

Fuels summary

A fuel is any substance that can burn to release heat to generate power.

A **renewable fuel** is one that can be replenished through natural processes in a short period of time so that it does not become depleted.

Know your equations:

- Photosynthesis $6\text{CO}_2(\text{g}) + 6\text{H}_2\text{O}(\text{l}) \rightarrow \text{C}_6\text{H}_{12}\text{O}_6(\text{aq}) + 6\text{O}_2(\text{g})$
- Fermentation $\text{C}_6\text{H}_{12}\text{O}_6(\text{aq}) \rightarrow 2\text{CH}_3\text{CH}_2\text{OH}(\text{aq}) + 2\text{CO}_2(\text{g})$
- Complete combustion $\text{Fuel} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$ (CO_2 is produced as a product)
- Incomplete combustion $\text{Fuel} + \text{O}_2 \rightarrow \text{CO} + \text{H}_2\text{O}$ (CO or C is produced as a product)

Fuel	Source	Renewable? Environmentally friendly?	Energy density kJ/g	Advantages	Disadvantages
Biogas	Usually consists of methane, CH_4 and CO_2 in a ratio of about 70% to 30% respectively. Produced by decomposition of organic material by anaerobic digestion.	Yes, it is renewable No, it is not environmentally friendly as it contributes to a net increase in atmospheric CO_2	26	It is renewable, does not contribute to a net increase in atmospheric CO_2 and in small scale usage reliable in its supply.	No large scale commercial usage as yet and there is no likelihood that this source of energy can supply the fuel needed to provide base-load power.
Coal seam gas	Methane trapped on the surface of coal. It is formed during the natural formation of coal and often adheres to the surface of coal under the influence of high water pressure	No it is not renewable No, it is not environmentally friendly as it contributes to a net increase in atmospheric CO_2	54	Accessible and relatively cheap to source. Reliable in large scale supply.	It is a fossil fuel and farmers argue the potential to contaminate underground water supplies is real and ever present.
Natural gas or LPG(liquid petroleum gas)	Usually consists of methane (CH_4) 90% and 5% CO_2 with small fraction of ethane and	No it is not renewable No, it is not environmentally friendly as it	54	It is relatively cheap and a cleaner fossil fuel than brown or black coal. Power stations	It is fossil fuel and produces greenhouse gases.

	propane. Is found in fossil fuel deposits of coal or oil	contributes to a net increase in atmospheric CO ₂		that run on gas can come online in a relatively short period of time to boost supply during critical periods of high energy demand. Reliable in large scale supply.	
Methane	Pure methane, CH ₄	Depending on its source. If it comes from a fossil fuel source, then it is not renewable and is not environmentally friendly as it contributes to a net increase in atmospheric CO ₂ . If it comes from bio-gas then Yes, it is renewable and no, it is not environmentally friendly as it contributes to a net increase in atmospheric CO ₂	56	See biogas above.	See biogas above.
Ethanol	<p>Bioethanol is produced from fermentation of plant matter such as corn, potatoes, grain (wheat, barley and rye) or sugar.</p> <p>Ethanol is also commercially produced by steam reformation $\text{CH}_4 + \text{H}_2\text{O} \rightarrow \text{CO}_2 + \text{C}_2\text{H}_6\text{O}$. Click to see the organic pathways that</p>	Yes, it is renewable and environmentally friendly as the CO ₂ produced during combustion does not contribute to a net increase in atmospheric CO ₂ as the CO ₂ expelled during combustion was trapped from the atmosphere during photosynthesis. Emissions of CO ₂ , however, during transport and manufacture (distill	30	Its net contribution to atmospheric CO ₂ is relatively small depending on where it is sourced. Reliable in large scale supply. Bioethanol is renewable and does not contribute to a net increase in atmospheric CO ₂	Crops must be grown and when harvested can be fermented to produce ethanol. Ethanol is recovered through distillation. This process competes with limited land with which to grow food. Production and transport of ethanol is energy consuming and

	can be used to produce ethanol	ation) of ethanol should be taken into account and can contribute, albeit a small, to a net atmospheric increase in CO ₂ levels.			this energy often comes from fossil fuels.
Biodiesel	Fatty acids obtained from plants or animal matter.	Yes it is renewable and environmentally friendly as the CO ₂ produced during combustion does not significantly contribute to a net increase in atmospheric CO ₂ as the CO ₂ produced during combustion was trapped from the atmosphere during photosynthesis. Emissions of CO ₂ , however, during transport and manufacture (distillation) of biodiesel should be taken into account and can contribute, albeit a small, to a net atmospheric increase in CO ₂ levels.	42	Similar to ethanol above. Reliable in large scale supply.	Similar to ethanol above. + Biodiesel is hygroscopic due to polar ester groups. Biodegradable and non-toxic.
Petrodiesel	Obtained from fossil fuel reservoirs.	No it is a mixture of hydrocarbons (fossil fuel) of chain length of 8 to 21 carbon atoms	45	It is cheap and relatively easy to source. Reliable in large scale supply.	It is a fossil fuel and contributes significantly to a net increase in atmospheric CO ₂ .
Hydrogen gas (green and blue hydrogen) - Green hydrogen is produced from	Hydrogen gas can be produced in a number of ways. Some are: - Electrolysis of water (green hydrogen),	Depends on how it is produced. Yes it is renewable if it is produced through the electrolysis of water using renewable energy sources	141	Reliable in large scale supply and although most of our industrial quantities currently, as of 2022, come from steam reformation	Expensive to store and transport. Infrastructure is currently, as of 2022, not available for widespread usage of H ₂ gas

<p>renewable sources and energy via the electrolysis of water. - Brown hydrogen is produced from non-renewable sources, such as fossil fuels with carbon capture and storage technology employed.</p>	<p>- Steam reformation (blue hydrogen) - gasification of brown coal (blue hydrogen)</p>	<p>No it is not if it is produced via steam reformation $CH_4 + 2H_2O \rightarrow 4H_2 + CO_2$ or gasification of brown coal.</p> <p>It is also environmentally friendly as its burning as a fuel does not contribute to a net increase in atmospheric CO_2. Transport and storage is a big problem for H_2 and requires a great deal of energy both to store and to produce and as such this factors must also be taken into account if we are to label H_2 as an environmentally friendly fuel.</p>		<p>using methane gas, great advances are currently being made other ways of producing renewable supplies of H_2 gas with minimal environmental impacts. It is one of the most promising and environmentally friendly fuels.</p>	<p>as a fuel in transport or industry. The nature of the H_2 molecule makes it hard to store and transport. It must be liquefied and stored at $-253^\circ C$ and up to 7.0×10^4 kPa. Such extreme conditions require expensive infrastructure is hard to maintain.</p>
<p>Brown coal</p>	<p>Obtained from fossil fuel reservoirs.</p>	<p>No, it is not renewable nor environmentally friendly it is a fossil fuel whose combustion causes a net increase in atmospheric CO_2.</p>	<p>16</p>	<p>Reliable in large scale supply. Since it is very close to the surface, only a metre or two, it is relatively cheap to dig out from the ground and as of 2022 Victoria has enough supply, at current usage, for the next 200 years.</p>	<p>It is a fossil fuel and as such contributes to global warming. It is also a dirtier form of coal. Dirtier in the sense that brown coal contains up to 60% water and must first be dried before it can be used. This requires more energy that is supplied from the burning of further fossil fuels which contribute even more to global warming. Mining of brown</p>

					coal causes land degradation so the land on which the mine exists needs to be rehabilitated after the mine has ceased operations.
Black coal	Obtained from fossil fuel reservoirs.	No, it is not renewable nor environmentally friendly it is a fossil fuel whose combustion causes a net increase in atmospheric CO ₂ .	34	It is a more refined form of coal that contains very little water. This fact alone makes it environmentally better than brown coal. It is found in large deposits in Australia and is relatively easy to dig out from the ground.	Like brown coal it is a fossil fuel and contributes to global warming. Mining of black coal causes land degradation so the land on which the mine exists needs to be rehabilitated after the mine has ceased operations.
LPG (Liquid propane gas)	Obtained from fossil fuel reservoirs.	No, it is not renewable nor environmentally friendly. It is a fossil fuel whose combustion causes a net increase in atmospheric CO ₂ .	51	It is relatively cheap and readily available to use in small scale such as BBQ or heating.	See methane above.

1. The term 'clean coal' is increasingly being used to describe black coal. On the other hand, brown coal is described as a dirty alternative to black coal. Terms such as “clean or dirty” tend to muddy the argument in the use of coal as a fuel.
 - a. Can coal, in all its forms, ever be a clean fuel alternative? Explain.

 - b. Explain why is black coal given the term “clean coal” over the alternative brown coal?

2. A 68.0 litre gas tank is used to store fuel at 25°C and 2300 kpa pressure in a passenger vehicle. Two fuels are considered for powering this vehicle, hydrogen or methane. The tank is filled with either methane or hydrogen and both fuels stored in the under identical conditions.
 - a. On a full tank of fuel, calculate the mol of each gas that is present. Give the answer to the right number of significant figures.



- b. Calculate the total amount of heat energy, kJ, that can be delivered on a full tank for each fuel.
Hydrogen

Methane

3. Hydrogen and methane are common fuels. Even though hydrogen has a higher energy density than methane
- Draw the molecule of:

methane

hydrogen

- Describe the intermolecular bonds found amongst the molecules of methane and hydrogen.
- Explain why methane is currently more widely used as a fuel than hydrogen. In your answer show an understanding of the role intermolecular forces play in each gas.

4. Liquefied ammonia and hydrogen can be transported via huge sea-going vessels. The cost of shipping hydrogen, however, is much greater than shipping ammonia. Given the boiling temperatures of hydrogen and ammonia are -253°C and -33°C respectively and that hydrogen is an odourless gas compared to the distinct and noticeable odour of ammonia, answer the following questions.

- Explain why, with reference to molecular structure of each molecule, transporting ammonia is a lot cheaper than the same mass of hydrogen gas.



- Why is it safer to transport ammonia than it is to transport pure hydrogen gas?

c. "A greater mass of hydrogen can be transported in a given storage tank, under identical conditions, in the form of ammonia gas than as pure hydrogen gas" Justify this comment.

d. Calculate the mass of hydrogen present in a 300.0 litre storage tank at 30°C and 400 kPa pressure containing:

i. pure hydrogen gas.

ii. pure ammonia gas.

Step 1	fermentation	$C_6H_{12}O_6(aq) \rightarrow 2CH_3CH_2OH(aq) + 2CO_2(g)$
Step 2	oxidation	$CH_3CH_2OH(aq) + O_2(aq) \rightarrow CH_3COOH(aq) + H_2O(l)$
Step 3	neutralisation	$2CH_3COOH(aq) + CaCO_3(s) \rightarrow Ca(CH_3COO)_2(aq) + CO_2(g) + H_2O(l)$
Step 4	bacterial conversion	$Ca(CH_3COO)_2(aq) + H_2O(l) \rightarrow 2CH_4(g) + CO_2(g) + CaCO_3(s)$

5. Biogas can be produced from waste water and organic material where sugars are present.

A 4 step process is used and pictured above.

a. Assuming ten molecules of glucose reacted, under identical conditions, in step 1 what is the value of the expression shown on the right?

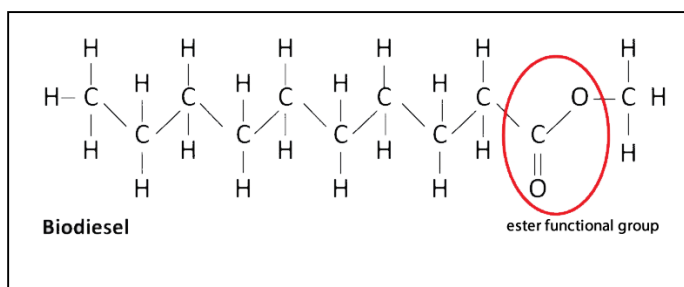
Final volume of CH₄ formed in step 4

Final volume of CO₂ formed in step 4

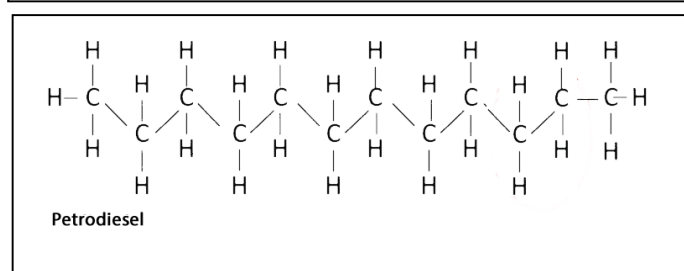
b. Is biogas, formed in this way, renewable and environmentally friendly?

6. On the right are two molecules that are typical of biodiesel and petrodiesel.

- a. Which one of these two molecules would you expect to form flammable vapours at the lowest temperature? Explain.



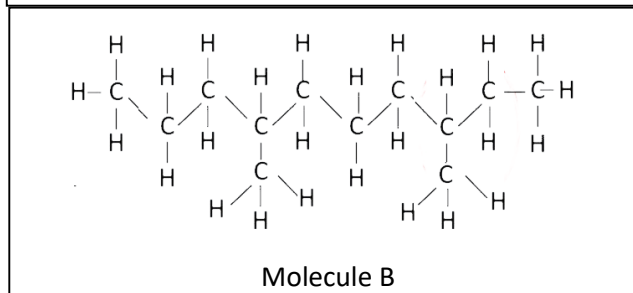
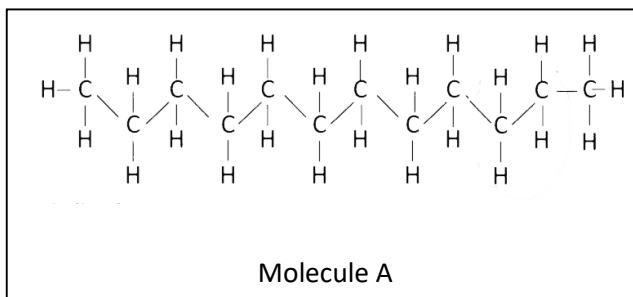
- b. Write the balanced chemical equations for the complete combustion reaction for each molecule. States not included.



- c. Which one of these two molecules is likely to burn completely in a low oxygen environment and produce less energy than the other? Explain.

7. Calculate the mass, in grams, of methane gas needed to be burnt completely in order to raise the temperature of 200 mL of water from 25.0 °C to 55.0 °C. Assume 100% of the heat energy is absorbed by the water sample.

8. Consider the two hydrocarbons shown on the right. These molecules are considered as a fuel in a town high in the mountains where the temperature can drop to below zero for several months of the year. Which molecule is best suited as a fuel under such conditions? Explain.



9. Below is information regarding cloud point and flash point. Answer the questions in the box below.

Cold weather can affect the performance of diesel fuels, such as petrodiesel and biodiesel. As the temperature is lowered, a point is reached at which the larger molecules in the fuel begin to solidify out of the liquid. When this point is reached, the fuel starts to become cloudy. The temperature at which this point is reached is known as the **cloud point**.

Flash point is the lowest temperature at which a liquid fuel will form a vapour above its surface that will ignite, on exposure to an open flame.

Consider the following four fuels, *propane*, *propan-1-ol*, *methyl hexanoate* and *heptane*

a. Identify the intermolecular bonding that exists in each.

- i. *propane* _____
- ii. *propan-1-ol* _____
- iii. *methyl hexanoate* _____
- iv. *Heptane* _____

b. Place the following four molecules in the appropriate box under each category.

Low	Strength of intermolecular forces of attraction				High
Low	Boiling point				High
Low	Flash point				High
Low	Cloud point				High

c. Which fuel is likely to cause an obstruction in the fuel lines during cold weather? Explain

d. Which fuel is more likely to produce explosive vapours in a closed space? Explain.

10. Climate change has been identified as a threat to the environment. Fossil fuels are recognised as a significant contributor to the rise in carbon dioxide levels in the atmosphere. The replacement of fossil fuels as an energy source represents a challenge and has been the focus of research for a number of years. However, there are different opinions/views about the suitability of using a biofuel, such as biodiesel, as a replacement for fossil fuels.

Using the chemistry that you studied, discuss the **carbon neutrality** and the **sustainability** of using biodiesel as a fuel for transport.

a. Carbon neutrality.

i. For

ii. Against

b. Sustainability

i. For

ii. Against