Cambridge IGCSE · Chemistry 0620 · Notes

Air quality and climate

Read online at **pastopic.com/cambridge/chemistry-0620/notes/air-quality-and-climate**

Last checked 30 September 2026

Read first: **Formulae and equations**, **Acids, bases and oxides**, **Redox**

What you need to know

By the end of this topic you should be able to:

1. **State what clean, dry air is made of**: about 78% nitrogen, $\mathrm{N_2}$, about 21% oxygen, $\mathrm{O_2}$, and the rest (about 1%) a mixture of noble gases and carbon dioxide, $\mathrm{CO_2}$.
2. **State where each air pollutant comes from**:
   - carbon dioxide: the complete combustion of fuels that contain carbon;
   - carbon monoxide and particulates: the incomplete combustion of fuels that contain carbon;
   - methane: decomposing vegetation, and the waste gases from digestion in animals;
   - oxides of nitrogen: car engines;
   - sulfur dioxide: burning fossil fuels that contain sulfur compounds.
3. **State the harm each pollutant does**:
   - carbon dioxide and methane: higher levels lead to increased global warming, which leads to climate change;
   - carbon monoxide: a toxic gas;
   - particulates: a higher risk of respiratory problems and cancer;
   - oxides of nitrogen: acid rain, photochemical smog and respiratory problems;
   - sulfur dioxide: acid rain.
4. **State and explain ways to reduce these problems**:
   - climate change: planting trees, less livestock farming, using less fossil fuel, and using more hydrogen and renewable energy such as wind and solar;
   - acid rain: catalytic converters in vehicles, low-sulfur fuels, and flue gas desulfurisation with calcium oxide.
5. **Describe photosynthesis** as the reaction between carbon dioxide and water that makes glucose and oxygen, in the presence of chlorophyll, using energy from light.
6. **State the word equation for photosynthesis**: carbon dioxide + water → glucose + oxygen.
7. **Extended only: describe how carbon dioxide and methane cause global warming**, using the absorption, reflection and emission of thermal energy, and the smaller loss of thermal energy to space.
8. **Extended only: explain how oxides of nitrogen form in car engines, and describe how catalytic converters remove them**, for example $2\mathrm{CO} + 2\mathrm{NO} \rightarrow 2\mathrm{CO_2} + \mathrm{N_2}$.

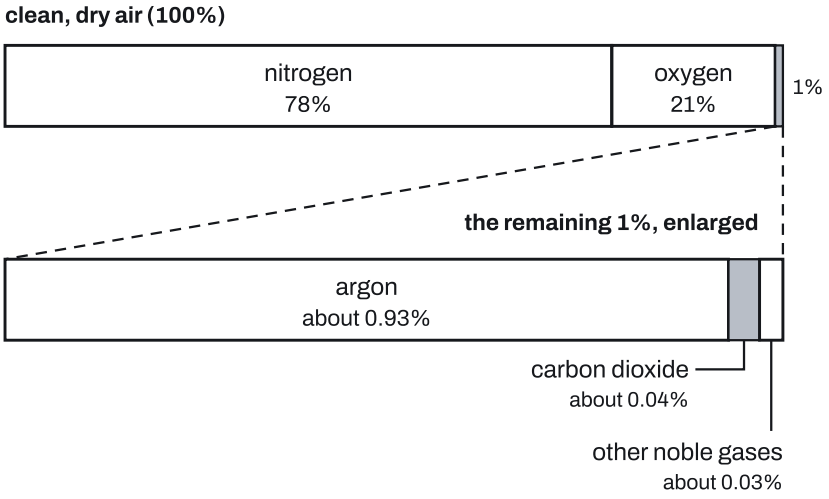
9. **Extended only: state the symbol equation for photosynthesis**: $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$.

Points 1 to 6 are Core; points 7 to 9 are Extended. Pollution of water (nitrates, sewage) is a separate topic, Water and fertilisers.

Understand it

What clean, dry air is made of

Air is a **mixture** of gases, not a compound: its gases are not chemically joined, and the amounts can vary. "Clean" means no pollutants; "dry" means the water vapour is left out, because the amount of water vapour changes from day to day.



- **Nitrogen**, N_2: about **78%**. It is an element.
- **Oxygen**, O_2: about **21%** (roughly one-fifth). It is an element.
- **The remaining 1%**: mostly **argon** (a noble gas and an element), a tiny amount of **carbon dioxide** (a compound, about 0.04%), and traces of the other noble gases.

So nitrogen and oxygen together make up about 99% of clean, dry air. Carbon dioxide is the one compound in clean, dry air, and it is also a greenhouse gas. Carbon monoxide, sulfur dioxide, oxides of nitrogen and particulates are **not** in clean air: they are pollutants.

Because air is a mixture, its gases can be separated by physical means. Nitrogen and oxygen are obtained by the fractional distillation of liquid air.

The percentages also let you work out volumes. In $500\ \text{cm}^3$ of clean, dry air there is about $0.78 \times 500 = 390\ \text{cm}^3$ of nitrogen and $0.21 \times 500 = 105\ \text{cm}^3$ of oxygen. If something removes all the oxygen (such as iron wool rusting, or a hot metal reacting with it), the volume of gas left is about 79% of the start.

Burning fuels: complete and incomplete combustion

Most fuels (coal, petrol, diesel, natural gas, wood) contain carbon. How they burn decides what pollutants they make:

- **Complete combustion** happens in **plenty of oxygen**. The carbon ends up as **carbon dioxide** (and any hydrogen as water). For methane: $\mathrm{CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O}$.
- **Incomplete combustion** happens when the **oxygen (air) supply is limited**. Some carbon ends up as **carbon monoxide**, CO, and some as tiny bits of solid carbon (soot), called **particulates**. Water still forms. For example $\mathrm{2CH_4 + 3O_2 \rightarrow 2CO + 4H_2O}$.

Fuels that contain **sulfur compounds** (many fossil fuels, especially coal) also make **sulfur dioxide** when they burn: the sulfur reacts with oxygen, $\mathrm{S + O_2 \rightarrow SO_2}$.

Hydrogen contains no carbon, so burning it makes only water: no carbon dioxide at all.

The pollutants: sources and effects

Pollutant	Where it comes from	What harm it does
Carbon dioxide, $\mathrm{CO_2}$	Complete combustion of carbon-containing fuels	More of it → increased global warming → climate change
Carbon monoxide, CO	Incomplete combustion of carbon-containing fuels	Toxic gas
Particulates (tiny solid particles, mainly carbon)	Incomplete combustion of carbon-containing fuels	Higher risk of respiratory problems and cancer
Methane, $\mathrm{CH_4}$	Decomposition of vegetation; waste gases from digestion in animals (such as cattle)	More of it → increased global warming → climate change
Oxides of nitrogen, NO and $\mathrm{NO_2}$ (often written $\mathrm{NO_x}$)	Car engines	Acid rain, photochemical smog, respiratory problems
Sulfur dioxide, $\mathrm{SO_2}$	Combustion of fossil fuels that contain sulfur compounds	Acid rain

Some effects need a little explaining:

- **Carbon monoxide is toxic** because it stops the blood carrying oxygen round the body. It has no colour or smell, so people don't notice it.
- **Acid rain.** Sulfur dioxide and oxides of nitrogen are acidic oxides. They dissolve in the water in clouds and make the rain acidic. Acid rain reacts with limestone and marble buildings and statues (chemical weathering, or erosion), corrodes metal, kills trees and makes lakes acidic. Only **sulfur dioxide and oxides of nitrogen** cause acid rain. Carbon dioxide is only very weakly acidic and is not counted as a cause, and carbon monoxide is a neutral oxide.
- **Photochemical smog** is a haze that forms when sunlight acts on oxides of nitrogen (and other exhaust gases) in the air of busy cities.

- **Respiratory problems** means breathing problems, such as asthma and irritated lungs.

Oxides of nitrogen are the only pollutant here with three effects (acid rain, smog and respiratory problems).

Extended only: how oxides of nitrogen form in a car engine. Petrol contains no nitrogen. The nitrogen and the oxygen **both come from the air** drawn into the engine. Nitrogen is very unreactive, but the temperature inside a burning engine is so high that it provides enough energy for nitrogen and oxygen to react:

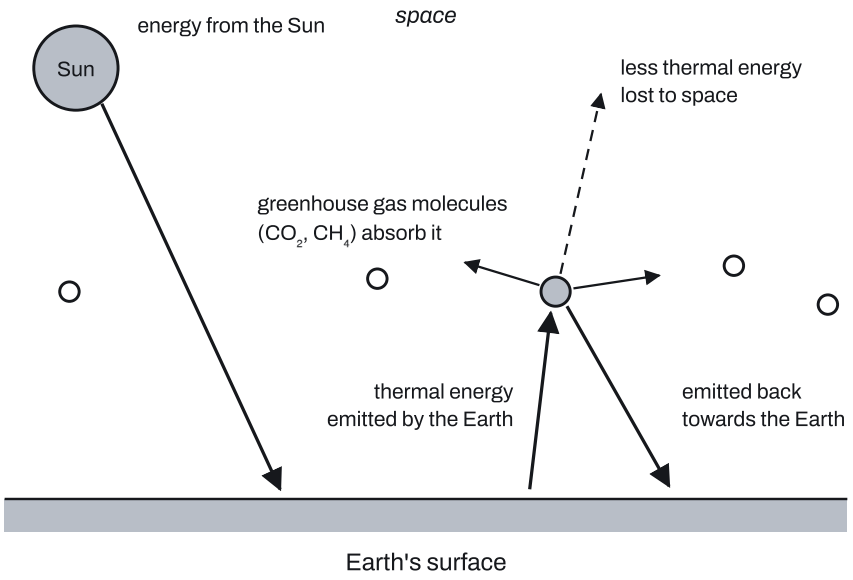
$$\mathrm{N_2 + O_2 \rightarrow 2NO}$$

In the air, nitrogen monoxide then reacts with more oxygen to give nitrogen dioxide, $\mathrm{2NO + O_2 \rightarrow 2NO_2}$.

The greenhouse effect and global warming

Carbon dioxide and methane are **greenhouse gases**. The Earth needs some greenhouse effect (without it the planet would be frozen), but **higher levels** of these gases lead to **increased global warming**, which leads to **climate change** (changing weather patterns, melting ice, rising sea levels).

Extended only: how greenhouse gases cause global warming.



1. Energy from the Sun passes through the atmosphere and warms the Earth's surface.
2. The warm **Earth emits thermal energy** (infrared radiation) back upwards.
3. **Greenhouse gas molecules absorb this thermal energy.** (It is the bonds in the molecules, such as the C–H bonds in methane and the C=O bonds in carbon dioxide, that absorb it.)
4. The molecules then **emit (or reflect) the thermal energy in all directions**, so some of it goes **back towards the Earth** instead of escaping.
5. So **less thermal energy is lost to space**, and the lower atmosphere and the Earth's surface get warmer. More greenhouse gas means more thermal energy kept in, and a higher temperature.

The thermal energy the gases trap comes **from the Earth**, not directly from the Sun. Greenhouse gases do not destroy the ozone layer, and they do not increase the energy lost to space: they reduce it.

Photosynthesis

Green plants make their own food, glucose, by **photosynthesis**. It is a reaction between **carbon dioxide** (from the air) and **water** (from the soil), which needs **chlorophyll** (the green substance in leaves) and **energy from light**. Oxygen is given out.

$$\text{carbon dioxide} + \text{water} \xrightarrow[\text{light}]{\text{chlorophyll}} \text{glucose} + \text{oxygen}$$

Extended only: the symbol equation, balanced:

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

Oxygen is a **product**, not a reactant. Photosynthesis **removes** carbon dioxide from the air and **adds** oxygen. The brighter the light, the faster it goes. It happens at ordinary temperatures, not only when it is hot.

It is the reverse of respiration (glucose + oxygen → carbon dioxide + water): in an exam option, check which way round the equation is.

Carbon dioxide in and out of the air

Many reactions put carbon dioxide into the air, but only one takes it out:

Adds carbon dioxide	Removes carbon dioxide
Combustion of any fuel that contains carbon (petrol, coal, methane, wood)	Photosynthesis
Respiration (in animals and plants)	
Fermentation of glucose (making ethanol)	
Thermal decomposition of carbonates, such as limestone: $CaCO_3 \rightarrow CaO + CO_2$	
Acids reacting with carbonates (including acid rain on limestone buildings)	

Burning hydrogen, cracking hydrocarbons and metals reacting with acids do **not** make carbon dioxide.

Reducing the effects

Each strategy works for a reason, and the syllabus asks you to explain it.

Climate change (too much carbon dioxide and methane):

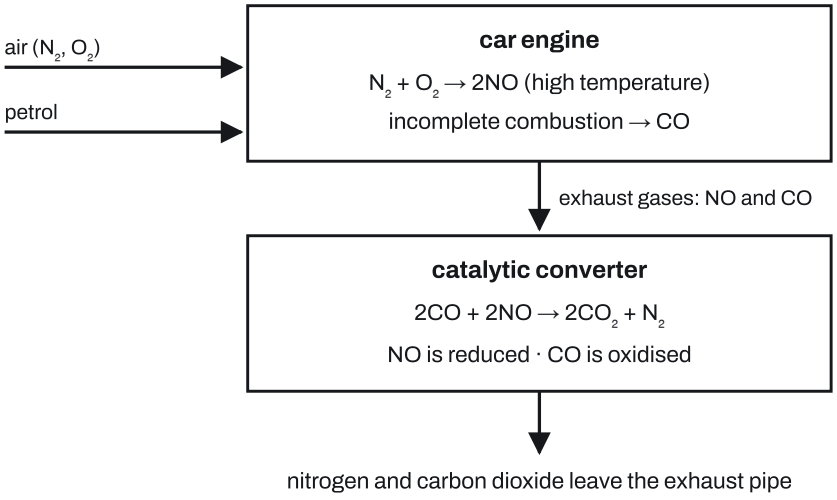
- **Planting trees**: trees take carbon dioxide out of the air by photosynthesis. It is the way to remove carbon dioxide that is already in the atmosphere.
- **Less livestock farming**: fewer cattle means less methane from digestion.
- **Using less fossil fuel**: less burning of carbon-containing fuels means less carbon dioxide made.
- **More hydrogen and renewable energy** (wind, solar): hydrogen burns to give only water, and wind and solar power burn nothing, so no carbon dioxide is made.

Acid rain (too much sulfur dioxide and oxides of nitrogen):

- **Catalytic converters** in vehicles remove oxides of nitrogen from the exhaust.
- **Low-sulfur fuels**: less sulfur in the fuel, so less sulfur dioxide when it burns.
- **Flue gas desulfurisation**: in power stations, the waste gases (flue gases) pass through **calcium oxide**. Calcium oxide is a basic oxide, and it **neutralises** the acidic sulfur dioxide, so the sulfur dioxide is removed before the gases reach the air.

Planting trees and farming fewer animals do nothing for acid rain; catalytic converters and low-sulfur fuel do little for climate change. Match the strategy to the problem.

Catalytic converters



A **catalytic converter** is fitted in a car's exhaust pipe. It contains a catalyst (on a honeycomb, to give a large surface area). **Core:** know that it removes oxides of nitrogen, which helps reduce acid rain.

Extended only: inside it, the two harmful gases from the engine react with each other. Oxides of nitrogen react with **carbon monoxide** (from incomplete combustion):

$$2\mathrm{CO} + 2\mathrm{NO} \rightarrow 2\mathrm{CO_2} + \mathrm{N_2}$$

- The oxide of nitrogen **loses oxygen**, so it is **reduced**, to **nitrogen**.
- Carbon monoxide **gains oxygen**, so it is **oxidised**, to **carbon dioxide**.
- Both products are **non-toxic**: nitrogen is already 78% of the air. The one drawback is that **carbon dioxide is a greenhouse gas**.

The products are always nitrogen and carbon dioxide, whichever oxide of nitrogen goes in. Balance the oxygen: each oxygen atom the oxide of nitrogen gives up turns one CO into one $\mathrm{CO_2}$.

Key facts and formulas

"Given" means the exam paper prints it. "Learn it" means you must remember it. Chemistry 0620 has no formula sheet, so everything here must be learned.

Formula	Status
Clean, dry air: about 78% $\mathrm{N_2}$, 21% $\mathrm{O_2}$, the rest noble gases (mainly argon) and $\mathrm{CO_2}$	Learn it
Volume of a gas in a sample of air $= \frac{\text{percentage}}{100} \times \text{volume of air}$	Learn it
Volume of air needed $= \text{volume of oxygen} \div 0.21$	Learn it
Complete combustion (plenty of oxygen) $\rightarrow \mathrm{CO_2}$; incomplete combustion (limited oxygen) $\rightarrow \mathrm{CO}$ and particulates	Learn it
Sources: $\mathrm{CH_4}$ from decomposing vegetation and animal digestion; NO_x from car engines; $\mathrm{SO_2}$ from fossil fuels containing sulfur	Learn it
Effects: $\mathrm{CO_2}$, $\mathrm{CH_4} \rightarrow$ global warming $\rightarrow$ climate change; CO toxic; particulates $\rightarrow$ respiratory problems and cancer; $\mathrm{NO}_x \rightarrow$ acid rain, photochemical smog, respiratory problems; $\mathrm{SO_2} \rightarrow$ acid rain	Learn it
carbon dioxide + water $\rightarrow$ glucose + oxygen (chlorophyll, light)	Learn it
Extended: $6\mathrm{CO_2} + 6\mathrm{H_2O} \rightarrow \mathrm{C_6H_{12}O_6} + 6\mathrm{O_2}$	Learn it
Extended: $\mathrm{N_2} + \mathrm{O_2} \rightarrow 2\mathrm{NO}$ (both from the air, high engine temperature)	Learn it
Extended: $2\mathrm{CO} + 2\mathrm{NO} \rightarrow 2\mathrm{CO_2} + \mathrm{N_2}$ (NO reduced, CO oxidised)	Learn it
Extended: greenhouse gases absorb thermal energy from the Earth, emit or reflect some back to the Earth, reduce thermal energy loss to space	Learn it
Flue gas desulfurisation: calcium oxide (basic) neutralises sulfur dioxide (acidic)	Learn it

How to do it

In the questions we have tagged for this topic (177 questions, 2021–2025, from all four papers), the types came up this often. 52 of the 177 questions mix types, so the counts add up to 252.

Question type	Questions
State or match the adverse effects of air pollutants	63
State the sources of air pollutants	50
State the composition of clean, dry air	42
Photosynthesis: equation, reactants, products and conditions	24
Identify greenhouse gases and explain global warming	20
Catalytic converters: the reaction and what is oxidised and reduced	17
Identify processes that add or remove carbon dioxide	15
State strategies that reduce acid rain or climate change	14
Calculate volumes from the composition of air or pollution data	7

1. State or match the adverse effects of air pollutants (63 questions)

Usually 1 mark: "state one adverse effect of ...", or choose the pollutant from a list, a table of formulae or a Periodic Table grid.

1. Name the pollutant exactly (sulfur **dioxide**, carbon **monoxide**).
2. Give the effect from the table in "Understand it", in its exact words: global warming or climate change (CO_2, CH_4); toxic (CO); respiratory problems or cancer (particulates); acid rain, photochemical smog or respiratory problems (NO_x); acid rain (SO_2).
3. Read what the effect must be **on**: "on health" wants respiratory problems (or toxic for CO; irritates the eyes, throat and lungs for SO_2), not acid rain; "on the environment" or "on buildings" wants acid rain or its damage.

Variations you will meet:

- **"One other adverse effect"** when the question has already said acid rain: for oxides of nitrogen give **photochemical smog** or **respiratory problems**. Repeating acid rain scores nothing.
- **Which pollutants cause acid rain?** Sulfur dioxide and oxides of nitrogen, and only those two. Carbon monoxide and carbon dioxide are wrong options.
- **Damage to limestone buildings and statues, or trees**: caused by acid rain, so sulfur dioxide (and oxides of nitrogen). Describe the effect as chemical weathering, erosion or corrosion of the stone.
- **Identify the pollutant from its effects**: acid rain + smog + breathing problems → oxides of nitrogen; toxic → carbon monoxide; cancer → particulates; global warming but not in clean air → methane.
- **Periodic Table grid**: "the element that forms an oxide which causes acid rain" is **S** or **N** (whichever is on the grid; not C).
- **Effect of acid rain** itself: damages (erodes) limestone buildings, kills trees, makes lakes acidic.
- **Sulfur dioxide's effect on health.** Older papers (2021–2022) also asked for this. Acid rain is not the answer there: say that it **irritates the eyes, throat and lungs**, causing breathing difficulties.

- **Older papers (2021–2022)** also asked about **lead compounds** (from leaded petrol; they damage the brain and nervous system). Lead is no longer on the syllabus list, but "lead compounds" still turns up as a wrong option.

2. State the sources of air pollutants (50 questions)

1. Give the source from the syllabus list: complete combustion of carbon-containing fuels ($\mathrm{CO_2}$); incomplete combustion of carbon-containing fuels (CO, particulates); decomposition of vegetation or digestion in animals ($\mathrm{CH_4}$); car engines (NO_x); burning fossil fuels that contain sulfur ($\mathrm{SO_2}$).
2. If asked **what incomplete combustion means**: burning when the supply of **oxygen (air) is limited**.

Variations you will meet:

- **Products of incomplete combustion** of a hydrocarbon: carbon monoxide, carbon (soot) and water. Hydrogen is not a product.
- **Match X, Y, Z**: the gas from animal digestion is methane; burning it in too little oxygen gives carbon monoxide; in excess oxygen, carbon dioxide.
- **Farming animals** gives both methane (digestion) and carbon dioxide (respiration).
- **A compost bin of rotting vegetation** has more methane inside than the air outside.
- **Write the equation** for incomplete combustion of carbon: $2\mathrm{C} + \mathrm{O_2} \rightarrow 2\mathrm{CO}$.
- **Which combustion makes a pollutant not in clean air?** Incomplete combustion (CO) and nitrogen reacting with oxygen (NO); not hydrogen burning (water) or complete combustion ($\mathrm{CO_2}$ is in clean air).
- **Extended: how do oxides of nitrogen form?** Two marks: **nitrogen and oxygen from the air react** (1) **because of the high temperature in the engine** (1). In multiple choice, reject every option that says the nitrogen comes from petrol, that nitrogen reacts with carbon monoxide, carbon dioxide or petrol, or that the oxides form in the catalytic converter.
- **Source of methane: read what the question is about.** If it is about methane as a pollutant in the air, give decomposing vegetation or digestion in animals; examiners do not accept plain "natural gas" there. If it asks for the main source of methane used as a **fuel**, give **natural gas**, which is mainly methane.

3. State the composition of clean, dry air (42 questions)

1. Nitrogen **78%**, oxygen **21%**. In a "using numbers only" question, write just the number.
2. The rest (about 1%) is noble gases, mainly **argon**, and **carbon dioxide**.

Variations you will meet:

- **"Which substance is 78% (or 21%) of clean, dry air?"** from a list, a set of structures or a Periodic Table grid: nitrogen (N) or oxygen (O). Hydrogen is a common wrong answer.
- **Which gas is over 30%?** Nitrogen (oxygen is only 21%).
- **Air is a mixture**, not a compound; statements calling it a compound, or giving 21% nitrogen and 78% oxygen, are wrong. Argon is **less than 1%**; carbon dioxide is far below 1%.

- **An element in clean air other than N and O**: argon (or another noble gas). **A compound in clean air**: carbon dioxide. **An element whose oxide is in clean air**: carbon.
- **Clean air versus polluted air**: argon and carbon dioxide are in clean air; carbon monoxide, sulfur dioxide, nitrogen dioxide and methane are only in polluted air. Water vapour doesn't count, because the air is dry.
- **Main products of the fractional distillation of liquid air**: nitrogen and oxygen.
- **A pie chart or table** of air's gases: the biggest part is nitrogen, the next oxygen. If the question gives the small remainder, argon is the larger part (about 0.9%) and carbon dioxide the smaller.

4. Photosynthesis: equation, reactants, products and conditions (24 questions)

1. **Reactants**: carbon dioxide and water. **Products**: glucose and oxygen.
2. **Conditions**: chlorophyll and energy from light.
3. **Extended**: $6\mathrm{CO_2} + 6\mathrm{H_2O} \rightarrow \mathrm{C_6H_{12}O_6} + 6\mathrm{O_2}$.

Variations you will meet:

- **Name the process** from the equation or from "made in plants from carbon dioxide and water": photosynthesis.
- **Complete the word equation**, or name "one other condition" or "one other substance" that is essential: light, chlorophyll, water or carbon dioxide (whichever the question has not given).
- **A gas needed for photosynthesis**: carbon dioxide. **A product of photosynthesis**: oxygen (a gas) or glucose.
- **Choose the equation** in multiple choice: reject the respiration equation (glucose + oxygen on the left), the fermentation equation (ethanol) and any with ethanol or methanol.
- **True or false statements**: it is a reaction between carbon dioxide and water (true); it needs light (true) and chlorophyll (true); it releases carbon dioxide (false); it lowers the oxygen in the air (false); it needs a temperature above 50 °C (false); oxygen is a reactant (false).
- **"Which reaction is speeded up by light?"**: photosynthesis.

5. Identify greenhouse gases and explain global warming (20 questions)

Core: name a greenhouse gas: carbon dioxide or methane. "A greenhouse gas found in clean, dry air" is carbon dioxide.

Extended, "explain in terms of thermal energy how greenhouse gases cause global warming" (about 3 marks). Write these points in order:

1. Energy from the Sun is absorbed by the Earth's surface, and **the Earth emits thermal energy**.
2. **Greenhouse gases absorb this thermal energy** (from the Earth).
3. They **emit (or reflect) it back towards the Earth**, in all directions.
4. So **less thermal energy is lost to space**, and the temperature of the atmosphere rises.

Variations you will meet:

- **Which gases lead directly to global warming?** Carbon dioxide and methane. Not carbon monoxide or sulfur dioxide. Carbon dioxide is **not** the only one.
- **Which statement explains it?** The right option has the gases absorbing thermal energy **from the Earth** and emitting some of it **back to the Earth**. Reject options where the gases absorb energy (or light) directly from the Sun, reflect energy into space, increase the energy lost to space, or cool the Earth.
- **The type of energy** is **thermal** energy radiated from the Earth's surface, not light.
- **"The three processes"**: absorption, emission and reflection of thermal energy. Not "creation" of thermal energy.
- **Flow diagrams**: emission from the Earth → absorption by greenhouse gases → emission back to the Earth → **reduced** thermal energy loss to space.
- **Statements to judge**: a greenhouse gas molecule can absorb and emit thermal energy (true); the Earth is a source of thermal energy (true); the energy emitted by a molecule goes in all directions (true); burning fossil fuels has raised the level of carbon dioxide (true).

6. Catalytic converters: the reaction and what is oxidised and reduced (17 questions)

Extended (Papers 2 and 4), except naming the catalytic converter, which is Core (type 8).

1. The oxides of nitrogen react with **carbon monoxide** (from incomplete combustion of the fuel).
2. The products are **nitrogen and carbon dioxide**: $2\mathrm{CO} + 2\mathrm{NO} \rightarrow 2\mathrm{CO_2} + \mathrm{N_2}$.
3. The oxide of nitrogen **loses oxygen: reduced**. Carbon monoxide **gains oxygen: oxidised**.

Variations you will meet:

- **Choose the equation**: the one with CO and NO on the left and $\mathrm{CO_2}$ and $\mathrm{N_2}$ on the right. Reject equations that make NO or $\mathrm{NO_2}$, or use $\mathrm{CO_2}$ or hydrogen as the reactant.
- **What happens to the oxides of nitrogen?** They are **reduced** (not oxidised, neutralised or hydrated). "Compound X" that removes them is carbon monoxide.
- **Name the two non-toxic gases formed**: nitrogen and carbon dioxide. Not sulfur dioxide, not oxygen.
- **Write the equation for a different oxide of nitrogen.** The products are still only $\mathrm{N_2}$ and $\mathrm{CO_2}$. Each oxygen atom removed from the oxide of nitrogen needs one CO. For $\mathrm{NO_2}$, each molecule gives up 2 oxygen atoms, so it needs 2 CO: $2\mathrm{NO_2} + 4\mathrm{CO} \rightarrow \mathrm{N_2} + 4\mathrm{CO_2}$.
- **A disadvantage**: it makes carbon dioxide, a greenhouse gas. (Nitrogen is neither toxic nor acidic.)
- **Combined statements**: often one statement about how oxides of nitrogen form (type 2) and one about the converter. Check each against the facts in both sections.

7. Identify processes that add or remove carbon dioxide (15 questions)

1. **Adds $\mathrm{CO_2}$**: burning anything that contains carbon, respiration, fermentation, thermal decomposition of carbonates (limestone), an acid reacting with a carbonate.
2. **Removes $\mathrm{CO_2}$**: photosynthesis only.

Variations you will meet:

- **"Which process removes carbon dioxide from the atmosphere?"** Photosynthesis (not combustion, decomposition, respiration or fermentation).
- **Numbered lists**: combustion of hydrogen and photosynthesis do not add carbon dioxide; combustion of methane, respiration, fermentation and heating limestone do.
- **"A product of respiration"** in a list question: carbon dioxide.
- **Name the type of reaction**: heating calcium carbonate to give carbon dioxide is **thermal decomposition**; methane giving carbon dioxide is **combustion**.
- **Which process does not produce a greenhouse gas?** A metal reacting with an acid (gives hydrogen). Acid rain on limestone gives carbon dioxide; burning wood gives carbon dioxide; digestion in cows gives methane.
- **The product when petrol burns completely**: carbon dioxide (carbon monoxide is from incomplete burning).

8. State strategies that reduce acid rain or climate change (14 questions)

1. Decide which problem the question is about.
2. **Climate change**: planting trees, less livestock farming, less fossil fuel, more hydrogen or renewable energy (wind, solar).
3. **Acid rain**: catalytic converters, low-sulfur fuels, flue gas desulfurisation.
4. If asked to **explain**, add the reason from "Reducing the effects".

Variations you will meet:

- **"Name the substance used in flue gas desulfurisation"**: calcium oxide. **"Name the gas it removes"**: sulfur dioxide.
- **"Describe how flue gas desulfurisation works"** (2 marks): the flue gases pass through **calcium oxide** (1), which **neutralises** the acidic sulfur dioxide (1).
- **"State one other way"** when low-sulfur fuel is already given: flue gas desulfurisation.
- **"Name the device that removes $\mathrm{NO_2}$ from car exhausts"**, or complete the sentence: a **catalytic converter**.
- **"A strategy to remove carbon dioxide already in the atmosphere"**: planting trees (the others only stop more being added).
- **Multiple choice sorting**: for acid rain, planting trees and less livestock farming are wrong.

9. Calculate volumes from the composition of air or pollution data (7 questions)

Mostly 1-mark multiple choice.

1. **A gas in a sample**: volume of gas $= \frac{\text{percentage}}{100} \times$ volume of air. For example, oxygen in $250\ \mathrm{cm^3}$ of air is $0.21 \times 250 = 52.5\ \mathrm{cm^3}$.
2. **Air needed for a volume of oxygen**: volume of air $=$ volume of oxygen $\div 0.21$. For example, $945\ \mathrm{dm^3}$ of oxygen needs at least $945 \div 0.21 = 4500\ \mathrm{dm^3}$ of air.

3. **Oxygen removed** (by heated metal, or iron wool rusting): the gas left is about 79% of the start, because only the 21% oxygen reacts. For $250\ \text{cm}^3$ of air, $250 - 52.5 = 197.5\ \text{cm}^3$ is left.
4. **Percentage of oxygen from an experiment**: $\frac{\text{start volume} - \text{end volume}}{\text{start volume}} \times 100$. For example, $80.0\ \text{cm}^3$ of a sample shrinking to $64.8\ \text{cm}^3$ gives $\frac{15.2}{80.0} \times 100 = 19\%$ oxygen. That is less than 21%, so the sample is not clean air.
5. **A table of pollutant concentrations** in ng per $1000\ \text{cm}^3$: scale by simple proportion. For example, 18.0 ng per $1000\ \text{cm}^3$ gives $18.0 \times \frac{150}{1000} = 2.7$ ng in $150\ \text{cm}^3$. Other parts ask which pollutant is highest or lowest in a given year, or which one falls every year: read only the row or column the question names.

Worked examples

Example 1

Which row correctly gives a source and an adverse effect of the pollutant? **[1]**

	pollutant	source	adverse effect
A	particulates	complete combustion of diesel	acid rain
B	sulfur dioxide	burning coal that contains sulfur compounds	acid rain
C	carbon monoxide	decomposition of vegetation	toxic gas
D	methane	car engines	photochemical smog

Check each row against the syllabus lists. A: particulates come from **incomplete** combustion and cause respiratory problems, not acid rain. C: carbon monoxide comes from incomplete combustion; decomposing vegetation gives methane. D: methane comes from vegetation and digestion, and causes global warming; car engines and smog belong to oxides of nitrogen. B is right on both counts.

Answer: **B (B1)**

Example 2

A power station burns coal. The coal contains carbon and some sulfur compounds.

(a) Name the gas formed from the sulfur compounds, and state its adverse effect on the environment. **[2]**

(b) Before the waste gases leave the chimney, they pass through powdered calcium oxide.

(i) Name this process. **[1]**

(ii) Explain why calcium oxide removes the gas you named in (a). **[1]**

(c) When the supply of air to the furnace is too low, a toxic gas forms.

(i) Name the toxic gas. **[1]**

(ii) State what is meant by incomplete combustion. **[1]**

(d) The power station's owners want to help reduce climate change. Suggest **two** strategies they could use. **[2]**

(a) Sulfur dioxide **(B1)**; acid rain **(B1)**.

(b)(i) Flue gas desulfurisation **(B1)**.

(b)(ii) Calcium oxide is a basic oxide, so it **neutralises** the acidic sulfur dioxide **(B1)**.

(c)(i) Carbon monoxide **(B1)**.

(c)(ii) Burning a fuel when the supply of oxygen (air) is limited **(B1)**.

(d) Any two, each with the fuel or process named: plant trees (they take in carbon dioxide by photosynthesis) **(B1)**; generate electricity from renewable energy such as wind or solar instead of coal **(B1)**. (Burning less fossil fuel, or using hydrogen as the fuel, also score.)

Example 3

A sample of air was collected beside a busy road. The table shows its composition.

gas	percentage by volume
nitrogen	78.00
oxygen	20.95
argon	0.93
carbon dioxide	0.10
carbon monoxide	0.01
nitrogen dioxide	0.01

(a) Name the **two** gases in the table that are not present in clean, dry air. **[1]**

(b) Name the gas in the table that is an element in Group VIII. **[1]**

(c) Calculate the volume of argon in $500\ \text{cm}^3$ of this air. **[1]**

(d) All the oxygen is removed from $400\ \text{cm}^3$ of this air. Calculate the volume of gas left. Give your answer to the nearest cm^3. **[1]**

(e) Name the source of the nitrogen dioxide, and state **one** adverse effect of it on health. **[2]**

(a) Carbon monoxide and nitrogen dioxide **(B1)** (both are pollutants; carbon dioxide is in clean air, although here there is more of it than usual).

(b) Argon **(B1)**.

(c) $\frac{0.93}{100} \times 500 = 4.65\ \text{cm}^3$ **(B1)**.

(d) Oxygen removed $= \frac{20.95}{100} \times 400 = 83.8\ \text{cm}^3$, so $400 - 83.8 = 316.2$, which is $316\ \text{cm}^3$ **(B1)**.

(e) Car engines **(B1)**; respiratory problems (breathing difficulties such as asthma) **(B1)**.

Example 4 (Extended)

(a) Explain how nitrogen monoxide, NO, forms in a car engine. **[2]**

(b) Another oxide of nitrogen in car exhaust is dinitrogen oxide, N_2O. In the catalytic converter it reacts with carbon monoxide. Only nitrogen and carbon dioxide are formed.

(i) Write the balanced symbol equation for this reaction. **[1]**

(ii) State which reactant is reduced. Explain your answer. **[1]**

(c) The carbon dioxide from car exhausts adds to global warming. Explain, in terms of thermal energy, how carbon dioxide causes global warming. **[3]**

(d) Planting trees helps to reduce climate change. Give the symbol equation for the process in trees that removes carbon dioxide. **[1]**

(a) Nitrogen and oxygen **from the air** react **(M1)** because of the **high temperature** inside the engine **(M1)**. $\text{N}_2 + \text{O}_2 \rightarrow 2\text{NO}$.

(b)(i) N_2O has one oxygen atom to give up, so it needs one CO:

$$\text{N}_2\text{O} + \text{CO} \rightarrow \text{N}_2 + \text{CO}_2$$

(B1). Check: 2 N, 2 O and 1 C on each side.

(b)(ii) Dinitrogen oxide is reduced, because it **loses oxygen** (to become nitrogen) **(B1)**.

(c) Any three:

- the Earth's surface, warmed by the Sun, **emits thermal energy (B1)**;
- carbon dioxide molecules **absorb this thermal energy (B1)**;
- they **emit (or reflect) it back towards the Earth (B1)**;
- so **less thermal energy is lost to space** and the temperature rises **(B1)**.

(d) $6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$ **(B1)** (photosynthesis).

Common mistakes

- **Vague effects.** "Harmful", "pollutes the air", "causes illness", "bad for the environment" or "has an effect on the lungs" score nothing. Write the syllabus effect: "respiratory problems", "acid rain", "toxic", "global warming". Examiners report this every year.

- **Answering the wrong kind of effect.** "State one effect on health" of oxides of nitrogen needs respiratory problems, not acid rain. Read whether the question wants health, buildings or the environment.
- **Ignoring "other".** If the question says oxides of nitrogen cause acid rain and asks for one **other** effect, acid rain is wrong. If it names one pollutant and asks for two **other** pollutants, don't give it again.
- **Blaming carbon dioxide or carbon monoxide for acid rain.** Only sulfur dioxide and oxides of nitrogen cause it. On a Periodic Table grid, the element whose oxide causes acid rain is S or N, not C.
- **Confusing oxides of nitrogen with nitrates.** Oxides of nitrogen pollute the air (acid rain, smog). Nitrates pollute water (Water and fertilisers). Examiners see the two swapped often.
- **Calling nitrogen dioxide a greenhouse gas.** The greenhouse gases in this topic are carbon dioxide and methane.
- **Not knowing what incomplete combustion means.** Examiners say this definition is rarely known: it is burning in a **limited supply of oxygen**. Its products are carbon monoxide, carbon and water, not hydrogen.
- **Inexact names.** Writing "sulfur" for sulfur dioxide or "carbon oxide" for carbon monoxide loses the mark. Name the compound exactly. For where methane **pollution** comes from, give the syllabus source (decomposing vegetation, digestion in animals), not plain "natural gas". Natural gas is the right answer only when the question asks where methane used as a fuel comes from.
- **Saying the nitrogen in oxides of nitrogen comes from petrol.** It comes from the air, as does the oxygen.
- **Getting the greenhouse effect backwards.** The gases absorb thermal energy **from the Earth**, not from the Sun, and they **reduce** the energy lost to space. "Damages the ozone layer" is a different problem and scores nothing.
- **Writing "photosynthesis" for "photochemical"** (smog), or the other way round.
- **Giving water vapour or a pollutant** as a gas in **clean, dry** air, or carbon dioxide when an **element** is asked for (argon).
- **Not knowing flue gas desulfurisation.** Examiners note that calcium oxide is often not known. Learn the whole phrase: flue gas desulfurisation with calcium oxide.
- **Vague acid rain damage.** "Decays", "rusts it" or "affects the building" are too vague: write that it erodes or chemically weathers the limestone (or corrodes the metal).
- **Mixing up the strategies.** Planting trees helps climate change, not acid rain; catalytic converters help acid rain.

How to get the marks

- **"State"** or **"Name"** needs a short answer, the exact name of the substance: "sulfur dioxide", "carbon monoxide", "calcium oxide". Formulas are usually accepted when correct, but a wrong formula loses the mark.
- **"Using numbers only"** means write "78" or "21", with no words.
- **"Give one"** means one: if you give two and one is wrong, the wrong one can cancel the right one.

- **Effects and sources**: use the syllabus words. For health, "respiratory problems" (breathing difficulties, asthma, irritated lungs) is the safe answer for oxides of nitrogen and particulates; "toxic" for carbon monoxide.
- **"Explain how oxides of nitrogen form"** (2 marks): both gases from the **air** (1) + **high temperature** in the engine (1).
- **"Explain, in terms of thermal energy, …"** (3 marks): Earth emits thermal energy → greenhouse gases absorb it → emit or reflect it back to the Earth → less lost to space. Use the words "thermal energy", "absorb" and "emit".
- **"Describe"** a strategy needs the method; **"explain"** needs the reason too (neutralises the acidic gas; absorbs carbon dioxide by photosynthesis; less methane from cattle).
- **Equations**: in a word equation write names; in a symbol equation, correct formulas and balancing. For catalytic converter equations the mark scheme first checks that the only products are $\mathrm{N_2}$ and $\mathrm{CO_2}$, then the balancing.
- **Calculations** usually carry 1 mark for the answer: show the working anyway, and give the unit ($\mathrm{cm^3}$, $\mathrm{dm^3}$ or ng) from the question.
- **Multiple choice with numbered statements**: decide true or false for each statement first, then find the letter.

Quick check

1. Name the two elements that make up about 99% of clean, dry air, with the percentage of each. Name one other element and one compound found in clean, dry air.
2. Calculate the volumes of nitrogen and of oxygen in $360\ \mathrm{cm^3}$ of clean, dry air.
3. State the source of each pollutant: (a) particulates, (b) methane, (c) sulfur dioxide.
4. Sort these into strategies that reduce acid rain and strategies that reduce climate change: low-sulfur fuel; wind turbines; flue gas desulfurisation; farming fewer cattle; catalytic converters.
5. (Extended) In the reaction $2\mathrm{CO} + 2\mathrm{NO} \rightarrow 2\mathrm{CO_2} + \mathrm{N_2}$, state which substance is oxidised and which is reduced, with a reason for each.

Answers

1. **Nitrogen, 78%** and **oxygen, 21%**. Another element: **argon** (or any noble gas). A compound: **carbon dioxide**.
2. Nitrogen: $0.78 \times 360 = 280.8\ \text{cm}^3$. Oxygen: $0.21 \times 360 = 75.6\ \text{cm}^3$.
3. (a) **Incomplete combustion** of carbon-containing fuels. (b) **Decomposition of vegetation**, or waste gases from **digestion in animals**. (c) **Burning fossil fuels that contain sulfur compounds**.
4. **Acid rain**: low-sulfur fuel, flue gas desulfurisation, catalytic converters. **Climate change**: wind turbines, farming fewer cattle.
5. **CO is oxidised**: it gains oxygen, becoming CO_2. **NO is reduced**: it loses oxygen, becoming N_2.

Past questions to try

- **0620/42/F/M/22 Q3**: how nitrogen dioxide forms in car engines, its effects, and the catalytic converter products.
- **0620/41/O/N/23 Q5**: part (c), a greenhouse gas in clean air and the thermal energy explanation of global warming.
- **0620/31/O/N/23 Q3**: a table of pollutant concentrations with a volume calculation, then sulfur dioxide's source, effect and flue gas desulfurisation.
- **0620/32/M/J/23 Q8**: part (b) and (c), methane's source and effect, incomplete combustion, and two ways to reduce acid rain.