5.9 Identifying hydrocarbon molecules

Get started

How would you test a liquid to show whether it was an acid or an alkali?

In the next two lessons, you will learn about some tests that will help you to identify organic molecules.

Identifying unknown chemicals

Forensic scientists analyse evidence brought in from crime scenes. This could be paint chips from cars, blood samples or bottles of unlabelled liquids, perhaps being used in the preparation of illegal substances.

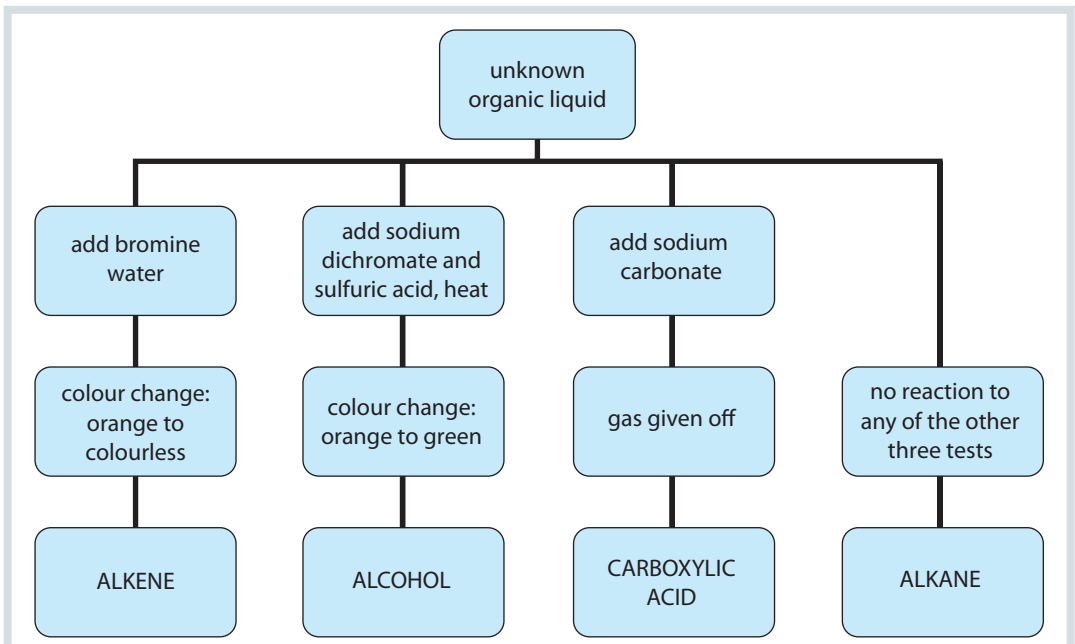
Imagine you are a forensic scientist trying to identify a clear, colourless, organic liquid. Is it an alkane, an alkene, an alcohol or a carboxylic acid?

Using a flowchart is a good way to help you decide how to test your substance to identify it. You will find out more about the tests in this flowchart in the next few pages.

Key term

Addition reaction – A reaction in which two molecules join together to make a single product molecule.

Forensic scientists may have to test unknown liquids to find out what they are.



A flowchart will help you to identify which family of organic molecules an unknown chemical belongs to.

Different kinds of tests

A good test must give an obvious positive result – a colour change perhaps, or a gas given off.

Here are two tests that can be done easily in the laboratory. They are carried out on liquid substances.

1 Fill a test tube about a quarter full with water. Add a few drops of the unknown liquid and shake gently.

   If the liquid floats on top, then it is **insoluble** in water. Many organic chemicals are insoluble in water because they cannot form bonds to the water molecules. However, alcohols and carboxylic acids can form bonds to water, so they are **soluble** in water.

Safety and hazards

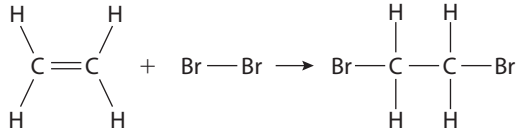
When you carry out these tests you will often be using pure samples of organic chemicals, not solutions. Many of these substances are flammable and harmful. It is very important to only use a few drops of the chemical when you carry out each test. Make sure you check how to dispose of the chemicals after you have used them.

2 Fill a test tube about a quarter full with bromine water. Add a few drops of the unknown liquid, place a bung on the top of the test tube, and shake gently.

If the bromine water changes colour from orange to colourless then the liquid is an alkene. The bromine has reacted with the double bond in the alkene so its colour disappears.

The orange colour of bromine disappears when it reacts with an alkene.

Alkenes react with bromine because they take part in an **addition reaction**. Two molecules react together to form just one product.



Alkenes react with bromine in an addition reaction.

Activity A

Look at the structure of the product which is formed when bromine reacts with ethene. Is this product molecule an alkene? How can you tell?

Activity B

Caroline is a lab technician. She has found three bottles of organic liquid, labelled only as A, B and C. She needs to identify them so that she can dispose of them safely. She thinks that the bottles contain an alkane, an alkene and an alcohol, but doesn't know which one is which.

- Liquid A dissolves in water.
- Liquid B does not dissolve in water. However, the colour of bromine water disappears when a few drops of liquid B are added to it.
- Liquid C does not dissolve in water and does not react with bromine water.

Can you identify which liquid is which?

Just checking

Look at the names of these four organic molecules:
A: hexane (an alkane) **B:** hexene (an alkene) **C:** ethanol (an alcohol) **D:** ethanoic acid (a carboxylic acid).

1 Which molecules are soluble in water?
2 Which molecule will react with bromine, turning it colourless?
3 Which molecule is insoluble in water and will not react with bromine water?

Lesson outcome

You should be able to use test tube reactions to tell the difference between alkanes and alkenes.

5.10 Identifying more organic molecules

Get started

In previous lessons you've come across some families of organic molecules which contain oxygen atoms. Can you name two of the families?

Key terms

Neutralisation – A reaction in which an acid reacts with a base to form a neutral salt and water.

Oxidation – A reaction in which a molecule gains oxygen atoms.

Link

To find out about the colour of universal indicator for different values of pH, see Principles of Applied Science lesson 1.15.

Activity A

What is the gas given off when an acid reacts with a carbonate? How could you test the gas to check this?

Safety and hazards

Sodium dichromate(VI) solution is toxic. You should wear gloves when handling it. When you shake the mixture you must make sure that it does not spill out of the test tube. Placing a bung on the test tube can help.

Is the substance a carboxylic acid?

You will normally use a solution of carboxylic acid because pure carboxylic acids are corrosive.

- Fill a test tube about a quarter full with a solution of a carboxylic acid.
- Add a few drops of universal indicator (UI), which is green to start with.
- An orange–red colour, or a pH of between 2 and 4, shows you that the liquid is an acid. However, there are several other types of organic molecule with acidic properties.
- To check that the substance is a carboxylic acid, add a small spatula measure of sodium carbonate and shake gently. A gas should be given off.

Carboxylic acids are the only common type of organic molecule that reacts with sodium carbonate.

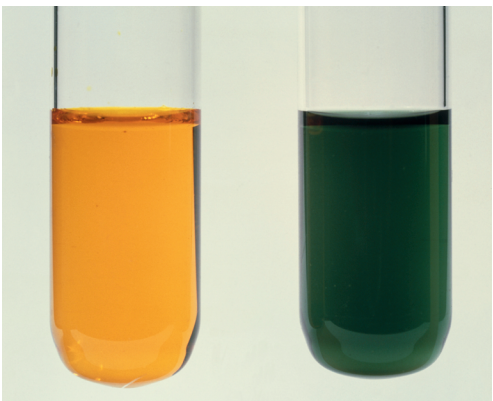
ethanoic acid + sodium carbonate → sodium ethanoate + carbon dioxide + water

This is a **neutralisation** reaction, and the sodium ethanoate is a salt – just like sodium chloride and calcium sulfate, which you met in Principles of Applied Science Unit 1.

Is the substance an alcohol?

To test if a substance is an alcohol:

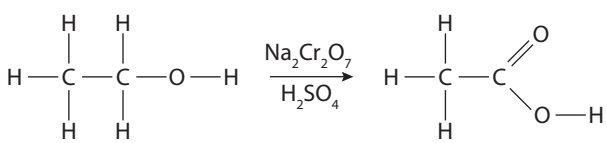
- Prepare a water bath by filling a 250 cm^3 beaker about half full with hot water from a kettle.
- Add 1–2 cm^3 of sodium dichromate(VI) solution to a test tube.
- Then add an equal volume of dilute sulfuric acid.
- Finally, add a few drops of the unknown liquid and shake gently.
- Place this test tube carefully in the hot water bath. Watch what happens over the next few minutes.



Acidified sodium dichromate(VI) solution goes from orange to green when it is warmed with an alcohol.

If the mixture changes colour from orange to green, then the liquid is an alcohol.

Alcohols react with acidified sodium dichromate in an **oxidation** reaction. The alcohol molecule gains an oxygen atom.



Ethanol is oxidised to ethanoic acid by gaining an oxygen atom.

Activity B

Rahul is a quality control chemist. He is monitoring the products of a reaction in which propanol (an alcohol) is being oxidised into propanoic acid (a carboxylic acid). Rahul suspects that in one of the batches, the reaction has not worked. Both the organic substances are colourless liquids so the reaction is not visible.
To check if the reaction has occurred, Rahul carries out two tests on each batch.

First he adds universal indicator to a sample from each batch.

Then he takes a second sample from each batch and heats it with acidified sodium dichromate.

Here are his results.

Batch	Observations when universal indicator (UI) is added	Observations when heated with acidified sodium dichromate
A	UI turns from green to orange	Sodium dichromate stays orange
B	UI stays green	Sodium dichromate turns from orange to green

What can Rahul conclude about the two batches?

Take it further

The oxidation of alcohols to carboxylic acids is an example of a reaction which happens in two separate steps.

Step 1: the alcohol is oxidised to an aldehyde which contains a C=O bond but not an OH group.

Step 2: the aldehyde is oxidised to a carboxylic acid, which contains both C=O and OH.

Assessment activity 5.4

2B.P4 | 2B.M4 | 2B.D3

You are the senior technician working in a large chemical company.
The company uses large amounts of four substances: hexane, hexene (CH_2=$CHCH_2CH_2CH_2CH_3$), ethanol and ethanoic acid. All of these are clear, colourless liquids. You have found four unlabelled bottles of liquid in the laboratory.

1 Write a report describing suitable tests you could carry out that would enable you to work out what is in each bottle.
2 Your report should include an explanation of what would happen in any reactions that you would carry out.

Grading tips

For 2B.P4, you should be able to identify an alcohol and a carboxylic acid from your results, as well as an alkane and an alkene.

For 2B.M4, you need to be able to explain how you used your results to make these identifications.

For 2B.D3, you need to be able to explain what happened in each of the reactions, including the structures and bonding of the molecules involved, and to give a correct description of what type of reaction has occurred.

Just checking

1 An unknown organic substance dissolves in water and fizzes when it is added to sodium carbonate. What family of molecules does it belong to?

2 Look at the names of these three substances:
A: ethanoic acid (a carboxylic acid)
B: ethanol (an alcohol)
C: hydroxybutanoic acid (contains an alcohol and a carboxylic acid group).

(a) Which molecules will turn universal indicator solution from green to orange?

(b) Which molecules will turn acidified sodium dichromate solution from orange to green when they are heated together?

(c) Which molecule does not fizz when it is added to sodium carbonate?

Lesson outcome

You should be able to use test tube reactions to identify carboxylic acids and alcohols.

5.13 Problems with organic molecules

Get started

Write a list of some properties of organic substances that make them useful.

Key term

Biodegradable – Able to be broken down by the action of living organisms such as bacteria.

Discussion point

On average, every person in the UK produces about 50 kg of plastic waste every year. Research the different ways of disposing of this waste, and discuss the advantages and disadvantages of these methods.

You have seen how organic molecules have properties that allow them to be used in a variety of ways, such as solvents and fuels. However, organic molecules often have other properties that can cause problems when they are used. Organic chemists need to decide whether the benefits of using the organic molecule outweigh the drawbacks.

What are the drawbacks?

- Flammability: most organic molecules are **flammable** (catch fire easily). If an organic substance has a low boiling point, this can create a serious fire risk when the vapours build up in an enclosed space.
- Toxicity: some organic molecules are **toxic** if they are breathed in or absorbed through the skin. This means that precautions need to be taken when using or disposing of them.
- Disposal in landfill: if organic molecules are toxic they will cause environmental problems if they leach into the soil, lakes or rivers. Some organic substances are not **biodegradable**, so they will last for thousands of years in landfill sites.
- Disposal by burning: this produces greenhouse gases like carbon dioxide and can also release new toxic products into the atmosphere.
- Non-renewable: most organic molecules are made using crude oil as a raw material. This is non-renewable and so is gradually running out.

There are concerns that additives in this packaging could leak into the environment.

Activity A

Greenhouse gases are molecules that trap energy which is emitted by the Earth, in the form of infrared radiation. This means that, as the amount of greenhouse gases in the atmosphere increases, the temperature of the atmosphere will increase as well. All industries now need to demonstrate that they are working to reduce their emissions of greenhouse gases.

Research, using books or the Internet, at least three different greenhouse gases and the steps being taken to reduce their emission.

Polyvinyl chloride (PVC)

PVC is used as a building material, for example in window frames and water pipes, as well as for insulation for cables, plastic coverings for furniture and packaging. Like most polymers, PVC is not toxic, but there are a number of drawbacks to using it. These have to be weighed against the benefits, as you will see summarised in the table.

Benefits of PVC	Drawbacks of PVC
Low cost	Plasticised PVC contains plasticiser molecules, called phthalates. These are slowly released from the PVC into the environment. They can affect the working of hormones in the body and could cause birth defects and illness in children.
Can be made rigid or flexible as required	When PVC is burnt, it releases molecules called dioxins, which are similar to some of the chemicals used in weedkillers. They are toxic molecules, and can build up in the food chain and can cause skin diseases and birth defects.
Weatherproof (not affected by water)	PVC molecules are not biodegradable so they will remain in landfill for thousands or millions of years.
PVC molecules are non-toxic	PVC is made from crude oil, which is a non-renewable resource.

Case study

Rupinder works for a company which runs a large incinerator.

'My job is to monitor the emissions produced by the incinerator. When the company built this incinerator it was very controversial – local residents were very worried by the possibility of hazardous emissions threatening their health. Every day I collect data on the emissions produced and we publish this on our website. There are very strict limits on the emissions that can be produced and we are well below these for substances such as particulates and volatile organic compounds, which can include dioxins. The nitrogen oxide emissions are the only ones which get anywhere near the government's limit of 200 mg/m^3.'

1 Why does Rupinder specifically mention dioxins?

2 Find out some of the environmental effects of nitrogen oxides. What are the other main sources of nitrogen oxides?

Just checking

1 List two ways of disposing of organic molecules.
2 What environmental problems are caused when organic molecules are disposed of in these ways?
3 Why should people be particularly careful when handling and using organic molecules?

Link

You learned about polymers in lesson 5.8 and about PVC in lesson 5.11.

Did you know?

One of the biggest uses for PVC in the past was the manufacture of 'vinyl' records. Some musicians and DJs still prefer this way of recording and playing music, and the records they use are still made from PVC.

Lesson outcome

You should be able to explain some of the problems associated with the use of organic molecules.

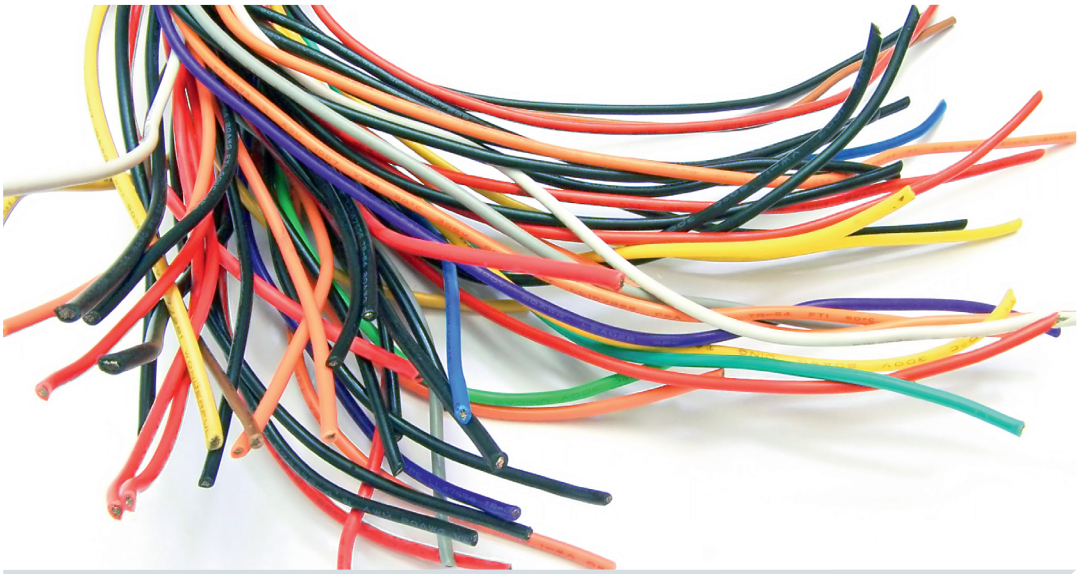
5.14 Benefits and drawbacks

Get started

Can you think of a situation in which you might have been exposed to a hazardous organic substance? Do you think the use of the substance was justified in that situation?

Various organisations and people may have to decide whether the benefits of using an organic chemical outweigh the risks.

- Governments may have to consider whether to pass laws to ban or restrict its use.
- Consumers may read stories in the media about the risks. They have to decide whether they are prepared to take the risks of using it.
- Manufacturers will need to carry out research to find out whether they can make a product less **hazardous** or find alternative substances to use.



Do the advantages of using this plasticised PVC outweigh the drawbacks?

Activity A

Look back at the information about PVC in the previous lesson. Do you think the advantages outweigh the disadvantages, for each of these uses?

1 Using unplasticised PVC to make underground water pipes.
2 Making a child's toy from plasticised PVC.

Assessment activity 5.5

| 2B.P5 | 2B.P3 [part] | 2B.M5 | 2B.D4

You are a development chemist working for a company that manufactures a range of chemicals for consumer products. These include: PVC from chloroethene, poly(ethene) from ethene, ethanol from ethene, ethanoic acid from ethanol and a range of chloromethanes.

The marketing team are concerned that reports of problems with the use and disposal of some of these molecules is affecting sales. They have asked you to write a brief report on the uses of these molecules, and the problems involved, focusing particularly on PVC and dichloromethane.

Grading tips

You need to identify the uses of ethene, ethanol and ethanoic acid.

For 2B.P3, your report should also include drawings of the structures of all of these molecules.

For 2B.P5, you should include a brief description of one use of each of these molecules.

For 2B.M5, you should explain in detail the problems and risks involved in the use or disposal of PVC and dichloromethane.

For 2B.D4, you must discuss the benefits of these molecules in more detail, and reach a judgement about whether the benefits outweigh the risks and problems.

Lesson outcome

You should be able to evaluate the use of some organic molecules, considering the benefits and drawbacks.

WorkSpace

Pierre

Environmental Health Officer

As part of my work, I am the chair of a committee that looks at the hazards involved in the use of various chemicals. One of the substances we have looked at is dichloromethane (DCM). It is a really good solvent for a variety of organic molecules, including some of the components of paint.

A lot of chlorohydrocarbon molecules are very toxic, but DCM is the least toxic. So, because of this, and the fact that it can be made cheaply, it has been really popular in the last few decades as an ingredient in paint stripper. But it is still toxic if it is breathed in, and because it has a low boiling point it can build up quickly in enclosed spaces.

The EU has banned this substance for use in the home, but we had to decide whether to request an exemption for use by professional decorators. The clincher for me was that some recent studies have suggested that there might be an increased risk of cancer among professional decorators who are using it all the time.

Because there are other ways of removing paint – maybe a combination of heat-stripping and using other chemicals – we decided that the drawbacks outweighed the benefits for this substance, and we wrote a report recommending that it should continue to be banned in the home, even when used by professionals.

Think about it

1. The committee didn't ban other uses of DCM, such as decaffeinating coffee. Why not?
2. Why do you think it has taken until now to discover that DCM may cause cancer?
3. Draw up a table, like the one for PVC in lesson 5.13, to summarise the benefits and drawbacks of using dichloromethane.