

Examiners' Report

June 2024

GCE Chemistry 9CH0 02

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Introduction

Paper 2 in the Pearson Edexcel Level 3 Advanced GCE in Chemistry (9CH0) qualification seemed accessible to many candidates and provided them with the opportunity to demonstrate their knowledge and understanding of the key concepts in Topics 2, 3, 5, 6, 7, 9 and 16-19.

Evidence from marked work suggested that candidates had sufficient time to attempt all questions, with significant blank spaces seen in only a few cases.

The mean mark for the paper was higher than in 2023, though the spread of marks was greater. There were many opportunities for candidates to highlight their knowledge in familiar contexts, such as organic mechanisms, use of the ideal gas equation and initial rates experiments, and these areas were a strength for this cohort.

As you would expect, more demanding problems required application of ideas to novel scenarios, such as in questions 3(d)(ii) and 5(d)(i), which provided a significant degree of discrimination.

The multiple-choice questions proved relatively straightforward in most cases, with a mean mark of just over 7 marks. The most challenging example was Q06(a), where only 50% of candidates realised that radio waves interact with nuclei in NMR. However, naming compounds proved to be a strength, with 94% of candidates able to deduce the IUPAC name to chloroprene.

Question 1 (c)(i)

Previous exam sessions have shown that candidates are often able to accurately recall diagrams to show mechanisms in organic chemistry. However, chemists need to be literate as well, and this question tested the ability of candidates to both recall **and** explain what is happening in the reaction. Many candidates correctly identified both roles of ammonia in the reaction. However, some answers showed a misunderstanding of basic behaviour by linking it to the acceptance of a bromide ion. Some candidates didn't make it clear which carbon atom was attacked by the nucleophilic ammonia, and others described the removal of a hydrogen, rather than hydrogen ion, with no clear reference to the source of this ion.

(c) Ammonia reacts with bromoethane as shown.



- (i) Explain, by referring to the reaction mechanism, the roles of ammonia in the formation of each of the products of this reaction.

(3)

Ammonia acts as a nucleophile to form ethylamine. Ammonia also acts as a base as it accepts ~~the~~ H^+ ions produced and forms an ionic bond with the bromide ion produced.



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Examiner Comments

This example identifies both the nucleophilic and basic behaviour of ammonia in the reaction.

Although the candidate realises that basic behaviour is defined as acceptance of a hydrogen ion, to score an additional mark they would have to identify the source of the ion, in this case from the intermediate $\text{CH}_3\text{CH}_2\text{NH}_3^+$ ion.



ResultsPlus
Examiner Tip

When explaining what happens in an organic reaction involving a base, remember to highlight the source of the hydrogen ion.

Question 1 (d)

Over 70% of candidates scored both marks, and it was pleasing to see few errors in the calculations of relative formula masses. Probably the most frequent error was a failure to give a final answer to one decimal place. The specification clearly defines atom economy in percentage terms, but a small number of candidates gave their final answer in decimal format.

- (d) The halogenoalkane, 1-bromobutane, can be formed by the reaction of butan-1-ol with sodium bromide and sulfuric acid.



Calculate the atom economy, by mass, for the formation of 1-bromobutane. Give your answer to **one** decimal place.

[A_r values: H = 1.0 C = 12.0 O = 16.0 Na = 23.0 S = 32.1 Br = 79.9]

(2)

$$\begin{array}{c} \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br} \\ (4 \times 12) + (9 \times 1) + 79.9 = 136.9 \end{array}$$



$$23 + 1 + 32.1 + (16 \times 4) + 16 = 138.1$$

$$138.1 + 136.9 = 275$$

$$\frac{136.9}{275} = 0.5$$



This candidate has correctly calculated the sum of molar masses of both the desired product and all products, but does not express their final answer as a percentage.



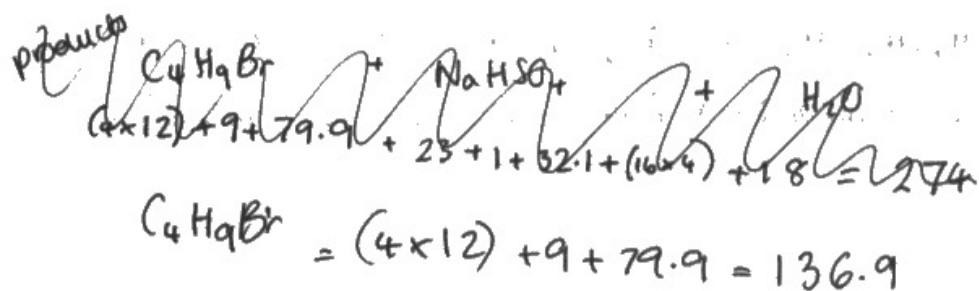
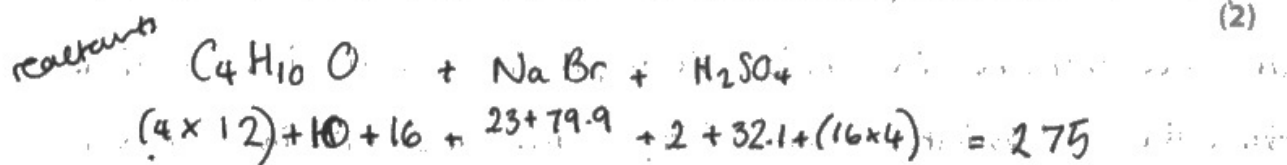
The specification defines atom economy and yields in terms of percentages, so examiners expect candidates to process their final answer in line with this definition.

- (d) The halogenoalkane, 1-bromobutane, can be formed by the reaction of butan-1-ol with sodium bromide and sulfuric acid.



Calculate the atom economy, by mass, for the formation of 1-bromobutane.
Give your answer to **one** decimal place.

[A_r values: H = 1.0 C = 12.0 O = 16.0 Na = 23.0 S = 32.1 Br = 79.9]



$$\frac{136.9}{275} \times 100 = 49.781$$

$$= \underline{\underline{49.8}}$$



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Examiner Comments

This candidate has correctly calculated the sum of molar masses of both the desired product and all products and does express their final answer as a percentage, including the rounding to one decimal place, as requested by the question.



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Examiner Tip

Remember to follow instructions regarding decimal places or significant figures given in the question.

Question 2 (b)

Most candidates understood the role of the Grignard reagent, in terms of either forming carbon-carbon bonds, or more frequently, to extend the carbon chain length. A small number of candidates missed out on the mark as they concentrated solely on the formation of the range of possible products rather than the carbon chain extension.

(b) State the use of Grignard reagents in organic synthesis.

(1)

To allow for the carbon to become δ^- ,
and therefore attach one compound as a nucleophile.



ResultsPlus
Examiner Comments

The candidate stops short of the key point here, as although they recognise the key carbon atom in a Grignard reagent has a partial negative charge, they do not point out that this enables a single bond to form with another carbon atom.



ResultsPlus
Examiner Tip

Remember that Grignard reagents allow new carbon-carbon single bonds to form so can extend carbon chains.

(b) State the use of Grignard reagents in organic synthesis.

(1)

To extend the carbon chain of reactants



ResultsPlus
Examiner Comments

A concise correct answer that clearly states the role of a Grignard reagent in organic chemistry.

Question 2 (d)

Candidates found this challenging, often hindered by assuming that the carbon atom attached to the magnesium atom would have a partial positive charge, even though over half the cohort recognised that Grignard reagents are classed as nucleophiles in Q02(c). As a result, many candidates assumed ethanol would form rather than ethane.

(d) Grignard reagents must be kept dry.

Predict the **organic** product that forms when $\text{CH}_3\text{CH}_2\text{MgBr}$ reacts with water.
Justify your answer by considering the polarity of both $\text{CH}_3\text{CH}_2\text{MgBr}$ and water.

Bromine of $\text{CH}_3\text{CH}_2\text{MgBr}$ is δ^- . In H_2O , ⁽²⁾Hydrogen
is δ^+ . Therefore, $\text{CH}_3\text{CH}_2\text{MgBr}$ attacks the ~~Oxygen~~ Hydrogen
of H_2O . Therefore, likely to form CH_3CH_3 .



ResultsPlus
Examiner Comments

The partial charges on both bromine and hydrogen atoms are identified accurately, but the key is to realise that the carbon attached to the magnesium has a partial negative charge. However the candidate did predict the correct product, so scored 1 mark.



ResultsPlus
Examiner Tip

In Grignard chemistry the key reaction site is the carbon atom with a partial negative charge.

(d) Grignard reagents must be kept dry.

Predict the **organic** product that forms when $\text{CH}_3\text{CH}_2\text{MgBr}$ reacts with water.
Justify your answer by considering the polarity of both $\text{CH}_3\text{CH}_2\text{MgBr}$ and water.

(2)

~~$\text{Mg}(\text{OH})\text{Br}$ will form and $\text{CH}_3\text{CH}_2\text{O}^-$~~

CH_3CH_3 will form as the water has a polar $\delta^-\text{O}-\delta^+\text{H}$ bond and the $\delta^-\text{C}$ will attack the hydrogen atom. The $\text{C}^{\delta-}-\text{Mg}^{\delta+}\text{Br}$ means the carbon acts as a nucleophile when it attacks the water.



ResultsPlus
Examiner Comments

The partial charges on both carbon and hydrogen atoms are identified accurately, enabling the candidate to predict the correct product, so 2 marks scored.

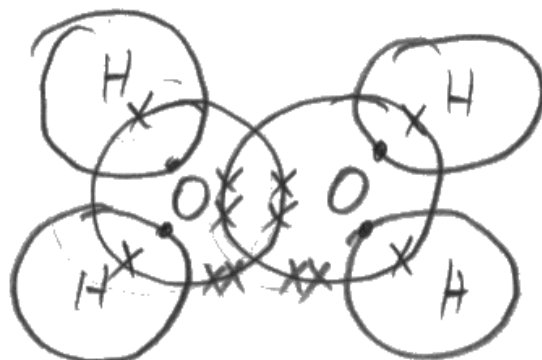
Question 3 (a)

The best answers went beyond the requirements of the mark scheme, providing a key to make it clear where each electron originated from. However, use of a double bond between two oxygen atoms, resulting in an oxygen outer shell containing nine electrons, was the most common error.

3 This question is about hydrogen peroxide, H_2O_2 .

(a) Draw a dot-and-cross diagram of a molecule of hydrogen peroxide.

(1)



The use of a double bond between the two oxygen atoms was a common mistake, compounded here by misreading the formulae and including four hydrogen atoms. In addition each oxygen outer shell contains 10 electrons, which is more than the 2nd main energy level can accommodate.



Check the number of electrons in the outer shells of dot-and-cross is consistent with the number of available orbitals.

Question 3 (b)

The marking team saw many excellent answers with candidates taking care to work out oxidation numbers and use them to deduce exactly what changes occurred in terms of oxidation and reduction. The most common error was probably in the calculation of the oxidation number of oxygen in hydrogen peroxide, with candidates omitting to take into account the two oxygen atoms in the formula. Other candidates' answers lacked clarity when describing the reactions, by not directly linking the terms oxidation and reduction to specific changes in oxidation number.

(b) Hydrogen peroxide decomposes to form water and oxygen.



Explain, using oxidation numbers, why the decomposition of hydrogen peroxide is classified as a disproportionation reaction.

(3)

Oxygen
oxidised from -1 in H_2O_2 to 0 in O_2
oxygen reduced from -1 in H_2O_2 to -2 in H_2O
one species is both oxidised and reduced, meaning
reaction is disproportionation.



ResultsPlus
Examiner Comments

This example correctly identifies all the oxidation numbers of oxygen atoms, and correctly links the changes in oxidation number to the correct type of reaction, so scores all 3 marks.



ResultsPlus
Examiner Tip

When using changes in oxidation to explain redox reactions, always link a specific change directly to either reduction or oxidation as appropriate.

Question 3 (c)(i)-(iii)

Candidates seemed well prepared for this type of question and for many, both orders were deduced correctly, even though both variables changed when considering experiments 2 and 3 from the table. Occasional slips were seen in (c)(ii), notably omission of the rate constant, k . The data in (c)(iii) was nearly always processed correctly to calculate k , sometimes the marks being awarded via a transferred error from the rate equation. The mean mark for the item overall was 4, and the area for candidates to consider in future series, is ensuring they can deduce the correct units for k as the omission of the units was probably the most common error.

- (c) The decomposition of hydrogen peroxide is catalysed by iodide ions, $\text{I}^-(\text{aq})$.

The kinetics of this reaction were investigated using different concentrations of hydrogen peroxide and iodide ions.

The results are shown in the table.

Experiment	$[\text{H}_2\text{O}_2(\text{aq})] / \text{mol dm}^{-3}$	$[\text{I}^-(\text{aq})] / \text{mol dm}^{-3}$	Rate / $\text{mol dm}^{-3} \text{s}^{-1}$
1	0.100	0.0500	8.90×10^{-7}
2	0.400	0.0500	3.56×10^{-6}
3	0.200	0.100	3.56×10^{-6}

- (i) Deduce the order of reaction with respect to hydrogen peroxide and to iodide ions.

(2)

Order with respect to hydrogen peroxide 1st order

Order with respect to iodide ions 0 order

- (ii) Write the rate equation for the reaction using your answer to (c)(i).

(1)

$$\text{Rate} = k [\text{H}_2\text{O}_2]$$

- (iii) Calculate the rate constant, k , using data from Experiment 3. Include units in your answer.

(2)

$$3.56 \times 10^{-6} = k(0.200)$$

$$k = 1.78 \times 10^{-5} \text{ s}^{-1}$$



Here the candidate has not deduced the order with respect to iodide ions correctly, so only scores 1 mark for part (c)(i). However their rate equation and subsequent calculation, including appropriate units, in parts (c)(ii) and (c)(iii) are consistent with their answer to (c)(i). This enabled transferred error marks to be awarded, giving an overall score of 4 marks for the three sections.



Always persevere with a multi-step problem, even if you are not sure whether earlier parts are correct. Where possible, examiners will look to award marks when candidates use the correct method with incorrect values calculated earlier in the question.

Question 3 (d)(i)

Around 80% of candidates were able to describe the test for oxygen clearly. Those who missed the mark tended to either discuss a 'lit splint' rather than glowing, or mistakenly thought the test outcome would be a 'squeaky pop'.

- (d) The breakdown of hydrogen peroxide with iodide ions as a catalyst is the basis of the demonstration 'Elephant's Toothpaste'.

The presence of a detergent results in a rapid eruption of foam as the oxygen gas is released.

- (i) Describe the test and the positive result that confirms the gas produced is oxygen.

(1)

~~relight damp splint.~~

put damp splint near gas produced,
if it is relit oxygen is present.



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Examiner Comments

This candidate has struggled to recall the test, describing a glowing splint incorrectly as a damp splint.



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Examiner Tip

Early on in your GCE course make sure you can recall key gas tests from GCSE including the tests for hydrogen, oxygen, carbon dioxide and chlorine.

Question 3 (d)(ii)

Candidates needed to link factual knowledge from the specification to solve this problem, and this proved demanding for many. Some candidates did try, noting that the iodide ions behaved as a catalyst so would be unchanged, therefore must cause the colour. Others suggested the source of the colour was nitrogen dioxide. However, the key to this question was recognition that aqueous iodine solution is yellow/brown in colour, but even those candidates that recognised this did not realise how it might form during the demonstration.

(ii) The foam produced often has a slight yellow/brown colour.

Explain what causes this colour, which is **not** caused by the detergent.

(2)

Some I^- ions will dissolve in water and form I_2 molecules, a low concentration of I_2 can give a yellow/brown colour.



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Examiner Comments

Iodine, using its formula, I_2 , has been correctly linked to the yellow/brown colour. However there is no attempt to justify how it formed, so only 1 mark is awarded.



ResultsPlus
Examiner Tip

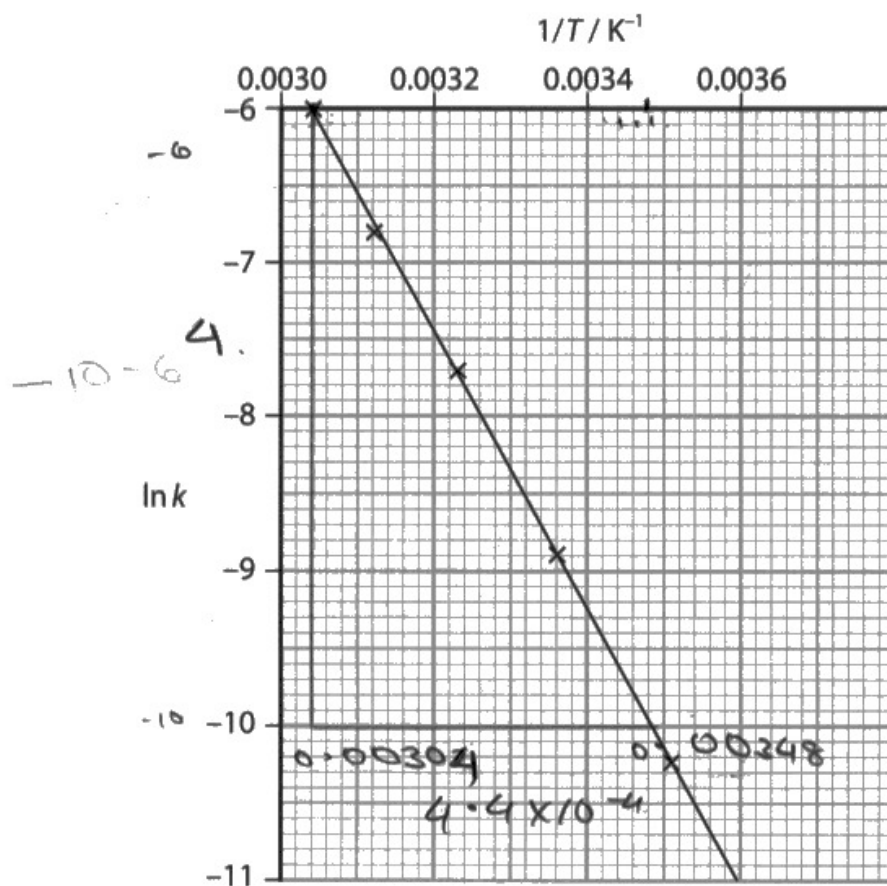
Remember that questions using the command word 'explain' require a justification / exemplification of a point in order to score full marks.

Question 3 (e)(i)-(ii)

Candidates were familiar with the processes required here and it was rare to see a response unable to score some credit. However, many answers showed errors and despite the candidates clearly knowing what to do, they missed at least one mark. Taking care when reading values from the axes is key, and as the question made clear, working to deduce these values had to be clearly shown on the graph. This could be as simple as extrapolation lines to the x and y axes. A small number of candidates didn't appreciate that the gradient had a negative value. The most common error concerned the units for the gradient. The units tended to be omitted completely or involved spurious units from the logarithmic scale. Most candidates were able to calculate a value for activation energy in (e)(ii), though a small number used incongruent units, eg using kJ mol^{-1} without converting their value appropriately.

- (e) The effect of temperature on the rate of the decomposition of hydrogen peroxide without a catalyst was also investigated.

A graph of $\ln k$ against $1/\text{temperature } (1/T)$ was plotted.



- (i) Determine the gradient of the graph.
Include units in your answer. You must show your working on the graph.

(3)

$$\text{gradient} = \frac{\text{rise}}{\text{run}} = \frac{-6 - -10}{0.00348 - 0.00304}$$

$$= \frac{4}{4.4 \times 10^{-4}}$$

$$\text{units} = \frac{\ln \text{mol}^{-1} \text{dm}^3 \text{s}^{-1}}{\text{K}^{-1}}$$

$$= 9090.91 \text{ K}$$

- (ii) Calculate the activation energy, E_a , of the reaction, in kJ mol^{-1} , using your answer to (e)(i) and the Arrhenius equation shown:

$$\ln k = -\frac{E_a}{R} \times \frac{1}{T} + \text{constant}$$

[Gas constant (R) = $8.31 \text{ J mol}^{-1} \text{ K}^{-1}$]

$$\text{gradient} = -\frac{E_a}{R}$$

$$9090 - 90 = \frac{-E_a}{8.31}$$

$$75545.45 = -E_a$$

$$E_a = -75545.45 \text{ J mol}^{-1} \text{ K}^{-1}$$

$$= 75.54 \text{ kJ mol}^{-1}$$



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Examiner Comments

Although the numerical value and units for the gradient are correct in (e)(i), the candidate has not realised, either by the way they framed their calculation, or by looking at the downward slope of the line, that the gradient is negative.

However they have appreciated this mistake in (e)(ii) and corrected the activation energy to ensure it is a positive value. Hence they were awarded 2 marks for (e)(i) and 1 mark for (e)(ii).



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Examiner Tip

Always check whether or not calculated gradients are negative or positive, including a sign to reinforce your understanding.

Question 3 (f)

Although the equation was unfamiliar many candidates could take into account both the rearrangement and use of 'e' in order to calculate a value for A. Even those candidates who struggled with the rearrangement could often gain some credit for transposing values correctly into the exponential expression.

(f) Another way to write the Arrhenius equation is shown.

$$k = Ae^{-E_a/RT}$$

The constant A is often called the collision factor as it is linked to the orientation of the particles colliding in a reaction.

The decomposition of hydrogen peroxide is also catalysed by aluminium.

Calculate a value for A at 370K, for the catalysed decomposition of hydrogen peroxide with an activation energy, E_a , of $5.02 \times 10^4 \text{ J mol}^{-1}$ and a numerical value for the rate constant of 1.60×10^{-3} .

Units are **not** required.

(2)

$$1.6 \times 10^{-3} = A e^{-\frac{5.02 \times 10^4}{8.31 \times 370}}$$

$$e^{-\frac{5.02 \times 10^4}{3074.7}} = 8.11638 \times 10^{-8}$$

$$\frac{1.6 \times 10^{-3}}{8.11638 \times 10^{-8}} = A$$

$$19713.21 = A$$



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Examiner Comments

Although the equation is unfamiliar this candidate follows a logical approach by initially transposing all the data from the question into the equation. Their method is clear, showing that they raise 'e' to the correct value, and use this to calculate A.



ResultsPlus
Examiner Tip

When using an unfamiliar equation, always start by transposing all the data for the question into the equation.

Question 4

This question attracted the full range of marks, with many candidates able to say something relevant to the way we can make polymer use more sustainable. A large number of candidates had used the specification effectively in their learning so were able to focus on recycling, incineration for energy and cracking for feedstock as the backbone of their response. Many candidates also realised that biodegradable polymers could be beneficial, though a minority focused on the use of plant materials in polymer production, rather than the ease of breakdown after use.

Although candidates tended to appreciate that incineration could lead to the production of toxic or harmful pollutants, far fewer went on to discuss the need to reduce the levels of these pollutants, which is key for a more sustainable use. It was common to see responses spend a lot of time discussing the negative impact of polymers related to landfill. Whilst true, this line of argument wasn't relevant to improvements in sustainability on its own and perhaps cost some candidates valuable time.

- *4 Discuss the role society, and chemists in particular, can play in order to contribute to a more sustainable use of polymers.

Your answer should consider

- the different ways of dealing with waste polymers
- how chemists can limit the problems caused by the disposal of polymers.

(6)

Waste polymers are first separated based on type of polymer. Some are able to be recycled so are melted down and remoulded to be used again. Others are used as organic feedstock for cracking that can be used to make useful shorter chain alkanes and alkenes. Others are incinerated, the thermal energy being used to generate useful energy for electricity. Sometimes when burning waste toxic gases such as HCl are created so chemists have created scrubbers which neutralise these gases to make them less acidic and toxic.

Chemists are also working on creating more sustainable sources of energy such as biofuels, bioalcohols and biogas that, unlike fossil fuels that release greenhouse gases such as CO_2 are considered carbon neutral as are made from plants that once burn it that CO_2 so no net gain. Limitations to this however include car engines needing to be modified and land being used to

grow these plants instead of food.

Chemists can try using more catalysts to speed up rate of reaction^{that makes polymers} by providing an alternative reaction pathway with a lower activation energy, as lower temperatures and pressures can be used so less fossil fuel need to be burned.

Using biodegradable polymers means that they naturally decompose and do not need to take up space on landfills or release CO_2 when burned.



ResultsPlus
Examiner Comments

There is clear evidence that this candidate has used the specification to support their learning, as they have focused on all the key points related to sustainable use of polymers without significant content not relevant to the question. Toxic / harmful products of combustion are clearly identified **and** it is made clear that chemists can help reduce the problems caused, including a specific example showing how this is achieved.



ResultsPlus
Examiner Tip

Always use the specification when learning / revising to help you focus on key content. It can act as a checklist to ensure you have covered all necessary material from across the course.

Question 5 (a)

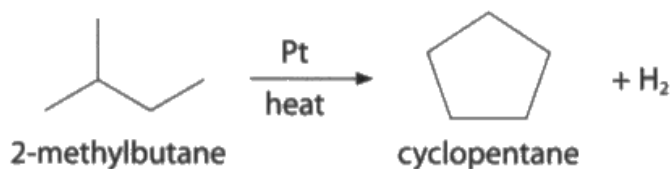
Over two-thirds of the cohort could recall this reaction, though a minority confused the process with other features of crude oil chemistry, such as cracking and fractional distillation.

5 This question is about cyclic compounds.

- (a) The hydrocarbon cyclopentane is present in some fuels and is used in the manufacture of insulation for freezers.



Cyclopentane can be synthesised by passing 2-methylbutane over a hot platinum catalyst.



Name the type of reaction that takes place in this synthesis.

(1)

Reformation



ResultsPlus
Examiner Comments

Although normally described as a reforming reaction, reformation was an allowable alternative, so this example scores the mark.



ResultsPlus
Examiner Tip

Make sure you can explain and differentiate between the wide range of processes associated with crude oil, such as cracking, reforming and fractional distillation.

Question 5 (b)

Just over 50% of candidates correctly determined the energy density, even though the term may have been unfamiliar. This is a credit to the ability of those candidates to apply their mathematical skills to an unfamiliar context. Some candidates did struggle, but often gained some credit for calculating the volume of cyclopentane correctly. A small but slightly frustrating cohort did the calculation correctly but misquoted the unit as MJ rather than MJ dm^{-3} .

- (b) The energy density of a fuel is defined as the energy released per dm^3 of the liquid fuel burned.

$$\frac{\text{MJ}}{\text{dm}^3}$$

A sample of cyclopentane with a mass of 30.0 g releases 1.41 MJ of energy.

Calculate the energy density of cyclopentane.
Include units in your answer.

[Density of cyclopentane = 0.751 g cm^{-3}]

$$0.751 \text{ g} = 1 \text{ cm}^3$$

(2)

$$\begin{aligned} \frac{30}{0.751} &= 39.95 \text{ cm}^3 \\ &= \frac{30}{751} \text{ dm}^3 (=0.0399) \\ \frac{1.41}{\left(\frac{30}{751}\right)} &= 35.297 \\ &\approx \underline{35.3 \text{ MJ dm}^{-3}} \end{aligned}$$



ResultsPlus
Examiner Comments

This is a good example of a clearly laid out calculation with the salient working for each step obvious to the examiner.



ResultsPlus
Examiner Tip

Although units aren't always a requirement for intermediate steps in a calculation, there are useful when unit conversions are required, to help you keep track of a route through a problem.

Question 5 (c)(i)

This was straightforward recall for most candidates. The most common incorrect answers were heat under reflux, and use of a halogen carrier such as iron(III) bromide. In the case of the latter answer, it seems as though some candidates misinterpreted the cyclic alkane as an arene.

alkane

- (c) Under appropriate conditions, cyclopentane reacts with bromine to form bromocyclopentane.



- (i) State the condition needed to initiate the reaction.

(1)

uv light and high temperature.



ResultsPlus
Examiner Comments

High temperature was treated as a neutral comment here, so the mark was awarded.



ResultsPlus
Examiner Tip

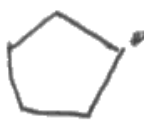
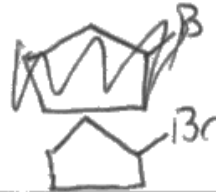
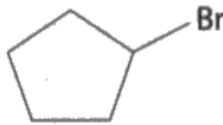
The question uses the word 'condition' here indicating only one answer is required. This candidate was fortunate in the sense that carrying out the reaction at temperatures above 250°C can result in free-radical substitution, but in general a second incorrect answer for a 1 mark question can result in loss of credit.

Question 5 (c)(ii)-(iii)

This question was an example of familiar chemistry in an unfamiliar context and as such it discriminated effectively. The initiation step was well known by nearly all candidates, though a few tried to extend their answer and included incorrect two-headed curly arrows. The propagation step was more challenging, with a significant minority of candidates failing to regenerate a bromine free radical. Part (c)(iii) differentiated constructively. In order to improve, many candidates need to be able to show a bond between two cyclic structures in skeletal format, as many candidates simply fused the two rings together via a single carbon atom.

- (ii) Complete the table showing the steps of the mechanism of this reaction.
Curly arrows are not required.

(3)

Step	Equation(s)
Initiation	$\text{Br}_2 \xrightarrow{\text{UV}} 2\text{Br}^\bullet$
Propagation	1.  + $\text{Br}^\bullet \longrightarrow$  + HBr 2.  + $\text{Br}_2 \longrightarrow$  + $\text{Br}^\bullet$
Termination	 + $\text{Br}^\bullet \longrightarrow$ 

- (iii) Draw the structure of the organic product of an alternative termination step.

(1)





All parts of the response in (c)(ii) are correct, so 3 marks were awarded. However in (c)(iii) although the candidate realises two cyclopentyl radicals combine together, they have fused the two rings via a single carbon, meaning the species shown only has 9 carbon atoms.

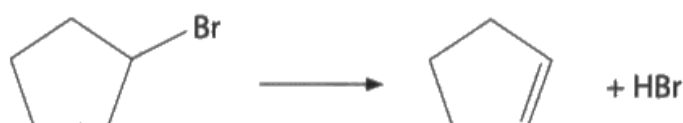


Practice drawing two rings joined together by bond between **two** carbon atoms.

Question 5 (d)(i)

This was another case of linking ideas from one part of the specification to another context, a vital skill for candidates hoping to obtain the higher grades. Recognition of anhydrous sodium sulfate as a drying agent was common, but a number of candidates didn't then link this to the idea that it was there to remove water from the solvent. Only a small number of those that managed this made the connection to the fact that the presence of water would favour a substitution reaction / production of an alcohol.

- (d) Bromocyclopentane forms cyclopentene when heated under reflux with a concentrated solution of potassium hydroxide in ethanol.



- (i) Explain why the solvent ethanol is treated with anhydrous sodium sulfate before use in this reaction.

(2)

Anhydrous sodium sulfate is a drying agent, so is used to ensure there is no water in the ethanol and KOH mixture. If water was present, the OH^- ions would act as a nucleophile, instead of a base, and a nucleophilic substitution reaction would occur, instead.



ResultsPlus
Examiner Comments

The candidate makes the point that the anhydrous sodium sulfate is present to remove the water from the ethanol, then exemplifies this by correctly identifying that the presence of water would favour a nucleophilic substitution reaction. Hence both marks were awarded.



ResultsPlus
Examiner Tip

When thinking about reaction conditions make sure to consider not just **what** conditions are needed but **why** they are required.

Question 5 (d)(ii)

Most candidates could recall the name of the reaction here. Some candidates included unnecessary references to electrophiles and nucleophiles, or confused the mechanism with nucleophilic addition-elimination.

(ii) Give the name of the reaction shown in the equation.



(1)

addition elimination



ResultsPlus
Examiner Comments

It looks like this candidate has mixed up the chemistry of carbonyl compounds with that of halogenoalkanes, resulting in this incorrect answer.



ResultsPlus
Examiner Tip

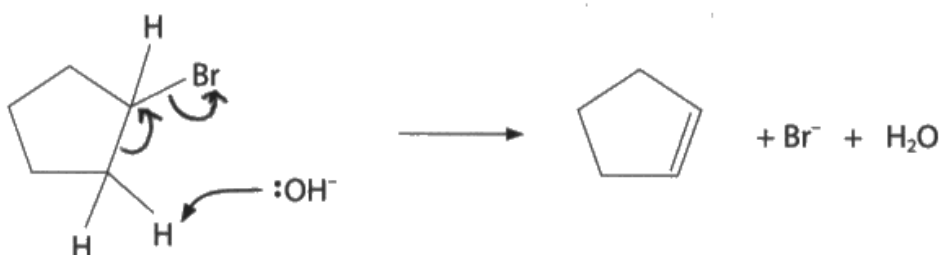
Make sure you know the difference between elimination and addition-elimination.

Question 5 (d)(iii)

Just over 40% of candidates answered this correctly, suggesting that the understanding of curly arrows is not as well embedded as the recall of curly arrows in familiar mechanisms. Amongst the work not given credit were some near misses. These included the C-H bond pair of electrons moving directly to a carbon atom and the same bond pair being moved into the centre of the cyclic ring. The latter mistake fits with the narrative that a small number of the cohort mistook the cyclic alkane for an arene.

(iii) Predict the mechanism for the reaction by adding two curly arrows.

(1)



ResultsPlus
Examiner Comments

The arrow from the C-C bond in the ring is incorrect and would result in the breaking of the bond, when the product of the reaction requires a second bond to form between the two carbon atoms.



ResultsPlus
Examiner Tip

Make sure you understand what a curly arrow means in terms of electron movement and the breaking / formation of bonds. This will provide a better grounding in understanding of mechanisms, enabling you to predict what might take place in an unfamiliar reaction.

Question 6 (b)

Candidates usually mentioned the function of TMS as a standard or reference and the most common way to access the second mark was to discuss the idea that TMS was inert, so would not react with the sample. Other candidates tried to justify the concept of a single or strong peak, but didn't always link this with the equivalent carbon or hydrogen environments.

(b) Explain why tetramethylsilane, TMS, is used in NMR spectroscopy.

(2)

Has a low boiling point and has 12 H atoms in the same environment meaning it will produce a strong signal.



ResultsPlus
Examiner Comments

This example scores 1 mark for the idea that the 12 hydrogen atoms in the same environment produce a strong peak. The low boiling point is correct, but this needs to be linked to ease of removal from the sample to be considered for credit. There is no reference to the key point of its use as a standard.



ResultsPlus
Examiner Tip

When considering TMS its most important feature in NMR is its use as a standard. Other points on the mark scheme then go on to exemplify why it makes a good standard.

This is another example of making a point, then justifying it.

Question 6 (c)(i)

This was a difficult question for many candidates, with a significant proportion attempting to use carbon atoms joined to the carbon attached to the nitrogen atom as opposed to the number of carbon atoms linked to the nitrogen atom itself. It seemed like such answers had mixed up secondary amines with secondary alcohols. Several answers referred to the number of carbon atoms joined to the amine rather than focusing specifically on the nitrogen atom.

- (c) A secondary amine, **Q**, has the molecular formula $C_6H_{15}N$.
The low resolution 1H NMR spectrum of **Q** has three peaks.

(i) State what is meant by the term 'secondary amine'.

(1)

a secondary amine is when the NH_2 is attached to a carbon that is also bonded to 2 other carbons.



ResultsPlus
Examiner Comments

This was a common answer where the candidate uses the definition of secondary in relation to alcohols, rather than amines, so does not score the mark.



ResultsPlus
Examiner Tip

Remember that defining primary, secondary and tertiary in relation to amines is related to the numbers of carbons bonded to the **nitrogen**, not the carbon adjacent to the nitrogen.

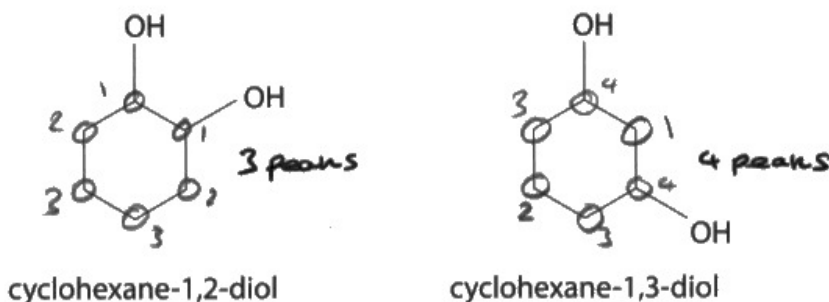
Question 6 (c)(ii)

This was probably the most challenging item on the paper, with less than 20% of the cohort able to deduce the structure. In many cases candidates were hindered by their inability to recognise a secondary amine, so included a NH_2 group. Even those candidates who suggested a secondary amine tended to draw *N*-propylpropan-1-amine, perhaps forgetting that the hydrogen atom attached to the nitrogen atom would also be responsible for a peak in the ^1H NMR spectrum.

Question 6 (d)

The marking team were pleased to see so many carefully labelled diagrams showing the carbon environments in each structure. Those candidates who didn't manage to score the second mark usually missed out because they didn't link the number of environments to the number of peaks one would see in the ^{13}C NMR spectrum.

(d) Two cyclic alcohols have the structures shown.



Show that the ^{13}C NMR spectra of these compounds can be used to distinguish between the two alcohols, labelling the diagrams to justify your answer.

(2)

There are 3 different carbon environments in cyclohexane-1,2-diol compared to 4 in cyclohexane-1,3-diol. This therefore shows the ^{13}C NMR spectra there will be 3 peaks in cyclohexane-1,2-diol compared to 4 in cyclohexane-1,3-diol.



ResultsPlus
Examiner Comments

This candidate annotates the diagrams with care to show the different environments, then in the text links this to the number of peaks you would see on the ^{13}C NMR spectrum, to enable them to distinguish between the two compounds.



ResultsPlus
Examiner Tip

When discussing either ^1H or ^{13}C NMR always try to link the number of peaks in the spectrum to the number of unique environments.

Question 7 (b)

Candidates are becoming more and more adept at dealing with problems based on the ideal gas equation. Unit conversions were handled with skill with candidates using standard form proficiently. Nearly half of the cohort scored full marks, with the most common errors linked to either a miscalculation of the molar mass of chloropropene, or a failure to quote the final answer to 2 or 3 significant figures.

- (b) Calculate the volume, in cm^3 , occupied by 10.0 g of chloroprene in the gaseous phase, at 80.0°C and 205 kPa.
Give your answer to an appropriate number of significant figures.

[Gas constant (R) = $8.31 \text{ J mol}^{-1} \text{ K}^{-1}$]

$$\frac{10}{M_r} = 0.113 \text{ mol}$$

(5)

$$205000 V = 0.113 \times 8.31 \times (80 + 273)$$

$$V = \frac{0.113 \times 8.31 \times (80 + 273)}{205000}$$

$$V = 1.727 \times 10^{-3} \text{ cm}^3$$



ResultsPlus
Examiner Comments

The candidate converts units of temperature and pressure appropriately and calculates the number of moles of chloroprene correctly, rounded to 3 significant figures. Although intermediate rounding is not best practice it was allowed here. However the subsequent calculation of the volume has a mistake, probably due to an input error on the calculator. In addition the volume quoted is in m^3 not cm^3 .

3 marks were awarded.



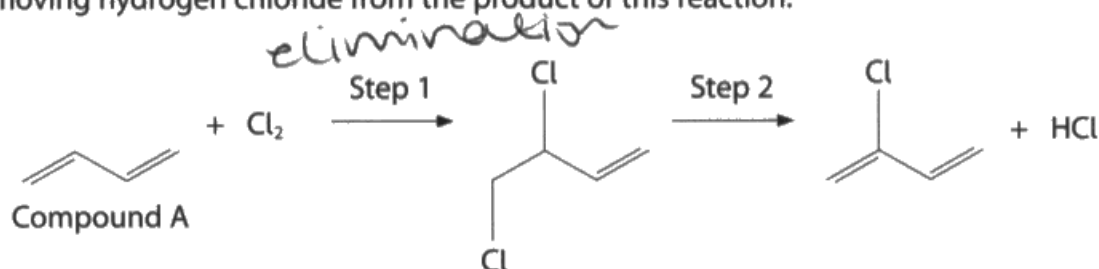
ResultsPlus
Examiner Tip

If time permits, check numerical answers for calculator errors.

Question 7 (c)(i)-(ii)

Parts (c)(i) and (c)(ii) showed a discrepancy between the ability of candidates to explain what happens in an organic reaction versus the recall of the mechanism using curly arrows. As a result part (c)(i) was less successful for most candidates. In many cases the assumption was made that the chlorine molecule was polar or answers were based on an instantaneous dipole model, rather like that used to explain London forces. The most successful candidates tended to describe or show a chlorine molecule very close to the carbon-carbon double bond and link this to the induction of a dipole in the molecule. The mechanism in (c)(ii) was answered perfectly by many candidates, with perhaps fewer of the predictable errors evident (such as partial charges on ions, absence of lone pairs) than in previous series.

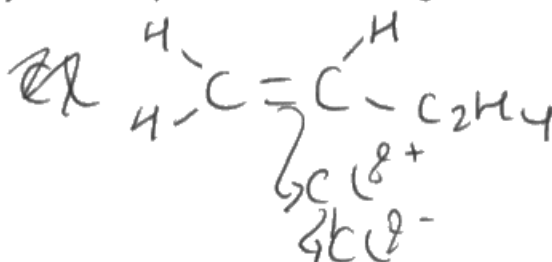
- (c) Chloroprene is formed by first adding chlorine, Cl_2 , to Compound A and then removing hydrogen chloride from the product of this reaction.



- (i) Explain how chlorine, Cl_2 , can act as an electrophile in Step 1 even though a chlorine molecule is symmetrical.

You may find it helpful to include a diagram.

(2)

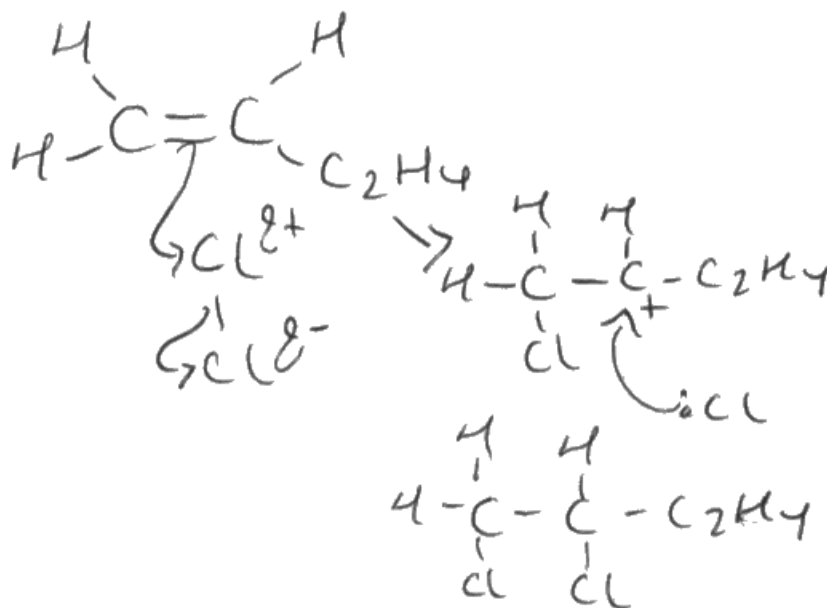


high electron density in double bond of alkene, pushes electrons to the furthest chlorine, making it more negative. Therefore breaking off as an electrophile ~~at its~~

- (ii) Draw the mechanism for Step 1.

Include curly arrows, and any relevant lone pairs and dipoles.

(3)





In (c)(i) the candidate correctly explains the electrophilic behaviour of chlorine by considering its proximity to the electron dense double bond, and the resulting negative nature of the chlorine atom nearest this bond. Hence both marks given.

The mechanism in (c)(ii) is almost perfect, but the absence of a negative charge on the chloride ion means 2 marks were awarded, rather than 3.

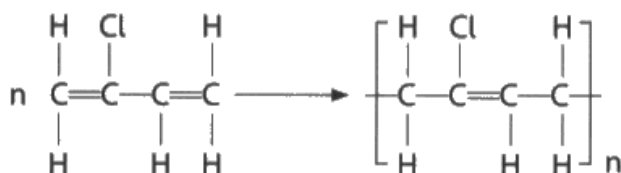


When drawing mechanisms, if time permits, check for unforced errors such as missing lone pairs or missing charges.

Question 7 (c)(iii)

The majority of candidates correctly suggested addition but use of extra incorrect information, for example, electrophilic, sometimes lost them the mark.

(iii) Chloroprene polymerises to form neoprene as shown.



Give the name of the type of reaction that occurs when chloroprene polymerises.

(1)

polymerisation



ResultsPlus
Examiner Comments

The type of reaction is addition, so polymerisation alone was not enough to score the mark.

Question 7 (d)(i)

Many candidates appreciated the link between solubility of an organic compound in water to its ability to form hydrogen bonds with water. However far fewer considered the relative strength of the forces between solute-solute and solvent-solvent, compared with solute-solvent forces. In this case, just the notion that the resultant forces were of similar strength to the forces in each separate component of the mixture would have been sufficient.

- (d) Flexible and water-resistant materials can be made by combining neoprene with polyester fabric.

A polyester may be made by the reaction of benzene-1,4-dicarboxylic acid with ethane-1,2-diol.

- (i) Explain why ethane-1,2-diol is soluble in water.
A detailed description of the forces involved is not required.

(2)

The δ^- oxygen in the ~~the OH groups~~ OH group can hydrogen bond with δ^+ hydrogen in water. δ^+ hydrogen in ethane-1,2-diol can hydrogen bond with δ^- O in water. Energy needed to overcome London forces and existing hydrogen bonds is less than energy needed to form new hydrogen bonds in water.



ResultsPlus
Examiner Comments

The recognition of hydrogen bonds between the two compounds is evident and it looks like there is some discussion of relative strengths of forces before and after mixing. Unfortunately this candidate believes that energy is needed to both break and form hydrogen bonds, so cannot access the second mark.



ResultsPlus
Examiner Tip

Remember bond forming is exothermic, bond breaking is endothermic.

Question 7 (d)(ii)

Whilst unit conversion when using the ideal gas equation was excellent with few errors, here the conversion of milligrams to grams proved problematic for around 25% of candidates. The two most common mistakes were to omit the conversion altogether or to multiply 4.25 (mg) by a factor of a thousand. The majority of candidates who could calculate a value for the number of moles, nearly always determined a value using the Avogadro constant, so could score at least 1 mark.

(ii) The molar mass of a polyester is 8400 g mol^{-1} .

mg $\rightarrow$ g

Calculate the number of polymer molecules in 4.25 mg of this polyester.

[Avogadro constant (L) = $6.02 \times 10^{23} \text{ mol}^{-1}$]

$$\text{moles} = \frac{m}{M_r}$$



(2)

$$\frac{4250}{8400} = 0.5059 \text{ mols}$$

$$4.25 \times 1000 = 4250$$

$$0.5059 \times 6.02 \times 10^{23}$$

$$= 3.04583 \times 10^{23}$$

$$3.05 \times 10^{23}$$



ResultsPlus
Examiner Comments

The working is clearly shown by this candidate which is good. However they have incorrectly converted milligrams, so only score a single transferred error mark for using their value for moles correctly with Avogadro's constant.



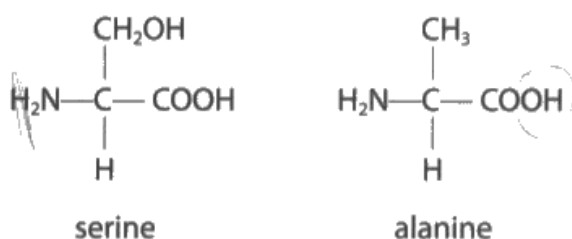
Make sure you can convert a wide range of units in different forms, not just the common units used in expressions such as the ideal gas equation.

Question 8 (a)(i)

The definition of a chiral carbon was clear to many candidates, with most definitions based on a carbon atom with four different groups attached, rather than the formation of a molecule with a non-superimposable mirror image. Occasional slips tended to be omission of either the word 'four' or 'different' or imprecise use of the word molecule, eg 'a carbon with four different molecules attached'.

8 This question is about amino acids and related compounds.

The structures of two amino acids are shown.



(a) Both amino acids contain a chiral carbon atom.

(i) State what is meant by the term 'chiral carbon atom'.

(1)

A carbon atom which is attached to 4 different groups,
and the isomers form non-superimposable images of
each other.



ResultsPlus
Examiner Comments

This candidate provides a model answer using both possible ways to define a chiral carbon atom.



ResultsPlus
Examiner Tip

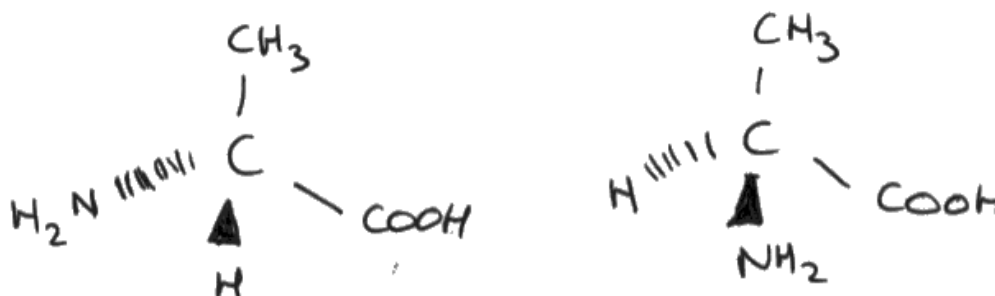
Learning key definitions by heart can help reduce cognitive load in exams, helping you focus time and energy on questions that require more application or problem solving.

Question 8 (a)(ii)

The best responses drew the mirror images to represent the stereoisomers. Other candidates tried to swap multiple groups to create a stereoisomer, and some of these responses ended up drawing the same stereoisomer twice. Practicing drawing 3 dimensional representations is a skill some candidates need to work on. This was evident by a small but significant number of answers that did not use wedges and/or dashed lines, and others who used wedges and/or dashed lines but clearly in a square planar orientation on the page.

- (ii) Draw diagrams of the two stereoisomers of **alanine**, showing their three-dimensional shape.

(2)



ResultsPlus
Examiner Comments

Here the candidate has flipped the position of two groups (the H and NH₂) which results in the two stereoisomers, so scores both marks. Unfortunately, other candidates changed the position of more than two groups, sometimes resulting in a drawing of the same compound.



ResultsPlus
Examiner Tip

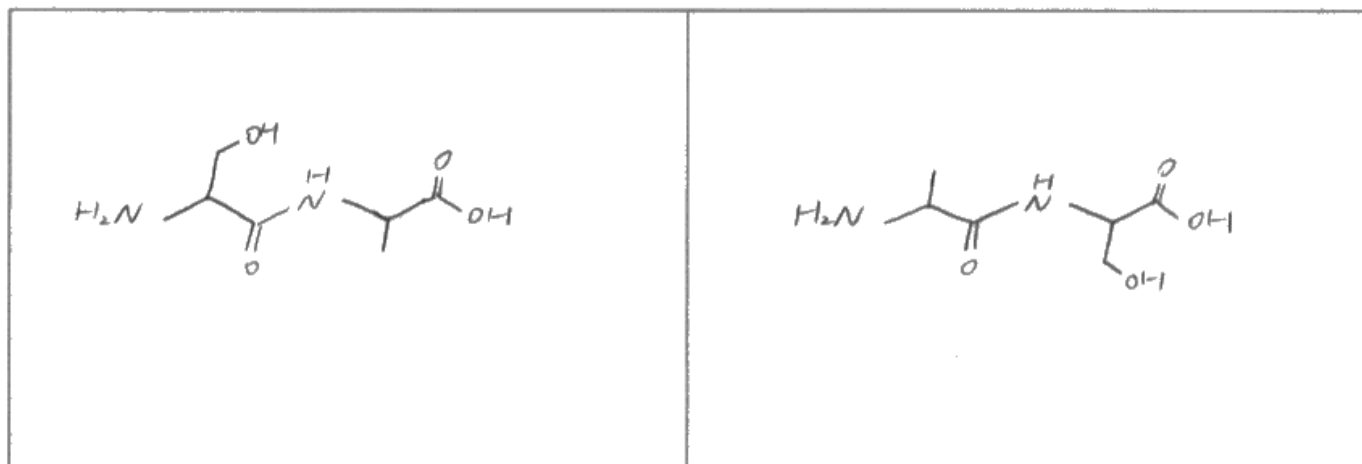
The easiest way to show a pair of optical stereoisomers is to show them drawn as two mirror images.

Question 8 (b)

This question demanded evidence of two skills, the ability to deduce the structure of dipeptides and to draw them in a skeletal format. The first of these attributes proved difficult enough, with some candidates unable to link together the two amino acids, introducing ester groups between them, influenced by the alcohol group in serine. Other candidates could recognise the products but omitted all hydrogen atoms from their skeletal structures, including those on the amide and carboxylic acid functional groups.

(b) Draw the **skeletal** formulae of the two dipeptides that could form when serine and alanine react.

(2)



ResultsPlus
Examiner Comments

Both the dipeptides are correct and the candidate understands how to construct skeletal formulae taking into account different functional groups.



ResultsPlus
Examiner Tip

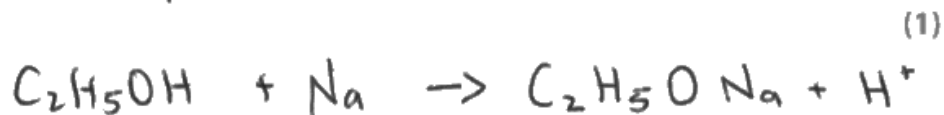
Remember to include hydrogen atoms on functional groups such as NH_2 or OH , in skeletal formulae.

Question 8 (d)(i)

Many candidates knew that the organic product was sodium ethoxide. However, they attempted to balance the equation in terms of numbers of atoms rather than charge, so often suggested the other product was a single hydrogen ion.

- (i) Sodium ethoxide, $\text{C}_2\text{H}_5\text{ONa}$, needed in Step 1, is formed by the reaction of sodium with ethanol.

Write the equation for this reaction.
State symbols are not required.



ResultsPlus
Examiner Comments

Although the reaction balances in terms of atoms, it does not balance in terms of charge so is incorrect.



ResultsPlus
Examiner Tip

For an equation to involve charged species, examiners will often guide you by using the phrase 'ionic equation'.

Question 8 (d)(ii)

Compound Y was unfamiliar, and some candidates found it difficult to unpick the detail of the structure and name the functional groups. As a result a significant proportion of candidates discussed ketones or aldehydes, drawn by the carbonyl bond, but not taking note of the neighbouring atoms.

(ii) Name the **two** functional groups present in Compound Y.

(2)

Ester

Amine



ResultsPlus
Examiner Comments

The candidate recognises the ester group in Compound Y but mistakes the amide for an amine, so only scores 1 mark.



ResultsPlus
Examiner Tip

Practice recognising functional groups in unfamiliar compounds.

Question 8 (d)(iii)

Although most candidates appreciated the need for acidic conditions and heat, a lack of detail prevented the award of full marks for some candidates, such as the name or formula of a specific strong acid, or the need to heat under reflux, to enable long periods of heating.

 (iii) Give the reagent needed and conditions required for Step 3.

(2)

+ KOH reflux



ResultsPlus
Examiner Comments

Although KOH is a suitable reagent for the hydrolysis of an ester, it would produce sodium ethanoate and the sodium salt of alanine. Hence in order to score both marks here, the reaction mixture would have to have excess hydrochloric acid, or similar, added after the reflux.



ResultsPlus
Examiner Tip

Consider the required product when thinking about reagents for hydrolysis reactions.

Question 8 (d)(iv)

Virtually all candidates scored at least a mark in this calculation via any one of the three methods. The commonest mistake was effectively to multiply by 0.55 instead of to divide when attempting to take into account the percentage yield. Another common error was a failure to work out correctly the molar mass of compound X.

- (iv) Calculate the mass of Compound X required to make 15.0g of alanine, assuming the overall yield of the synthesis is 55%.

(3)

$$M_r : 3 \times C + 2 \times O + \underset{14}{N} + 7H = 89 \text{ g mol}^{-1}$$

$$15 / 89 = 0.169 \text{ mol}$$

$$\begin{array}{c} 9 \\ M_r : 8 \times C + 5 \times O + 15H \\ = 203 \text{ g mol}^{-1} \end{array}$$

$$\frac{15}{89} \times 203 \div 55 = 34.2 \text{ g}$$

$$34.2 / 55\% = 62.2 \text{ g}$$



ResultsPlus
Examiner Comments

The working is generally clear here, though the scaling factor required to take into account the percentage yield has been shown as it would be inputted into a calculator, rather than the expected mathematical expression. However, the calculated value is correct, so this approach is acceptable. 1 mark is lost though, as the molar mass of Compound X is incorrect, with 203 used instead of 217.



ResultsPlus
Examiner Tip

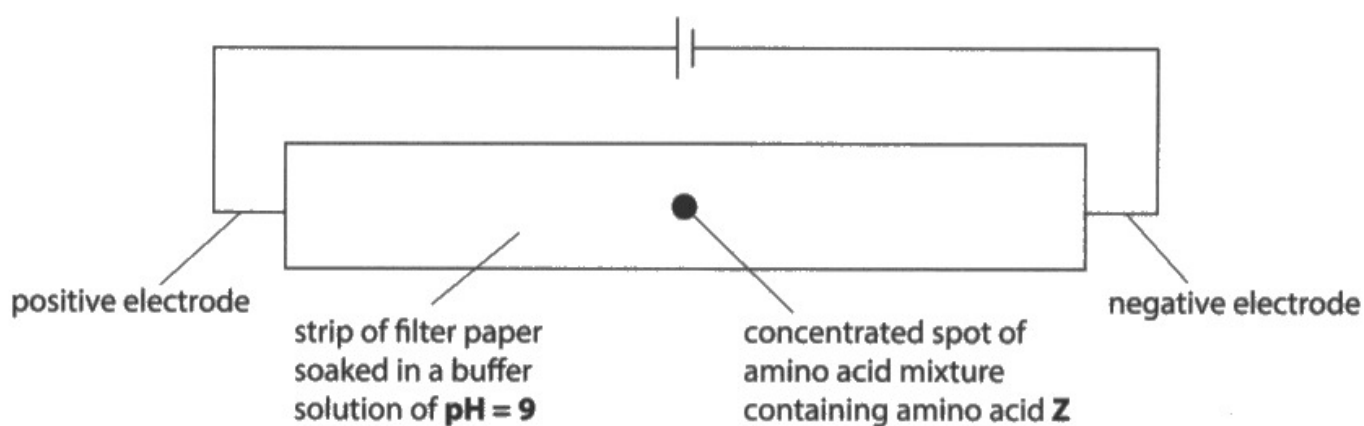
Double check any molar masses used in a calculation as it can be easy to make a slip and lose a mark.

Question 8 (e)

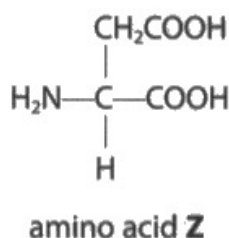
A majority of candidates knew that Z would move towards the positive electrode and that this was because the amino acid would be in the form of a negative ion, under basic conditions. Fewer candidates appreciated that this was because of the presence of two carboxylate ions. A small number of candidates incorrectly referred to the ion formed as a zwitterion, not realising that this would mean an equal number of negative and positive charges.

(e) A mixture of amino acids can be separated using a technique called paper electrophoresis. A simplified diagram is shown.

The movement of the amino acid on the paper depends on any charge on the amino acid, and this is determined by the pH of the buffer solution.



Amino acid Z has the structure shown.



Explain in which direction, if any, amino acid Z would move when a current flows in the circuit with a buffer solution of pH = 9.

(2)

As its pH 9, the amino acid Z is in alkaline conditions so the $-\text{COOH}$ groups will lose a H and form COO^- meaning Z will become negatively charged so it will move to the left towards the positive electrode.



The candidate has recognised that both carboxyl groups will deprotonate to form an ion with a charge of -2 , so in conjunction with the predicted movement of the ion, scores both marks.



Remember that amino acids can have more than one acid or base group, which will affect their behaviour in reactions with strong acids or bases.

Paper Summary

Based on their performance on this paper, candidates should:

- Try, when revising mechanisms, to write an explanation of what is happening as well as recalling each step as a diagram.
- Remember in any question with the command word 'explain', to make a point and then exemplify or justify it.
- Practice drawing shapes of pairs of stereoisomers shown as mirror images to clearly show both their 3-dimensional nature and different arrangement in space.
- Use extrapolation lines to indicate your chosen points when calculating a gradient from a graph and take care to check whether the gradient is negative or positive.
- Practice converting a range of different units, not just those required in the ideal gas equation.
- Remember to take into account percentage yield when calculating masses of products formed or reactants needed.

Grade boundaries

Grade boundaries for this, and all other papers, can be found on the website on this link:

<https://qualifications.pearson.com/en/support/support-topics/results-certification/grade-boundaries.html>

