The ‘whoosh’ bottle experiment

This experiment shows the power of the reaction that can take place when an alcohol burns.

Here is a method used by a teacher to show this experiment:

- Use an empty polycarbonate water bottle of volume 20 dm$^3$.
- Add approximately 10 cm$^3$ of methanol into the bottle.
- Swirl the methanol inside the bottle.
- Then decant the excess methanol from the bottle.
- Place a rubber stopper or bung into the top of the bottle.
- Connect a wooden splint to the end of a metre rule, and light the end of the splint with a match.
- Carefully place the lighted splint (now at arm’s length) above the stopper on the bottle, and remove the stopper with the other hand.
- A spectacular reaction should now take place. Watch the reaction at https://youtu.be/yl89heCsBpQ.

Answer the questions below.

1. Explain why the methanol is swirled within the bottle before it is ignited.
   
   **Answer:** To increase the surface area of the methanol so that it may form a vapour.

2. Define the following terms used in this method:

   a) Decant
   
   **Answer:** To pour off a liquid or to pour from one container to another.

   b) Excess
   
   **Answer:** More than that needed, or left over.

3. State the molecular formula of methanol.
   
   **Answer:** CH$_4$O.
4. Draw the structure of a methanol molecule in which all bonds are shown.

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  H
 /|
 H — C —— O —— H
 | 
 H
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5. In the reaction in the bottle, methanol is burning to form carbon dioxide and water.
   Write a chemical equation to show this reaction.

   Answer: \( \text{CH}_3\text{OH} + \frac{3}{2}\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} \) or \( 2\text{CH}_3\text{OH} + 3\text{O}_2 \rightarrow 2\text{CO}_2 + 4\text{H}_2\text{O} \)

6. Explain why this reaction produces a ‘whoosh’ when it takes place within a bottle.

   Answer: Hot gases form and are forced out of the bottle opening under high pressure.

7. The internal volume of the bottle was 20 dm\(^3\).
   Write this volume in the following units:

   a) cm\(^3\).
   Answer: 20,000 cm\(^3\).

   b) m\(^3\).
   Answer: 0.020 m\(^3\).

8. The mass of methanol vapour remaining in the bottle before ignition was 5.2 g.
   Calculate the concentration of the methanol vapour in:

   a) g / dm\(^3\).
   Answer: \( \frac{5.2 \text{ g}}{20 \text{ dm}^3} = 0.26 \text{ g/dm}^3 \)
b) **mol / dm³**, and writing this answer in standard form.

RAM data: C = 12, H = 1, O = 16.

**Answer:** RFM for methanol = 32

\[
\text{Moles of methanol} = \frac{0.26 \text{ g}}{32} = 8.125 \times 10^{-3} \text{ mol / dm}^3
\]

c) **Calculate the mass of carbon dioxide formed when 5.2 g of methanol vapour is ignited.**

You will need to use your chemical equation from question 5 to help you. Show your working clearly.

**Answer:** \( \text{CH}_3\text{OH} + \frac{3}{2}\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} \)

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\text{Moles of methanol} = \frac{5.2 \text{ g}}{32} = 0.1625 \text{ mol.}
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\text{Moles of carbon dioxide formed} = 0.1625 \text{ mol (1 : 1 ratio from the chemical equation).}
\]
\[
\text{Mass of carbon dioxide} = 0.1625 \times \text{RFM of CO}_2
\]
\[
= 0.1625 \times 44 = 7.15 \text{ g}
\]

9. **After the reaction in a different bottle had taken place, it was allowed to cool.**

A colourless liquid, A, is observed at the base of the bottle.

a) **Name liquid A.**

**Answer:** Water.

b) **If the volume of liquid A was 4.50 cm³, calculate the mass of methanol that was burnt in the bottle.**

Assume that the density of liquid A = 1 g / cm³.

**Answer:** \( \text{CH}_3\text{OH} + \frac{3}{2}\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} \)

As the density of water = 1 g/cm³, the mass of water formed = 4.50 g.

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\text{Moles of water formed} = \frac{4.50 \text{ g}}{18} = 0.25 \text{ mol.}
\]
\[
\text{Moles of methanol used} = \frac{0.25 \text{ mol}}{2} = 0.125 \text{ mol.}
\]
\[
\text{Mass of methanol} = 0.125 \times 32 = 4.0 \text{ g}
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Instructions for this teacher demonstration are available at [rsc.li/30q7C4S](https://rsc.li/30q7C4S).