

A LEVEL

Examiners' report

CHEMISTRY B (SALTERS)

H433

For first teaching in 2015

H433/02 Summer 2018 series

Version 1

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Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates. The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report. A full copy of the question paper can be downloaded from OCR.

Paper H433/02 series overview

H433/02 is one of the three examination components for GCE A Level Chemistry B. This component, entitled 'Scientific literacy in chemistry', links together different areas of chemistry within different contexts, some practical, some familiar and some novel. The paper also includes questions based on a pre-released Advance Notice article, included as an insert with the question paper. To do well on this paper, candidates need to be comfortable applying their knowledge and understanding to unfamiliar contexts and be familiar with a range of practical techniques that they should recognise from completing the practical elements of the course.

Candidate performance overview

Candidates who did well on this paper generally demonstrated the following characteristics

- Used information about spectroscopic techniques in 2a, structure and bonding in questions 2d, 2e(i), 3a, 4b/c, and question 5e and 5f.
- Demonstrate knowledge and understanding relating to practical techniques (1e and 3c).
- Produced a clear and concise answers to the Level of Response questions, (2e(ii) and 3c).
- Performed standard calculations showing clear working and, where appropriate, conversion to the required number of significant figures (1c, 2c(ii), 3f, 4d(i), 4e(i), and 4f).

Candidates who did less well on this paper, generally demonstrated the following characteristics

- Struggled to identify the limitations of spectroscopic techniques in distinguishing between structural isomers (2a(iii)).
- Gave responses in 2e(i) and 2e(ii) that indicated that the structure of cyclohexene contained 3 double bonds, akin to the Kekulé structure proposed for benzene.
- Found it difficult to apply their knowledge in novel situations, and consequently scored low marks in question 5.
- Often struggled to structure their responses to mathematical questions.

There was no evidence that candidates had struggled to complete the paper within the time allocated. Scripts where there was no response to the final question were scarce, suggesting that the time allocated to this paper was fair and that candidates had ample time to complete the question paper.

Question 1 (a) (i) and 1 (a) (ii)

- 1 'Morton's salt'™ contains a mixture of sodium chloride with magnesium carbonate. It is advertised using the slogan 'When it rains it pours' indicating that the table salt is free-flowing in humid weather.

Magnesium carbonate is hygroscopic (absorbs water) and forms hydrated salts, eg $\text{MgCO}_3 \cdot 3\text{H}_2\text{O}$, but does not dissolve. This stops the sodium chloride absorbing water.

Q1a(i) and (ii) were generally well answered by candidates. The majority of candidates scored full marks. However, there were a few examples where candidates had carried out their calculation incorrectly and arrived at a final answer of -4kJ/mol in part a(i). Others had identified the ions incorrectly in a(ii) such that the smaller ion was labelled as Cl^- and the larger ion as Na^+ . The numbers of candidates making these errors was small and most scored at least 2 marks across these introductory questions.

Question 1 (b)

- (b) Some students heat a sample of $\text{MgCO}_3 \cdot 3\text{H}_2\text{O}$ to try to make MgCO_3 .

Calculate the percentage loss in mass they will obtain if they succeed.

percentage loss in mass = % [2]

This question required candidates to use the information from the stem of the question to identify that when the salt was heated, the loss in mass was due to water being evaporated. Using the information provided they should have calculated the M_r for the hydrated salt, and then the M_r for the moles of water lost. Using these two values they should then have derived the percentage loss in mass.

Many candidates calculated the M_r of the hydrated salt correctly, but then calculated the mass of 3 moles of water and subtracted this from the mass of the hydrated salt. This gave them a figure of 84.3 which they then used in their calculation, arriving at the incorrect figure of 61% for the loss in mass. These responses did score 1 mark for the error carried forward (ecf) from the incorrect calculation of M_r values.

Question 1 (c)

- (c) The students continue to heat the MgCO_3 formed and realise that the compound is decomposing, giving off CO_2 gas.

The students want to obtain 200 cm^3 CO_2 at 290 K and 99 kPa.

What mass of MgCO_3 should they heat?

mass of $\text{MgCO}_3 = \dots\dots\dots$ g [3]

This was the first question where candidates were required to carry out a multi-step calculation. It required them to re-arrange a familiar equation, and then to convert the data provided into the required standard units. Whilst many candidates were able to carry out the first part of the task, there were many examples of candidates struggling with the conversion of units, particularly from cm^3 to m^3 for the volume of gas. In this instance credit was allowed where the candidate had rearranged the ideal gas equation correctly and had then used the correct equation to calculate the required mass of magnesium carbonate from their incorrectly calculated number of moles.

Exemplar 1

What mass of MgCO_3 should they heat?

$Pv = nRT$
 $n = \frac{Pv}{RT}$

$n = 8.212$ moles.

$M_r = 84.3$

$n = \frac{99 \times 10^3 \times 0.2}{8.314 \times 290}$

$\text{MgCO}_3 \rightarrow \text{MgO} + \text{CO}_2$

mass of $\text{MgCO}_3 = \dots\dots\dots 692 \dots\dots\dots$ g [3]

Example of the most common incorrect final answer, as a result of failing to convert 200 cm^3 correctly.

Question 1 (d) (ii)

(d) Magnesium has a higher first ionisation enthalpy than calcium.

(ii) Explain why magnesium has a higher first ionisation enthalpy than calcium.

.....

.....

..... [2]

Most candidates scored well on d(i); the only common error was the incorrect state symbols being used with (s) for both the Mg atom and the Mg⁺ ion. In part d(ii) many candidates scored full marks as they were able to explain that as a result of magnesium being above calcium in the periodic table the magnesium atom was smaller, and therefore the electrons were closer to the nucleus and were attracted more strongly by its positive charge. In d(ii) many candidates did not score full marks. Many correctly identified that the atom was smaller (or the electrons were closer to the nucleus), but did not then link this to the fact that the electrons are more strongly attracted to the nucleus.

Question 1 (e) (i) and (e) (ii)

(e) Some students are given a mixture of magnesium carbonate with another Group 2 carbonate. They dissolve the mixture in an acid. They test the solution of salts formed as shown in the table below.

Test	Result
Flame test	Green flame
Add dilute nitric acid followed by silver nitrate solution	White precipitate

(i) Name the acid that the students used to dissolve the mixture of carbonates.

..... [1]

(ii) Name the other Group 2 carbonate that was mixed with the magnesium carbonate.

..... [1]

In general, these final two elements of question 1 were well answered by most candidates. The only common errors were the use of sulfuric acid in e(i), or the presence of calcium (carbonate) in e(ii). Both of these potentially came as a result of misinterpreting the cause of the white precipitate stated in the results table.

Question 2 (a) (i)

2 Propene gas, C_3H_6 , is obtained industrially from a variety of sources. Propene is mainly used as a starting material for making polymers.

(a) The mass spectrum of propene has several peaks including those at m/z 27 and 43.

(i) Give the species responsible for these peaks

27

43

[2]

Many candidates lost marks here for failing to include the charge on the species identified. However, if they had correctly identified the species and this was their only error then 1 mark was credited. The other common error was failing to recognise that the peak at 43 was a result of the presence of one atom of the Carbon-13 isotope in the fragment. Many candidates gave a formula of $C_3H_7^+$ even though they are told the molecular formula for propene in the stem of the question.

Question 2 (a) (ii)

(ii) Propene has an isomer, cyclopropane.

Explain why high-resolution mass spectrometry would **not** distinguish between propene and cyclopropane.

.....
.....
.....
..... [2]

This question ought to have been straightforward. However many candidates gave incomplete responses. They either correctly stated that the structural isomers had the same formula mass, or that they had the same molecular formula. However, many candidates, having identified one of these two key statements, then left that as their final answer. With two marks being available candidates should have realised that they needed to make two statements.

Question 2 (a) (iii)

- (iii) Suggest, with reasons, **two** spectroscopic methods (apart from mass spectroscopy) that would distinguish between cyclopropane and propene.

Method 1

Reason:

.....

.....

Method 2

Reason:

.....

.....

[4]

There were a few issues raised in this question, which teachers may wish to consider when teaching this topic. This question was characterised by incomplete responses, or responses that lacked precision. To score well on this question, candidates needed to demonstrate their understanding of spectroscopic techniques precisely. This question was of high demand and this was reflected in the marks credited. Very few candidates scored full marks, and many candidates struggled to score more than two marks. Many chose appropriate methods to use, but then struggled to explain how the method chosen would distinguish between the two isomers. Many responses identified that one of the isomers contained a double bond, which was absent in the other isomer, but did not say how the method chosen would identify which isomer contained the double bond. Alternatively, if they did identify that propene had a double bond present, it was not linked to the specific data values quoted for IR spectroscopy, CNMR or HNMR spectroscopy. Also candidates knew that the splitting patterns in CNMR and HNMR were dependant on the environments of the carbon (or hydrogen) atoms and that the pattern could be used to identify the isomer, but again did not show precision in their responses.

Question 2 (b) (i) and (b) (ii)

- (b) (i) How many σ and π bonds are there in a propene molecule?

Number of σ bonds Number of π bonds [1]

- (ii) Propene has a H–C–H bond where the C atom forms a double bond.

What is the bond angle of this H–C–H bond?

..... [1]

These two questions showed no overall pattern in terms of candidates' knowledge and understanding and their overall performance on the paper. There were many candidates who scored both marks at all levels of ability, and equally there were many candidates who scored no marks at all levels of ability. In b(i) there were many examples of structures being drawn where candidates seemed to be trying to count up the number of each type of bond (with varying degrees of success), and similarly a full range of bond angles were suggested with 180° , 109.5° and 90° being the most common incorrect responses.

Question 2 (c) (i) and 2 (c) (ii)

- (c) Propene, C_3H_6 , can be made by cracking longer-chain hydrocarbons.

- (i) Write the equation for the cracking of nonane to give two molecules of propene and one other molecule.

[1]

- (ii) What mass of propene (in kg) would be obtained from 15 kg of nonane in the reaction in (i) if the percentage yield was 85%?

mass of propene = kg [2]

These two questions were generally well attempted. Many candidates correctly constructed the equation in part (i), and used this to arrive at the correct mass of propene in part (ii). Candidates who were less successful generally gave the formula of hexane as a product in part (i) and subsequently arrived at a value of 4.2 kg in part (ii). This was allowed for both marks as an example of the use of error carried forward from an incorrect equation in (i).


Exemplar 2

$$\frac{15 \times 1000}{(12 \times 3) + 6} = 117.2 \text{ mol} \quad = 99.6 \text{ mol}$$

$\times 0.88$ ECF

$$99.6 \times [(12 \times 3) + 6] = 4183.6 \text{ g}$$

$\div 1000$
= 4.18 kg


mass of propene = 4.18 kg [2]

This candidate has used the incorrect equation in (i) but use of error carried forward (ecf) in (ii) resulted in 2 marks being credited.

Question 2 (d)

(d) Most of the propene that is manufactured is used to make the polymer poly(propene).

Draw the **full** structural formula of the repeating unit of poly(propene).

[1]

Generally a straightforward question and many candidates scored this mark. A common error evident here was where candidates did not read the stem of the question fully and had not picked up on the instruction in bold requiring them to draw a full structural formula – i.e. a formula showing all the bonds and elements present. These candidates often included a $-\text{CH}_3$ group attached to a carbon atom within the repeating unit, which was not allowed as it was not a full structure.

Exemplar 3

° Benzene contains delocalised electrons which make it a very stable molecule. This means it undergoes only electrophilic substitution reactions so that delocalised electrons & structure aren't disrupted; Benzene if heated under reflux with a catalyst (FeBr_3) undergoes a substitution reaction in which bromobenzene & HBr are formed in this way delocalised electrons do not react; Cyclohexene has it has only one $\text{C}=\text{C}$ reacts with Br_2 through an electrophilic addition (at room temperature) in which the $\text{C}=\text{C}$ breaks down so that 1,2-dibromocyclohexane can be formed; this happens because cyclohexene does not have delocalised electrons & Br_2 reacts only where the $\text{C}=\text{C}$ bond is present.

L3

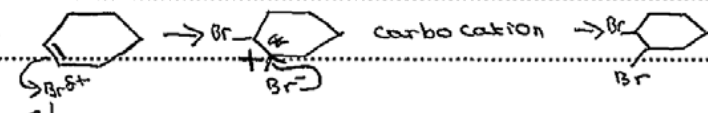
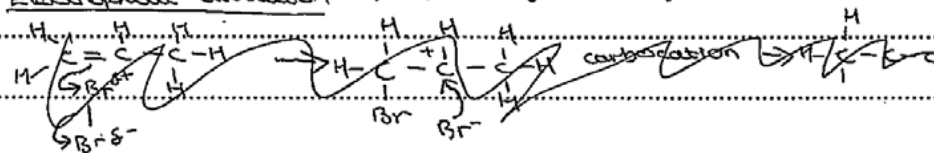
A clear succinct response, which addresses the Level 3 descriptor fully, scoring 6 marks.

Exemplar 4

Cyclohexene reacts with bromine by an addition reaction but benzene reacts with bromine in a substitution reaction. This is because addition would break the delocalised electrons in benzene resulting in the products being less stable than benzene. Cyclohexene reacts with bromine by electrophilic addition. A δ^+ Bromine acts as an electrophile as an induced dipole forms as the bromine approaches the double bond. The bromine bonds to the C breaking the double bond and forming a carbocation. The Br^- then bonds to the C^+ by donating a pair of electrons to it. This means ~~substitution~~. To preserve the delocalisation, bromine reacts with benzene by electrophilic substitution. The $\text{Br}^{\delta+}$ bonds to the benzene ring by accepting a pair of electrons from the region of delocalisation. This breaks the delocalisation and results in ~~an~~ a positive charge. To reform the delocalised ~~extra paper~~ [6]

2e ii ring of electrons the H atom attached to the C the Bromine is also attracted to donates its electrons and

so the C-H bond breaks
Electrophilic addition - prepare cyclohexene



L2

only 1 Br is added in the reaction with benzene but 2 are in the reaction with cyclohexene. Also an additional product HBr is formed in the reaction with benzene.

L2 response scoring 4 marks, as both reaction types have been identified and products given via equations. To progress to L3 the candidate would have needed to include the reactants and reaction conditions for both reactions

Exemplar 5

Cyclohexene undergoes electrophilic addition, whereas benzene undergoes electrophilic substitution. With cyclohexene, bromine molecules gain ~~an instantaneous~~ a dipole as electrons in the bond repel from those in the C=C double bond. The slightly positive bromine then accepts electrons from the C=C bond, leaving a negative bromine to donate electrons forming another bond. In benzene, a bromine nucleophile is produced instead, as a positive bromide ion. This accepts electrons from the delocalised ring in benzene, replacing a hydrogen which donates electrons to the ring and leaves as an H⁺ ion. The reason for different reactions is that the delocalised electron rings of benzene give it high stability, whereas the single double bond of cyclohexene means it's not as stable. Therefore, more energy is required to break the delocalised ring of benzene in order to add groups, therefore it's less likely to occur so substitution happens instead.

L1 response scoring 2 marks. The candidate identifies both reaction types but gives an explanation only in terms of mechanism involved. Does not address any of the criteria in AO2.1 for either reaction so cannot progress beyond Level 1

Question 3 (a)

- 3 Why does human hair turn grey? Studies have shown that this is caused by lower levels of the enzyme catalase in hair follicles. Catalase catalyses the breakdown of hydrogen peroxide as shown in **equation 3.1**.



When levels of hydrogen peroxide increase, the melanin (dye) in the hair is bleached.

- (a) Catalase has an active site.

Explain how this results in faster decomposition of hydrogen peroxide.

.....

.....

.....

..... [3]

This question was well attempted by most candidates, with many scoring at least two marks. Most candidates recognised that the hydrogen peroxide fits into the active site on the catalase (forming an enzyme – substrate complex), and that this resulted in a lowering of the activation enthalpy which increased the rate of reaction. Very few candidates made any reference to the fact that the complex formed resulted in the bonds within the peroxide molecule being broken more easily. Higher ability candidates often started their response by indicating that the active site in catalase has a complementary shape to the hydrogen peroxide and therefore scored all 3 marks.

Question 3 (b)

- (b) Suggest the **type** of reaction by which hydrogen peroxide bleaches melanin.

..... [1]

Very few candidates scored this mark. Some of the more common reactions suggested included hydrolysis, condensation, hydration and reduction.

Question 3 (c)

(c)* Some students are given a solution of catalase and solutions of hydrogen peroxide of different concentrations. They study the rate of reaction in **equation 3.1**.

They determine the relative initial rates of reaction at the different hydrogen peroxide concentrations, using the volume of oxygen produced.

Suggest the procedure they follow, including how the students should process their results. You may include a diagram as part of your answer.

This Level of Response question was well tackled by the vast majority of candidates. Most candidates scored at Level 2, with higher ability candidates regularly scoring at Level 3. There were two strands to this question that candidates needed to address; (i) designing a suitable procedure giving essential details (including some relevant fine detail), and (ii) explaining how they would process the data that they had collected.

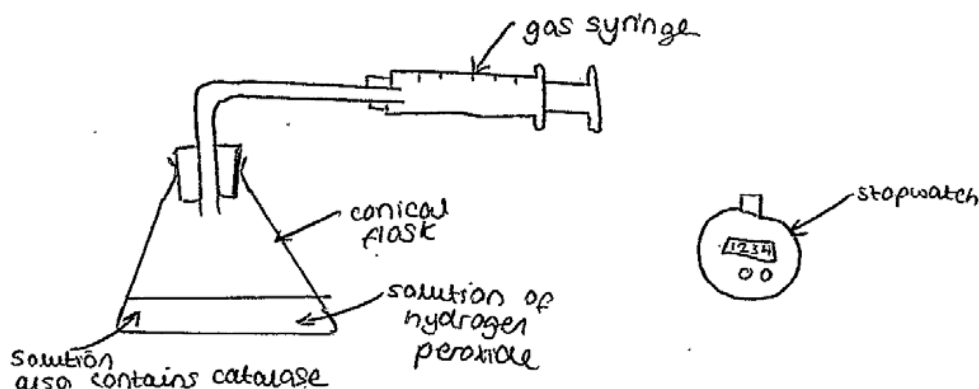
This is a practical procedure that candidates should be familiar with. Candidates should be able to describe a suitable workable method for this reaction, and indeed this was often the case. Many candidates produced diagrams of the apparatus which were a good indicator that their response was likely to be at least at Level 2 in the first strand.

The second strand of this question provided an element of discrimination. Candidates were required to explain how they would process their results; some produced outlines of the graphs that they would plot indicating the tangent to be drawn, which again gave examiners a quick idea of what the appropriate level was likely to be.

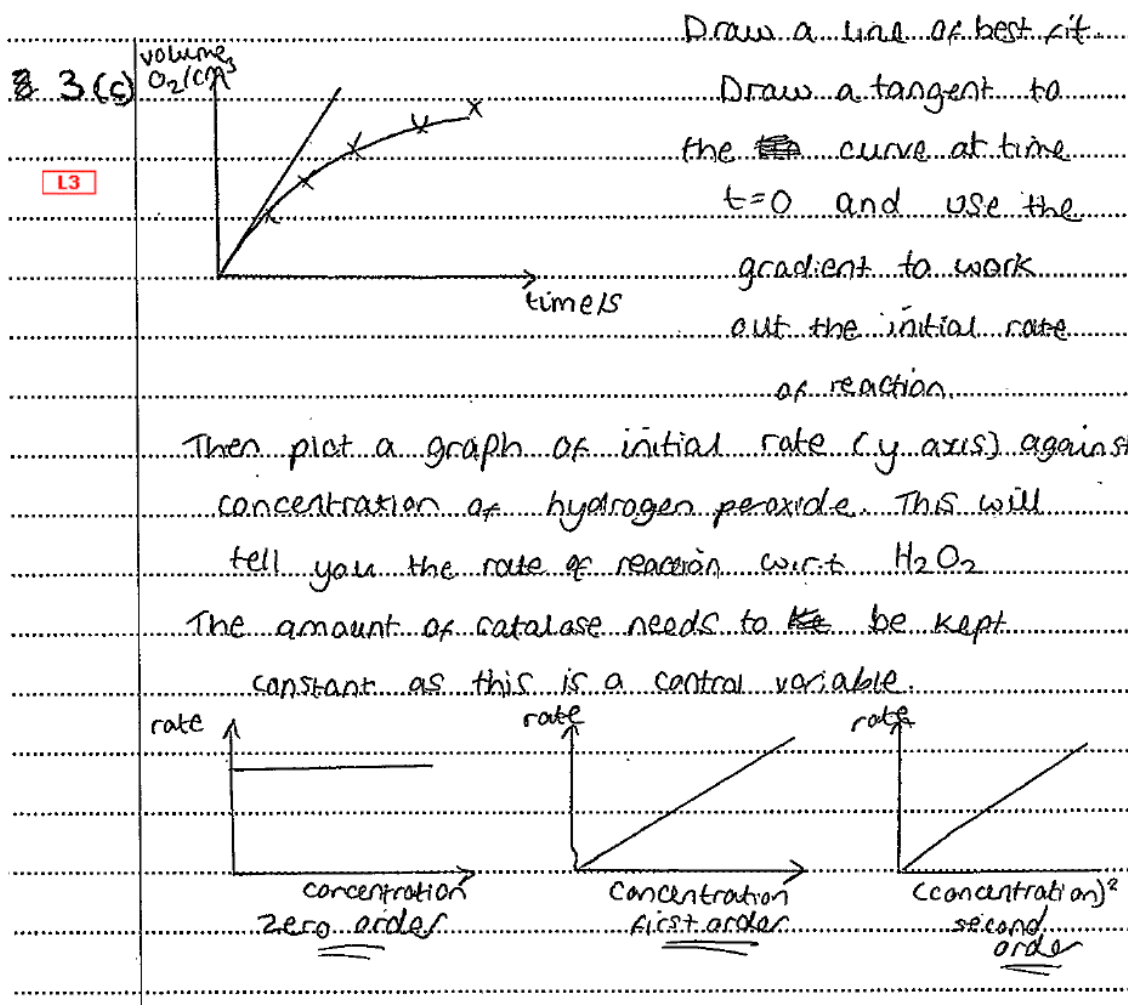
However, whilst many knew that they needed to produce a graph, they often suggested using a concentration vs rate graph, which was incorrect within the context of this question. This often meant that candidates who had produced a very detailed method were limited to Level 2 as the processing strand was weak.

Where candidates did not address one of the strands within their response, unfortunately this resulted in them being limited to Level 1.

Exemplar 6

Known

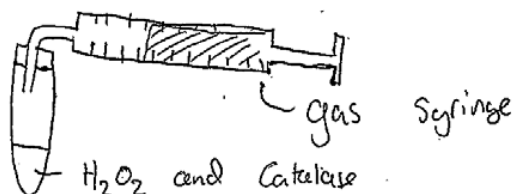
- Measure out equal volumes of different concentrations of hydrogen peroxide solution (eg. 25.0 cm³) using a burette or volumetric pipette. A clean, dry pipette can be used to run the solution into a clean conical flask.
 - Add a fixed volume of enzyme ~~activity~~ catalase solution to the conical flask, stopper the flask and start the stopwatch. The conical flask should be connected to a gas syringe to collect the oxygen gas formed.
 - At equal time intervals, (eg. every 10 seconds) measure the volume of oxygen in the gas syringe, to the nearest 0.05 cm³.
 - Keep doing this for 2 minutes, or until no more gas is produced. Repeat this procedure for all different concentrations of hydrogen peroxide.
 - Record results in a table of volume of oxygen (cm³) against time (s) and use this to plot a graph of volume of oxygen against time
- * Please see back page for the rest *



Level 3 response, scoring 6 marks. This includes all key variables, and a significant amount of fine detail, explaining clearly how to process the results collected. The answer continues onto additional space of answer booklet.

Whilst this was a Level 3 response, the candidate could have made their answer more succinct. Candidates are advised that the answer space provided should be sufficient to gain full marks for Level of Response questions, without needing to continue onto the additional answer space. In this case, the candidate could have omitted the superfluous discussion and diagrams of rate-concentration graphs they have included at the end of their response. The suggested procedure could also have been written more concisely whilst retaining sufficient detail to receive full credit.

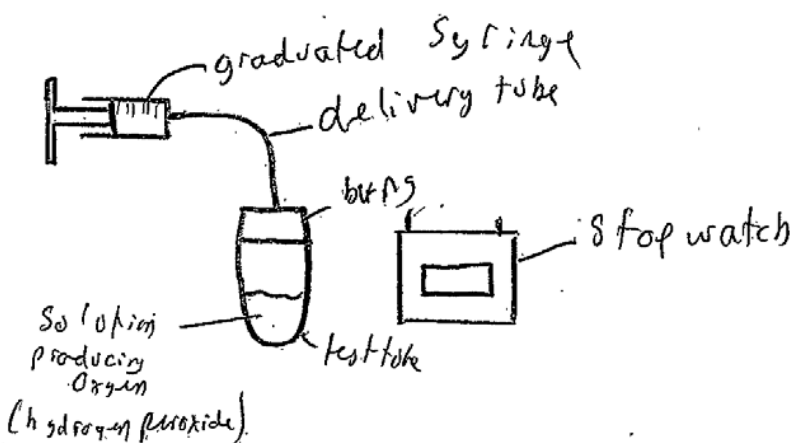
Exemplar 7



- The students will firstly produce equal moles of Catalase and H_2O_2 and the same concentration of Catalase enzyme will be used. Produce at least 5 different H_2O_2 concentrations.
- The students will measure the volume of gas being produced for each different concentration of H_2O_2 for a set interval of time (10 mins) using a stopwatch. This means for each concentration of H_2O_2 you will have the volume of O_2 produced by the recording of the gas syringe after the set time of 10 minutes. Repeat the procedure 10 times for each H_2O_2 concentration.
- The students can plot a graph of ~~concentration vs~~ volume of O_2 produced vs time (x-axis). Next plot the volumes for each H_2O_2 concentration. Draw a line of best fit for each of the graphs produced for each H_2O_2 concentration. [6]
- Next produce a tangent at $t=0$ for each H_2O_2 concentration graph and calculate gradient of tangents $(\frac{\Delta Y}{\Delta X})$ and therefore you will have the initial rate of reactions for each H_2O_2 concentration.

Level 2 response, scoring 4 marks. A workable procedure is outlined, but lacks fine detail which would have allowed the candidate to progress to Level 3. Good explanation of processing of results.

Exemplar 8

Method

- 1) Place a known volume of hydrogen peroxide in the test tube. Add the catalyst. Start the timer and place the bung in the top of the test tube.
- 2) Record how long 50 cm^3 of oxygen takes to be produced. Record the final time.
- 3) Repeat 3 times with the same volume.
- 4) Increase volume of hydrogen peroxide by 10 cm^3 and repeat for 6 results.

Process results

- V_g of oxygen = 1 cm^3
- find moles of O_2 produced with $n = \frac{m}{M_r}$ [6]
- 1:2 ratio. ~~double~~ the n_{O_2} for moles of H_2O_2
double
- $n = cV$
- concentration of hydrogen peroxide = $\frac{\text{moles}}{\text{volume}}$

Level 1 response scoring 2 marks. Provides an outline of a method that might work but makes no reference to the use of time to calculate a rate value.

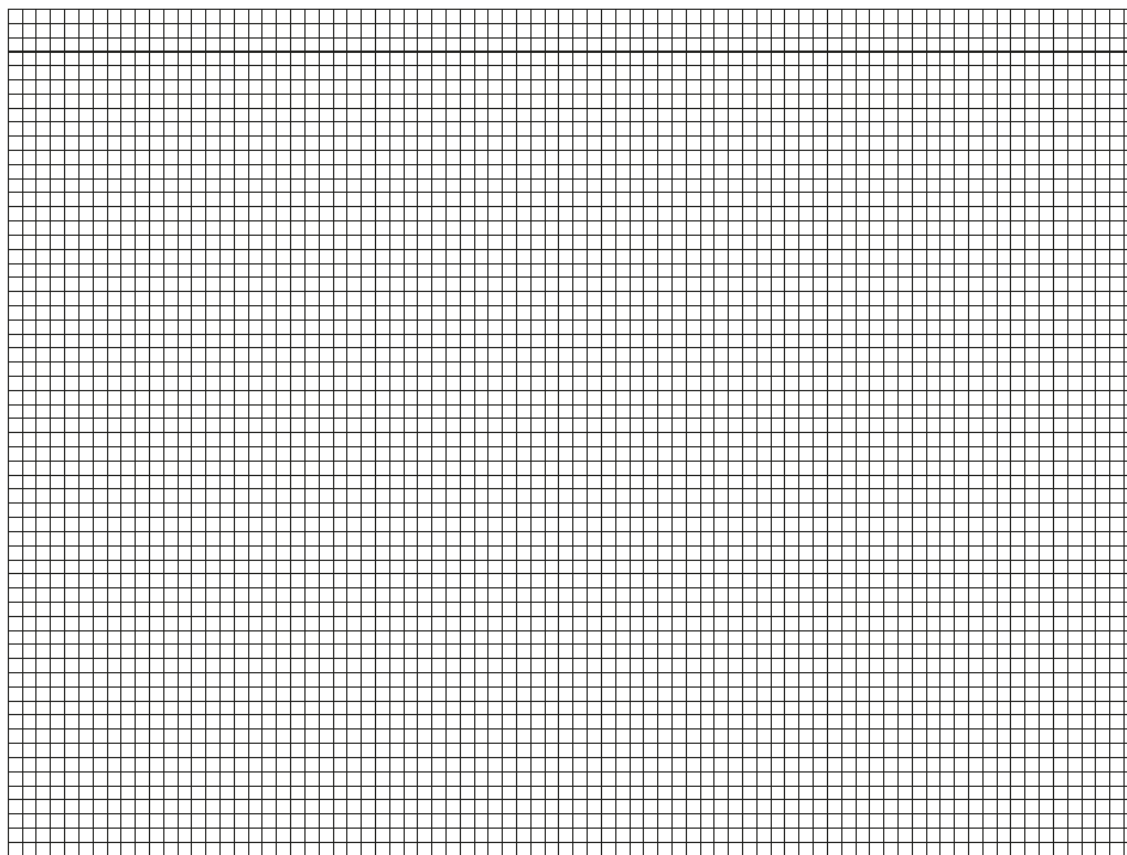
Question 3 (d) (i) and (ii)

(d) The students record their results as shown in the box below.

Concentrations of hydrogen peroxide: 0.05 – 0.35 in 0.05 intervals.
Units of concentration mol dm^{-3}
Corresponding relative rates of reaction: 1.0; 2.1; 3.0; 3.8; 4.0; 4.1; 4.1
Temperature: 20°C

(i) Arrange the results in a more appropriate format.

(ii) Use the grid below to plot a graph of the results and draw a line of best fit.



[4]

This question was generally well answered, with most candidates scoring at least 4 marks, and many scoring the full 6 marks. The only common errors were in part (i) the inclusion of some units for the rate of reaction column, and in (ii) reversing the x and y axis. Some candidates did lose one mark in part (ii) for failing to choose an appropriate scale to use that should have taken up a minimum of half the space available.

Question 3 (e) (i)

(e) A student says that the graph shows that the decomposition of hydrogen peroxide is first order with respect to both the hydrogen peroxide concentration and the catalase concentration.

- (i) Write the rate equation that would follow from the student's statement.
Give the units of the rate constant.

Rate equation:

Units of rate constant

[2]

This was a tricky question for many candidates. Most struggled to work out the units for the rate constant. The only other common error was the omission of "rate =" at the start of the rate equation.

Question 3 (e) (ii)

- (ii) Explain why the student is incorrect and give the correct information.

.....

.....

.....

.....

.....

.....

..... [3]

There were a lot of varied responses to this question. The majority of candidates scored at least one mark, but very few scored all three.

Many candidates used the graph in d(ii) to state that 'up to 0.2mol dm^{-3} (or, at low concentration) the reaction is first order with respect to hydrogen peroxide as the graph is a straight line'. Some also scored a second mark for realising that when the graph levelled off the rate became zero order as no matter how the concentration of peroxide changed, there was no further change in rate. They then tended to link this to the idea of the active sites being saturated.

Very few candidates identified that the statement was incorrect with regard to catalase as the catalase concentration was kept constant in this reaction.

Question 3 (f)

- (f) Hydrogen peroxide concentration is often measured as 'volume strength'.
1 cm³ of '1 volume' hydrogen peroxide produces 1 cm³ of oxygen at RTP.

Calculate the 'volume strength' of the 0.35 mol dm⁻³ hydrogen peroxide used by the students.



Give your answer to an **appropriate** number of significant figures.

'volume strength' = volume [3]

This question was a good discriminator, producing a full range of marks from 3 to 0. Lower ability candidates often struggled to score any marks here. Higher ability candidates also found this challenging. The most common mark was credited for identifying that the molar ratio between the peroxide and oxygen was 2:1, and so the moles of O₂ should be 0.175 (or 1.75 x 10⁻⁴ if converted from dm³ to cm³). Where candidates subsequently lost marks was in the next step for not realising that because oxygen is a gas, they needed to multiply their calculated number of moles by 24(dm³) or 24000(cm³) to then arrive at the final answer. This question included a mark that was for displaying their working, in order that where a candidate had not spotted the molar ratio, or had calculated the number of moles of oxygen by a different method, then examiners could award a mark for the use of 'x 24 (or 24,000)' as an error carried forward with the final mark being for converting their calculated value to 2 significant figures. A candidate who simply gave an incorrect final answer to this question scored 0, whereas candidates who did not arrive at the correct final answer but had displayed their working often scored 2 marks.

Exemplar 9

- (f) Hydrogen peroxide concentration is often measured as 'volume strength'.
1 cm³ of '1 volume' hydrogen peroxide produces 1 cm³ of oxygen at RTP.

Calculate the 'volume strength' of the 0.35 mol dm⁻³ hydrogen peroxide used by the students.



Give your answer to an **appropriate** number of significant figures.

Handwritten student work:

be rate = k [catalase] as this is the slowest step - rate determining step.

$\text{O}_2 = 1 \text{ cm}^3 = 1 \times 10^{-3} \text{ dm}^3$
 $\times 24000 \times 10^{-3} \text{ dm}^3 = 24 \text{ mole}$

$1 \times \frac{1}{24000} = 4.16667 \times 10^{-5} \text{ moles of O}_2$ *2 sig fig in Q.*

$n = 8.33333 \times 10^{-5} \text{ moles of H}_2\text{O}_2$

$c = 0.35 \text{ mol dm}^{-3}$

$v = \frac{8.33333 \times 10^{-5}}{0.35} = 2.38095 \times 10^{-4}$ 'volume strength' = 2.4×10^{-4} volume [3]

Calculation showing working being given credit, even though final answer is incorrect.

Question 3 (g)

(g) The students have 20.0 cm^3 0.35 mol dm^{-3} H_2O_2 and wish to make a 0.05 mol dm^{-3} solution.

How much water should they add?

volume of water to add = cm^3 [2]

Generally well answered. Most candidates scored at least one mark for arriving at an answer of 140 cm^3 , as they did not subtract the initial 20 cm^3 of peroxide solution.

Question 4 (a) (i) and (a) (ii)

- 4 The pH of human blood needs to be held within strict limits for good health. The pH is controlled using buffer systems. One buffer system is based on the equilibrium in **equation 4.1**.



- (a) (i) Give the **systematic** name for HCO_3^- .

..... [1]

- (ii) HCO_3^- can act as either an acid or a base.

Give the **formula** of the conjugate **base** of HCO_3^- .

..... [1]

This question produced mixed responses. A variety of (incorrect) oxidation states were quoted for the hydrogen carbonate ion in part (i) which negated the mark. In part (ii) common incorrect responses included H_2O , CO_2 and CO_3^- .

Question 4 (b) (i)

- (b) (i) Draw a 'dot-and-cross' diagram for CO_2 and use it to name the shape of the molecule.

'Dot-and-cross' diagram:

Shape of molecule [2]

Although the majority of candidates scored both marks here, there were a significant number of candidates who scored either 1 mark or 0. The most common errors evident included failing to include the lone pairs of electrons on the oxygen atoms in the 'dot and cross' diagram, or giving an incorrect shape for the molecule (e.g. bent, planar, 180°).

Question 4 (b) (ii)

- (ii) A CO_2 molecule has no dipole.
A student says that this is because bonds between carbon and oxygen atoms are not polar.

Discuss the student's statement.

.....
.....
.....
..... [2]

Many candidates did not score any marks at all here, and those who did score often only scored 1 mark for identifying the difference in electronegativity between the oxygen and carbon atoms. Lots of candidates discussed the shape of the molecule being symmetrical and so the charges/bonds cancelled out, or the charges pulled in the opposite directions. However, the question asked them to explain why CO_2 has no dipole, and so they needed to state that the bonds are polar but that the dipoles present cancel one another out. The issue here was more about the use of appropriate terminology rather than any fundamental misunderstanding.

Question 4 (c)

- (c) Another student says that CO₂ will form only instantaneous dipole-induced dipole bonds with water molecules.

Explain why this is incorrect.

.....

.....

.....

..... [2]

Many candidates correctly identified that the carbon dioxide molecule was capable of forming hydrogen bonds to the water molecules, but did not identify that it was the lone pair on the oxygen atom (of the CO₂ molecule) that was forming the bond to the δ+ charge on the hydrogen atoms of the water molecules. Higher ability candidates did score both of these marks.

Question 4 (d) (i) and (d) (ii)

- (d) For the equilibrium in **equation 4.1**:

$$K_a = \frac{[\text{HCO}_3^-][\text{H}^+]}{[\text{CO}_2(\text{aq})]} = 7.9 \times 10^{-7} \text{ mol dm}^{-3}$$

- (i) A saturated solution of CO₂ at 298 K has a concentration of 3.3 × 10⁻² mol dm⁻³.

Calculate the pH of this solution.

pH = [2]

- (ii) Calculate the concentration of a solution of HCl that has the same pH as the solution in (i).

concentration = mol dm⁻³ [1]

In general, this section of questions (4d(i) – 4f), were well answered, clearly showing that candidates and teachers had spent an appropriate amount of time working through many examples of these calculations. In many cases the answers were very clearly laid out and it was easy to see where marks could be credited. This was especially helpful where candidates had made some slips, as it allowed examiners to award credit for use of the appropriate methodology, even if the final answer did not match that expected on the mark scheme.

In 4d(i), most candidates used the data provided to arrive at the correct answer and scored 2 marks. There were a small number of candidates who used an incorrect value for the concentration of H^+ ions (usually either 3.3×10^{-2} or 7.9×10^{-7}), but used this correctly to calculate a pH value.

Where candidates did not arrive at the correct pH value in part (i), they could still gain the mark in part (ii) but only if their suggested pH was in the range pH 3 – 6. The rationale behind this was that candidates were told in the stem of the question that they were using a solution of hydrochloric acid, which they should realise is a strong acid, and so the pH value definitely should not exceed pH 7.

Question 4 (e) (i)

(e) (i) The pH of healthy human blood is 7.4.

Calculate the ratio of $\frac{[\text{HCO}_3^-]}{[\text{CO}_2]}$ in healthy human blood.

$$\frac{[\text{HCO}_3^-]}{[\text{CO}_2]} = \dots\dots\dots [2]$$

Many candidates scored at least one mark here as they correctly converted the pH value for the blood into a concentration value for H^+ ions to then use. Once this was arrived at some stumbled and did not realise that they needed to use the K_a value from part d(i) to work out the ratio. However, there was clear evidence that candidates had worked through this type of question in their preparation for the examination, and many scored both marks. Again as with all other parts of this question, where candidates had incorrectly calculated a value for the H^+ concentration, or had used an incorrect value for K_a , credit was given for showing their working.

Exemplar 10

when pH = 7.4

$$[\text{H}^+] = e^{-7.4} = 6.1125 \times 10^{-4}$$

$$K_a = \frac{[\text{HCO}_3^-][6.1125 \times 10^{-4}]}{[\text{CO}_2]}$$

$$\frac{K_a}{6.1125 \times 10^{-4}} = \frac{[\text{HCO}_3^-]}{[\text{CO}_2]}$$

$$\frac{7.9 \times 10^{-7}}{6.1125 \times 10^{-4}} = \frac{79}{61125}$$

$$\frac{[\text{HCO}_3^-]}{[\text{CO}_2]} = 1.29 \times 10^{-3} [2]$$

This candidate has calculated an incorrect value for $[\text{H}^+]$ from the pH value, but has then used this appropriately to calculate the ratio. As their working is shown clearly, they have received partial credit for this question through error carried forward.

Question 4 (e) (ii)

- (ii) A patient's blood has a pH below 7.4. A student says that HCO_3^- needs to be added to the patient's blood.

Say, with reasons, whether the student is correct.

.....

.....

.....

..... [2]

Most candidates scored 1 mark for correctly stating that the addition of HCO_3^- would move the equilibrium to the left, or, that it would increase the pH. However, they did not identify that the patient's blood was too acidic, or contained too many H^+ ions, and consequently many candidates only scored 1 mark here.

Question 4 (f)

- (f) Some students mix 20 cm^3 of $5.0 \times 10^{-3}\text{ mol dm}^{-3}\text{ HCl}$ with 20 cm^3 of $1.0 \times 10^{-2}\text{ mol dm}^{-3}\text{ NaOH}$.

Calculate the pH of the resulting solution.

pH = [3]

Very few candidates scored more than 1 mark here. Many did calculate that the NaOH was in excess, and that once the reaction was complete there were 1×10^{-4} moles of NaOH remaining, scoring 1 mark. At this stage a variety of approaches were taken that did not involve calculating the new concentration of OH^- ions. Candidates did not appreciate that the total volume of the solution was 40 cm^3 , and so used their value of 1×10^{-4} to calculate a pH value of 10. However, the convention is for pH values to be quoted to 1 decimal place and this was stated in the mark scheme. Therefore an answer of pH = 10 did not score a second mark.

Some candidates had not realised that the NaOH was in excess, and had simply calculated the number of moles of NaOH initially present. This did not gain any credit. If they did then recognise that the total volume of solution was 40 cm^3 , and used this appropriately, they could still score marking points 2 and 3.

Question 5 (a)

5 This question concerns the pre-release article *The Strange Story of Napoleon's Wallpaper* that is included as an insert with this paper.

(a) One reason arsenic is poisonous because it reacts with –SH groups in amino acids.

Suggest how the removal of –SH groups might interfere with the way these amino acids form proteins.

.....
..... [1]

Question 5 required that centres had given candidates time and opportunity to study the pre-release article "The Strange Story of Napoleon's Wallpaper". It was anticipated that teachers would have spent some time discussing some of the chemistry within the article. The focus of the article should have prompted teachers to guide candidates towards looking at the properties and reactivity of Group V elements, nitrogen and phosphorous. These could be used to predict some of the reactions and properties of arsenic by extending the group trend(s).

In part (a) most candidates recognised that the removal of the –SH groups would interfere with the ability of the protein to form the correct tertiary structure. However, to score the mark here they had to make it clear that the arsenic was preventing the formation of S—S bonds (disulfide bridges). It was pleasing to see that in the vast majority of responses that this was the answer given.

Question 5 (b)

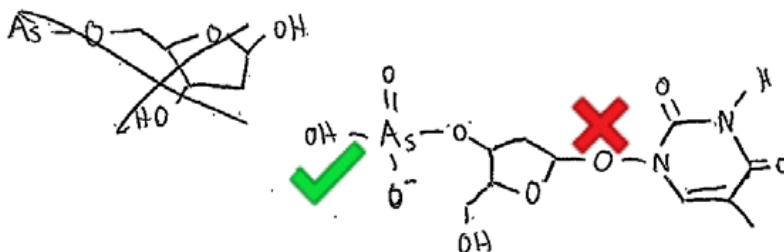
(b) Arsenate(V) can replace phosphate(V) in nucleic acids.

Draw the skeletal formula of a DNA nucleotide containing thymine and with As instead of P.

[2]

In part (b) candidates needed to make use of the relevant section from the Data Sheet provided. They needed to select the appropriate sugar structure (deoxyribose) and derive the structure of thymine. Finally they needed to substitute As for P in the phosphate group and then join the fragments together in order to produce the correct structure. Many candidates succeeded in this and scored both of the marks available. The two most commonly seen errors were the inclusion of a bridging O atom between the thymine molecule and the deoxyribose ring, or the omission of the C=C within the thymine structure.

Exemplar 11



Exemplar response showing the incorrect depiction of a bridging O between thymine and the deoxyribose ring

Question 5 (c)

- (c) Write an equation for the reaction of a solution of As^{3+} with hydrogen sulfide. Show state symbols.

[2]

This was found difficult by candidates, with. Most candidates did not realise the need to balance the charges within the equation and so gave $3\text{H}_2(\text{g})$ as a product rather than $6\text{H}^+(\text{aq})$, losing 1 mark. Many gave the formula of $\text{As}_2\text{S}_3(\text{s})$ in an unbalanced equation, and this was allowed for 1 mark.

Question 5 (d) (i)

- (d) A Marsh test is carried out for arsenic in a sample of As_2O_3 .
- (i) Draw a labelled diagram of a suitable apparatus, showing the reactants and products.

[3]

This was a well answered question and most candidates scored full marks. There were some examples of apparatus that, whilst being impractical or potentially dangerous, did match to the description given in the pre-release material. The marks were not for designing something that would meet today's Health and Safety requirements, but for recognising candidates' ability to extrapolate a description into a suitable diagram of a set up that might work. Therefore sealed tubes, or open tubes with hydrogen escaping near a naked flame, did not result in the loss of any marks. The only common error evident was in failing to label the apparatus appropriately (e.g. failing to label where the arsenic metal would be deposited, or failing to label the heating of the glass tube leaving the reaction flask) Marks were lost through carelessness rather than an inability to produce a suitable diagram..

Question 5 (d) (ii)

- (ii) Write equations for the formation and decomposition of arsine in the apparatus.

Many candidates did not write a balanced equation for the formation of arsine in the reaction vessel, but were able to write a balanced equation for the decomposition of arsine to form arsenic and hydrogen as the products and so scored 1 mark here. In the first equation a common error that was observed was the inclusion of oxygen gas, O_2 , as one of the products of an otherwise balanced equation, which resulted in the mark not being credited.

Question 5 (e) (i)

- (e) The structure of Scheele's green can be represented as $Cu^{2+}(AsO_2OH)^{2-}$.

- (i) Suggest a 'dot-and-cross' diagram for the anion in Scheele's green.

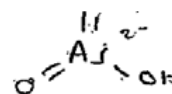
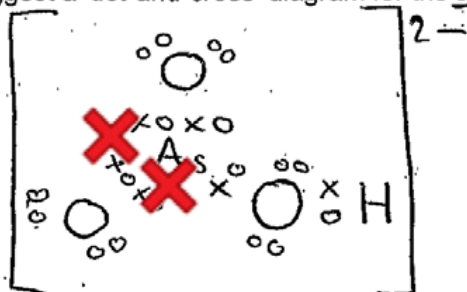
[2]

A number of candidates identified the anion present in *Scheele's Green*, but were unable to then draw the appropriate dot and cross diagram. The most common errors were to produce diagrams containing double bonds to one or more oxygen atom giving ten or more electrons around the central As atom, failing to include a lone pair of electrons on the As atom, and failing to check that each oxygen atom satisfied the octet rule.

Exemplar 12

- (e) The structure of Scheele's green can be represented as $Cu^{2+}(AsO_2OH)^{2-}$.

- (i) Suggest a 'dot-and-cross' diagram for the anion in Scheele's green.

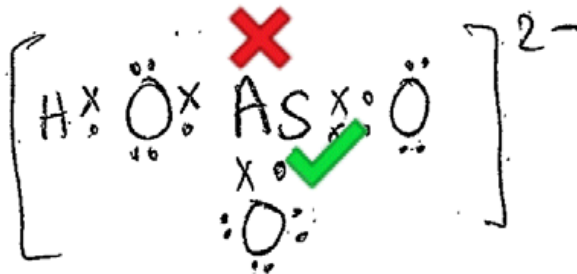


Commonly seen incorrect dot and cross diagram for bonding of Scheele's Green anion.

Exemplar 13

(e) The structure of Scheele's green can be represented as $\text{Cu}^{2+}(\text{AsO}_2\text{OH})^{2-}$.

(i) Suggest a 'dot-and-cross' diagram for the anion in Scheele's green. *negative ion*



No lone pair on central As atom, but each atom has its full complement of electrons around its outer shell arrived at by drawing a double bond to one of the oxygen atoms.

Question 5 (e) (ii)

(ii) State which part of Scheele's green is responsible for the green colour.

..... [1]

Most candidates scored this mark as they recognised that coloured substances usually contain a transition metal ion, and so gave Cu^{2+} or copper(II) as their answer. The only common errors were the omission of the charge on the ion, or the omission of the oxidation state after the name of the element.

Question 5 (f)

(f) State and explain the C-As-C bond angle in trimethylarsine.

.....

 [4]

Most candidates scored at least three marks here, and many went on to score all four marks. The only common omission was in failing to make it clear that the lone pair of electrons present on the central arsenic atom had a stronger repulsion on the bonding pairs of electrons and that this produced the bond angle of 107.5° .

Question 5 (g)

(g) Summarise the evidence that Napoleon was killed by his wallpaper.

.....

.....

.....

.....

.....

.....

..... [3]

Most of the candidates were able to provide a response here that scored two if not all three marks. They had clearly studied the pre-release material appropriately and were able to summarise the three key pieces of evidence accurately. Where candidates only scored two marks was often a result of omitting marking point 1 – that traces of arsenic were found in the sample of Napoleon's hair. Most candidates made the link between the Scheele's Green pigment found in the wall paper sample, and that the island environment would have caused the paper to become mouldy. This would then result in releasing toxic arsenic compounds as a vapour that Napoleon would have been exposed to over a period of time.

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