Coal

Coal is a rock formed from ancient plants that have been decomposed and heated under pressure underground. This process is called metamorphism. Coal varies widely in its composition, as it is a complicated mixture of hydrocarbons and carbohydrates, with small amounts of nitrogen, sulphur, water and minerals. It must be mined from the ground, either from deep mines (which creates spoil heaps), or by open-cast surface mining (which devastates the landscape). There are enough reserves for 200–250 years at the present rate of consumption.

Coal burns in air with a yellow smoky flame, leaving ash behind. The energy content of coal depends upon its type. The heat of combustion of brown coal or lignite is about 25 kJ/g, but the heat of combustion of bituminous coal (used in industry) and anthracite (used in homes) is about 32 kJ/g. When coal burns, it produces water and carbon dioxide. It also produces harmful sulphur dioxide, carbon monoxide, oxides of nitrogen (known as NO_x), hydrocarbons and soot.

Coal cannot be used in cars and aircraft, but it can be converted into gaseous or liquid fuel. This fuel can be used to power diesel engines, and German aircraft flew using it in the Second World War. The "liquefaction plants" needed to make it produce carcinogenic (cancer-causing) hydrocarbons.

Natural Gas

Natural gas is nearly always found associated with oil (see the Oil sheet). It consists almost entirely of methane. For example, the Frigg gas field in the North Sea produces gas which is 95% methane and 4% ethane, with only traces of other hydrocarbons. It has no smell and does not contain carbon monoxide, so it is not poisonous. However, it can asphyxiate (suffocate), and so an artificial smell is added before it is distributed so that leaks can be detected.

Natural gas ignites easily, and will cause explosions if sufficiently large quantities escape. It is a relatively clean fuel, and produces only carbon dioxide and water when it burns completely. Its heat of combustion is –890.3 kJ/mol, equivalent to an energy content of 55.6 kJ/g. There are sufficient reserves of natural gas for only 20 years at the present rate of consumption. However, rotting rubbish in landfill sites generates it, and some companies are now pumping it out for sale. It also can be produced by deliberate production of "biogas", which is about 50% methane. Biogas is produced from decaying organic matter in biogas digesters, and is particularly popular in India and China.

Natural gas is not very portable, and is usually delivered to the customer through underground pipes. It can be liquefied to form NGL (natural gas liquid). This is different from LPG (liquid petroleum gas), which is a liquefied by-product of oil refineries). NGL (and LPG) can be used to power vehicles, and some experimental aircraft.

Ethanol

Ethanol is a member of a large class of compounds called alcohols. It is a colourless liquid (boiling point 78ºC) which will mix with water. It can be made by reacting ethene (a product of crude oil) and water at 300ºC and high pressure with phosphoric acid as a catalyst. It can also be produced from carbohydrates, such as sugar, by fermentation using yeast. This is the method of choice for producing alcoholic drinks.

Ethanol burns very easily with a pale yellow flame to form carbon dioxide and water. Its heat of combustion is –1367.3 kJ/mol, which is equivalent to an energy content of 29.6 kJ/g. Alcohol has been used as a fuel for a long time, for example in spirit lamps and as methylated spirits. It is relatively safe and easy to transport, as it is a liquid. Petrol can be blended with up to 20% ethanol for use in an ordinary car engine without adjustment. Recently, ethanol has been produced by fermentation in industrial quantities to power vehicles. Brazil, in its Proalcohol programme, produces 3,200 million litres of ethanol ("Gasohol") per year from crops such as sugar cane, sorghum and cassava. Brazil has also designed and manufactured cars to run on pure ethanol. The fuel is more expensive than petrol, but effectively is a renewable energy source and does not have to be imported. However, it is doubtful that hungry people see this as a benefit.

Hydrogen

Hydrogen is the most abundant element in the Universe, but on Earth free hydrogen is less than one part per million of the atmosphere. However, it is abundant on Earth in the form of water, which is an almost inexhaustible supply of the element.

Several million tonnes of hydrogen are manufactured in the world each year, including 500,000 tonnes per year in the U.K. It can be made by the electrolysis of brine (sodium chloride solution), but this process is expensive and inefficient. Other methods include passing steam over white-hot coke (the Bosch or Water Gas Process), and the oxidation of natural gas using a catalyst. It is also found as a by-product in oil refineries.

When hydrogen burns completely, the only product is water. The heat of combustion for hydrogen is –285.8 kJ/mol, which is equivalent to an energy content of 142.9 kJ/g. Hydrogen is very easy to ignite, and caused dreadful accidents (such as the famous "Hindenburg" disaster) when used to lift airships in the days before helium became plentiful. Hydrogen is stored in gas cylinders or liquid containers, allowing it to be used in some domestic or industrial situations where natural gas might be used. It would be difficult to use in cars or aircraft in this way, but large quantities can be absorbed by expensive metals such as palladium, and released later by warming.

Crude Oil

Crude oil is formed from ancient animals, buried under sedimentary rocks and decomposed under high pressure and temperature. It is held in between rock grains in porous oil-bearing rocks, usually deep underground or under the sea. It is found in many parts of the world, including the U.S.A., Nigeria, Russia, the countries around the Arabian Gulf, and under the North Sea. Sometimes, for example in Canada, it is found as tar mixed with sand or as oil mixed with shale. At the present rate of consumption, there is enough oil to last 30–40 years.

Crude oil is a complex mix of hydrocarbons, forming a viscous black liquid that does not burn very easily. As a result, it is usually separated into a number of "fractions" by fractional distillation. These fractions are not pure compounds, but are mixtures of different substances that have varying energy contents. For example, the heat of combustion of octane (found in petrol) is –5470.2 kJ/mol, equivalent to an energy content of 47.9 kJ/g. Some fractions burn more easily than others, but complete combustion will produce carbon dioxide and water. However, most fractions will also produce sulphur dioxide, carbon monoxide, oxides of nitrogen (NO_x) hydrocarbons and soot. Large molecules (which do not burn easily) can be converted into more useful small molecules (which burn more easily) by a process called "cracking".

Crude oil is easy to transport, particularly in bulk by sea, but the environmental impact of any accidents is enormous, as it is toxic and extremely difficult to remove. Oil products, such as diesel, kerosene and petrol, are well-suited to use in vehicles and aircraft, but they can burn easily after accidents. At the moment, the price of oil products is controlled by political pressure, but will rise rapidly as supplies dwindle. Crude oil has an important alternative use in the production of plastics.

Fuels – The Good, The Bad and The Ugly

Many substances burn and release energy, but do they make good fuels? What are the qualities of a good fuel? Some questions you could ask about potential fuels include:

- Does it ignite easily?
- Does it keep burning once alight?
- Does it burn rapidly or steadily?
- Does it give off dangerous fumes?
- Is much smoke formed?
- How much residue is left after burning?
- Does it release a lot of energy?
- Is it expensive?
- Is it plentiful?
- Is it naturally occurring or man-made?
- Is it safe, and easy to store and transport?
- Is there a better use for it than as a fuel?

Your task today

There are copies of five information sheets covering coal, crude oil, natural gas, ethanol and hydrogen. Decide for yourself the most important questions to answer, and then use the information sheets to answer them for each fuel. Write down your findings in your book (a table is probably the best way to compare the fuels). Is there a "best fuel"? Give reasons for your answer.

