A-level
CHEMISTRY
7405/3

Paper 3

Mark scheme

June 2024

Version: 1.0 Final

246A7405/3/MS

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.

No student should be disadvantaged on the basis of their gender identity and/or how they refer to the gender identity of others in their exam responses.

A consistent use of 'they/them' as a singular and pronouns beyond 'she/her' or 'he/him' will be credited in exam responses in line with existing mark scheme criteria.

Further copies of this mark scheme are available from aqa.org.uk

AS and 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 (i.e. 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 <u>not</u> 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 $Ag(NH_3)_2^+$ 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

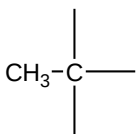
Where students are asked to draw organic structures, unless a specific type is required in the question and stated in the mark scheme, these may be given as displayed, structural or skeletal formulas or a combination of all three as long as the result is unambiguous.

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, eg 1-bromopropane should be shown as $CH_3CH_2CH_2Br$ and not as the molecular formula C_3H_7Br 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 C ─ HO, they should be penalised **on every occasion**.

- Latitude should be given to the representation of C ─ C bonds in alkyl groups, given that CH_3─ is considered to be interchangeable with H_3C ─ 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 H_2N─ C would be preferred.
- Poor presentation of vertical C ─ CH_3 bonds or vertical C ─ NH_2 bonds should **not** be penalised. For other functional groups, such as ─ OH and ─ 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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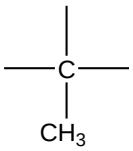

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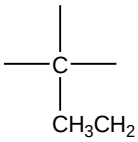

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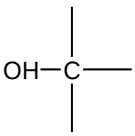

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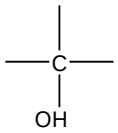

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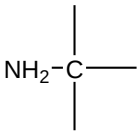

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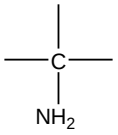

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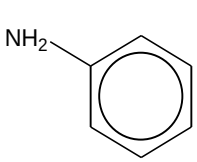

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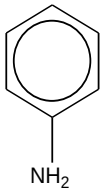

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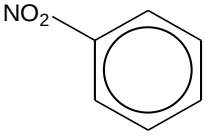

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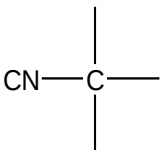

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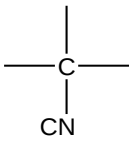

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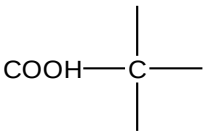

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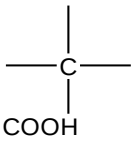

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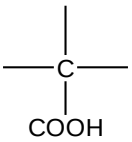

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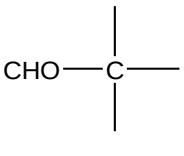

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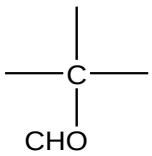

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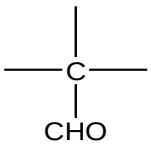

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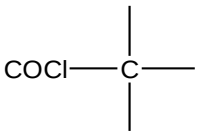

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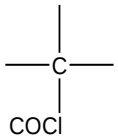


not allowed

- 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 <u>may</u> be made in the context of balancing equations)

CH_3COH	for	ethanal
CH_3CH_2HO	for	ethanol
$OHCH_2CH_3$	for	ethanol
C_2H_6O	for	ethanol
CH_2CH_2	for	ethene
$CH_2.CH_2$	for	ethene

CH_2**:**CH_2 for ethene

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

$CH_2 = CH_2$	for	ethene, $H_2C=CH_2$
$CH_3CHOHCH_3$	for	propan-2-ol, $CH_3CH(OH)CH_3$

- 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.

Unnecessary but not wrong numbers will **not** be penalised such as the number '2' in 2-methylpropane or the number '1' in 2-chlorobutan-1-oic acid.

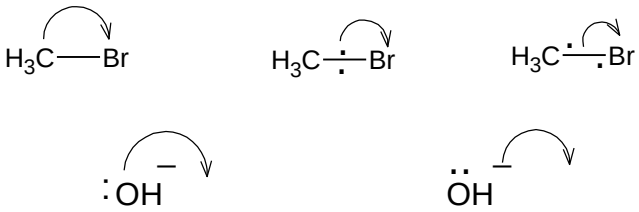
but-2-ol	should be **butan-2-ol**
2-hydroxybutane	should be **butan-2-ol**
butane-2-ol	should be **butan-2-ol**
2-butanol	should be **butan-2-ol**
ethan-1,2-diol	should be **ethane-1,2-diol**
2-methpropan-2-ol	should be **2-methylpropan-2-ol**
2-methylbutan-3-ol	should be **3-methylbutan-2-ol**
3-methylpentan	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**

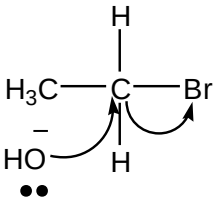
3.14 Organic reaction mechanisms

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.

3.15 Extended responses

For questions marked using a 'Levels of Response' mark scheme:

Level of response mark schemes are broken down into three levels, each of which has a descriptor. Each descriptor contains two statements. The first statement is the Chemistry content statement and the second statement is the communication statement.

Determining a level

Start at the lowest level of the mark scheme and use it as a ladder to see whether the answer meets the Chemistry content descriptor for that level. The descriptor for the level indicates the qualities that might be seen in the student's answer for that level. If it meets

the lowest level, then go to the next one and decide if it meets this level, and so on, until you have a match between the level descriptor and the answer.

When assigning a level you should look at the overall quality of the answer and not look to pick holes in small and specific parts of the answer where the student has not performed quite as well as the rest. If the answer covers different aspects of different levels of the mark scheme you should use a best fit approach for defining the level.

Once the level has been decided, the mark within the level is determined by the communication statement:

• If the answer completely matches the communication descriptor, award the higher mark within the level.

• If the answer does not completely match the communication descriptor, award the lower mark within the level.

The exemplar materials used during standardisation will help you to determine the appropriate level. There will be an exemplar in the standardising materials which will correspond with each level of the mark scheme and for each mark within each level. This answer will have been awarded a mark by the Lead Examiner. You can compare the student's answer with the exemplar to determine if it is the same standard, better or worse than the example. You can then use this to allocate a mark for the answer based on the Lead Examiner's mark on the exemplar.

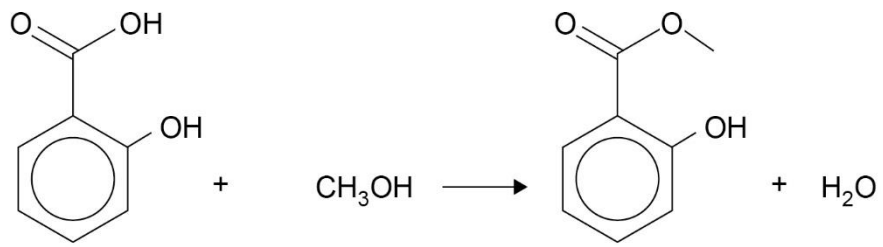
You may well need to read back through the answer as you apply the mark scheme to clarify points and assure yourself that the level and the mark are appropriate.

Indicative content in the mark scheme is provided as a guide for examiners. It is not intended to be exhaustive and you must credit other chemically valid points. Students may not have to cover all of the points mentioned in the indicative content to reach the highest level of the mark scheme. The mark scheme will state how much chemical content is required for the highest level.

An answer which contains nothing of relevance to the question must be awarded no marks.

For other extended response answers:

Where a mark scheme includes linkage words (such as 'therefore', 'so', 'because' etc), these are optional. However, a student's marks for the question may be limited if they do not demonstrate the ability to construct and develop a sustained line of reasoning which is coherent, relevant, substantiated and logically structured. In particular answers in the form of bullet pointed lists may not be awarded full marks if there is no indication of logical flow between each point or if points are in an illogical order. The mark schemes for some questions state that the maximum mark available for an extended response answer is limited if the answer is not coherent, relevant, substantiated and logically structured. During the standardisation process, the Lead Examiner will provide marked exemplar material to demonstrate answers which have not met these criteria. You should use these exemplars as a comparison when marking student answer.

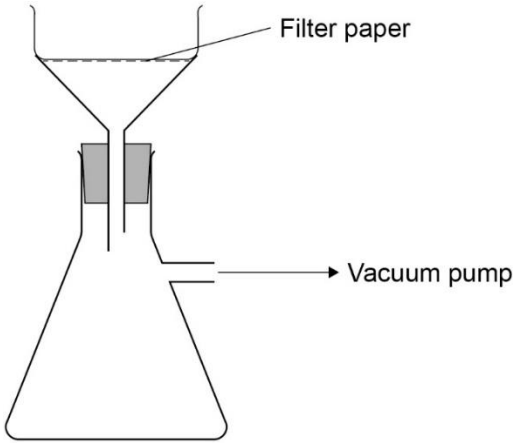
Question	Answers	Additional comments/Guidelines	Mark
1.1	**M1** skeletal formula of organic product **M2** rest of equation 	**M1** Need H on alcohol OH **M1** Allow O–H for alcohol OH **M2** for correct formulae for 2-hydroxybenzenecarboxylic acid and methanol on left and H_2O on right **M2** Allow $C_7H_6O_3$/HOC_6H_4COOH and CH_4O Ignore additional non-skeletal structures for ester (assume it is working out) Allow Kekulé structures for rings	2 (2 x AO2)

Question	Answers	Additional comments/Guidelines	Mark
1.2	Ethanoic anhydride/It is less/not corrosive OR Ethanoic anhydride/It does not form strong acid/HCl /(only) forms weak/ethanoic/carboxylic acid OR Ethanoic anhydride/It is less/not vulnerable to hydrolysis	Allow reverse argument for ethanoyl chloride e.g. ethanoyl chloride is (more) corrosive Ignore cost / less volatile / products are less harmful / safer / toxic / produces toxic fumes Ignore references to less/more exothermic/violent/vigorous	1 (1 x AO1)

Question	Answers	Additional comments/Guidelines	Mark
1.3	(nucleophilic) addition-elimination	Ignore esterification / acylation	1 (1 x AO1)

Question	Answers	Additional comments/Guidelines	Mark
1.4	catalyst	Ignore proton donor / heterogeneous / homogeneous Allow speeds up reaction / lowers activation energy	1 (1 x AO3)

Question	Answers	Additional comments/Guidelines	Mark
1.5	boiling points are above 85 °C	Allow product(s) or reactant(s) or named product(s) or reactant(s) boiling points are above 85 °C Allow none of them would boil / mixture would not boil / do not need to boil the mixture Allow no volatile reagent(s)/product(s)/reactant(s) Ignore reference to mixture/substances not evaporating / vaporising	1 (1 x AO3)

Question	Answers	Additional comments/Guidelines	Mark
1.6	 **M1** • Cross sectional (i.e. funnel top and bottom shown open) • Bung or collar drawn (with funnel spout visible through) • (Buchner/Hirsch) Funnel – approximate shape • Horizontal filter paper – allow solid or dashed line **M2** Labels must include filter paper and indication of vacuum/water pump / reduced pressure / suction		2 (2 x AO3)

Question	Answers	Additional comments/Guidelines	Mark
1.7	Any 2 of: • ethanoic acid • phosphoric acid • 2-hydroxybenzenecarboxylic acid • ethanoic anhydride • water	Ignore catalyst / unreacted reactants Allow names or correct formulae Allow salicylic acid / 2-hydroxybenzoic acid	2 (2 x AO3)

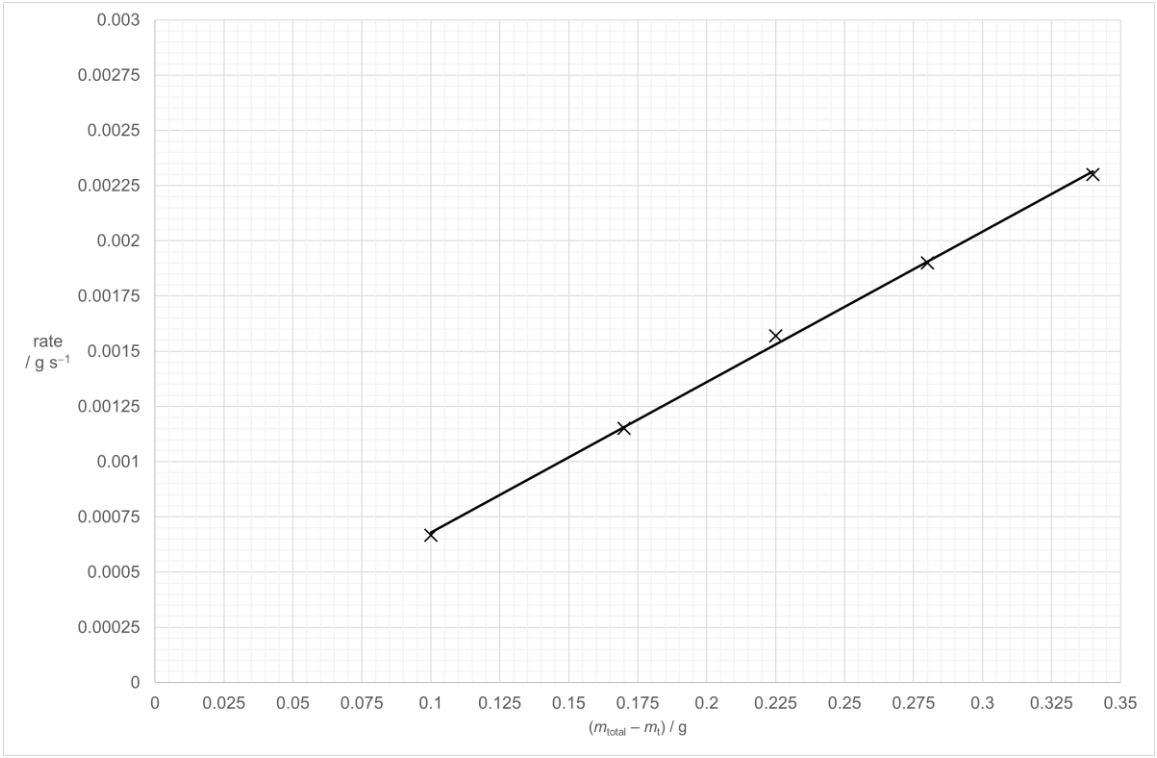
Question	Answers	Additional comments/Guidelines	Mark
1.8		Ignore initial filtration	6 (6 x AO1)
	M1 Dissolve crude product in <u>hot</u> solvent (water and ethanol)	**M1** not wrong solvent if named	
	M2 of minimum volume	**M2** allow reference to saturated solution as alternative to minimum volume	
	M3 Filter (hot to remove insoluble impurities)	**M3** ignore method of filtration allow decant	
	M4 Cool (to recrystallise)		
	M5 Filter under reduced pressure / with Buchner/Hirsch apparatus		
	M6 wash (with cold solvent) **and** dry	**M6** allow water and/or ethanol	
		Apply list principle for each additional process (e.g. drying agent added, base to neutralise acid added, distillation, solvent extraction) in an incorrect method	
		Ignore reference to melting point determination	

Question	Answers	Additional comments/Guidelines	Mark
1.9	**M1** melting point **M2** lower (than data book value) **M3** melts over a (wide) range of temperature (rather than sharp/narrow range if pure)	**M1** Ignore boiling point **M2/3** in either order **M2** Ignore 'different' **M2** ECF for 'higher' if b.pt in M1 **M2** If b.pt in M1 NOT 'lower' **M3** ECF from b.pt	3 (3 x AO1)

Question	Answers	Additional comments/Guidelines	Mark
2.1	**M1** (instead of leaving the flask open) to avoid acid/solution/liquid escaping OR to avoid (acid/solution/liquid) splashing/spraying/spitting (out) **M2** (instead of inserting a bung) to allow gas/CO_2 to escape	Ignore evaporation / spilling / to let gas escape / to avoid loss of product/reactant / impurities getting in Ignore pressure would build up Ignore air NOT other wrongly identified gas(es)	2 (2 x AO3)

Question	Answers	Additional comments/Guidelines	Mark
2.2	so that surface area/mass/amount stays (approx./effectively) constant	Ignore concentration stays constant Ignore volume Ignore so HCl is the limiting factor Ignore so rate is only affected by [HCl] (as in Q)	1 (1 x AO3)

Question	Answers	Additional comments/Guidelines	Mark
2.3	**M1** m_t/mass of CO_2 produced in time *t* is proportional to the (amount/concentration of) HCl that has reacted (at time *t*) **M2** m_{total}/total mass of CO_2 produced is proportional to the total (amount/concentration of) HCl that has reacted/was present initially (therefore $m_{total} - m_t$ is proportional to (amount/conc of) HCl present at time *t*)	Allow 'equal to' / 'represents' for proportional to Allow m_{total} is proportional to HCl 'added' Alternative answer: **M1** $m_{total} - m_t$ is equal/proportional to (mass/amount of) CO_2 still to be produced **M2** (mass/amount of) CO_2 still to be produced is proportional to (amount/concentration of) HCl still to react	2 (2 x AO2)

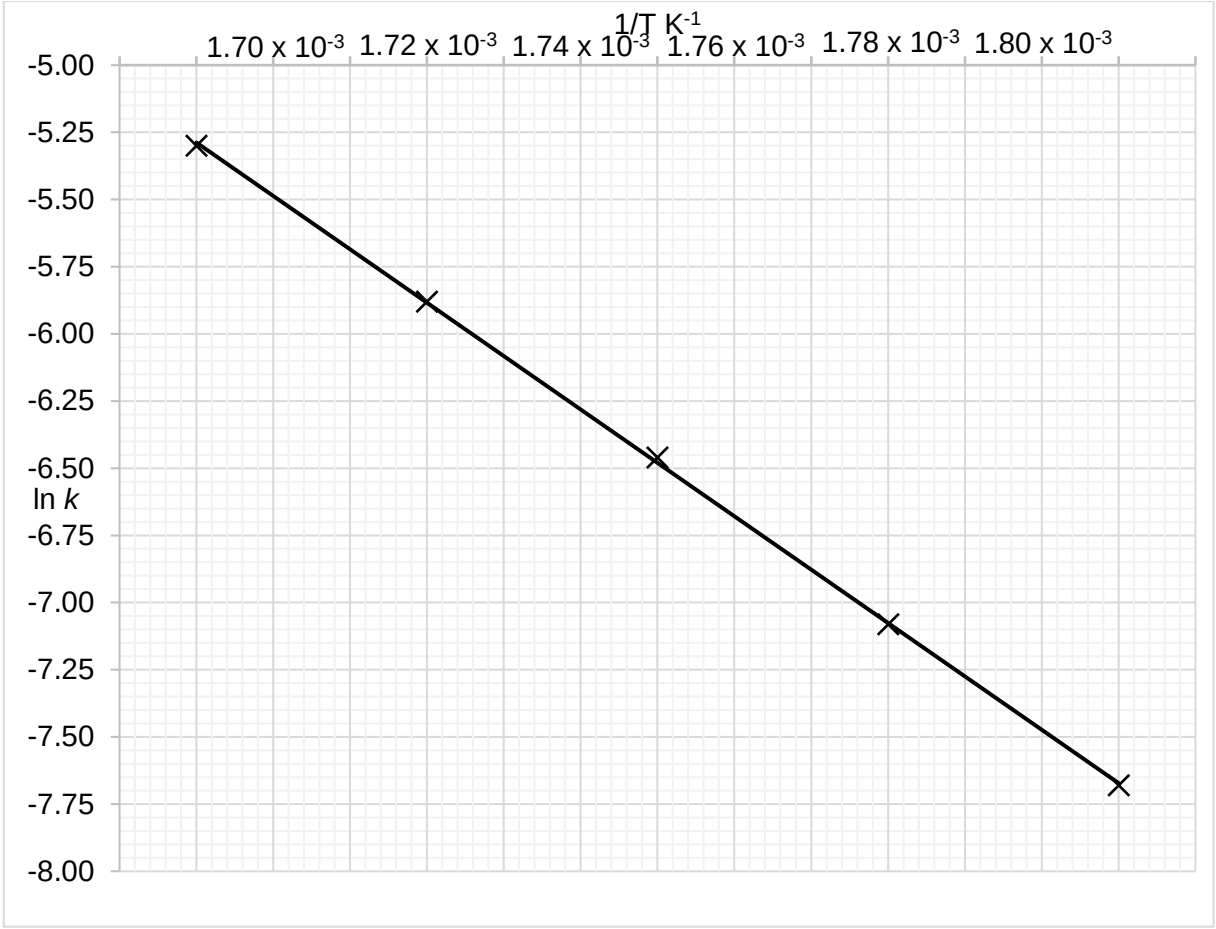
Question	Answers	Additional comments/Guidelines	Mark
2.4	 **M1** scales designed so that plotted points (and origin if shown) occupy >50% along each axis **and** axes labelled including units **M2** plotted points (all within half a small square) **M3** suitable straight line (should be within one square of all points except potentially the middle one)	**NOT** if either/both scale reversed but allow ecf M2 and M3 **M3** ECF for best fit line (points above and below) from their plotted points	3 (3 x AO2)

Question	Answers	Additional comments/Guidelines	Mark
2.5	straight line **AND** through origin	Allow 'constant gradient' for straight line Ignore (directly) proportional	1 (1 x AO3)

Question	Answers	Additional comments/Guidelines	Mark
2.6	Any two from: • volume of gas / CO_2 • pH • concentration of HCl/acid/H^+ • conductivity	NOT temperature NOT 'volume' or 'concentration' unqualified NOT time for $CaCO_3$ to 'dissolve'/disappear (as in excess) Ignore mass loss Ignore amount of CO_2	2 (2 x AO3)

Question	Answers	Additional comments/Guidelines	Mark
3.1	1.75×10^{-3} AND –6.46	Allow 0.00175 NOT other sig figs (e.g. 1.7×10^{-3}, –6.5) NOT 1.74×10^{-3}	1 (1 x AO2)

Question	Answers	Additional comments/Guidelines	Mark
3.2	**M1** unit of *k* (is s^{-1}) **M2** (order) 1 / first	Mark independently **M1** Allow s^{-1} or *k* / s^{-1} or *k* in s^{-1} NOT just *k*	2 (2 x AO1)

Question	Answers	Mark
3.3	 **M1** points plotted (all within half a square) (ECF from 3.1 for 3rd point including if no values in the table) **M2** best fit straight line (line within one square of each point) (best fit line – points above and below - based on their plotted points)	2 (2 x AOa2)

Question	Answers	Additional comments/Guidelines	Mark
3.4	**M1** gradient (expected value = –19900) **M2** $-\frac{E_a}{R}$ = gradient **M3** $E_a = \frac{-M1 \times 8.31}{1000}$ = (+)165 (kJ mol^{-1})	Answer of (+)161 to (+)170 gets 3/3 Allow range from –19400 to –20400 from correct plotting and best fit line ECF from any straight line can be implied by calculation shown e.g. E_a = –M1 × 8.31 gets M2 Allow negative E_a if positive gradient in M1	3 (3 x AO2)

Question	Answers	Additional comments/Guidelines	Mark
3.5	**M1** (alkene) $CH_2=CHCH_3$ **M2** (carbonyl) $(CH_3)_2CO$ / CH_3COCH_3	Allow any correct structural representations C=C must be shown Allow $C(CH_3)_2O$ If correct two structures are given but the wrong way round, then scores 1 mark	2 (2 x AO2)

Question	Answers	Additional comments/Guidelines	Mark
4.1	only a (small) fraction of the molecules dissociate (into ions) / ionise (when added to water / in aqueous solution) OR partially dissociates / does not fully dissociate (into ions) / ionise (when added to water / in aqueous solution)	Not 'reaction is reversible' Not if incorrect ions suggested Not "Hydrogen ions do not fully dissociate"	1 (1 x AO1)

Question	Answers	Additional comments/Guidelines	Mark
4.2	as there is a large pH change (for a small addition of alkali)	Need idea of rapid/large change in pH Allow pH change is rapid / gradient is steep (at equivalence point) Ignore equivalence/end point is very steep Ignore so they do not miss the equivalence point	1 (1 x AO3)

Question	Answers	Additional comments/Guidelines	Mark
4.3	**M1** $K_a = \frac{[H^+]\,[CH_3CH_2COO^-]}{[CH_3CH_2COOH]}$	Allow $[H_3O^+]$ for $[H^+]$ NOT () for concentration NOT $K_a = \frac{[H^+]^2}{[CH_3CH_2COOH]}$	3 (3 x AO2)
	M2 $[CH_3CH_2COOH] = [CH_3CH_2COO^-]$	Allow $[HA] = [A^-]$ / mol/amount of HA = mol/amount of A^- Allow $[HA]/[A^-]$ OR $[A^-]/[HA] = 1$	
	M3 $K_a = [H^+]$ (therefore pH = pK_a)	Allow Log 1 = 0	

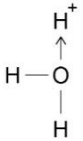
Question	Answers	Additional comments/Guidelines	Mark
4.4	**M1** allow pH between 4.4 – 4.7 **M2** answer from $K_a = 10^{-M1}$ to min 2sf	M2 ECF from M1 only if M1 is in range 4.0 to <4.4 or >4.7 to 5.0 If M1 in range shown, M2 = 1.99526×10^{-5} to 3.9811×10^{-5} to at least 2 sf Using pH at start (= 2.80) scores 0/2	2 (2 x AO3)

Question	Answers	Additional comments/Guidelines	Mark
4.5	**M1** OH^- reacts with propanoic acid OR reacts with H^+ **M2** EITHER ratio of $[CH_3CH_2COOH]$ to $[CH_3CH_2COO^-]$ remains almost constant OR Equilibrium **for dissociation of CH_3CH_2COOH** moves right to maintain $[H^+]$ /replace H^+	Allow CH_3CH_2COOH dissociates to maintain $[H^+]$ /replace H^+	2 (2 x AO1)

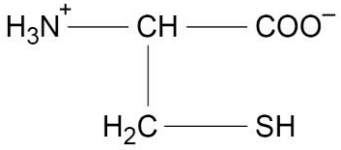
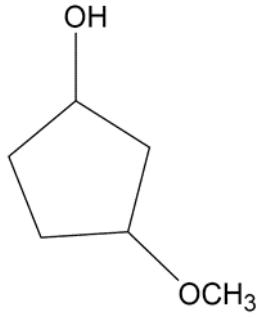
Question	Answers	Additional comments/Guidelines	Mark
4.6	**M1** methyl orange – would not change colour at the equivalence point (allow end-point) / pH range does not match rapid pH change / pH range does not include/match equivalence point **M2** universal indicator – idea of range of colours during titration / no distinct colour change (at equivalence/end-point)	Allow methyl orange changes colour before/below equivalence point Allow pH range does not fall in the range of pH from 6-11 Ignore reference to this being a weak acid – strong base titration	2 (2 x AO3)

<table>
<tr><th>Question</th><th>Answers</th><th>Additional comments/Guidelines</th><th>Mark</th></tr>
<tr>
<td>5.1</td>
<td>
<table>
<tr><td colspan="2">This question is marked using Levels of Response. Refer to the Mark Scheme Instructions for Examiners for guidance.</td></tr>
<tr><td>Level 3
5–6 marks</td><td>All stages are covered, and the explanation of each stage is correct and virtually complete
Answer communicates the whole explanation coherently and shows a logical progression through all three stages.</td></tr>
<tr><td>Level 2
3–4 marks</td><td>All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies.
OR
two stages are covered, and the explanations are generally correct and virtually complete.
Answer is coherent and shows some progression through all three stages. Some steps in each stage may be incomplete.</td></tr>
<tr><td>Level 1
1–2 marks</td><td>Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies.
OR
only one stage is covered but the explanation is generally correct and virtually complete.
Answer shows some progression between two stages.</td></tr>
<tr><td>0 mark</td><td>Insufficient correct chemistry to gain a mark.</td></tr>
</table>
</td>
<td>
Indicative Chemistry content
<u>Stage 1 absorption of light</u>
(3/4 virtually complete, 1/4 for covered)
1a d orbitals have different energy / d orbital (energies) are split
1b electrons move to higher (energy) (d) orbitals / electrons move to excited state
1c absorb visible/white light
1d colour seen is that from complementary colours / colours transmitted/reflected/not absorbed
<u>Stage 2 reasons for different colours</u>
(3/4 virtually complete, 1/4 for covered)
2a the metal
2b the oxidation state (of the metal) / charge of metal (ion)
2c the ligand(s)
2d the co-ordination number / shape
<u>Stage 3 Colorimetry</u>
(2/3 virtually complete, 1/3 for covered)
3a measure the absorbance for a range of (known) concentrations
3b plot graph of absorbance v concentration / calibration curve (of absorbance v concentration)
3c measure absorbance of the coloured complex and find concentration from graph
</td>
<td>6
(6 x AO1)</td>
</tr>
</table>

Question	Answers	Additional comments/Guidelines	Mark
5.2	**M1** wavelength = 800 (nm) ± 5 **M2** $\Delta E \left(= \frac{hc}{\lambda} \right) = \frac{6.63 \times 10^{-34} \times 3.00 \times 10^{8}}{M1 \times 10^{-9}}$ **M3** 2.49×10^{-19} (J) (allow ECF from M1 or M2)	Range 2.47×10^{-19} to 2.502×10^{-19} = 3/3 Range 2.47×10^{-28} to 2.502×10^{-28} = 2/3 800 nm on bottom of expression scores M1 at least 2sf NOT ECF from M2 if equation re-arranged incorrectly	3 (3 x AO3)

Question	Marking Guidance	Mark	Comments
06	C	1 (AO2)	H_3O^+ and HF_2^+
07	B	1 (AO1)	Be
08	A	1 (AO2)	15%
09	B	1 (AO1)	$(NH_4)_2C_2O_4$
10	C	1 (AO2)	
11	C	1 (AO1)	cyclohexane
12	D	1 (AO2)	$SiCl_4$
13	A	1 (AO2)	CH_3CH_2COOH
14	C	1 (AO1)	The total number of molecules in the reaction mixture
15	A	1 (AO2)	0.4
16	C	1 (AO1)	The proportion of successful collisions increases because there is a decrease in activation energy.
17	C	1 (AO2)	+1.69 V
18	A	1 (AO3)	The concentration of hydroxide ions in water at 18 °C is 8.00×10^{-8} mol dm^{-3}

19	D	1 (AO2)	Chlorine has the highest first ionisation energy.
20	A	1 (AO1)	The boiling point of HX increases.
21	C	1 (AO1)	They form a cobalt(II) complex with a tetrahedral shape.
22	D	1 (AO2)	$Al(H_2O)_3(OH)_3$ and CO_2
23	C	1 (AO2)	$CH_3CHClCH=C(CH_3)COOH$
24	D	1 (AO1)	$CH_3CH_2CHO \longrightarrow CH_3CH_2CH(OH)CN$
25	D	1 (AO2)	propyl propanoate
26	D	1 (AO2)	3-methylpent-2-ene
27	A	1 (AO3)	2-hydroxy-2,3-dimethylbutanenitrile
28	C	1 (AO2)	Nylon-6,6 can be hydrolysed by aqueous sodium hydroxide.
29	D	1 (AO2)	An increase in pressure, at constant temperature, increases the equilibrium yield of ethanol.
30	D	1 (AO2)	C_6H_5COOH
31	A	1 (AO1)	polyalkene
32	B	1 (AO3)	a polyamide

33	D	1 (AO1)	
34	B	1 (AO3)	
35	A	1 (AO2)