The combustion of stoichiometric hydrogen–oxygen mixtures – technician notes

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A quick demonstration to show the dramatic impact of mixing chemicals in correct proportions

Kit

For the bubble mixture

- Deionised water
- Washing-up liquid
- Glycerol (propane-1,2,3-triol)

For the production of hydrogen and oxygen

- Source of hydrogen and oxygen, eg gas cylinder/Mattson gas microscale gas preparation kit (see below)
- 3 cm^3 20 vol hydrogen peroxide (irritant)
- 0.05 g potassium iodide
- 3–5 cm^3 of 1 M hydrochloric acid
- 0.05 g magnesium powder (flammable)

For the demonstration

- Bubble mixture
- Syringe of H_2 (extremely flammable)
- Syringe of O_2 (may cause or intensify fire)
- 10 cm^3 syringe
- Syringe cap, sticky tack, or small section of silicone tubing with a Hofmann clamp
- Petri dish or similar
- Wooden splints for lighting
- Eye protection
- Ear plugs/ear defenders

Health and safety

CLEAPSS members should consult SRA027.

The audience should be two metres away and instructed to cup their hands over their ears. The demonstrator should wear ear plugs/ear defenders.

Although hydrogen–oxygen combustion may sometimes be demonstrated at the party balloon-scale in large lecture theatres, the smaller spaces in school laboratories are likely to lead to sound levels that could cause hearing damage. Do not deviate from the above protocol or exceed the volumes stipulated.

Both audience and demonstrator should wear eye protection.

Preparation

For the bubble mixture, mix together deionised water, washing-up liquid and glycerol (propane-1,2,3-triol) in a roughly 85:10:5 ratio by volume.

Wear eye protection.

A hydrogen syringe and an oxygen syringe can be preloaded from gas cylinders, a Hofmann voltameter, an Andrews gas generator, or produced in-situ using the Mattson technique (illustrated in a previous Exhibition chemistry, Lighting up oxygen; also see Bruce Mattson's free online book Microscale gas chemistry chapter 1 and the video above). Gases can be sealed inside with either a syringe cap or sticky tack.

Connect the syringes of gas one at a time to the 10 cm3 syringe with tight-fitting silicone tubing and push/pull the plungers to draw in 6 cm3 of hydrogen and 3 cm3 of oxygen.

In front of the class

Position the audience two metres away. Both audience and demonstrator should wear eye protection. Fill a Petri dish or similar vessel (see tips box below) with bubble mixture. Keep loaded syringes at least two metres from the dish when not in use.

First demonstrate the effect seen by igniting pure hydrogen for comparison. Slowly bubble approximately 10 cm3 of gas from the pure hydrogen syringe into the solution and remove the syringe to a two-metre distance before igniting the bubbles with a lit splint. The gas will burn unimpressively with a pale orange flame and a very dull pop. You could also demonstrate that a bubble of oxygen alone will visibly intensify the flame of the lit splint.

Now warn the students that the next mixture will produce a loud bang and that they should cup their hands over their ears. The demonstrator should wear ear plugs or ear defenders.

Slowly bubble the contents of the 10 cm3 syringe into the bubble solution and light with a splint at arm's length. The gases will burn with a loud report.

Top tip

One potential source of frustration with this demonstration is blowing the bubbles in the Petri dish and having them pop before you can light them. Improve your chances by making up the CLEAPSS bubble mixture recipe described above rather than working with shop-bought bubble mixtures. Connecting a Pasteur pipette to the end of the syringe with a small section of tubing will allow you to generate a raft of smaller bubbles which tend to be more stable than fewer large ones. A plastic tealight holder makes a nice substitute for a Petri dish, plus the narrower vessel with taller sides gives a surface to support the bubbles' structure from the side and keep them in one place as you inflate them.

Teaching goal

In a previous Exhibition chemistry, Eggsplosive chemistry, we saw how changing fuel–oxygen ratios affected flame characteristics, leading to a cleaner burn until the explosive limit was reached. Hydrogen is explosive in mixtures with air ranging between 4–75% so the 'squeaky pop' test is quite forgiving, but this demonstration shows the dramatic impact chemists can have on the outcome of a reaction if they fully understand the reaction.