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.

   a) **Name the two products made in this reaction?**

   \[ \text{Answer: Carbon dioxide and water.} \]

   b) **Complete the symbol equation for the reaction:**

   \[ \text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} \]

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

   \[ \text{Answer: The stoichiometric numbers in the symbol equation are in the ratio of 1 : 2 for methane to oxygen, and this is also the same as the ratio in which the volumes react.} \]
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 = \(\frac{1}{3} \times 2000 = 666.6\ldots \text{ cm}^3 = 666.7 \text{ cm}^3\) (to 4 significant figures).

Volume of oxygen = 2000 – 666.6\ldots \text{ cm}^3 = 1333.3\ldots \text{ cm}^3 = 1333 \text{ 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.**

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.

<table>
<thead>
<tr>
<th>Propane</th>
<th>Butane</th>
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<tr>
<td><img src="image" alt="Propane Structure" /></td>
<td><img src="image" alt="Butane Structure" /></td>
</tr>
</tbody>
</table>

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: $\text{C}_3\text{H}_8 + 5\text{O}_2 \rightarrow 3\text{CO}_2 + 4\text{H}_2\text{O}$

Butane: $\text{C}_4\text{H}_{10} + \frac{13}{2}\text{O}_2 \rightarrow 4\text{CO}_2 + 5\text{H}_2\text{O}$

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 $37.8 \text{ cm}^3$ of fuel.

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

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

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

The volume of propane in the mixture was $9.80 \text{ cm}^3$.
Calculate the volume of the fuel.
Show your working.

**Answer:** $\frac{2}{3}$ of the volume of the fuel is due to propane.

So $\frac{2}{3} \times \text{total volume} = 9.80$, 
so total volume $= \frac{3}{2} \times 9.80 = 14.7 \text{ cm}^3$. 