

## Non-burning paper

These notes accompany the video demonstration **Non-burning paper: investigate the fire triangle and conditions for combustion** from *Education in Chemistry*, which you can view at: [rsc.li/4dWh18G](https://rsc.li/4dWh18G).

The Non-burning £5 note, once a classic chemistry demonstration, is no longer possible for most teachers. Modern polymer bank notes are completely unsuitable because of their hydrophobic surface. This alternative method offers an equally eye-catching way to explore the fire triangle and conditions for combustion, demonstrating evaporating water's ability to hold a material's temperature below its ignition point.

## Curriculum links

Use this demonstration when teaching the fire triangle and combustion to learners aged 11–16. You could also use it when teaching enthalpy of combustion and combustion of organic substances at post-16.

## Kit

- Filter paper (or water colour paper)
- Tongs
- 3 x heat-resistant mats
- 45 cm<sup>3</sup> ethanol or industrial denatured alcohol (IDA), (DANGER: highly flammable liquid and vapour, harmful)
- Water, 45 cm<sup>3</sup>
- 3 x 250 cm<sup>3</sup> beakers (diameter 7 cm)
- Bunsen burner
- Sodium chloride (optional)

## Preparation

1. Prepare and label three 250 cm<sup>3</sup> beakers: one containing 30 cm<sup>3</sup> of water; one containing 30 cm<sup>3</sup> of ethanol or IDA; and one containing a mixture of 15 cm<sup>3</sup> of each.
2. Place on a heat-resistant mat.
3. Set up a Bunsen burner well away from the beakers (at least 1 m) on its own heat-resistant mat.
4. Place the third mat near to the Bunsen in case you need to smother a flame.
5. If you are not doing the demo in a dimly lit room, add a spatula of sodium chloride to the alcohol-containing beakers to improve the visibility of the blue ethanol/IDA flame.

## Health, safety and disposal

Read our standard health and safety guidance, available from [rsc.li/4a0NS9J](https://rsc.li/4a0NS9J), and carry out a risk assessment before running any live demonstration.

- Wear eye protection.
- Clear the desk of any flammable material you are not using in the demonstration.
- Ethanol and IDA are dangerous – highly flammable liquid and vapour and may cause serious eye irritation. IDA is also harmful if swallowed and may cause damage to organs. CLEAPSS members should consult HC040A: [bit.ly/4e011Uj](https://bit.ly/4e011Uj)
- To dispose of leftover ethanol or IDA, dilute to 5% v/v and pour down a foul-water drain.



## In front of the class

Wear eye protection. Ensure the Bunsen burner is set to a yellow (luminous) flame. Use the tongs to soak one piece of filter paper in the water. Each time allow excess liquid to drip off into the beaker before moving it over the bench to the Bunsen. Pass the paper through the flame. The paper will not burn at all.

Repeat the process with another piece of paper dipped into the ethanol/IDA. This time the liquid ignites immediately. Keep holding the burning paper over the heat-resistant mat. After a few seconds the paper begins to burn.

When you soak a fresh piece of paper in the 50:50 alcohol-water mixture and you repeat the process, the liquid lights instantaneously but the paper is left unburned.

## Teaching goal

This demonstration illustrates the necessary conditions for combustion using the cooling power of evaporation. Although the enthalpy of vaporisation for both water and ethanol are significant due to hydrogen bonding (+44 and +39 kJ mol<sup>-1</sup> respectively), this pales in comparison to the enthalpy of combustion of ethanol, –1367 kJ mol<sup>-1</sup>. A portion of ethanol exposed to an ignition source will evaporate and combust at the air-fuel interface. The heat released will be sufficient to vaporise and combust more ethanol in turn. Although some cooling occurs in the evaporation, the flame heats the paper until it reaches its own ignition point at approximately 230°C.

Where sufficient water is present, the evaporative debt is not repaid. In theory there should be enough energy to heat, vaporise and still burn the paper. But most of this energy is lost to the room, not directed into the paper, which stays well below its ignition temperature.

### Tips

The appeal of this demonstration was always in its visual simplicity: with real money the stakes were clear. Therefore, there is great benefit from you creating your own story around it. Here are some ideas:

- Try drawing on the paper in pencil or an ink which is insoluble in both solvents.
- Or, cut words into the paper. The word 'hate' on the ethanol-only paper with the word 'hope' on the ethanol-water mix would be a good option.
- If you are using watercolour paper you have the option to run through a printer but do test that your printer ink is insoluble in both solvents first.
- You could decorate only the ethanol-water paper and use your school symbols, crest or colours.