

Chemistry of the Atmosphere

Mark Scheme



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1. The chemistry of the atmosphere explores the 4.6 billion year story of the air we breathe, tracing its evolution from early volcanic origins to the modern-day impact of pollutants and greenhouse gases on our climate. Circle the letter of the correct answer for each of the following questions.

- a) A space probe has analysed the atmosphere of a newly discovered moon.

The table below shows the composition of its atmosphere:

Which gas is present in the moon's atmosphere in a **higher** percentage than it is in the Earth's atmosphere?

B – is the only correct answer.	1 mark
	Total: 1 mark

- b) Which gas was the most abundant in the Earth's early atmosphere?

A – is the only correct answer.	1 mark
	Total: 1 mark

- c) Which biological process is responsible for the gradual increase of oxygen in the Earth's atmosphere over the last 2.7 billion years?

C – is the only correct answer.	1 mark
	Total: 1 mark

- d) An article about climate change in a newspaper made the following claims about carbon dioxide. Carbon dioxide can be produced by the following:
Which of these statements are correct?

D – is the only correct answer.	1 mark
	Total: 1 mark

- e) The pie chart below shows the percentages of different gases in the Earth's atmosphere today.

Which row of the table identifies gases 1, 2, and 3 correctly?

C – is the only correct answer.	1 mark
	Total: 1 mark

(Total for Question 1 is 5 marks)

2. As the Earth aged, the temperature of the planet dropped significantly, allowing liquid water to exist.
- a) State how the drop in the temperature of the planet affected the amount of water vapour in the early atmosphere.

Water vapour in the atmosphere condensed to form oceans.	1 mark
	Total: 1 mark

- b) Explain how the process of photosynthesis in early organisms altered the percentage of carbon dioxide and oxygen in the air.

Photosynthesis uses or takes in carbon dioxide.	1 mark
and releases / produces oxygen.	1 mark
	Total: 2 marks

- c) Given that dry air contains 21% oxygen, calculate the volume of gas that will be left in the apparatus once all the oxygen has reacted with the copper.

$50 \times (21 \div 100) = 10.5 \text{ cm}^3$	1 mark
$(50 - 10.5) = 39.5 \text{ (cm}^3\text{)}$	1 mark
	Total: 2 marks

- d) Write the **balanced** chemical equation for the reaction of copper with oxygen in the tube.

$2\text{Cu} + \text{O}_2 \rightarrow 2\text{CuO}$	
Allow correct multiples.	
Award 1 mark for correct reactants.	1 mark
Award 1 mark for the correct product.	1 mark
Award 1 mark for the correct balancing.	1 mark
	Total: 3 marks

- e) After the teacher had finished her demonstration a large volume of gas remained in the tube. This gas does not react with the copper and remains as the primary component of the gas syringe after cooling. Identify this gas.

Nitrogen.	1 mark
	Total: 1 mark

- f) A student carries out the same experiment as the teacher but calculates the percentage of oxygen in the air to be 15%. This is lower than the expected value of 21%.

Suggest **three** practical reasons why the final volume of gas collected was higher than it should have been.

Any three of the following:	
- The copper was not in excess (ran out). - The heating was stopped too early (reaction incomplete). - The apparatus was not allowed to cool back to room temperature (gas expanded). - There was a leak in the apparatus (air entered).	
	Total: 3 marks

(Total for Question 2 is 12 marks)

3. Scientists think that the Earth's early atmosphere was formed by volcanic activity and was very similar to the atmosphere of Mars today.

The table below shows the composition of the atmosphere on Mars.

Gas	Percentage by Volume
Carbon Dioxide	95.0
Nitrogen	3.0
Oxygen	0.1
Argon	1.6

- a) Using the data in the table and your knowledge of the Earth's atmosphere today, describe two major changes that have happened to the gas composition of Earth's atmosphere over the last 4.6 billion years.

A description to include the following:	
Carbon dioxide (percentage) has decreased.	1 mark
Allow: there is much less carbon dioxide now.	
Oxygen (percentage) has increased.	1 mark
Allow: there is much more oxygen now.	
Allow: nitrogen (percentage) has increased.	
	Total: 2 marks

The Earth's early atmosphere contained a large amount of water vapour.

As the Earth cooled, this water vapour played a key role in reducing the levels of carbon dioxide.

- b) Explain how the cooling of the Earth led to a decrease in atmospheric carbon dioxide.

An explanation to include the following:	
Water vapour condensed to form oceans.	1 mark
Carbon dioxide dissolved in the water / oceans.	1 mark
Carbonates were precipitated (producing sediments).	1 mark
Allow: marine animals used carbonates to build shells / skeletons.	
	Total: 3 marks

- c) Much of the carbon from the early atmosphere is now "locked up" in the Earth's crust.

Name one type of sedimentary rock formed from carbon dioxide.

Limestone.	1 mark
Allow: chalk and or calcium carbonate	
	Total: 1 mark

(Total for Question 3 is 6 marks)

4. The table below compares the atmosphere of the planet Venus today with the atmosphere of the Earth today.

Gas	Percentage in Venus's Atmosphere (%)	Percentage in Earth's Atmosphere (%)
Carbon Dioxide	96.5	0.04
Nitrogen	3.5	78.0
Oxygen	0.00	21.0

Scientists believe that billions of years ago, the Earth's early atmosphere was very similar to the atmosphere of Venus today.

Describe the changes that have taken place in the Earth's atmosphere over time and explain the processes that caused these changes.

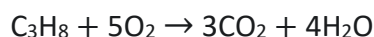
Marking guidance		
Level	Marks	Descriptor
Level 1	1 - 2	Simple statements are made about the changes (e.g., "oxygen went up, CO ₂ went down") or simple processes are named (e.g., "plants made oxygen"). The answer may be disjointed or lack scientific detail.
Level 2	3 - 4	A description of changes is given with some explanation of the processes. The links between processes (e.g., photosynthesis) and gas changes are made but may lack full detail (e.g., missing sedimentary rocks or fossil fuels).
Level 3	5 - 6	A comprehensive description of the changes in the atmosphere is given, with clear explanations of the processes involved for both carbon dioxide decrease and oxygen increase. The answer is coherent and logically structured

Indicative content:	
Decrease in carbon dioxide: - Carbon dioxide dissolved in the newly formed oceans. - Carbonates were precipitated producing sediments. - Carbon became 'locked up' in sedimentary rocks (e.g., limestone) and fossil fuels (coal, oil, gas). - Algae and plants evolved and absorbed carbon dioxide via photosynthesis. Increase in oxygen: - Algae and plants produced oxygen via photosynthesis. - Equation: $6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$ - Over billions of years, oxygen levels rose gradually to a level that enabled animals to evolve. Change in nitrogen: - Nitrogen was released by volcanoes. - Nitrogen built up because it is unreactive (and not removed).	
	Total: 6 marks

(Total for Question 4 is 6 marks)

5. Propane (C₃H₈) is a hydrocarbon fuel often used for heating.

When propane burns completely, it reacts with oxygen in the air to produce carbon dioxide and water.
The equation for the reaction is:



A canister contains 1.10 g of propane.

- a) Calculate the minimum volume of air required to completely burn this sample of propane at room temperature and pressure.

Assume that dry air contains 21.0% oxygen by volume.

(Molar volume of a gas at r.t.p. = 24.0 dm³/mol)

Give your answer in dm³ and to **3 significant figures**.

Mr of C ₃ H ₈ = 44	1 mark
Moles of C ₃ H ₈ = (1.10 ÷ 44) = 0.025	1 mark
Moles of O ₂ needed = 0.025 × 5 = 0.125	1 mark
Volume of O ₂ = 0.125 × 24 = 3.0 dm ³	1 mark
Volume of air = 3.0 ÷ 0.21	
Volume of air = 14.3 dm ³	1 mark
	Total: 5 marks

- b) Most fossil fuels, such as coal, contain sulfur as an impurity.

Explain how burning these fuels causes acid rain to be produced, and state one adverse effect of acid rain on the environment.

An explanation to include the following:	
Sulfur reacts with oxygen / burns (to form sulfur dioxide).	1 mark
Allow: S + O ₂ → SO ₂	
Sulfur dioxide dissolves in water / clouds.	1 mark
Allow: SO ₂ reacts with water.	
Forming sulfuric acid or acid rain.	1 mark
Then any one from:	
- damages trees / plants. - kills fish / aquatic life. - damages limestone / marble buildings / statues. - corrodes metal.	
	Total: 4 marks

(Total for Question 5 is 9 marks)

6. The table below shows the approximate percentage of gases in the Earth's early atmosphere and the Earth's atmosphere today.

Describe how the Earth's atmosphere has changed over billions of years and explain the processes that caused these changes.

In your answer, you should refer to:

- How the oceans were formed.
- The changes in carbon dioxide levels.
- The changes in oxygen levels.

Marking guidance		
Level	Marks	Descriptor
Level 1	1 - 2	Simple statements are made about the data in the table (e.g. "CO ₂ went down, oxygen went up"). There is limited or no explanation of the processes.
Level 2	3 - 4	The student describes the changes and explains the processes for at least two of the bullet points. The answer has some structure but may lack detail in the explanation (e.g. mentioning photosynthesis but not the equation or specific organisms).
Level 3	5 - 6	A coherent and detailed description of the changes is given, covering all three required aspects (oceans, carbon dioxide, and oxygen). The processes are scientifically explained and linked logically.

Indicative content:	
Formation of oceans: • As the Earth cooled, temperatures dropped below 100°C. • Water vapour in the atmosphere condensed. • This formed the oceans. Decrease in carbon dioxide: • Carbon dioxide dissolved in the newly formed oceans. • Carbonates were precipitated and formed sediments / sedimentary rocks (like limestone). • Algae and plants evolved and absorbed CO₂ by photosynthesis. • Carbon became locked up in fossil fuels (coal, crude oil, natural gas) formed from dead organic matter. Increase in oxygen: • Algae and plants (evolved and) produced oxygen. • By the process of photosynthesis. • Word or symbol equation: carbon dioxide + water → glucose + oxygen $6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$	
	Total: 6 marks

(Total for Question 6 is 6 marks)