Image courtesy of craftvisioncraftvision / iStockphoto

Fizzy fun: CO_2 in primary-school science

Marlene Rau presents some fizzy and fun activities involving carbon dioxide, developed by Chemol and Science on the Shelves.

One of the El Tatio geysers in the Chilean Andes

Image courtesy of ecololo; image source: Flickr

Introduction

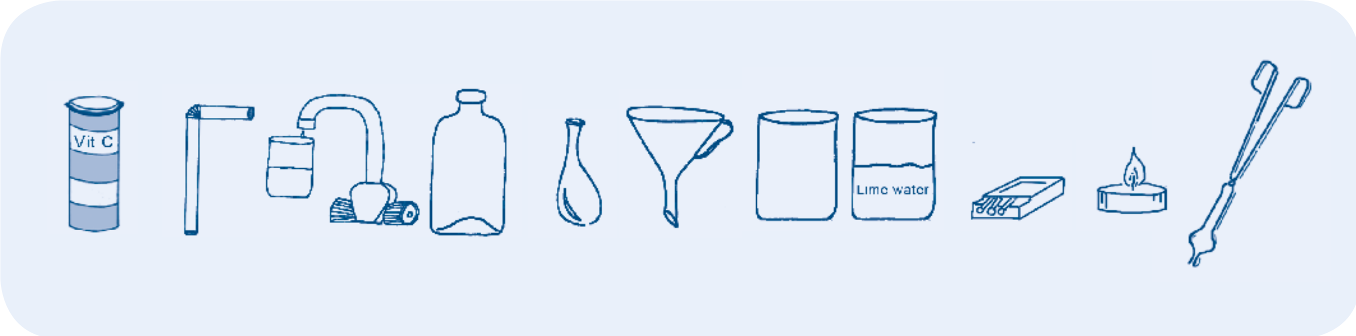
Carbon dioxide (CO_2) is not only one of the most important greenhouse gases, it is found all around us: in the air (0.0388 vol%) we breathe; in the air we exhale (4 vol%); in fizzy drinks; in cakes, which rise thanks to the CO_2 produced by baking powder; and when organic compounds such as paraffin, paper, wood or petroleum are burned. In liquid form, it is used in fire extinguishers and as a refrigerant in the food industry (for example to store and transport ice cream).

In high concentrations, CO_2 can become dangerous for humans and other animals, but it is also the source of life: during photosynthesis, plants use CO_2 and light to produce sugar, starch, fats and proteins, as well as the oxygen we need to survive.

The following teaching activities from Chemol[w1] and Science on the Shelves[w2] (see box on page 26) introduce primary-school children to this important gas. To support the activities, more background information on the chemistry, physiological importance, detection and occurrence of CO_2 is available on the *Science in School* website[w3].

Note: the amounts of carbon dioxide produced in these activities are not high enough to be dangerous.

Image courtesy of Chemol



Fizzy balloons

When you add water to effervescent (fizzy) tablets or baking powder, bubbles are formed: a gas is produced. You can use this gas to inflate a balloon without blowing it up yourself. What kind of gas is it? Let us collect and analyse it.

Materials

- Balloons
- A funnel
- Effervescent tablets (e.g. vitamin C tablets) or baking powder
- A transparent 500 ml bottle
- Water
- Beakers
- A tea light
- Matches
- A pair of tongs (or a wooden skewer)
- Lime water: mix a spoonful of cement or mortar with about 250 ml water. Let the suspension settle, then filter it using two paper coffee filters. The filtrate is lime water.
- A thick drinking straw

Procedure

The first six steps are common to both activities – then you have two options as to how to proceed.

1. Blow up a balloon and let the air out again to make the rubber more elastic.
2. Use the funnel to fill the balloon with a packet of baking powder (20 g) or five crushed effervescent tablets.
3. Pour 2-3 cm of water into the bottle.
4. Cover the bottleneck with the balloon and tip the baking soda / effervescent tablets into the bottle. You may need to hold the balloon onto the bottleneck to prevent it from slipping off.
5. Shake the bottle lightly. The balloon fills with a gas that is produced in the effervescence.
6. When the balloon has stopped inflating, twist it shut so that no gas can escape and pull it off the bottle.

Image courtesy of craftvisioncraftvision / iStockphoto

REVIEW

- ✔ **Chemistry**
- ✔ **Physics**
- ✔ **Biology**
- ✔ **Earth science**
- ✔ **Environmental studies / ecology**
- ✔ **Maths**
- ✔ **Ages 8-14**

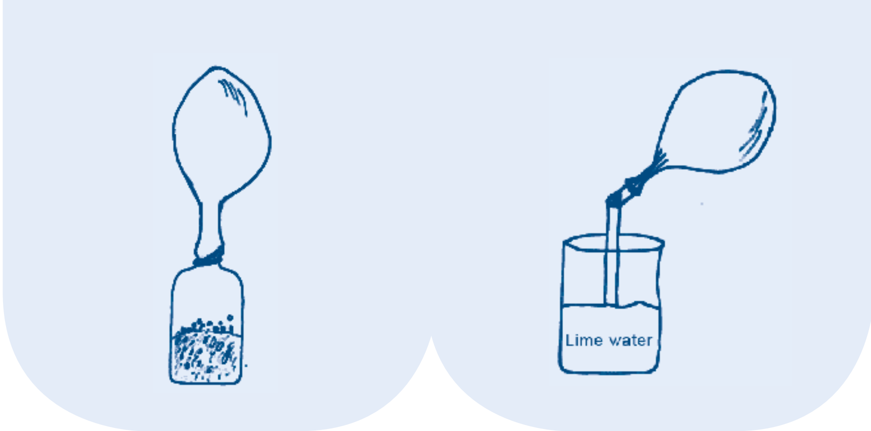
This article offers simple ways to unravel science mysteries. It helps everyone understand natural phenomena and facts, both everyday (breathing) and occasional (volcanic activity). It can inspire the class to develop further hands-on experiments. Both at a global level (climate change) and at a much smaller one (experiments), it allows students to realise that dangers exist and that it is necessary to take measures to avoid them.

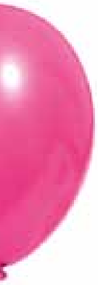
The article can be linked to current events or local natural phenomena such as Icelandic volcano eruptions or geothermal pools. It may also contribute to the awakening of a more ecological conscience. Interdisciplinary links can be made between environmental and ecological issues in chemistry and physics, biology (breathing), earth sciences, maths (measures and proportions) and literacy (instructions and rules).

Younger children will love the fizzy balloons and geysers; I would reserve the more explosive activities for the older students.

Maria João Lucena, Portugal

Image courtesy of Chemol





A) What kind of gas is it?

7. Put some lime water into a beaker.
8. Place the drinking straw into the mouth of the balloon, then slowly and carefully release the gas from the balloon into the lime water. The lime water will become cloudy.

Safety note: If you get lime water into your eyes, rinse them immediately with water. See also the *Science in School* general safety note on page 65 and on our website (www.scienceinschool.org/safety).

The lime-water test to detect CO_2 was developed by chemist Joseph Black (1728–1799). Both cement and mortar contain calcium hydroxide ($Ca(OH)_2$). When CO_2 is added to aqueous $Ca(OH)_2$, very small particles of calcium carbonate ($CaCO_3$) are produced; this is what makes the lime water cloudy.

Where did our CO_2 come from? Both baking powder and effervescent tablets contain sodium bicarbonate ($NaHCO_3$) and a solid acid (such as citric acid crystals or monocalcium phosphate). In contact with water, sodium bicarbonate and the acid react with one another, ultimately forming water and CO_2. This gas is what forms the bubbles when a fizzy tablet dissolves; it is also what makes cakes rise.

B) The gas is heavy

7. Hold the mouth of the balloon into a beaker and let the gas flow out. You cannot see anything, but we will see whether anything has happened. Put the beaker to one side.
8. Light a tea light and use a pair of tongs to place it in a second, empty, beaker (alternatively, you could stick the wooden skewer into the wax and use that to lift the tea light into the beaker). It should continue to burn.
9. Now place the tea light in the first beaker, which contains the gas from the balloon. What happens?

The candle should stop burning because the gas (CO_2) will choke the flame.

10. Repeat steps 1-7 to collect more CO2 in a beaker. Now pour the invisible contents of this beaker into yet another empty beaker. Place a burning tea light into this beaker. What happens?

BACKGROUND

The sources of these and other activities

Chemol

Chemol[w1] is a project based at the University of Oldenburg, Germany, to bring primary-school children into contact with chemistry. The team, which includes trainee teachers and is led by Dr Julia Michaelis, offers workshops for children on the topics of fire, earth, air and water, as well as training for primary-school teachers.

Further Chemol activities about carbon dioxide include building your own CO_2-based fire extinguisher, experimenting with carbonated drinks, measuring how much gas is produced by one effervescent tablet, and testing the effect of temperature on the solubility of CO_2 in water. Details can be found on the Chemol website[w1].

Science on the Shelves

Science on the Shelves is a website[w2] providing instructions for a wide range of simple science experiments using food and other supermarket products, suitable for 6- to 11-year-olds and their teachers and families. The UK-based project, coordinated by Dr Nigel Lowe, is a collaboration between the University of York and the Engineering and Physical Sciences Research Council. If you have ideas for great experiments, Nigel is waiting to hear from you.

@ EIROforum

Carbon dioxide at the workplace – on Earth and in space

Carbon dioxide can be a hazard if it builds up in sufficiently high concentrations. To monitor this and hazardous gases in the workplace, EFDA-JET[w4] uses a variety of instruments, both handheld and installed in buildings, to detect gases that lower the oxygen concentration and can thus lead to asphyxiation. The monitored gases include not only carbon dioxide and other cryogenic gases such as helium, but also nitrogen (used for fire suppression), sulphur hexafluoride (SF_6, an electrical insulation gas) and the vapour of liquid coolants such as Galden®. Before working in areas where these gases are a hazard, staff must check the installed instrumentation or request a measurement with a handheld instrument to confirm that the atmosphere is safe.

Carbon dioxide is also a potential hazard 350 km above Earth's surface – for astronauts aboard the International Space Station (ISS), a collaboration between the European Space Agency (ESA)[w5] and other international partners. When humans breathe, they consume oxygen and produce carbon dioxide. As a result, in closed habitats such as submarines, aeroplanes and the ISS, oxygen levels will fall and carbon dioxide will accumulate, endangering the crew (as described in the film *Apollo 13*). Levels of both gases there need to be regulated.

Currently, the ISS uses an open approach: trapping carbon dioxide in specific gas traps (e.g. lithium hydroxide, LiOH, which combines with CO_2 to form lithium carbonate and water), and transporting bottles of oxygen from Earth. In future, the ISS will use a closed, recycling approach: recovering O_2 from CO_2, using either physico-chemical techniques (essentially 'cutting' the oxygen part from carbon part) or algae and other plants (photosynthesis).

EFDA-JET and ESA are members of EIROforum[w6], the publisher of *Science in School*.

Again, the flame is extinguished, showing that we were able to pour the gas from one beaker to another, as though it were a liquid. This demonstrates that CO_2 is heavier than air.

Making your own sherbet or fizzy drink

Mix 3 spoonfuls of sodium bicarbonate with 1 spoonful of citric acid crystals (food grade). To improve the flavour, add either 2-4 spoonfuls of icing sugar or 1 spoonful of instant jelly powder and 1 spoonful of sugar. Your sherbet is ready to taste.

The citric acid crystals dissolve on your tongue and react with the bicarbonate of soda. This produces bubbles of carbon dioxide gas, which cause the fizzing feeling on your tongue. To make a fizzy drink, mix the sherbet with water.

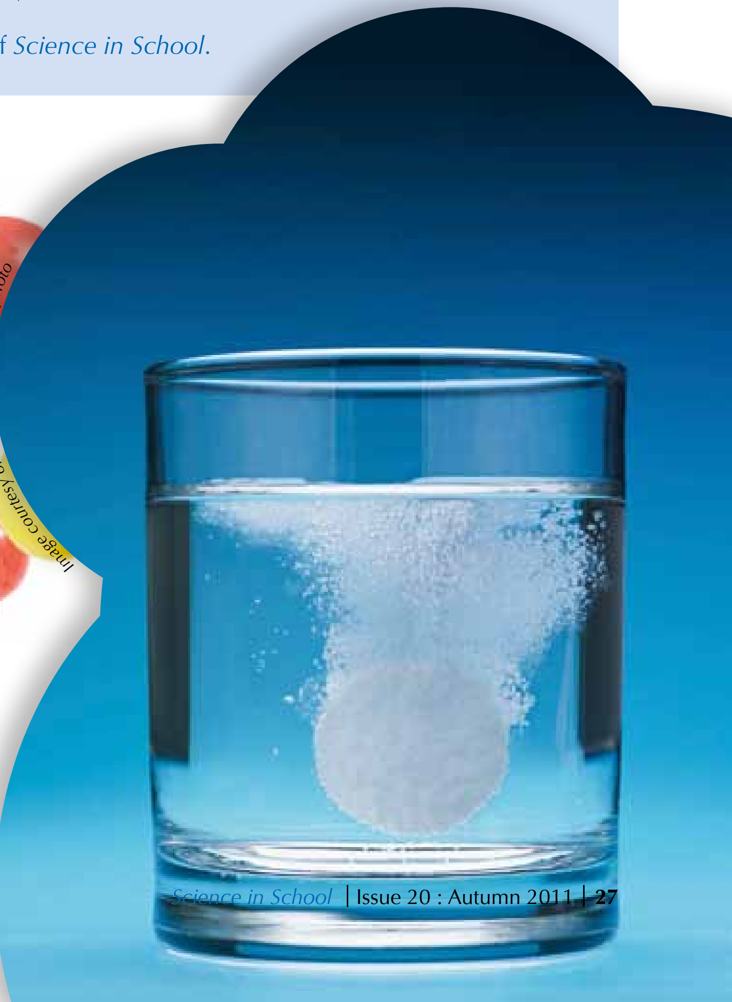


Image courtesy of diego_cervo / iStockphoto

Image courtesy of Eleanor Hayes

Plastic bottles with retractable nozzles

Fizzy explosives

Rockets and explosives work by generating huge volumes of gas in a short time. You can create your own rockets using citric acid and baking soda or effervescent tablets.

Safety note: the following experiments produce high-speed projectiles. Follow all the safety guidance below and wear safety goggles. Perform all the experiments outside, as they make a mess. See also the *Science in School* general safety note on page 65 and on our website (www.scienceinschool.org/safety).

The fizzy cannon

Materials

- An empty tube (with lid) from effervescent tablets, or a small plastic photo film canister; this will be your cannon
- An effervescent tablet, or baking soda and citric acid crystals
- Water
- A transparent plastic tube or glass in which the tube or canister can stand upright; this is your launch pad

Procedure

1. Pour about 2 cm of water into the tube or film canister, then add the effervescent tablet; alternatively, mix about ¼ teaspoon each of baking soda and citric acid crystals in the tube and add a few drops of water.
2. Quickly snap the lid on, place the cannon into the launch pad and stand well clear (at least 1-2 m away).

Image courtesy of Chemol

Safety note: Never allow anyone to look over the top once the cannon is 'charged'. If it fails to go off (as it does sometimes if the lid is not airtight), open it very carefully, keeping your face turned well away.

When the citric acid crystals and baking soda dissolve in water, they react with one another to produce carbon dioxide gas. Effervescent tablets already contain both ingredients (sodium bicarbonate and an acid), which will react with one another when water is added. The resulting gas expands, pressing on the walls and lid of the cannon. When the pressure becomes stronger than the weakest point of the surrounding wall (the lid), the cannon will explode dramatically, with the lid shooting up to 5 m into the air, releasing the gas.

3. Replace the lid and repeat the experiment.

Time how long it takes for the lid to come off and then experiment with quantities: for example, try to get the lid to come off after exactly 1 min.

The cold-water geyser in Wallenborn, Germany

Image courtesy of Sonja Pieper; image source: Flickr

The CO_2 geyser

Geyser comes from the Old Norse word *geysa*, meaning gushing. First used for The Great Geysir, a hot spring in the Haukadalur valley, Iceland, which hurls boiling water up to 70 m into the air, the term is now used more generally for springs with intermittent, jet-like eruptions of water. As well as geysers powered by boiling water, there are also cold geysers, powered by CO_2. Rising from the depths of Earth, the gas collects at the bottom of a subterranean water reservoir and builds up pressure. This is regularly released in form of a fountain of cold water. There may

be one closer to your home than you think – for example in Herl'any, in Slovakia, or in Wallenborn and near Andernach, in Germany.

If not, you can build one yourself. Place 200 ml water in a plastic bottle with a retractable nozzle (for example, one that contained washing-up liquid; see image on page 28), add a heaped teaspoon of sodium bicarbonate and mix well. Add about 35 ml washing-up liquid and shake again. Using a funnel, rapidly add three heaped teaspoons of citric acid crystals. Very quickly, screw the closed nozzle onto the bottle, shake briefly and pull the nozzle up to open it.

A foam fountain up to 5 m high will shoot into the air. Alternatively, you can wait until the nozzle pops open by itself. Either way, after a short while, the pressure will be released and the fountain will stop. Close the bottle by pressing the nozzle down; about 30 seconds later, the pressure will again be high enough to start the geyser. You can repeat this several times.

Web references

w1 – For more information on Chemol (in German), see: www.chemol.uni-oldenburg.de

w2 – To find out more about Science on the Shelves, see: www.york.ac.uk/res/sots

w3 – For background information on CO_2, see: www.scienceinschool.org/2011/issue20/co2#resources

w4 – Situated in Culham, UK, JET is Europe's fusion device. Scientific exploitation of JET is undertaken through the European Fusion Development Agreement (EFDA). To learn more, see: www.jet.efda.org

w5 – ESA is Europe's gateway to space, with its headquarters in Paris, France. For more information, see: www.esa.int

w6 – To learn more about EIROforum, see: www.eiroforum.org

Resources

For variations on fizzy rockets, see:

de Vries T (2002) Vitamintabletten einmal anders. *Chemkon* **9(3)**: 144-146. doi: 10.1002/1521-3730(200207)9:3<144::AID-CKON144>3.0.CO;2-K

The Portuguese Pollen project has developed a downloadable booklet of science teaching activities with food (*The Fun-Flavoured Way to Learn Science*), available in English and Portuguese. See: www.cienciaviva.pt/projectos/pollen

Norwegian chemist Erik Fooladi offers a set of experiments comparing the chemistry of baking soda, horn salts and baking powder in Christmas cakes on his website of gastronomic science activities (in Norwegian). See www.naturfag.no or follow the direct link: http://tinyurl.com/3spkkwm

For primary-school teaching activities with carbon dioxide and oxygen, on the topic of climate change, see:

Johnson S (2008) Planting ideas: climate-change activities for primary school. *Science in School* **10**: 55-63. www.scienceinschool.org/2008/issue10/psiclimate

In this issue, you will find a positive approach at climate change – what we can realistically do to stop it:

Shallcross D, Harrison T (2011) Is climate change all gloom and doom? Introducing stabilisation wedges. *Science in School* **20**: 60-64. www.scienceinschool.org/2011/issue20/wedges

If you enjoyed reading this article, why not browse the full collection of *Science in School* articles for primary-school teachers? See: www.scienceinschool.org/primary

You may also be interested in our series on climate change. See: www.scienceinschool.org/climate

Dr Marlene Rau was born in Germany and grew up in Spain. After obtaining a PhD in developmental biology at the European Molecular Biology Laboratory in Heidelberg, Germany, she studied journalism and went into science communication. Since 2008, she has been one of the editors of *Science in School*.

To learn how to use this code, see page 65.

Image courtesy of Chemol