RoshChem

VCE Chemistry

Fuels

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What are fuels?

Fuels are the substances that have chemical energy stored within them and they can release energy when burnt.

Eg: wood, coal, natural gas, LPG, ethanol, petrol

Sustainable energy

The efficient provision of energy that can full fills the needs of the present without compromising the energy needs of future generations. All renewable energy sources such as solar, wind, hydro power are sustainable as they are available in huge amounts.

Renewable energy resources

Resources are those that are continually being replaced a by natural processes at a shorter period of time.

Eg: solar power, biochemical fuels

Non renewable energy resources

Resources that are used at a faster rate than they can be replaced

Eg: fossil fuels

Fossil Fuels

They are made from primitive plants and animals. Formation of fossil fuels take millions of years and plant and animal material undergo many changes during this period. The energy that we get by combustion of fossil fuels comes from the energy that plants absorbed from the sun millions of years ago.

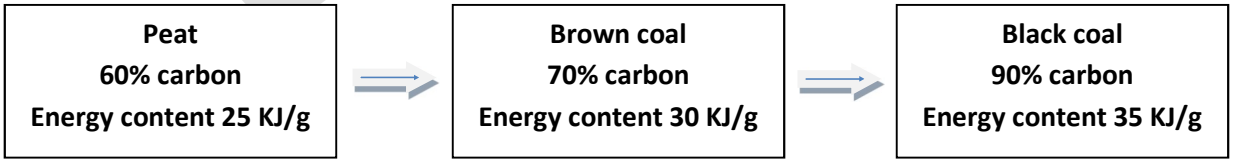
Eg: Coal, crude oil (petroleum), petroleum gas, coal seam gas

1. Coal

Coal is composed mainly of carbon together with other elements such as hydrogen, nitrogen, sulfur.

As wood is converted into peat, brown coal and then to black coal, the carbon content increases and the proportion of hydrogen and oxygen decreases. The amount of water also decreases.

When coal is burnt, some amount of energy is used to vaporise water. This decreases the energy content of coal with high percentage of water. Therefore, black coal with less amount of water can release more energy than peat or brown coal.



2. Crude oil

Crude oil is a naturally occurring flammable liquid consisting of a complex mixture of hydrocarbons (mostly alkanes) of various molecular weights and other liquid organic compounds. Crude oil itself is of no use as a fuel, but many of the compounds in it are. Crude oil is separated into fractions with a process called fractional

distillation. Fractions such as Petrol, deiessel, kerosene, liquefied petroleum gas (LPG) are used as fuels while some fractions can be use as raw materials for plastics and pharmaceuticals.

3. Natural gas

Natural gas is mainly methane (CH_4) with small amounts of other hydrocarbons such as ethane and propane.

Natural gas can be found trapped between layers of rocks and also as a component of petroleum deposits.

Natural gas is accessed by drilling a hole to the required depths of the rocks. This causes the natural gas to flow to the surface.

a. Coal seam gas or CSG.

Natural gas can be found in coal deposits where it is bonded to the surface of the coal. Coal seams usually contain water and it is the pressure of the water that keeps the gas adsorbed to the coal surface. Natural gas found this way is known as coal seam gas.

b. Shale gas

Natural gas can be found trapped in shale rock, where it is referred to as **shale gas**.

Fracking

This is a process used to extract natural gas from coal or shale rocks. First a well is created by drilling a hole into the deposit. Water, sand and other chemicals are then pumped into the well under high pressure. This high pressure fractures the rock and creates fissures where the gas can flow.

4. Liquefied petroleum gas

Propane and butane is present in natural gas and these can be separated from natural gas by fractional distillation. Propane and butane can liquefy under high pressures and can be stored in gas cylinders as liquids. This is known as liquefied petroleum gas (LPG) and is used as a fuel in cars and in home gas cylinders.

Disadvantages of using fossil fuels

- Pollution
- Global worming which can increase the sea levels and changing the weather patterns
- Crude oil reserves are limited

Biochemical fuels:

(biofuels) are fuels derived from plant material. These fuels release carbon dioxide during combustion. However they are made by plants and plants absorb carbon dioxide during photosynthesis. So the net carbon dioxide emission is less.

Eg: bioethanol, biodiesel and biogas

1. **Bioethanol**

This is produced by **fermentation** of glucose in the presence of yeast.

$$C_6H_{12}O_6(aq) \xrightarrow{yeast} 2C_2H_5OH(aq) + 2CO_2(g)$$

Why bioethanol contributes to less carbon dioxide emmision?

This is because the carbon dioxide release during their combustion is absorbed by the plants during photosynthesis. As shown in the equations below, fermentation releases 2 moles of CO_2 and combustion of bioethanol releases 4 moles of CO_2 (2 moles of CO_2 from 1 mole of bioethanol). These 6 moles of CO_2 are absorbed by plants during photosynthesis.

Photosynthesis

$$6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(s) + 6O_2(g)$$

Fermentation

$$C_6H_{12}O_6(aq) \xrightarrow{yeast} 2C_2H_5OH(aq) + 2CO_2(g)$$

Combustion

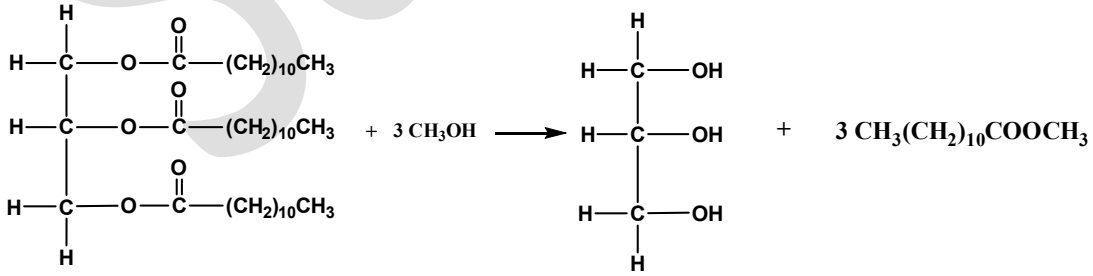
$$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$$

2. Biodiesel

Biodiesel is a mix of esters produced by chemical reaction between vegetable oil and an alcohol such as methanol.

The triglyceride (fat/oil) is **hydrolysed** by warming it with methanol and potassium hydroxide/sodium hydroxide solution (catalyst). The triglyceride breaks down into three '**fatty acid**' molecules and a molecule of glycerol. Then the fatty acid reacts with methanol to produce methyl ester of the fatty acid which is known as biodiesel.

Formation of biodiesel



3. **Biogas**

Consists mainly of **carbon dioxide and methane** and is generated when organic materials decays

anaerobically (in the absence of oxygen). This also contains other gases such as nitrogen, hydrogen sulphide and hydrogen in small amounts. It can be used for heating to power homes and farms.

Comparison of fossil fuels and biofuels

a. Energy content of different fuels

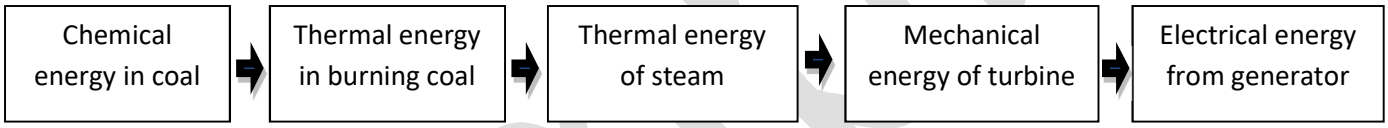
The chemical energy present in a substance is called its energy content. By burning fuels chemical energy in them can transform to another form of energy such as heat energy, electrical energy, mechanical energy, ect...

Energy content is measured in KJ/g, this is the amount of energy released when 1g of fuel burnt.

The **energy efficiency** of a fuel is what percentage of chemical energy in a fuel transformed to the required form of energy. For example solar cells are about 18% efficient. This means only 18% of the energy coming from the sun on to the solar panel is converted to electrical energy. The rest is converted to other forms of energy such as heat energy.

i. Coal

Coal is used to produce electricity in coal fired power stations. Following energy transformations occur when coal is generating electricity.



Energy is lost in each energy transformation and the overall efficiency of coal fired power stations is 30-40%.

Burning coal $C(s)+)O_2(g) \rightarrow CO_2(g)$

Above reaction released about 32 KJ of energy when 1g of coal burned. So the energy content of coal is 32 KJ/g.

ii. Natural gas

Natural gas is used to generate electricity in gas fired power stations. The energy efficiency in gas fired power stations is about 40%.

Burning natural gas $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$

The energy content of methane is about 56 KJ/g.

iii. petrol

Petrol is a fraction obtain from crude oil and contain mixture of hydrocarbons including octane. This is used as a vehicle fuel. The efficiency of petrol engine is about 25%.

Burning of petrol $2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(l)$

The energy content of petrol is about 48 KJ/g.

iv. Liquefied petroleum gas (LPG)

This can also be used in vehicles. This is also used in home gas cylinders for cooking.

Burning of propane (major component of LPG) $2C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$

The energy content of LPG is about 51 KJ/g.

v. Biogas

Electricity generation from bio gas is carried out in small scale in sites where the biogas is produced.

Burning biogas $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$

The energy content of biogas is less than that of natural gas because methane content in biogas is lower.

vi. Bioethanol

Bioethanol is used in vehicles blended with petrol. E10 petrol is the petrol containing 10% bioethanol.

Burning bioethanol $C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$

The energy content of bioethanol is about 30 KJ/g. The lower energy content of bioethanol is due to the presence of oxygen atom in ethanol. Because of this the carbon atom in ethanol molecule is in a partly oxidized state.

b. Environmental impact from combustion of fuels

All fuels release carbon dioxide during combustion. Carbon dioxide is a green house gas and increased levels of carbon dioxide can cause global warming and climate changes. The mass of carbon dioxide released per MJ of energy produced by different fuels in given below.

Fuel	Mass of carbon dioxide (g) released per MJ of energy produced
Coal	93
Natural gas	56
LPG	65
Petrol	73
Bioethanol	72

Even though bioethanol releases CO_2 during combustion,CO_2 is also absorb by plants during photosynthesis. Therefore use of this fuel should lead to net CO_2 reduction. However, we cannot consider bioethanol as **carbon neutral**. Because during the period of growing plants, transporting and refining of the fuel uses energy and CO_2 is released.

Other emissions from burning fuels are SO_2, NO_2, O_3, particulates (eg: ash), CO. Petrol can produce more CO and particulates than other fuels. This is because its combustion is less complete due to the larger size of the molecule.

SO_2 and NO_2 are pollutants which contributes to the acid rain.

b. Environmental impact of sourcing the fuels

Fuel	Source	Impact on environment
Biogas	Sewage farms and rubbish tips	Methane is 21 times effective as a green house gas than carbon dioxide. So it is better to burn methane present in biogas to release carbon dioxide than releasing methane to atmosphere. Therefore collection of biogas can minimize the emissions.
Crude oil	Oil rigs	They have a low impact on the environment. However, if a spill or explosion occurs significant issues can arise.
Coal	Coal mines	Open cut coal mines are damaging the local environment. Accidents such as fire can cause adverse health effects in people living in areas close to the mine.
Bioethanol	Crops such as sugar cane and wheat	Growing crops need energy, water and fertilizers. Farming can cause land degradation and erosion. Cost of some food such as corn can increase because they are also used to make biofuels.

Advantages and disadvantages of different types of fuels

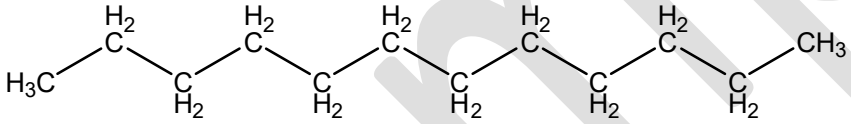
Fuel	Advantage	Disadvantage
Coal	Large Australian reserves Easily mined Relatively high energy content	Non renewable High amounts of emissions
Natural gas	High energy efficiency than coal Relatively high energy content Easily transported through pipes	Non renewable Limited Australian reserves Causes pollution (less than coal and crude oil)
Crude oil (Eg: petrol)	Easily transported High energy content	Non-renewable Causes pollution (less than coal) Limited reserves
Biogas	Renewable Reduces waste disposal Low cost as it is made from waste	Low energy content Supply of waste is limited

	CO_2 absorbed by plants Reduces methane emission	
LPG	Relatively high energy content Low cost	Non renewable Cause pollution (less than petrol)
Bioethanol	Renewable CO_2 absorbed by plants Fewer particulates emission than petrol	Lower energy content Limited supply of raw materials Growing crops can cause land degradation and erosion. Cost of some food such as corn can increase

Comparison of petro diesel and biodiesel

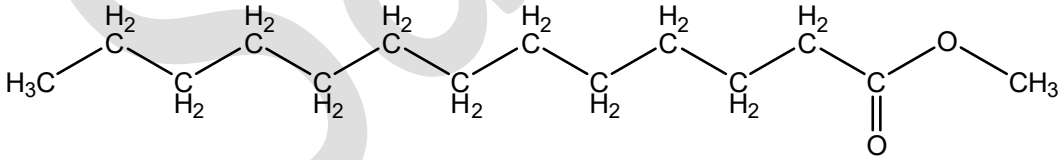
Structures of petro diesel and biodiesel

Petrodiesel is one of the fractions obtained from crude oil and consist of alkanes (C_{10}-C_{15}) and aromatic compounds.
Eg: dodecane



The forces between these non polar molecules are weak dispersion forces.

Biodiesel consist of esters of fatty acids as shown below.



The forces between these molecules are diole-dipole interactions.

Property	**Fuel with the greatest value**	**Reason**

Viscosity (Measure of fluids resistance to flow)	Biodiesel	Dipole-dipole interactions found in biodiesel are stronger than the dispersion forces found petrodiesel. So molecules of biodiesel are attracted closely.
Cloud point (Lowest temperature at which crystals appear)	Biodiesel	Dipole-dipole interactions found in biodiesel are stronger than the dispersion forces found petrodiesel. So molecules of biodiesel are attracted closely. So when the temperature drops molecules come closer and solidify. However for petrodiesel much lower temperatures are required for crystallisation.
Density (Mass per given volume)	Biodiesel	Dipole-dipole interactions found in biodiesel are stronger than the dispersion forces found petrodiesel. So molecules of biodiesel are attracted closely and takes a lower volume.
Hygroscopicity (tendency to absorb water)	Biodiesel	Presence of polar groups in biodiesel can attract polar water molecules

Combustion and emissions in petro diesel and biodiesel

Petrodiesel

$$2C_{12}H_{26}(l) + 37O_2(g) \rightarrow 24CO_2(g) + 26H_2O(g)$$

Biodiesel

$$2C_{17}H_{34}O_2(l) + 49O_2(g) \rightarrow 34CO_2(g) + 34H_2O(g)$$

Both forms of fuel relese carbon dioxide during combustion. However, use of biodiesel reduces the net impact of carbon dioxide because as it is a biofuel and growing plants absorb carbon dioxide.

Both forms of diesel can also emit pollutants such as nitrogen oxides, carbon monoxide and unburnt hydrocarbons. Petro diesel also emits sulfur dioxide. However, biodiesel does not release sulfur dioxide always. This depends on the origin of the fuel. If it is made by an oil containing sulfur such as canola oil it will release sulfur dioxide.