

Topic 7 Fossil Fuels and Carbon Compounds

Unit 25 Fossil fuels





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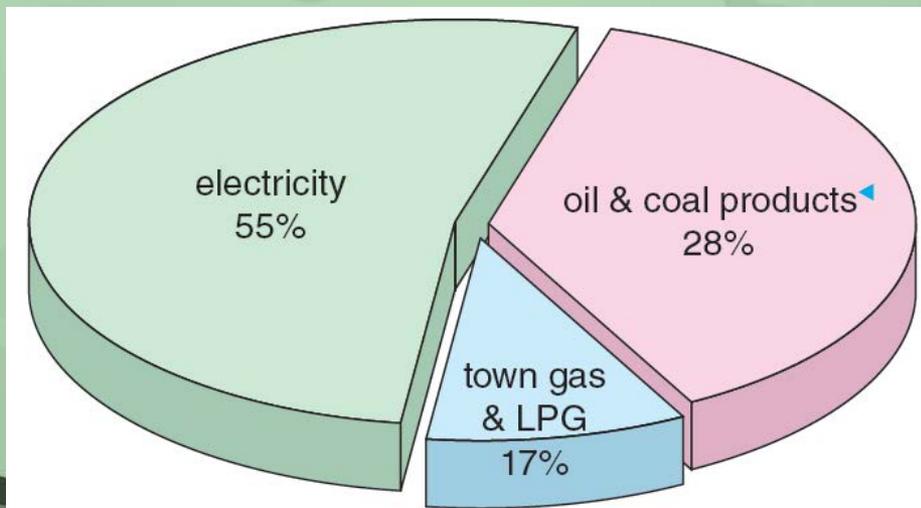
Content

- ➔ **25.13 Impacts of using fossil fuels on our quality of life and the environment**
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25.1 Different sources of energy in Hong Kong (p.2)

- ◆ Common energy sources for Hong Kong end-users:
 - electricity—by nuclear power or burning **fossil fuels (化石燃料)** like **coal (煤)** and **natural gas (天然氣)**
 - town gas & LPG—from **petroleum (石油)**
 - oil & coal products—include petrol and diesel
- ◆ Almost all types of energy come from fossil fuels.





25.2 Fossil fuels (p.3)

- ◆ Fossil fuels—remains of dead organisms that lived million of years ago, such as
 - coal (from dead plants) and
 - petroleum and natural gas (from dead sea creatures)
- ◆ They will run out and are **non-renewable** (不可再生的).



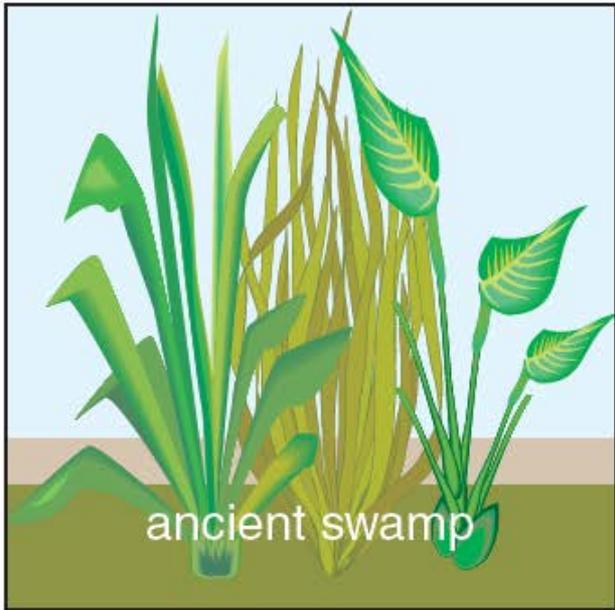
Sheets of coal with fossilised ferns



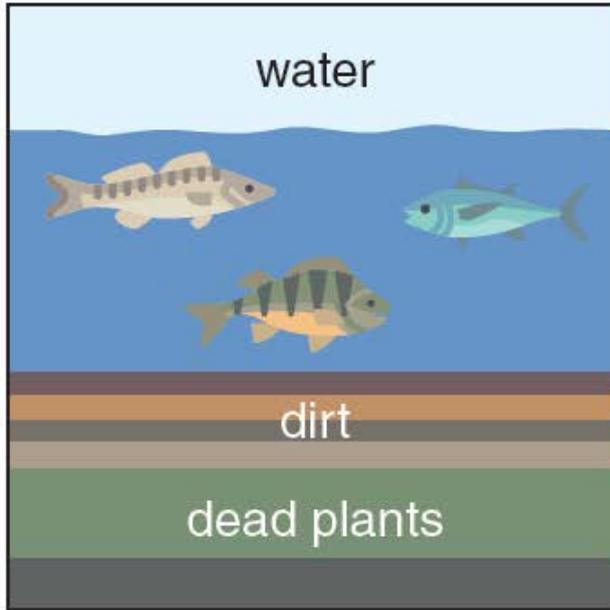
Petroleum

25.2 Fossil fuels (p.3)

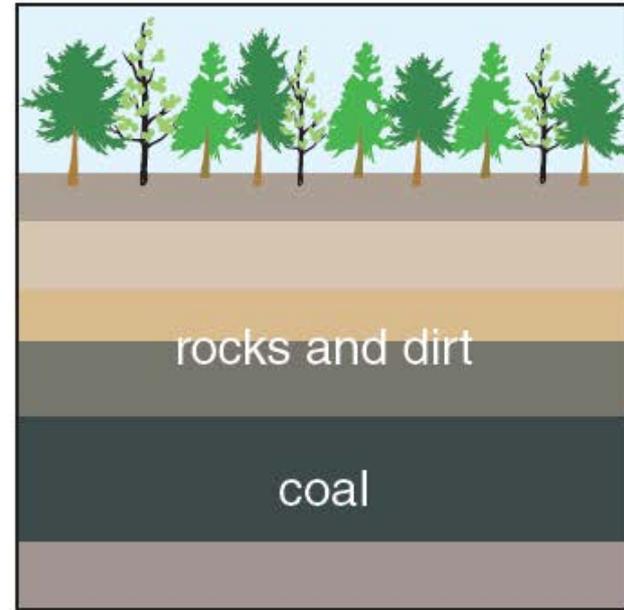
How coal was formed



Many giant plants died in ancient swamps.



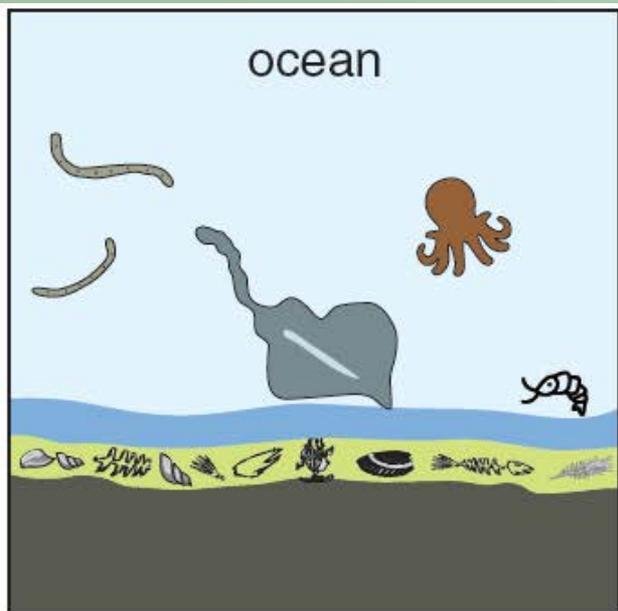
Over millions of years, the dead plants were buried under water and dirt.



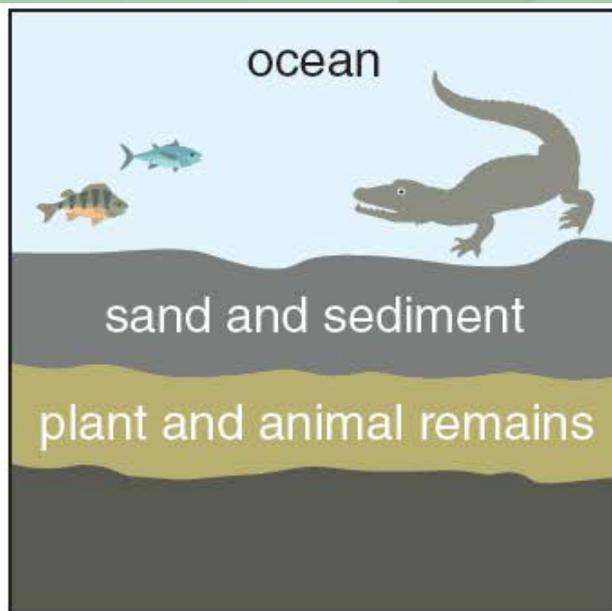
Pressure, heat and bacteria action turned the dead plants into coal.

25.2 Fossil fuels (p.3)

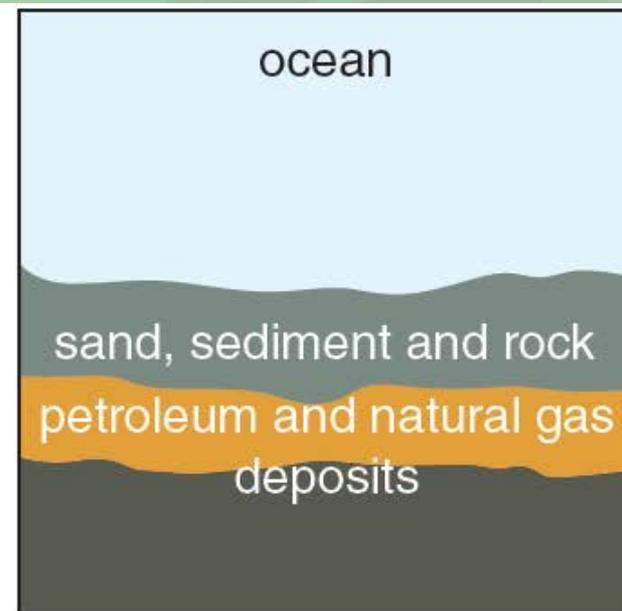
How petroleum and natural gas were formed



Marine plants and animals died and sank to the seabed.



Over time, the remains were covered by layers of sand and sediment.



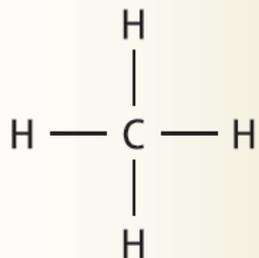
Pressure, heat and bacteria action turned the remains into petroleum and natural gas.



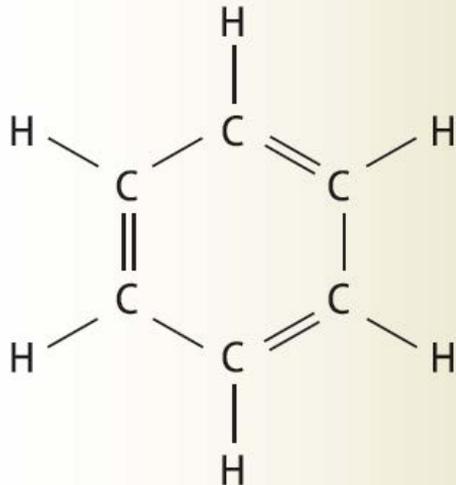
25.3 Hydrocarbons (p.5)

- ◆ Nearly all the compounds in petroleum are composed of only hydrogen atoms and carbon atoms.
- ◆ These compounds are called **hydrocarbons (烴)**.

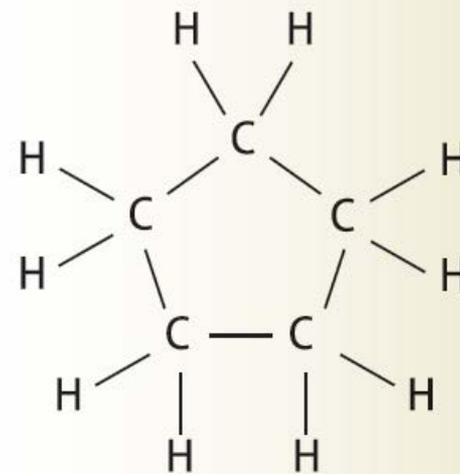
Methane, CH₄



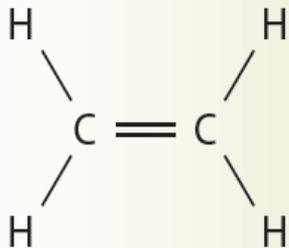
Benzene, C₆H₆



Cyclopentane, C₅H₁₀



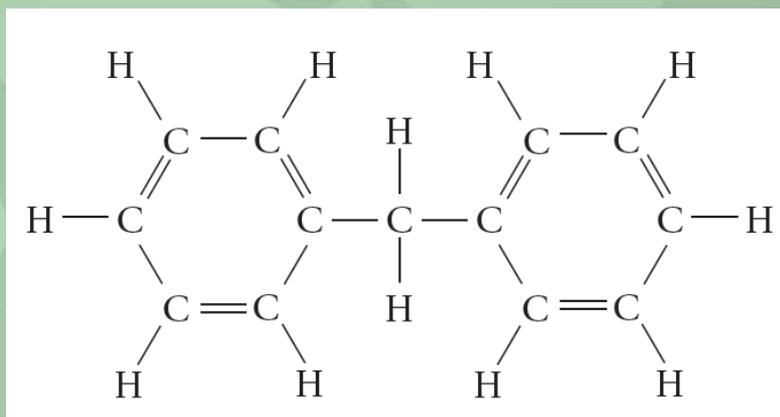
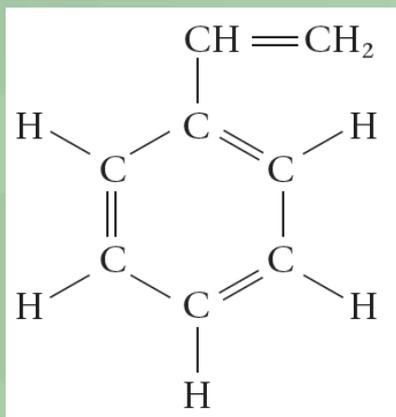
Ethene, C₂H₄





25.3 Hydrocarbons (p.5)

- ◆ **Aromatic hydrocarbons (芳香族烴)**—a hydrocarbon with at least one benzene ring in its structure



- ◆ **Aliphatic hydrocarbons (脂肪族烴)**—hydrocarbons with straight or branched carbon chains, or with rings that are not benzene rings

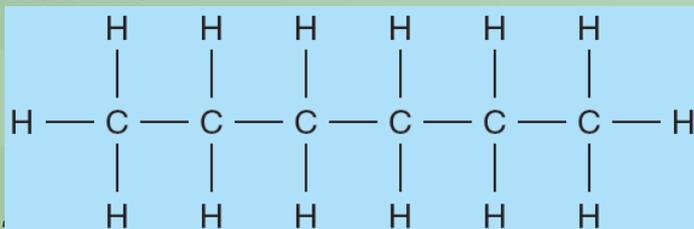


25.3 Hydrocarbons (p.5)

- Three major classes of hydrocarbons found in petroleum:

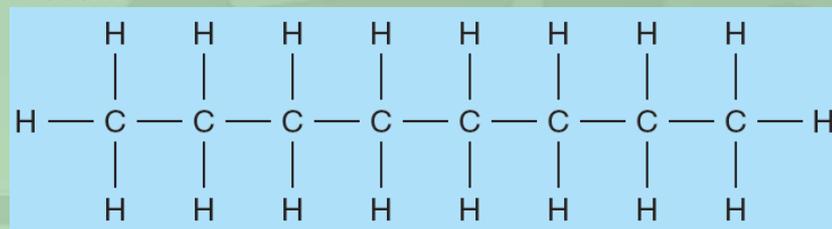
a) **alkanes** (烷);

hexane



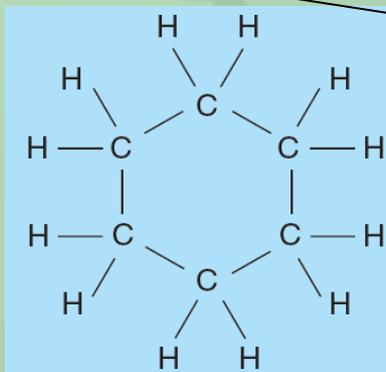
e.g.

octane



b) **cycloalkanes** (環烷); and

cyclohexane



e.g.

c) aromatic hydrocarbons.

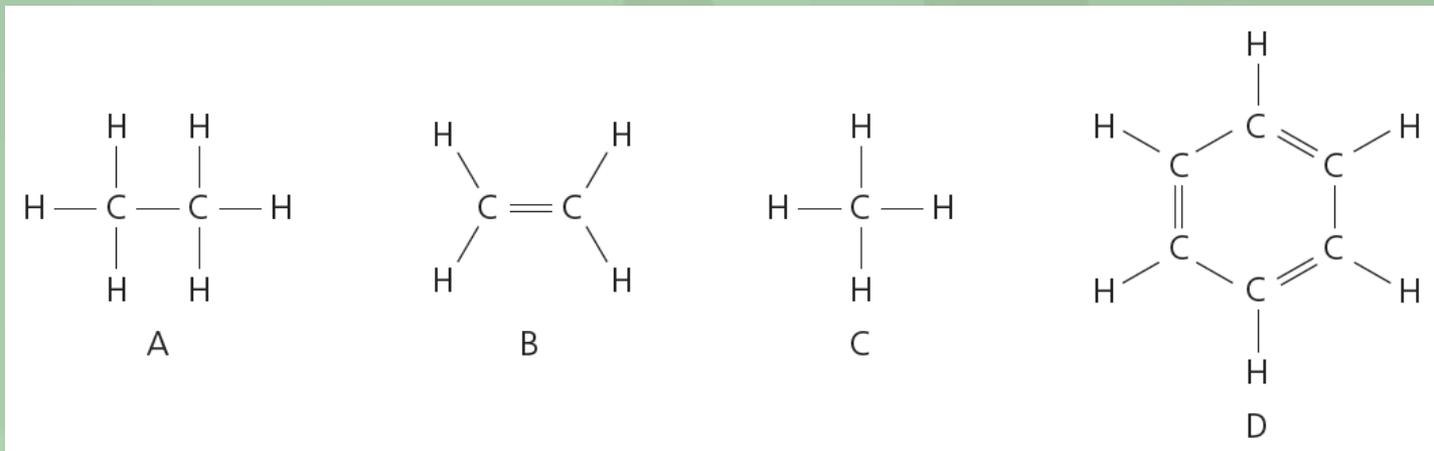
saturated (飽和) — already have the maximum possible number of hydrogen atoms in their molecules (i.e. no multiple bond).



25.3 Hydrocarbons (p.5)

Practice 25.1

The structures of four hydrocarbons are shown.



a) What is the meaning of the term ‘hydrocarbons’?

A hydrocarbon is a compound containing only hydrogen atoms and carbon atoms.

b) Which hydrocarbon is aromatic? **D**

c) i) State the meaning of the term ‘saturated’ as applied to hydrocarbons.

In a saturated hydrocarbon, all the carbon-carbon bonds in the hydrocarbon molecule are single covalent bonds.

ii) Which TWO hydrocarbons are saturated?

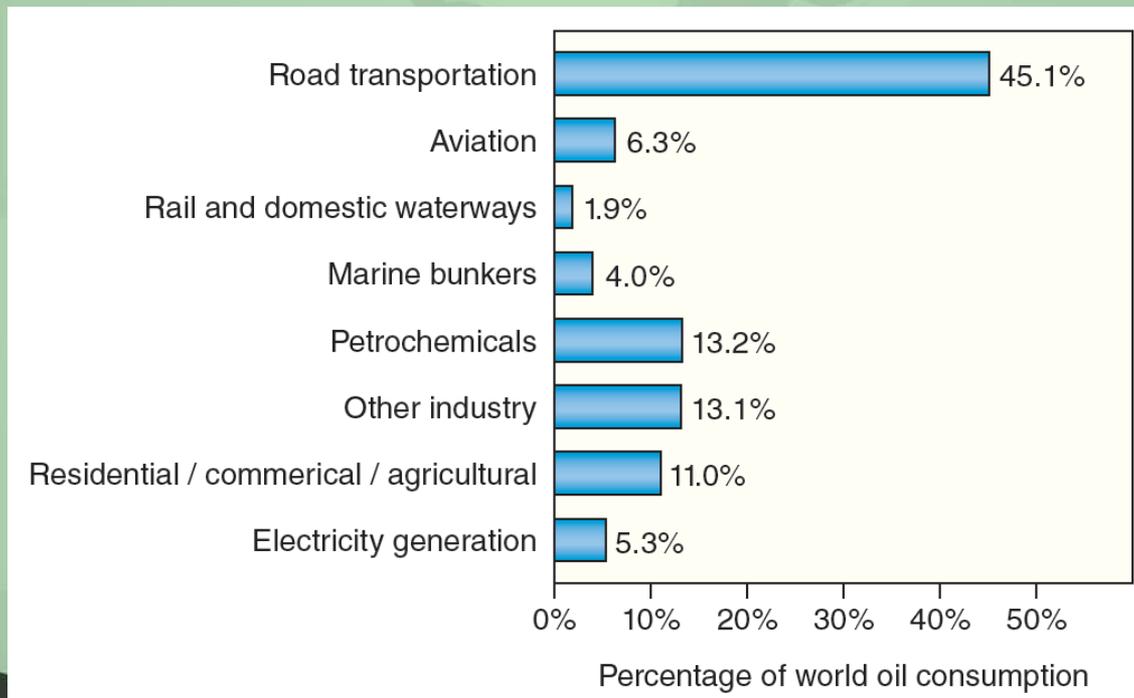
A and C



25.4 Why is petroleum important (p.8)

- ◆ Petroleum provides
 - fuels for transportation;
 - petrochemicals;
 - fuels for domestic and industrial heating and for cooking;
 - fuels for electricity generation.

World demand of oil in 2016





25.4 Why is petroleum important (p.8)

- Petroleum serves as a raw material of a large number of chemicals, e.g. ethene (C_2H_4), propene (C_3H_6) and benzene (C_6H_6), called **petrochemicals** (石油化學產品).

Products from petrochemicals





25.5 Fractional distillation of petroleum (p.11)

- ◆ Petroleum—a major source of fuel + an important raw material
- ◆ Petroleum is not very useful until it has been processed:
 - **fractional distillation (分餾)**—a technique to separate petroleum into different **fractions (餾分)** in an **oil refinery (精煉廠)**;
 - with each fraction having a specific range of boiling point because it is a mixture of many different hydrocarbons.



Fractional distillation of crude oil in a refinery



25.5 Fractional distillation of petroleum (p.11)

◆ The industrial fractional distillation of petroleum is carried out in a tall metal **fractionating tower (分餾塔)**.

5) hydrocarbons with small molecules and low b.p. collected at the top

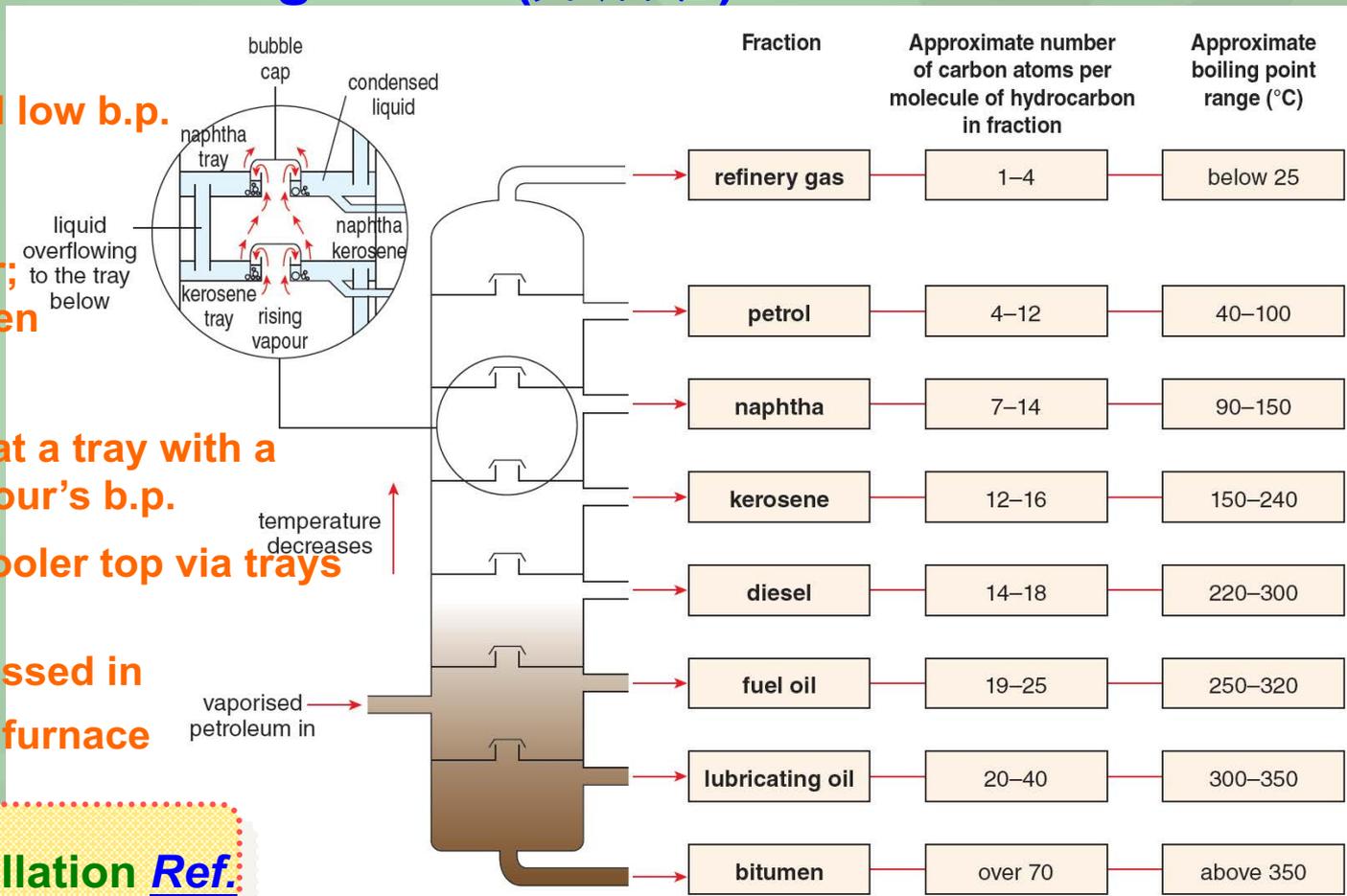
(the larger, the lower; thick residue bitumen the lowest)

4) vapour condensing at a tray with a temp. below the vapour's b.p.

3) vapour passing to cooler top via trays

2) liquid and vapour passed in

1) petroleum heated in furnace



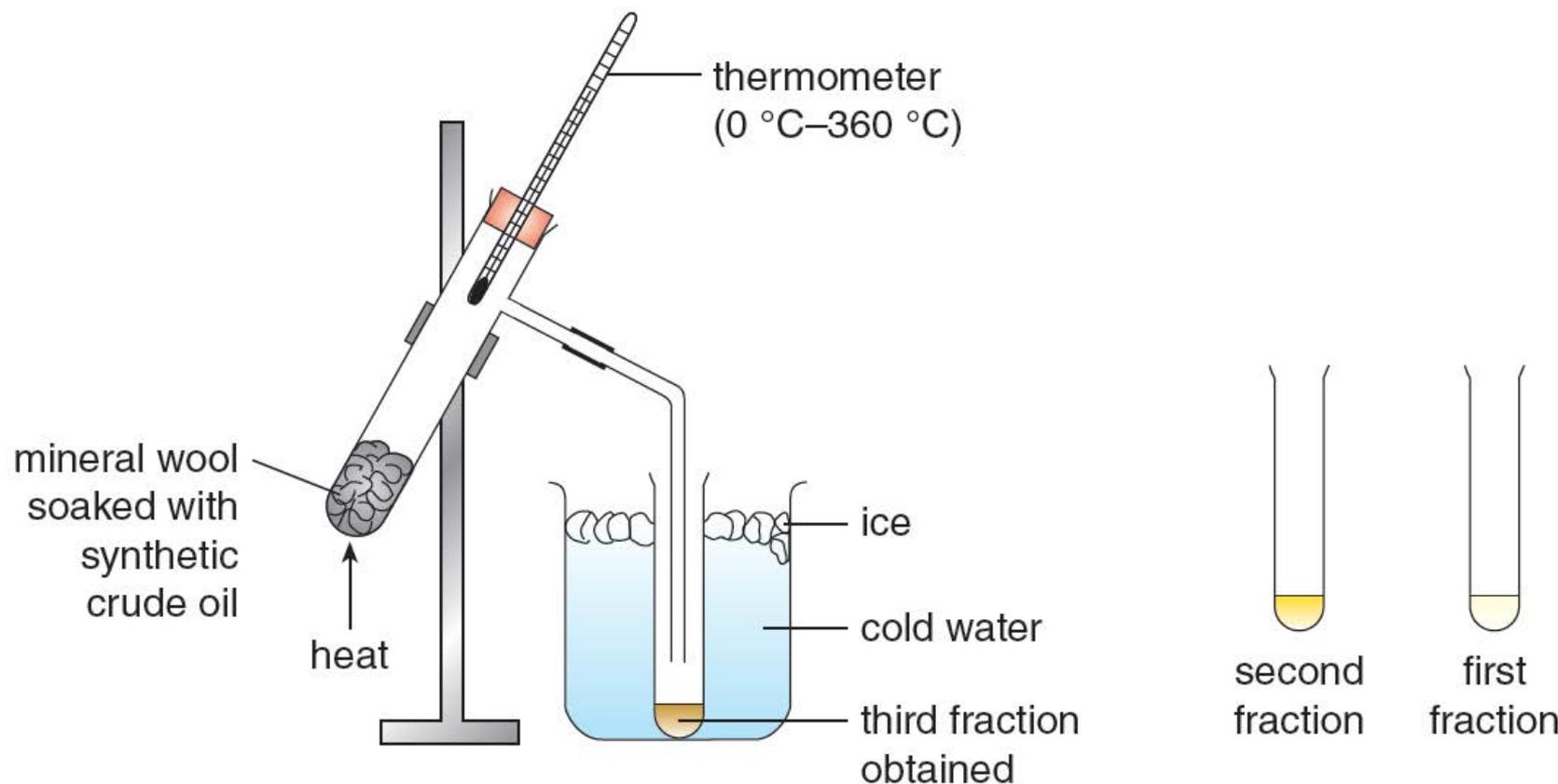
Fractional distillation [Ref.](#)





25.5 Fractional distillation of petroleum (p.11)

- You can carry out the fractional distillation of synthetic crude oil in a laboratory using the experimental set-up shown:





25.6 Trends in properties of fractions from petroleum (p.13)

- ◆ In general, the more carbon atoms there are in the molecules of a hydrocarbon,
 - the larger the molecules;
 - the stronger the van der Waals' forces;
 - the higher the melting and boiling points.
- ◆ A petroleum fraction with a lower boiling point range contains hydrocarbons with a small number of carbon atoms in their molecules.
- ◆ A petroleum fraction with a higher boiling point range contains hydrocarbons with a greater number of carbon atoms in their molecules.

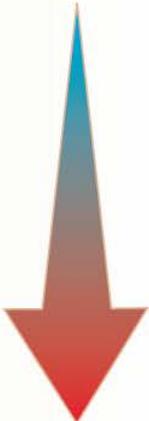
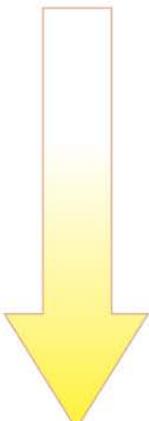
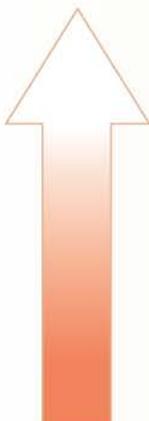
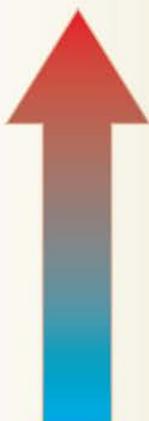


Investigating the different properties of two petroleum fractions [Ref.](#)



25.6 Trends in properties of fractions from petroleum (p.13)

Table 25.2 Trends in properties of the petroleum fractions leaving a fractionating tower

Fraction	Number of carbon atoms per molecule of hydrocarbon in fraction	Boiling point range	Colour	Volatility (how easily it evaporates) N4	Flammability (how easily it burns)	Viscosity
Refinery gases	smallest  greatest	lowest  highest	lightest  darkest	highest  lowest	highest  lowest	lowest (flows most easily)  highest (flows with difficulty)
Petrol						
Naphtha						
Kerosene						
Diesel						
Fuel oil						
Lubricating oil						
Bitumen						



25.7 Uses of fractions from petroleum (p.14)

- Some uses of petroleum fractions include:
 - refinery gas as fuels (burn easily, low viscosity, readily piped around);
 - bitumen for surfacing roads and roofs (solid at r.t., waterproof)

Refinery gases	 as gaseous fuel
Petrol	 as fuel for vehicles
Naphtha	 for making chemicals and manufacturing town gas
Kerosene	 as fuel for aircraft and as heating oil



25.7 Uses of fractions from petroleum (p.14)

Diesel		as fuel for heavy vehicles and trains
Fuel oil		as fuel for ships and power plants
Lubricating oil		as lubricants, waxes and polishes
Bitumen		for road surfaces and roofs



25.7 Uses of fractions from petroleum (p.14)

Q (Example 25.1)

Diesel is a commonly used fuel for heavy vehicles. It can be obtained from petroleum by fractional distillation.

- a) Explain, from molecular level, why diesel can be obtained from petroleum by fractional distillation.
- b) To reduce air pollution caused by vehicles, all taxis in Hong Kong have switched from using diesel to liquefied petroleum gas (LPG).
 - i) Give the name of a compound which is a major component of LPG.
 - ii) Why is LPG considered a 'cleaner' fuel than diesel?



25.7 Uses of fractions from petroleum (p.14)

A

- a) Components having different boiling points can be separated from each other by fractional distillation.

The larger the molecular size of a hydrocarbon, the higher is its boiling point.

- b) i) Propane / butane
ii) LPG burns more completely. / LPG gives a less sooty flame on burning.



25.7 Uses of fractions from petroleum (p.14)

Practice 25.2

The table shows some fractions obtained from the fractional distillation of petroleum.

Fraction	Number of carbon atoms per molecule of hydrocarbon in fraction
Refinery gas	1–4
Petrol	4–12
Kerosene	12–16
Diesel	14–18
Fuel oil	19–25

- a) Which fraction has the lowest boiling point range? **Refinery gas**
b) State the names of TWO petroleum fractions NOT given in the table.

Any two of the following:

- Naphtha
- Lubricating oil
- Bitumen



25.7 Uses of fractions from petroleum (p.14)

c) What is the relationship between the number of carbon atoms per molecule of hydrocarbon in fraction and the boiling point range of the fraction?

The more carbon atoms per molecule of hydrocarbon in a fraction, the higher the boiling point range of the fraction is.

d) Describe how the colour and viscosity of the fuel oil fraction differ from those of the petrol fraction.

The colour of the fuel oil fraction is darker than that of the petrol fraction.

The viscosity of the fuel oil fraction is higher than that of the petrol fraction.

e) The petroleum fractions have many uses. Name TWO uses of petroleum fractions. Any two of the following:

- As fuels
- As lubricants
- For chemical synthesis
- As waxes
- For road surfaces / roofs



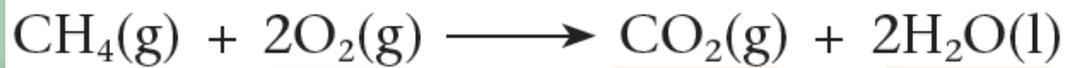
25.8 Combustion of fuels (p.18)

- ◆ **Complete combustion (完全燃燒)**—burning completely in a plentiful supply of air or oxygen.

e.g. burning coal (mainly carbon): $\text{C(s)} + \text{O}_2\text{(g)} \longrightarrow \text{CO}_2\text{(g)}$

It is **exothermic (放熱的)**—releasing heat to the surroundings.

e.g. burning natural gas (mainly methane):



- ◆ **Incomplete combustion (不完全燃燒)**—burning with limited supply of air or oxygen, giving also soot (carbon particles) and CO(g).

Black smoke contains soot, due to incomplete combustion





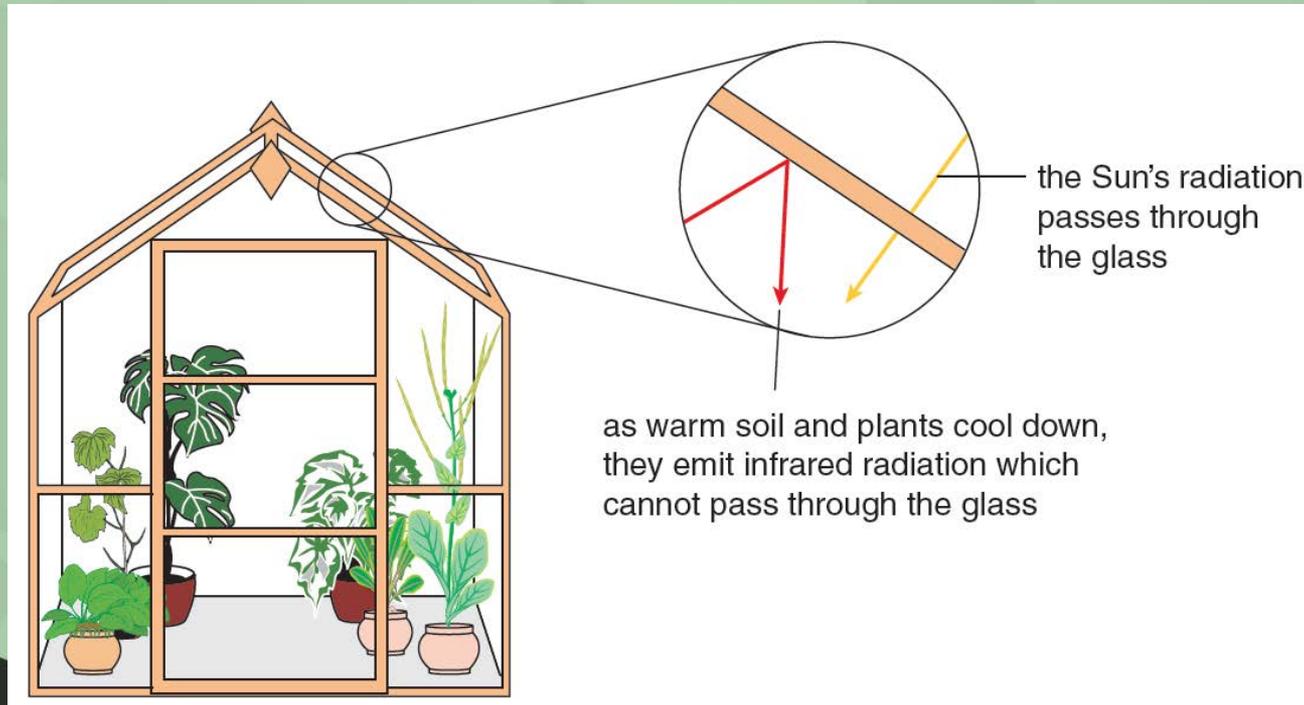
25.9 What is the greenhouse effect? (p.19)

- ◆ Objects in a greenhouse absorb Sun's radiation.
(Earth and the atmosphere absorb part of Sun's radiation.)
- ◆ The warmed objects emit **infrared radiation, IR (紅外輻射)** when cooling down.
(Earth emits IR radiation back into space when it cools down.)
- ◆ The glass is opaque to IR radiation and traps the heat. The heat warms the air inside.
(Carbon dioxide and methane absorb some of the IR radiation emitted from Earth and re-emit them in all directions. This prevents the IR radiation from being re-radiated into space.)



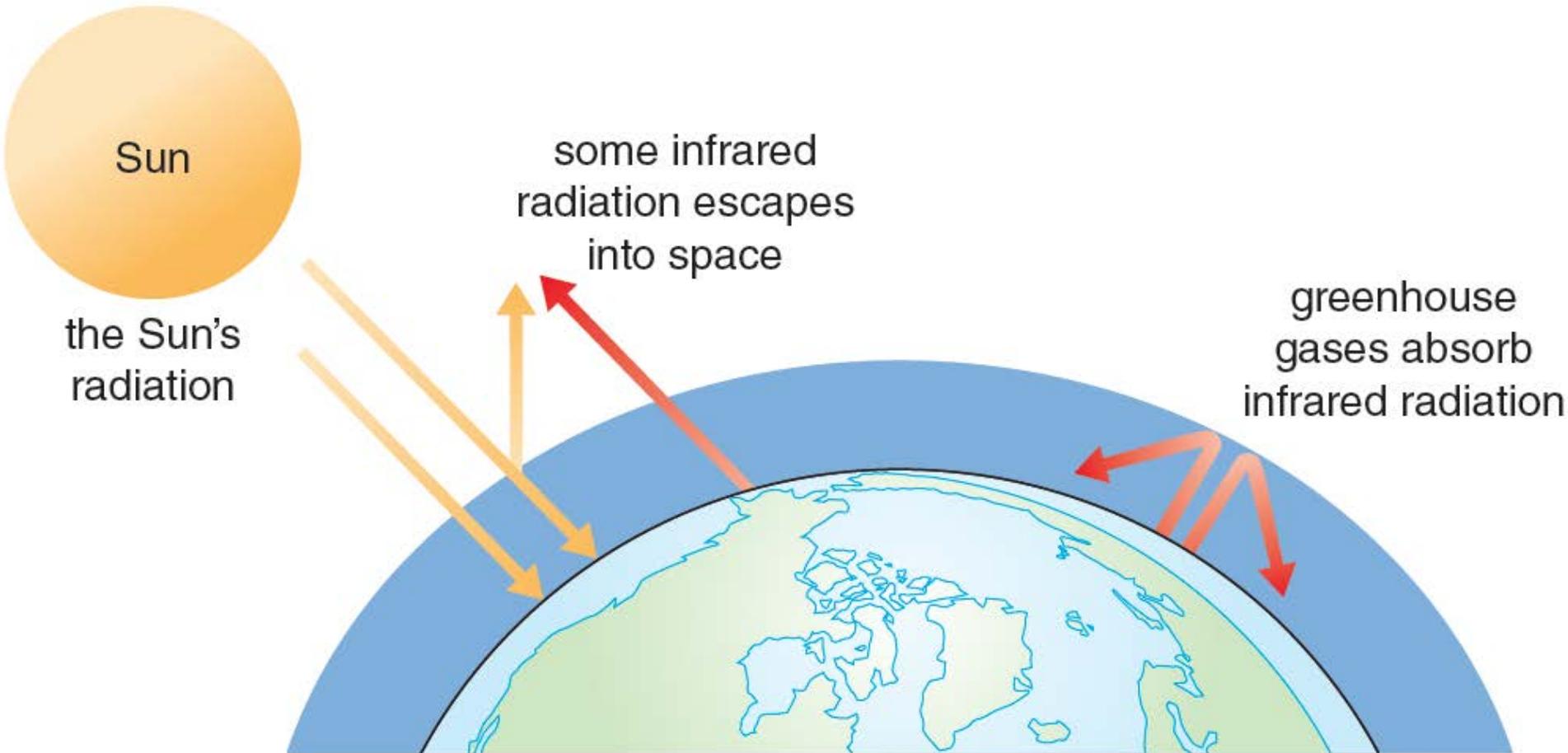
25.9 What is the greenhouse effect? (p.19)

- ◆ **Greenhouse effect (溫室效應)**—the effect of trapping the heat from Sun.
- ◆ The gases which cause the phenomenon are known as **greenhouse gases (溫室氣體)**.





25.9 What is the greenhouse effect? (p.19)





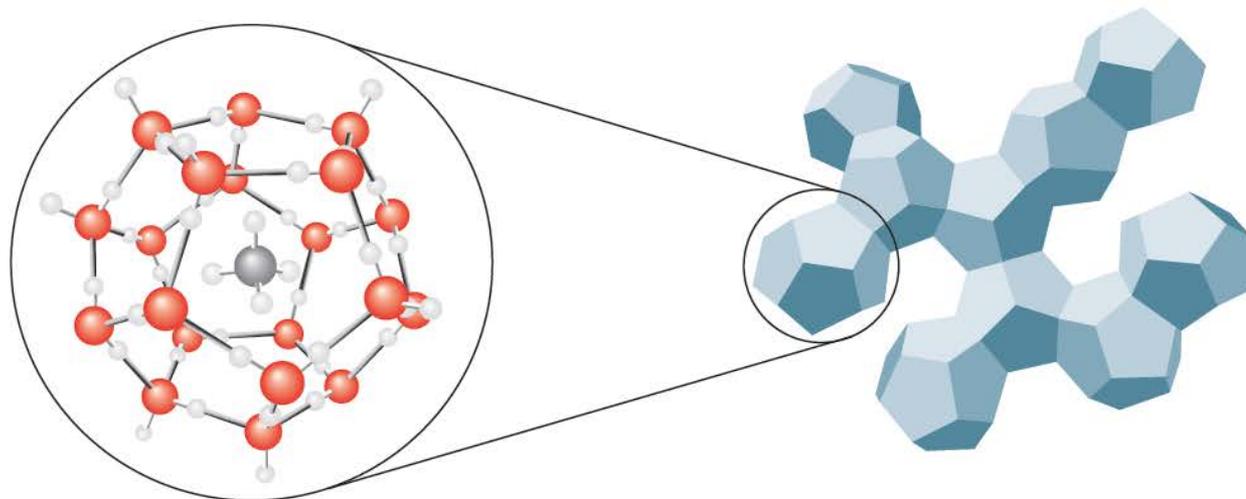
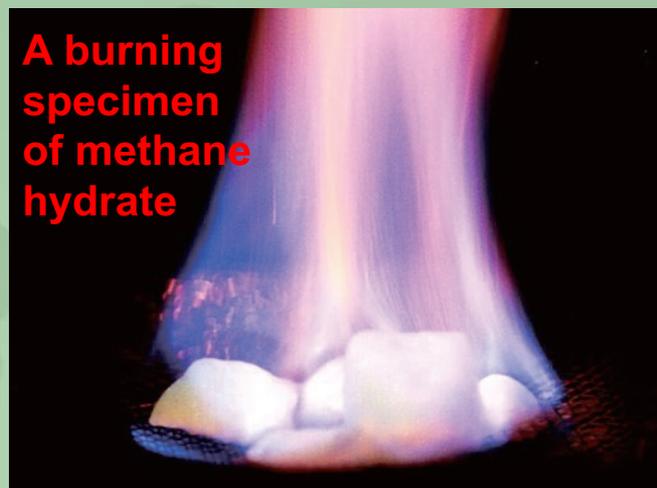
25.9 What is the greenhouse effect? (p.19)

- ◆ Without greenhouse effect,
 - atmosphere at Earth's surface would be 60 °C lower;
 - Earth would not be able to sustain life;
 - possible new source of methane—**methane hydrate (甲烷水合物)** is not possible.
- ◆ Methane hydrate—a crystalline solid surrounded by cages of interlocking H₂O molecules—will revert back to water and methane gas if it is warmed or depressurised.

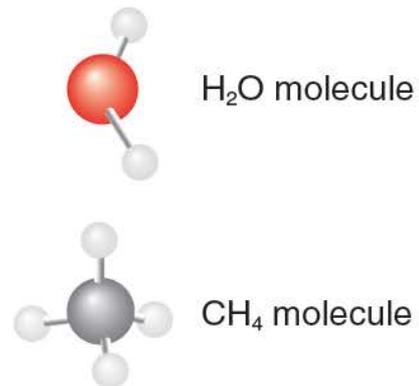


25.9 What is the greenhouse effect? (p.19)

- ◆ Methane hydrate deposits generally occur under Arctic permfrost and beneath the ocean floor as stored methane.
- ◆ Huge economic benefits if released vs. damaging environmental impact if over



key:



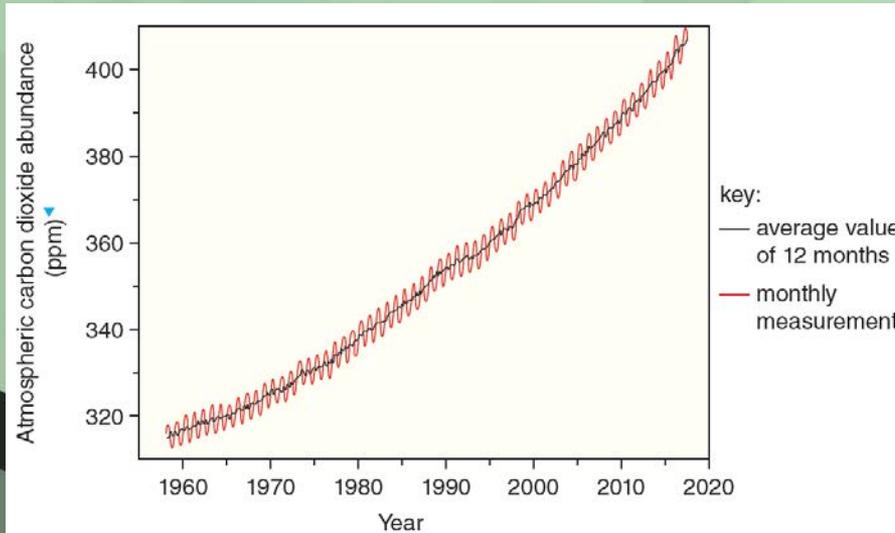
a ball-and-stick model of a methane molecule surrounded by H₂O molecules



25.10 Increasing the greenhouse effect of the atmosphere (p.22)

- ◆ The levels of carbon dioxide and methane (two main greenhouse gases) are rising and causing further natural warming because
 - more fossil fuels are burnt each year;
 - livestock farming and rice farming increase.

Atmospheric carbon dioxide abundance:



Rice farming produces much methane:

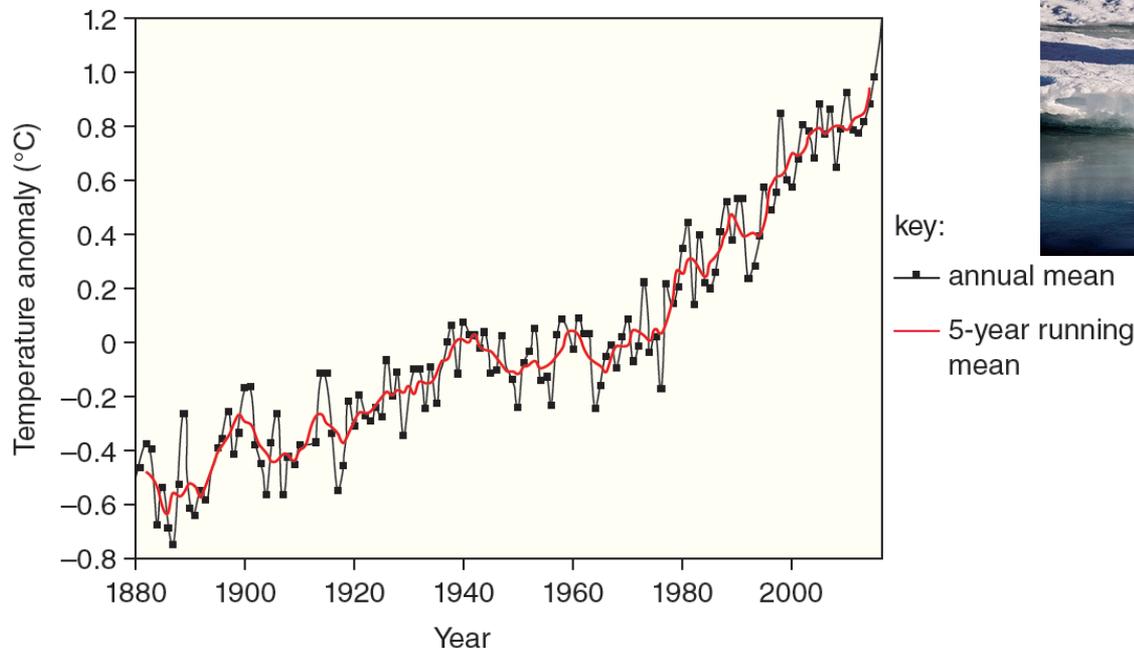




25.10 Increasing the greenhouse effect of the atmosphere (p.22)

- ◆ Gradually the global surface air temperature is rising too.
- ◆ The majority of scientists believe that the increasing level of carbon dioxide and methane is the main cause of **global warming (全球暖化)**.

Temperature anomaly





25.10 Increasing the greenhouse effect of the atmosphere (p.22)

Practice 25.3

1 Combustion of petrol increases the concentration of carbon dioxide in the atmosphere. Carbon dioxide is a greenhouse gas.

a) Write the chemical equation for the complete combustion of heptane (C_7H_{16}), a component in petrol.



b) State the importance of greenhouse gases to life on the Earth.

The Earth absorbs the radiation from the sun and also emits infrared radiation back into space when it cools down.

Greenhouse gases absorb some of the infrared radiation emitted from the Earth and re-emit them in all directions. This keeps the atmosphere warm for life to sustain on Earth.

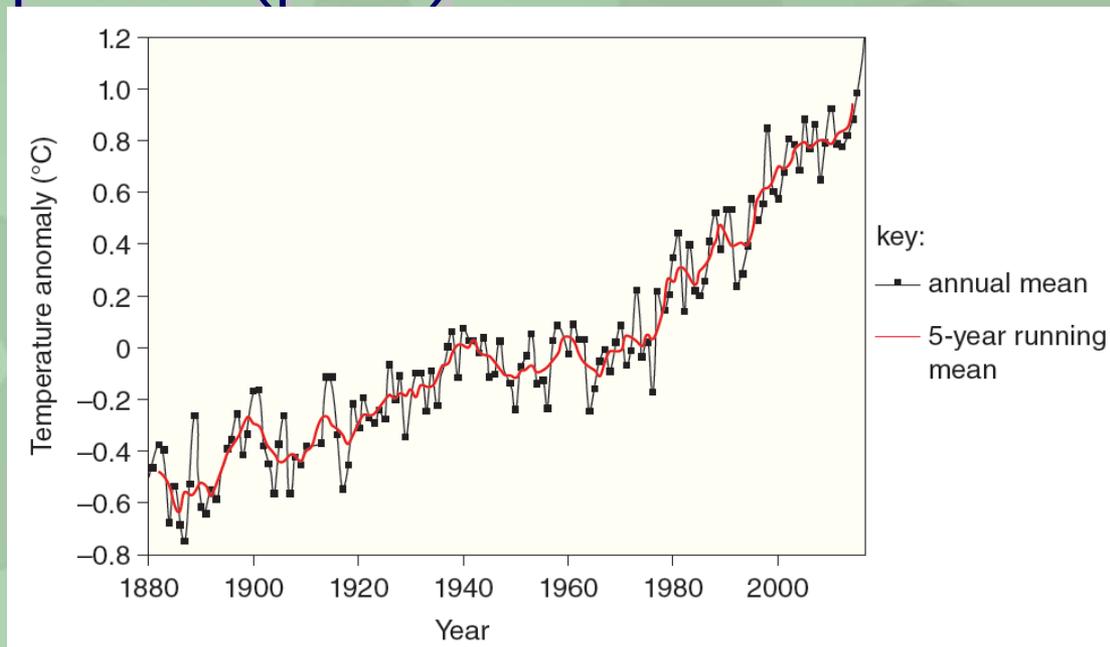
c) Carbon monoxide is one of the poisonous air pollutants emitted from the combustion of petrol. Under what condition would carbon monoxide be formed during the combustion of petrol?

Limited supply of air or oxygen



25.10 Increasing the greenhouse effect of the atmosphere (p.22)

2 The figure shows the global annual-mean surface air temperature since 1880. Explain how human activities have contributed to the main trend shown from 1910.



The general increase in global annual-mean surface air temperature since 1880 is caused by increasing level of greenhouse gases.

Human activities contributed to the main trend:

- Increased burning of fossil fuels causes more carbon dioxide.
- Deforestation causes more carbon dioxide.
- More cattle production causes more methane.
- Use of landfill causes more methane.



25.11 Polluting the atmosphere (p.25)

Burning of fossil fuels produces harmful substances.

Formation of pollutants

- 1) **Carbon monoxide**—produced when coal or natural gas burnt in a poor supply of air or oxygen, or in vehicle engines.



25.11 Polluting the atmosphere (p.25)

2) Particulate



- produced during the incomplete combustion of fuels that contain carbon;
- appear as black smoke from diesel-powered vehicles with poor maintenance;
- small particles that remain suspended in the air for a long time are called **suspended particulates** (懸浮粒子).



25.11 Polluting the atmosphere (p.25)

3) **Unburnt hydrocarbons**—enter the atmosphere as a result of leaks or spills.

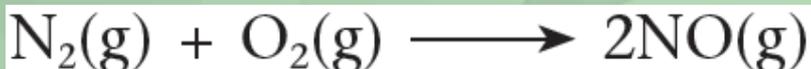
- Volatile hydrocarbons, a kind of **volatile organic compounds (VOCs)** (揮發性有機化合物), may evaporate from the petrol tank of a vehicle and enter the atmosphere.



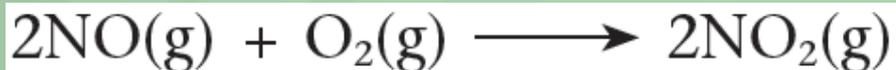
25.11 Polluting the atmosphere (p.25)

4) Oxides of nitrogen

- At very high temperatures in furnaces or engines, nitrogen combines with oxygen to produce various oxides of nitrogen (NO_x), mainly NO and NO_2 .
- At very high temperatures, the main reaction is:



- NO reacts with oxygen in the atmosphere:

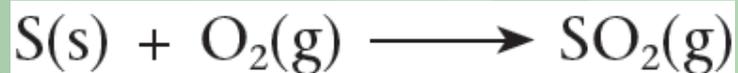




25.11 Polluting the atmosphere (p.25)

5) Sulphur dioxide

- Fossil fuels often contain small amounts of sulphur. When the fuel burns, the sulphur is oxidised to form sulphur dioxide gas.





25.11 Polluting the atmosphere (p.25)

Effects of pollutants

Table 25.4

Sources and effects of pollutants

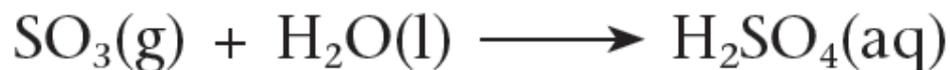
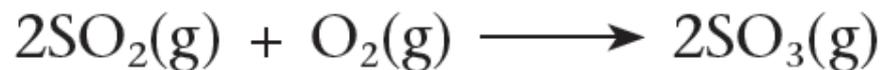
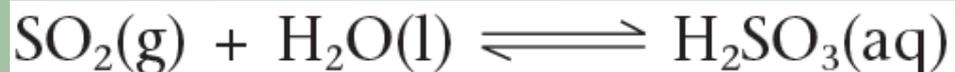
Pollutant	Major source(s)	Major polluting effect(s)
Carbon monoxide	<ul style="list-style-type: none"> incomplete combustion of fossil fuels 	<ul style="list-style-type: none"> a very poisonous gas
Suspended particulates (mainly carbon particles)	<ul style="list-style-type: none"> burning fuels (such as coal) 	<ul style="list-style-type: none"> can be breathed into the lungs to cause breathing problems and worsen asthma reduce visibility
Volatile organic compounds	<ul style="list-style-type: none"> unburnt fuel from petrol engines 	<ul style="list-style-type: none"> some hydrocarbons (e.g. benzene) may cause cancer
Oxides of nitrogen	<ul style="list-style-type: none"> combustion of fuels in power plants and vehicles 	<ul style="list-style-type: none"> can cause breathing problems and worsen asthma form acid rain give photochemical smog with unburnt hydrocarbons
Sulphur dioxide	<ul style="list-style-type: none"> volcanoes burning of fuels containing sulphur 	<ul style="list-style-type: none"> irritates the eyes and throat causes breathing problems forms acid rain



25.11 Polluting the atmosphere (p.25)

Acid rain

- Both oxides of nitrogen and sulphur dioxide cause acid rain if they escape into the atmosphere.
- $\text{NO}_2(\text{g})$ and $\text{SO}_2(\text{g})$ dissolve in the rain, snow, fog, hail or moisture in clouds, and $\text{SO}_2(\text{g})$ also reacts with $\text{O}_2(\text{g})$ before dissolving:





25.11 Polluting the atmosphere (p.25)

- The mixture of acids in the atmosphere causes problems when it falls as acid rain.

e.g.

- attacking stonework in buildings (limestone and marble, which are $\text{CaCO}_3(\text{s})$;
- lowering the pH in rivers and lakes and killing aquatic life;
- causing damage to crops and forests





25.11 Polluting the atmosphere (p.25)

Practice 25.4

In recent years, there has been worldwide interest in the possible extraction of 'shale gas' (a form of natural gas).

The table below shows a comparison of the relative amounts of pollutants released when 'shale gas', fuel oil and coal are burnt to produce the same amount of energy.

Pollutant	Shale gas	Fuel oil	Coal
CO	0.040	0.033	0.208
NO ₂	0.092	0.548	0.457
SO ₂	0.001	1.12	2.59
Particulates	0.007	0.84	2.74



25.11 Polluting the atmosphere (p.25)

a) Which of the three fuels is the largest contributor to acid rain? Explain your answer. **Coal**

It produces the largest combined amount of SO_2 and NO_2 .

b) Suggest a reason why burning fuel oil and coal will produce more NO_2 than burning shale gas.

They burn at higher temperatures.

c) State ONE harmful effect of particulates on health.

Causing breathing problems



25.12 Air pollution in Hong Kong (p.30)

Air pollution in Hong Kong is mainly caused by power plants and motor vehicles

Reducing emissions from power plants

- ◆ The Government has prohibited the construction of new coal-fired power plant since 1997.
- ◆ The Government also implemented a policy to encourage power companies to use natural gas for electricity generation.
- ◆ Comparing with burning coal, burning natural gas gives a less sooty flame and reduces emissions of other pollutants such as sulphur dioxide.



25.12 Air pollution in Hong Kong (p.30)

Reducing emissions from motor vehicles

- ◆ The Government has implemented measures, such as
 - to set up an incentive programme to replace diesel taxis / light buses with liquefied petroleum gas vehicles;
 - to adopt a higher fuel and vehicle emission standard;
 - to set up an incentive programme to retrofit old diesel vehicles with particulate reduction devices;
 - to reduce the first registration tax for environmentally friendly vehicles.



25.12 Air pollution in Hong Kong (p.30)

Table 25.5 Measures for reducing emissions of air pollutants

Pollutant	Measures for reducing emission of the pollutant
Sulphur dioxide	<ul style="list-style-type: none"> • increase use of fuels with low sulphur content • install flue gas desulphurisation plants (Fig. 25.37) or scrubbers in power plants
Oxides of nitrogen	<ul style="list-style-type: none"> • install low nitrogen oxide burners in power plants • install catalytic converters in exhaust systems of motor vehicles
Particulates	<ul style="list-style-type: none"> • install electrostatic precipitators in power plants • install particulate reduction devices in motor vehicles



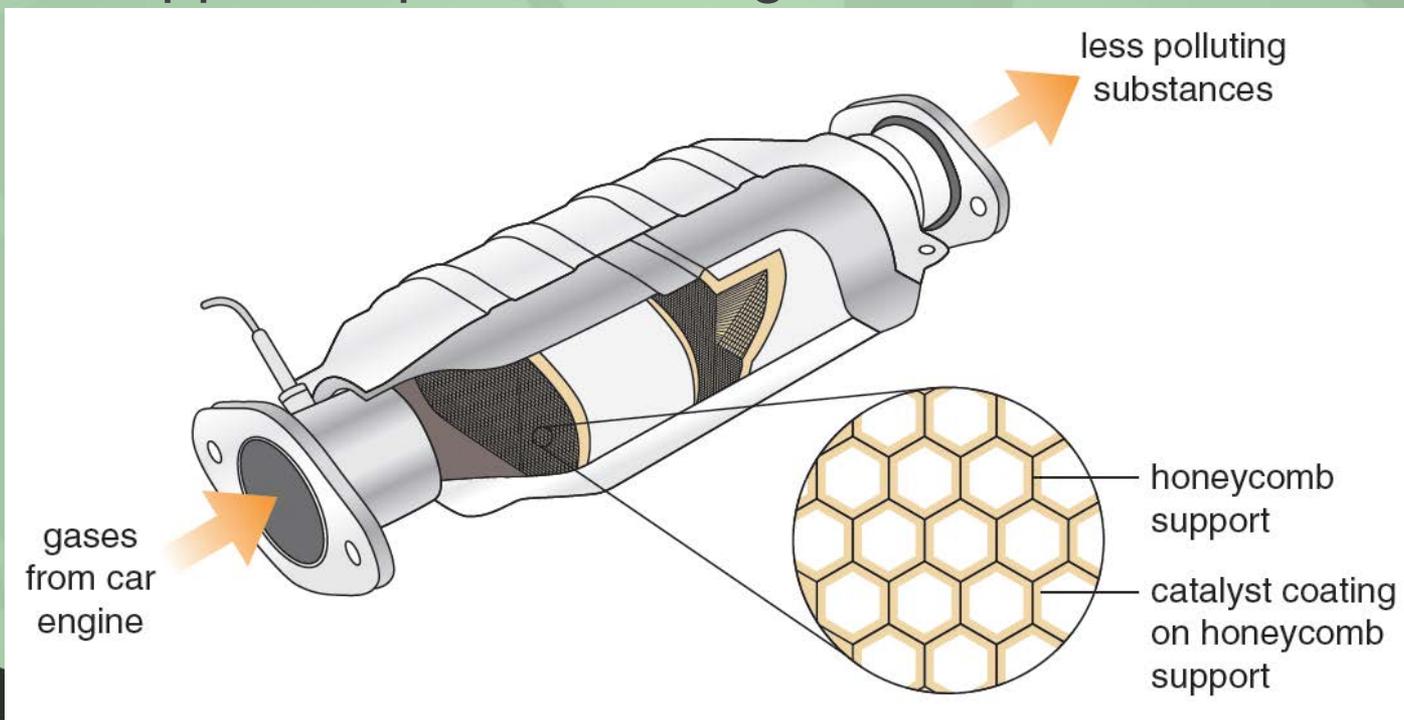
25.12 Air pollution in Hong Kong (p.30)

- ◆ All new cars with petrol engines are now equipped with catalytic converters in their exhaust systems.
- ◆ A catalytic converter reduces the amounts of carbon monoxide, unburnt hydrocarbons and nitrogen monoxide released from the engine into the atmosphere by converting the pollutants into less harmful substances.



25.12 Air pollution in Hong Kong (p.30)

- ◆ A catalytic converter uses small quantities of precious metals such as platinum, rhodium and palladium as catalysts.
- ◆ The metals are spread thinly over a ceramic honeycomb-shaped support to provide a large surface area for reactions.

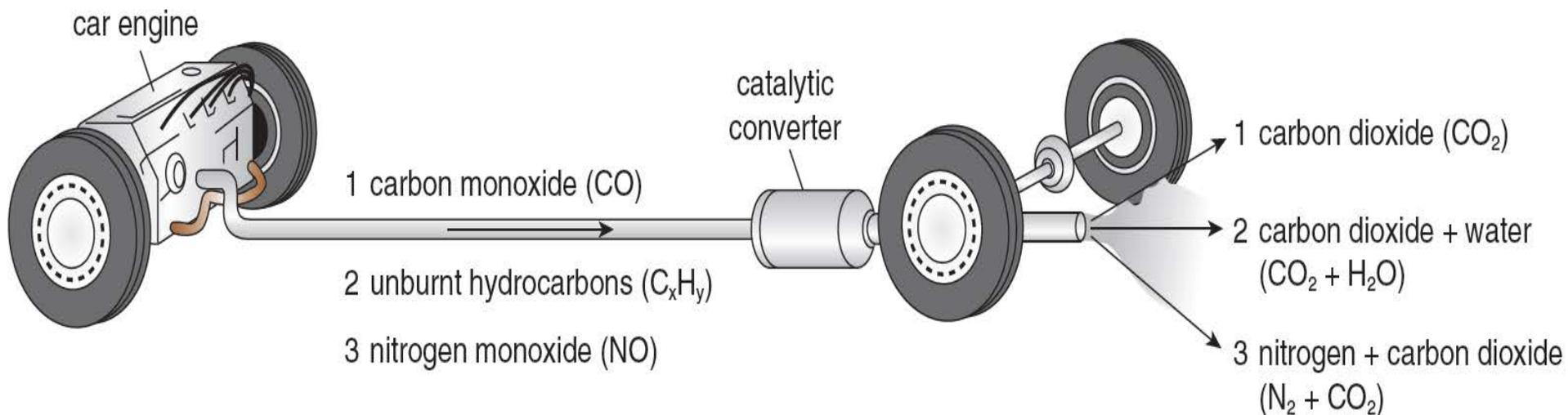




25.12 Air pollution in Hong Kong (p.30)

◆ The main pollutants are removed by these reactions:

- carbon monoxide $2\text{CO}(\text{g}) + \text{O}_2(\text{g}) \longrightarrow 2\text{CO}_2(\text{g})$
- unburnt hydrocarbons $\text{C}_7\text{H}_{16}(\text{l}) + 11\text{O}_2(\text{g}) \longrightarrow 7\text{CO}_2(\text{g}) + 8\text{H}_2\text{O}(\text{l})$
- nitrogen monoxide $2\text{NO}(\text{g}) + 2\text{CO}(\text{g}) \longrightarrow \text{N}_2(\text{g}) + 2\text{CO}_2(\text{g})$





25.12 Air pollution in Hong Kong (p.30)

- ◆ A catalytic converter cannot reduce the amount of carbon dioxide (a greenhouse gas) in the car exhaust.
- ◆ The catalytic converter currently used cannot effectively remove sulphur compounds.
 - It is best to remove the sulphur compounds from the fuel (low sulphur or ultra-low sulphur fuel) before the fuel is burnt.



25.12 Air pollution in Hong Kong (p.30)

Practice 25.5

Catalytic converters have been installed in most petrol-driven vehicles.

a) State TWO functions of catalytic converters.

Any two of the following:

- Reduce the amount of oxides of nitrogen in the exhaust.
- Reduce the amount of carbon monoxide in the exhaust.
- Reduce the amount of unburnt hydrocarbons in the exhaust.

b) Suggest ONE air pollutant in car exhaust which cannot be removed by catalytic converters. Any one of the following:

- Particulates
- Suspended particulates
- Sulphur dioxide

c) A student wrote the following statement in an examination answer:

‘Catalytic converters help reduce global warming.’

State whether you think that the statement is right or wrong. Explain your answer. **The statement is wrong.**

Catalytic converters increase the emission of carbon dioxide which contributes to the greenhouse effect.



25.13 Impacts of using fossil fuels on our quality of life and the environment (p.33)

- ◆ Fossil fuels are vital to our modern lifestyles:
e.g. to produce fuels to run vehicles, to cook food, to heat homes and to generate electricity
- ◆ Petroleum-based chemicals are important in making synthetic polymers, fertilisers and many other products.
- ◆ However, there are serious concerns about relying on the combustion of fossil fuels to produce energy.



25.14 Benefits and risks of using fossil fuels to the society and environment (p.34)

Benefits of using fossil fuels

- ◆ Fossil fuels are readily available at a relatively cheap price.
- ◆ Fossil fuels are extremely efficient. They can generate huge amounts of energy, even if you just use a small amount of them.



25.14 Benefits and risks of using fossil fuels to the society and environment (p.34)

- ◆ Transporting fossil fuels is relatively easy. Petroleum and natural gas can be transported easily and safely by pipes.



- ◆ Fossil-fuels related industries generate enormous job opportunities every year.



25.14 Benefits and risks of using fossil fuels to the society and environment (p.34)

Risks of using fossil fuels

- ◆ Burning fossil fuels puts a great deal of carbon dioxide into the atmosphere. This increases the greenhouse effect and contributes to global warming.
- ◆ Burning fossil fuels produces sulphur dioxide and oxides of nitrogen, which contribute to acid rain.
- ◆ Exploration and mining of fossil fuels have a major impact on the environment.



25.14 Benefits and risks of using fossil fuels to the society and environment (p.34)

- ◆ The mining of coal is a difficult and dangerous task. Coal miners face series threats of their lives.
- ◆ Coal-fired power plants require huge amounts of coal each day. Transportation increases the consumption of fossil fuels and damages the Earth even more.





25.14 Benefits and risks of using fossil fuels to the society and environment (p.34)

- ◆ Accidents which occur while transporting petroleum by ships have led to major pollution incidents, causing disastrous damage to local wildlife.





Key terms (p.37)

fossil fuel	化石燃料	cycloalkane	環烷
coal	煤	saturated	飽和
natural gas	天然氣	petrochemical	石油化學產品
petroleum	石油	fractional distillation	分餾
non-renewable	不可再生的	fraction	餾分
hydrocarbon	烴 (碳氫化合物)	oil refinery	煉油廠
aromatic hydrocarbon	芳香族烴	fractionating tower	分餾塔
aliphatic hydrocarbon	脂肪族烴	refinery gas	煉油氣
alkane	烷	petrol	汽油



Key terms (p.37)

naphtha	石腦油	incomplete combustion	不完全燃燒
kerosene	煤油	infrared radiation	紅外光
diesel oil	柴油	greenhouse effect	溫室效應
fuel oil	燃料油	greenhouse gas	溫室氣體
lubricating oil	潤滑油	methane hydrate	甲烷水合物
bitumen	瀝青	global warming	全球增溫
flammability	易燃性	suspended particulate	懸浮粒子
volatility	揮發性	volatile organic compound	揮發性有機化合物
complete combustion	完全燃燒	photochemical smog	光化煙霧
exothermic	放熱的	flue gas desulphurisation plant	煙氣脫硫裝置



Key terms (p.37)

scrubber	滌氣器	electrostatic precipitator	靜電沉積器
catalytic converter	催化轉化器	particulate removal device	減少粒子器件



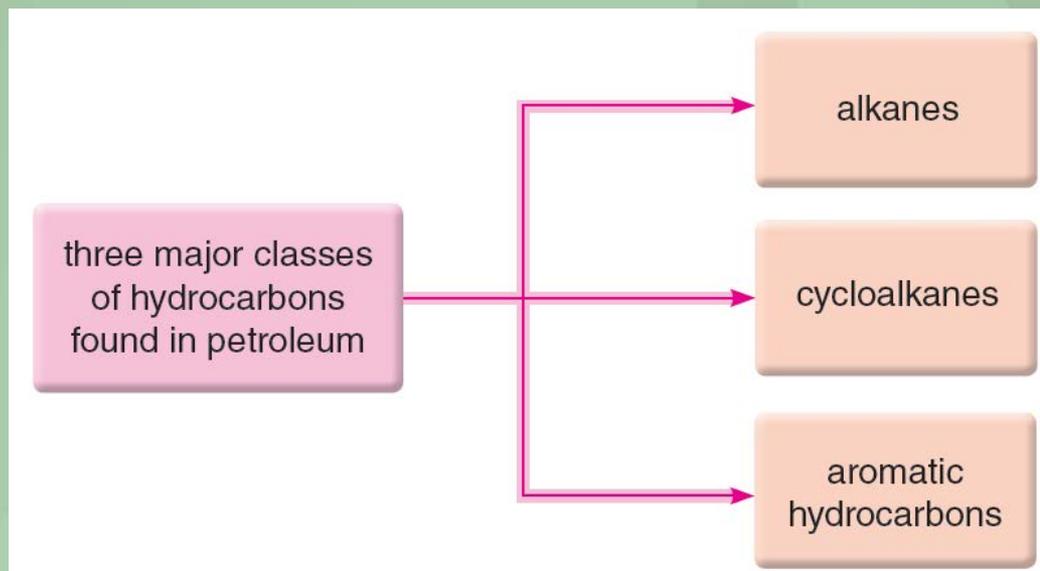
Summary (p.38)

- 1 Petroleum (crude oil), coal and natural gas are fossil fuels.
- 2 Fossil fuels were formed from the dead organisms that lived millions of years ago.
- 3 A hydrocarbon is a compound containing only hydrogen atoms and carbon atoms.
- 4 A hydrocarbon with at least one benzene ring in its structure is called an aromatic hydrocarbon.
Hydrocarbons with chains of carbon atoms which may be straight or branched, or with rings that are not benzene rings are called aliphatic hydrocarbons.



Summary (p.38)

5 Petroleum is a mixture of many hundreds of hydrocarbons.



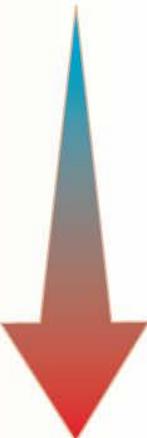
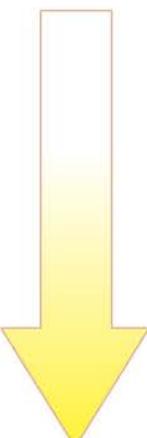
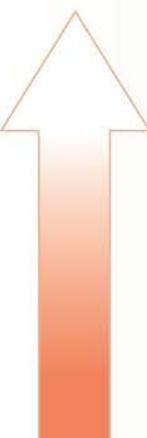
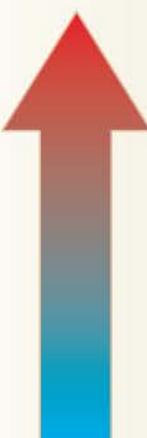
6 Alkanes are saturated hydrocarbons.

7 Fractional distillation separates petroleum into different fractions, each having a specific boiling point range.



Summary (p.38)

8 Trends in properties of the petroleum fractions are shown below:

Fraction	Number of carbon atoms per molecule of hydrocarbon in fraction	Boiling point range	Colour	Volatility (how easily it evaporates)	Flammability (how easily it burns)	Viscosity
Refinery gases	smallest  greatest	lowest  highest	lightest  darkest	highest  lowest	highest  lowest	lowest (flows most easily)  highest (flows with difficulty)
Petrol						
Naphtha						
Kerosene						
Diesel						
Fuel oil						
Lubricating oil						
Bitumen						



Summary (p.38)

- 9 Combustion of hydrocarbons is an example of exothermic reactions.
- 10 The level of carbon dioxide is rising because more fossil fuels are burnt each year. The level of carbon dioxide and methane is rising, amplifying the greenhouse effect, leading to global warming.
- 11 Major air pollutants from using fossil fuels include:
 - a) carbon monoxide;
 - b) suspended particulates;
 - c) unburnt hydrocarbons / volatile organic compounds;
 - d) oxides of nitrogen;
 - e) sulphur dioxide.



Summary (p.38)

12 The table below summarises the measures for reducing the emission of various air pollutants.

Pollutant	Measures for reducing emission of the pollutant
Sulphur dioxide	<ul style="list-style-type: none">• increase use of fuels with low sulphur content• install flue gas desulphurisation plants or scrubbers in power plants
Oxides of nitrogen	<ul style="list-style-type: none">• install low nitrogen oxide burners in power plants• install catalytic converters in exhaust systems of motor vehicles
Particulates	<ul style="list-style-type: none">• install electrostatic precipitators in power plants• install particulate reduction devices in motor vehicles



Unit Exercise (p.41)

Note: Questions are rated according to ascending level of difficulty (from 1 to 5):



question targeted at level 3 and above;



question targeted at level 4 and above;



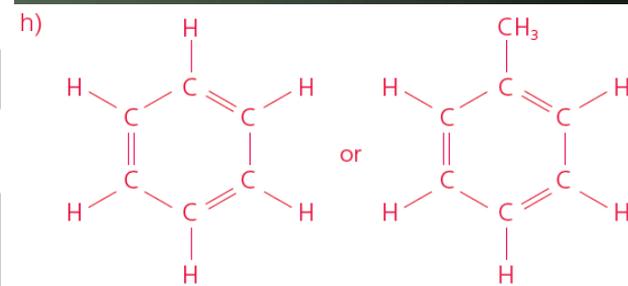
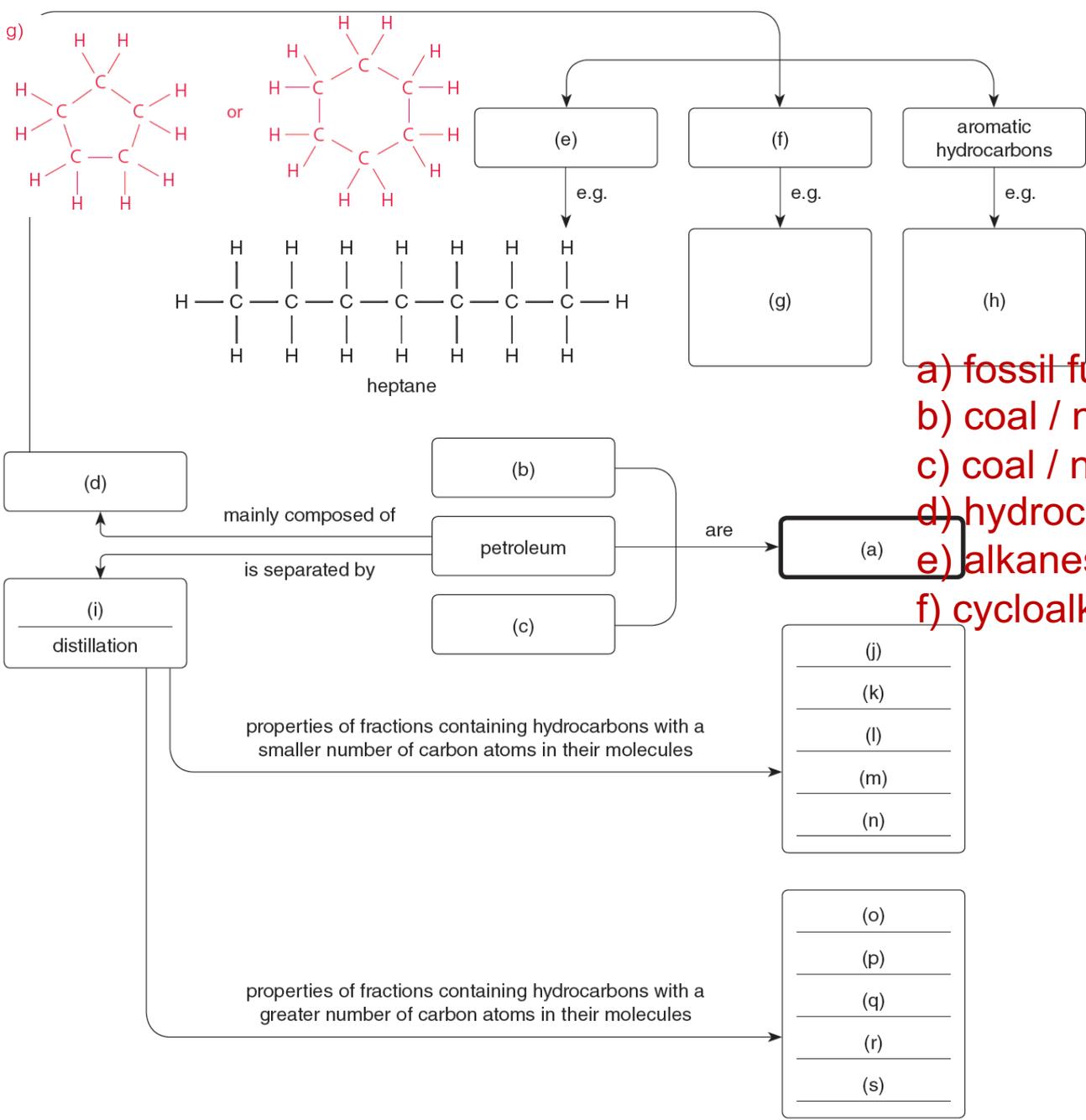
question targeted at level 5.

' * ' indicates 1 mark is given for effective communication.

Unit Exercise (p.41)

PART I KNOWLEDGE AND UNDERSTANDING

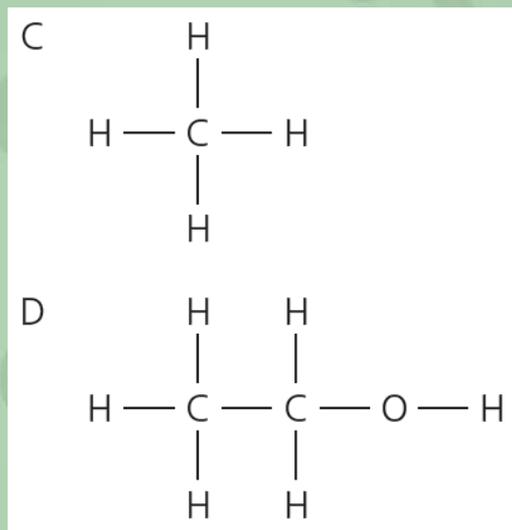
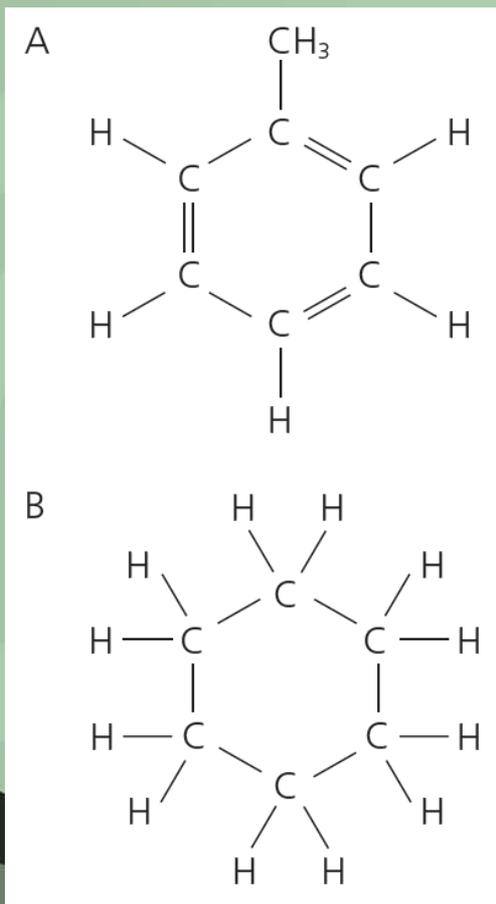
1 Complete the following concept map.



- a) fossil fuels
- b) coal / natural gas
- c) coal / natural gas
- d) hydrocarbons
- e) alkanes
- f) cycloalkanes
- g)
- h)
- i) fractional
- j) low boiling point range
- k) light colour
- l) high volatility
- m) high flammability
- n) low viscosity
- o) high boiling point range
- p) dark colour
- q) low volatility
- r) low flammability
- s) high viscosity

 Unit Exercise (p.41)**PART II MULTIPLE CHOICE QUESTIONS**

2 Which of the following is an aromatic hydrocarbon?



Answer: A

 Unit Exercise (p.41)

- 3 Which of the following statements concerning natural gas is correct?
- A Natural gas consists mainly of ethane.
 - B Natural gas is a common domestic fuel in Hong Kong.
 - C Taxis in Hong Kong use natural gas as fuel.
 - D Combustion of natural gas is an exothermic reaction.

Answer: D

 Unit Exercise (p.41)

4 Which of the following petroleum fractions contains hydrocarbons with the greatest number of carbon atoms in their molecules?

- A Diesel
- B Lubricating oil
- C Petrol
- D Kerosene

Answer: B

 Unit Exercise (p.41)

5 Which of the following statements concerning fractional distillation of petroleum in industry is INCORRECT?

- A The process involves a physical change.
- B The fractionating tower is cooler at the top than at the bottom.
- C The process involves breaking and forming of covalent bonds.
- D Refinery gas is obtained from the top of the fractionating tower.

Answer: C

Explanation:

Fractional distillation of petroleum is a physical change.

It does NOT involve breaking and forming of covalent bonds.



Unit Exercise (p.41)

6 Crude oil can be separated in the laboratory into fractions which have different boiling points.



Which letter represents the correct relationship between the boiling point, number of carbon atoms and size of intermolecular forces?

	<u>Boiling point</u>	<u>Number of carbon atoms in the molecule</u>	<u>Size of intermolecular forces</u>
A	high	more than 50	small
B	low	more than 50	large
C	high	less than 20	large
D	low	less than 20	small

Answer: D

(OCR GCSE (Higher Tier), Chem. A (Gateway Science), J248/03, Paper 3, Sample Question Paper 2016, 9)



Unit Exercise (p.41)

7 Sulphur dioxide, SO_2 , nitrogen dioxide, NO_2 , and carbon monoxide, CO , are air pollutants.

Which row correctly shows their major source?

	<u>Motor car engines</u>	<u>Power stations</u>
A	CO	NO_2, SO_2
B	NO_2, CO	SO_2
C	SO_2, NO_2	CO
D	SO_2	NO_2, CO

Answer: B

(Cambridge IGCSE, 0620/12, Paper 1, Jun. 2014, 33)

 Unit Exercise (p.41)

8 Which of the following CANNOT be converted into substances that are less harmful when passed through a catalytic converter?

- A Nitrogen oxides
- B Sulphur dioxide
- C Carbon monoxide
- D Unburnt hydrocarbons

Answer: B

(HKDSE, Paper 1A, 2016, 10)



Unit Exercise (p.41)

9 Which of the following statements concerning burning coal under room conditions are correct?

- (1) Burning coal forms both acidic and non-acidic substances.
- (2) Burning coal forms both gaseous and non-gaseous substances.
- (3) Burning coal forms both poisonous and non-poisonous substances.

- A (1) and (2) only
- B (1) and (3) only
- C (2) and (3) only
- D (1), (2) and (3)

(HKDSE, Paper 1A, 2017, 22)

Answer: D



Unit Exercise (p.41)

10 Which of the following statements concerning petroleum is / are correct?

- (1) It consists mainly of hydrocarbons.
- (2) Its main use is for making lubricants and polishes.
- (3) It originates from plants in swamp forests which covered the Earth's surface millions of years ago.

Answer: C

- A (1) only
- B (2) only
- C (1) and (3) only
- D (2) and (3) only

Explanation:

Petroleum originates from ancient marine plants and animals.



Unit Exercise (p.41)

- 11 Comparing samples of fuel oil and naphtha, which of the following combinations is / are correct?

Fuel oil

- (1) contains hydrocarbons with large molecules
- (2) burns more easily
- (3) more viscous

Naphtha

- contains hydrocarbons with small molecules
- burns less easily
- less viscous

- A (1) only
- B (2) only
- C (1) and (3) only
- D (2) and (3) only

Answer: C

Explanation:

(2) Fuel oil burns less easily than naphtha.



Unit Exercise (p.41)

12 Which of the following statements concerning acid rain are correct?



- (1) One major air pollutant that causes the formation of acid rain is carbon dioxide.
- (2) Installing catalytic converters in petrol-driven cars can reduce the formation of acid rain.
- (3) Acid rain can corrode marble buildings.

- A (1) and (2) only
- B (1) and (3) only
- C (2) and (3) only
- D (1), (2) and (3)

Answer: C

Explanation:

(1) Carbon dioxide is **NOT** considered to be an air pollutant.



Unit Exercise (p.41)

13 Which of the following measures can help reduce the level of sulphur dioxide in the air?


- (1) Use natural gas instead of coal for generating electricity.
- (2) Install catalytic converters in motor vehicles.
- (3) Install flue gas scrubbers in power plants.

- A (1) only
B (2) only
C (1) and (3) only
D (2) and (3) only

Answer: C

Explanation:

- (1) Natural gas contains less sulphur-containing impurities.
(2) Catalytic converter **CANNOT** convert sulphur dioxide into less harmful substance(s).

 Unit Exercise (p.41)**PART III STRUCTURED QUESTIONS**

14 Petroleum is an important source of hydrocarbons.
Describe the origin of petroleum.

(HKDSE, Paper 1B, 2018, 4(a))

Answers for the questions of the public examinations in Hong Kong are not provided (if applicable).

Unit Exercise (p.41)

15 This apparatus can be used to separate the substances present in a sample of crude oil into several fractions.

These sentences describe the steps in the method for separating the substances into fractions, but the steps are in the wrong order.

R Connect a delivery tube to the boiling tube.

S Pour crude oil into a boiling tube.

T Collect each fraction in a different test tube.

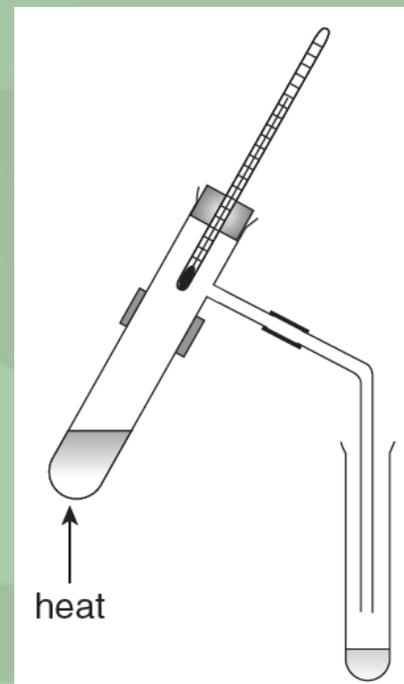
U Fit a thermometer into the boiling tube.

V Heat the crude oil gently at first, then more strongly.

Put a letter in each box to show the correct order. One has been done for you.

 S U R V T (1)

(Edexcel IGCSE, Paper 1C, Jun. 2014, 2(b))



Unit Exercise (p.41)

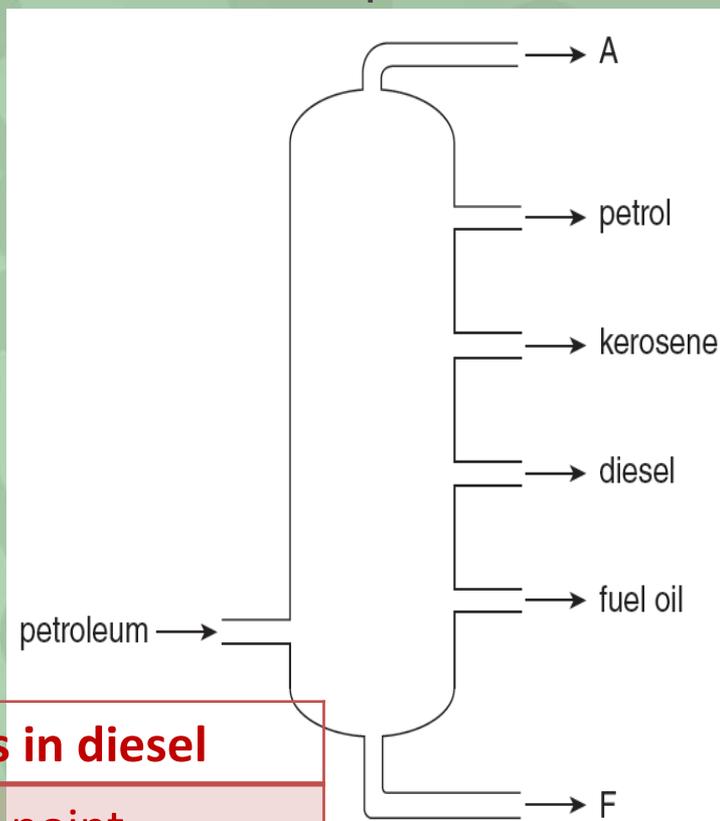
16 The diagram shows a typical fractionating column used to separate petroleum into fractions.

a) The diagram shows the names of some of the fractions.

State the name of fraction A and the name of fraction F. **Fraction A is refinery gas. (1)**
Fraction F is bitumen. (1)

b) Compare the hydrocarbons in petrol and diesel in terms of

- boiling point;
- size of molecules;
- viscosity.

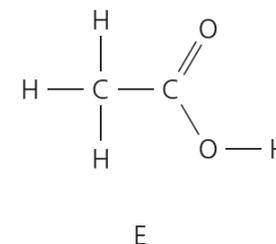
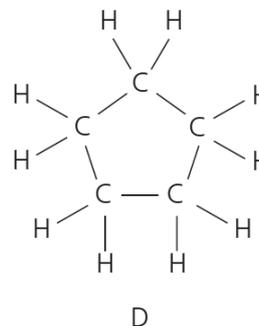
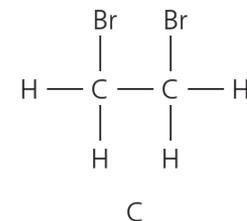
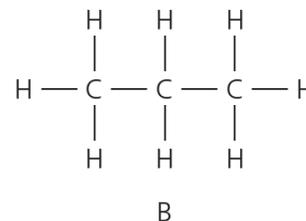
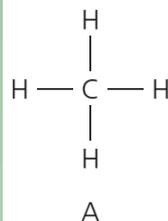


Hydrocarbons in petrol	Hydrocarbons in diesel
low boiling point	higher boiling point
smaller molecules	bigger molecules
less viscous	more viscous



Unit Exercise (p.41)

17 The structure of five carbon compounds are shown below.



- Which compounds are aliphatic hydrocarbons? **A, B, D (1)**
- Which compound is the main constituent of natural gas? **A (1)**
- Which compound is ethanoic acid? **E (1)**
- Which compound is causing concern as a greenhouse gas? **A (1)**
- Complete the chemical equation for the complete combustion of compound B.





Unit Exercise (p.41)

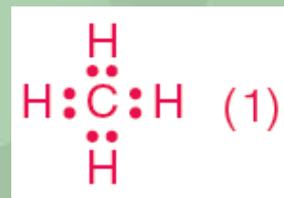
18 The table lists the boiling point ranges of four fractions obtained from the fractional distillation of petroleum.

Fraction	Boiling point range of fraction (°C)
Refinery gas	below 25
Naphtha	90–150
Kerosene	150–240
Fuel oil	250–320

a) What is the relationship between the number of carbon atoms per molecule of hydrocarbon in a fraction and the boiling point range of the fraction? **The more carbon atoms per molecule of hydrocarbons in a fraction, the higher the boiling point range of the fraction is. (1)**

b) Methane is found in refinery gas.

Draw the electron diagram of methane, showing electrons in the *outermost shells* only.



c) Which of the four fractions burns with the least amount of soot? **Refinery gas (1)**

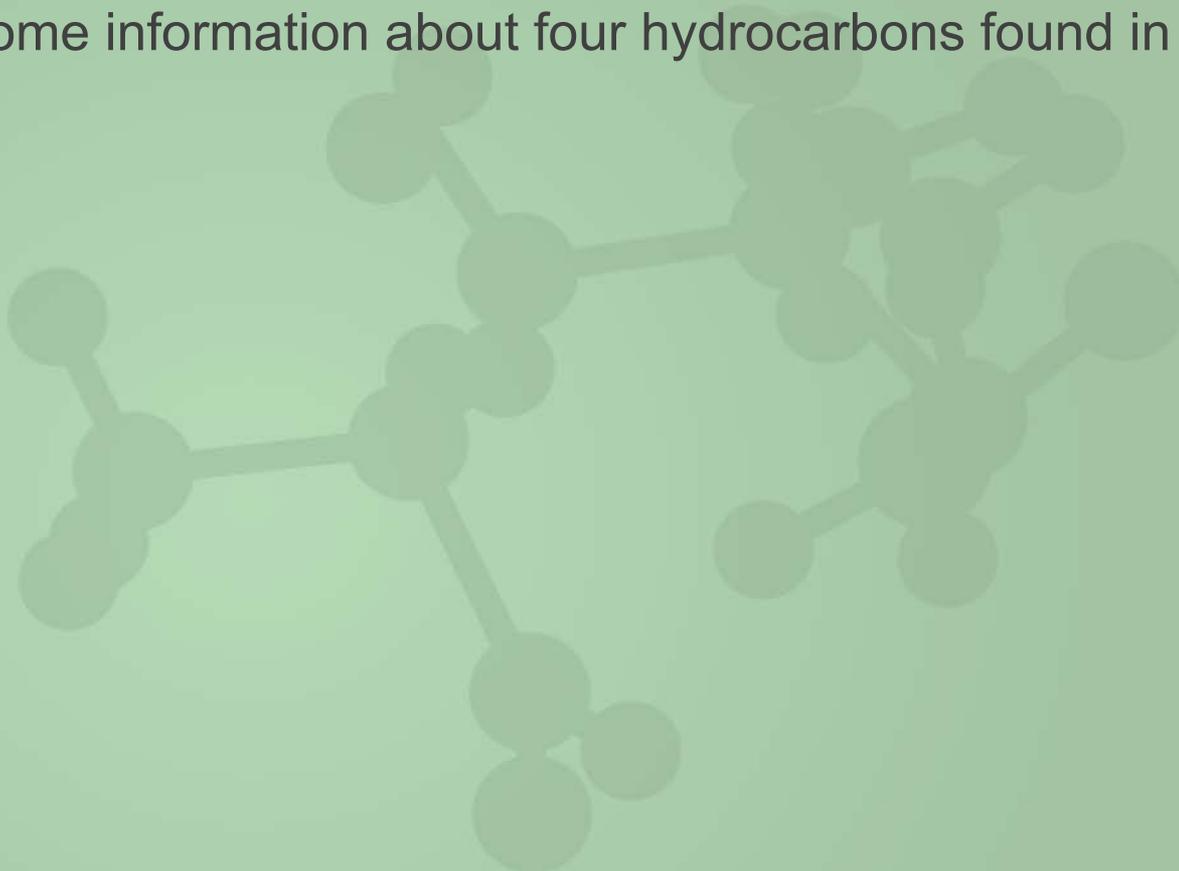
d) Which of the four fractions is the most viscous? **Fuel oil (1)**

e) Which of the four fractions is the most volatile? **Refinery gas (1)**



Unit Exercise (p.41)

19 The table below shows some information about four hydrocarbons found in petroleum.





Unit Exercise (p.41)

- a) Explain, from molecular level, why different fractions can be obtained from petroleum by fractional distillation.

Components with different boiling points can be separated from each other by fractional distillation. (1)

The longer the carbon chain in a hydrocarbon molecule, the higher the boiling point of the hydrocarbon is. (1)

- b) Propane is a hydrocarbon.

What is meant by a 'hydrocarbon'?

A hydrocarbon is a compound containing only hydrogen atoms and carbon atoms. (1)

- c) Propane is a saturated hydrocarbon.

What is meant by a 'saturated' hydrocarbon?

In a saturated hydrocarbon, all the carbon-carbon bonds in the hydrocarbon molecule are single covalent bonds. (1)



Unit Exercise (p.41)

- d) Identify an aromatic hydrocarbon from the table. **Ethylbenzene (1)**
- e) State ONE major use of each petroleum fraction listed in the table.

Petroleum fraction	Use	
Refinery gas	as gaseous fuel	(1)
Petrol	as fuel for vehicles	(1)
Naphtha	for making chemicals / manufacturing town gas	(1)
Diesel	as fuel for heavy vehicles / trains	(1)

 Unit Exercise (p.41)

20 Paraffin wax is a mixture of aliphatic hydrocarbons with more than 20 carbon atoms per molecule. Paraffin wax can be obtained from petroleum.

 a) State the meaning of both the words 'aliphatic' and 'hydrocarbon' as applied to the term 'aliphatic hydrocarbon'.

A hydrocarbon is a compound containing only hydrogen atoms and carbon atoms. (1)

An aliphatic hydrocarbon has carbon atoms that may be in straight chain, or in branched chain, or in ring form that is NOT a benzene ring. (1)

b) i) What is the name of the process used to separate mixtures of hydrocarbons of different molecular sizes from petroleum?

Fractional distillation (1)

ii) Besides paraffin wax, petrol is also obtained from petroleum in the process. Suggest TWO properties in which you expect paraffin wax and petrol to differ from each other.

Any two of the following:

- Boiling point range (1)
- Flammability (1)
- Colour (1)
- Viscosity (1)
- Volatility (1)



Unit Exercise (p.41)

21 Carbon dioxide and methane are two major greenhouse gases. There were large increases in the average concentrations of the two gases in the atmosphere in the past ten decades.

a) Suggest ONE reason why there was a large increase in the concentration of each gas in the atmosphere in the past ten decades.

- i) Carbon dioxide
- ii) Methane

a) i) Any one of the following:

- The number of motor vehicles increases rapidly. Burning a large amount of petrol / diesel produces carbon dioxide. (1)
- The rapid growth in population leads to deforestation, providing more land for housing. Thus, less carbon dioxide is removed from the atmosphere by photosynthesis. (1)

ii) Any one of the following:

- Increase in the number of rice paddies / cattle. The remains / manure decay to give methane. (1)
- Use of landfills which emit methane. (1)



Unit Exercise (p.41)

b) Too much greenhouse gases in the atmosphere can cause global warming.

State ONE severe environmental consequence associated with global warming.

Any one of the following:

- Causing polar ice caps to melt (1)
- Flooding (1)
- Change in rainfall pattern (1)



Unit Exercise (p.41)

c) Suggest ONE possible way to prevent further increase in the concentration of each gas in the atmosphere.

i) Carbon dioxide

ii) Methane

i) Any one of the following:

- Use alternative energy sources (e.g. wind energy, solar energy etc.) to generate electricity. (1)
- Use biofuels derived from plants. (1)
- Use hydrogen as fuel in fuel cells for cars. (1)
- Stop cutting down or burning forests. (1)
- Plant more trees. (1)
- Pump carbon dioxide from power plants into old oil and natural gas wells. (1)

ii) Use methane from biomass as fuel.



Unit Exercise (p.41)

- 22  Combustion of petrol increases the concentration of carbon dioxide in the atmosphere, and may contribute to global warming. Combustion of petrol also emits poisonous air pollutants.
- Write the chemical equation for the complete combustion of octane (C_8H_{18}), a component in petrol.
 - Draw the electron diagram for a molecule of carbon dioxide, showing electrons in the *outermost shells* only.
 - Give one reason FOR and one reason AGAINST the following statement:
‘Switching from using petrol-driven cars to using electric cars can help alleviate global warming.’
 - Carbon monoxide is one of the poisonous air pollutants emitted from the combustion of petrol. Under what condition would carbon monoxide be formed during the combustion of petrol?
 - Name a device that can be installed in petrol-driven cars so as to reduce the emission of carbon monoxide.
 - Suggest ONE air pollutant in car exhaust which CANNOT be removed by the device in (i).

Answers for the questions of the public examinations in Hong Kong are not provided (if applicable).

(HKDSE, Paper 1B, 2017, 8)



Unit Exercise (p.41)

- 23  Induced hydraulic fracturing, commonly known as fracking, which was developed in 1947, is a technique for extracting natural gas (mainly methane) from shale deposits. While natural gas is a much cleaner fuel than coal, it is difficult to carry out fracking without leakage. Because methane is a far more potent greenhouse gas than carbon dioxide, it has been calculated that leakage rate of around 2% are sufficient to increase global warming.
- a) Suggest what is meant by ‘natural gas is a much cleaner fuel than coal’.
- Any one of the following:**
- Natural gas burns more completely. (1)
 - Burning of natural gas produces less carbon monoxide. (1)
 - Burning of natural gas emits no / less soot / particulates. (1)
 - Burning of natural gas emits no / less sulphur dioxide. (1)
- (Any of these points can be reversed for coal)



Unit Exercise (p.41)

b) Explain how greenhouse gases cause global warming.

(EdExcel Advanced Subsidiary GCE, Unit 2, Jun. 2015, 20(a)–(b))

The Earth absorbs the radiation from the sun and also emits infrared radiation back into space when it cools down. (1)

Greenhouse gases absorb some of the infrared radiation emitted from the Earth and re-emit them in all directions.

This prevents the infrared radiation from being re-radiated into space. (1)



Unit Exercise (p.41)

24 Petrol-driven cars emit air pollutants such as NO and CO.



a) Write the chemical equation to show how nitrogen monoxide is formed and give a condition needed for its formation. $\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{NO}(\text{g})$ (1)

Condition: very high temperature (1)

b) Under what condition would carbon monoxide be formed during the combustion of petrol? **Limited supply of air or oxygen** (1)

c) Name a device that can be installed in a petrol-driven car so as to reduce the emissions of nitrogen monoxide and carbon monoxide. **Catalytic converter** (1)

d) With the help of appropriate chemical equation(s), explain how the device named in (c) can reduce the emissions of nitrogen monoxide and carbon monoxide.

Carbon monoxide reacts with nitrogen monoxide as they pass through the catalyst in the catalytic converter. Less harmful carbon dioxide and nitrogen are formed. (1)



The excess carbon monoxide is oxidised by air to carbon dioxide. (1)





Unit Exercise (p.41)

25  In a car engine, petrol vapour (a mixture of alkanes containing 4 to 12 carbon atoms per molecule) and air are ignited by an electric spark.

a) Alkanes are saturated hydrocarbons.

State the meaning of the word 'saturated' as applied to the term 'saturated hydrocarbons'.

In a saturated hydrocarbon, all the carbon-carbon bonds in the hydrocarbon molecule are single covalent bonds. (1)

 Unit Exercise (p.41)

b) A typical composition of the gases in petrol engine exhaust fumes is:

Substance	%
Water vapour	9
Carbon dioxide	8
Carbon monoxide	4–6
Oxygen	4
Hydrogen	2
Hydrocarbons	0.2
Oxides of nitrogen	0.3

- i) Which gas in the exhaust fumes is a consequence of incomplete combustion? **Carbon monoxide (1)**
- ii) The percentages of the gases above do not add up to 100%. Suggest the names of the TWO missing gases.
Nitrogen and sulphur dioxide / any named noble gas (1)
- iii) State ONE harmful effect of oxides of nitrogen.
Causing acid rain / photochemical smog (1)

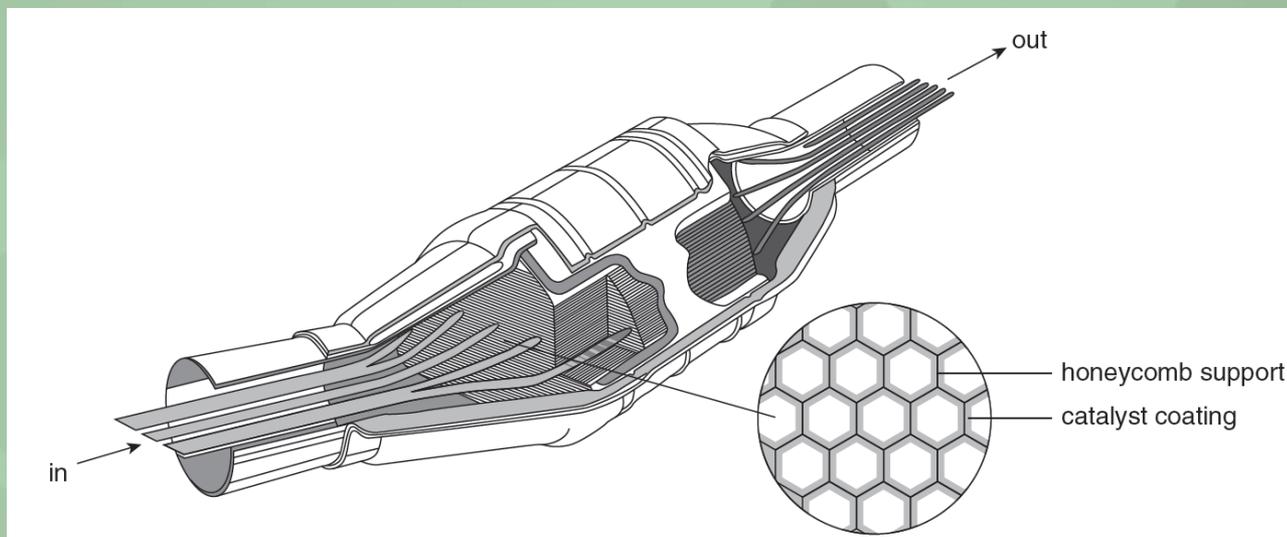


Unit Exercise (p.41)

- c) Suggest TWO measures that can help reduce the level of carbon monoxide at the street level.
- Use liquefied petroleum gas as fuel for motor vehicles. (1)
 - Install catalytic converters for motor vehicles. (1)

 Unit Exercise (p.41)

-  26 The following diagram shows a device used in cars to remove toxic gases, nitrogen monoxide and carbon monoxide, that are produced when petrol is burnt.



- a) What is the name of the device? **Catalytic converter (1)**
- b) Why is a honeycomb support used in the device? Suggest TWO reasons.
- It maximises the surface area on which reactions can take place. (1)**
- It minimises the amount of catalysts used. (1)**

 Unit Exercise (p.41)

c) Write the chemical equation for the reaction between nitrogen monoxide and carbon monoxide that occurs in the device when these gases are removed.



d) Besides nitrogen monoxide and carbon monoxide, unburnt hydrocarbons are also found in car exhaust.

i) State ONE health hazard associated with unburnt hydrocarbons.

May cause cancer (1)

ii) Octane (C_8H_{18}) is a component of petrol. Write the chemical equation to show how octane in the car exhaust is removed by the device.





Unit Exercise (p.41)

27 Coal contains sulphur impurities. Coal is used as an energy source for generating electricity. Explain how the presence of sulphur in coal can lead to damage to the environment and how the amount of damage can be reduced.



Sulphur burns to form sulphur dioxide which dissolves in rainwater to form acid rain. (1)

Acid rain may lead to acidification of lakes / kill fish / kill trees / damage stonework. (1)

The release can be reduced by installing flue gas desulphurisation systems / scrubbers in power plants. (1)

Communication mark (1)