker (see **Practical guidance**).

Alternatively, show students a video clip of a carbon dioxide fire extinguisher in action e.g. www.youtube.com/watch?v=0TxhUmU7Jfk

Ask, 'How does the carbon dioxide put out the fire?'

Carbon dioxide covers the fire, smothering it so that oxygen cannot get to it. Without oxygen, the fire triangle is broken and the fire goes out.

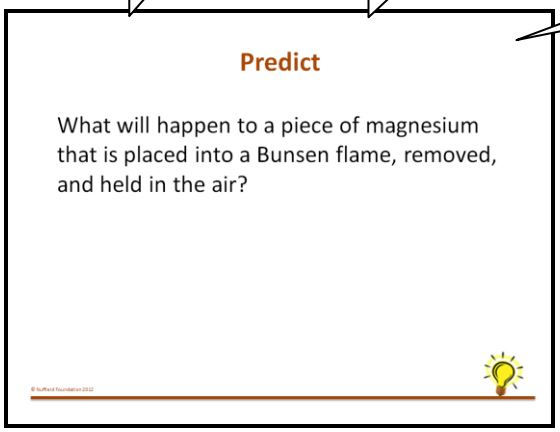
Slide 3



Explain: Introduce objectives for the lesson, and explain what makes a good scientific argument.

A good scientific argument uses evidence and scientific ideas to justify a point.

Slide 4 **Practical**



Task: Ask the question on **slide 4**.
Students make their predictions.

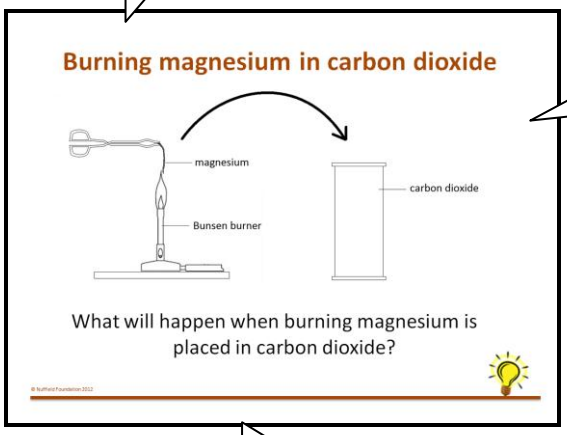
Task: Demonstrate the burning of magnesium (see **practical guidance**). This is a good time to remind students how to safely watch magnesium burning.

Ask 'why does the magnesium burn? What reaction is taking place?'

Magnesium is reacting with oxygen from the air to make magnesium oxide (white powder). Remind students that magnesium is a very reactive metal; it is high in the reactivity series.

Magnesium and carbon dioxide – Teacher guidance

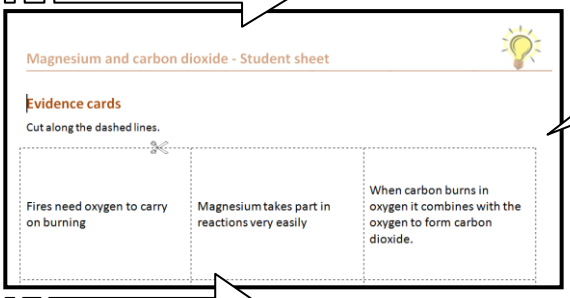
Slide 5



Explain: Explain to students that they are going to see what happens when burning magnesium is placed into a gas jar of carbon dioxide. But first they will **predict** what will happen based on evidence that they will be provided with.

One of two things is going to happen: either the magnesium will continue to burn, or it will go out. Students are to use the evidence cards to help them decide what they think will happen **and why**. They will need to make a prediction **based on evidence**.

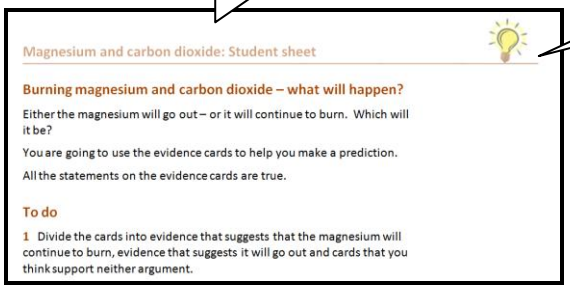
Evidence cards



Task: Put students in pairs and give each pair a set of **evidence cards**. Do not include the blank cards at this stage. Explain that *all* of the statements on the cards are true.

Cut out the cards in advance of the lesson. The cards can be laminated to help them last.

Worksheet 1

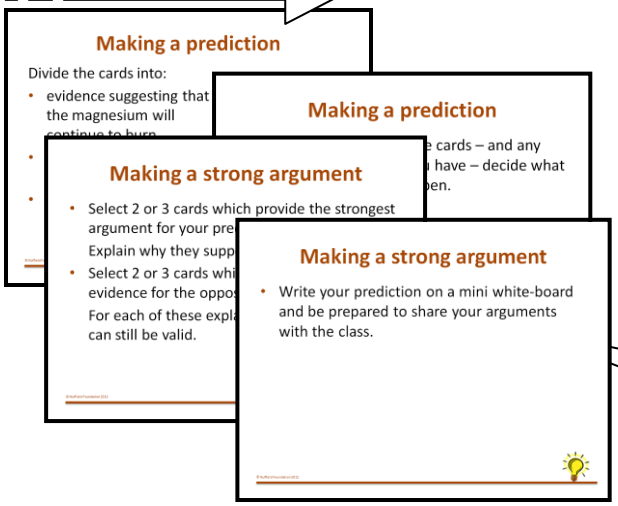


Task: The task can be broken down into six stages as described on **Worksheet 1**.

Examples of statements for stage 5.

- Carbon dioxide does put out fires, but not all fires.
- The fire triangle shows that fires need oxygen, but the magnesium can get the oxygen from the carbon dioxide.

Option: Slides 6-9



Pairs could join into fours to discuss and reach consensus. Giving them roles will ensure all students participate, e.g. chairperson (mediates discussion between group members making sure only one person speaks at a time); speaker A (presents evidence 'it will go out'); speaker B (presents evidence 'it will continue to burn'); timekeeper and scribe (keeps track of time and keeps a written record of the debate).

Optional: As an alternative to **Worksheet 1**, the instructions are on **slides 6–9**.

Slide 10

Making a strong argument

- Check your argument against these criteria.
  - Is the claim clear?
  - Is the claim linked to the evidence?
  - Does the evidence support the claim?
  - How could the argument be improved?

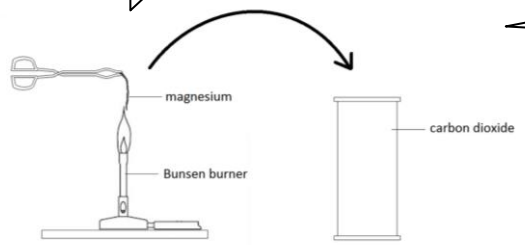
Task: Do a class straw poll of who thinks the magnesium will continue to burn and who thinks it will go out.
Ask the chairperson or timekeeper from a few groups to share which cards they selected to support their prediction and why they think that evidence is good.

Ensure that arguments are **supported with evidence** and not just a straightforward prediction.

Differentiation: Introduce greater challenge by asking students to share their evidence for the opposing position and explain how their prediction is still valid.

Task: Students **review their predictions** thinking about what makes a good argument and decide if they wish to amend their prediction.
If any group wishes to change their prediction, ask them to explain why. Which evidence, or whose argument, has convinced them?

Practical



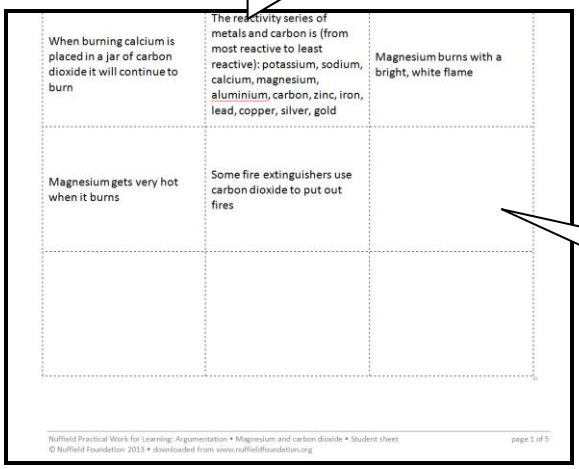
Task: Have a gas jar of carbon dioxide ready, and demonstrate the magnesium and carbon dioxide reaction (see **Practical guidance**).

Remind students to protect their eyes as they observe what happens – do not look directly at the magnesium flame. You may want to carry the reaction out a second time to convince students of the result.

Task: Students write down what they **observed** in as much detail as they can.

This should include what the reactants and products looked like and what happened during the reaction. Draw students' attention to the black specs that will appear on the sides of the gas jar.

Evidence cards



When burning calcium is placed in a jar of carbon dioxide it will continue to burn	The reactivity series of metals and carbon is (from most reactive to least reactive): potassium, sodium, calcium, magnesium, aluminium, carbon, zinc, iron, lead, copper, silver, gold	Magnesium burns with a bright, white flame
Magnesium gets very hot when it burns	Some fire extinguishers use carbon dioxide to put out fires	

Nuffield Practical Work for Learning: Argumentation • Magnesium and carbon dioxide • Student sheet page 1 of 5
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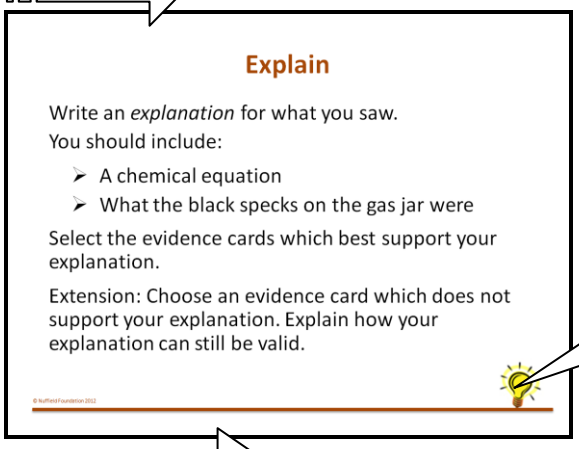
Task: Draw the whole class together to discuss the results and agree an **explanation**.

Possible questions:
- What are these black specs?
- Were they there before the reaction?
- Where have they come from?
- What are the products of this reaction?
- What were the reactants?
- Can you write a chemical equation for the reaction?
- Are the results what you predicted?
- Why does magnesium burn in / react with carbon dioxide when many other substances will not?

Task: Ask students to suggest two more pieces of evidence from the results of the experiment to support the agreed explanation. Write these onto **blank evidence cards**.

Suggested pieces of evidence might be:
- After magnesium has burned in carbon dioxide black specks can be seen.
- Magnesium will burn in carbon dioxide until there is no magnesium left.

Slide 11



Explain

Write an *explanation* for what you saw.
You should include:

- A chemical equation
- What the black specks on the gas jar were

Select the evidence cards which best support your explanation.

Extension: Choose an evidence card which does not support your explanation. Explain how your explanation can still be valid.

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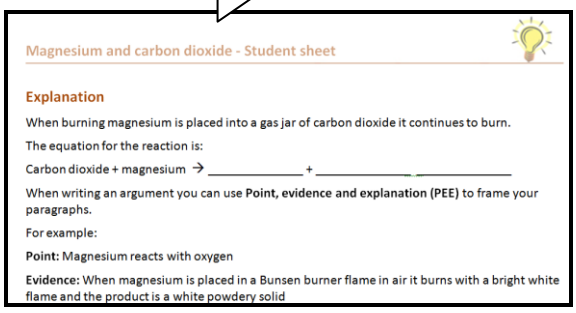
Explain: Establish that magnesium is above carbon in the reactivity series and so can remove oxygen from carbon dioxide and continue to burn. Black specs of carbon can be seen in the gas jar after the reaction showing that carbon is one of the products.

Task: Students choose the evidence cards which can **best support this explanation** for the outcome of the demonstration. They use these to develop a good written argument. **Slide 11** provides guidance.

Worksheet 2



Magnesium and carbon dioxide - Student sheet

Explanation

When burning magnesium is placed into a gas jar of carbon dioxide it continues to burn.

The equation for the reaction is:

Carbon dioxide + magnesium → _____ + _____

When writing an argument you can use **Point, evidence and explanation (PEE)** to frame your paragraphs.

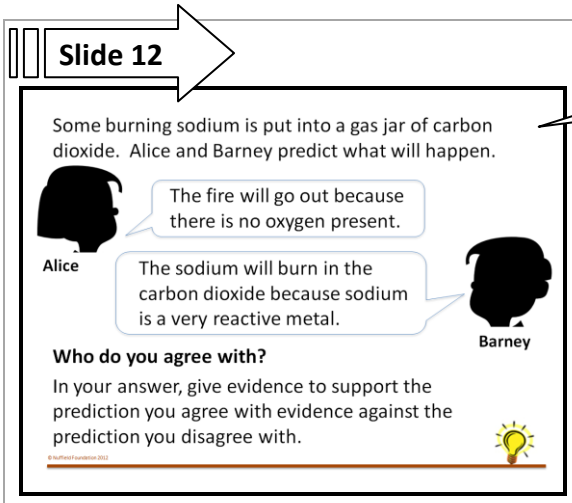
For example:

Point: Magnesium reacts with oxygen

Evidence: When magnesium is placed in a Bunsen burner flame in air it burns with a bright white flame and the product is a white powdery solid

This is an opportunity to target students' literacy skills. 'Point, evidence, explanation' is often used in English and History; students can use this to structure their paragraphs when answering questions. You may need to model this for them first on the board.

Differentiation: Some students will be capable of choosing an evidence card which does not support their explanation and argue for the validity of their explanation.



Task: Students work in pairs to answer the 'assessing learning' question from **slide 12**.

Answers: Student sheet 2

Suggested answers

Evidence: When burning magnesium is placed in carbon dioxide it keeps burning with a bright flame. One product is a black solid.

Equation for reaction:
magnesium + carbon dioxide → carbon + magnesium oxide

Evidence: Fires need oxygen to keep burning. Some fire extinguishers use carbon dioxide to put out fires.

Explanation: Magnesium is higher in the reactivity series than carbon so it is more reactive than carbon and removes the oxygen from the carbon dioxide (to give carbon and magnesium oxide).

Answers: Assessing learning

Suggested answer

I agree with Barney that the fire will continue to burn because sodium is a very reactive metal. Sodium is above carbon in the reactivity series. It will remove the oxygen from the carbon dioxide to give carbon and sodium oxide. The fire will not go out even though there is no oxygen gas present. There is oxygen in the carbon dioxide and this can allow the fire to continue to burn.

Magnesium and carbon dioxide – Practical guidance

Students are often very surprised by the results of this experiment – that magnesium will continue to burn when placed in carbon dioxide.

Equipment and materials

Eye protection

For fire extinguisher demonstration
Carbon dioxide cylinder with regulator *or* carbon dioxide generator (see notes 1 and 2)
Limewater
Candles (short 1–2 cm pieces or tea-lights), 2
Gas jar
Beakers (100 cm^3), 2
Test tube
Pipette
Heat-resistant mat
Matches or lighter
Wooden splints
Optional: Flexicam linked to data projector

For burning magnesium demonstration
Magnesium ribbon, about 5–10 cm (Refer to CLEAPSS *Hazcard*)
Bunsen burner
Heat-resistant mat
Tongs
Matches or lighter
Optional: Polaroid or blue filters for students. See CLEAPSS *Hazcard* 59A

For magnesium and carbon dioxide demonstration
Students may want to see the demonstration more than once so it is best to have enough magnesium and gas jars for at least two attempts
Magnesium ribbon, pre-cut strips about 10 cm in length (Refer to CLEAPSS *Hazcard*)
Gas jars and lids – the gas jars should be full of carbon dioxide
Bunsen burner
Heat-resistant mat
Tongs
Matches or lighter

Health and safety and technical notes

Before carrying out these practical activities, 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 Carbon dioxide cylinder – see CLEAPSS *Hazcard* and also *Laboratory Handbook* section 9.9 about the safe storage and use of gas cylinders.

2 Carbon dioxide generator – If a carbon dioxide cylinder is not available, carbon dioxide gas may be generated chemically – see Standard techniques: Generating collecting and testing gases. Replace the thistle funnel with a tap funnel or unstoppered separating funnel. Add the hydrochloric acid (100 cm^3, 2M) a few cm^3 at a time to the marble chips (10 g) to generate a steady stream of carbon dioxide; allow the heavier gas to displace the air from the gas jar. This can be checked by sampling the gas emerging from the neck of the flask using a dropping pipette to suck up a sample of gas, then bubbling it through fresh limewater in a test tube. Immediate and dense milkiness of the limewater should indicate the flask is full of carbon dioxide, which may then be sealed with a greased gas jar lid until required for the demonstration. Refer to CLEAPSS *Recipe Sheet* 21 for more information.

3 For burning magnesium in carbon dioxide refer to CLEAPSS *Hazcard* 20.

4 Warn students not to look directly at the burning magnesium. See CLEAPSS *Hazcard* 59A.

Procedure

Fire extinguisher demonstration

A flexicam or similar can help with the visibility of this quick demonstration.

1 In advance, fill a gas jar with carbon dioxide using either a cylinder or a gas generator.

2 Place the two beakers side by side on the bench and place a short candle or tea-light in each.

3 Light the candles with a splint. They will continue to burn.

4 Pour carbon dioxide from the gas jar into one of the beakers and the candle will go out while the candle in the other beaker continues to burn. The second candle is a control.

5 Attempt to relight the first candle with a splint. This will fail and the splint will go out.

6 You may want to test the gas to show it is carbon dioxide. To do this use a pipette to suck up some of the gas and then bubble it through a small amount of limewater in a test tube. The limewater should go milky.

7 Now pour the carbon dioxide out of the beaker and try again to relight the candle. This should now succeed.

Burning magneisum demonstration

Wear eye protection (teacher and students)

1 Hold a piece of magnesium ribbon in tongs.

2 Place the end of the magnesium in a hot Bunsen flame to set fire to it.

Reaction of magnesium with carbon dioxide

Wear eye protection (teacher and students)

1 In advance, fill a gas jar with carbon dioxide using either a cylinder or a gas generator.

2 Using scissors cut a 10 cm piece of magnesium ribbon.

3 Light a Bunsen burner.

4 Hold the piece of magnesium ribbon in tongs, and place one end in the Bunsen burner flame. As soon as it ignites, remove the lid from the gas jar and quickly plunge the ribbon into the carbon dioxide – *but keep hold of it with the tongs*. The magnesium continues to burn in the carbon dioxide, forming some black specs of carbon and white magnesium oxide.

Evidence cards

Cut along the dashed lines.

Fires need oxygen to carry on burning.	Magnesium takes part in reactions very easily.	When carbon burns in oxygen it combines with the oxygen to form carbon dioxide.
When you drop a lit match into a gas jar of carbon dioxide it will go out.	Carbon reacts with copper oxide to form carbon dioxide and copper.	Carbon does not react with magnesium oxide.
When burning calcium is placed in a jar of carbon dioxide it will continue to burn.	The reactivity series of metals and carbon is (from most reactive to least reactive): potassium, sodium, calcium, magnesium, aluminium, carbon, zinc, iron, lead, copper, silver, gold.	Magnesium burns with a bright, white flame.
Magnesium gets very hot when it burns.	Some fire extinguishers use carbon dioxide to put out fires.	