



How to Answer Questions on Alkane Combustion and Environmental Pollution

Introduction

The three major examination boards (AQA, EDEXCEL and OCR) all require the same knowledge and understanding of the products of combustion of alkanes and their possible effects on the environment. Whilst the style of the questions may vary their essence is the same. The background knowledge will have been taught as part of the AS course but may also be met in A2 questions. As you revise and prepare this section of your work it is recommended that you also consult Factsheets 143 (Are Biofuels Carbon Neutral?) and 144 (Catalytic Converters) wherein can be found much useful, related material.

Advice: Before You Begin Practising Exam Style Questions.

There is no point in you trying to answer questions if you have not already learned the material. It will be too depressing! You will become more confident in your abilities if you do the learning first. Firstly revise and learn a small topic, then tackle one question at a time. Follow this by going over the correct answer and guidance very carefully. Learn from every error that you make.

Why do students lose marks?

For this topic the most frequent exam errors arise from:

- Not knowing the key material thoroughly enough and hence being confused over *the types of pollution* caused by the various pollutants.
- Incorrect reading of the question.
- Incomplete answering of a question.

Exam Advice: Read the question very carefully. Use a highlighter to go over key words in the question. Assume that all information given is needed. If more than one task is involved, label them "a, b, c" etc then cross out in turn as you complete them. Never use the phrase "harmful to the environment" as this is frowned upon. A more detailed response is expected.

Prior knowledge

To get the most from this Factsheet you need to be confident in the correct use of the following terms: *alkane, pollution / pollutant, complete combustion, incomplete combustion, efficient combustion, catalytic converters, carbon neutral, greenhouse effect, ozone layer pollution, greenhouse gases, global warming, acid rain, toxic / toxicity, non renewable fossil fuels, particulates and contamination.*

You also need to know under what circumstances each of the following products of combustion are formed, equations for their formation and exactly how each can affect the environment: **carbon, "unburnt" hydrocarbons, carbon monoxide, carbon dioxide, sulfur dioxide, nitrogen oxides.** A summary of these is given in table 1 at the end of this FactSheet.

Revision Suggestions:

- If you have a text book that is dedicated to your course, use its glossary to make revision cards of key meanings and definitions like those listed here in "prior knowledge".
- Go to the web site of your exam board and download the specification as a pdf file. Open the file and using the "search" facility type in each of the key terms listed, one at a time. You will find where and how they fit into your course. Some exam boards include useful explanations of the terms.

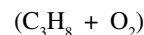
Example Question 1.

The alkane propane is used as a fuel. Write an equation for its complete combustion. (1 mark)

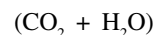
Example Question 1– Answer and Guidance

This question will be seen many times over, using different alkanes. The approach is the same. Follow this example and then practice for others such as methane, butane, hexane, and heptane.

Left hand side - Write the formulae of the alkane and oxygen.



Right hand side - Write the formulae of the products of complete combustion of a hydrocarbon – carbon dioxide and water.



Count the number of carbons in the alkane. This gives the number of moles of carbon dioxide molecules formed. (3 CO₂)

Count the number of hydrogens in the alkane. Divide this by two. This gives the number of moles of water molecules formed. (4H₂O)

Count the number of oxygens on the right hand side. Divide this by two. This gives the number of moles of oxygen molecules needed on the left hand side. (10/2 = 5. 5 O₂)

Hence, the answer is: $\text{C}_3\text{H}_8 + 5\text{O}_2 \rightarrow 3\text{CO}_2 + 4\text{H}_2\text{O}$

Example Question 2

One of the pollutants emitted from car exhausts is sulfur dioxide. Explain briefly how it forms and why it is harmful. (2 marks)

Example Question 2 – Answer and Guidance

This question and similar ones depend upon specific knowledge.

There are two tasks:

1. Sulfur dioxide forms due to the combustion of **sulfur impurities** in fuel. (1 mark).
2. Sulfur dioxide is harmful as it is **toxic / forms acid rain /causes breathing problems.** (1 mark).

Example Question 3

State how the sulfur dioxide can be removed from the waste gases produced when propane is burned on a large scale in industry. Suggest a reason why the method you have stated may not be 100% efficient. (2 marks)

Example Question 3 – Answer and Guidance

There are two tasks:

1. How it is removed

Remembering its link to **acid** rain, sulfur dioxide (an oxide of a non metal) is **acidic** so will react with an alkali or a base. You must choose a readily available substance so that it is not expensive.

Ans: **React the sulfur dioxide with CaO / calcium oxide / quicklime / lime.** (1 mark)

2. Reason for less than 100% efficiency

Ans: **All the sulfur dioxide may not react with the CaO / incomplete reaction / may not have time to react.** (1 mark)

Example Question 4

State a condition which may cause carbon to be formed as a product when propane is burned on a large scale in industry. (1 mark)

Example Question 4 – Answer and Guidance

Here it is important to read the question very carefully. The key word is **condition** meaning circumstance or situation.

Ans: **Carbon will be formed if there is insufficient oxygen / a low temperature / poor mixing of propane and air.** (1 mark)

Notice that the answer is **not incomplete combustion**. This does not answer the question as it is not a **condition**.

Table 1

Pollutant found in car exhaust fumes	How each pollutant in the exhaust gases is formed	Environmental problems associated with each product
Nitrogen oxides, NO _x	NO is formed from the reaction of nitrogen and oxygen gas in the air , at the high temperatures and high pressure of the combustion chamber when the air/fuel mixture is sparked and explodes. This provides the activation energy/E _A (sufficient heat / energy) to break the nitrogen to nitrogen bonds. N ₂ + O ₂ → 2NO NO + O ₂ → 2NO ₂	Nitrogen oxides are toxic, dissolving in water droplets to cause respiratory problems and forming acid rain (nitric acid) which can damage plants and animals. 4NO ₂ + O ₂ + 2H ₂ O → 4HNO ₃
Sulfur dioxide	Combustion of sulfur containing impurities in fuel. S + O ₂ → SO ₂	Sulfur dioxide – as for nitrogen oxides. (All fossil fuels contain some sulfur compounds.) Acid rain due to sulfuric acid SO ₂ + H ₂ O + ½O ₂ → H ₂ SO ₄
Carbon monoxide	Partial / incomplete combustion of the fuel. e.g. C ₃ H ₈ + 3 ½ O ₂ → 3CO + 4H ₂ O	Carbon monoxide is toxic . It affects the amount of oxygen that blood can carry . It is particularly serious for people with heart problems.
Carbon	Partial / incomplete combustion of the fuel. e.g. C ₃ H ₈ + 4O ₂ → C + 2CO ₂ + 4H ₂ O	These “particulates” - tiny particles made up of carbon are believed to be harmful to health causing respiratory problems . (They travel into the upper atmosphere where they reflect sunlight back into space causing global dimming .)
Hydrocarbons	Unburnt fuel .	Hydrocarbons harm the lungs, irritate the eyes, and cause respiratory difficulties . (Some hydrocarbons are known to be very toxic and are even capable of causing major health problems such as cancer .)

Carbon dioxide

Notice that this gas, despite being a product of the combustion of alkanes, is not included in the table of pollutants. Why not? Pollution is the contamination of air, water or soil by substances which are **harmful to living organisms**. Hence carbon dioxide is not a pollutant. It is however a **greenhouse gas** and its effects on the environment are linked to **global warming**.

Damage to the Ozone Layer... ..

is not mentioned in the summary table. Why not? None of the products of combustion of alkanes is damaging to the ozone layer. For details of this topic see Factsheet 142 (The Chemistry of the Ozone Layer).

Practice Questions

- The alkane butane is used as a fuel. Write an equation for the complete combustion of one mole of butane. (1 mark)
- More challenging: Write an equation for the complete combustion of the alkane which requires 11 moles of oxygen per mole of alkane for complete combustion. (2 marks).
- Explain how NO is produced in the engine of a motor vehicle and why it is harmful. (3 marks)
- Hydrocarbon fuels obtained from crude oil may contain trace amounts of an impurity. On burning the fuel the impurity produces a toxic gas that can be removed by reacting it with calcium oxide coated onto a mesh.

Suggest the name of the toxic gas and why calcium oxide reacts with it. Why is the calcium oxide coated onto a mesh? (3 marks)

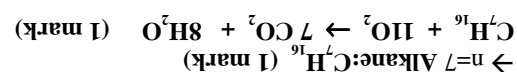
- Explain, using an equation, what is meant by the incomplete combustion of an alkane such as methane in a limited supply of oxygen and outline the potential dangers arising from production of carbon monoxide in the home. (3 marks)

5 This has been set as an "How Science Works" question. It requires the same detail of factual chemistry as any other. The usual products of combustion for alkanes are carbon dioxide and water. However, in a limited supply of oxygen the products are **carbon monoxide and water** (1 mark)
The potential dangers from production of carbon monoxide in the home arise from the fact that carbon monoxide is highly **poisonous** (as it lowers the oxygen-carrying capacity of the blood) (1 mark) and is **odourless** (and colourless) so may go **unnoticed** (1 mark)

4 Again, 3 marks so 3 points are needed. You need to remember that sulfur compounds are impurities in all fossil fuels. (You might like to think about where it comes from.) (The sulphur-based impurity burns to produce) sulfur dioxide/SO₂. (1 mark)
(Calcium oxide reacts with sulfur dioxide because) **calcium oxide is basic / sulfur dioxide is acidic**. (1 mark)
(The examiner is looking for the chemistry idea of neutralisation.) (The calcium oxide is coated onto a mesh) so that it has a **large surface area compared to volume**. (1 mark)

3 Notice that there are 3 key ideas are needed. NO is formed from the **reaction of nitrogen and oxygen gas in the air**, at the **high temperatures** and high pressure of the combustion chamber when the air / fuel mixture is sparked and explodes. (1 mark)
This provides the activation energy / E_a (sufficient heat / energy) to **break** the nitrogen to nitrogen bonds. (1 mark)
Nitrogen oxides form acid rain which can damage plants and animals. (1 mark)

2 Alkane: C_nH_{2n+2} Number moles H₂O (Number moles H)/2 = (2n + 2)/2 = n + 1. This is the number of moles O in H₂O product.
Number moles CO₂: Number moles C = n. Number moles O in CO₂ product = n x 2
Total number moles O in products = (n + 1 + 2n) = 3n + 1
Total number moles O on left hand side = (1 x 2) = 2

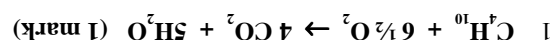


→ n=7 Alkane: C_nH_{2n+2} (1 mark)

$$\rightarrow 3n = 21$$

$$\rightarrow 3n + 1 = 22$$

$$\rightarrow \text{Total number moles O on left hand side} = (1 \times 2) = 2$$



Answers