24 Fuels and Crude Oil

Introduction

The first chapter in Section 7 looks at fossil fuels as sources of energy with the main focus being on petroleum and natural gas, the fuels of direct interest to our country. The separation of petroleum into useful fractions is discussed together with problems associated with its use, such as limited reserves, and alternatives to petroleum as an energy source.

Chapter Opener (page 386)

1. Begin the chapter by discussing the following question. Precise answers are not needed at this stage.

   What is a fuel? What are the main fuel sources in the world today?

   Answer: A fuel is a substance that is burnt to produce heat energy. Petroleum (crude oil) and natural gas are the main fuel sources in the world today.

   Petroleum is a mixture of compounds. How is the mixture separated in an oil refinery? How are the products useful in our daily lives?

   Answer: The petroleum mixture is separated by fractional distillation. Refer to Table 24.1 on page 392 of the Textbook.

   How long can reserves of petroleum and natural gas last? What alternative fuels can be used when they run out?

   Answer: Petroleum and natural gas may last for about another 50 years. Ethanol and hydrogen can be used as alternative fuels.

2. Carry out an 'Inquiry Preview'.

Learning Outcomes

After completing this chapter, the students should be able to:

- name natural gas and petroleum as sources of energy
- describe petroleum as a mixture of substances and its separation into useful fractions by fractional distillation
- name the fractions from the fractional distillation of petroleum and state their uses
- discuss issues relating to the competing uses of oil as an energy source and as a chemical feedstock

Teaching Notes for

ChemMystery (page 387)

Go green! How can we drive environmentally-friendly cars?

Initial Investigation

- Bioplastic — a plastic that is made from plant material and not from oil.

  Green — Same as eco-friendly.

  Eco-friendly — products, actions, laws, etc, that inflict minimal or no harm on the environment.
- Problems include pollution during their manufacture and use, the fact that petroleum will run out one day, and many plastics are non-biodegradable and so remain in landfills for a very long time.
- The refineries separate petroleum into fractions that are used as fuels or as the feedstock (raw material) in the manufacture of plastics.

Teaching pointers

24.1 Why are Fuels Needed? (page 388)

Stimulation

Here are two suggestions for introducing the topic. They could be used separately or combined.

1. Several days before this topic is to be taught, get students to ask their grandparents or other elderly people what fuels they used at home in the past. List their findings on the board and then ask them to suggest other fuels that were used in the past, fuels that are used in the present and to give examples of how they are used. Perhaps show pictures of former and present-day fuels and their uses to facilitate the discussion. If possible, also show a kerosene or charcoal burner and a kerosene lamp to

illustrate what was used as a fuel in the recent past and get the class to state the sources of energy that have replaced them. (If students suggest that 'electricity' has replaced these fuels, lead the class to the idea that fuels such as oil are used in power stations to generate this electricity.)

2. Students should know the difference between energy sources from fuels and those not from fuels (such as moving water, wind energy, solar energy, geothermal energy and tidal energy). Ask them to name some sources of energy. (Prompt them if necessary.) List the sources of energy on the board and then ask the class which of these energy come from fuels (e.g. petrol, kerosene) and which do not (e.g. wind energy, water/hydroelectricity, solar energy). Again, as in Suggestion 1, show the class pictures and objects depicting the uses of fuels as sources of energy in the past and the present.

Notes for Teachers

World's reserves of fossil fuels

At the end on 2005, the countries with the largest reserves of fossil fuels are (in order of quantity) were:

- Petroleum: Saudi Arabia, Iran, Iraq, Kuwait.
- Natural Gas: Russia, Iran, Qatar.
- Coal: United States, Russia, China, India.

The following website provides more information on the above:
http://www.geohive.com/charts/en_oilres.aspx
http://www.bp.com/sectiongenericarticle800.do?categoryId=9037157&contentId=7068604

Natural gas in China

Most people think that the use of natural gas as a fuel is a recent invention. In fact, it was first used as a fuel in towns over 1600 years ago. In the Szechwan Province of China, natural gas was sent to people's homes for heating and lighting as early as A.D. 347. The gas was sent over many kilometres through a network of bamboo pipes. It was then mixed with air and set alight to produce permanent 50-cm high 'lights' at night.

Teaching pointers

24.2 What are Petroleum and Natural Gas? (page 388)

1. Singapore has no petroleum sources of its own and has to import all of the fuel it needs.
2. If possible, show students some crude oil so they can appreciate how thick the liquid is.
3. The term reserves is used a number of times in this chapter. Point out that this term refers to the amount of petroleum known to be present in the Earth. This will change from time to time as more reserves are discovered and are used up.
4. When discussing the formation of petroleum, it may be useful to point out at this stage that there are limited amounts of petroleum (and other fossil fuels) in the Earth and no more will be formed in the future. This is unlike wood, which is renewable, as trees can be grown to replace those that have been used.
5. Natural gas is mainly methane. Other gases that are present in small amounts in natural gas include ethane, propane, carbon dioxide, hydrogen sulfide and nitrogen.
6. Ensure students appreciate the reason for changing natural gas into a liquid for transportation by tanker.

Skills Practice (page 390)

1. Oil is back in colour and is valuable, like gold.
2. Liquid occupies a much smaller volume than an equal mass of gas, thus allowing more natural gas to be transported and stored.
3. **(a)** Coal, petroleum and natural gas.
   (b) Coal
   (c) Petroleum is transported by tanker. Natural gas is transported through pipelines.
4. $CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(l)$
5. **(a)** Compressed Natural Gas
   (b) The main difference is the way in which the gas is stored. For LNG, natural gas is liquefied and stored at a very low temperature (at almost atmospheric pressure) in highly-insulated containers.
   For CNG, natural gas is compressed to a high pressure and stored in high pressure cylinders.

(page 390)

Mystery Clue

Through photosynthesis, green plants manufacture glucose which stores energy from the Sun. The remains of plants over millions of years changed into petroleum, from which petrol is obtained. Today, petrol can also be produced from plants. When the petrol is burnt, it releases energy that originally came from the Sun.

Notes for Teachers

Fossil fuels and Singapore

Singapore has no fossil fuels. The little coal on Pulau Tekong was exploited during the Second World War. There is too little present today to be of any significance. All the natural gas and petroleum that we need to obtain petrol and diesel for our vehicles and generate the electricity we need, have to be imported in from other countries. The money needed to pay for these fuels come from other activities, such as the petroleum refining industry and tourism.

Teaching pointers

24.3 How is Petroleum Made into Useful Products? (page 391)

1. Link the fractional distillation of petroleum with the earlier discussion of the principle of fractional distillation in Chapter 2. The boiling points in Table 24.1 on page 392 of the Textbook show a range of temperatures, indicating that each fraction is a mixture. The separation works because the fractions have different boiling points, just as water and ethanol can be separated by fractional distillation because they have different boiling points.
2. In an actual fractional distillation column in the industry, a single tower cannot cover the full range of temperatures needed to split up the heavier fractions. Two towers are used. The first tower is at atmospheric pressure and separates most of the fractions. The last three fractions are separated in the second tower at a reduced pressure (to lower the temperatures needed).
3. Notice that in fractional distillation, the boiling point ranges overlap. This is because the separation process is not exact. For example, some C20 hydrocarbons will condense at the level for the separation of diesel in the fractionating column while others will condense lower down in the column. This overlap is not important for the heavier fractions. However, the lighter fractions need to be separated more precisely.
4. Students must remember the names of the fractions and their order and a major use for each fraction. However, they do not have to remember the boiling point ranges.
5. There are about 900 refineries around the world. Singapore is the third-largest petroleum-refining centre in the world.

(page 392)

Mystery Clue

Carbohydrates contain the elements carbon, hydrogen and oxygen. To convert them into hydrocarbons, the oxygen must be removed.

6. Point out that the products obtained from the fractional distillation of petroleum are not the same at all the refineries in the world, as the petroleum from different parts of the Earth are different in their composition. Also in the fractionating process, fractions can be condensed at different temperatures. Thus, the fractions and boiling point ranges in Table 24.1 on page 392 of the Textbook are to be regarded as typical examples only and will vary from one refinery to another.
7. From the products obtained from the fractional distillation of crude oil, it is found that the quantities of useful products produced do not match the ratio required for commercial needs. For example, we have an insatiable appetite for petrol and diesel in our cars but there are insufficient quantities in petroleum to meet this demand. On the other hand, the amounts of fuel oil exceed the demand for it. In addition, alkenes are not found in crude oil and they are one of the most valuable types of organic molecules in the chemical industry. For example, alkenes are used to make polymers (plastics) and ethanol (an alcohol). This mismatch is partially solved through the cracking of larger oil fractions, which is discussed in Section 25.7 of Chapter 25.
8. An optional additional experiment is included at the end of the chapter to separate petroleum into fractions and to compare the properties of these fractions. The worksheets can be photocopied and distributed to students. Refer to the notes below on the experiment.

Additional Experiment 1: Investigating the Properties of Petroleum Fractions

In this experiment, the change in pH during neutralisation is measured using a pH sensor connected to a computer. You may conduct this experiment either as a teacher demonstration or as a class activity.

Here are some comments on this experiment:

As care must be taken during the distillation, a teacher demonstration is recommended.

Notes:

- Crude oil is a carcinogen and so must be handled carefully and gloves must be worn. For this reason, students should not clean the distillation after the experiment.
- With crude oil that has been stored for a long time, the more volatile fractions may have evaporated off. In this case, only the higher boiling point fractions will be collected.
- The colours of the fractions and the temperatures at which they distil will depend on the petroleum sample and so may differ slightly from those shown in the teacher's edition of the worksheets.
- The residue may not burn easily.

Teachers might like to compare the similarities and differences of the fractional distillation process in an oil refinery with that in the experiment:

Laboratory apparatus	Oil refinery process
Similarities:	
fractionating column	fractionating column/tower
heating test tube	furnace
receiving test tube	trays
Differences:	
fractions separate in series, one at a time, from the top of the test tube.	fractions separate in parallel at each level of the column/tower.
vapours cool in column/tower	vapours cool in condenser (plastic tube)
residue remains in test tube	residue is vaporised and distilled off

Skills Practice (page 393)

1. The liquids have a wide difference in their boiling points.
2. **(a)** **(i)** Most motorcars use petrol.
   (ii) Many buses and taxis use diesel.
   (b) Lubricating oil is used as waxes, polishes and grease for lubricating machines.
3. **(a)** Bitumen
   (b) Lubricating oil
   (c) Petroleum gases
   (d) Lubricating oil (wax/polish)
4. As the number of carbon atoms in the molecules increases, the boiling points of the petroleum fractions also increase.
5. **(a)** Carbon and hydrogen.
   (b) The long lubricating oil molecules get tangled up and cannot slide over each other easily. The smaller the molecules, the easier it is for them to move about.

Chemistry in **Society** (page 393)

The Petrochemical Industry

Petroleum throughout history

Petroleum has been used by many different civilizations throughout history. The Egyptians used pitch, a tar residue, to seal pyramids and coat mummies, while ancient Babylonians used pitch to pave their roads and to hold building stones together. Bitumen, a thick black oily substance, was used in Mesopotamia to caulk ships and set stones in jewellery. In North America, Native Americans used crude oil as body paint and fuel for ceremonial fires.

Crude oil was successfully drilled from the Earth in 1859 by Col. Edward Drake in Pennsylvania, USA. The kerosene produced from the first oil refinery was used to replace whale oil in oil lamps.

Exercise

Suggestions for exercise questions

(a) Factors to consider before deciding to build more refineries:
- Does Singapore have sufficient land?
- Is there a need to reclaim land?
- Is there a market (both domestic and foreign) for the products obtained from the refinery?
- How much will it cost the taxpayer?
- Does it provide jobs for local workers and engineers?
- Could there be environmental problems, e.g. oil spills?
- Are there any dangers involved, e.g. fires, hazards in transporting products?
- What is the cost of producing oil from a refinery as compared to the cost of just importing the oil to Singapore?
- What is the proximity of the refinery to populated areas?

(b) Advantages of having more refineries:
- Oil companies will build and pay for the refiners, not taxpayers.
- Creation of jobs for local workers and engineers.
- There will be a supply of petroleum products for Singapore.
- It may be cheaper to produce the products in Singapore than to import them from overseas.
- A boost to the local economy through exporting petroleum products.
- Geographic location of Singapore is ideal for serving regional markets.

Disadvantages of having more refineries:
- Taxpayer may have to pay for infrastructure, such as reclaiming land, construction of ports and roads.
- Loss of a lot of land if the refinery is built on existing land.
- Destruction of marine ecosystems if land is reclaimed.
- Risk of oil spills and fires.
- The refinery may be too close to populated areas.
- Oil-producing countries may stop selling oil to Singapore (unlikely).

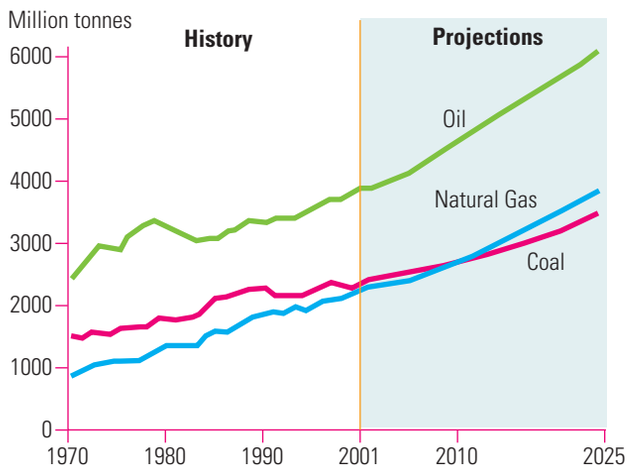
(c) –

(d) Existing refineries in Singapore are located on Jurong Island and Pulau Bukom. Future refineries (and related cracking and chemical plants) could be built at the same locations.

Teaching pointers

24.4 What Issues Arise From the of Fossil Fuels? (page 394)

1. Fossil fuels can be regarded as non-renewable energy sources and so cannot be replaced when they are used up. Today, the world uses large amounts of fossil fuels and the demand is increasing. The chart below shows how the annual consumption of fossil fuels has increased in recent years.



2. The chart in Figure 24.12 on page 394 of the Textbook is only an estimate. The chart is based on current rates of consumption and current known reserves of fossil fuels. The estimates can be affected by the following three factors:
- The future rate of consumption of fossil fuels.
- The possibility of finding more reserves of fossil fuels (that can be readily extracted).
- The possibility of finding fossil fuels sources containing low percentages of fuel, which are not economical to exploit today. For example, there are large amounts of rocks and sands with low concentrations of petroleum which have yet to be exploited (some of these are now being exploited in Alberta, Canada). In addition, a new study shows that natural gas may also form in the much deeper layer of the Earth called the mantle. This means that new sources of energy could lie at depths of 100 kilometres (62 miles) or more compared with present-day extraction which normally goes no deeper than 6 kilometres.

3. Coal can be converted into petrol though at present the process is expensive. As reserves of coal are much greater than reserves of petroleum, it is possible that this process will be used more in the future as petroleum begins to run out. Additional Exercise 1 on an alternative fuel for Singapore to natural gas and petroleum (i.e. coal) can also be used. The worksheets may be photocopied and distributed to the class.

4. The use of ethanol and gasohol as alternative fuels is introduced in this section and developed later in Chapter 26.

Skills Practice (page 395)

(a) Charcoal is a renewable energy source as it comes from wood. More trees can be grown.

(b) Being a solid, charcoal does not flow like a liquid or gas and so it cannot be pumped through pipes. It is not possible to control the burning of charcoal like a liquid or gaseous fuel by turning it on and off at will.

(c) No, because it would not be possible to produce enough charcoal for Singapore's needs.

(page 394)

Mystery Clue

The plants that are used to produce petrol and plastics can be replaced by growing more plants. Hence, plants will always be available even when the Earth's sources of petroleum run out.

Notes for Teachers

The rubber industry in Singapore
Much of Singapore was covered by rubber estates until after the Second World War. People had to be resourceful as there was a serious shortage of petrol and kerosene during the Japanese Occupation. Singaporeans had to burn rubber and charcoal as fuel to do their cooking. The charcoal was made from rubber wood.

Alternative fuels
Burning rubber would be wasteful. Rubber is not an efficient fuel as it does not burn completely. There are better sources of fuels. Potentially, the most useful alternative fuel for the future may be hydrogen. It can be generated by passing electricity through water. The electricity would be obtained from solar energy. Hydrogen is non-polluting, because it burns to produce harmless water.

24 Chapter Review

Self-Management

Misconception Analysis (page 396)

1. **True** Petroleum, also called crude oil, is a thick liquid that has few uses if not separated into fractions.
2. **False** The lightest fraction called petroleum gas is a gas. The heaviest fraction, bitumen, is a solid.
3. **False** Although natural gas and petroleum may be used up soon, there are enough coal reserves to last for hundreds of years.
4. **True** The size and mass of the hydrocarbon molecules in the petroleum fractions gradually increases as we go down the column. This increase affects the physical properties of the fractions such as density, viscosity and boiling point.
3. **False** Alternatives to fossil fuels are available though they may be expensive and not widely available. For example, hydrogen gas, ethanol and gasohol, fuel cells and petrol from coal are alternatives to fossil fuels.

Practice

Structured Questions (pages 396 – 397)

1. (a) Fractional distillation
   (b) A difference in boiling points among the compounds (hydrocarbons) in petroleum.
   (c) Each fraction has a range of boiling points which indicates a mixture, rather than a single sharp boiling point which indicates a single/pure substance.
   (d) **A** is petrol (gasoline).
   B is naphtha.
   C is kerosene (paraffin).
   D is diesel.
   (e) (i) **D**
   (ii) **A**
   (iii) **D**
   (f) (i) Petroleum gases is used as cylinder gas / liquefied gas lighters.
   (ii) Bitumen is used for surfacing roads.

2.

Name of fraction	Boiling point (°C)	Average number of carbon atoms in a molecule
top of fractionating column		
petrol	35 – 75	8
naphtha	75–170	10
kerosene	170 – 250	12
diesel	250 – 340	20
bottom of fractionating column		

   (b) It boils over a range of temperatures, not at a single temperature.
   (c) Bitumen which is used for surfacing roads.

3. (a) (i) Kerosene
   (ii) It has larger and heavier molecules. / There are more carbon atoms in the molecules.
   (b) Petrol
   (c) Kerosene
   (d) Petrol is easier to ignite.
   (e) Petrol is more dangerous to handle as it is highly volatile and ignites very easily.

4. (a) (i) Petroleum (crude oil)
   (ii) Natural gas
   (b) (i) A hydrocarbon is a compound consisting of carbon and hydrogen only.
   (ii) Methane
   (iii) Approximately 15 to 25 carbon atoms.
   (c) CNG burns with a cleaner, less sooty flame than diesel and so produces fewer air pollutants.
   (d) Hydrogen

5. (a) Natural gas
   (b) Kerosene (or several others)
   (c) (i) Coal
   (ii) Burning solid fuels produces a lot of pollution.
   (d) Burning natural gas and petroleum produce large amounts of CO_2, which causes global warming. This causes sea levels to rise and flooding to occur.
   (e) These fossil fuels will run out. This will result in an energy crisis and a lack of raw materials for making a lot of useful chemicals and products such as plastics.
   (f) Singapore has no hydroelectric energy sources.

Free Response Question (page 397)

1. Responses to this question may include the following points:
   - Petroleum is heated. It vaporises and passes up a tall/fractionating column/tower.
   - The fractions come out of the column/tower at various heights depending on their boiling points; the lowest boiling point fraction comes out of the top of the column.
   - Four fractions in increasing order of boiling point (range) are:
     Petroleum gas ⟶ petrol ⟶ naphtha ⟶ kerosene
   - One use for each fraction:
     Petroleum gas is used as a cylinder gas for cooking/heating.
     Petrol is used as fuel for cars.
     Naphtha is used in the preparation of petrochemicals such as alcohol, plastics and drugs.
     Kerosene is used as fuel for jet aircraft.

2. Responses to this question may include the following points:
   - Crude oil (also called petroleum) is transported by tanker. Natural gas, formed with the crude oil, can be transported by an undersea pipeline or, if the distance is too great, liquefied and transported by tanker as liquefied natural gas (LNG).
   - The crude oil is heated in a furnace and fractionally distilled to give various fractions.
   - Natural gas is used in the reaction with steam to give hydrogen, and as a fuel in factories and at home.
   - Name any three fractions and their uses (refer to Table 24.1 on page 392 of the Textbook).

   Note: Reference may also be made to cracking (studied in Chapter 25) to produce more petrol and chemicals such as ethene. Ethene is used as raw materials in the manufacture of products such as plastics.

Extension (page 397)

Should Oil be Used as Fuel?

(a) This topic could also be used as a debate. Some points 'for' and 'against' are as follows:
'For':
- Many everyday products are derived from chemicals in oil, e.g., plastics.
- There would be less pollution if oil is not used.
- Oil would last longer if large amounts of it are not used as fuels.
- Oil reserves are limited. Therefore oil should be used only when other alternatives do not exist.

'Against':
- Modern life depends on oil.
- Chemists will find ways to overcome pollution problems associated with burning.
- Alternatives to oil products can be used, e.g., use metals instead of plastics.
- Many alternatives to oil products also cause pollution.

Additional Teaching Material

Additional Experiment 1: Investigating the Properties of Petroleum Fractions

Aim

- To separate petroleum into fractions using simple laboratory apparatus
- To compare the properties of these fractions

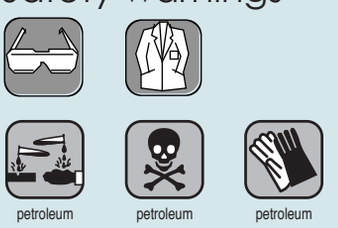
Key Skills and Processes

CIT: sound reasoning [*inferring*, *comparing*, *identifying patterns*]
ICS: communicating effectively [*observing*, *measuring*, *recording results*]

Apparatus and chemicals

- boiling tube
- rubber stopper fitted with a thermometer
- test-tube rack
- test-tubes with stoppers and labels (4)
- retort stand, boss and clamp
- beaker (250 cm^3)
- Bunsen burner
- heat-insulating surface
- watch glasses
- evaporating dishes (4)
- dropper
- petroleum (crude oil)
- cotton wool or mineral wool
- filter paper
- wooden splints

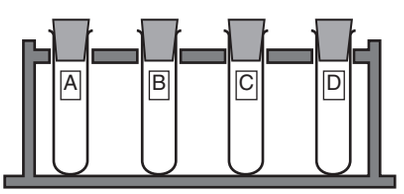
Safety warnings



Procedure

A Separating petroleum into fractions

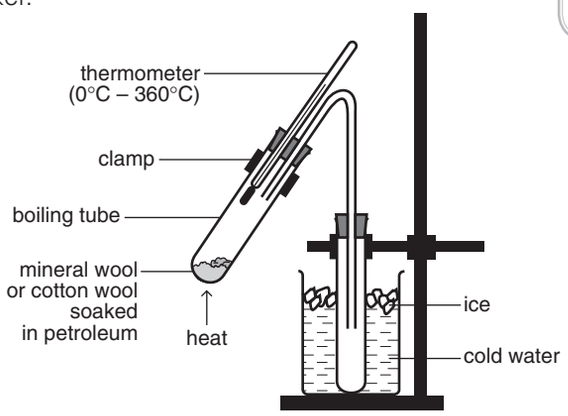
1. Label four clean test-tubes A, B, C and D. Place them in a test-tube rack.



Petroleum may cause cancer. Wash your hands thoroughly with detergent if you get petroleum on them.

2. Set up the apparatus as shown in the diagram below.
Place test-tube A in the beaker.

> ! Carry out the experiment in a well-ventilated laboratory.



Heat the test tubes of contents gently. Collect the distillate in Test tube A. This is Fraction **A**.

3. When the temperature reaches about 80 °C, replace Test-tube A with Test-tube B. Continue heating. Collect the fraction that distils between 80 °C and 140 °C in test-tube B.
This is Fraction **B**.

4. Similarly, repeat Step 3. Replace Test-tube B with Test-tube C and collect Fraction **C** with a boiling point range of 140 °C to 200 °C.

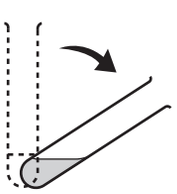
5. Stop heating when the temperature reaches about 250 °C. Pour some of the liquid from the boiling tube into Test-tube D. This is Fraction **D**.

B What properties do the fractions have?

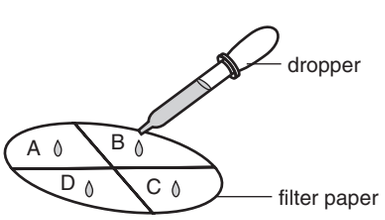
Examine each fraction as described below.
Record your observations in the table under the Results section.

1. *Colour*
Note the colour.

2. *Viscosity (i.e. how easily the liquid flows)*
Slant the test-tube gently and observe how the liquid flows. (A liquid that moves more easily has a lower viscosity.)

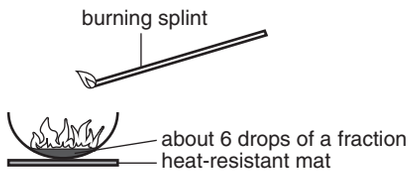


3. *Volatility (i.e. how easily the liquid evaporates)*
Place a drop of the liquid onto a piece of filter paper marked for each fraction. Note if the liquid evaporates quickly or slowly.



4. *Flammability (i.e. how well it burns)*
Place about 6 drops of the liquid in an evaporating dish. Try to ignite it (i.e. start it burning) with a burning splint. Does the fraction ignite (start burning) easily? What colour is the flame? Is the flame clean or sooty?

! Keep the fractions not being tested well away from the flame.



Results

Property \ Fraction	A Room temperature – 80°C	B 81–140°C	C 141–200°C	D over 200°C
colour				
viscosity				
ease of evaporation				
flammability • ease of ignition • colour/sootiness of flame				

Discussion

1. What is the name of the process used to separate petroleum into fractions?

2. Each of the fractions in the experiment is a mixture rather than a pure substance. How do we know this?

3. Identifying patterns
As the boiling point increases, what happens to
(a) the colour of the fractions?

(b) the viscosity of the fractions?

(c) the speed of evaporation of the fractions?

(d) the ease of ignition of the fractions?

(e) the amount of soot produced during the burning of the fractions?

Additional Teaching Material

Additional Exercise 1: An Alternative Fuel for Singapore

Aim

- To discuss the possible use of alternatives to petroleum and natural gas in Singapore

Key Competencies

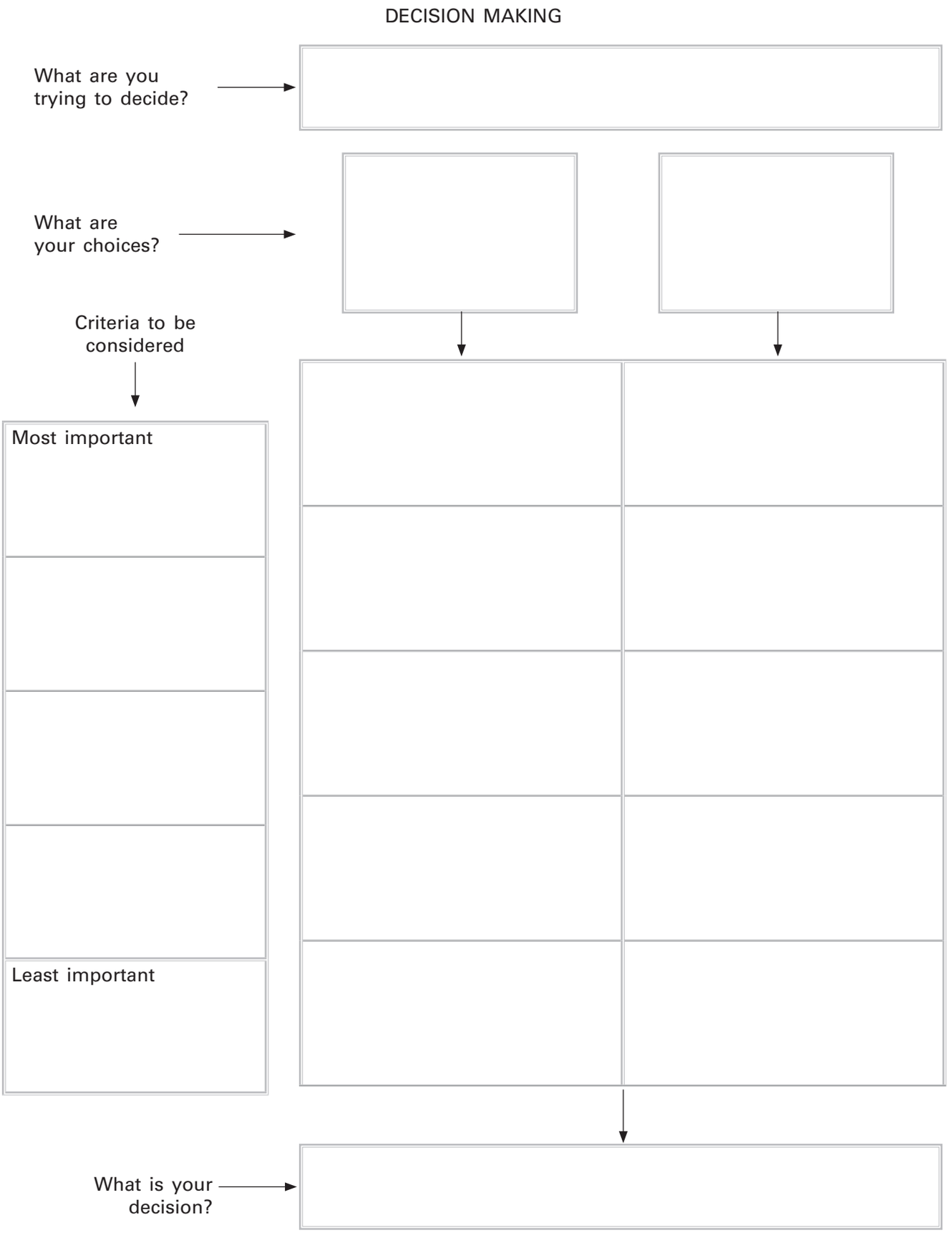
CIT: decision making

At present, Singapore imports all the oil and natural gas that is needed to supply the country's energy needs. Now imagine that huge coal deposits are found on Pulau Ubin. The newspapers are talking about a 'great coal bonanza' to supply 'all of Singapore's energy needs for the next millennium'.

Discuss this great discovery with other students. Think about the possible advantages and disadvantages of the two options.

1. Mine the coal and burn it to produce energy.

2. Leave the coal where it is and continue to use imported oil and gas.
   Use the graphic organiser on the next page to:
   - consider the criteria which are important in making this decision and rank them in order, and
   - decide whether or not to mine the coal.



Answers

Additional Experiment 1:

Results

Property \ Fraction	A Room temperature – 80°C	B 81–140°C	C 141–200°C	D over 200°C
colour	colourless	pale yellow	yellow	(dark) brown
viscosity	non-viscous	→ viscosity	increases →	fairly viscous
ease of evaporation	very easy	easy	more difficult	difficult
flammability • ease of ignition	very easy	more difficult	difficult	difficult
• colour/sootiness of flame	yellow; not sooty	yellow/orange; slightly sooty	orange; sooty	orange; very sooty

Discussion

1. Fractional distillation

2. Each fraction boils over a range of temperatures rather than having a single, fixed boiling point.

3. **(a)** The colour changes from colourless/pale yellow to yellow then to brown.
(b) The viscosity increases.
(c) The speed of evaporation decreases.
(d) The ease of ignition decreases.
(e) The sootiness of the flame increases.

Additional Exercise 1:

DECISION MAKING

What are you trying to decide? → Whether or not to exploit the coal on Pulau Ubin

What are your choices? →

Extract and use the coal	Do not extract the coal and continue to rely on imported oil and coal.

Criteria to be considered ↓

Criteria to be considered	Extract and use the coal	Do not extract the coal and continue to rely on imported oil and coal.
Most important Pollution effects	very big damage as coal is a very dirty fuel, causing smoke, and solid waste and mining is unsightly	some pollution due to risk of oil spillage
Effect on Singapore's dependance on imported fuel	much less imported fuel would be needed, but Singapore would still need to import some oil to make fuel for vehicles	no change (Singapore depends on imported oil and gas for energy)
Effect on cost of energy	cheaper energy for generating electricity and for industry	no change
Effect on jobs	many jobs created in mining and transporting coal	no change
Least important Effects on transport	vehicles would be needed to transport the coal as it is solid	no change

What is your decision? → Do not make the coal because the damage caused by pollution would be so great that it does not justify the economic gain, especially as some oil and gas would still have to be imported