

15 Fuels and Crude Oil

Study Station >>

A Why Are Natural Gas and Crude Oil Important in Daily Life?

Learning Outcomes

- Recognise natural gas and crude oil as non-renewable sources of energy.
- Describe crude oil as a mixture of hydrocarbons.

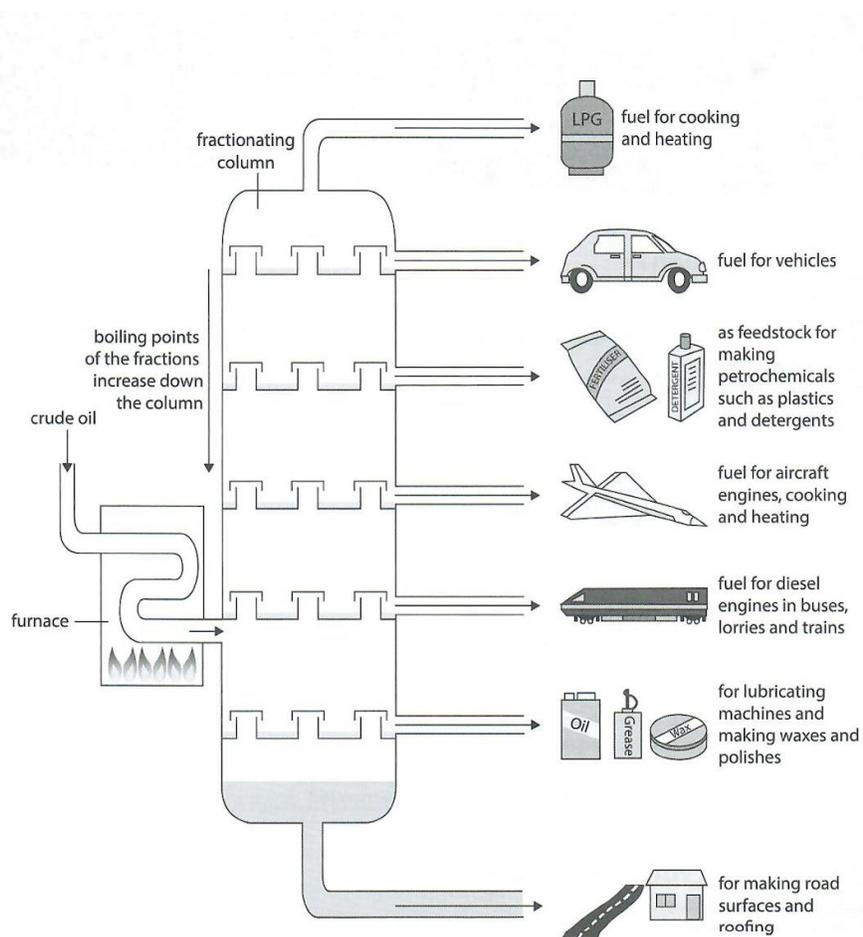
1. **Fossil fuels** are formed from the remains of plants and animals buried underground for millions of years.
2. Examples of fossil fuels are **crude oil** and **natural gas**.
3. Crude oil is made up of different hydrocarbons. **Hydrocarbons** are compounds made up of carbon and hydrogen only.
4. Crude oil is also known as **petroleum**.
5. Natural gas contains mainly **methane (CH₄)**.
6. Crude oil and natural gas are **non-renewable** sources of energy as they cannot be replenished at the same rate at which they are used.

 **Link** Discover Chemistry (3rd Edition) Textbook — Section 15.1

B How Can Crude Oil Be Separated?

Learning Outcomes

- Describe the separation of crude oil by fractional distillation.
 - Describe the competing uses of the crude oil fractions as fuels and a source of chemicals.
1. Crude oil can be separated into different fractions in oil refineries by **fractional distillation**.
 - The fractions of crude oil are miscible and have different boiling points.
 - The crude oil is heated to about 400 °C in a furnace. It changes into a vapour.
 - The hot vapour rises up a fractionating column.
 - Different hydrocarbon fractions condense and are collected at different levels of the column.
 - Smaller hydrocarbon fractions have lower boiling points and are collected at the higher levels of the column. They are less viscous (flow more easily) and more flammable (burn more easily).
 - Larger hydrocarbon fractions have higher boiling points and are collected at the lower levels of the fractionating column. They are more viscous and less flammable.

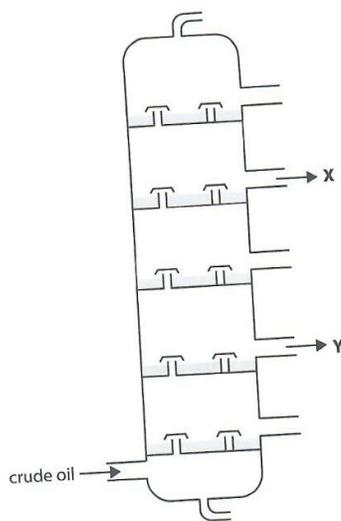

Tip

- Take note that the individual fractions of crude oil are mixtures, not pure compounds, as they have a range of boiling points.
- As the crude oil fractions are simple covalent compounds, their boiling points increase with their molecular sizes due to stronger intermolecular forces of attraction.

2. Different crude oil fractions have different uses.
 - 90% of the fractions is used as fuel for generating electricity in vehicles, homes and industries.
 - 10% of the fractions is used as petrochemical feedstock for the manufacture of products such as plastics and detergents.
3. Crude oil is a finite resource. Its two uses are said to be competing due to its limited supply.

Worked Example 15.1

Crude oil undergoes fractional distillation in a fractionating column. Fractions **X** and **Y** are collected as shown below.



Which of the following about **X** and **Y** is **correct**?

- A **X** condenses at a higher temperature than **Y**.
- B **X** has a higher boiling point than **Y**.
- C **X** has a lower density than **Y**.
- D **X** is a larger hydrocarbon than **Y**.

 **Solution**

C

Explanation
X is found above **Y** in the fractionating column. This shows that **X** is a smaller hydrocarbon with a smaller molecular mass and hence a lower density than **Y**. With a smaller relative molecular mass, the forces of attraction between molecules of **X** are weaker. Thus, **X** has a lower boiling point and condenses at a lower temperature than **Y**.

Worked Example 15.2

Three crude oil fractions, **P**, **Q** and **R**, are collected at different levels of a fractionating column. Fraction **P** is collected first, followed by fraction **Q** and lastly fraction **R**.

Some information on three crude oil fractions are shown below.

Crude Oil Fraction	Number of Carbon Atoms Per Molecule	Boiling Point Range / °C
diesel	13–20	280–360
naphtha	7–14	90–150
petrol	5–11	50–230

Based on the information provided, identify **P**, **Q** and **R**.

 **Strategy**

During fractional distillation, hydrocarbon fractions with smaller molecular sizes are collected at the top of the fractionating column, while hydrocarbon fractions with larger molecular sizes are collected at the bottom of the column. The larger the hydrocarbon, the greater the number of carbon atoms per molecule and the higher its boiling point.

 **Solution**

P is petrol. **Q** is naphtha. **R** is diesel.

Worked Example 15.3

Describe how petroleum is separated.

 **Strategy**

State the conditions required for the fractional distillation of petroleum and describe what happens to the different petroleum fractions during the process.

 **Solution**

Petroleum is separated by fractional distillation. It is heated to about 400 °C in a furnace and vaporises. The hot vapour rises up a fractionating column and separates into fractions according to their molecular sizes and boiling points. Small hydrocarbons with lower boiling points condense at lower temperatures and are collected at the top of the fractionating column. Large hydrocarbons with higher boiling points condense at higher temperatures and are collected at the bottom of the fractionating column.

 **Link** — Discover Chemistry (3rd Edition) Textbook — Section 15.2

C Are Biofuels More Environmentally Sustainable?

Learning Outcomes

- State that ethanol obtained from sugarcane is a biofuel.
- Describe biofuels as a renewable alternative to natural gas and crude oil.
- Describe how biofuels can be more environmentally sustainable than fossil fuels.

1. **Biofuel** is an alternative fuel made from biomass. Biomass is a raw material that comes from wood, plants and waste.
2. **Bioethanol** is a type of biofuel. It is ethanol produced using plants such as sugarcane and corn.
3. Bioethanol is a **renewable** source of energy as sugarcane and corn can be grown and replaced within a short period of time, compared to fossil fuels which take millions of years to form.
4. The use of biofuels such as bioethanol is more environmentally sustainable than the use of fossil fuels.
 - Like the combustion of any organic compound, the combustion of bioethanol releases carbon dioxide into the atmosphere. Carbon dioxide, a greenhouse gas, traps heat on Earth, thus leading to global warming.
 - Carbon dioxide is absorbed by the plants which are grown as feedstock for the production of bioethanol. This offsets the carbon dioxide released during the combustion of bioethanol, thus reducing the impact on the environment.
5. However, the processes involved in the production of biofuels may still require the use of fossil fuels and generate carbon dioxide.

Common Misconception

-  The use of biofuels does not generate any carbon dioxide.
-  The use of biofuels may generate carbon dioxide due to the planting, transportation and treatment of crops for the production of biofuels.

Worked Example 15.4

Carbon dioxide is released during the production of bioethanol and the use of bioethanol as a fuel in vehicles. However, less carbon dioxide is released into the atmosphere when bioethanol is used than when fossil fuels are used.

Which of the following explains this advantage of using bioethanol as a fuel?

- A Carbon dioxide is given out by plants during respiration.
- B Plants take in carbon dioxide during photosynthesis.
- C The amount of carbon dioxide absorbed by plants during photosynthesis is less than the amount of carbon dioxide released from the production and combustion of bioethanol.
- D The carbon dioxide that is released into the atmosphere dissolves in rainwater.

Solution

B

Explanation

The amount of carbon dioxide released into the atmosphere due to the production and combustion of bioethanol is offset by the amount of carbon dioxide taken in by sugarcane crops during photosynthesis.

Worked Example 15.5

Which of the following best explains why bioethanol is a renewable source of energy?

- A Sugarcane plants absorb carbon dioxide from the atmosphere.
- B Sugarcane plants are harvested annually.
- C The combustion of bioethanol does not release greenhouse gases.
- D The production of bioethanol is a rapid process.

 **Solution****B****Explanation**

Sugarcane plants can be grown for the production of bioethanol in a short period of time. They do not become depleted and can be replaced quite quickly. Thus, bioethanol is a renewable source of energy.

Sugarcane plants absorb carbon dioxide during photosynthesis. This cancels out the carbon dioxide released during the production of bioethanol. Thus, using bioethanol is environmentally sustainable. The combustion of all organic compounds including bioethanol releases carbon dioxide, which is a greenhouse gas. The production of bioethanol involves several processes such as crushing and juice extraction. Thus, it is not a rapid process.

 **Link** → Discover Chemistry (3rd Edition) Textbook — Section 15.3

Checkpoint 15.1

1. Fossil fuels are one of the major sources of energy in the world.
 - (a) What elements do fossil fuels contain?
 - (b) Explain why fossil fuels are considered non-renewable.
 - (c) Are fossil fuels an environmentally friendly source of energy? Explain your answer.
2. Table 15.1 shows some information on four crude oil fractions.

Table 15.1

Crude Oil Fraction	Number of Carbon Atoms Per Molecule	Boiling Point Range (°C)
petroleum gas	1–4	<40
petrol	5–10	
naphtha	7–14	75–100
kerosene	11–16	160–250

- (a) Estimate the boiling point range of petrol.
- (b) Is petrol a pure substance? Explain your answer.

3. Figure 15.1 shows three petroleum fractions, X, Y and Z, being obtained by fractional distillation.

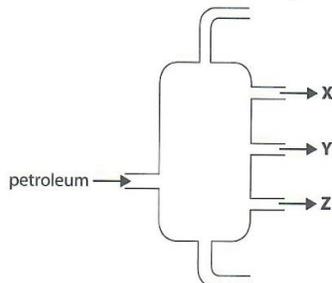


Figure 15.1

- Why is fractional distillation used to separate the petroleum fractions?
- How can X, Y and Z be arranged in order of increasing boiling points? Explain your answer.
- What can be inferred from the boiling point of each petroleum fraction?

 **Test Station** >>

- Which of the following statements about fossil fuels are **true**?
 - They are formed from the remains of plants and animals that died millions of years ago.
 - They are in the liquid state.
 - They are renewable.
 - They contain carbon.

A 1 and 2 only
B 1 and 4 only
C 2 and 3 only
D 3 and 4 only

2. Figure 15.2 shows the fractional distillation of petroleum.

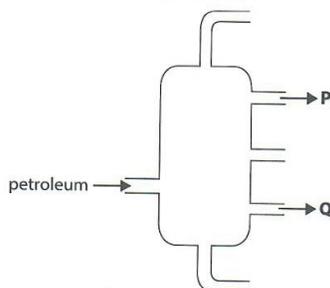


Figure 15.2

Which of the following statements about fractions **P** and **Q** is **correct**?

- A **P** burns more easily and has a higher boiling point than **Q**.
 - B **P** burns more easily and has a lower boiling point than **Q**.
 - C **Q** burns more easily and has a higher boiling point than **P**.
 - D **Q** burns more easily and has a lower boiling point than **P**.
3. Four hydrocarbons, **W**, **X**, **Y** and **Z**, are extracted from a sample of crude oil by fractional distillation.

The following observations are made about the hydrocarbons.

- **Z** flows less easily than **X**.
- **Y** burns more easily than **X** and **Z**.
- **W** burns less easily than **Z**.

Which of the following **correctly** shows how the four hydrocarbons are arranged in order of decreasing boiling points?

- A **W, X, Z, Y**
- B **W, Z, X, Y**
- C **Y, X, Z, W**
- D **Z, W, Y, X**

4. Crude oil undergoes fractional distillation and cracking in an oil refinery. Cracking is a process in which a larger hydrocarbon is broken down into smaller hydrocarbons. Table 15.2 shows the percentage demand and supply of the crude oil fractions in a barrel of oil extracted from a gulf.

Table 15.2

Crude Oil Fraction	Number of Carbon Atoms Per Molecule	Percentage Supply of Fraction (%)	Percentage Demand for Fraction (%)
petroleum gas	1–4	4	11
petrol	5–9	11	22
kerosene	10–14	12	20
diesel oil	14–20	18	15
lubricating oil and bitumen	>20	23	4

- (a) State the physical property which is used to separate crude oil by fractional distillation. Explain your answer. [3]
- (b) Based on the information in Table 15.2, identify the fractions that would undergo cracking to meet the demand for petrol. Explain your answer. [2]
5. Scientists have been exploring alternative fuels like bioethanol, which is said to be more environmentally friendly.
- Bioethanol is made by first grinding crops such as corn and separating them into sugars. The sugars undergo a process called fermentation to produce ethanol, which can be used as fuel. When ethanol is burnt, carbon dioxide is released. The gas is then taken in by crops when they make food.
- (a) Name the process by which bioethanol is obtained from corn or sugar. [1]
- (b) Explain why bioethanol is more environmentally friendly than petrol. [2]
- (c) What is **one** possible reason for limiting the use of biofuels despite their environmental benefits? [1]