



## 88. Catalysts for the thermal decomposition of potassium chlorate

### Topic

Reaction rates, catalysis.

### Timing

About 5 min to demonstrate catalysis, depending on the number of catalysts demonstrated. It will take about a further 10 min to demonstrate the recovery of the catalyst plus some time to allow the recovered catalyst to dry. The final weighing will probably have to be left until a subsequent lesson.

### Description

Potassium (or sodium) chlorate is heated in a test-tube and the time noted for enough oxygen to be produced to light a glowing taper. The heating is repeated with the addition of various oxide catalysts and the reduced time for the evolution of oxygen is noted. The water insoluble catalyst can be separated from the soluble chlorate salt and weighed to show that it is not used up.

### Apparatus

- ▼ Pyrex test-tubes about 150 mm x 15 mm – one for each catalyst to be shown plus one for the control.
- ▼ Bunsen burner.
- ▼ Retort stand with boss and clamp.
- ▼ Filter funnel.
- ▼ Conical flask, about 1 dm<sup>3</sup> to collect filtrate.
- ▼ Access to top pan balance and an oven.
- ▼ Watch glass, a little larger than the filter paper.
- ▼ Stopwatch or stopclock.

### Chemicals

The quantities given are for one demonstration.

- ▼ 5 g of **potassium chlorate** (potassium chlorate(V), KClO<sub>3</sub>). This is sufficient to demonstrate one catalyst plus a control. A further 2.5 g will be required for each additional catalyst. **Sodium chlorate** (sodium chlorate(V), NaClO<sub>3</sub>) may be used instead of potassium chlorate.
- ▼ 0.25 g of each catalyst to be used. Suitable catalysts include: **copper oxide** (copper(II) oxide), (CuO); manganese dioxide, (MnO<sub>2</sub>) ; iron(III) oxide, (Fe<sub>2</sub>O<sub>3</sub>); silica dioxide (silica gel, SiO<sub>2</sub>).
- ▼ Wash bottle of deionised water.
- ▼ Filter paper, eg Whatman no. 1.



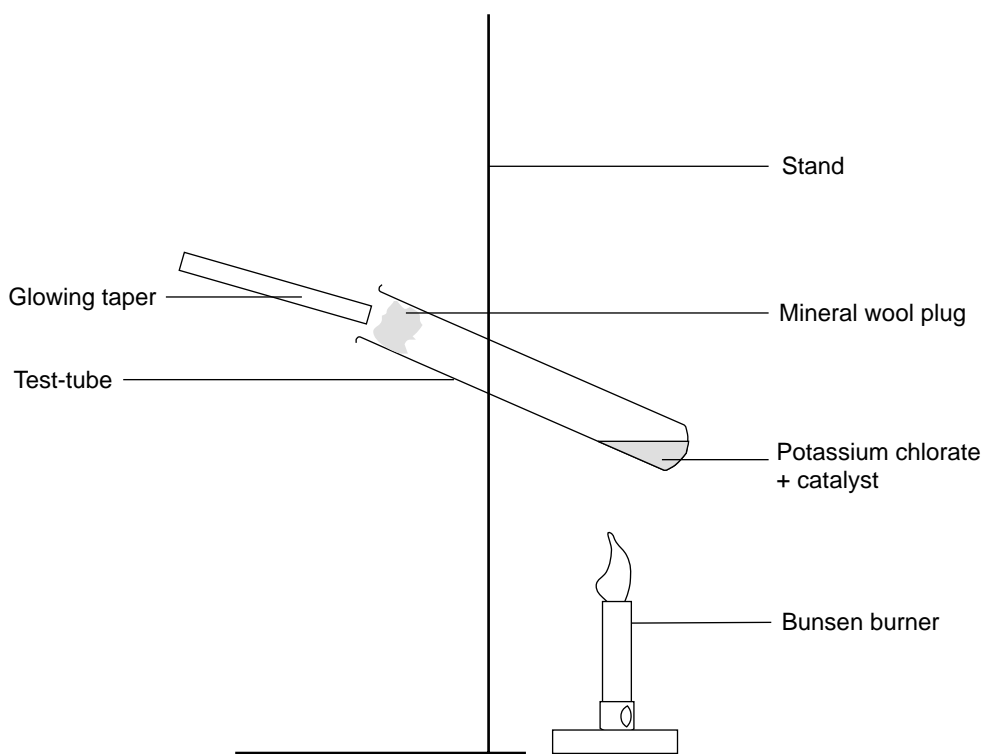
- ▼ Wooden tapers.
- ▼ A little mineral wool (optional).

## Method

### Before the demonstration

Set up a Bunsen burner and a stand and clamp so that a test-tube can be clamped at about  $45^\circ$  with its base about 5 cm above the burner (so that it will be about 2 cm above the tip of the blue cone of the flame when the Bunsen burner is on) – Fig. 1. It is worth doing a preliminary experiment to determine a suitable distance with the burner to be used. Mark the positions of the clamp and burner on the bench so that they can be replaced if disturbed accidentally.

Dry some filter papers in an oven if catalyst recovery is to be attempted.



**Fig.1 Effect of catalysts on the decomposition of potassium chlorate**

### The demonstration

Weigh 2.5 g of potassium chlorate into a test-tube and clamp the tube above the burner. Light the burner with gas fully on and air hole open. At the same time start the stopwatch. The solid will melt and begin to give off bubbles of oxygen as it decomposes. Hold a glowing wooden taper in the mouth of the tube until it re-lights. Note the time taken for the taper to relight. This will be about one minute. Turn off the burner.

Now weigh 2.5 g of potassium chlorate into a second identical test-tube, add 0.25 g of copper oxide catalyst and mix well. Clamp the tube as before, light the burner and start the stopwatch. Hold a glowing taper in the mouth of the tube and



note the time taken for it to re-light. This will be about one quarter to one third of the time taken without a catalyst.

Repeat the procedure with other catalysts as desired.

It is important that all details are kept the same between runs – the positioning of the tube and burner, the gas flow, the position of the glowing taper *etc.*

Demonstrate the solubility of potassium chlorate and the insolubility of the catalysts in water by shaking a little of each with water in test-tubes. Ask the students to suggest a method of recovering the catalyst to find out whether any of it has been used up.

### Catalyst recovery (optional)

Weigh one of the filter papers after they have been dried in the oven. Allow the tube containing the potassium chlorate and copper oxide to cool. Add a little distilled water to the tube and warm gently to dissolve the potassium chlorate. When it has dissolved, filter the contents of the tube through the pre-weighed filter paper, using a wash bottle and distilled water to ensure that all the contents are transferred. Wash the residue on the filter paper two or three times with distilled water to remove any potassium chlorate. Place the filter paper on a watch glass in an oven to dry. When dry (this may need to be the following lesson), re-weigh the filter paper and dry catalyst. With care and good technique, the weight of the recovered catalyst is within a few per cent of the initial amount used.

### Visual tips

Catalyst recovery is most obvious with the black catalysts, copper oxide and manganese dioxide.

A large stopclock is ideal.

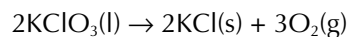
### Teaching tips

There are opportunities to discuss the factors that must be controlled to make the experiment a 'fair test'.

Teachers may prefer not to do the catalyst recovery part of the demonstration, leaving it as a 'thought experiment'.

### Theory

The overall reaction for the thermal decomposition is:



However, it takes place in the following steps:

formation of potassium perchlorate (potassium chlorate(VII))



decomposition of potassium perchlorate



It is possible to isolate the perchlorate if the heating is controlled carefully. See, for example, *Nuffield advanced science: chemistry, students' book 1*, p123. London: Longman, 1970.



## Extensions

Other oxides could be tried as catalysts.

Compare the effectiveness of the different catalysts.

Does the amount of catalyst make a difference?

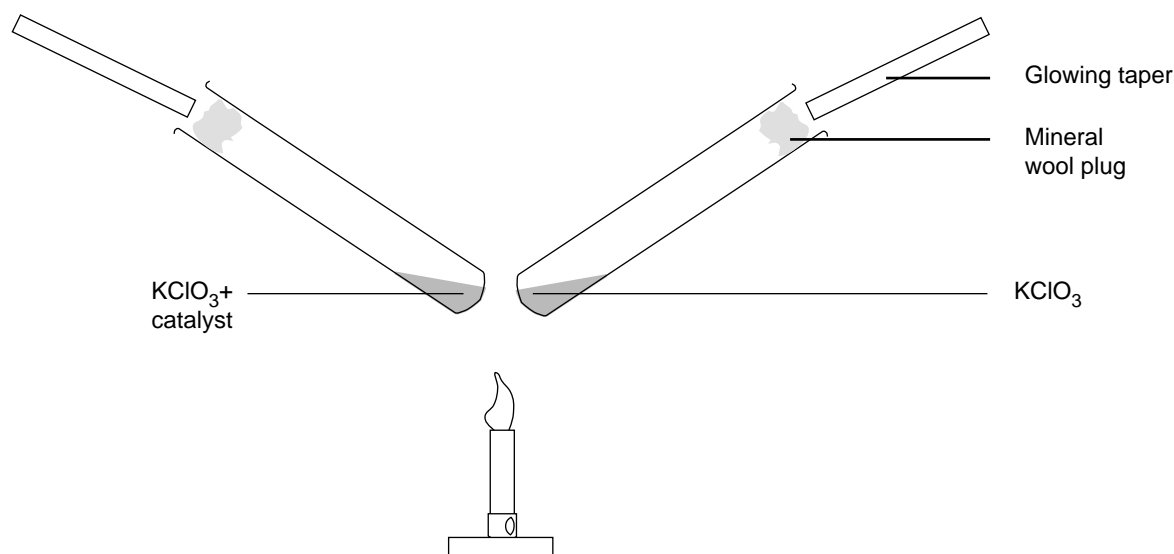
## Further details

An alternative set up would be to clamp two test-tubes above the Bunsen burner so that they are heated equally (*Fig. 2*). The catalyst and control tubes can then be done at the same time. This has a little more impact, but is more difficult to convince the audience that heating of the two test-tubes is equal.

Some teachers may prefer to use equimolar quantities of the catalysts rather than equal masses.

Both sodium chlorate and potassium chlorate react at similar rates.

There is very little difference in effectiveness between the catalysts suggested in this demonstration.



**Fig. 2** Alternative method for comparing catalysts

## Safety

Wear eye protection.

Avoid dropping the taper into the molten chlorate as this can react quite violently. A loose plug of mineral wool pushed about 1 cm down the test-tube can prevent this. This also ensures that the taper is held at the same position in each experiment.

It is the responsibility of teachers doing this demonstration to carry out an appropriate risk assessment.