

**OXFORD**

INTERNATIONAL  
AQA EXAMINATIONS

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# INTERNATIONAL A-LEVEL **CHEMISTRY (9620)**

## **CH04**

Unit 4 Organic 2 and Physical 2

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Mark scheme

January 2022

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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.

Further copies of this mark scheme are available from [oxfordaqaexams.org.uk](http://oxfordaqaexams.org.uk)

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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. Emboldening

- 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  $\text{CN}^-$  when the reagent should be potassium cyanide or KCN;
- the hydroxide ion or  $\text{OH}^-$  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.

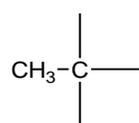
### 3.12 Organic structures

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.

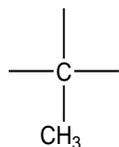
In general

- 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**.
- Latitute should be given to the representation of  $\text{C} - \text{C}$  bonds in alkyl groups, given that  $\text{CH}_3-$  is considered to be interchangeable with  $\text{H}_3\text{C}-$  even though the latter would be preferred.
- Similar latitute should be given to the representation of amines where  $\text{NH}_2-$  C will be allowed, although  $\text{H}_2\text{N}-$  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.

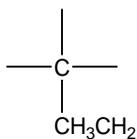
By way of illustration, the following would apply.



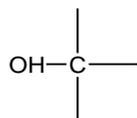
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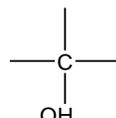
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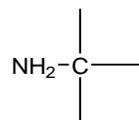
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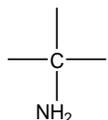
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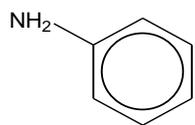
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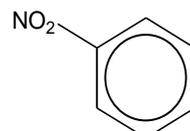
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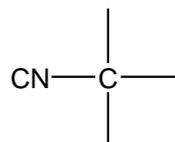
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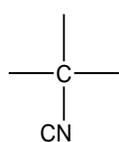
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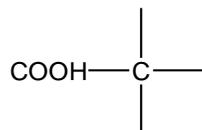
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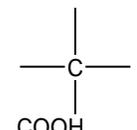
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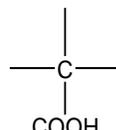
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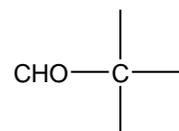
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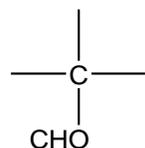
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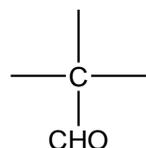
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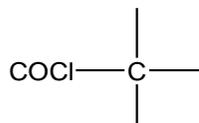
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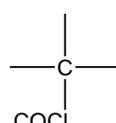
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- Representation of  $\text{CH}_2$  by  $\text{C-H}_2$  will be penalised
- Some examples are given here of **structures** for specific compounds that should **not** gain credit (but, exceptions may be made in the context of balancing equations)

$\text{CH}_3\text{COH}$  for ethanal

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

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

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

$\text{CH}_2\text{CH}_2$  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  $\text{C-H}$  bonds in a structure should **not** be penalised. The exceptions to this when “sticks” will be penalised include
  - structures in mechanisms where the  $\text{C-H}$  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

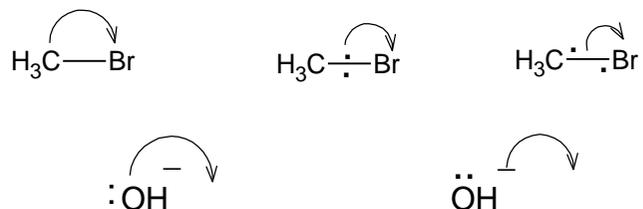
As a general principle, non-IUPAC names or incorrect spelling or incomplete names should **not** gain credit. Some illustrations are given here.

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

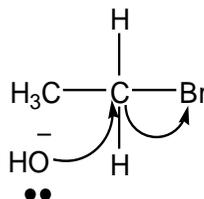
**3.14 Organic reaction mechanisms**

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	the <u>power</u> to which the concentration of a substance is raised in the rate equation	1	

Question	Marking guidance	Mark	Comments
01.2	$k = \frac{\text{rate}}{[\text{A}]^2[\text{H}^+]} = \frac{3.42 \times 10^{-7}}{(0.05)^2(0.1)}$	1	M1 for rearranged equation
	$= 1.37 \times 10^{-3}$	1	
	(units) $\text{dm}^6 \text{mol}^{-2} \text{s}^{-1}$	1	

Question	Marking guidance	Mark	Comments
01.3	$6.84 \times 10^{-7}$	1	
	0.133	1	

Question	Marking guidance	Mark	Comments
01.4	catalyst	1	
	not present in the overall equation but present in the rate equation	1	

Question	Marking guidance	Mark	Comments
01.5	the rate is independent of <b>B</b> <b>or</b> rate equation only involves <b>A</b> <b>or</b> [H <sup>+</sup> ] is in the rate equation but not in the overall equation	1	allow <b>B</b> is not in the rate equation
	<b>Total</b>	<b>9</b>	

Question	Marking guidance	Mark	Comments
02.1	(NO) 0.22 mol	1	allow M1 ÷ 2
	(Cl <sub>2</sub> ) 0.11 mol	1	

Question	Marking guidance	Mark	Comments
02.2	mole fraction of NOCl = $\left(\frac{0.24}{0.49}\right) = 0.490$	1	allow M1 × 52 M3 must be to 3 sig fig
	partial pressure of NOCl = 0.490 × 52	1	
	= 25.5 (kPa)	1	

Question	Marking guidance	Mark	Comments
02.3	$K_p = \frac{pp(\text{NO})^2 pp(\text{Cl}_2)}{pp(\text{NOCl})^2}$	1	do <b>not</b> accept square brackets

Question	Marking guidance	Mark	Comments
02.4	tick in final box: increases increases	1	

	<b>Total</b>	<b>7</b>	
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Question	Marking guidance	Mark	Comments
03.1	(2-)methylpropanal	1	

Question	Marking guidance	Mark	Comments
03.2		4	M1 $\text{:CN}^-$ <b>and</b> curly arrow from lone pair on C of $\text{:CN}^-$ (or $\text{:CN}^-$ ) to C of $\text{C=O}$ M2 curly arrow from $\text{C=O}$ to O M3 structure of intermediate including charge on O M4 curly arrow from lone pair on O to $\text{H}^+$

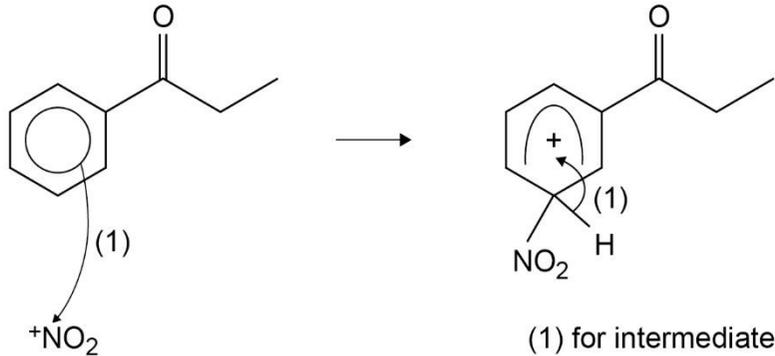
Question	Marking guidance	Mark	Comments
03.3	KCN is toxic	1	allow poisonous ignore dangerous to the environment <b>or</b> harmful.

Question	Marking guidance	Mark	Comments
03.4	a racemic mixture has no effect on plane polarised light	1	allow plane polarised light would not be rotated
	<b>Total</b>	<b>7</b>	

Question	Marking guidance	Mark	Comments
04.1	(enthalpy of hydrogenation of cyclohexa-1,3,5-triene = $3 \times -120$ )		
	= $-360 \text{ kJ mol}^{-1}$	1	
	(difference) = $152 \text{ kJ mol}^{-1}$	1	allow +/-152 $\text{kJ mol}^{-1}$
	(benzene releases less enthalpy when hydrogenated) as it is more stable than cyclohexa-1,3,5-triene	1	if $-300 \text{ (kJ mol}^{-1})$ used, difference = 92 ( $\text{kJ mol}^{-1}$ )
	because of the delocalisation of the (p) electrons	1	

Question	Marking guidance	Mark	Comments
04.2	propanoyl chloride / $\text{CH}_3\text{CH}_2\text{COCl}$	1	
	aluminium chloride / $\text{AlCl}_3$	1	

Question	Marking guidance	Mark	Comments
<b>04.3</b>	amount of <b>F</b> = $\frac{1.21}{134.0} = 0.00903$ (mol)	1	
	mass of benzene = $0.00903 \times 78.0 = 0.704$ (g)	1	allow M1 $\times 78.0$
	mass needed = $0.704 \times \frac{100}{65} = 1.08$ (g)	1	allow M2 $\times \frac{100}{65}$
	<b>Alternative method</b>		
	amount of <b>F</b> = $\frac{1.21}{134.0} = 0.00903$ (mol) (1)		
amount of <b>F</b> (assuming 100% yield) = $0.00903 \times \frac{100}{65} = 0.139$ (mol) (1)		allow M1 $\times \frac{100}{65}$	
mass of benzene = $0.139 \times 78.0 = 1.08$ (g) (1)		allow M2 $\times 78.0$	

Question	Marking guidance	Mark	Comments
04.4	<p>M1 (electrophile) <math>^+\text{NO}_2</math></p>  <p>(1) for intermediate</p>	<p>1 3</p>	<p>M2 curly arrow from circle to N of <math>^+\text{NO}_2</math></p> <p>M3 intermediate with horseshoe centred on 6-position <b>and</b> + charge in the centre <b>and</b> <math>\text{NO}_2</math> group attached to ring at 3-position</p> <p>M4 curly arrow from C-H bond into ring</p>
Total		13	

Question	Marking guidance	Mark	Comments
05.1	benzoic acid has hydrogen bonding between molecules	1	between molecules <b>must</b> appear in M1 <b>or</b> M2 to award M1 <b>or</b> M2
	propyl benzoate has (permanent) dipole-dipole interactions/forces between molecules	1	
	hydrogen bonds are stronger than (permanent) dipole-dipole forces	1	

Question	Marking guidance	Mark	Comments
05.2	(minimum volume) to give a saturated solution	1	allow to improve yield <b>once only</b> in 5.2, 5.3 or 5.4

Question	Marking guidance	Mark	Comments
05.3	(filtered while hot) to prevent crystallisation (of benzoic acid) before <b>or</b> during filtration <b>or</b> to remove insoluble impurities	1	allow to improve yield <b>once only</b> in 5.2, 5.3 or 5.4

Question	Marking guidance	Mark	Comments
05.4	(washed with cold water) to remove water soluble impurities or cold water to prevent (recrystallised) benzoic acid dissolving	1	allow to improve yield <b>once only</b> in 5.2, 5.3 or 5.4

Question	Marking guidance	Mark	Comments
05.5	(benzoic acid) crystals melt below 122 °C or crystals melt over a range of temperatures	1	

Question	Marking guidance	Mark	Comments
05.6	(reagent) Br <sub>2</sub> / bromine water (observation) turns from orange/yellow to colourless	1 1	allow decolourises do <b>not</b> accept turns clear





Question	Marking guidance	Mark	Comments
06.3	it gives the $M_r$ (as it is the molecular ion peak) <b>or</b> (fatty acid) <b>N</b> has an $M_r$ of 144(.0)	1	
	<b>Total</b>	<b>4</b>	

Question	Marking guidance	Mark	Comments
07.1	(reactant) $2\text{NH}_3$ <b>and</b> (product) $\text{NH}_4\text{Cl}$	1	allow multiples

Question	Marking guidance	Mark	Comments
07.2	$  \begin{array}{c}  \text{H} \\    \\  \text{H}-\text{C}-\text{C}\equiv\text{N} \\    \\  \text{H}  \end{array}  $	1	
	$\text{H}_2$ <b>and</b> Ni/Pt/Pd catalyst  <b>or</b> $\text{LiAlH}_4$ <b>and</b> ether	1	

Question	Marking guidance	Mark	Comments
07.3	further substitution reactions may occur for synthesis 1  <b>or</b> secondary/tertiary amines or quaternary ammonium salt may be formed in synthesis 1	1	allow mixture of amine products formed in synthesis 1

Question	Marking guidance	Mark	Comments
07.4	(nucleophilic) addition-elimination	1	allow $\text{CH}_3\text{COO}^- \text{CH}_3\text{CH}_2\text{NH}_3^+$
	(N-)ethylethanamide	1	
	$\text{CH}_3\text{COOH}$ or ethanoic acid	1	

Question	Marking guidance	Mark	Comments
07.5	$\text{H}_2\text{N}(\text{CH}_2)_6\text{NH}_2$ or $\text{H}_2\text{NCH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2$	1	allow correct displayed formula or skeletal formula

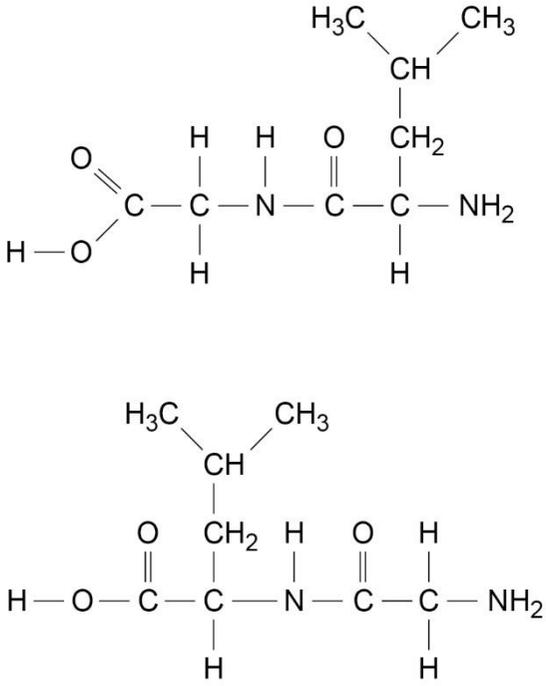
Question	Marking guidance	Mark	Comments
07.6	condensation (polymer)	1	

Question	Marking guidance	Mark	Comments
07.7	base or proton acceptor	1	allow acid-base reaction

	<b>Total</b>	<b>10</b>	
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Question	Marking guidance	Mark	Comments
08.1	2-amino-4-methylpentanoic acid	1	

Question	Marking guidance	Mark	Comments
08.2	$  \begin{array}{c}  \text{O} \\  \parallel \\  \text{O} - \text{C} - \text{C} - \text{NH}_3^+ \\    \quad   \\  \text{H} \quad \text{H}  \end{array}  $ zwitterion	1  1	

Question	Marking guidance	Mark	Comments
08.3	 <p>The image shows two structural diagrams of the dipeptide alanine-glycine. The top diagram shows the structure with the methyl group of the alanine side chain drawn as H<sub>3</sub>C and CH<sub>3</sub>. The bottom diagram shows the same structure with the methyl group drawn as H<sub>3</sub>C and CH.</p>	<p>1</p> <p>1</p>	<p>either order</p>

Question	Marking guidance	Mark	Comments
08.4	the sequence/order of amino acids in the protein	1	allow chain of amino acids in the protein

Question	Marking guidance	Mark	Comments
08.5	$\alpha$ -helix	1	
	hydrogen bonds	1	

Question	Marking guidance	Mark	Comments
08.6	S-S or disulfide bridge or disulfide bond	1	

Question	Marking guidance	Mark	Comments
08.7	cisplatin binds to N atom in DNA/protein/guanine bases	1	allow guanine bases are able to substitute for Cl ligands in cisplatin
	prevents DNA replication	1	

	<b>Total</b>	<b>11</b>	
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Question	Marking guidance	Mark	Comments
09.1	3	1	

Question	Marking guidance	Mark	Comments
09.2	$\begin{array}{ccccccc} & & \text{H} & & & & \\ & &   & & & & \\ & \text{H} & \text{O} & \text{H} & & & \\ &   &   &   & & & \\ \text{H} & - \text{C} & - \text{C} & - \text{C} & - \text{H} & & \\ &   &   &   & & & \\ & \text{H} & \text{H} & \text{H} & & & \end{array}$	1	allow any correct structure of propan-2-ol



Question	Marking guidance	Mark	Comments
09.5	(singlet at $\delta = 3.2$ due to) $\text{CH}_3$ attached to O or $\begin{array}{c} \text{H} \\   \\ -\text{O}-\text{C}-\text{H} \\   \\ \text{H} \end{array}$	1	

Question	Marking guidance	Mark	Comments
09.6	(quartet at $\delta = 3.5$ due to) $\text{O-CH}_2$ attached to (and coupled with) $\text{CH}_3$ or $\begin{array}{c} \text{H} \quad \text{H} \\   \quad   \\ -\text{O}-\text{C}-\text{C}-\text{H} \\   \quad   \\ \text{H} \quad \text{H} \end{array}$	1	

Question	Marking guidance	Mark	Comments
09.7	$\begin{array}{ccccccc} & \text{H} & & \text{H} & & \text{H} & \\ &   & &   & &   & \\ \text{H} & - \text{C} & - \text{O} & - \text{C} & - & \text{C} & - \text{H} \\ &   & &   & &   & \\ & \text{H} & & \text{H} & & \text{H} & \end{array}$	1	allow correct structural formula <b>or</b> skeletal formula
	<b>Total</b>	<b>8</b>	