Fractional distillation of crude oil

This investigation is part of the **Nuffield practical collection**, developed by the Nuffield Foundation and the Royal Society of Chemistry. Delve into a wide range of chemical concepts and processes with this collection of over 200 step-by-step practicals: rsc.li/43bjGql

Learning objectives

1. Distil a crude oil substitute to simulate industrial fractional distillation of crude oil.
2. Observe and record the different properties of the fractions produced.
3. Describe how the different fractions are formed and link this to their physical properties.
4. Explain why different fractions have different properties.

Introduction

Crude oil is a mixture of chemical compounds, mostly hydrocarbons, which are molecules consisting of carbon and hydrogen only. It is an incredibly useful resource. The molecules within the mixture have different physical and chemical properties which can then be used in a wide variety of ways.

To separate the mixture into its separate parts (or fractions), a process known as fractional distillation must be used.

In this experiment, learners will use a crude oil substitute to model the fractional distillation process. After collecting four fractions at different temperatures, they will test each one for viscosity, colour, smell and flammability.

Scaffolding

Integrated practical instructions are included in the PowerPoint for the practical activity and are available to download from: rsc.li/4ylvdB1

Two versions of the worksheet are included: a scaffolded (✪) and an unscaffolded (✪✪) version. Questions in the scaffolded worksheet provide more prompts about the correct use of keywords and how to structure answers, whereas the unscaffolded worksheet provides less guidance.

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Technician notes

Read our standard health and safety guidance (rsc.li/3zyJLkx) and carry out a risk assessment before running any live practical.

Equipment

- Safety glasses
- Bunsen burner
- Heat resistant mat
- Side-arm hard glass test tube
- Bent delivery tube and rubber connection tubing
- Small sample tubes, at least 20 mm x 5 mm (or small test tubes), x 4
- Thermometer, 0–360°C, with cork to fit side-arm test tube
- Teat pipette
- Beaker, 100 cm^3
- Hard glass (borosilicate) watch glass
- Mineral or ceramic fibre
- Wooden splints

Chemicals (per group)

- Crude oil substitute (HIGHLY FLAMMABLE and HARMFUL), about 2 cm^3



Preparing crude oil substitute

To prepare the crude oil substitute, mix together the following chemicals and a squeeze of black oil paint, then pour the solution into a labelled bottle.

Chemicals for crude oil substitute, 100cm^3

- Liquid (medicinal) paraffin, 55 cm^3
- Paraffin oil (kerosene), 20 cm^3
- White spirit, 11 cm^3
- Petroleum ether 100–120°C, 4 cm^3
- Petroleum ether 80–100°C, 4 cm^3
- Petroleum ether 60–80°C, 6 cm^3



For more information see CLEAPSS Recipe Book RB032.

Safety and hazards

- Wear safety glasses throughout.
- Crude oil substitute (HIGHLY FLAMMABLE and HARMFUL). Refer to CLEAPSS Hazcards HC045a and HC045b, plus CLEAPSS Recipe Book RB032. Real crude oil contains more than 0.1% benzene, which is carcinogenic, which makes it unsuitable for use in schools.



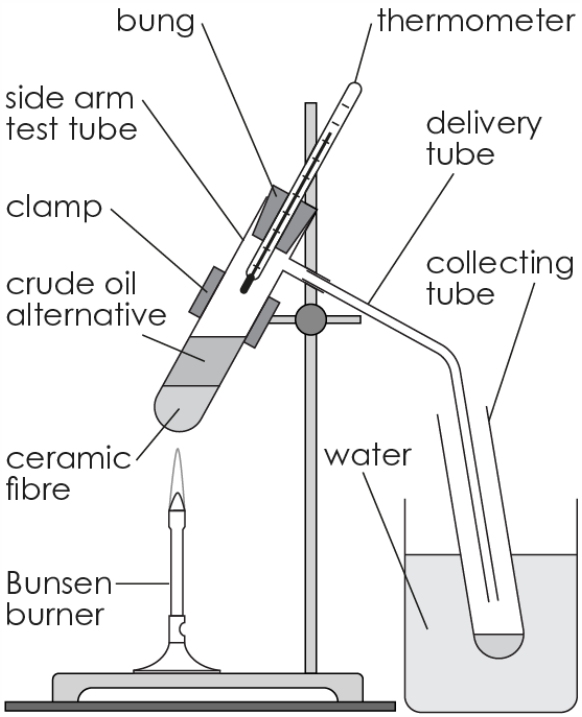
- When preparing the crude oil substitute, avoid skin contact and ensure there are no naked flames or ignition sources.

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- Side-arm boiling tubes produce more consistent results than boiling tubes fitted with bungs with two holes, where one is for a thermometer and one is for a delivery tube.
- It is important to try the experiment before the lesson. It may be necessary to add an additional low boiling point fraction to the 'crude oil' mixture – e.g. cyclohexane – to obtain something below 70°C.
- This is quite a messy experiment. If it is done regularly, it is a good idea to keep sets of apparatus – apart from the thermometer and watch glasses – dedicated for this experiment. This is because it is difficult to clean the apparatus afterwards, and the experiment still works if oil residues are present.

Method

1. Place about a 2 cm^3 depth of ceramic fibre in the bottom of the side-arm test tube. Add about 2 cm^3 of crude oil substitute to this, using the teat pipette.



2. Set up the apparatus as shown in the diagram. For the first fraction only, make sure that you place a beaker of cold water around the collecting tube. The bulb of the thermometer should be level with, or just below the side-arm. Heat the bottom of the side-arm test tube gently, with the lowest Bunsen flame. Watch the thermometer.
3. When the temperature reaches 100°C, replace the collection tube with another empty one. The beaker of water is no longer necessary.

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4. Collect three further fractions at the following temperatures:
    - Room temperature to 100°C
    - 100–150°C
    - 150–200°C
    - 200–250°C
5. A black residue remains in the side-arm test tube. Test the four fractions for viscosity (how easily do they pour?), colour, smell and flammability, and record what you observe in your results table.
    - To test the smell, gently waft the smell towards you with your hand.
    - To test for flammability, pour the fraction onto a hard glass watch glass and light the fraction with a burning splint.
6. Keep one set of fractions and combine them to show that they form a mixture very like the original sample.

Teaching notes

During the practical activity, learners will need support in order to set up the equipment safely. It is important to guide learners throughout the practical and to promote positive group work, as there are often several things to consider at any one time. It may be useful to demonstrate the practical to learners before they carry it out themselves. You could also consider making this a slow practical – one in which you and the learners go through the steps together. During the demonstration and whilst learners are working, ask them questions about their observations and use their answers to develop their understanding of why these occur.

Your questions could include any or all of the following discussion points:

- What visible changes can you see in the test tube as we heat the crude oil substitute, and where do you notice the gas turning back into a liquid?
- Do you think the first fraction you collect will be thin and runny or thick and viscous? How easily do you think it will catch fire?
- What is happening to the energy and movement of the hydrocarbon molecules as we heat the mixture?
- Right now, where in the equipment are the molecules existing as a gas, and where are they condensing?
- When these hydrocarbons boil, are we breaking covalent bonds or intermolecular forces?
- Why do shorter chain hydrocarbon molecules boil at lower temperatures than longer chain ones?

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Answers

1. Crude oil is a **mixture** of compounds called **hydrocarbons**. These contain **hydrogen** and **carbon** only.

2. Crude oil is a valuable resource as it contains a **mixture** of compounds including **fuels** that we can use for **heating** and **transport** as well as chemicals that act as a **feedstock** to manufacture solvents, **plastics** and **lubricants.**

3. The viscosity increases as the boiling point range increases.

4. The flammability decreases as the boiling point range increases.

5. Crude oil is an example of a **non-renewable (finite)** resource. This is because it is being used **more quickly** than it is being replaced.

6. During distillation, the liquid is first **heated**. It then turns into a **gas**. This process is known as **evaporation**. When it **cools** it begins to **condense** back into **a liquid**.

7. Fractions with **higher** boiling points contain larger molecules. Larger molecules are **less** volatile (they do not evaporate easily into a gas at room temperature), making it much **harder** for them to catch fire compared with light, highly volatile molecules.

8. Fractions with **higher** boiling points contain longer hydrocarbon chains. These longer chain molecules easily tangle together and have **stronger** intermolecular forces between them, making the liquid thicker and **harder** to pour.

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