Fuels, Alkanes and Alkenes: Further Reading

The search for fuels to replace oil-based products is gathering momentum not only because the Earth's reserves will run out (perhaps during this century, if current consumption is maintained) but because of the need to limit air pollution. Many countries wish to reduce their dependence on oil-producing nations and, ideally, also reduce costs. Alternatives that fulfil these objectives are not easy to find, particularly because huge quantities of fuel are required.

Fuels often require specific chemical properties. The fuel in cars has to be volatile enough to allow the engine to start in cold conditions, but not so volatile as to be dangerous in hot conditions. It should burn cleanly and vigorously during acceleration and run smoothly when cruising. Indeed, the isomerisation and reforming processes in the oil industry provide mixtures of components that optimise these properties.

Alternatives that meet some of the required objectives include ethanol, methanol, biodiesel, liquefied petroleum gas (LPG) and hydrogen. There are no easy answers and research is dedicated to establishing a way forward.

In Brazil, ethanol derived from sugar cane is widely used as a fuel. Ethanol can also be made from corn. It is a promising alternative, in that it is carbon neutral. However, even if all corn production were used for this purpose, the amount of ethanol produced would fall short of current demand. Other crops and organic waste might be a partial answer and a number of different lines of research are being followed. In particular, cellulose-based materials such as grasses have been utilised, which has succeeded in reducing production costs.

Another potential fuel is methanol, which can be obtained from coal in a two-stage process that requires suitable catalysts:

$$\mathbf{C(s) + H_2O(g) \rightarrow CO(g) + H_2(g)}$$
$$\mathbf{CO(g) + 2H_2(g) \rightarrow CH_3OH(g)}$$

This is not ideal as coal is a non-renewable fossil fuel and there are pollution problems associated with its use. It contains sulphur, which is oxidised to sulphur dioxide, although this could be removed by absorption into an alkali. Coal has an empirical formula of around $C_{240}H_{90}O_4S$, though this is variable.

It may be better to use carbon dioxide as the starting material for methanol production:

$$CO_2(g) + 3H_2(g) \rightarrow CH_3OH(g)$$

This has the advantage of using up unwanted carbon dioxide produced by industrial processes - for example, the manufacture of lime. The hydrogen gas could be generated by the electrolysis of water, but this process requires energy that, on a large scale, could be provided only by nuclear power. However, methanol is in many ways an ideal fuel. Current car engines would not need significant adaptation. Like ethanol, it has the disadvantage of low volatility, which means that cold-starting the engine is problematic. However, used in combination with 15% petrol, methanol has been shown to be an effective fuel.

Biodiesel made from soybean oil, waste cooking oil or rapeseed oil is a potentially cheap fuel. When burned, it produces less carbon monoxide and unburned particles than petrol but releases more nitrogen oxides. This is a concern, because not only are nitrogen oxides poisonous, they are also components of chemical smog and, in the upper atmosphere, attack the ozone layer.

In terms of reducing pollution, hydrogen is the ideal fuel because its combustion product is water. At present, much hydrogen is made from natural gas, but it can also be obtained from the electrolysis of water, which requires a large energy input. It is important to consider the downside of this, before hailing hydrogen as the best way forward. There is a further problem in that using hydrogen as a fuel increases the likelihood of more nitrogen oxide emissions because hydrogen burns at a higher temperature.

LPG is efficient, but its source is mainly oil deposits and underground reserves. Therefore, it may not be a long-term solution to the supply of fuel. LPG does have the advantage of producing smaller quantities of polluting gases than petrol does.

There is not a single solution to the future need for fuels; a mixture of technologies is likely to be used. Hybrid vehicles (partly powered by electricity) are already available and the use of fuel cells will develop rapidly in the near future.

A* Questions

The action of the bacterium *Clostridium acetobutylicum* on biomass, such as sugar beet, wheat or straw, is used to produce compound X, which is a fuel. The fuel, X, can produce almost as much power as petrol, although it cannot be used in a pure form because it exists as a gel below 25.5°C.

A sample of X contained the following elements by mass:
carbon 64.9%, hydrogen 13.5%, oxygen 2I .6%.

a) Calculate the empirical formula of X.

When X is vaporised, it is found that 0.2 g of X has a volume of 65 cm^3 measured at room temperature and pressure.

b) Calculate the molecular formula of X.

Compound X reacts with concentrated sulphuric acid and a hydrocarbon, Y, is formed that contains the same number of carbon atoms as X.
When bubbled into aqueous bromine, the bromine is decolorised.

c) Compound Y could be one of four isomers.
Draw the displayed formulae of these .

d) Choose one of the isomers and write a balanced equation for its reaction with bromine.

Compound Y reacts with hydrogen to give an unbranched hydrocarbon, Z.

e) Give the conditions for the reaction of compound Y with hydrogen.
f) Name hydrocarbon Z.

When compound Y reacts with steam, two products are obtained, one of which is X.

g) Give the structural formulae of the two products.
h) The functional group of X is at the end of its carbon chain.
Give the name of compound X.