Practical pyrotechnics

Hot, luminous and destructive: fire is a force of nature. Here we look at how to use and control it safely with water and carbon dioxide.

Image courtesy of Thomas's Pics; image source: Flickr

By Małgorzata Krzeczkowska, Emilia Grygo-Szymanko and Paweł Świt

Fire has a place in prehistory, culture, and technology. Early humans would have encountered fires of natural origin – from forest fires and lightning to perhaps volcanic eruptions. Later, humans learned how to create and sustain fire at will and to use it for light and heat. Much later, we came to understand its chemistry and how to adapt it for use in the most exquisitely controlled way – as in, for example, the internal combustion engine.

Today, as well as being an essential part of technology, fire is a hazard: in Europe, several thousand people lose their lives each year due to fire, with economic losses estimated at one per cent of GDP[w1]. Fire is thus an important topic, for both its power and its risks.

Inspired by this idea, we have developed a set of activities for students aged 11–14 to safely explore the nature of fire. In the first activity, we show how to 'burn money', while the second activity demonstrates the fire-extinguishing properties of carbon dioxide. Finally, we give students a chance to discuss how to stay safe from fire. The activities require a total of around 35 minutes (the first activity about 15 minutes, and the second and third are 10 minutes each).

As a prelude to the practical activities, we asked the students to name five ideas they associate with the word 'fire'. The most frequent associations are presented in figure 1.

Activity 1: Money to burn?

This activity is a bit like a magic trick – a demonstration of how you can burn your money and still keep it!

Materials

- Fake bank note
- Metal tongs
- Two crystallising dishes
- Approximately 25 g sodium chloride (table salt)
- Water
- Methylated spirits or another version of denatured alcohol (ethanol)
- Fireproof surface, e.g. covered with metal, tiles or silver foil
- Fire-extinguishing equipment (a fire extinguisher or a wet cotton towel) – as a precaution.

REVIEW

✓ Chemistry

✓ Ages 11–14

This article is a great opportunity for teachers to connect lessons with the children's everyday experiences. It combines exciting activities with a final discussion about safety; I like the fact that the article is based on learning about fire safely. Furthermore, the final activity makes the article suitable for discussions relating to the limits and dangers of chemistry and science, and their application in real life.

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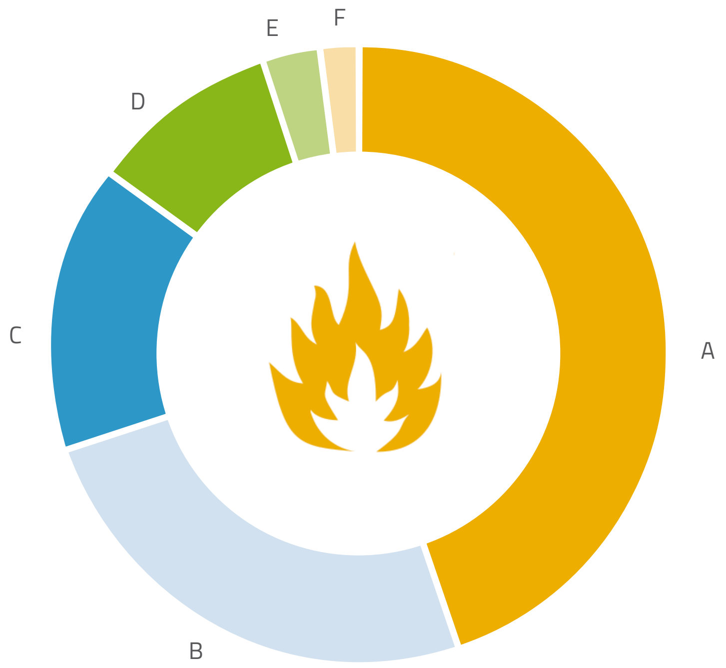

Figure 1: Students' associations with the word 'fire'. A: Heat; B: Burning; C: Campfire; D: Flames; E: Part of our environment; F: Matches

Images courtesy of Emilia Grygo-Szymanko

Figure 2: Materials for activity 1

Figure 3: The bank note is first dipped into water.

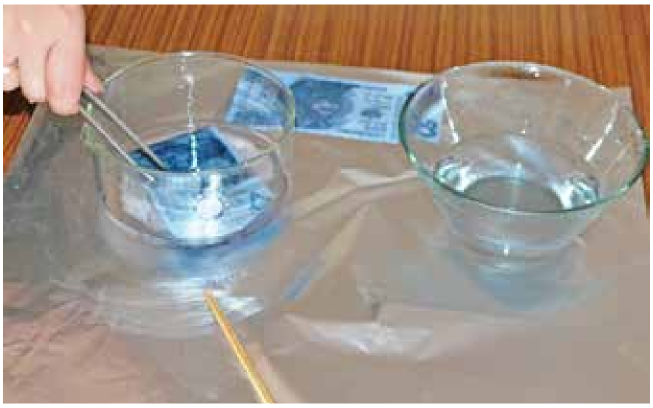

Figure 4: The bank note is then dipped into the methylated spirits.

Figure 5: A burning match is held to the edge of the bank note.

Procedure

This activity should be carried out by the teacher as a demonstration.

Safety note: Safety glasses, a lab coat and gloves should be worn. Special care should be taken with the open flames and when handling the methylated spirits to avoid causing a fire.

1. Place two crystallising dishes on the fireproof surface. Fill one with about 50 ml of water and the other with 50 ml of methylated spirits (figure 2).
2. Add the salt to the dish containing the methylated spirits and stir until the mixture is clear.
3. Pick up the bank note with metal tongs. Dip it first into water so that it is fully immersed for a few seconds (figure 3).
4. Shake off any excess water, and then dip the note into the methylated spirits (figure 4). Move away from the dish containing the methylated spirits to avoid the risk of igniting the alcohol vapour in the next stage.
5. Still holding the note with tongs, quickly (and very carefully) put the burning match to the corner of the bank note and let it burn (figure 5).
6. Once it stops burning, ask the students to check the note. Did it burn away? Was it damaged at all?

Discussion

After the experiment, ask the students to discuss among themselves in groups what happened. Encourage them to come up with their own ideas, using a worksheet[w2] or the following questions:

- Did the note burn?
- If not, why not? (Water moistened the bank note, preventing it from burning. Alcohol is more volatile than water; the methylated spirit vapour burns just above the surface of the paper.)
- What colour were the flames – and why? (The yellow flame indicates the presence of sodium from the salt.)

Then discuss the students' ideas as a class, guiding them if needed to the correct explanations.

Activity 2: Making a chemical fire extinguisher

This activity is carried out by the students under teacher supervision. There are two variations: in the simpler one (version 1), we produce carbon dioxide

in a beaker and then find that it will extinguish a lighted match or candle placed in the beaker. In version 2, we tip the carbon dioxide over the flame – an action similar to that of using a fire extinguisher to put out a fire.

Safety note: Safety glasses, a lab coat and gloves should be worn, and the activity should be carried out in a well-ventilated area. Special care should be taken with the open flames and when handling the methylated spirits to avoid causing a fire. Students should be reminded how to work safety with flames, and what to do with the hot remains after the experiment.

Materials

- One beaker (version 1) or three beakers (version 2)
- Candle
- Matches
- 20–50 g baking soda (sodium hydrogen carbonate, $NaHCO_3$)
- 25 ml of 10% white vinegar

Procedure

1. Place the baking soda in a beaker.
2. Pour about 25 ml vinegar onto the baking soda (figure 6) – a vigorous reaction should take place.

Version 1

3. After the reaction has continued for a few seconds, carefully light a match or candle and hold the burning item in the beaker, above the liquid (figure 7). What happens?

Version 2

3. As soon as the reaction starts, place another beaker on top of the first and hold it in place, so that the gas produced in the reaction is trapped (figure 8).
4. When gas production in the bottom beaker stops, turn the top beaker upright and place it on a table. (The carbon dioxide will stay inside because it is heavier than air.)
5. Light a candle and place the burning candle in the third beaker. Then tip up the seemingly empty second beaker, which contains the gas, so that the invisible gas flows into the beaker with the burning candle (figure 9). What happens?

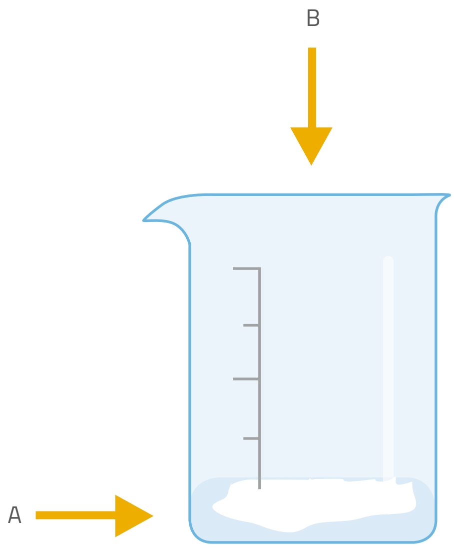

Figure 6: Baking soda (A) is placed in a beaker, followed by vinegar (B).

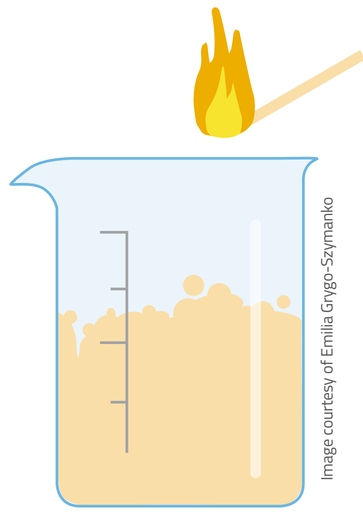

Figure 7: A match is placed over the beaker.

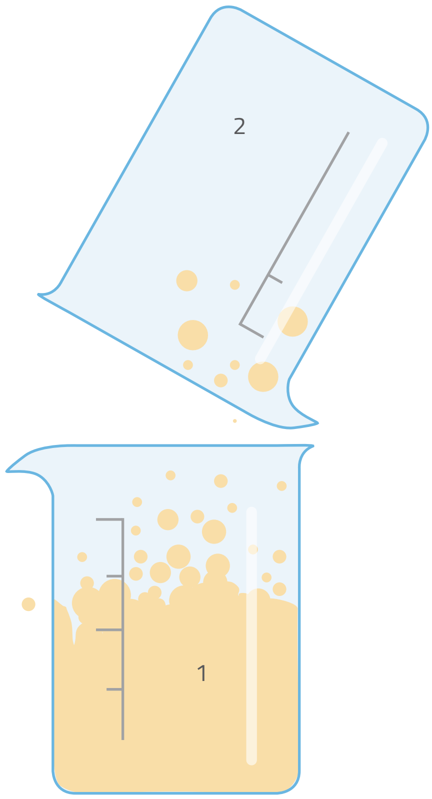

Figure 8: Holding a second beaker on top traps the gas produced.

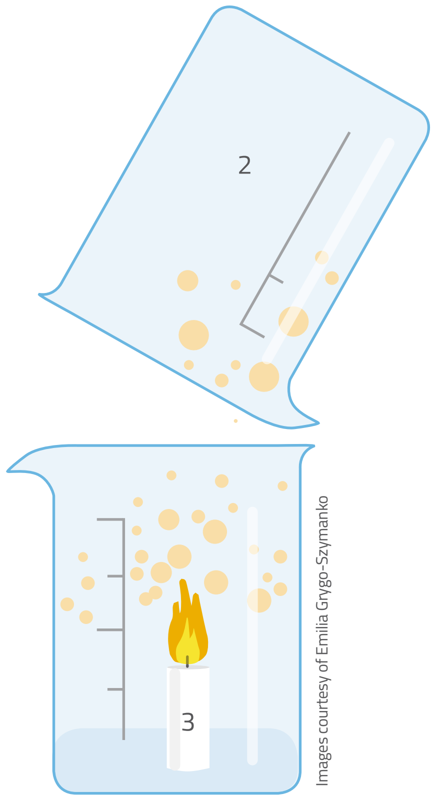

Figure 9: Pour the invisible gas onto the burning candle.

Discussion

Ask the students to discuss among themselves in groups what happened (in either version of the experiment). Prompt them with questions such as:

- What happened to the candle or match flame – and why?
- What gas is produced in the reaction?
- Why does the gas stay in the beaker and not escape?

Use a worksheet[w2] to provide a structured approach to these questions, guiding students to the correct explanation.

The gas produced in the reaction of baking soda with vinegar is carbon dioxide (CO_2):

$$NaHCO_3 + CH_3COOH \rightarrow CH_3COONa + H_2O + CO_2$$

Carbon dioxide is heavier than air, so it stays in the beaker. It also does not support combustion – in fact, it prevents oxygen from reaching the flame, which is needed to sustain burning, so the flame goes out. The fact that carbon dioxide is heavier than air also means it can be 'poured' from beaker to beaker.

Carbon dioxide can also be dangerous for humans and other animals, when it occurs in higher concentrations or in an enclosed space (which is why it is necessary to carry out this experiment in a well-ventilated area). This is not simply because we need oxygen to breathe, but also because our bodies sense carbon dioxide levels and use this to regulate breathing – so an atmosphere containing just one per cent carbon dioxide can interfere with this mechanism. But carbon dioxide is also useful: plants use carbon dioxide, water and light for photosynthesis, which produces oxygen and enables plants to grow.

Activity 3: How to stay safe

The aim of this final activity is to raise students' awareness of the risks associated with fire. Topics to cover include:

- Everyday items or activities that cause the main fire risks
- How to prevent fires at home and outdoors
- How to put out a fire (types of fire extinguishers and how to use them)
- What to do in the event of a fire (important fire-fighting dos and don'ts)
- What to do if someone gets burned (important first-aid dos and don'ts)

We suggest starting with an initial teacher-led discussion, followed by students carrying out Internet research in groups. Each group can tackle one of the questions above (or similar questions), creating a poster or a presentation to show the rest of the class.

It is also worth considering inviting a guest speaker – ideally a fire-fighter or a first-aid provider trained in dealing with burns. As well as providing information, this will underline the fact that fires really do happen – and while we rely on trained experts when things go wrong, it's up to all of us to help prevent fires from happening in the first place.

Web references

w1 To see the world fire statistics from The Geneva Association, visit: www.genevaassociation.org/media/874729/ga2014-wfs29.pdf

w2 The worksheets for activity 1 and two are available to download from the *Science in School* website. See: www.scienceinschool.org/2016/issue38/fire

Resources

For an explanation of how fire extinguishers work and how to use them, see: http://home.howstuffworks.com/home-improvement/household-safety/fire/question346.htm

For ideas for some CO_2-related activities, see:
Rau M (2011) Fizzy fun: CO_2 in primary school science. *Science in School* **20**: 24-29. www.scienceinschool.org/2011/issue20/co2

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