Earth and Atmosphere

Name ________________________________

Class ________________________________

Teacher ________________________________

L1 The atmosphere – Then vs Now

Proportions of Gases in the Atmosphere Today (The layers of gases that surround the Earth.)

For around 200 million years, the proportions of gases in the Earth's atmosphere have remained relatively constant. Understanding these proportions is essential for studying the atmosphere:

- **Nitrogen (N_2)**: Makes up about four-fifths, or approximately 80%, of the atmosphere. It is a crucial component but largely inert, meaning it doesn't readily react with other substances under normal conditions.
- **Oxygen (O_2)**: Constitutes about one-fifth, or approximately 20%, of the atmosphere. Oxygen is essential for aerobic respiration in most living organisms and is also necessary for combustion.
- **Other Gases**: These are present in much smaller amounts and include:
    - **Carbon Dioxide (CO_2)**: Although present in tiny amounts, it is vital for photosynthesis in plants and contributes to the greenhouse effect.
    - **Water Vapour (H_2O)**: The amount of water vapour can vary but plays a significant role in weather and climate.
    - **Noble Gases**: Such as argon (Ar), which are chemically inert and do not readily form compounds.

The Earth's Early Atmosphere

The composition of the Earth's atmosphere has evolved dramatically since the planet's formation around 4.6 billion years ago. Theories about the early atmosphere have developed over time, though direct evidence is scarce due to the immense time scales involved.

Theories on the Formation of the Early Atmosphere

One widely accepted theory suggests that during the first billion years of Earth's existence, intense volcanic activity was prevalent. This volcanic activity released various gases, shaping the early atmosphere and oceans:

- **Intense Volcanic Activity**: Volcanos released a significant amount of gases, primarily carbon dioxide (CO_2), water vapour (H_2O), and nitrogen (N_2). This resulted in an atmosphere that might have resembled those of Mars and Venus today, composed mainly of carbon dioxide with little or no oxygen.
- **Formation of Oceans**: As the Earth cooled, water vapour condensed to form oceans. These bodies of water played a crucial role in reducing atmospheric CO_2 levels.
- **Dissolution of Carbon Dioxide**: CO_2 dissolved in the ocean water which reduced the amount of CO_2 in the atmosphere over time.
- **Production of Nitrogen**: Volcanoes also emitted nitrogen, which accumulated in the atmosphere. This gradual build-up contributed to the nitrogen-dominated atmosphere we have today.
- **Minor Gases**: Small amounts of methane (CH_4) and ammonia (NH_3) might also have been present, released from volcanic activity and other sources.

Independent practice

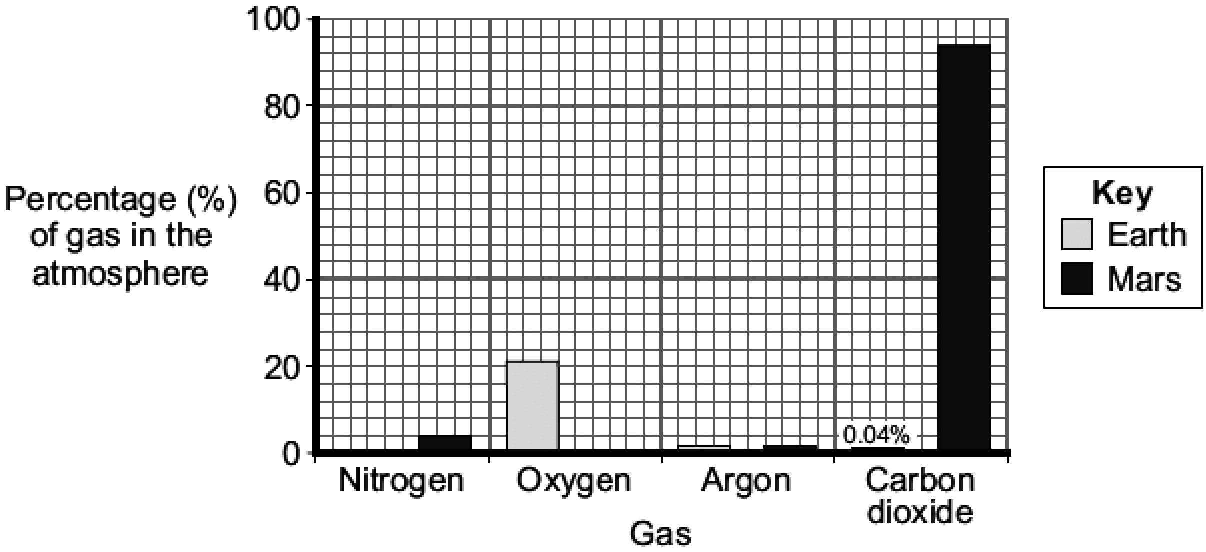
1. Define atmosphere.
2. Which gas makes up most of the current atmosphere?
3. Explain the term inert.
4. Which gas in the atmosphere is important for photosynthesis?
5. During the first billion years of Earth there was intense what?
6. Describe the Earth's early atmosphere.
7. Explain how the oceans formed and what this did to carbon dioxide levels.
8. The table below shows the percentage of some gases in the atmospheres of Earth and Mars today.

Gas	**Percentage of gas in atmosphere (%)**	
	Earth	Mars
Argon	0.90	1.9
Carbon dioxide	0.04	95
Nitrogen	78	2.6
Oxygen	21	0.20

(a) Which gas has the highest percentage in the Earth's atmosphere?

(b) Calculate how many times more carbon dioxide there is in the atmosphere of Mars than in the atmosphere of Earth. Use the table above. Give your answer in standard form. **(3)**

10. The bar chart shows some of the gases in the atmospheres of Earth today and Mars today.



(a) Complete the bar chart to show the percentage of nitrogen in the Earth's atmosphere today.

(b) Some scientists suggest that the Earth's early atmosphere was like the atmosphere of Mars today.

(i) There is **not** much oxygen in the atmosphere of Mars.

Suggest why.

L2 The changing atmosphere

The Early atmosphere on Earth was very different to the current atmosphere. This change in the atmosphere has occurred over billions of years through a variety of mechanisms.

Main Changes in the Atmosphere Over Time:

1. **Early Atmosphere**: Dominated by carbon dioxide with little or no oxygen.
2. **Introduction of Oxygen**: Initiated by algae and sustained by plants through photosynthesis.
3. **Reduction of Carbon Dioxide**: Accomplished through photosynthesis and the formation of carbon-containing rocks and fossil fuels.

How Oxygen Increased

Photosynthesis by Algae and Plants:

- **Photosynthesis** is the process by which algae and plants produce oxygen. The chemical equation for photosynthesis is: Carbon dioxide + Water →Glucose + Oxygen

Timeline of Oxygen Increase:

- **2.7 billion years ago**: Algae first produced oxygen. This marked the beginning of oxygen appearing in the atmosphere.
- **Next billion years**: Plants evolved, and the percentage of oxygen in the atmosphere gradually increased.
- **Oxygen Levels Enable Animal Evolution**: The rise in oxygen levels eventually reached a point where it supported the evolution of animals.

How Carbon Dioxide Decreased

Photosynthesis by Algae and Plants:

- **Photosynthesis** not only produces oxygen but also uses up carbon dioxide. This process significantly reduced the amount of CO_2 in the atmosphere.

Formation of Sedimentary Rocks and Fossil Fuels:

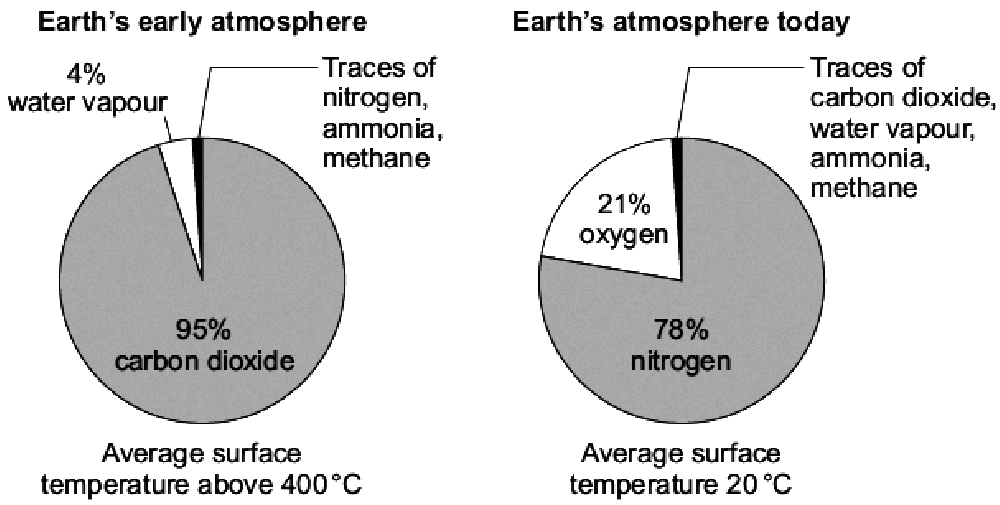
- **Sedimentary Rocks**: Over millions of years, carbon dioxide dissolved in water bodies and formed carbonate compounds. These compounds eventually precipitated and formed sedimentary rocks like limestone.
- **Fossil Fuels**: Dead plants and animals, over long periods, were buried and subjected to heat and pressure. This process transformed them into fossil fuels such as coal, crude oil, and natural gas, all of which contain carbon, thus trapping CO_2.

Formation of Deposits:

- **Limestone**: Formed from the accumulation and compression of carbonate sediments.
- **Coal**: Created from plant material that was buried and compressed over millions of years.
- **Crude Oil and Natural Gas**: Resulted from the remains of marine organisms that were buried under sediment, subjected to heat and pressure, and converted into hydrocarbons.

Independent practice

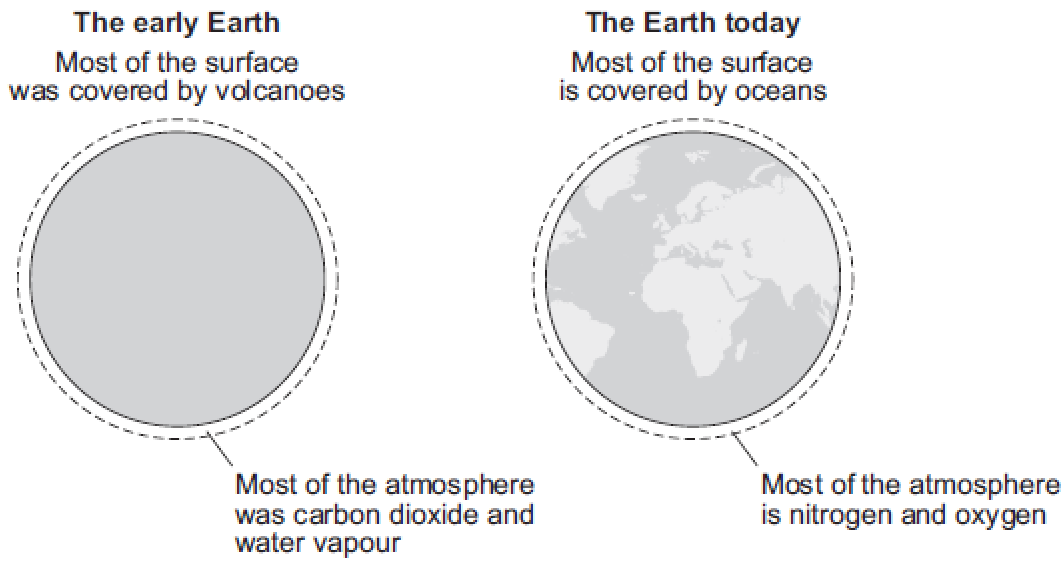
1. What process increased oxygen levels?
2. What did the oxygen allow for the evolution of?
3. Link photosynthesis to carbon dioxide levels.
4. What did the formation of sedimentary rocks do to the carbon dioxide levels in the atmosphere?
5. Name the three fossil fuels.
6. What did the formation of fossil fuels do to the levels or carbon dioxide?
7. Finish the sentences below
    a. Volcanoes caused….
    b. Photosynthesis of plants…
    c. Carbon dioxide levels reduced because….
8. The pie charts show the approximate percentages of gases in the Earth's early atmosphere and in the Earth's atmosphere today.



(a) Explain what has happened to most of the water vapour in the Earth's early atmosphere. **(2)**

(b) Give **two** reasons why the percentage of carbon dioxide in the Earth's early atmosphere decreased. **(2)**

9.



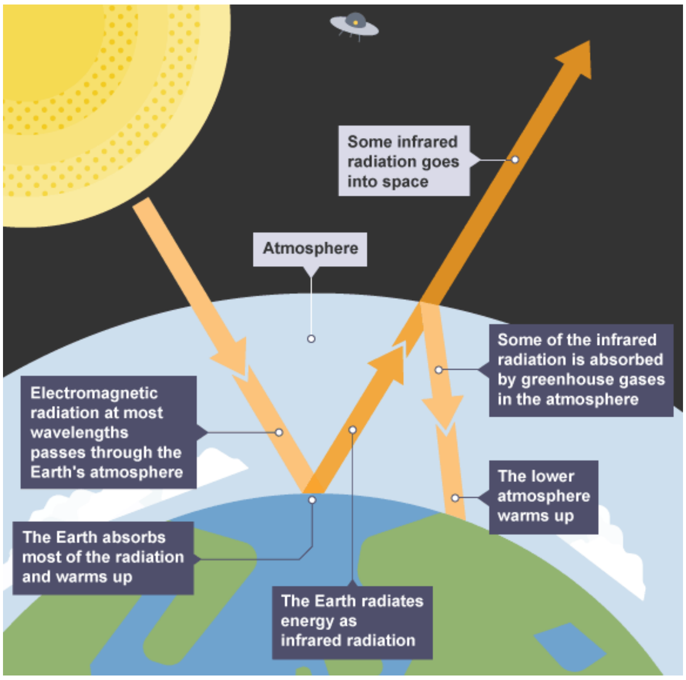
Describe and explain how the surface of the early Earth and its atmosphere have changed to form the surface of the Earth and its atmosphere today. **(6)**

L3 The greenhouse effect

Greenhouse Gases

Greenhouse gases in the atmosphere are crucial for maintaining temperatures on Earth high enough to support life. The main greenhouse gases include: **Water vapour, Carbon dioxide (CO_2), Methane (CH_4)**

The Greenhouse Effect



The greenhouse effect can be described in terms of the interaction between short and long wavelength radiation with matter:

1. **Short Wavelength Radiation:** When sunlight, which is short wavelength radiation, reaches the Earth, it passes through the atmosphere and warms the surface of the Earth.
2. **Long Wavelength Radiation:** The Earth's surface then emits long wavelength radiation (infrared) back into the atmosphere.
3. **Absorption and Re-emission:** Greenhouse gases absorb this long wavelength radiation and re-emit it in all directions, including back towards the Earth, warming the surface and lower atmosphere.

This process is essential for keeping our planet warm enough to support life.

Human Activities and Greenhouse Gases

Certain human activities significantly increase the amounts of greenhouse gases in the atmosphere. These include:

Carbon Dioxide (CO_2)

- **Burning Fossil Fuels:** When we burn coal, oil, and natural gas for energy and transportation, CO2 is released into the atmosphere.
- **Deforestation:** Cutting down trees reduces the amount of CO2 that is absorbed from the atmosphere during photosynthesis, leading to higher CO2 levels.

Methane (CH_4)

- **Agriculture:** Livestock, such as cows, produce methane during digestion. Rice paddies also emit methane.
- **Waste Management:** Landfills and waste treatment processes can release methane as organic waste decomposes.

Climate Change and Evidence

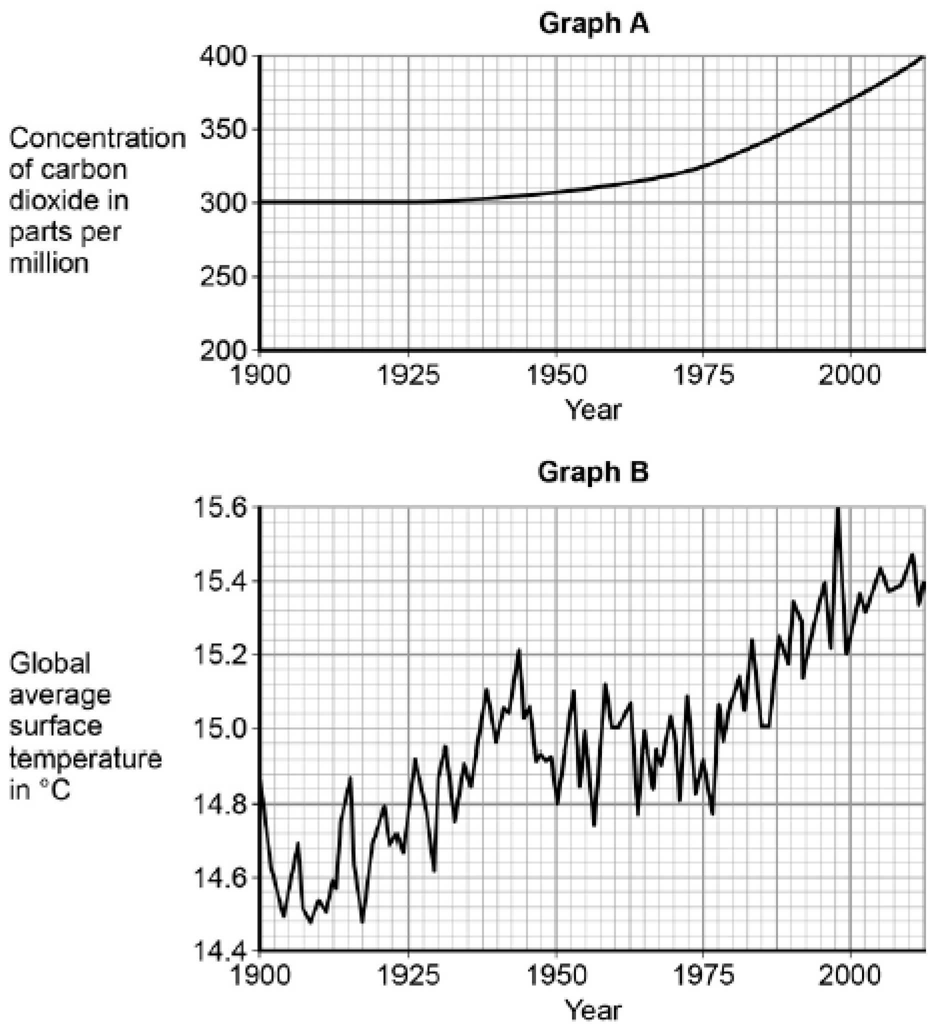
Many scientists, based on peer-reviewed evidence, believe that human activities will increase the Earth's surface temperature, leading to global climate change. However, there are complexities involved in modelling global climate change, which can lead to:

- **Simplified Models:** These are easier to understand but may not capture all the details of climate processes.
- **Speculation and Opinions:** Media may present biased views based on incomplete evidence.

Independent practice

1. Name the 3 greenhouse gases.
2. Levels of which greenhouse gas increases due to burning fossil fuels.
3. How do cows and rice fields link to the greenhouse effect?
4. Does the sun emit short or long wavelength radiation?
5. Does the earth emit short or long wavelength radiation?
6. What do the greenhouse gases do to the radiation?
7. Complete the sentences
    a. The greenhouse effect is important and
    b. The greenhouse effect is important but
    c. The greenhouse effect is important so
8. Explain how greenhouse gases cause global warming. (4 marks exam question)
9. The graphs in **Figure 1** show the concentration of carbon dioxide in the atmosphere and global average surface temperature since 1900.

Figure 1



(a) Calculate the percentage increase in the concentration of carbon dioxide from 1975 to 2000.

(b) What was the global average surface temperature in 1980?

(c) A student stated: ‘The graphs show that increasing the concentration of carbon dioxide in the atmosphere causes global temperature increases.’

Discuss why this statement is only partially true. **(4)**

L4 Global climate change

The Earth's climate has been constantly changing since the Earth was formed 4.6 billion years ago. This includes several *ice ages* and periods of much warmer global temperatures. Until 200 years ago, these changes were all caused by natural changes such as *volcanic eruptions* and changes in the energy that reaches the Earth from the Sun.

- **Increase in Average Global Temperature:** A major cause of climate change is the rise in average global temperatures. This increase affects the Earth's climate system and leads to various changes in weather patterns, sea levels, and ecosystems.

Potential Effects of Global Climate Change

Four Potential Effects

1. **Glaciers and Polar Ice Melting: Cause:** Increased global temperatures lead to the melting of glaciers and polar ice caps. **Effect:** This contributes to rising sea levels and the loss of natural habitats for species that depend on ice-covered regions.
2. **Sea Levels Rising: Cause:** Melting ice from glaciers and polar regions, combined with the expansion of seawater as it warms. **Effect:** Increased risk of coastal flooding, loss of land, and displacement of communities living in low-lying areas.
3. **Patterns of Rainfall Changing, Producing Floods or Droughts: Cause:** Changes in global weather patterns affect precipitation rates and distribution. **Effect:** Some regions may experience increased rainfall leading to floods, while others may face severe droughts, impacting agriculture, water supply, and natural ecosystems.
4. **Habitats Changing: Cause:** Alterations in temperature and precipitation affect the natural environments where plants and animals live. **Effect:** Species may be forced to migrate to new areas, leading to changes in biodiversity and ecosystem dynamics, with some species potentially facing extinction if they cannot adapt.

Discussing the Scale, Risk, and Environmental Implications

Scale of Climate Change

- **Global Impact:** Climate change affects the entire planet, but the severity and specific impacts can vary by region.
- **Long-Term Changes:** The effects of climate change are expected to continue and possibly worsen over decades and centuries, impacting future generations.

Risk Assessment

- **High Risk Areas:** Coastal regions, small island nations, and areas prone to extreme weather events are at greater risk.
- **Vulnerable Populations:** Communities with limited resources and infrastructure are more vulnerable to the impacts of climate change, leading to social and economic challenges.

Environmental Implications

- **Ecosystem Disruption:** Altered habitats and migration patterns can lead to a loss of biodiversity and changes in ecosystem services, which are the benefits that humans derive from ecosystems.
- **Agricultural Challenges:** Changes in weather patterns and increased frequency of extreme weather events can affect crop yields, food security (having enough food to feed the population), and livelihoods dependent on agriculture.
- **Human Health:** Increased temperatures and extreme weather can lead to health problems such as heatstroke, respiratory issues, and the spread of diseases.

Independent practice

1. Has the Earth's climate only changed since humans evolved?
2. What is happening to the average Earth temperature?
3. Link glaciers to sea levels.
4. Will all regions experience the same changes in weather?
5. Link climate change to extinction.
6. What is food security?
7. Why might climate change cause food prices to rise?
8. What health problems might arise in humans due to climate change?
9. Is the UK a high risk area?
10. Suggest why some countries in the Caribbean are considered high risk and vulnerable areas.
11. Explain why it is important to try reduce the impact climate change.

L5 Carbon Footprint

What is a Carbon Footprint? The carbon footprint is the total amount of carbon dioxide (CO_2) and other greenhouse gases that are released into the atmosphere over the full life cycle of a product, service, or event. This includes everything from the production and transportation of goods to their use and disposal. Greenhouse gases like CO_2 and methane (CH_4) contribute to global warming and climate change by trapping heat in the Earth's atmosphere.

Why is Reducing Carbon Footprint Important? Reducing our carbon footprint is crucial for mitigating climate change and protecting our environment. By lowering the emissions of greenhouse gases, we can slow down global warming, reduce pollution, and minimize the negative impacts on ecosystems and human health.

How Can We Reduce Carbon Footprint? There are several actions individuals, companies, and governments can take to reduce emissions of carbon dioxide and methane when producing products:

- **Using Renewable Energy Sources:** Switching from fossil fuels (like coal, oil, and natural gas) to renewable energy sources (such as solar, wind, and hydroelectric power) can significantly reduce CO_2 emissions.
- **Improving Energy Efficiency:** Using energy-efficient appliances and lighting, insulating homes properly, and promoting energy-saving practices can lower energy consumption and emissions.
- **Manufacturing:** When companies produce their products they could use recycled plastic, or less plastic in their products as a method to reduce the carbon footprint. If less new plastic needs to be produced, there is less emission of greenhouse gases.

Challenges and Limitations: While there are many ways to reduce our carbon footprint, there are also challenges and limitations to consider:

- **Economic Costs:** Transitioning to renewable energy and implementing sustainable practices can be expensive. Not all companies, or countries can afford these changes without financial support or incentives.
- **Technological Barriers:** Some renewable energy technologies are still developing, and their efficiency and availability can be limited in certain areas.
- **Political and Regulatory Issues:** Governments need to implement and enforce policies to reduce emissions, but political disagreements and lack of international cooperation can hinder progress.
- **Infrastructure Limitations:** In many places, the existing infrastructure is built around fossil fuel use. Upgrading or replacing this infrastructure to support sustainable practices can be a long and costly process.

Independent practice

1. The carbon footprint includes which gases?
2. Is the carbon footprint over the full or half of the products life cycle?
3. What does the carbon footprint include?
4. Why is it important to reduce the carbon footprint?
5. Planting trees doesn't reduce the carbon footprint of the product, but does help offset it. Explain how.

Finish the sentences

6. Using renewable energy reduces the carbon footprint of a product by…
7. Changing in manufacturing reduces the carbon footprint by…..

8. 4.1 kg of a plastic, used to make plastic bottles, has a carbon footprint of 6.0 kg of carbon dioxide. Calculate the carbon footprint of one plastic bottle of mass 23.5 g
9. Give one way that carbon dioxide emissions can be reduced when a plastic bottle is manufactured.
10. The table shows the carbon footprint during the manufacture and use of three cars.

Car	Mass of CO_2 produced during manufacture in kg	Mass of CO_2 produced when driving in kg per km	Total mass of CO_2 produced from manufacture and 40 000 km driving in kg	Total mass of CO_2 produced from manufacture and 100 000 km driving in kg
Car A	14 000	0.123	18 920	26 300
Car B	20 000	0.085	23 400	28 500
Car C	23 000	0.044	24 760	27 400

Evaluate the carbon footprint of the cars. Use information from the table above. **(6)**

- Include which car produces the most CO_2 in the different stages
- Compare the CO_2 produced in the different stages.
- Provide a judgment about which car has the smallest/largest carbon footprint.

L6 Atmospheric pollution

The combustion of fuels is a significant source of atmospheric pollutants. These pollutants have various harmful effects on the environment and human health. Understanding how these pollutants are produced, and their impacts is crucial for addressing air quality issues.

Production of Atmospheric Pollutants

1. Combustion of Fuels:

- **Major Source of Pollutants:** Burning fuels like coal, oil, and gas releases several harmful substances into the atmosphere.
- **Components of Fuels:** Most fuels contain carbon (C) and hydrogen (H), and may also have sulfur (S).

2. Gases Released During Combustion:

Complete combustion. Hydrocarbon (fuel) + oxygen → carbon dioxide + water

Incomplete combustion occurs when there is less oxygen. Hydrocarbon + oxygen → carbon monoxide + carbon + water

- **Sulfur Dioxide (SO_2):** Released when sulfur in the fuel reacts with oxygen.
- **Oxides of Nitrogen (NO_x):** Formed at high temperatures when nitrogen (N) in the air reacts with oxygen.

3. Particulates:

- **Solid Particles and Unburned Hydrocarbons:** These can be released as soot (carbon particles) and other tiny particles that form particulates.

Properties and Effects of Atmospheric Pollutants

1. Carbon Monoxide (CO):

- **Properties:** A toxic gas that is colourless and odourless, making it hard to detect.
- **Effects:** Interferes with the blood's ability to carry oxygen, leading to health issues such as headaches, dizziness, and even death in high concentrations.

2. Sulfur Dioxide (SO_2) and Oxides of Nitrogen (NO_x):

- **Properties:** Gases that can cause respiratory problems and contribute to environmental issues.
    - **Respiratory Problems:** These gases can irritate the respiratory system, leading to conditions like asthma and bronchitis.
    - **Acid Rain:** When these gases react with water vapour in the atmosphere, they form acids that fall as acid rain. Acid rain can damage buildings, harm wildlife, and acidify water bodies, impacting aquatic life.

3. Particulates:

- **Properties:** Tiny solid particles that can remain suspended in the air.
    - **Global Dimming:** Particulates reflect sunlight away from the Earth, reducing the amount of sunlight reaching the surface, which can affect climate patterns.
    - **Health Problems:** Inhalation of particulates can cause respiratory issues, including lung cancer, cardiovascular diseases, and other serious health conditions.

Independent practice

1. What is combustion the scientific word for?
2. Which type of combustion occurs when there is enough oxygen?
3. True or false: All fuels contain sulfur.
4. Name the 5 gases that could be produced in combustion.
5. Which two gases are produced in complete combustion?
6. Which gases are produced in incomplete combustion?
7. Why is carbon monoxide a problem?
8. What problems can Sulfur Dioxide (SO_2) and Oxides of Nitrogen cause?
9. Explain the term global dimming.
10. **Figure 1** shows the mass of sulfur dioxide in the Earth's atmosphere between 1984 and 2014

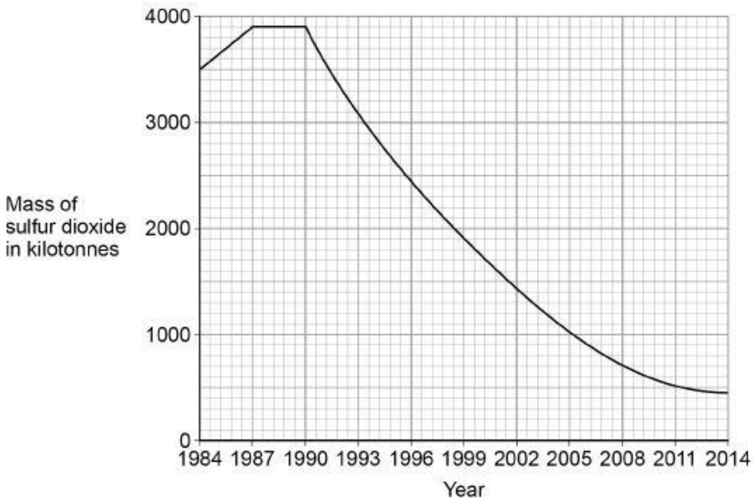


Figure 1

A student said:

'the mass of sulfur dioxide in the atmosphere decreased every year between 1984 and 2014'

Is the student correct? Use data from **Figure 3** to justify your answer. **(3)**

11. Cars cause atmospheric pollution. Some car emissions contain nitrogen dioxide. The table below shows the concentration of nitrogen dioxide in the air in three different areas for 1 week.

	Concentration of nitrogen dioxide in the air in arbitrary units		
Day	**City centre**	**Countryside**	**Motorway**
Monday	35	8	22
Tuesday	37	8	23
Wednesday	37	8	23
Thursday	34	8	23
Friday	37	8	23
Saturday	29	7	20
Sunday	22	6	17

(a) Which column of data has the greatest range?

(b) Explain why the concentration of nitrogen dioxide in the air is lower on Sunday.

(c) Calculate the mean value for the concentration of nitrogen dioxide in the air in the city centre for the days from Monday to Friday. Use the table above.