The candle in the bell-jar

Introduction

In 1990 Stephen Pople wrote an article in the *Education Guardian* describing the hidden dangers of insulation in modern homes. Although energy can be saved by cutting out draughts it is dangerous to seal a room completely. A building needs to have a steady supply of fresh air because the oxygen used up by fires and people has to be replaced. A version of an experiment, known in old textbooks as 'The candle in the bell-jar' was given in the article as a way of showing children how oxygen can be used up in a room that is sealed too tightly.

In the traditional experiment a candle is burnt in a bell-jar over water. The candle burns for a short time and is then extinguished. As the candle burns the water level rises, apparently showing that a fraction of the air is being used up. A reduction in volume of the gas by about one-fifth may be observed and this is sometimes claimed to be a neat 'proof' that air is 20% oxygen.

Stephen Pople claimed that:

the rise in water level shows how much oxygen is used up during combustion

His claim was challenged in a letter:

In the demonstration with the "suffocating candle" the explanation given is that the oxygen is used up and the water rises to take its place. A word equation for this combustion would be: Hydrocarbon in candle wax (solid) and oxygen (gas) becomes carbon dioxide (gas) and hydrogen oxide or water (liquid).

As oxygen is used up then carbon dioxide is produced. The demonstration is puzzling because it does not account for where the carbon dioxide produced has gone. The given explanation encourages children to think of combustion as the using up of oxygen with no thought about the products of combustion. If Stephen Pople tries the demonstration again and carefully observes the water level, he will notice that the water does not start to rise as the beaker seals the floating candle. This suggests that the change in water level may be more to do with the physics of cooling gases than the chemistry of combustion.

This letter was followed by a letter from a second person, a research chemist. He did not accept the explanation in terms of cooling gases and wrote:

There may well be an effect such as he [the author] describes which may contribute to the observed volume change. There is however one fatal flaw in his reasoning for rejecting the chemical explanation, which he dismisses on the grounds that an equal quantity of gaseous carbon dioxide is formed and hence there is no volume change. If we think more carefully on the products of combustion we will see that his word equation is incomplete. Paraffin wax is a solid hydrocarbon with a chain length of 20 – 30 and the molecular structure approximates to CH_2. The chemical equation for the combustion reaction is therefore:

$2CH_2(solid) + 3O_2(gas) \rightarrow 2CO_2(gas) + 2H_2O(liquid)$

In other words, three volumes of oxygen are replaced by two volumes of carbon dioxide, representing an overall reduction in gas volume. I believe the experiment is still a valuable educational aid.

- Find out as much as you can about what is going on when a candle burns in an enclosed space to investigate the claims made above. Try repeating the original experiment and then develop and modify it.

Health & Safety

In planning this activity, you should consider health and safety. Check your plans with your teacher before implementing them.

Keep away from flammable/combustible materials.

Credits

Health & safety checked May 2018

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