In context

Subject area: Organic chemistry | **Level: 14–16 years (Higher)**

Topic: Hydrocarbons | **Source: rsc.li/34Fv93j**

1. The methane rocket

A mixture of methane and oxygen in the proportion of 1 : 2 (by volume) can be exploded in a plastic bottle.

This experiment can be watched at https://youtu.be/xDlGSkTbh2A.

In this experiment, methane reacts violently with oxygen to form two products.

Source: Royal Society of Chemistry

a) Name the two products made in this reaction?

Answer: *Carbon dioxide and water.*

b) Complete the symbol equation for the reaction:

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

c) Using your answer to part b), explain why the proportion of methane to oxygen must be 1 : 2.

Answer: *The stoichiometric numbers in the symbol equation are in the ratio of 1 : 2 for methane to oxygen, and this is also the same as the ratio in which the volumes react.*

d) The bottle has a volume of 2.00 dm^3.

Calculate the volume of methane and oxygen in the bottle, in cm^3. Show your working. Give your answers to 4 significant figures.

Answer: *The fraction due to methane is $\frac{1}{3}$ and oxygen is $\frac{2}{3}$.*
Unit conversion: 2.00 dm^3 = 2000 cm^3.
So volume of methane = $\frac{1}{3}$ × 2000 = 666.6… cm^3 = 666.7 cm^3 (to 4 significant figures).
Volume of oxygen = 2000 – 666.6… = 1333.3… cm^3 = 1333 cm^3 (to 4 significant figures).

e) Explain why the bottle moves when the gases are ignited.

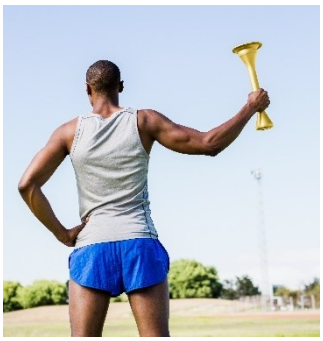
Answer: *Methane reacts exothermically with oxygen, and also reacts very quickly (when the volume ratio is 1 : 2).*
Hot gases are produced that expand rapidly and exit the nozzle of the bottle.
This forces the bottle in the opposite direction.

f) Methane is a saturated hydrocarbon.

Explain what 'saturated' means.

Answer: *It is only made of single bonds (no double bonds to mention in this particular case).*

2. The torch used to start the modern Olympic Games uses a mixture of propane and butane.


Source: Envato Elements

When propane and butane burn in air, they produce heat energy, and a flame.

a) Propane and butane are chemical compounds.

Name the two elements that make these compounds.

Answer: *Hydrogen and carbon.*

b) State the name of the compounds that contain the elements in part a).

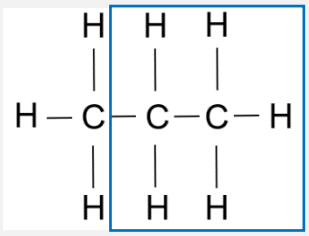
Answer: *Hydrocarbons.*

c) To which homologous series do propane and butane belong?

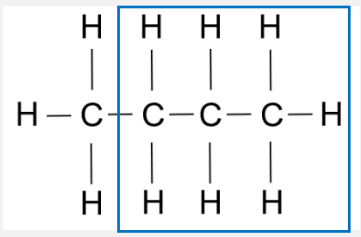
Answer: *The alkanes.*

d) Below are the incomplete molecular structures for propane and butane.

Complete these structures.



Propane



Butane

e) Using your answers to part d), explain what is meant when these substances are described as 'saturated'.

Answer: *Hydrocarbons containing carbon single bonds only.*

f) Complete the symbol equations to show what happens when these gases burn in air:

Propane: $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

Butane: $C_4H_{10} + \frac{13}{2}O_2 \rightarrow 4CO_2 + 5H_2O$

The ratio in which propane and butane are mixed together as a fuel in the torch (by volume) is 2 : 1.

g) What fraction of the fuel is butane?

Answer: $\frac{1}{3}$

h) An Olympic torch contains 37.8 cm^3 of fuel.

Calculate the volume of butane in the fuel.
Show your working.

Answer: $\frac{1}{3} \times 37.8 = 12.6\ cm^3$

i) In a different Olympic torch, the same fuel was used as in the previous torch.

The volume of propane in the mixture was 9.80 cm^3.
Calculate the volume of the fuel.
Show your working.

Answer: $\frac{2}{3}$ *of the volume of the fuel is due to propane.*
So $\frac{2}{3} \times$ *total volume = 9.80,*
so total volume = $\frac{3}{2} \times 9.80 = 14.7\ cm^3$.