

OXFORD

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INTERNATIONAL A-LEVEL CHEMISTRY (9620)

CH04

Unit 4 Organic 2 and Physical 2

Mark scheme

June 2023

Version: 1.0 Final



Mark schemes are prepared by the Lead Assessment Writer and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all associates participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every associate understands and applies it in the same correct way. As preparation for standardisation each associate analyses a number of students' scripts. Alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of students' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

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A-level Chemistry

Mark Scheme Instructions for Examiners

1. General

The mark scheme for each question shows:

- the marks available for each part of the question
- the total marks available for the question
- the typical answer or answers which are expected
- extra information to help the examiner make his or her judgement and help to delineate what is acceptable or not worthy of credit or, in discursive answers, to give an overview of the area in which a mark or marks may be awarded.

The extra information in the 'Comments' column is aligned to the appropriate answer in the left-hand part of the mark scheme and should only be applied to that item in the mark scheme.

You should mark according to the contents of the mark scheme. If you are in any doubt about applying the mark scheme to a particular response, consult your Team Leader.

At the beginning of a part of a question a reminder may be given, for example: where consequential marking needs to be considered in a calculation; or the answer may be on the diagram or at a different place on the script.

In general the right-hand side of the mark scheme is there to provide those extra details which might confuse the main part of the mark scheme yet may be helpful in ensuring that marking is straightforward and consistent.

The use of M1, M2, M3 etc in the right-hand column refers to the marking points in the order in which they appear in the mark scheme. So, M1 refers to the first marking point, M2 the second marking point etc.

2. Boldening

- 2.1** In a list of acceptable answers where more than one mark is available 'any **two** from' is used, with the number of marks emboldened. Each of the following bullet points is a potential mark.
- 2.2** A bold **and** is used to indicate that both parts of the answer are required to award the mark.
- 2.3** Alternative answers acceptable for a mark are indicated by the use of **OR**. Different terms in the mark scheme are shown by a / ; eg allow smooth / free movement.

3. Marking points

3.1 Marking of lists

This applies to questions requiring a set number of responses, but for which students have provided extra responses. The general 'List' principle to be followed in such a situation is that 'right + wrong = wrong'.

Each error / contradiction negates each correct response. So, if the number of error / contradictions equals or exceeds the number of marks available for the question, no marks can be awarded.

However, responses considered to be neutral (often prefaced by 'Ignore' in the mark scheme) are not penalised.

For example, in a question requiring 2 answers for 2 marks:

Correct answers	Incorrect answers (ie incorrect rather than neutral)	Mark (2)	Comment
1	0	1	
1	1	1	They have not exceeded the maximum number of responses so there is no penalty.
1	2	0	They have exceeded the maximum number of responses so the extra incorrect response cancels the correct one.
2	0	2	
2	1	1	
2	2	0	
3	0	2	The maximum mark is 2
3	1	1	The incorrect response cancels out one of the two correct responses that gained credit.
3	2	0	Two incorrect responses cancel out the two marks gained.
3	3	0	

3.2 Marking procedure for calculations

Full marks should be awarded for a correct numerical answer, without any working shown, unless the question states 'Show your working' or 'justify your answer'. In this case, the mark scheme will clearly indicate what is required to gain full credit.

If an answer to a calculation is incorrect and working is shown, process mark(s) can usually be gained by correct substitution / working and this is shown in the 'Comments' column or by each stage of a longer calculation.

3.3 Errors carried forward, consequential marking and arithmetic errors

Allowances for errors carried forward are most likely to be restricted to calculation questions and should be shown by the abbreviation ECF or consequential in the marking scheme.

An arithmetic error should be penalised for one mark only unless otherwise amplified in the marking scheme. Arithmetic errors may arise from a slip in a calculation or from an incorrect transfer of a numerical value from data given in a question.

3.4 Equations

In questions requiring students to write equations, state symbols are generally ignored unless otherwise stated in the 'Comments' column.

Examiners should also credit correct equations using multiples and fractions unless otherwise stated in the 'Comments' column.

3.5 Oxidation states

In general, the sign for an oxidation state will be assumed to be positive unless specifically shown to be negative.

3.6 Interpretation of 'it'

Answers using the word 'it' should be given credit only if it is clear that the 'it' refers to the correct subject.

3.7 Phonetic spelling

The phonetic spelling of correct scientific terminology should be credited **unless** there is a possible confusion with another technical term or if the question requires correct IUPAC nomenclature.

3.8 Brackets

(.....) are used to indicate information which is not essential for the mark to be awarded but is included to help the examiner identify the sense of the answer required.

3.9 Ignore / Insufficient / Do not allow

Ignore or insufficient is used when the information given is irrelevant to the question or not enough to gain the marking point. Any further correct amplification could gain the marking point.

Do **not** allow means that this is a wrong answer which, even if the correct answer is given, will still mean that the mark is not awarded.

3.10 Marking crossed out work

Crossed out work that **has not been** replaced should be marked as if it were not crossed out, if possible. Where crossed out work **has been** replaced, the replacement work and not the crossed out work should be marked.

3.11 Reagents

The command word “Identify”, allows the student to choose to use **either** the name or the formula of a reagent in their answer. In some circumstances, the list principle may apply when both the name and the formula are used. Specific details will be given in mark schemes.

The guiding principle is that a reagent is a chemical which can be taken out of a bottle or container. Failure to identify complete reagents **will be penalised**, but follow-on marks (eg for a subsequent equation or observation) can be scored from an incorrect attempt (possibly an incomplete reagent) at the correct reagent. Specific details will be given in mark schemes.

For example, **no credit** would be given for

- the cyanide ion or CN^- when the reagent should be potassium cyanide or KCN;
- the hydroxide ion or OH^- when the reagent should be sodium hydroxide or NaOH;
- the $\text{Ag}(\text{NH}_3)_2^+$ ion when the reagent should be Tollens' reagent (or ammoniacal silver nitrate). In this example, no credit is given for the ion, but credit could be given for a correct observation following on from the use of the ion. Specific details will be given in mark schemes.

In the event that a student provides, for example, **both** KCN and cyanide ion, it would be usual to ignore the reference to the cyanide ion (because this is not contradictory) and credit the KCN. Specific details will be given in mark schemes.

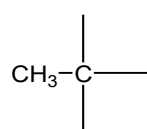
3.12 Organic structures

Where students are asked to draw organic structures, unless a specific type is required in the question and stated in the mark scheme, these may be given as displayed, structural or skeletal formulas or a combination of all three as long as the result is unambiguous.

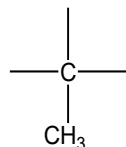
In general

- Displayed formulae must show all of the bonds and all of the atoms in the molecule, but need not show correct bond angles.
- Skeletal formulae must show carbon atoms by an angle or suitable intersection in the skeleton chain. Functional groups must be shown and it is essential that all atoms other than C atoms are shown in these (except H atoms in the functional groups of aldehydes, secondary amines and N-substituted amides which do not need to be shown).
- Structures must not be ambiguous, e.g. 1-bromopropane should be shown as $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$ and not as the molecular formula $\text{C}_3\text{H}_7\text{Br}$ which could also represent the isomeric 2-bromopropane.
- Bonds should be drawn correctly between the relevant atoms. This principle applies in all cases where the attached functional group contains a carbon atom, eg nitrile, carboxylic acid, aldehyde and acid chloride. The carbon-carbon bond should be clearly shown. Wrongly bonded atoms will be penalised **on every occasion**. (see the examples below)
- The same principle should also be applied to the structure of alcohols. For example, if students show the alcohol functional group as $\text{C} - \text{HO}$, they should be penalised **on every occasion**.
- Latitude should be given to the representation of $\text{C} - \text{C}$ bonds in alkyl groups, given that CH_3- is considered to be interchangeable with $\text{H}_3\text{C}-$ even though the latter would be preferred.
- Similar latitude should be given to the representation of amines where NH_2-C will be allowed, although $\text{H}_2\text{N}-\text{C}$ would be preferred.
- Poor presentation of vertical $\text{C} - \text{CH}_3$ bonds or vertical $\text{C} - \text{NH}_2$ bonds should **not** be penalised. For other functional groups, such as $-\text{OH}$ and $-\text{CN}$, the limit of tolerance is the half-way position between the vertical bond and the relevant atoms in the attached group.

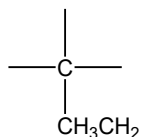
By way of illustration, the following would apply.



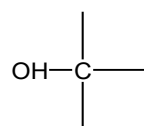
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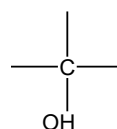
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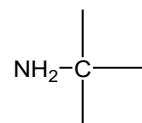
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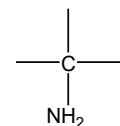
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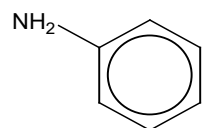
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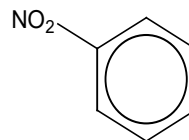
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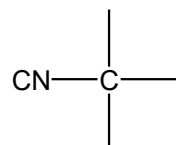
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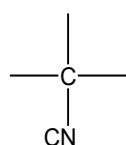
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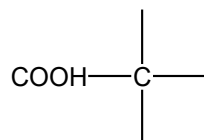
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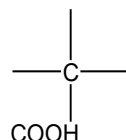
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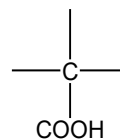
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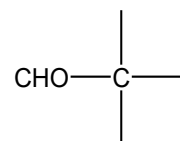
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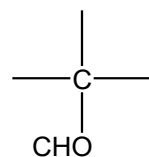
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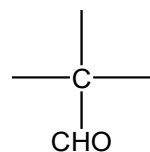
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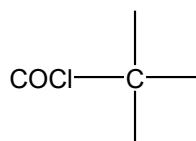
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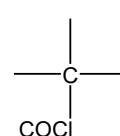
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- Representation of CH_2 by C-H_2 will be penalised
- Some examples are given here of **structures** for specific compounds that should **not** gain credit (but, exceptions may be made in the context of balancing equations)

CH_3COH for ethanal

$\text{CH}_3\text{CH}_2\text{HO}$ for ethanol

OHCH_2CH_3 for ethanol

$\text{C}_2\text{H}_6\text{O}$ for ethanol

CH_2CH_2 for ethene

$\text{CH}_2.\text{CH}_2$ for ethene

$\text{CH}_2:\text{CH}_2$ for ethene

- Each of the following **should gain credit** as alternatives to correct representations of the structures.

$\text{CH}_2 = \text{CH}_2$ for ethene, $\text{H}_2\text{C}=\text{CH}_2$

$\text{CH}_3\text{CHOHCH}_3$ for propan-2-ol, $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$

- In most cases, the use of “sticks” to represent C-H bonds in a structure should **not** be penalised. The exceptions to this when “sticks” will be penalised include
 - structures in mechanisms where the C-H bond is essential (e.g. elimination reactions in halogenoalkanes and alcohols)
 - when a displayed formula is required
 - when a skeletal structure is required or has been drawn by the candidate

3.13 Organic names

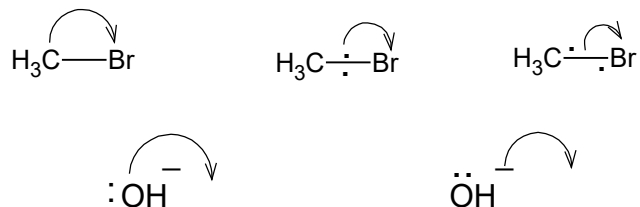
As a general principle, non-IUPAC names or incorrect spelling or incomplete names should **not** gain credit. Some illustrations are given here.

but-2-ol	should be butan-2-ol
2-hydroxybutane	should be butan-2-ol
butane-2-ol	should be butan-2-ol
2-butanol	should be butan-2-ol
ethan-1,2-diol	should be ethane-1,2-diol
2-methopropan-2-ol	should be 2-methylpropan-2-ol
2-methylbutan-3-ol	should be 3-methylbutan-2-ol
3-methylpentan	should be 3-methylpentane
3-mythylpentane	should be 3-methylpentane
3-methypentane	should be 3-methylpentane
propanitrile	should be propanenitrile
aminethane	should be ethylamine (although aminoethane can gain credit)
2-methyl-3-bromobutane	should be 2-bromo-3-methylbutane
3-bromo-2-methylbutane	should be 2-bromo-3-methylbutane
3-methyl-2-bromobutane	should be 2-bromo-3-methylbutane
2-methylbut-3-ene	should be 3-methylbut-1-ene
difluorodichloromethane	should be dichlorodifluoromethane

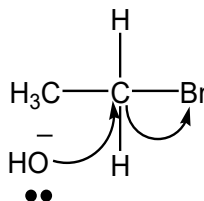
3.14 Organic reaction mechanisms

Curly arrows should originate either from a lone pair of electrons or from a bond.

The following representations should not gain credit **and will be penalised each time** within a clip.



For example, the following would score zero marks



When the curly arrow is showing the formation of a bond to an atom, the arrow can go directly to the relevant atom, alongside the relevant atom or **more than half-way** towards the relevant atom.

In free-radical substitution

- the absence of a radical dot should be penalised **once only** within a clip.
- the use of half-headed arrows is not required, but the use of double-headed arrows or the incorrect use of half-headed arrows in free-radical mechanisms should be penalised **once only** within a clip

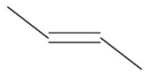
The correct use of skeletal formulae in mechanisms is acceptable, but where a C-H bond breaks both the bond and the H must be drawn to gain credit.

Question	Marking guidance	Mark	Comments
01.1	nucleophilic substitution	1	
	elimination	1	

Question	Marking guidance	Mark	Comments
01.2	any two of: • use (a greater proportion of) ethanol (in/as the solvent) • increase the concentration (of potassium hydroxide) • use a higher temperature	2	apply list principle allow do not use water in the solvent allow use a high concentration (of potassium hydroxide)

Question	Marking guidance	Mark	Comments
01.3	$\begin{array}{c} \text{CH}_2\text{CH}_3 \\ \\ \text{HO} \cdots \text{C} \cdots \text{H} \\ \nearrow \\ \text{CH}_3 \end{array}$ $\begin{array}{c} \text{CH}_2\text{CH}_3 \\ \\ \text{H} \cdots \text{C} \cdots \text{OH} \\ \searrow \\ \text{CH}_3 \end{array}$	1	allow two correct structures that are mirror images

Question	Marking guidance	Mark	Comments
01.4	pass plane-polarised light (through each enantiomer) planes of polarisation rotated in opposite directions or one enantiomer is laevorotatory and the other is dextrorotatory or one enantiomer rotates light clockwise and the other anticlockwise	2	ignore references to polarimeter

Question	Marking guidance	Mark	Comments
01.5		1	allow other skeletal structures with diagonal; lines opposite each other

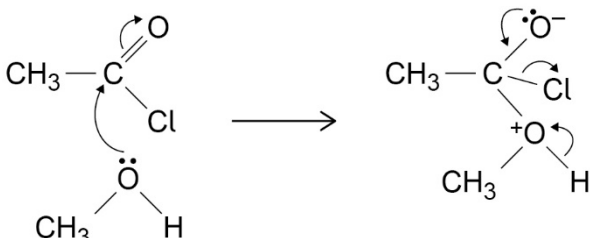
Question	Marking guidance	Mark	Comments
01.6	C E B	2	all correct = 2 two correct = 1 one or none correct = 0

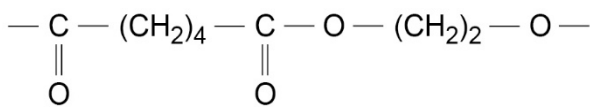
Question	Marking guidance	Mark	Comments
01.7	(secondary amine) $\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3 - \text{NH} - \text{CH} - \text{CH}_3 \end{array}$	1	allow other structural formulas and skeletal formulas
	(tertiary amine) $\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3 - \text{N} - \text{CH}_2 - \text{CH}_3 \end{array}$	1	award 1 mark for two correct structures in wrong places

Question	Marking guidance	Mark	Comments
01.8	(methylamine stronger base than ammonia) electron density on N is increased or lone pair on N is more available	1	ignore throughout references to accepting protons/H ⁺ more readily or less readily
	(because) methyl/CH ₃ is electron-releasing or methyl/CH ₃ has positive inductive effect	1	
	(phenylamine weaker base than ammonia) electron density on N is decreased or lone pair on N is less available	1	
	(because) lone pair (of electrons) on N is attracted to aromatic ring/phenyl/C ₆ H ₅	1	

	Total	16	
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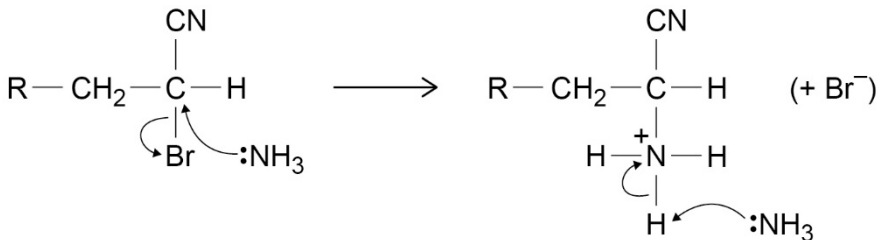
Question	Marking guidance	Mark	Comments
02.1	(alcohol) $\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3 - \text{CH} - \text{OH} \end{array}$	1	allow other structural formulas
	(acid anhydride) $\begin{array}{c} \text{O} \\ // \\ \text{CH}_3 - \text{C} \\ \backslash \\ \text{O} \\ \\ \text{CH}_3 - \text{C} \\ // \\ \text{O} \end{array}$	1	

Question	Marking guidance	Mark	Comments
02.2	(nucleophilic) addition-elimination 	1 3	M1 curly arrows from lone pair of O to C of C=O and from C=O bond to O M2 structure of intermediate with + and – charges M3 for lone pair on O and 3 curly arrows to show C=O formation, loss of H ⁺ and loss of Cl [–] allow 2 curly arrows to show C=O formation and loss of Cl [–] to form second intermediate with 3 rd curly arrow to show subsequent loss of H ⁺ ignore structure of final product even if incorrect

Question	Marking guidance	Mark	Comments
02.3		1	allow other structures with atoms/groups in correct order ignore brackets and subscripted n

Question	Marking guidance	Mark	Comments
02.4	(permanent) dipole-dipole forces	1	

	Total	8	
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Question	Marking guidance	Mark	Comments
03.1	nucleophilic substitution 	1 3	M1 for lone pair on N and first two curly arrows M2 for intermediate including + charge M3 for curly arrow showing loss of H⁺ do not accept removal of H⁺ by Br⁻ ignore reaction with lone pair on N of NH₃

Question	Marking guidance	Mark	Comments
03.2	molecule contains a carbon atom joined to four different groups	1	allow asymmetric or chiral carbon

Question	Marking guidance	Mark	Comments
03.3	sodium hydroxide / hydroxide ions do not attack benzene rings or sodium hydroxide / hydroxide ions repelled by delocalised pi electrons	1	either order allow sodium hydroxide / hydroxide ions convert OH groups on aromatic ring into O ⁻ (so another step needed)
	sodium hydroxide / hydroxide ions would react with the COOH group (to form COO ⁻ so another step needed)	1	allow deprotonates tyrosine

Question	Marking guidance	Mark	Comments
03.4	NaBH_4 / sodium tetrahydridoborate(III)	1	allow sodium borohydride
	H^- / hydride ion	1	
	Total	9	

Question	Marking guidance	Mark	Comments
04.1	concentrated nitric acid and concentrated sulfuric acid	1	allow c.HNO ₃ and c.H ₂ SO ₄

Question	Marking guidance	Mark	Comments
04.2		3	M1 for curly arrow from ring to N or + on ⁺ NO ₂ M2 for structure of intermediate including + charge M3 for curly arrow from C-H bond into hexagon

Question	Marking guidance	Mark	Comments
04.3	7	1	

Question	Marking guidance	Mark	Comments
04.4	$n(\text{benzocaine}) = \frac{10.7}{165.0} = 0.0648 \text{ (mol)}$	1	allow range of final answers (86.8 – 86.9) correct final answer scores 3 marks alternative method: $\text{mass (benzocaine)} = 10.7 \times \frac{100}{11.2} = 95.5 \text{ (g)}$ $n(\text{benzocaine}) = 95.5 \div 165.0 = 0.579 \text{ (mol)}$ $\text{mass (ethyl benzoate)} = 0.579 \times 150.0 = 86.8 \text{ (g)}$
	(assuming 100% yield) $\text{mass (ethyl benzoate)} = 0.0648 \times 150.0 = 9.72 \text{ (g)}$	1	
	(assuming 11.2% yield) $\text{mass (ethyl benzoate)} = 9.72 \times \frac{100}{11.2} = 86.8 \text{ (g)}$	1	

Question	Marking guidance	Mark	Comments
04.5	multi-step process / two-step process or step 1 produces a mixture of isomers or 2-isomer also formed	1	allow practical reasons such as loss during recrystallisation

	Total	9	
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Question	Marking guidance	Mark	Comments
05.1	$\text{H}_2\text{N}-\text{CH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{NH}-\text{CH}_2-\text{COOH}$	1	allow more detailed structures and skeletal structures

Question	Marking guidance	Mark	Comments
05.2	$(75.0 + 105.0 - 18.0 =) 162.0$	1	

Question	Marking guidance	Mark	Comments
05.3	ala-gly-ser ala-ser-gly gly-ser-ala ser-gly-ala	2	allow answers in any order four correct = 2 three or two correct = 1 one or none correct = 0 ignore abbreviations given in the question

Question	Marking guidance	Mark	Comments
05.4	2-aminopropanoic acid	1	

Question	Marking guidance	Mark	Comments
05.5	(with an excess of hydrochloric acid) $\begin{array}{c} \text{}^+\text{NH}_3 \\ \\ \text{HO} - \text{CH}_2 - \text{CH} - \text{COOH} \end{array}$	1	allow abbreviated and displayed structural formulas
	(with ethanoyl chloride) $\begin{array}{c} \text{CH}_3 - \text{CO} - \text{O} - \text{CH}_2 - \text{CH} - \text{COOH} \\ \\ \text{NH} \\ \\ \text{COCH}_3 \end{array}$	1	allow $\begin{array}{c} \text{HO} - \text{CH}_2 - \text{CH} - \text{COOH} \\ \\ \text{NH} \\ \\ \text{COCH}_3 \end{array}$ and $\begin{array}{c} \text{CH}_3 - \text{CO} - \text{O} - \text{CH}_2 - \text{CH} - \text{COOH} \\ \\ \text{NH}_2 \end{array}$

Question	Marking guidance	Mark	Comments
05.6	(secondary structure) hydrogen bonding	1	
	(tertiary structure) S–S bonding / disulfide bridge(s) or ionic interactions	1	allow hydrogen bonding if not mentioned in secondary structure answer allow weak London forces or induced dipole-dipole forces or dispersion forces or van der Waals' forces between molecules

Question	Marking guidance	Mark	Comments
05.7	hydrolysis or heat with (hydrochloric) acid	1	

Question	Marking guidance	Mark	Comments
05.8	aspartic acid and phenylalanine	1	

Question	Marking guidance	Mark	Comments
05.9	$(\frac{3.2}{8} =) 0.40$	1	

	Total	12	
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Question	Marking guidance	Mark	Comments
06.1	$k = \frac{\text{rate}}{[\text{G}]^2 \times [\text{H}]}$ or $\frac{1.5 \times 10^{-5}}{0.0150^2 \times 0.0250}$	1	
	2.67	1	
	(units) $\text{mol}^{-2} \text{dm}^6 \text{s}^{-1}$	1	

Question	Marking guidance				Mark	Comments
06.2						
	Experiment	Initial [G] / mol dm ⁻³	Initial [H] / mol dm ⁻³	Initial rate / mol dm ⁻³ s ⁻¹		
	1	0.0150	0.0250	1.50 × 10 ⁻⁵		if three different answers seen, allow ECF from their value of <i>k</i> in question 06.1 :
	2	0.0450	0.0250	1.35 × 10⁻⁴	1	M1 = 5.0625 × 10 ⁻⁵ × <i>k</i>
	3	0.0300	0.00625	1.50 × 10 ⁻⁵	1	M2 = $\frac{1}{60 \times k}$
	4	0.0245	0.0750	1.20 × 10 ⁻⁴	1	M3 = $\sqrt{\frac{1}{625 \times k}}$

	Total	6	
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Question	Marking guidance	Mark	Comments
07.1	(xy values for tangent at $[J] = 0.200 \text{ mol dm}^{-3}$) $\frac{0.370}{900}$	1	allow measurements from part of tangent
	(calculation of rate at $[J] = 0.200 \text{ mol dm}^{-3}$) $4.11 \times 10^{-4} \text{ mol dm}^{-3} \text{ s}^{-1}$	1	
	(xy values for tangent at $[J] = 0.100 \text{ mol dm}^{-3}$) $\frac{0.200}{1950}$	1	allow measurements from part of tangent
	(calculation of rate at $[J] = 0.100 \text{ mol dm}^{-3}$) $1.03 \times 10^{-4} \text{ mol dm}^{-3} \text{ s}^{-1}$	1	

Question	Marking guidance	Mark	Comments
07.2	2 or second order	1	
	when concentration halves, rate decreases fourfold or when concentration doubles, rate quadruples	1	

	Total	6	
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Question	Marking guidance	Mark	Comments
08.1	n (hydrogen) (= 3 – (3 × 0.26) =) 2.22 (mol)	1	M3 = 0.74 + M1 + M2
	n (ammonia) (= 2 × 0.26 =) 0.52 (mol)	1	
	n (total gas) (= 0.74 + 2.22 + 0.52 =) 3.48 (mol)	1	

Question	Marking guidance	Mark	Comments
08.2	$K_p = \frac{p(\text{NH}_3)^2}{p(\text{N}_2) \times p(\text{H}_2)^3}$	1	do not accept []

Question	Marking guidance	Mark	Comments
08.3	K_p decreases	1	

Question	Marking guidance	Mark	Comments
08.4	(effect on rate of reverse reaction) increases	1	
	activation energy decreased or $E_a(\text{cat}) < E_a$ or more (ammonia) molecules have $E \geq E_a$	1	
	(effect on yield of ammonia) no change	1	
	catalyst increases rates of forward and reverse reactions equally	1	
	Total	9	

Question	Marking guidance	Mark	Comments
09	$13.34 = \left(\frac{-E_a}{500 \times R} \right) + \ln A$	1	substitution of both sets of values into equation
	$18.18 = \left(\frac{-E_a}{1000 \times R} \right) + \ln A$	1	
	$4.84 = \left(\frac{-E_a}{1000 \times R} \right) - \left(\frac{-E_a}{500 \times R} \right)$	1	subtraction of equations to eliminate $\ln A$
	$E_a = (4.84 \times 8.31 \times 1000) = 40\,220 \text{ (J mol}^{-1}\text{)}$	1	evaluation of E_a in J mol^{-1}
	$40.2 \text{ (kJ mol}^{-1}\text{)}$	1	conversion from J mol^{-1} to kJ mol^{-1}
	alternative approach		
	$\ln k_1 = 13.34 \quad \text{and} \quad \ln k_2 = 18.18 \quad (1)$		calculation of both values of $\ln k$
	$\frac{1}{T_1} = 2.00 \times 10^{-3} \quad \text{and} \quad \frac{1}{T_2} = 1.00 \times 10^{-3} \quad (1)$		calculation of both values of $\frac{1}{T}$
	$13.34 - 18.18 = \left(\frac{-E_a}{4155} \right) - \left(\frac{-E_a}{8310} \right) \quad (1)$		subtraction of equations to eliminate $\ln A$
	$E_a = 40\,220 \text{ (J mol}^{-1}\text{)} \quad (1)$ $= 40.2 \text{ (kJ mol}^{-1}\text{)} \quad (1)$		evaluation of E_a in J mol^{-1} conversion from J mol^{-1} to kJ mol^{-1}
Total		5	