Demonstrations with dry ice

These notes accompany the video Demonstrations with dry ice: explore changes of state and neutralisation reactions from *Education in Chemistry* which you can view at: rsc.li/3WiEzw8.

These visually striking experiments demonstrate the sublimation of carbon dioxide and a colour-change neutralisation reaction accompanied by cloud-filled bubbles that spill a mist of water onto the desk. The final demonstration compares strong and weak bases and helps explain why indicators are not suitable for titrating weak acids with weak bases.

Curriculum links

Use demonstration 1 when teaching changes of state to learners aged 11–14. Use demonstrations 2 and 3 when teaching neutralisation reactions, pH changes and strong and weak acids and bases to your 14–16 learners.

Equipment

- 100 g dry ice (see tips)
- Safety glasses
- Insulating gloves (eg thick garden gloves, not rubber)

Demonstration 1

- Empty 500 cm^3 PET bottle made for carbonated beverages
- Rubber bung or cork to fit bottle
- Safety screens

Demonstration 2

- Large measuring cylinder (eg 500 cm^3 or 1 dm^3)
- Long stirring rod
- Universal indicator (DANGER highly flammable, eye irritant, harmful by ingestion)
- 20 cm^3 sodium hydroxide, 0.4 mol dm^{-3} (irritant)

Demonstration 3

- Two large measuring cylinders (eg 500 cm^3 or 1 dm^3)
- Two long stirring rods
- Universal indicator (DANGER highly flammable, eye irritant, harmful by ingestion)
- 500 cm^3 sodium hydroxide, 0.1 mol dm^{-3}
- 500 cm^3 ammonia, 0.1 mol dm^{-3}

Health, safety and disposal

- The demonstrations are unlikely to be covered by your employer's model risk assessments. CLEAPSS members can obtain a Special Risk Assessment (SRA 030) from them.
- Wear eye protection.
- If showing to a primary class do not seat them on the floor in case dropped pellets scatter towards them.
- Never seal bottles containing dry ice.
- Levels of carbon dioxide will remain safe in a well-ventilated lab, but do not leave dry ice in contained spaces like small store cupboards or fridges/freezers, where concentrations could rise to hazardous levels.
- Pour used solutions down a foul water drain.

In front of the class

Ensure students are 2–3 metres away from all demonstrations. Work in a well-ventilated space. Wear eye protection.

Demontration 1. Sublimation: solid carbon dioxide turns straight into a gas

Use safety screens to protect the audience and demonstrator. Use insulated gloves to place a couple of pellets of dry ice in an empty carbonated drinks bottle and insert a rubber bung (do not seal with the lid). A few moments later the bung will fly off with a pop. You can show the students that the pellets remain inside and there is no liquid present despite the gas pressure causing the bung to pop off.

Demonstration 2. A colourful neutralisation accompanied by cloud-filled bubbles

Three-quarters-fill a large measuring cylinder with tap water (see tips). Warm water is not essential but will make the cloud effect more dramatic. Add a splash of universal indicator to give a clearly visible green colour. Stir the indicator through and add a few millilitres of 0.4 M sodium hydroxide to turn the solution purple. Finally, use insulated gloves to add a handful of dry ice pellets. The pellets will sink to the bottom of the solution, cloud-filled bubbles will rise to the surface, spilling a mist of water over the desk. After a few moments the purple solution will turn green and then, after a delay, yellow and finally orange.

Demonstration 3. Behaviour of strong and weak bases

If you are exploring the difference between strong and weak acids and bases, repeat the demonstration above with two 0.1 M solutions of ammonia and sodium hydroxide of equal volume. Students might expect the two solutions to behave the same way but the weak base changes colour immediately and steadily moves through the full range of colours, while the strong base remains purple for some time before skipping through the shades of blue to go green. This highlights why indicators are unsuitable for titrating weak acids with weak bases.

Teaching goal

As the dry ice is dropped into the water, bubbles of carbon dioxide (CO_2) form from the sublimation of the dry ice. Water from the bulk solution evaporates into the bubbles but under the cold, humid conditions, a mist rapidly forms. The misting effect does not happen when water is replaced by an alcohol. Meanwhile, at the edge of the bubble, CO_2 dissolves into the water and a small amount reacts to form carbonic acid (H_2CO_3):

$$CO_2(aq) + H_2O(l) \leftrightharpoons H_2CO_3(aq)$$

Sodium hydroxide is a strong base. Essentially, all the hydroxide ions dissociate into solution when we add it to the tap water, and this causes the pH to shoot past 11 leading to a rapid change from green to purple. As hydrogen ions form in the solution following the addition of the dry ice and the dissociation of the carbonic acid, they react with the hydroxide ions, so the universal indicator changes from purple through to green. Eventually as more CO_2 dissolves, the solution becomes slightly acidic. Yellows and shades of orange can be seen but the high first pK_a (6.35) usually prevents the final change to red.

Tips

- You can buy dry ice online. In July 2024, a 2.5 kg pack costs around £33.
- Alternatively, you can make it yourself but use tap water: deionized water is likely to already be acidic due to dissolved carbon dioxide from the atmosphere.