

Atmospheric pollutants from fuels

4.9.3.1 · Chemistry of the atmosphere · revision notes

Which pollutants are released when fuels burn and how each one forms: carbon dioxide, water vapour, carbon monoxide, soot and other particulates, sulfur dioxide and oxides of nitrogen. Expect 'describe how X is produced' questions, combustion equations, and questions where you predict the products from information about a fuel and how it is burned.

Key facts

- Complete combustion: $C \rightarrow CO_2$, $H \rightarrow H_2O$
- Incomplete combustion (limited oxygen): CO and C (soot), as well as H_2O
- Sulfur in the fuel + oxygen $\rightarrow$ sulfur dioxide: $S + O_2 \rightarrow SO_2$
- Oxides of nitrogen: nitrogen and oxygen from the air react at high temperatures (e.g. in engines)
- Particulates = solid particles (e.g. soot) and unburned hydrocarbons
- $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

Notes

What is in fuels

- Burning fuels is a **major source of the pollutants** in the atmosphere.
- Most fuels, coal included, are made mainly of **carbon** and/or **hydrogen**, and some also contain a little **sulfur**.
- Combustion is an oxidation reaction: the elements in the fuel react with oxygen from the air.

Complete and incomplete combustion

- Complete combustion** (plenty of oxygen): carbon forms **carbon dioxide** and hydrogen forms **water vapour**, e.g. $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$.
- Incomplete combustion** (limited supply of oxygen): some of the carbon forms **carbon monoxide**, CO, and some forms solid **carbon particles (soot)**. Water is still formed.
- Solid particles (such as soot) and **unburned hydrocarbons** can also be released. These form **particulates** in the atmosphere.

Sulfur dioxide and oxides of nitrogen

- Sulfur dioxide**: sulfur in the fuel reacts with oxygen as the fuel burns: $S + O_2 \rightarrow SO_2$.
- Oxides of nitrogen (NO_x)**: at the **high temperatures** in engines, **nitrogen and oxygen from the air** react together. The nitrogen comes from the air, not from petrol or diesel.

How to answer each type of question

Describe how a pollutant is produced

2 to 4 marks

Grade 5

1. Say where the element comes from: the fuel (carbon, sulfur) or the air (nitrogen).
2. Give the condition: limited oxygen for carbon monoxide and soot, high temperature for oxides of nitrogen.
3. Name the product.

Example. Describe how sulfur dioxide and oxides of nitrogen are produced when diesel fuel is burned in a lorry engine.

Model answer. The diesel contains sulfur (1), which reacts with oxygen to form sulfur dioxide (1). Nitrogen and oxygen from the air (1) react at the high temperature inside the engine to form oxides of nitrogen (1).

Don't lose marks

- ✗ Saying oxides of nitrogen come from nitrogen in petrol or diesel. They form from nitrogen and oxygen in the air at high temperatures.
- ✗ Saying sulfur dioxide comes from sulfur in the air. The sulfur is in the fuel.
- ✗ Writing 'carbon' when you mean carbon monoxide, or CO_2 when you mean CO.
- ✗ Forgetting that incomplete combustion still produces water.
- ✗ Saying incomplete combustion is caused by 'not enough fuel'. It is caused by not enough oxygen.

More tips

Memory tricks

- Element $\rightarrow$ product: $\text{C} \rightarrow \text{CO}_2$, $\text{H} \rightarrow \text{H}_2\text{O}$, $\text{S} \rightarrow \text{SO}_2$. Oxides of nitrogen come from the AIR, not the fuel.
- Less oxygen, less oxidised carbon: CO_2 (plenty of oxygen) $\rightarrow$ CO (less) $\rightarrow$ C, soot (even less).
- Hot engine $\rightarrow$ NO_x . Sulfur in the fuel $\rightarrow$ SO_2 .
- Balancing combustion: C, then H, then O, and double everything if you get a half.

Exam technique

- For 'describe how X is produced', give the source (fuel or air) AND the condition (limited oxygen or high temperature).
- In prediction questions, go through the fuel element by element, then check the conditions.
- Write 'a limited supply of oxygen', not 'no oxygen': with no oxygen, nothing burns.
- Use correct formulae in equations: CO, CO_2 , SO_2 , NO_2 , H_2O .

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3

Name the products of complete combustion

A fuel containing carbon and hydrogen forms carbon dioxide and water when it burns in plenty of oxygen.

Grade 4

Name the pollutants released by burning fuels

Carbon dioxide, water vapour, carbon monoxide, sulfur dioxide, oxides of nitrogen and particulates.

Grade 5

Describe how carbon monoxide and soot form

Incomplete combustion in a limited supply of oxygen produces carbon monoxide and carbon particles (soot).

Grade 5

Describe how sulfur dioxide forms

Sulfur in the fuel reacts with oxygen when the fuel burns.

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