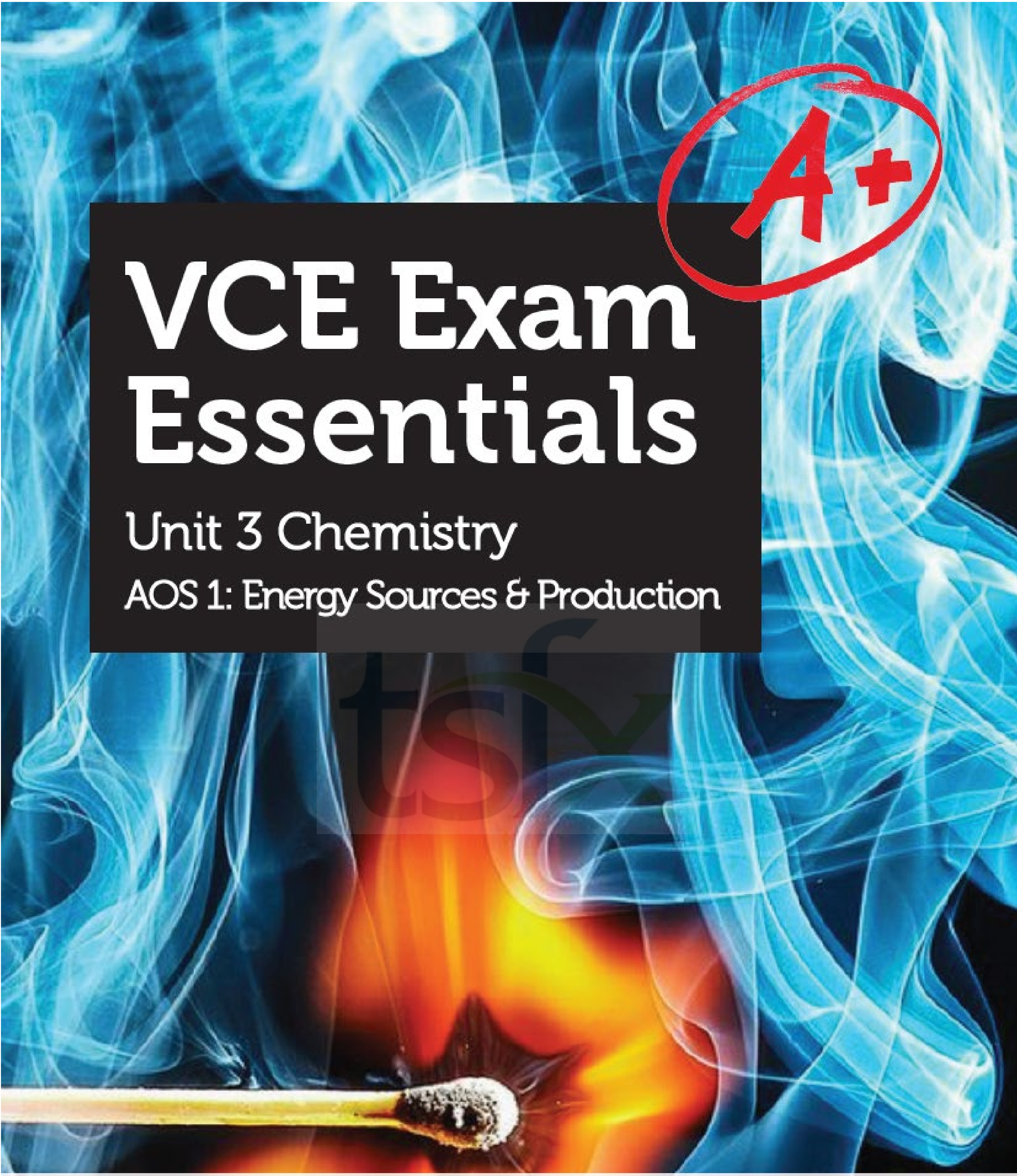

VCE Exam Essentials

Unit 3 Chemistry

AOS 1: Energy Sources & Production

- ✓ A Complete Guide to the VCE Exams
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VCE EXAM ESSENTIALS

Unit 3 Chemistry

Energy

Area of Study 1

What Are the Options for Energy Production?

VCE Accreditation Period 2017 – 2023

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SECTION 1: FUEL CHOICES

ENERGY

Energy is not a physical entity. It's a property of physical substances that can be transferred or converted, but never destroyed. Energy takes on many forms: kinetic, thermal, sound, light and chemical are just a few. These different forms of energy can be used to do a variety of work:

- Mechanical energy is used to move a car.
- Light energy produced in a light bulb is used to illuminate a room.
- Thermal energy is used to heat objects.

In order for life to exist, it must have a source of energy. Biological systems rely on the sun's energy which is absorbed during photosynthesis and then stored as glucose in plants.

Photosynthesis:

$$6CO_{2(g)} + 6H_2O_{(l)} \xrightarrow{UV\ light/chlorophyll} C_6H_{12}O_{6(aq)} + 6O_{2(g)} \quad \textit{Energy absorbed}$$

This energy can then be transferred to other living organisms further down the food chain and eventually gets converted back into thermal energy via respiration. This energy is then used in the biological processes needed to keep organisms alive.

Respiration:

$$C_6H_{12}O_{6(aq)} + 6O_{2(g)} \rightarrow 6CO_{2(g)} + 6H_2O_{(l)} \quad \textit{Energy released}$$

In modern society, we rely on the chemical energy that's contained in **fuels** to power our homes, cars and industry.

Fuel: A chemical substance that can react via a chemical or nuclear reaction to produce useful energy.

Traditionally, we have relied on fossil fuels as our main source of energy. Other energy sources include nuclear, biofuels, wind, tidal, hydroelectric and geothermal.

Biological Fuels: Living organisms use glucose as an energy source. Its energy is released via cellular respiration.

Radioactive Fuels: Release energy via nuclear reactions. Examples include plutonium and uranium.

Fuel: A chemical substance that can react via a chemical or nuclear reaction to produce useful energy.

Fossil Fuels: Most commonly used fuel for society's energy needs. These fuels are formed from the fossilised remains of plants which lived millions of years ago.

Biofuels: Fuels which originate from organic material or animal waste.

Unit 3 Chemistry focuses on energy obtained from fossil fuels and biofuels.

FOSSIL FUELS

Fossil fuels are traditionally the most common type of fuel used to produce the energy that society relies on. These types of fuels are made from the fossilised remains of dead plants that lived millions of years ago.

Fossil fuels have a **high carbon content** and the energy they contain is released via **combustion** to produce heat. This energy can then be converted to other useful forms such as electricity.

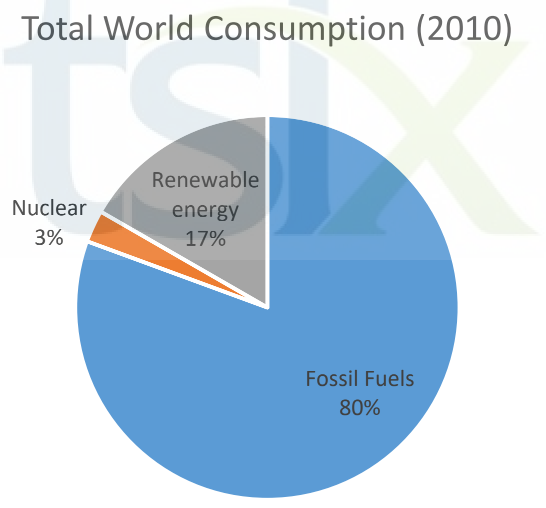
$$Fossil\ Fuel + Oxygen \rightarrow CO_2 + H_2O + Energy$$

Fossil fuels are also used as the raw materials for a wide range of products produced by industrial processes e.g. plastics, drugs and fibres.

Examples of fossil fuels:

- Coal
- Coal seam gas
- Natural gas
- Oil

The graph below shows how dependent the world is on these types of fuels.



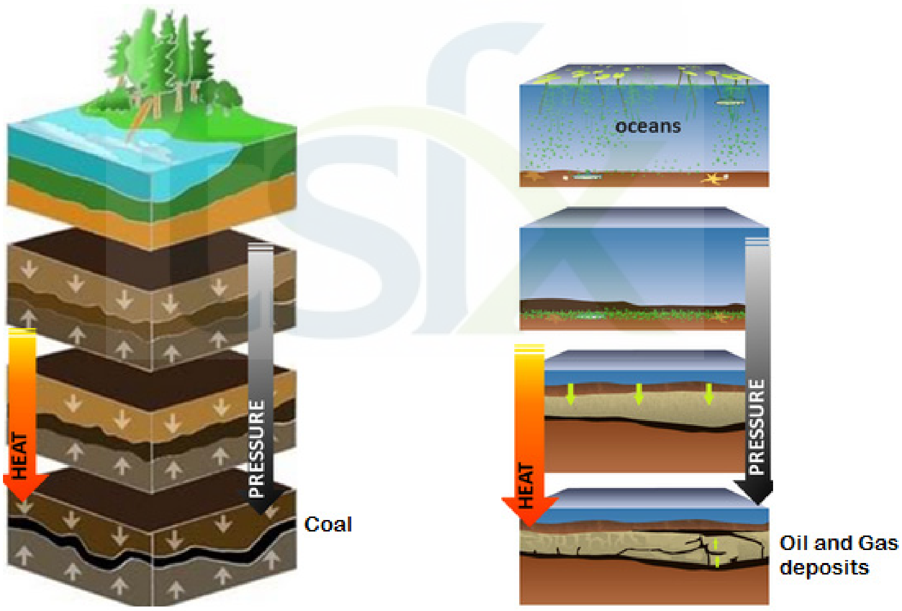
FORMATION OF FOSSIL FUELS

All fossil fuels are made from the remains of organic material that was present on Earth in the Carboniferous Period (360 – 286 million years ago). During the Carboniferous period, the land masses were just forming. The landscape was dominated by swamps and bogs and the warm climate allowed large trees, ferns and other plants to thrive. Strange animals and fish were present. The oceans contained one-celled organisms called protoplankton.

When the plant and animals from this period died, their remains decomposed and became buried under layers of mud, rock and sand. These layers of organic matter eventually became trapped deep under the Earth. In some cases they formed under ocean floors, in other areas the oceans receded leaving the deposits in land based areas.

Over millions of years, these organic remains were transformed by heat and pressure into different types of fossil fuels. The type of fossil fuels that formed depended on how long the organic material was buried, and the amount of heat and pressure present during their decomposition.

- Natural oil and gas were formed from water based organisms.
- Coal was formed from the remains of plant material.



SOURCING FOSSIL FUELS

Coal, oil and gas accumulate in underground deposits which can be land based or under the ocean floor. These deposits are discovered by sophisocated exploration techniques such as gravity, magnetic or seismic surveys.

Once deposits are found, an exploration well is drilled in order to determine the quality and extent of the deposit. Off shore operations are expensive and high risk, while land based exploration is less costly and safer.

Once profitable deposits have been discovered, permanent mining and drilling operations are developed.

Open Cut Coal Mine

Drilling for Oil

BIOFUELS

Biofuels (biochemical fuels) originate directly or indirectly from organic material including plant material and animal waste. This organic material is called **biomass**.

The energy contained in these fuels originates in the sun. The sun's energy is converted into chemical energy via photosynthesis and stored as glucose molecules.

Plants process the glucose into complex carbohydrates. It's the energy that's trapped within these compounds that's released upon combustion. Combustion of biomass transforms the chemical energy stored within the chemical bonds of the fuel to heat energy, which may then be used as an energy source.

$$Biomass + O_{2(g)} \rightarrow CO_{2(g)} + H_2O_{(g)} + Heat$$

PRIMARY BIOFUELS

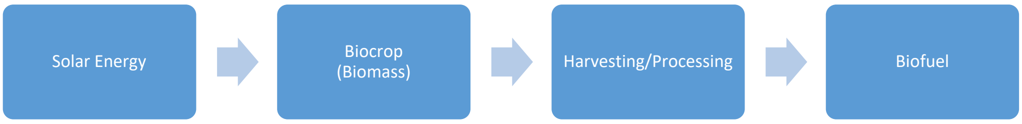
Unprocessed biomass can be used directly as a source of energy and are called **primary biofuels**.

For example:

- Burning wood in a wood heater to warm a house.
- Burning animal dung for cooking.

SECONDARY BIOFUELS

Secondary biofuels result from the processing of biomass.



For example:

- Bioethanol and biodiesel which are used as transport fuels.
- Biogas which is used domestically and in power production.

The biofuels produced from biomass can be solids, liquids or gases.

Unlike fossil fuels, biofuels can be produced rapidly through modern processes rather than by the time-consuming geological processes needed for the formation of fossil fuels.

Summary:

There are 3 types of biofuels (biochemical fuels):

- Biomass
- Biogas
- Liquid fuels

RENEWABLE & NON-RENEWABLE ENERGY SOURCES

Renewable Energy Source:

The energy source can be replaced by natural processes within a relatively short period of time.

Rate of Production ≥ Rate of Consumption

Examples include: Wind, tides, waves, **biofuels** (from plant and animal matter), the sun.

Non-Renewable Energy Source:

Energy sources which are finite and will run out, as they are consumed at a rate faster than they can be produced.

Rate of Production ≤ Rate of Consumption

Examples include **fossil fuels** (coal, oil and gas) as well as nuclear materials.

Important Note:

Renewability is a sourcing issue, **NOT** an environmental issue.

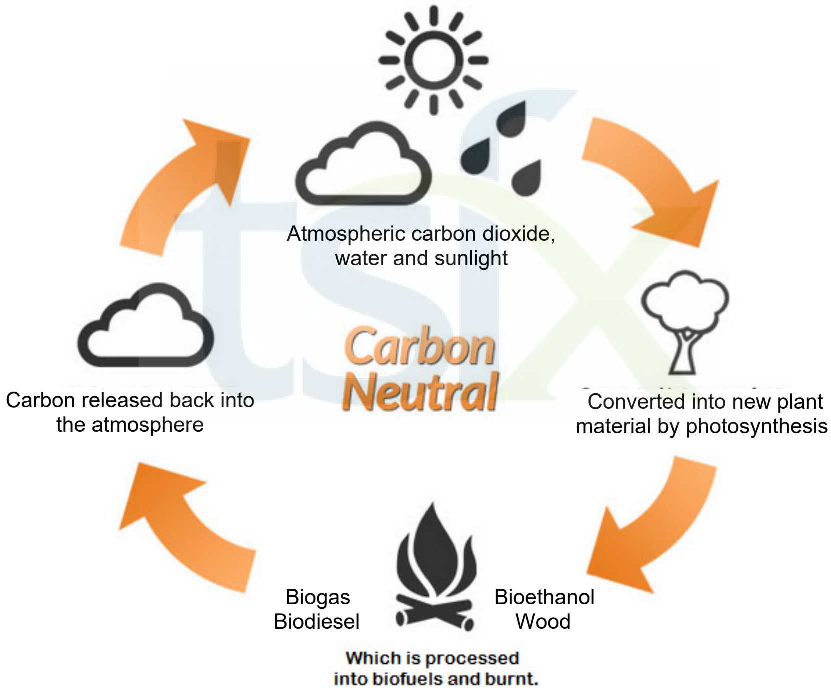
CARBON NEUTRAL FUELS

When fuels are burnt, they emit carbon dioxide into the atmosphere. This is of great concern since carbon dioxide is a greenhouse gas and elevated concentrations of it in the atmosphere cause an increase in global warming.

Fuel + Oxygen → Carbon Dioxide + Water

Fossil fuels are carbon rich and when burnt, this carbon, which has remained trapped underground for millions of years, is released as carbon dioxide into the atmosphere. Therefore, the combustion of fossil fuels **ADDS** to the amount of carbon dioxide in the atmosphere. They are **not carbon neutral**.

Biofuels are described as **carbon neutral** fuels. These fuels are derived mainly from plant matter (biomass) so carbon dioxide is absorbed from the atmosphere during the growth of the biomass. The biomass is then converted into a biofuel. The combustion of the biofuel releases the same amount of carbon dioxide into the atmosphere as was absorbed when the biomass was formed. Therefore, there is not net increase in the amount of carbon dioxide in the atmosphere due to the *combustion* of the biofuel.



During plant growth – Photosynthesis occurs and carbon dioxide from the atmosphere is trapped.

$$6CO_{2(g)} + 6H_2O_{(l)} + Energy \rightarrow C_6H_{12}O_{6(aq)} + 6O_{2(g)}$$

Gets incorporated into biomass

When plants are burned – Oxidation occurs and carbon dioxide is released to the atmosphere.

$$Biomass + O_{2(g)} \rightarrow CO_{2(g)} + H_2O_{(g)}$$

Important Notes:

- A fuel is deemed carbon neutral if the time it takes to produce the fuel and recycle the carbon released into the atmosphere when that fuel is combusted is much shorter than the amount of time before global warming effects occur i.e. a few years.

- Carbon neutrality is a misleading term for biofuels. Although biofuels absorb as much carbon dioxide during photosynthesis as is released *when the fuel is burnt*, this does not mean that biofuels don't contribute to the amount of carbon dioxide in the atmosphere. This is because carbon dioxide is produced during the clearing of land for biofuel crops as well as the production and transportation of the biofuels.

- Fuels that don't release any carbon dioxide are also called carbon neutral. For example, nuclear fuels.

- Carbon sequestration is one method of removing the carbon dioxide produced by non – carbon neutral fuels.

SUMMARY

Fossil Fuels:

- Are **NON-RENEWABLE** since the rate they are consumed > the rate they are formed.
- Are **NOT CARBON NEUTRAL** since the rate of CO_2 production > rate CO_2 is removed from the atmosphere.
- Are the largest source of emissions of carbon dioxide, which is a greenhouse gas and a major contributor to global warming.

Biofuels:

- Are **RENEWABLE** since the rate they are consumed ≤ the rate they are formed.
- Are **CARBON NEUTRAL** since the amount of CO_2 produced when the fuel is burnt is equal to the amount of CO_2 absorbed when the biomass is grown.

The CO_2 produced during the production, transport or distribution of the biofuel has not been taken into consideration.

NATURAL & SYNTHETIC FUELS

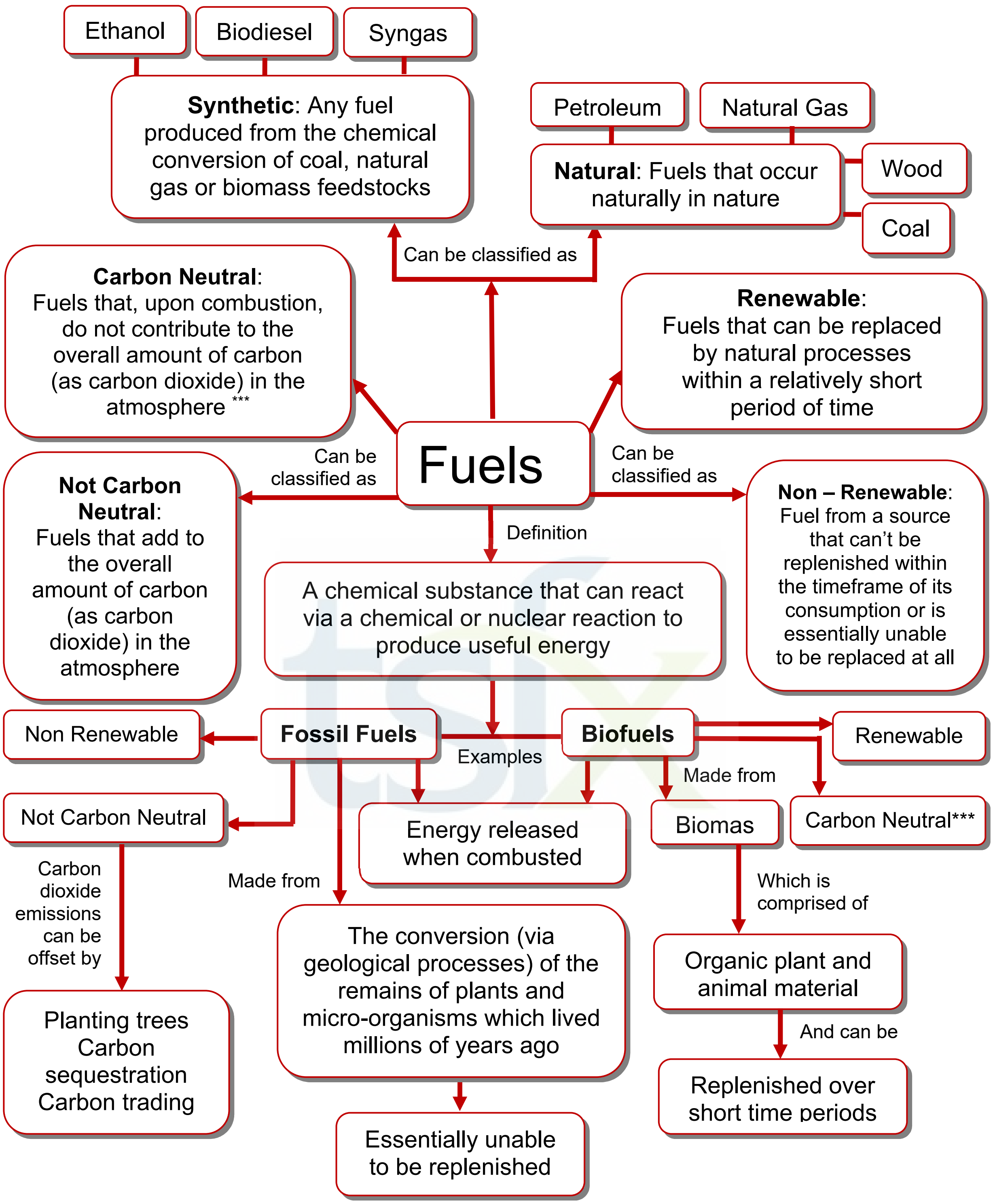
Synthetic fuels (synfuels) are liquid fuels that have been manufactured from an energy source such as coal, natural gas, tar sands or biomass. That is, the original energy source has undergone some sort of chemical conversion to enhance its usefulness.

For example: Bioethanol, syngas

Natural fuels can be found in nature and used in an unprocessed form.

For example: Petroleum, wood.

FUELS SUMMARY



***Remember:**

When fuels are described as carbon neutral, this often doesn't take into account the carbon dioxide released in the production or transportation of the fuel.

QUESTION 1
Complete the following table by placing a tick in the correct columns.

Fuel Source	Renewable	Non-Renewable	Carbon Neutral	Not Carbon Neutral
Nuclear				
Wind				
Hydro				
Wood				
Coal				
Biodiesel				
Petrodiesel				
Methane (from Natural Gas)				
Biomethane				
Bioethanol				
Hydrogen (from Biomass)				
LPG				
Petrol				
Crude Oil				

Note:

This table doesn't take into account the carbon dioxide produced from power plant construction, auxiliary systems, transport and decommissioning. Once these considerations are taken into account, some fuels may not be 100% carbon neutral.

QUESTION 2
Problems associated with renewable energy include:

A The costs involved with developing renewable energy.
B Lack of necessary infrastructure.
C Lack of energy storage options.
D All of the above.

QUESTION 3
Biofuels are renewable energy sources since:

A The carbon dioxide released when they're combusted is offset by the carbon dioxide absorbed by the biomass grown to produce them.

B They have no impact on the environment.

C They can be replaced at a rate greater or equal to the rate of their consumption.

D Their use reverses the impact of global warming.

QUESTION 4
Solar energy stored in materials such as wood, grain, sugar and municipal waste is called:

A Fossil fuels
B Biomass
C Geothermal energy
D Organic potential energy

QUESTION 5
Bioethanol is an example of a:

A Fossil fuel, renewable energy source
B Fossil fuel, non-renewable energy source
C Biofuel, renewable energy source
D Biofuel, non-renewable energy source

QUESTION 6
The South Australian government has moved away from burning fossil fuels for energy and has invested in wind turbines. There has been a change from:

A Non-renewable energy to biomass.
B Non-renewable energy to a carbon neutral energy source.
C A carbon neutral energy source to a renewable energy source.
D An energy source with high impact on global warming to an energy source with no environmental impact.

QUESTION 7
Hydrogen is a natural component of natural gas and can be used as a fuel in combustion engines. Discuss the renewability and carbon neutrality of this fuel.

Solution

QUESTION 8
State the main similarities of, and differences, between biomass and fossil fuels.

Solution

MAKING FUEL CHOICES

Prior to the 18th century, the economy of the world was based on producing and maintaining crops and farmland. When the Industrial Revolution took off in the 18th century, there was a shift machine manufacturing which was made possible by using fossil fuels as an energy source. Supplies of coal were plentiful, easily obtainable by mining and could be used without processing. The oil industry provided oil and gas which became extensively used in transport and electricity production. This enabled huge advancements in technological and economic growth with little regard to the environmental impacts.

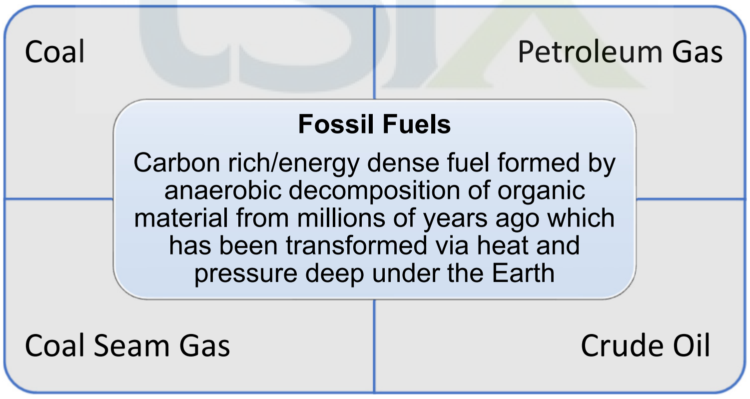
By the mid 1800's, environmental laws started being introduced to reduce the environmental impacts that were becoming apparent. Since this time, scientists and governments have identified, highlighted and tried to reverse some of the environmental impacts associated with burning fuels. Choosing clean, efficient and sustainable energy sources has become one of the top priorities of governments all around the world.

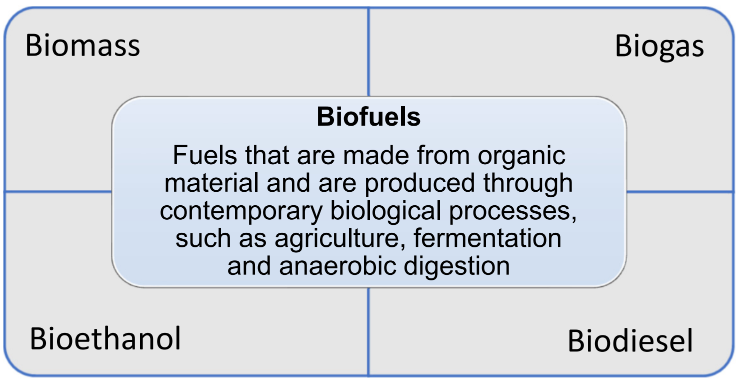
Considerations for choosing fuel sources should include:

- What fuels are available?
- What are the environmental issues associated with obtaining the fuel?
- How much energy do they contain?
- How efficiently can the energy in fuels be converted to the desired form?
- What are the environmental issues involved in burning the fuel?

SOURCING FUELS

The majority of the world's energy is sourced from **fossil fuels** and renewable energy which includes **biofuels**.

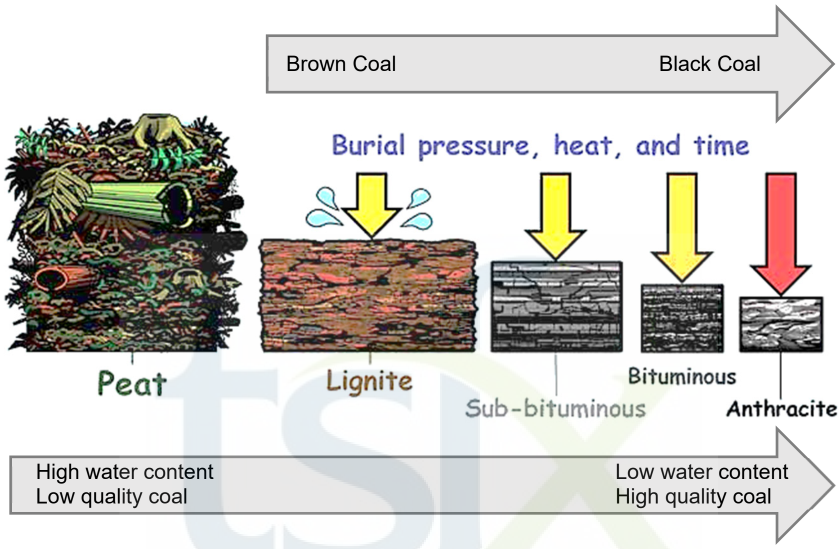




COAL

Coal is the most abundant fossil fuel and is the end product of the decomposition of wood. It starts of as peat, which is basically plant matter with a very high water content. As time, heat and pressure increase, the peat metamorphosises into lignite, then sub-bituminous coal, bituminous coal and finally anthracite. Throughout this process, the water content decreases and the coal content increases. Since the composition of coal varies, it is not a homologous substance and hence doesn't have a molar mass.

Anthracite is the highest grade and most desirable form of coal to use as an energy source. It's low water content and high carbon content make it the most energy dense type of coal per unit of mass and the cleanest to combust. Anthracite is usually found deeper under ground than the other types of coal since this is where the most extreme conditions of temperature and pressure occur. However, geological upheaval may bring these deposits closer to the surface.



Coal may also contain other elements such as sulfur. Sulfur content typically ranges from $0.4-4.0\ \%w/w$ depending on the type and source of the coal. Low sulfur content is desireable since upon combustion, it forms sulfur dioxide, which then leads to acid rain.

A major use of coal is power generation. Approximately 40% of global power generation is obtained via coal. In Australia, coal produces around two-thirds of Australia's electricity generation which is quite a high percentage when compared to many other countries. Coal remains a popular choice for energy production for many governments due to the huge deposits still available, and its relative cost effectiveness compared to other energy sources.

Environmental Impacts of Mining Coal

Heavy Metals

When coal is mined, the ore contains unwanted material such as soil and rock. The ore is washed to remove these substances and the resulting waste water contains heavy metals which are toxic to the environment and have a wide range of serious health implications.

Heavy metals include: mercury, arsenic, cadmium, nickel and selenium.

These toxins can end up in ground water if waste water isn't managed properly.

Air Pollution

Drilling, blasting, collection and transportation processes all cause air pollution at mine sites. Pollutants include:

- Methane (a potent greenhouse gas) which is released from exposed rock and commonly vented directly into the atmosphere or burnt in flares.
- Dust, coal particles and soot released from blasting and transport vehicles.
- Sulfur, nitrogen and carbon oxides from blasting and mine fires.

Water Quality

Rainwater runoff is modified by sulfur containing rocks that become exposed due to mining activities. The water reacts with sulfur and the air to produce sulfuric acid. The acidity of the water is toxic to biological organisms and can cause corrosion to metallic structures.

Underground aquifiers can also be disturbed or contaminanted. This can affect water supplies for other uses such as farming. Food quality of crops can't be assured when they're grown using contaminated ground water.

Destruction of the Environment

Mining damages plant life, soil structure and the topography of the land. It creates barren patches of land that are aesthetically unpleasing and contribute to loss of topsoil, erosion and dust storms. The removal of earth and vegetation devastates wildlife habitats and ecosystems. If underground mines are not maintained or are abandoned, they can collapse, which causes land subsidence (sinking of ground level). This can have serious implications on surrounding structures.

ADVANTAGES OF COAL AS AN ENERGY SOURCE

- Large reserves are still available.
- Infrastructure is already in place for its extraction and processing.
- It's an affordable energy source.
- It's easy to burn and produces large amounts of energy.
- It's a reliable energy source.

DISADVANTAGES OF COAL AS AN ENERGY SOURCE

- It produces large amounts of carbon dioxide upon combustion, which contributes to the greenhouse effect.
- Its combustion also releases sulfur dioxide, nitrogen oxides and carbon monoxide, all of which can contribute to acid rain.
- Mining coal is detrimental to the environment.
- It's non-renewable.
- It's not carbon neutral.

SUMMARY

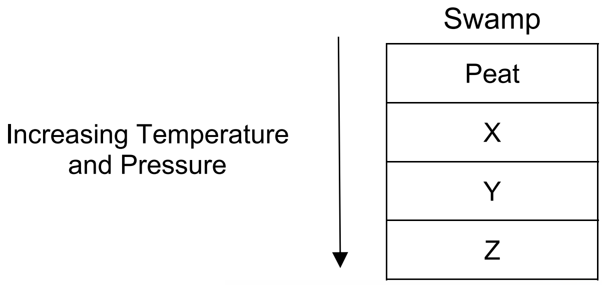
- Coal is a solid fossil fuel made from the decomposition of plant material.
- Coal is not a homologous substance; it has a variable composition.
- Coal is extracted from underground deposits via open cut mining or sub-surface mining. Mining can have serious environmental implications.
- Coal is graded according to the % carbon content.
- High carbon content is desirable as it produces less pollution (less smoke) upon combustion.
- Low water content is desirable to maximise energy released upon combustion.
- Anthracite has the highest carbon content and lowest water content.
- Low sulfur content is desirable to minimise the formation of acid rain.
- Globally, coal is the predominant energy source for electricity production.
- It can be used for large scale electricity production.

QUESTION 9
Coal forms via:

i. Geological processes
ii. Biological processes
iii. Chemical processes

A i only
B ii only
C i, ii and iii
D ii and iii

Use the diagram below to answer Questions 10 and 11:



QUESTION 10
Layer Z is:

A Anthracite
B Sub-bituminous coal
C Natural gas
D Bed rock

QUESTION 11
In addition to increasing temperature and pressure, the arrow on the left also represents increasing:

A Metamorphism of organic material
B Heat content
C Coal content
D All of the above

QUESTION 12
Which of the following would release the most energy per gram?

A Brown coal
B Peat
C Lignite
D Anthracite

QUESTION 13
An advantage of coal is that:

A It's easy to burn.
B It's clean to burn.
C It doesn't cause major harm to the environment.
D It's common and cheap.

QUESTION 14
Coal with high energy content is:

A Very old with low moisture content.
B Relatively young with low moisture content.
C Very old with high moisture content.
D Relatively young with high moisture content.

QUESTION 15
Which type of coal is least likely to produce smoke when burnt?

A Anthracite
B Lignite
C Brown coal
D Peat

COAL SEAM GAS

Coal seam gas (CSG) is a type of natural gas that is primarily comprised of methane. This gas collects in underground coal seams by adsorbing to the surface of coal particles. The coal seams are generally filled with water and it's the pressure of the water that keeps the gas as a thin film on the surface of the coal. CSG is a type of fossil fuel since it originates from the coal deposit.

Coal seam gas is used in exactly the same way as natural gas obtained from other sources. Once extracted from the coal seam it is pumped through a network of pipes to stations where it's compressed, purified and sent to customers. Once compressed and liquefied, the gas is called liquefied natural gas (LNG). This gas can be used for cooking, heating, electricity production and many other uses. There is high export demand for Australia's LNG.

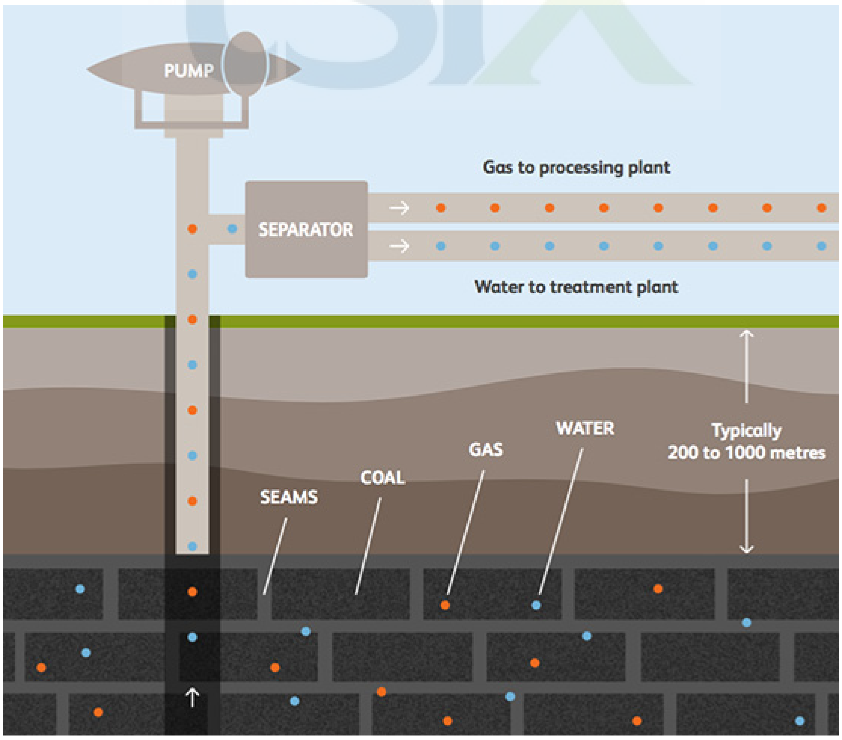
Coal seam gas is also commonly used in gas fired power stations instead of coal. It produces 50% fewer greenhouse gas emissions compared to black coal and 70% less than brown coal. However, methane leakage is an issue with gas power production since it's a potent greenhouse gas. Natural gas is also more difficult to transport and store safely and the CSG reserves are not as extensive as coal deposits.

Removal of Coal Seam Gas:

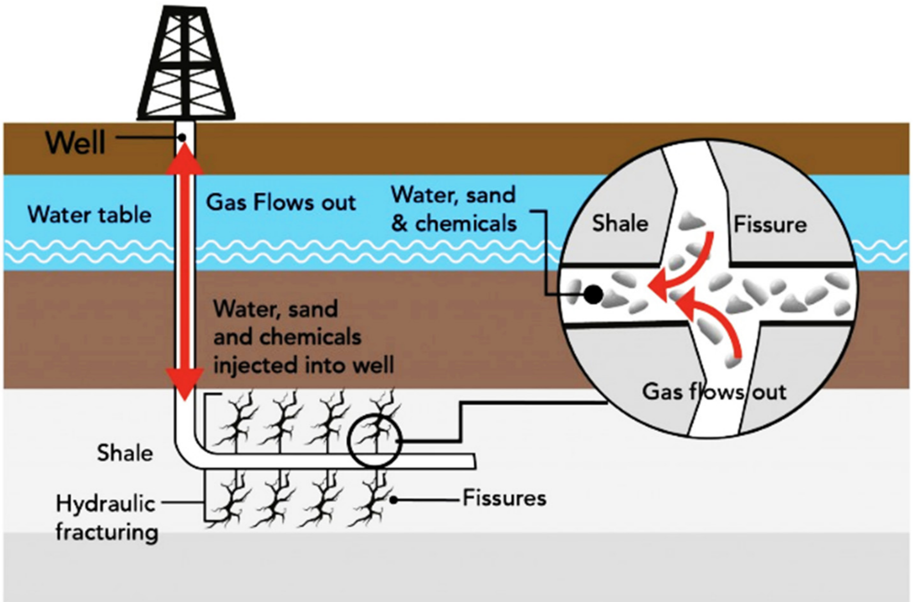
1. A well is drilled to the required depth.

2. The pressure on the ground water is relieved so that water and gas can be pumped to the surface.

3. The water and gas are separated and processed at ground level.



HYDRAULIC FRACTURING



Some gas seams have low permeability and resist the flow of water and gas. In order to widen the coal seams, a mixture of water, sand and some other additives are pumped into them.

The sand creates or widens cracks providing a pathway for gas to flow more easily into the extraction pipe.

The chemicals added to the fracking water have a number of functions including:

- Dissolving minerals and aiding in crack formation.
- Reducing bacterial growth.
- Restricting fluid loss.
- Reducing friction in the fissures to allow proppant delivery and the flow back of water to the surface.
- Minimising corrosion of metal components (drill casings, etc.).

Environmental Impacts of Extracting CSG

Contamination of Water Supplies

Careful use, treatment and storage of fracking water is required to ensure that it doesn't contaminate drinking water, aquatic ecosystems or ground water supplies. Once these water sources are contaminated, it can be very difficult to remove the toxic chemicals that are present. This is particularly the case for ground water supplies.

Waste Water

Water that is removed from the coal seam will contain containments from the coal deposit and from the chemicals added to the fracking water. This includes hydrocarbons and volatile organic substances, both of which are known to cause serious health issues. The waste water also has a very high salt content. The removal of this salt via evaporation results in millions of tonnes of salt being produced, all of which needs to be transported and stored.

Leakage of Methane Gas

Methane gas is a potent greenhouse gas that traps 86 times as much heat as carbon dioxide over a 20 year period. Therefore, even very small leakages can have huge enviromental consequences. At present, there have been few studies that have measured the amount of gas leakage from CSG. However, there is mounting evidence that it could be significant enough to cancel out the perceived benefits of lower carbon dioxide emissions from the burning natural gas.

Effect on Food Production

Sustainable safe food production may become more difficult due to the decrease in water quality via:

- Increased salinity and contaminants.
- Loss of productive land.
- Altering of the soil structure (e.g. changing pH) and contamination of crops.

This could affect Australia's reputation for clean food production and potentially reduce export earnings.

ADVANTAGES OF CSG AS AN ENERGY SOURCE

- Methane gas is a useful energy source that can be used close to its extraction point or can be piped to homes and industries.
- Can be processed into liquefied natural gas plant (LNG) and exported worldwide.
- Relatively inexpensive to produce and distribute.
- Produces 50% fewer greenhouse gas emissions compared to black coal and 70% less than brown coal.
- When burnt, it produces much lower levels of noxious substances such as sulphur dioxide, nitrogen oxides and fine particle emissions.
- Gas fired power stations are reliable and able to provide base load power.
- Australia has large reserves of gas that could be used for electricity production.

DISADVANTAGES OF CSG AS AN ENERGY SOURCE

- Since CSG is a fossil fuel, it is non-renewable and not carbon neutral.
- Methane is a potent greenhouse gas so leakage is of significant environmental concern.
- Methane is volatile and explosive so it's more difficult to handle than coal.
- Contamination of water supplies could significantly affect the health of humans, stock and crops.

SUMMARY

- Coal seam gas (CSG) is a fossil fuel that’s found in coal seam deposits.
- CSG is mainly comprised of methane which adsorbs to the surface of the coal deposits and remains there due to underground water pressure.
- Drilling relieves the pressure within the coal seam, which allows the ground water and gas to escape to the surface.
- At the surface, the gas and water are separated from one another.
- Fracking may be undertaken to widen or create cracks in the coal seam to assist in the removal of the gas.
- The CSG is processed, compressed and the delivered to point of use.
- CSG is also referred to as natural gas.
- CSG is sometimes liquified, in which case, is called Liquified Natural Gas (LNG).
- LNG is a major export earner for Australia.
- A major use of CSG is in the production of electricity.
- CSG is seen as an enviromentally friendly alternative to coal for electricity production since its combustion releases less carbon dioxide than coal.
- The environmental benefits of burning CSG may be negated by the negative impact of methane leakage which is a more potent greenhouse gas than carbon dioxide.
- Waste water from the extraction of CSG contains high levels of salt. The removal, transport and storage of this salt is an increasingly large enviromental problem.
- Waste water can be contaminated by hydrocarbons, volatile organic substances and chemicals from the fracking process, all of which could potentially contaminate natural water supplies and negatively affect the health of people, livestock and crops.

QUESTION 16
The main type of gas found in coal seam gas is:

A Methane
B Ethane
C Hydrogen
D Carbon dioxide

QUESTION 17
Coal seam gas is considered a better alternative to coal for electricity production since:

A There are larger reserves of CSG than there are of coal.

B It's cleaner to burn than coal.

C It's production and use for electricity production has little effect on the amount of greenhouse gases emitted into the atmosphere.

D The waste water produced is much cleaner than that produced from coal production.

QUESTION 18
Obtaining coal seam gas can lead to degradation of the quality of surrounding water supplies due to all of the following except:

A Increased salinity
B Leaching of hydrocarbons
C Addition of toxic chemicals
D Increased acidity due to acid rain

QUESTION 19
Using CSG to generate electricity is said to be better for the environment than using coal since less greenhouse gases are emitted into the atmosphere. Discuss the accuracy of this statement.

Solution

QUESTION 20
One of the advantages of coal over CSG is that it's a solid fuel. Explain why this is an advantage.

Solution

CRUDE OIL & PETROLEUM GASES

Most crude oil/petroleum gas is formed from the action of intense pressure and heat on buried dead zooplankton and algae (microscopic plant and animals) over millions of years.

Tiny sea plants and animals died and were buried on the ocean floor. Over time, they were covered by layers of silt and sand.

Over millions of years, the remains were buried deeper and deeper. The enormous heat and pressure turned them into oil and gas.

Today, we drill down through layers of sand, silt and rock to reach the rock formations that contain oil and gas deposits.

Crude oil (petroleum) is a mixture of hydrocarbons that exists as a liquid in natural underground reservoirs and remains a liquid when brought to the surface. The range of hydrocarbons found in crude oil is diverse and includes straight chained alkanes, cycloalkanes and aromatic hydrocarbons. Every oil deposit will have a unique composition of hydrocarbons which are refined and separated using fractional distillation.

Petroleum Gases (often referred to as natural gas) consists mainly of methane but also of other small gaseous hydrocarbons. These gases occur naturally underground.

Petroleum gas is classified according to how it is found:

- **Associated:** Found as a component of crude oil deposits.
- **Non-associated:** Gas deposit without accompanying oil.

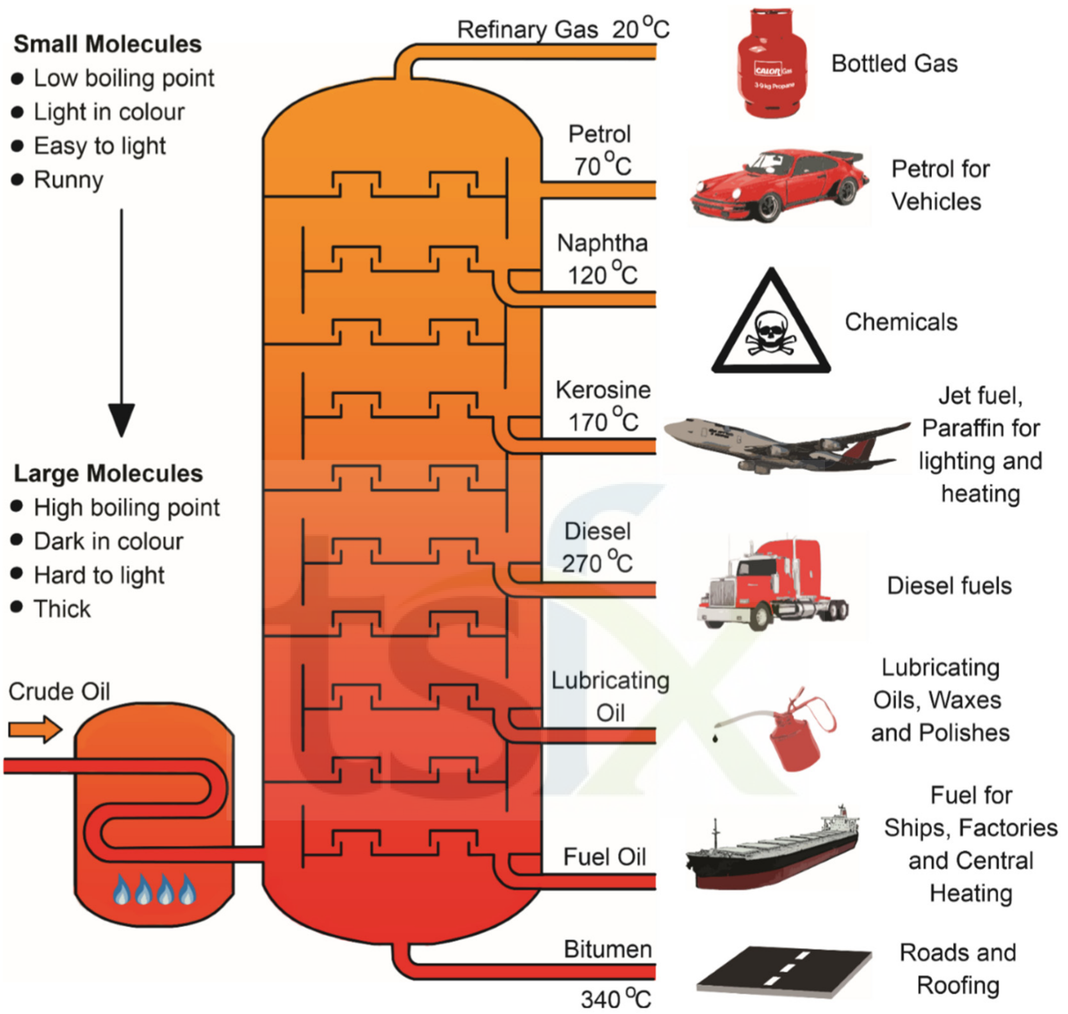
Petroleum products are made by processing of crude oil and petroleum gases.

Petrol (also called gas or gasoline in the USA):

A particular class of crude oil (a fraction) that includes hydrocarbons with carbon chains that are 5 to 12 carbons long.

FRACTIONAL DISTILLATION

Fractional distillation is used to separate crude oil into groups of hydrocarbons of similar sizes called fractions. Since the hydrocarbons within each fraction are of similar size, they will also have similar boiling points which fall within a specific range. This allows the fractions to be separated according to their boiling points.



SEPARATION OF HYDROCARBONS VIA DISTILLATION

- Crude oil enters the fractionating tower at the bottom where it's heated to high temperatures, which turns most of its components into a gas.
- The gas, which contains a large number of different hydrocarbons, rises through the column and cools.
- Eventually, each hydrocarbon will cool to the point where it condenses. The temperature at which this occurs depends on the size of the hydrocarbons.
  - Smaller hydrocarbons have weaker intermolecular forces of attraction and hence will remain gaseous at lower temperatures. They condense at the top of the column where the temperature is at it's lowest.
  - Larger hydrocarbons with stronger intermolecular bonding condense at higher temperatures, which occur lower in the column.
- Bubble caps are used in the column to force the gases through the condensed liquids that have formed in trays at various levels in the column.
- Gases will condense in the trays once they are forced through a liquid that has a similar boiling point to its own. This causes the different hydrocarbons to be separated and collected into fractions.

CRUDE OIL FRACTIONS AS ENERGY SOURCES

Different crude oil fractions have different properties which allow them to be used as fuel sources for a wide variety of uses.

REFINERY GAS

Refinery gas contains small gaseous hydrocarbons ranging in size from $C_1 \to C_4$.
These hydrocarbons can be separated further into natural gas and liquefied petroleum gas.

NATURAL GAS:

- Primary consists of methane. When first extracted, it may contain larger hydrocarbons as well as sulfur, water and hydrogen sulfide. These are removed before use.
- Is colourless and odourless.
- Burns relatively cleanly to produce heat energy.
- Natural gas is lighter than air. Methane leaks disperse quickly and easily rather than forming pockets of explosive gas.
- In certain concentrations, natural gas can be explosive, so it should always be treated with care.
- Stenching agents are added to the gas so that leakages can be smelt.

- Is delivered as a gas via pipelines to point of use.

- May be cooled and compressed to Liquefied Natural Gas (LNG) but this is usually not cost effective for most natural gas users.

- Methane from CSG can also be referred to as natural gas.

LIQUEFIED PETROLEUM GAS (LPG):

- Comprises of propane and butane gases.

- Is separated from natural gas or by the refining of crude oil.

- LPG is stored under pressure as a liquid in specialised gas bottles which can withstand higher than normal pressures.

- LPG gas bottles are connected to appliances. When the appliance is turned on, the pressure within the gas bottle is released, which allows the liquefied gas to turn back into a vapour, which is then burnt.

- Is used domestically and commercially where a mains supply of natural gas is not available.

- Is denser than air making leakage harder to disperse.

- A stenching agent is added so that leakages can be smelt.

Natural Gas and LPG Comparison

Property	Natural Gas	LPG
Chemical Composition	Methane	Propane
Energy Content (by Volume) MJ/m^3	38.7	93.2
Energy Content (by Mass) MJ/kg	52.5	50
Boiling Point °C	-161.5	-42
Density at 15°C kg/m^3	0.668	1.899

- LPG has more energy per unit of volume but not by unit of mass.

- LPG is denser than both natural gas and air.

- Natural gas primarily consists of methane, LPG can be propane, butane or a mixture of both.

PETROL

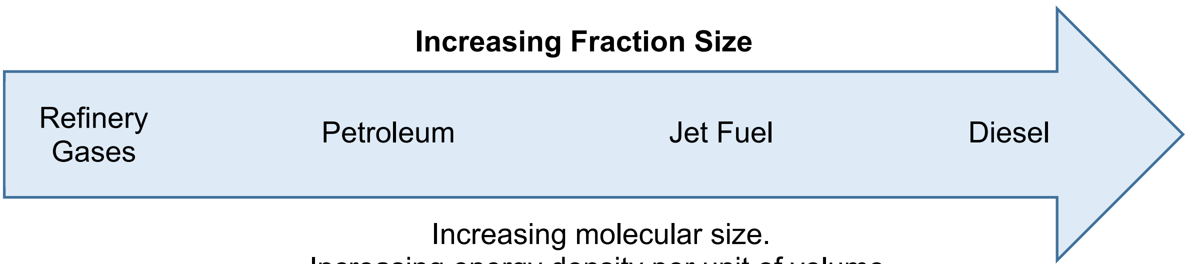
- Petrol is a liquid hydrocarbon mixture comprising of straight chain hydrocarbons in the order of $C_5 - C_{12}$. Some cyclic and aromatic hydrocarbons are also present.
- Is the most widely used transport fuel.
- Is more energy dense and less volatile than natural gas or LPG due to its liquid state.
- May be mixed with ethanol in order reduce the environmental impacts of burning fossil fuels.
- The relatively small size of the molecules means that the intermolecular forces between the molecules still allow the petroleum liquid to flow easily.

JET FUEL

- Jet fuel is comprised of hydrocarbons ranging between $C_8 - C_{16}$.
- Is more resistant to auto-ignition than petrol.
- It has low flammability and can be used in cold temperatures (like those associated with high altitude) without freezing.

DIESEL

- Diesel is comprised of hydrocarbons ranging between $C_{14} - C_{20}$.
- Has a higher energy density per unit of volume than petrol, and is less volatile.
- Commonly used as a transport fuel.



Increasing molecular size.
Increasing energy density per unit of volume.
Increasing boiling point.
Increasing viscosity.
Decreasing volatility.

THE ENVIRONMENTAL IMPACTS OF EXTRACTING CRUDE OIL & PETROLEUM GAS

Water Quality Issues

Degradation of natural water resources can occur due to:

- Effluent discharge such as drilling fluids which may contain hydrocarbons, hydraulic fluids and spilt fuel.
- Thermal pollution from water discharges at elevated temperatures.
- Seepage from storage/waste tanks.
- Oil spills.
- Damage to natural aquifers due to drilling.
- Depletion of aquifers if the ground water is removed so that extraction can occur.

Environmental Degradation

Disturbances to land surface or the ocean floor can destroy local habitats which can:

- Reduce biodiversity.
- Increase erosion.
- Lead to infestation by noxious plants.
- Reduce plant health and inhibit their growth due to the deposition of dust.

Blasting and drilling significantly changes the topography of the environment which can impact water flow and natural phenomena such as bush fires.

Soils can be compacted which alters water runoff and inhibits plant growth.

Air Quality Issues

Emissions that occur during drilling include:

- Vehicle emissions.
- Carbon monoxide, nitrogen oxides and particulate matter if waste gases are burnt in flares.
- Dust and particulate matter from clearing land, excavation, blasting and drilling.

Environmental Impacts of Extracting Crude Oil & Petroleum Gas

Other Issues

- Noise pollution from drilling and blasting.
- Disturbance to traditional tribal lands leading to changes in native ways of life.
- Destruction of cultural or religiously important sites.
- Loss of farmland.
- Intrusion of traffic around mining sites. Increased use of heavy vehicles in local communities.
- Visual degradation of the landscape.

ADVANTAGES OF USING FOSSIL FUELS

- Although oil and gas deposits are a non-renewable resource, they are still found in huge quantities, which makes it economically viable to mine and reliable as a major energy source.

- Oil and gas deposits are distributed widely across the globe and there is a huge infrastructure in place which allows for the worldwide use of this energy source.

- The enormous range of chemicals found in crude oil and petroleum gases has allowed for the development of many industries including plastics, medicines and the manufacturing of a huge variety of other consumer goods.

- Its reliability makes it a good choice as a transport fuel and for the generation of electricity; two of the most energy demanding sectors in modern society.

DISADVANTAGES OF USING FOSSIL FUELS

- The combustion of fossil fuels releases large amounts of CO_2 which has led to an increase in global warming.

- Oil spills are devastating to the local environment and wildlife. They occur at the site of drilling and also wherever large oil supertankers are involved in accidents that lead to the spilling of their load.

- The oil industry produces huge amounts of profits. Some of this wealth is not distributed equitably via governments for the benefit of their people, but is instead amassed by individuals.

- The refining and processing of fossil fuels generates a large amount of toxic waste materials.

- Oil and gas reserves are non-renewable and are not carbon neutral.

SUMMARY

- Crude oil and petroleum gases are fossil fuels.
- Petroleum gases include hydrocarbons in the range of $C_1 - C_4$.
- Petroleum gases can be separated into natural gas and liquefied petrolum gas (LPG).
- Natural gas is mainly comprised of methane.
- LPG is comprised of propane, butane or a mixture of both. The gases are liquefied under pressure.
- Fractional distillation is used to separate the hydrocarbons found in petroleum gas and crude oil according to their boiling points.
- Separated fractions contain hydrocarbons of similar sizes.
- Different fractions have different uses.
- There is a predicable change in the physical properties of the fractions as the size of the carbon chain increases. Fractions containing hydrocarbons with long carbon chains will have higher boiling points, be more viscous and be less volatile.
- There are significant environmental issues associated with the extraction of land or ocean based fossil fuel deposits.

QUESTION 21
An advantage of using LPG rather than natural gas as a cooking fuel is?

A Gas leakages will disperse more readily.
B Gas leakages can be smelt more easily.
C LPG is less volatile.
D LPG can easily be piped into homes.

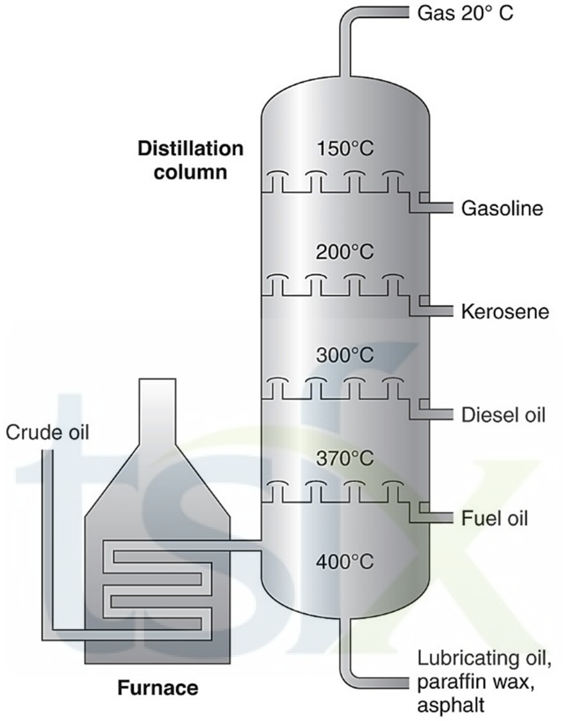
QUESTION 22
The hydrocarbons collected from the top of a fractional distillation column will have:

A High boiling points and high molecular mass.
B High boiling points and low molecular mass.
C Low boiling points and high molecular mass.
D Low boiling points and low molecular mass.

QUESTION 23
In a fractionating column, hydrocarbons are separated according to their:

A Boiling point
B Density
C Ignition temperatures
D Flammability

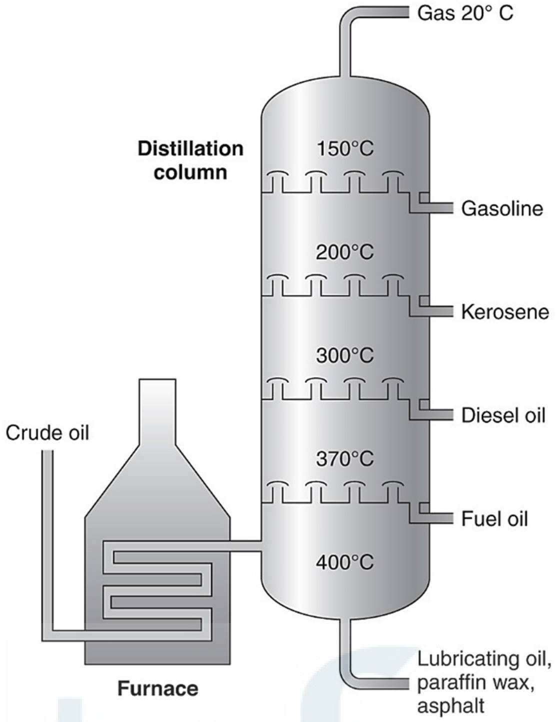
QUESTION 24
When crude oil is distilled, it forms a number of fractions.



Compared with petroleum gas, kerosene is:

A Less viscous and more volatile.
B Less viscous and less volatile.
C More viscous and less volatile.
D More viscous and more volatile.

QUESTION 25
When crude oil is distilled, it forms a number of fractions.

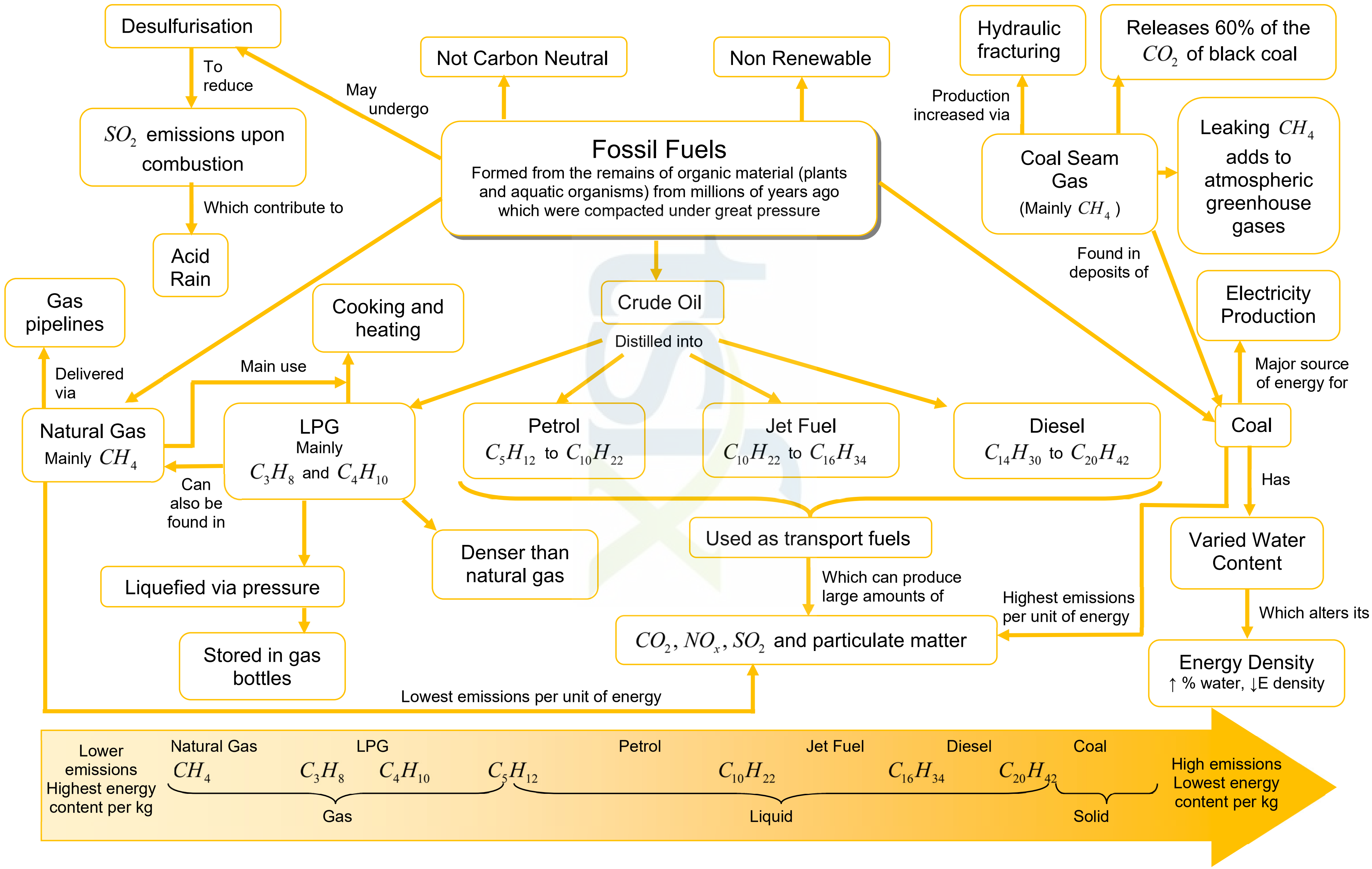


It is true to say that:

A Gasoline is more volatile than heavy gas oil.
B Gasoline has a higher molar mass than heavy gas oil.
C Petroleum gas has a higher boiling point than gasoline or fuel oil.
D Fuel oil has stronger covalent bonds than gasoline.

QUESTION 26
Which fraction in the fractionating column is hardest to ignite?

A The fraction at the top of the column.
B The fraction in the middle of the column.
C The fraction at the bottom of the column.
D The crude oil.


Desulfurisation
To reduce
May undergo
Not Carbon Neutral
Non Renewable
Hydraulic fracturing
Production increased via
Releases 60% of the CO_2 of black coal
SO_2 emissions upon combustion
Fossil Fuels
Formed from the remains of organic material (plants and aquatic organisms) from millions of years ago which were compacted under great pressure
Coal Seam Gas (Mainly CH_4)
Leaking CH_4 adds to atmospheric greenhouse gases
Which contribute to
Acid Rain
Crude Oil
Found in deposits of
Electricity Production
Gas pipelines
Cooking and heating
Distilled into
Main use
Delivered via
Major source of energy for
Natural Gas Mainly CH_4
LPG Mainly C_3H_8 and C_4H_{10}
Petrol C_5H_{12} to $C_{10}H_{22}$
Jet Fuel $C_{10}H_{22}$ to $C_{16}H_{34}$
Diesel $C_{14}H_{30}$ to $C_{20}H_{42}$
Coal
Can also be found in
Has
Used as transport fuels
Denser than natural gas
Varied Water Content
Liquefied via pressure
Which can produce large amounts of
Highest emissions per unit of energy
Which alters its
CO_2, NO_x, SO_2 and particulate matter
Stored in gas bottles
Energy Density ↑ % water, ↓E density
Lowest emissions per unit of energy
Lower emissions Highest energy content per kg
Natural Gas CH_4
LPG C_3H_8 C_4H_{10}
C_5H_{12}
Petrol
Jet Fuel $C_{10}H_{22}$
Diesel $C_{16}H_{34}$
$C_{20}H_{42}$
Coal
Gas
Liquid
Solid
High emissions Lowest energy content per kg