# The photochemical reaction of hydrogen with chlorine

## *Introduction*

The majority of chemical reactions are initiated by heat, but this is not the only source of activation energy. For example, light provides the energy for the chemical reactions which take place during photosynthesis and the exposure of photographic film. Another light-initiated process is the spectacular, explosive reaction between the gases, hydrogen and chlorine.

## *What you will need*

### Chemicals

hydrogen, cylinder (we used the new 20 l disposable cylinders obtainable from Scientific & Chemical - see p12) **or**

sulphuric acid, 2M
zinc, granular

copper(II) sulphate solution, 1M

hydrochloric acid (concentrated)

potassium manganate(VII), crystals

### Equipment

chlorine generator, (Pyrex Büchner flask with dropping funnel and delivery tube running from side arm).

hydrogen generator, (Büchner flask with dropping funnel – all polypropylene).

trough of cold water.

aluminium foil or a UV-light absorbing brown plastic hood (e.g. the top section of a dark brown plastic cider bottle)

camera flash unit, old

stand, with boss-head and clamp

centrifuge tubes or similar, polycarbonate, 15 $cm^3$ capacity, 16 mm O.D.

fume cupboard

goggles, indirect vent

gloves, nitrile

ear protectors

safety screens, 2 (for front & back of experiment)

## *Generating the chlorine*

Cylinders of chlorine gas are not recommended for school use. Chlorine gas (Toxic & Dangerous for the Environment) can be generated in a fume cupboard by dripping concentrated hydrochloric acid (Corrosive), from a dropping funnel, into a Büchner flask containing potassium manganate(VII) crystals (Oxidizing, Harmful & Dangerous for the Environment). As this can be a very vigorous reaction, ensure that either the acid is dripped in slowly, or that a little water has first been added to cover the potassium manganate(VII) crystals, before the acid is added.

## *Generating the hydrogen*

If a cylinder is not available then hydrogen gas (Extremely Flammable) can be generated in a fume cupboard, or well-ventilated room, by the reaction between 2M sulphuric acid (Corrosive) and zinc granules. Polypropylene equipment should be used in the preparation as a safety precaution (see *Hazardous Chemicals* section of *SafetyNet* - website [1] and CD). Slowly add 2M sulphuric acid from a dropping funnel into a Büchner flask containing the granulated zinc, and maintain a steady stream of gas production. It is important to ensure that all of the air has been displaced from the flask before starting to collect the hydrogen. A dropping funnel is preferable to a thistle funnel as

the latter may allow air to be pushed into the flask upon the addition of more acid. To improve the reaction rate add some copper(II) sulphate solution to the flask.

## Preparing the gas mixture

Draw a line on the outside of the polycarbonate centrifuge tube with a permanent marker just under the half-volume position. Fill the centrifuge tube to the mark with chlorine gas by the downward displacement of water in the trough. Ensure that the lighting level is dim, before filling the rest of the centrifuge tube with hydrogen by the same method. Having a slight excess of hydrogen gas will minimize the amount of chlorine gas remaining after the reaction. Stopper the tube and cover with aluminium foil or a UV-light absorbing plastic hood. Filling the tube with the gases in this order will start the mixing process, and leaving the stoppered tube for a further five minutes allows the gases to thoroughly mix by diffusion.

## The demonstration

There are two methods for exploding the gaseous mixture. In both cases the container should be used only once:

**Method 1: Using an immobilised plastic tube (Fig. 1)**

Clamp the stoppered centrifuge tube between two safety screens with the mouth pointing in a safe direction, and at an angle to prevent damage or ricochets. A polycarbonate tube is safer than a glass tube, as it is less likely to shatter if undue force has been used to stopper the tube.

Place the flash unit directly behind the clamped tube. Make certain that the audience is at least three metres away, and warn them to cover their ears. Remove the cover from the tube and switch on the light source.

**Method 2: Using an immobilised rubber stopper (Fig. 2)**

This method uses a rubber stopper which is firmly screwed into a heavy wooden base, with a camera flash unit mounted next to the polycarbonate centrifuge tube.

Hold the covered polycarbonate centrifuge tube vertically. Quickly remove its stopper and push the mouth of the tube over the immobilized rubber stopper.

Arrange the safety screens on the audience and demonstrator sides of the apparatus, with the audience at least three metres away. Warn the audience to cover their ears before removing the cover from the centrifuge tube.

Trigger the flash unit, by remote control if possible, and the force of the explosion will project the centrifuge tube vertically into the air. This method should only be attempted indoors if the room has a high, solid, ceiling.

| Chemicals & procedures | Main Hazard | Control Measures |
|---|---|---|
| sulphuric acid (2M) | Corrosive | Wear nitrile gloves & indirect vent goggles. |
| hydrogen gas | Extremely Flammable | Check that there are no sources of ignition. |
| hydrochloric acid (concentrated) | Corrosive | Wear nitrile gloves and indirect vent goggles. |
| potassium manganate(VII) | Oxidising agent, Harmful & Dangerous for the Environment | Wear nitrile gloves and indirect vent goggles. |
| chlorine gas | Toxic & Dangerous for the Environment | Carry out preparation in a fume cupboard |
| Mixing of hydrogen and chlorine gases | Explosion | Prepare in dimmed light. Cover filled container with aluminium foil or UV-light absorbing brown plastic hood before transporting it. |
| Reaction of hydrogen and chlorine | High velocity impact<br><br>Noise | Use double safety screens and fire in a safe direction.<br><br>Demonstrator should use ear plugs, and audience must be told to protect their ears. |
| hydrogen chloride (reaction product) | Toxic & Corrosive | Use a well ventilated room |

**Table 1 -** Hazards and control measures

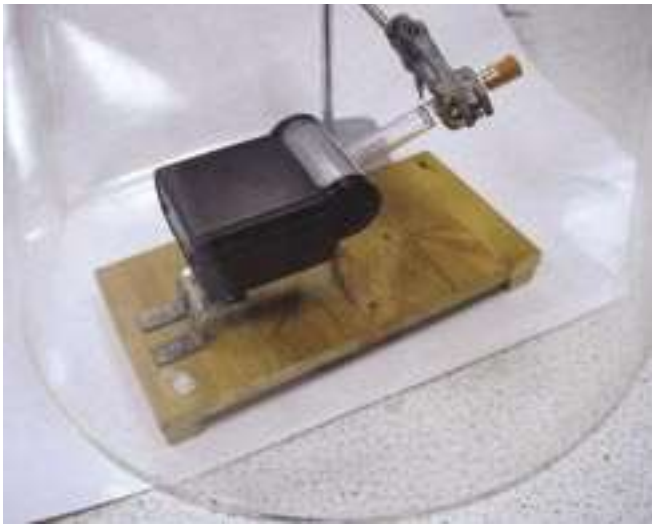

**Figure 1 -** Method 1 - Using an immobilised plastic tube.

The same apparatus could be used in the open air, with a wide exclusion zone, to explode larger volumes of the hydrogen – chlorine gas mixture using 100 $cm^3$ plastic bottles.

It has been found that some types of plastic mineral-water bottles are weakest at the base and will split or disintegrate, unless taped. (Figure 3).

For either method, if the gaseous mixture repeatedly fails to react, cover the tube and remove it to a safe place for later disposal in a darkened fume cupboard.

[1] - http://www.sserc.org.uk/members/SafetyNet/HazChem/NewHaz15/ETOL/CM/hydrogen.HTM

**Figure 2 -** Method 2 - Using an immobilised rubber stopper.

**Figure 3 -** Apparatus for larger-scale explosions of hydrogen & chlorine - only suitable for rooms with high ceilings or preferably in the open air.