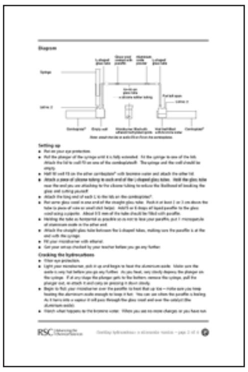
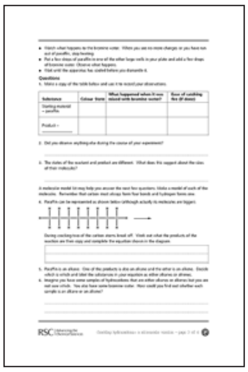
Cracking hydrocarbons: a microscale version

Index 2.5
4 sheets

Paraffin can be cracked to form ethene and a shorter alkane as a class practical. However, the safety concerns of many teachers and equipment shortages in some schools have meant that this key and interesting experiment is often performed as a demonstration. While there is much value in demonstrations as part of students' experience of chemistry, many prefer to do as much as possible hands-on. Microscale experiments offer a potential solution to the problem.

This experiment uses a far smaller quantity of chemicals than the traditional set-up and avoids the problem of suck-back of cold water into a hot tube. You may not wish to buy the microscale equipment for just this one experiment, but if you already have the comboplates® in your school or are considering purchasing some then this is a great way to use them. **The extraction of copper: a microscale version** in this resource also uses comboplates®.

The RSC sent the book Microscale Chemistry by John Skinner to all schools in 1996, along with a small trial kit. This book is available online at **http://www.chemsoc.org/networks/learnnet/microscale.htm** .

Acknowledgements

This experiment was developed by Jason Shirley of Microscalescience.com and is presented here with his permission.

Microscale equipment suppliers

Microscale equipment can be sourced on the Internet.

Phillip Harris has a range of suitable equipment.

http://www.philipharris.co.uk (accessed November 2005).

Equipment required

Per pair or small group of students:

- 2 comboplates®
- 1 x 10 cm^3 syringe

RSC | Advancing the Chemical Sciences

- 1 x 10–15 cm straight glass tube, approx 2–3 mm bore – must be narrow enough to allow the silicone tubing to expand over it
- 2 x L-shaped pieces of glass tubing – 5–6 cm in height, 2–3 cm long L piece and 2–3 mm bore
- 4 x 1–2 cm length silicone tubing – 3 mm bore, 1 mm wall
- 1 plastic pipette
- 1 microburner filled with ethanol
- 2 x lid number 2 for the comboplate® (with one long and one short port)
- Mineral wool
- Aluminium oxide – microspatula per group
- Liquid paraffin – about 0.5 cm^3 per group
- Bromine water (less than 1%) – about 3 cm^3 per group (**Harmful and Irritant**)
- Eye protection.

A molecular model kit such as a Molymod® or Orbit kit would be very helpful for students when answering the questions that follow the experiment.

Health and safety

- Eye protection should be worn at all times during this experiment, including during set-up and dismantling.
- Ethanol is highly flammable. The burner must be held upright to prevent spillage of any fuel and should be presented to students already filled.
- Care should be taken in handling glass tubes to ensure that they do not break and cut hands. The glass tube should be held near the end to which the silicone tubing is being attached to minimise the risk of breakage.
- Bromine water is toxic and corrosive at or above a concentration of 1%. A dilute solution shows the results well so a more concentrated one is not necessary. The dilute solution is harmful and an irritant.
- Allow all equipment to cool before dismantling.

Diagram

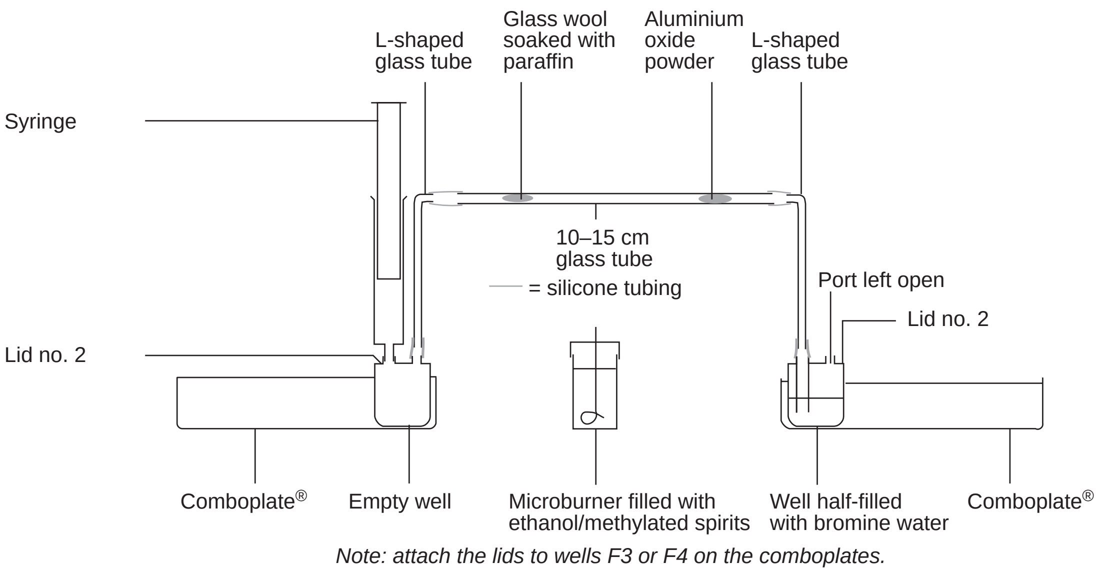


Figure 1 Apparatus for the experiment

Notes

- The equipment could be set up for the students if they are likely to find putting all the pieces together very difficult.
- As the hole and therefore the drop size of a pipette can vary, it is a good idea to trial this practical before the students do it to ensure that sufficient ethene is generated to discolour the bromine water. If the bromine water is dilute (0.1%) then this is less of a problem.
- The catalyst should be heated strongly initially. Once it is hot, the paraffin can be heated: the flame should remain under the catalyst and the occasional flick of the burner used to heat the paraffin – it is possible to see when the paraffin is boiling.
- Continual gentle depression of the syringe will ensure that no suck-back takes place and the gases flow through the system into the bromine water. When the syringe is empty, simply remove it, pull the plunger back, re-attach and continue depressing it.
- The disadvantage of this experiment is that it is not possible to collect enough product to fill a container and show that it is a gas at room temperature. However, at the end of the reaction any remaining ethene can be lit as it comes out of the open port hole on the lid over the bromine. This should be done with care, but an impressive 10–15 cm flame can be achieved. You could compare the behaviour of paraffin by trying to set fire to it. Put a few drops in a watch glass and attempt to light it using a splint NOT the microburner. It does not light easily. An extra column can be added to the table in the students' notes to allow for observations relating to this additional aspect of the experiment.

Timing

This experiment is far quicker than the traditional version. How long it takes a class will depend on how familiar they are with the microscale equipment, but students should be able to complete it easily within 30 minutes. This leaves time for the model-making and theory work in the same lesson.

RSC | Advancing the Chemical Sciences

Answers

1.

Substance	Colour	State	What happened when it was mixed with bromine water?	Ease of catching fire (if done)
Starting material – paraffin	Colourless	Liquid	No reaction	Does not catch fire easily, although it will make a lighted splint burn with a larger flame
Product – ethene/alkene	Colourless	Gas	Reacts and turns the bromine water from orange/ yellow to colourless	Burns easily and quickly

Table 1 Expected experiment results

2. Students may observe a second, liquid product towards the end of the tube. This is often mistaken for unreacted paraffin but is usually the smaller alkane product. It is sometimes yellowish in colour because it contains impurities.
3. The starting material is a liquid and the product a gas, which suggests that the reactant has larger molecules than the product.
4.

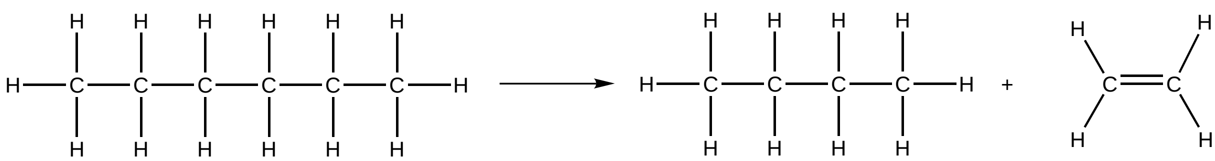


Figure 2 Equation for the cracking reaction

5. Alkane → Alkane + Alkene
6. Add a few drops of bromine water to a little of each sample. If there is no reaction it is an alkane, if the bromine water turns colourless it is an alkene.
7.

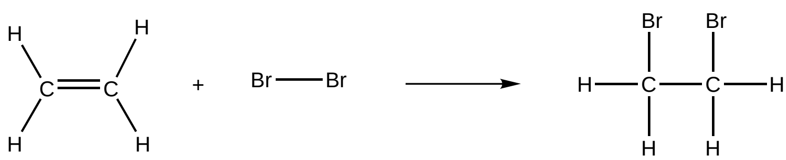


Figure 3 Reaction of bromine with an alkene

8. Alkanes do not react with bromine because they do not have a double bond. The double bond of an alkene can open up and allow other atoms to bond to the carbon atoms. As the carbon atoms in an alkane are each already bonded to four atoms, there is no room for any other atoms to attach.

Cracking hydrocarbons: a microscale version

A barrel of crude oil contains hydrocarbons of many different sizes. The exact composition of the crude oil varies depending on where it comes from, but most oil contains more of the larger molecules than the smaller ones. The smaller ones, however, are more useful and therefore more valuable. To increase the profit that can be made from a barrel of oil, the larger hydrocarbons are broken down into smaller ones. You are going to carry out a small scale version of this conversion, which is performed in industry every day.

What you need

- 2 comboplates®
- 1 x 10 cm^3 syringe
- 1 x 10–15 cm piece straight glass tube
- 2 x L-shaped pieces of glass tube
- 4 x 1–2 cm length of silicone tubing
- 1 plastic pipette
- 1 microburner filled with ethanol
- 2 x lid number 2 for the comboplate® (with one long and one short port)
- Mineral wool
- Aluminium oxide
- Liquid paraffin – about 0.5 cm^3
- Bromine water (less than 1%) – about 3 cm^3 (**Harmful** and **Irritant**)
- Eye protection.

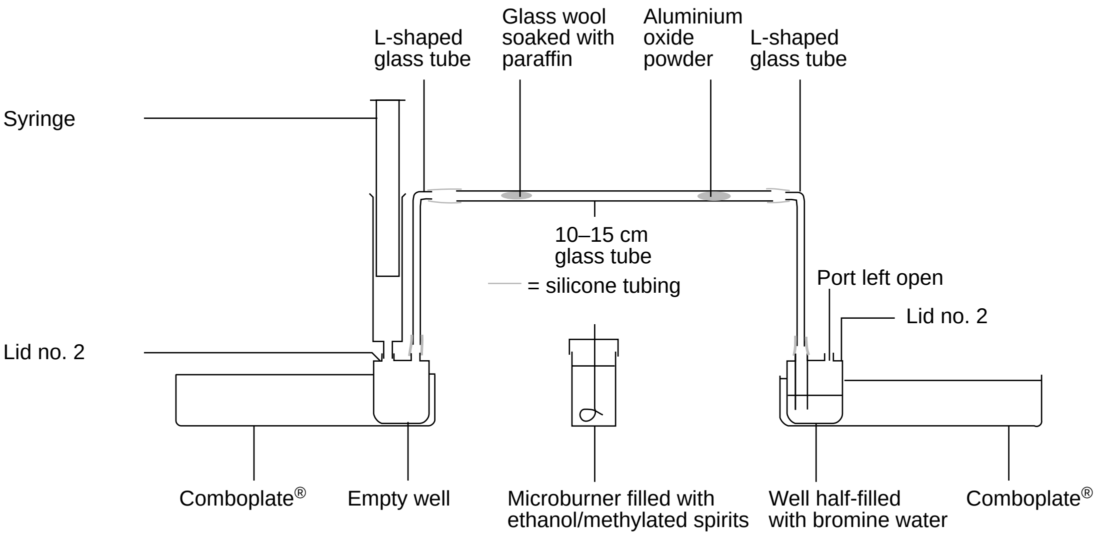
Health and safety

Wear eye protection at all times during this experiment, including during set-up and dismantling.

Ethanol is highly flammable. Always keep the microburner upright to prevent spills.

Bromine water is harmful and an irritant. Avoid contact with the skin and do not breathe in the fumes. If you get bromine on your hands, wash them straight away.

Diagram



Note: attach the lids to wells F3 or F4 on the comboplates.

Setting up

- Put on your eye protection.
- Pull the plunger of the syringe until it is fully extended. Fit the syringe to one of the lids. Attach the lid to well F3 on one of the comboplates®. The syringe and the well should be empty.
- Half fill well F3 on the other comboplate® with bromine water and attach the other lid.
- Attach a piece of silicone tubing to each end of the L-shaped glass tubes. Hold the glass tube near the end you are attaching to the silicone tubing to reduce the likelihood of breaking the glass and cutting yourself.
- Attach the long end of each L-shaped tube to the lids on the comboplates®.
- Put some glass wool in one end of the straight glass tube. Push it at least 2 or 3 cm down the tube (a piece of wire or small stick helps). Add 5 or 6 drops of liquid paraffin to the glass wool using a pipette. About 0.5 cm of the tube should be filled with paraffin.
- Holding the tube as horizontal as possible so as not to lose your paraffin, put 1 microspatula of aluminium oxide in the other end.
- Attach the straight glass tube between the L-shaped tubes, making sure the paraffin is at the end with the syringe.
- Get your set-up checked by your teacher before you go any further.

Cracking the hydrocarbons

- Wear eye protection.
- Light your microburner, pick it up and begin to heat the aluminium oxide. Make sure the oxide is very hot before you go any further. As you heat, very slowly depress the plunger on the syringe. If at any stage the plunger gets to the bottom, remove the syringe, pull the plunger out, re-attach it and carry on pressing it down slowly.
- Begin to flick your microburner over the paraffin to heat that up too – make sure you keep heating the aluminium oxide enough to keep it hot. You can see when the paraffin is boiling. As it turns into a vapour it will pass through the glass wool and over the catalyst (the aluminium oxide).

- Watch what happens to the bromine water. When you see no more changes or you have run out of paraffin, stop heating.
- Put a few drops of paraffin in one of the other large wells in your plate and add a few drops of bromine water. Observe what happens.
- Wait until the apparatus has cooled before you dismantle it.

Questions

1. Make a copy of the table below and use it to record your observations.

Substance	**Colour**	**State**	**What happened when it was mixed with bromine water?**	**Ease of catching fire (if done)**
Starting material paraffin				
Product ______________				

2. Did you observe anything else during the course of your experiment?

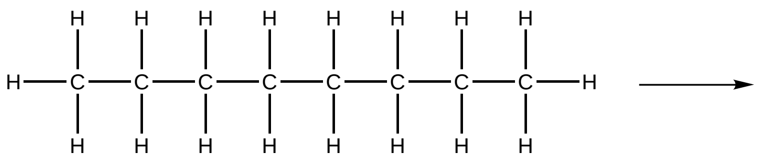
....

3. The states of the reactant and product are different. What does this suggest about the sizes of their molecules?

....

A molecular model kit may help you answer the next few questions. Make a model of each of the molecules. Remember that carbon must always form four bonds and hydrogen forms one.

4. Paraffin can be represented as shown below (although actually its molecules are bigger).



During cracking two of the carbon atoms break off. Work out what the products of the reaction are and complete the equation started above.

5. Paraffin is an alkane. One of the products is also an alkane and the other is an alkene. Decide which is which and label the substances in your equation as either alkanes or alkenes.

6. How could you use bromine water to find out if hydrocarbons were alkanes or alkenes?

....

....

7. Make a model of bromine, Br–Br. Use two green atoms for the model. Work out what happens when bromine reacts with an alkene like ethene and draw an equation for the reaction.

8. Explain why alkanes do not react with bromine.

....