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HIGHER

# C9H Chemistry of the Atmosphere: Higher Tier Practice

AQA 8462 · Calculator allowed · about 110 minutes

Total Marks

Name: ______________________________ Date: ____ / ____ / ______

**Answer ALL questions. Show all your working.**

**1** Name two gases that were much more abundant in the Earth's early atmosphere than they are today.

**(a)** Give two gases that were much more abundant in the Earth's early atmosphere than they are today. **(2)**

**(Total for Question 1 is 2 marks)**

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**2** Plants, algae and cyanobacteria changed the composition of the atmosphere by producing a gas as a waste product during photosynthesis. Name the gas.

**(a)** Name the gas produced as a waste product during photosynthesis that increased in the atmosphere. **(1)**

**(Total for Question 2 is 1 mark)**

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**3** Incomplete combustion of fossil fuels can produce carbon monoxide. Give one reason why carbon monoxide is hazardous to humans.

**(a)** Give one reason why carbon monoxide is hazardous to humans. **(1)**

**(Total for Question 3 is 1 mark)**

**4** Sulfate particles and soot released by volcanic eruptions can affect the climate. State one way sulfate particles affect the climate and one way soot affects the climate.

**(a)** State one way sulfate particles affect the climate. **(1)**

**(b)** State one way soot affects the climate. **(1)**

**(Total for Question 4 is 2 marks)**

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**5** Nitrogen monoxide, NO, reacts with oxygen in the air to form nitrogen dioxide, NO2. Write the balanced symbol equation for the reaction between 2 molecules of NO and O2 to form NO2.

**(a)** Write the balanced symbol equation for the reaction described. **(3)**

**(Total for Question 5 is 3 marks)**

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**6** A sample of air contains 0.040 mol of carbon dioxide in a 1.00 mol sample of gas. Calculate the percentage by volume of carbon dioxide in this sample. Show your working.

**(a)** Calculate the percentage by volume of CO2 in the sample. **(4)**

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**(Total for Question 6 is 4 marks)**

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**7** Explain why the concentration of oxygen in the atmosphere rose after photosynthetic organisms evolved. Give two linked points.

**(a)** Explain why atmospheric oxygen increased after photosynthetic organisms evolved. Give two linked points. **(3)**

**(Total for Question 7 is 3 marks)**

**8** The greenhouse gas methane is produced by biological activity and by fossil fuel extraction. A farmer measures methane emissions from a small cattle shed. He records 2.5 mol of methane released in one day from the shed, and estimates the shed atmosphere volume that mixes with the emissions is 500 m3 at standard conditions. Calculate the concentration of methane in ppm by volume in the shed atmosphere for that day. (1 mol of an ideal gas occupies 24.0 L at the conditions used by the farmer.) Show all working.

**(a)** Calculate the concentration of methane in ppm by volume. Show working and give final answer in ppm. **(4)**

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**(Total for Question 8 is 4 marks)**

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**9** Oxides of nitrogen (NOx) formed in car engines can produce acid rain. A catalytic converter reduces NOx by converting NO to harmless N2 and O2. Suggest why catalytic converters are less effective at very low temperatures, and give one practical change an engineer could make to improve cold-start performance of the converter.

**(a)** Suggest why catalytic converters are less effective at very low temperatures, and give one practical change an engineer could make to improve cold-start performance. **(5)**

**(Total for Question 9 is 5 marks)**

**10** Extended response: Explain how human activities since the Industrial Revolution have changed the composition of the atmosphere and how those changes affect global climate. In your answer you should describe at least three gases or particle types, explain the processes that change their concentrations and evaluate the relative importance of the changes for climate over the next 50 years.

**(Total for Question 10 is 6 marks)**

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**11** A chemist investigates the formation of sulfur dioxide from burning a coal sample. The coal sample contains 1.20 g of sulfur. When burned in excess oxygen, sulfur forms SO2 gas. (Ar: S = 32.1, O = 16.0) Calculate: (a) the number of moles of sulfur in the sample, (b) the mass of SO2 produced, and (c) the concentration in g per m3 of SO2 if the gas is collected into a 15.0 L container at the conditions used. Show working and give answers to appropriate significant figures.

**(a)** Calculate the number of moles of sulfur in 1.20 g of sulfur. (Ar S = 32.1) **(2)**

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**(b)** Calculate the mass of SO2 produced when all the sulfur forms SO2. (Mr SO2 = 32.1 + 2x16.0 = 64.1) **(4)**

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**(c)** Calculate the concentration in g per m3 of SO2 if the gas is collected into a 15.0 L container. **(4)**

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**(Total for Question 11 is 10 marks)**

**12** Hard question: A power station burns methane (natural gas) to generate electricity. Complete combustion of methane is described by the equation: $CH4 + 2O2 \rightarrow CO2 + 2H2O$. (a) Explain, using this equation, why burning methane increases the concentration of the greenhouse gas carbon dioxide in the atmosphere and describe how this contributes to the greenhouse effect. (b) The power station burns $4.00 \times 10^4$ kg of methane in one day. (Mr: CH4 = 16, CO2 = 44) (i) Calculate the mass of carbon dioxide released that day. (ii) A carbon capture system is then fitted that removes $8.80 \times 10^4$ kg of CO2 per day from the exhaust gas. Calculate the percentage decrease in the mass of CO2 released to the atmosphere as a result of the carbon capture system. Show working.

**(a)** Explain, using the equation, why burning methane increases atmospheric carbon dioxide and describe how this contributes to the greenhouse effect. **(4)**

**(b)** Calculate the mass of carbon dioxide released in one day, then calculate the percentage decrease in CO2 released once the carbon capture system removes $8.80 \times 10^4$ kg per day. **(6)**

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**(Total for Question 12 is 10 marks)**

# Mark scheme · C9H Chemistry of the Atmosphere: Higher Tier Practice

### Question 1

- (a) **B1** carbon dioxide
- (a) **B1** water vapour or methane or ammonia, oe
- **(a) Answer: Carbon dioxide; water vapour or methane or ammonia.**

### Question 2

- (a) **B1** oxygen cao
- **(a) Answer: Oxygen**

### Question 3

- (a) **B1** it binds to haemoglobin, reducing oxygen transport in blood
- **(a) Answer: It binds to haemoglobin, reducing oxygen transport in the blood.**

### Question 4

- (a) **B1** sulfate particles reflect sunlight, causing cooling
- **(a) Answer: Sulfate particles reflect sunlight, causing cooling.**
- (b) **B1** soot absorbs sunlight, contributing to warming
- **(b) Answer: Soot absorbs sunlight, contributing to warming.**

### Question 5

- (a) **M1** recognises need to balance coefficients and writes formulae (NO, O2, NO2) in an equation
- (a) **M1** uses coefficient 2 where needed so that numbers of N and O atoms match
- (a) **A1** 2NO + O2 -> 2NO2 cao
- **(a) Answer: 2NO + O2 -> 2NO2**

### Question 6

- (a) **M1** method: percentage = (moles CO2 / total moles) x 100 and substitutes correct values
- (a) **M1** performs calculation: (0.040 / 1.00) x 100
- (a) **A1** 4.0 % cao
- (a) **A1** includes unit percent or %
- **(a) Answer: 4.0 %**

### Question 7

- (a) **B1** photosynthetic organisms use carbon dioxide and water and produce oxygen as a product
- (a) **B1** as photosynthesising organisms became more numerous, more oxygen was produced
- (a) **B1** oxygen accumulated in the atmosphere because sinks were insufficient to remove all the oxygen immediately, oe
- **(a) Answer: Photosynthetic organisms used CO2 and H2O to produce oxygen; as they became more numerous they produced more oxygen and it accumulated in the atmosphere because the sinks could not remove it all immediately.**

### Question 8

- (a) **M1** calculates volume of methane: 2.5 mol x 24.0 L/mol = 60.0 L
- (a) **M1** converts shed volume to litres: 500 m3 = 500000 L
- (a) **M1** calculates ppm: (volume methane / total volume) x $10^6$ and substitutes values
- (a) **A1** final numeric answer 120 ppm cao
- **(a) Answer: 120 ppm**

## Question 9

- (a) **B1** at low temperature reaction rates on the catalyst surface are slower because molecules have less kinetic energy
- (a) **B1** the catalyst surface may be partially poisoned or less active when cold, reducing conversion efficiency, oe
- (a) **B1** practical change: fit a close-coupled converter nearer the engine so it heats up faster or use electrically heated catalyst, oe
- (a) **B1** practical change explanation: nearer engine or heating raises temperature quickly so converter reaches operating temperature faster
- (a) **B1** gives a realistic engineering trade-off or consequence such as increased cost or packaging complexity
- **(a) Answer: Converters are less effective when cold because surface reaction rates are slower and the catalyst may be less active; fitting the converter closer to the engine or using an electrically heated catalyst warms it faster so it reaches operating temperature sooner, though this increases cost or packaging complexity.**

## Question 10

- **Level 3** (5-6): Detailed explanation and evaluation. Describes at least three gases or particle types (for example $CO_2$, $CH_4$, $N_2O$, sulfate aerosols, soot), explains human processes that increased or decreased each (fossil fuel burning, agriculture, industrial chemistry, aerosol emissions), links each change to climate effects (greenhouse trapping, aerosol cooling, albedo changes), and evaluates relative importance and timescales with justified judgement about which changes will most influence climate over next 50 years.
- **Level 2** (3-4): Clear explanation with two or three relevant points. Describes some gases/particles and their climate effects but evaluation or links to timescale may be brief or partially supported.
- **Level 1** (0-2): Basic statements about gases or climate with limited explanation and little or no evaluation; may be fragmented or mainly descriptive.
- **Indicative content:**
  - $CO_2$ increased due to combustion of fossil fuels and deforestation; $CO_2$ is long-lived and increases greenhouse effect, likely the dominant driver over 50 years.
  - Methane ($CH_4$) increased from agriculture, landfill and fossil fuel extraction; stronger greenhouse gas but shorter lifetime; reducing $CH_4$ can give near-term climate benefits.
  - Nitrous oxide ($N_2O$) from fertiliser use is a potent greenhouse gas and affects stratospheric ozone chemistry.
  - Sulfate aerosols from industry and volcanoes reflect sunlight and cool climate; they have short lifetimes so changes are regional and short-term but influenced by pollution controls.
  - Soot/black carbon absorbs sunlight, warming atmosphere and darkening ice surfaces; impact concentrated regionally and on cryosphere.
  - Evaluation: $CO_2$ control is most important for long-term warming, methane reductions give faster benefits, aerosols complicate near-term temperature trends; policy and technological factors determine which changes dominate over 50 years.

## Question 11

- (a) **M1** uses n = mass / Mr and substitutes: n = 1.20 / 32.1
- (a) **A1** 0.0374 mol cao to 3 s.f.
- **(a) Answer: 0.0374 mol**
- (b) **M1** uses mole ratio 1:1 so moles $SO_2$ = moles S and substitutes value 0.0374 mol
- (b) **M1** calculates mass = moles x Mr = 0.0374 x 64.1
- (b) **A1** mass = 2.40 g cao (allow 2.40 to 2.41 depending on rounding)
- (b) **A1** states unit g
- **(b) Answer: 2.40 g**
- (c) **M1** converts 15.0 L to m3: 15.0 L = 0.0150 m3
- (c) **M1** calculates concentration = mass / volume and substitutes mass 2.40 g and volume 0.0150 m3
- (c) **A1** gives numeric value 160 g per m3 cao
- (c) **A1** includes units g per m3
- **(c) Answer: 160 g per m3**

### Question 12

- (a) **B1** burning methane (a fossil fuel) releases carbon dioxide, a greenhouse gas, into the atmosphere, oe
- (a) **B1** this carbon was previously locked away in the fossil fuel, so burning fossil fuels increases the concentration of CO2 in the atmosphere, oe
- (a) **B1** the increased CO2 absorbs infrared (long-wave) radiation re-radiated from the Earth's surface, oe
- (a) **B1** this traps more energy in the atmosphere, causing an enhanced greenhouse effect and global warming, oe
- **(a) Answer: Burning methane releases CO2 that was previously locked in the fossil fuel, increasing atmospheric CO2 concentration. CO2 absorbs infrared radiation re-radiated from the Earth's surface, trapping more energy in the atmosphere; this enhanced greenhouse effect causes global warming.**
- (b) **M1** uses the 1:1 mole ratio (CH4:CO2) and the Mr ratio to find mass of CO2: mass CO2 = mass CH4 x (44/16)
- (b) **A1** mass of CO2 released before capture = 4.00 x $10^4$ x 2.75 = 1.10 x $10^5$ kg cao
- (b) **B1** uses consistent units (kg) throughout
- (b) **M1** sets up percentage decrease = (mass CO2 captured / mass CO2 originally released) x 100 = (8.80 x $10^4$ / 1.10 x $10^5$) x 100
- (b) **A1** = 80.0 % cao
- (b) **B1** includes the % unit with the final answer
- **(b) Answer: Mass of CO2 released before capture = 4.00 x $10^4$ x (44/16) = 1.10 x $10^5$ kg. Percentage decrease = (8.80 x $10^4$ / 1.10 x $10^5$) x 100 = 80.0 %.**