

Mark Scheme (Results)

Summer 2022

Pearson Edexcel GCE
Chemistry (9CH0)
Paper 03 General and Practical Principles in Chemistry

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Summer 2022
Question Paper Log Number P67905
Publications Code 9CH0_03_2206_MS
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General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.
- Mark schemes will indicate within the table where, and which strands of QWC, are being assessed. The strands are as follows:

  i) ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear
  ii) select and use a form and style of writing appropriate to purpose and to complex subject matter
  iii) organise information clearly and coherently, using specialist vocabulary when appropriate

Using the Mark Scheme

Examiners should look for qualities to reward rather than faults to penalise. This does NOT mean giving credit for incorrect or inadequate answers, but it does mean allowing candidates to be rewarded for answers showing correct application of principles and knowledge. Examiners should therefore read carefully and consider every response: even if it is not what is expected it may be worthy of credit.

The mark scheme gives examiners:
- an idea of the types of response expected
- how individual marks are to be awarded
- the total mark for each question
- examples of responses that should NOT receive credit.

/ means that the responses are alternatives and either answer should receive full credit.
( ) means that a phrase/word is not essential for the award of the mark, but helps the examiner to get the sense of the expected answer.
Phrases/words in **bold** indicate that the meaning of the phrase or the actual word is **essential** to the answer.
ecf/TE/cq (error carried forward) means that a wrong answer given in an earlier part of a question is used correctly in answer to a later part of the same question.

Candidates must make their meaning clear to the examiner to gain the mark. Make sure that the answer makes sense. Do not give credit for correct words/phrases which are put together in a meaningless manner. Answers must be in the correct context.

Quality of Written Communication
Questions which involve the writing of continuous prose will expect candidates to:
- write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear
- select and use a form and style of writing appropriate to purpose and to complex subject matter
- organise information clearly and coherently, using specialist vocabulary when appropriate.

Full marks will be awarded if the candidate has demonstrated the above abilities.
Questions where QWC is likely to be particularly important are indicated (QWC) in the mark scheme, but this does not preclude others.

Question Number	Answer	Additional guidance	Mark
1(a)	An answer that makes reference to the following points: • (the relative atomic mass of an element is) the **weighted** mean of the masses of its atoms / isotopes **(1)** • relative to 1/12 of the mass of carbon-12 / relative to carbon-12 which has a mass of exactly 12 units **(1)**	mass and atom only need to be mentioned once each in M1 or M2 Accept the weighted mean mass of an atom Allow 'average' for 'mean' but not for 'weighted' Allow the mean mass of **all** atoms Do not award just 'element' for atom / isotope Do not award the weighted mean mass of an isotope Ignore mention of mole. Allow compared instead of relative Do not award M2 if mass number mentioned **Note**: the equation: $\frac{weighted\ mean\ mass\ of\ an\ atom}{\frac{1}{12}of\ the\ mass\ of\ a\ carbon\ 12\ atom}$ scores both marks	**(2)**

Question Number	Answer	Additional guidance	Mark
1(b)	• expression for weighted mean **(1)** • calculation of relative atomic mass and correct rounding to 3 SF **(1)**	Example of calculation $\frac{(84.80 \times 20) + (2.26 \times 21) + (12.94 \times 22)}{100}$ = (20.2814) = 20.3 Correct answer with no / some working scores (2) Allow TE **only** on a transcription error from data Ignore units	**(2)**

(Total for Question 1 = 4 marks)

Question Number	Answer	Additional Guidance	Mark
2(a)(i)	An explanation that makes reference to the following points: **Splitting** • (ligand / water molecule causes) d orbitals to split (into 2 energy levels) **(1)** **Absorption** • electrons absorb energy (in the visible region) / photons (of visible light) **(1)** **Promotion** • to promote electrons (to higher d orbitals) **or** electrons move from lower to higher energy (d) orbitals / levels **(1)** **Colour** • the remaining light / unabsorbed light / complementary colour / pink light is transmitted **(1)**	Penalise omission of 'd' once only Allow d subshell / shell for d orbitals Do not award 'a d orbital is split' Do not award 'electrons are split' Allow energy / photons / light absorbed Allow d-d transitions occur Allow electrons are excited / jump for promote Ignore reference to electron(s) relaxing / dropping to ground state Do not award d-s transitions Allow reflected / emerged / seen Do not award 'emitted'	**(4)**

Question Number	Answer	Additional Guidance	Mark
2(a)(ii)	An explanation that makes reference to the following points: **Electron pairs** • 6 (dative) pairs of (bonding) electrons (around cobalt ion) **(1)** **Minimise repulsion** • (electron / bond pairs) arranged in order to minimise repulsion **(1)** **Shape** • so shape is octahedral **(1)**	Pairs only needs to be mentioned once in M1 or M2 Allow areas of electron density for pairs of electrons Allow 6 bond(ing) pairs May be shown on diagram but dative bonds must be between O and Co^{2+} Do not award mention of having any lone pairs Allow to maximise separation between electron / bond pairs or the electron / bond pairs are as far apart as possible Ignore equal repulsion between bond pairs Ignore comments based on repulsion / separation between bonds / atoms Ignore comments on repulsion between bond pairs and lone pairs Allow 3-D diagram to show octahedral shape Allow square based **bi**pyramidal Do not award octagonal No TE on incorrect number of electron pairs Ignore bond angles	**(3)**

Question Number	Answer	Additional Guidance	Mark
2(a)(iii)	An answer that makes reference to the following points: **Rinsed** • rinsed to remove cobalt(II) sulfate (solution) **(1)** **Ice-cold water** • ice-cold water minimises / prevents ammonium cobalt(II) sulfate / crystals (re)dissolving **(1)** **Warm oven** • warm oven (rather than hot) to ensure water of crystallisation is not removed (during drying) **or** to stop the crystals melting **(1)**	Allow to remove remaining solution Allow to remove impurities that didn't crystallise Allow just 'to remove impurities' Ignore to remove ammonium sulfate Ignore to remove solvent Do not award to remove insoluble impurities Allow the crystals are insoluble / less soluble in cold water Ignore to stop the reaction Do not award to stop the crystals melting Allow to dry crystals / remove water Do not award to remove water of crystallisation / heat to constant mass	**(3)**

Question Number	Answer	Additional Guidance	Mark
2(b)	An answer that makes reference to **two** of the following points: • some ammonium cobalt(II) sulfate solution lost if it 'spits' out of basin when heated (in Step 1) **(1)** • some ammonium cobalt(II) sulfate remains in solution (in Step 1) **(1)** • some ammonium cobalt(II) sulfate is soaked into the filter paper/ some ammonium cobalt(II) sulfate crystals remain on filter paper (in Step 2) **(1)** • transfer losses from reaction flask / beaker to evaporating basin / from evaporating basin to filter funnel (in Steps 1 and 2) **(1)** • some water of crystallisation is lost during the drying process (in Step 4) **(1)**	Allow e.g. crystals / salt / solid / product for ammonium cobalt(II) sulfate Do not award crystals evaporated for M1 only Allow the crystals weren't left to crystallise for long enough Allow just 'solid is lost during filtration' Allow any type of specific transfer loss e.g. some product left behind in the beaker / flask / evaporating basin Allow crystals decompose during drying Allow some ammonium cobalt(II) sulfate dissolves in ice-cold water (in Step 3) Ignore formation of alternative product Ignore reaction is reversible	**(2)**

(Total for Question 2 = 12 marks)

Question Number	Answer	Additional Guidance	Mark
3(a)(i)	A description that makes reference to the following points: • any mention of platinum / nichrome wire / loop **(1)** • dip the wire into (clean / fresh concentrated) hydrochloric acid / HCl **(1)** • dip the (wet) wire into the solid and place **in** a (non-luminous / roaring / blue Bunsen) **flame** **(1)**	Allow NiCr for nichrome Allow silica rod Ignore 'inoculating' / 'sterilising' Do not award just nickel or chromium Allow mention of HCl before or after dipping wire into solid e.g. cleaning or mixing solid and HCl to make a paste Ignore concentration of HCl Ignore just 'acid' / other acids specified Do not award HCl reacting with flame test wire Allow salt / compound / paste / sample / solution for solid Allow through the flame / on the edge of the flame for in the flame Do not award element / metal for solid Do not award over / above / under the flame Do not award just 'into a Bunsen' Do not award 'burn in flame' Do not award flame if Bunsen has air-hole closed / safety flame	**(3)**

Question Number	Answer	Additional guidance	Mark
3(a)(ii)	• Na^+	Ignore state symbols Ignore sodium / sodium ion Do not award incorrect charge	**(1)**

Question Number	Answer	Additional Guidance	Mark
3(b)(i)	• SO_4^{2-}	Ignore state symbols Ignore sulfate(VI) / sulfate/ sulphate Do not award sulfate(IV) / sulfite / hydrogensulfate Do not award incorrect charge	**(1)**

Question Number	Answer	Additional Guidance	Mark
3(b)(ii)	• Na_2SO_4	Ignore state symbols Ignore names Allow TE from other **ions,** with correct charges, given in (a)(ii) and (b)(i) Allow large numbers e.g. Na2SO4 but not superscripts e.g. Na^2SO^4	**(1)**

Question Number	Answer	Additional Guidance	Mark
3(c)(i)	An explanation that makes reference to the following points: • (not using a lid means) some of salt **Y** could be lost from crucible during heating **(1)** • (mass loss greater than expected), so *n* / amount of water (of crystallisation) greater (than expected) **(1)**	Allow solid / product / crystals for 'salt' Allow 'salt spits / jumps out' / 'salt escapes' from crucible Ignore gas escapes Do not award 'salt evaporates' M2 dependent on M1 or salt evaporates	**(2)**

Question Number	Answer	Additional Guidance	Mark
3(c)(ii)	An explanation that makes reference to the following points: • (heating for only 1 minute may mean) not all the water (of crystallisation) has been removed **(1)** • (mass loss less than expected), so *n* / amount of water (of crystallisation) less (than expected) **(1)**	Allow evaporated / boiled off for removed Allow (only) partial dehydration Ignore incomplete reaction M2 dependent on M1 or incomplete reaction	**(2)**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>3(c)(iii)</td><td>

- calculation of moles of K_2CO_3 **(1)**
- calculation of moles of H_2O **(1)**
- deduction of n **(1)**

</td><td>
Example of calculation
<table>
<tr><td></td><td>K_2CO_3</td><td>H_2O</td></tr>
<tr><td>Moles =</td><td>71.9 / (138.2)
= 0.52026</td><td>(100 - 71.9) / 18
= 1.56111</td></tr>
<tr><td>Ratio =</td><td>= 0.52026 /
0.52026
= 1</td><td>= 1.56111 /
0.52026
= 3</td></tr>
<tr><td>n =</td><td colspan="2">3</td></tr>
</table>
Accept use of 0.719 / 0.281 in M1
Allow TE from M1
Allow use of 138 for M_r of K_2CO_3 – gives 0.52101
Ignore SF including 1SF in M1 and M2
M3 must be 1 SF

Accept alternative methods e.g.
$\frac{138.2}{138.2 + 18n} = 0.719$ (1)
$38.8342 = 12.942n$ (1) so $n = 3$ (1)
or
M_r of hydrated salt = $\frac{138.2}{0.719} = 192.2$ (1)
mass of water = 192.2 – 138.2 = 54 (1)
$n = 54/18 = 3$ (1)
or
138.2 = 71.9% so 28.1% is water (1) $\frac{138.2}{71.9} \times 28.1 = 54$ (1)
$n = 54/18 = 3$ (1)

Correct answer with no working scores (1)
Correct answer with some correct working scores (3)
</td><td>(3)</td></tr>
</table>

(Total for Question 3 = 13 marks)

Question Number	Answer	Additional Guidance	Mark
4(a)(i)	• calculation of ΔS_{system} **(1)** • calculation of $\Delta S_{surroundings}$ **(1)** • conversion of ΔS_{system} or $\Delta S_{surroundings}$ for consistent units **(1)** • calculation of ΔS_{total} **and** corresponding units **(1)** • comment on thermal stability at 298 K **(1)** **Alternative method on next page**	Marks should be awarded for method 1 or method 2 but not via mixed methods. If both methods used, then award higher mark. Example of calculation (213.6 + 70.4) – 112.1 = 171.9 (J K^{-1} mol^{-1}) −169.3 / 298 = −0.56812 (kJ K^{-1} mol^{-1}) or (−169.3 x 1000) / 298 = −568.12 (J K^{-1} mol^{-1}) $\Delta S_{surroundings}$ converted to J K^{-1} mol^{-1} **or** ΔS_{system} converted to kJ $K^{-1}$$mol^{-1}$ M3 could be subsumed as part of either M1 or M2 171.9 + (− 568.12) = − 396.22 J K^{-1} mol^{-1} **or** 0.1719 + (−0.56812) = −0.39622 kJ K^{-1} mol^{-1} Allow units to be missing here if correct units given for ΔS_{system} **and** $\Delta S_{surroundings}$ Correct answer with units with some or no working scores (4) Ignore SF except 1 SF Allow TE throughout calculation Stand alone mark on any negative value for ΔS_{total} Negative value / <0 **and** so reaction is not feasible / it is thermodynamically stable (at 298 K)/ Ignore just 'so the reaction is not feasible' No TE for positive values for ΔS_{total}	**(5)**

4(a)(i) continued	**Alternative method using Δ*G***	Example of calculation	**(5)**
	• calculation of ΔS_{system} **(1)**	$(213.6 + 70.4) - 112.1 = 171.9$ (J K^{-1} mol^{-1})	
	• calculation of $T\Delta S_{system}$ **(1)**	298 x 171.9 = 51226 (J mol^{-1}) M2 could be subsumed as part of M3	
	• conversion of $T\Delta S_{system}$ or ΔS_{system} or ΔH for consistent units **(1)**	ΔH converted to J mol^{-1} **or** ΔS_{system} converted to kJ K^{-1} mol^{-1} **or** $T\Delta S_{system}$ converted to kJ mol^{-1} M3 could be subsumed as part of M4	
	• calculation of ΔG_{total} **and** corresponding units **(1)**	169300 − 51226 = (+) 118074 J mol^{-1} **or** (+) 118.074 kJ mol^{-1} Correct answer with units with some or no working scores (4) Ignore SF except 1 SF Allow TE from M1 to M4	
	• comment on thermal stability at 298 K **(1)**	Stand alone mark on any positive value for Δ*G* Positive value / >0 **and** so reaction is not feasible (at 298 K) Ignore just 'so reaction is not feasible' No TE on negative values for Δ*G*	

Question Number	Answer	Additional Guidance	Mark
4(a)(ii)	• recognition that $\Delta S_{surroundings} \geq -171.9$ J K^{-1} mol^{-1} for decomposition to be feasible **(1)** • substitution **and** rearrangement to find T **(1)** • calculation of T **and** conversion to °C **and** answer given to 3 SF **(1)**	Example of calculation $\Delta S_{total} = \Delta S_{system} - \frac{\Delta H}{T} = 0$ Or $\Delta S_{system} = \frac{\Delta H}{T}$ Allow this equation rearranged This may be subsumed in M2 $-171.9 = (-169.3 \times 1000) / T$ $T = (-169.3 \times 1000) / -171.9$ TE on ΔS_{system} from 4(a)(i) (= 984.87 K) (= 711.87°C) = 712°C TE on M1 and M2 but do not award any temperature below 0°C Correct answer to 3 SF and in °C scores (3) Alternative method for M1 and M2 $\Delta G = \Delta H - T\Delta S = 0$ or $\Delta H = T\Delta S$ This may be subsumed in M2 (1) 169300 = T x 171.9 T = 169300/171.9 (1) TE on ΔS_{system} from 4(a)(i)	**(3)**

Question Number	Answer	Additional Guidance	Mark
4(b)	An explanation that makes reference to the following points: (Magnesium carbonate is less thermally stable because) **Size** • the magnesium ion / Mg^{2+} is smaller / has a greater charge density **(1)** **Polarising power** • so more likely to polarise / distort (the carbonate (ion) / anion) **(1)** **Bonds** • and so weaken the C-O bond or the bond(s) within the carbonate ion **(1)**	Allow reverse arguments Ignore reference to 'covalent character' Ignore reference to lattice energies Allow ionic radius of cation increases down the group / charge density of cation decreases down the group Allow magnesium carbonate has a smaller **cation** Allow magnesium ions have fewer shells of electrons Ignore 'magnesium (atom) is smaller' Ignore atomic radius Do not award M1 if mention of different / incorrect charges on magnesium and barium ions Allow 'magnesium ion has more polarising power' Allow polarising power decreases down the group Allow magnesium ion has more electron pulling power on (the carbonate (ion) / anion) Do not award if $MgCO_3$ stated as more stable Allow break (more easily) for weaken Allow C=O bonds for C−O Do not award reference to weakening unspecified bonds Do not award weakening bond between cation and anion	**(3)**

Question Number	Answer	Additional Guidance	Mark
4(c)	An answer that makes reference to the following points: • (usually carbonates react with acids and) produce a (colourless) gas / CO_2 (which is an expected observation for the test) **(1)** • (but) the barium sulfate produced is insoluble (so the carbonate may appear to not react / not dissolve in acid) **(1)**	Allow effervescence / fizzing / bubbles for observation Allow little / no gas / CO_2 formed when sulfuric acid is used Ignore references to limewater / lighted splint to test for CO_2 Allow a (white) precipitate (of barium sulfate) forms Allow they should have used hydrochloric / nitric acid as the salts formed are soluble Accept bubbles of gas would not be expected because barium sulfate is insoluble for 2 marks	**(2)**

(Total for Question 4 = 13 marks)

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>5*</td>
<td>This question assesses a student’s ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5–4</td><td>3</td></tr>
<tr><td>3–2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>

The following table shows how the marks should be awarded for structure and lines of reasoning.</td>
<td>Guidance on how the mark scheme should be applied:
The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 5 marks (3 marks for indicative content and 2 marks for partial structure and some linkages and lines of reasoning).
If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td>
<td>(6)</td>
</tr>
</table>

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2
Answer is partially structured with some linkages and lines of reasoning.	1
Answer has no linkages between points and is unstructured.	0

Comment:
Look for the indicative marking points first, then consider the mark for structure of answer and sustained line of reasoning

In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning.

General points to note
If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).

	Indicative content • **IP1 Type of reaction** **Both** reactions are (examples of) electrophilic substitution • **IP2 Products** Benzene forms bromobenzene **and** phenol forms 2,4,6-tribromophenol • **IP3 Comparison of reactivity** Benzene is less reactive (than phenol) / phenol is more reactive (than benzene) • **IP4 Conditions** Benzene requires (a catalyst of) $FeBr_3$ **and** phenol does not require a catalyst / can react with just bromine water • **IP5 Lone pair** (Phenol is more susceptible to electrophilic attack) because the lone pair on the oxygen (atom in phenol) delocalises into the ring / π system • **IP6 Electron density** Increasing the electron density of the ring / π system	If names and formulae are given, both must be correct Do not award addition-elimination for substitution Allow these products shown as structures in equations, even if equations are not fully correct Allow any feasible dibromophenol / tribromophenol Ignore dibromobenzene / tribromobenzene Allow Fe / $FeCl_3$ / $AlBr_3$ / $AlCl_3$ / Lewis Acid catalyst Allow Friedel-Crafts catalyst / halogen carrier Can be shown in equation Allow phenol reacts at room temperature Ignore reference to heat / mechanism Allow IP4 if stated that only benzene requires a catalyst Allow lone pair on oxygen is donated into the ring Allow OH for oxygen Allow activates the ring Do not award increases the electronegativity / charge density of the ring Penalise omission of 'the ring / π system' once only in IP5 and 6	

(Total for Question 5 = 6 marks)

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>6(a)</td><td>

- calculation of masses of carbon and hydrogen **(1)**
- calculation of mass of oxygen **(1)**
- calculation of moles of carbon, hydrogen and oxygen **(1)**
- calculation of ratio (and matched to empirical formula) **(1)**

</td><td>

Example of calculation

<table>
<tr><td></td><td>C</td><td>H</td><td>O</td></tr>
<tr><td>mass =</td><td>4.594 x 12/44 = 1.253(g)</td><td>1.879 x 2/18 = 0.209(g)</td><td>1.879 – (1.253+0.209) =0.417 (g)</td></tr>
<tr><td>Moles =</td><td>= 1.253 / 12 = 0.1044</td><td>= 0.209 / 1 = 0.209</td><td>= 0.417 / 16 0.0261</td></tr>
<tr><td>Ratio</td><td>4</td><td>8</td><td>1</td></tr>
<tr><td>(Formula =</td><td colspan="3">C_4H_8O)</td></tr>
</table>

Note – no mark for C_4H_8O as this is given in the question so no TE

Ignore SF except 1 SF in M1 and M2

Allow alternative methods, for example:

mol CO_2 = 4.954/44 = 0.1044 (mol)

and

mol H_2O = 1.879/18 = 0.1044 (mol) (1)

mol $C_8H_{16}O_2$ = 1.879/144 = 0.013 (mol) (1)

ratio $C_8H_{16}O_2$: CO_2 : H_2O – conditional on moles of $C_8H_{16}O_2$

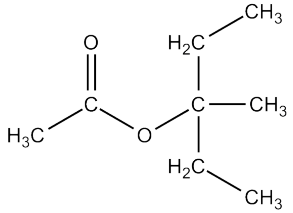
= 1 : 8 : 8 or 0.5 : 4 : 4 (1)

this matches the balanced equation

$C_8H_{16}O_2 + 11O_2 \rightarrow 8CO_2 + 8H_2O$ /

$C_4H_8O + 11/2O_2 \rightarrow 4CO_2 + 4H_2O$ (1)

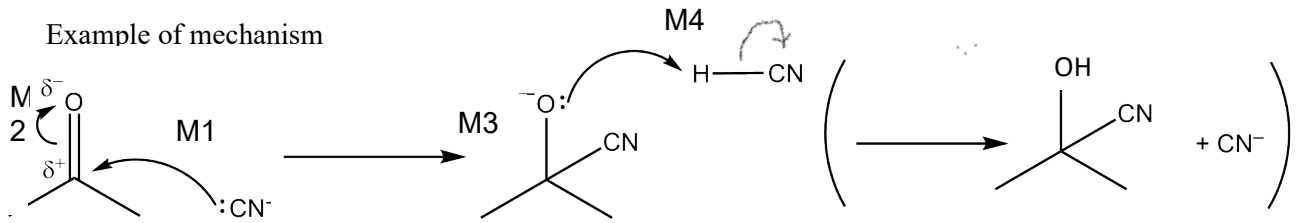
</td><td>(4)</td></tr>
</table>

Question Number	Answer	Additional Guidance	Mark
6(b)	An answer that makes reference to the following points: **Peak at 2.50 ppm** • identified as C**H₃**CO (as relative peak area = 3 / singlet so no protons on adjacent C) **(1)** **Peak at 1.56 ppm** • 2 C**H₂** groups as relative peak area = 4 **(1)** • (the 2 C**H₂** groups / hydrogen environment) next to CH_3 groups as peak is a quartet **(1)** **Peak at 0.92 ppm** • 2 C**H₃** groups as relative peak area = 6 **(1)** • (the 2 C**H₃** groups / hydrogen environment) next to CH_2 groups as peak is a triplet **(1)** **Peak at 1.43 ppm** • C**H₃** group with no protons on adjacent carbon atoms as (relative peak area = 3 and) singlet **(1)** • structure of **Q** **(1)**	Allow credit for annotations on table in p14 and on labelled structures Allow adjacent protons / hydrogens for protons on adjacent C Penalise H^+ for protons once only Allow ester group / H-C-C=O / CH_3 on left of structure given is indicated Do not award if aldehyde / ketone mentioned Allow 4 protons / hydrogens Allow 6 protons / hydrogens Allow just CH_3 identified in M6 if singlet explained in M1 	**(7)**

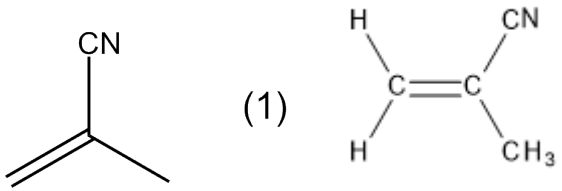
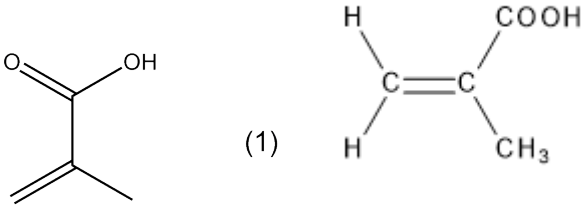
(Total for Question 6 = 11 marks)

Question Number	Answer	Additional Guidance	Mark
7(a)(i)	• curly arrow from lone pair on C of CN^- ion to C of C=O **(1)** • dipole on C=O **and** curly arrow from C=O bond to or just beyond O **(1)** • intermediate structure **(1)** • curly arrow from lone pair on O to H of HCN **and** curly arrow from H-C bond to anywhere on CN **(1)**	Penalise omission of lone pair once in M1 and M4 Penalise use of single-headed arrows only once Penalise use of incorrect nucleophile once only in M1 e.g. OH^- Allow skeletal, displayed or structural formulae Allow CN^- to attack from any angle Allow CN triple bond displayed Do not award curly arrow from lone pair on N Do not award $CN^{\delta-}$ Ignore missing lone pair on O Ignore connectivity for vertical CN group if M1 awarded Do not award $O^{\delta-}$ Allow curly arrow from lone pair on O^- to H^+ Ignore dipole on HCN Ignore products, even if incorrect	**(4)**

Example of mechanism



Allow straight arrows
Curly arrows in M1 and M4 must start from, or close to, at least 1 of the electrons in the lone pair, but penalise this once only
If candidate shows dipole on C=O and curly arrow first, allow M2 but if CN− then attacks C+, do not allow M1. M3 can score for the correct intermediate and M4 as per MS

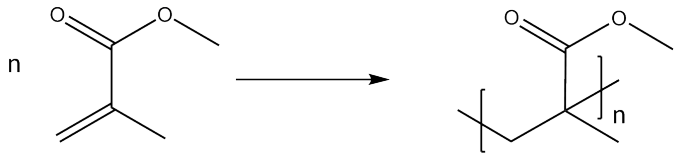
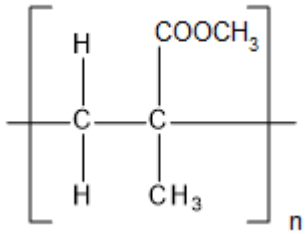
<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>7(a)(ii)</td><td>
<table>
<tr><td>Reagent 2</td><td>(conc) phosphoric acid / H_3PO_4
(conc) sulfuric acid/ H_2SO_4
aluminium oxide / Al_2O_3 (1)</td></tr>
<tr><td>Structure of compound A</td><td>
</td></tr>
<tr><td>Reaction type 3</td><td>(acid) Hydrolysis (1)</td></tr>
<tr><td>Structure of compound B</td><td>
</td></tr>
<tr><td>Reagent 4</td><td>CH_3OH / methanol (1)</td></tr>
<tr><td>Reaction type 4</td><td>Esterification / condensation (1)</td></tr>
</table>
</td><td>Ignore connectivity of groups
All marks are stand alone
Allow ‘alumina’
Do not award steam / water
Do not award dilute for either acid

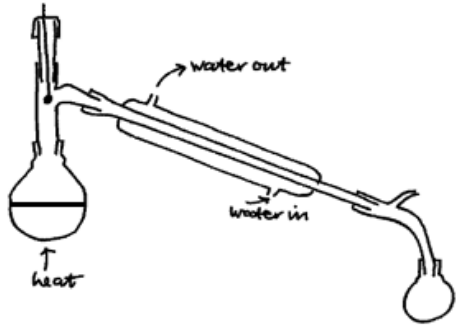
Allow structural, displayed or any combination of structural, displayed or skeletal for Compounds A and B

Do not award hydration / halogenation for M3

Allow TE for M4 based on incorrect M2 structure provided the nitrile group has been hydrolysed correctly and no other changes

Allow addition-elimination for condensation in M6</td><td>(6)</td></tr>
</table>

Question Number	Answer	Additional Guidance	Mark
7(a)(iii)	• correct repeat unit shown **(1)** • equation balanced **(1)**	 Allow displayed or structural formulae or a combination of these e.g.  Do not award 2 as the balancing number	**(2)**

Question Number		Additional guidance	Mark
7(b)	A diagram that shows the following points: **Left-hand side** • heat source, flask with reaction mixture and anti-bumping granules, still head and thermometer opposite 'exit' **(1)** **Centre** • downward angled condenser with separated water jacket and with correct water flow **(1)** **Right-hand side** • collection vessel **(1)**	<u>Example of diagram</u>  Allow pear shaped flask Do not allow one-piece apparatus for flask and still head Ignore missing thermometer / reaction mixture in flask / anti-bumping granules Ignore fractionating column Do not award conical flask Do not award M1 if noticeable gaps at joints / still head open at top **Note** – if thermometer is present, it must be within the still head Allow M2 if condenser is horizontal but not vertical Allow beaker / any type of flask Do not award M3 if apparatus is sealed **Notes:** Diagram of heat under reflux scores (0) Ignore lines across joints as part of Quickfit apparatus	**(3)**

Question Number	Answer	Additional Guidance	Mark
7(c)(i)	An explanation that makes reference to any **two** of the following points: • to make sure the solution doesn't cool down (significantly) **(1)** • to prevent (premature) crystallization taking place (in funnel / on filter paper) **(1)** • which would reduce yield (of product) **(1)**	Ignore general references to removing impurities Allow crystals / solid / precipitate forming for crystallisation Allow to keep the solution warm Accept to prevent crystals forming during filtration Allow to make sure the substance stays in solution	**(2)**

Question Number	Answer	Additional Guidance	Mark
7(c)(ii)	An explanation that makes reference to any two of the following points: • Step 4: product less soluble in cooler solvent (than hot solvent, so product crystallises out) **(1)** • Step 4 : (soluble) impurities present (in small amount so) stay in solution / remain dissolved (while product crystallises) **(1)** • Step 5: filtering under reduced pressure removes more of the soluble impurities / removes the soluble impurities faster / produces a drier product **(1)**	Allow crystals / solid / precipitate for product Allow product is insoluble in cold solvent Allow filtration removes the solution containing the impurities / separates the crystals from the soluble impurities Allow filtering under reduced pressure is faster (than gravity filtration) Ignore just 'use a Buchner funnel'	**(2)**

Question Number	Answer	Additional Guidance	Mark
7(c)(iii)	An answer that makes reference to the following points: • (measure) melting temperature (of purified crystals) **(1)** • compare to literature value (matched to original carbonyl compound) **(1)**	Allow compare to data book value / compare to value from (credible) internet source / compare to known melting temperature / compare to values in a database	**(2)**

(Total for Question 7 = 21 marks)

Question Number	Answer	Additional Guidance	Mark
8(a)	An answer that makes reference to the following points: **Titration** • titrate (ethanoic acid /weak acid) with strong base / sodium hydroxide **(1)** **Then follow the three points for Method 1 or Method 2** **Method 1** • measure pH at regular intervals **(1)** • plot pH against volume (of strong base) **(1)** • use graph to find pH at half-equivalence point **(1)** **OR** **Method 2** • use phenolphthalein indicator to find end-point **(1)** • then add same volume of **acid** to mixture (at end-point) **(1)** • measure pH of resultant mixture (with pH meter) **(1)** **Determining K_a** • (at half neutralisation pH = pK_a so) $K_a = 10^{-pH}$ **(1)**	Stand alone Allow any indication of a titration Allow acid added to base or base added to acid In both methods, ignore reference to making a standard solution / calibration of the pH probe or meter / practical details of carrying out the titration Allow plot a titration / pH curve Allow use graph to find pH at volume when half neutralised Allow thymol blue / thymolphthalein indicators Ignore colour change even if incorrect Allow repeat titration (with same volumes but without indicator) then add original volume of acid to mixture (at end-point) or use same volume of acid and half the volume of base Do not award pH at end point is 7 Stand alone Allow $[H^+] = 10^{-pH}$ **and** $K_a = [H^+]$	**(5)**

Question Number	Answer	Additional Guidance	Mark
8(b)	EITHER • calculation of $[H^+(aq)]$ **(1)** • calculation of ratio of [acid]/[salt] or [salt]/[acid] **or** correct values substituted into expression for ratio **(1)** • calculation of volume of acid required and salt required **(1)** OR • calculation of log [acid]/[salt] using Henderson-Hasselbalch **(1)** • calculation of ratio of [acid]/[salt] **(1)** • calculation volume of acid required and salt required **(1)**	<u>Example of calculation</u> $[H^+(aq)] = 10^{-4.70} = 1.9953 \times 10^{-5}$ (mol dm^{-3}) [acid]/[salt] = $1.9953 \times 10^{-5} / 1.74 \times 10^{-5}$ = 1.1467 : 1 / 1 : 0.872 **or** [salt]/[acid] = $1.74 \times 10^{-5} / 1.9953 \times 10^{-5}$ = 0.872 : 1 / 1 : 1.1467 (1.1467 /2.1467) x 500 = 267 cm^3 acid 500 – 267 = 233 cm^3 salt 4.7595 – 4.70 = 0.05945 $10^{0.05945}$ = 1.1467 : 1 (1.1467 / 2.1467) x 500 = 267 cm^3 acid 500 – 267 = 233 cm^3 salt Allow 270 cm^3 acid and 230 cm^3 salt Ignore SF except 1 SF but allow 2 / 2.0 / 2.00 x 10^{-5} for M1 in 'EITHER' Allow TE from M1 throughout Correct answer with no working scores (3)	**(3)**

Question Number	Answer	Additional Guidance	Mark
8(c)	• calculation amount of $H_2SO_4(aq)$ in mol **(1)** • calculation amount of $H^+(aq)$ in mol / amount $OH^-(aq)$ needed **(1)** • calculation amount of $OH^-(aq)$ in mol **(1)** • calculation amount of excess $OH^-(aq)$ in mol **(1)** • calculation $[OH^-]$ in resultant mixture **(1)** • calculation pH of resultant mixture **(1)**	Example of calculation = (40.4/1000) x 0.370 = 0.014948 0.014948 x 2 = 0.029896 (mol) = (51.2/1000) x 0.927 = 0.047462 (mol) = 0.047462 – 0.029896 = 0.017566 (mol) = 0.017566 / (91.6/1000) = 0.19177 (mol dm^{-3}) $[H^+] = 1.00 \times 10^{-14}/0.19177 = 5.2146 \times 10^{-14}$ (mol dm^{-3}) pH = $-\log 5.2146 \times 10^{-14}$ = 13.3 **or** 14 – (– log(0.19177)) = 13.3 Final answer needs to be to at least 1dp Allow TE throughout but TE from M5 to M6 must give a pH > 7 Correct answer with no / some working scores 6 marks Ignore SF except 1 SF in M1 to M5	**(6)**

(Total for Question 8 = 14 marks)

Question Number	Answer	Additional Guidance	Mark
9(a)(i)	An answer that makes reference to one of the following points: • the colour of the pineapple juice masks the colour change **or** methyl orange only works with a strong acid **or** methyl orange does not change colour in the vertical section of the titration curve	Allow methyl orange is a similar colour to pineapple juice Accept methyl orange cannot be used with a weak acid (and strong alkali) Allow the pH range / 3.2-4.4 / pK_{in} of methyl orange is below the equivalence point / too low Allow the colour change would occur before the equivalence point / is not over the equivalence point Allow the pH at the equivalence point is not in the pH range of methyl orange Allow end point for equivalence point Ignore just 'no colour change observed' Ignore just 'end point is not accurate'	**(1)**

Question Number	Answer	Additional Guidance	Mark
9(a)(ii)	An explanation that makes reference to the following points: • the titre value would be greater (than expected) **(1)** • as the titre value includes the volume of the air bubble (as well as sodium hydroxide solution) **(1)**	M2 conditional on M1 scored Allow some alkali / solution is used to fill the air bubble / jet Allow there is less sodium hydroxide in the burette than expected	**(2)**

Question Number	Answer	Additional Guidance	Mark
9(b)(i)	An explanation that makes reference to the following points: • (at the end point) all ascorbic acid is used up so the iodine is no longer reduced (to iodide ions) **or** ascorbic acid reacts with the iodine until all the (ascorbic) acid is used up **(1)** • the (slight excess) iodine reacts / forms complex with the starch **(1)** • (changing from yellow) to a blue/black colour **(1)**	Stand alone Allow starch in the presence of iodine Do not award starch and iodide ions Stand alone Allow just black or just (dark) blue Ignore initial colour of solution Do not award blue/black to colourless	**(3)**

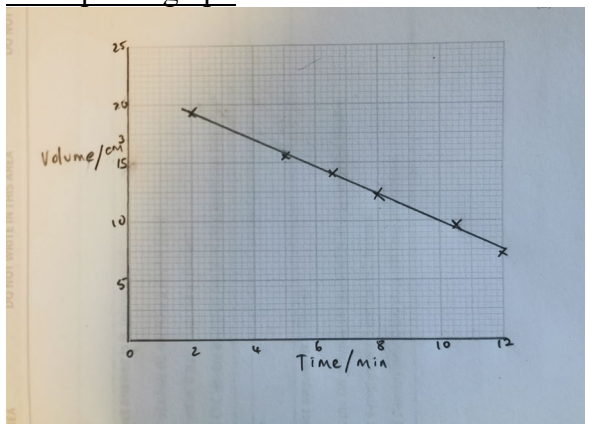
Question Number	Answer	Additional Guidance	Mark
9(b)(ii)	• calculation of amount of IO_3^- (aq) **(1)** • calculation of amount of iodine / ascorbic acid in 5.00 cm^3 sample **(1)** • calculation of amount of ascorbic acid in 150.0 cm^3 sample **(1)** • calculation of amount of citric acid in 150.0 cm^3 sample **(1)** • calculation of mass of citric acid in 150.0 cm^3 sample **(1)**	Example of calculation = (9.50/1000) x 0.00100 = 9.50 x 10^{-6} (mol) = 9.50 x 10^{-6} x 3 = 2.85 x 10^{-5} (mol) TE on M1 = 2.85 x 10^{-5} x 30 = 8.55 x 10^{-4} (mol) TE on M2 = 8.00 x 10^{-3} – 8.55 x 10^{-4} = 7.145 x 10^{-3} (mol) TE on M3 = 7.145 x 10^{-3} x 192 = 1.37184 g = 1.37 (g) TE on M4 Ignore SF except 1 SF Correct answer with some or no working scores (5)	**(5)**

Question Number	Answer	Additional Guidance	Mark
9(c)	An explanation that makes reference to the following points: • compound **E** **and** as it has (two) COOH / (carboxylic) acid group(s) **(1)** • these / this will (also) react with the NaOH / in the titration (in Experiment **1**) **(1)** • (the titre will be greater in Experiment **1** so suggests a greater total amount of acid) so the final mass of citric acid calculated will be greater (than the true amount) **or** the total amount of acid (calculated from the titration) includes citric acid and **E** so the actual mass of citric acid is less (than calculated in (b)(ii) **(1)**	Allow Compound **E** is a (di)carboxylic acid Ignore reference to OH group Do not award carbonyl group(s) Do not award if OH group reacts with NaOH Conditional on compound **E** selected	**(3)**

(Total for Question 9 = 14 marks)

Question Number	Answer	Additional Guidance	Mark
10(a)(i)	An explanation that makes reference to the following points: • to stop / freeze / quench the reaction **(1)** • by neutralising the (remaining sulfuric) acid / H^+ **(1)**	 Allow 'to allow time for the titration to be carried out' Ignore just 'slows down the reaction' Allow by reacting with the acid / removing the acid Allow catalyst for acid Do not award if incorrect acid specified	**(2)**

Question Number	Answer	Additional Guidance	Mark
10(a)(ii)	• ionic equation	<u>Examples of equations</u> $NaHCO_3 + H^+ \rightarrow CO_2 + H_2O + Na^+$ Or $NaHCO_3 + H_3O^+ \rightarrow CO_2 + 2H_2O + Na^+$ Allow $HCO_3^- + H^+ \rightarrow CO_2 + H_2O$ $HCO_3^- + H^+ \rightarrow H_2CO_3$ Allow multiples Allow balanced equations with H_3O^+ Allow Na^+ and SO_4^{2-} in equations, provided they are crossed through Ignore state symbols, even if incorrect Do not award $CO_3^{2-} + 2H^+ \rightarrow CO_2 + H_2O$	**(1)**

Question Number	Answer	Additional Guidance	Mark
10(b)(i)	• y axis labelled with volume and cm^3 **and** x axis labelled with time and min **and** suitable scale **(1)** • all points plotted correctly and line of best fit **(1)**	Example of graph  Do not award time in seconds Suitable scale so that points cover at least half the available space along the x axis and at least 2 large squares on y axis (as shown) ± ½ a small square Allow M2 as TE if axes wrong way around Ignore extrapolations	**(2)**

Question Number	Answer	Additional Guidance	Mark
10(b)(ii)	An explanation that makes reference to the following points: • $[I_2]$ is proportional to the volume (of sodium thiosulfate) **(1)** • gradient does not change / is constant / the graph shows a straight line / is linear (as $[I_2]$ decreases) **(1)** • which means the rate doesn't change / increase or decrease (as $[I_2]$ increases or decreases) **(1)**	Ignore references to half-life Allow description of proportional Allow decreases at a constant rate Ignore volume (of sodium thiosulfate) / $[I_2]$ is proportional to time Allow $[I_2]$ does not affect the rate (of reaction) / rate is independent of $[I_2]$	**(3)**

Question Number	Answer	Additional Guidance	Mark
10(c)(i)	An answer that makes reference to the following points: • Step **1** is the rate determining step **(1)** • as it involves (1 mol of) both propanone and hydrogen ions (which matches the rate equation) **(1)**	 Stand alone Allow RDS / slow step Conditional on M1 Allow it does not involve I_2 (which is zero order) Allow it involves both species in the rate equation Allow I_2 is not involved in the RDS so RDS must be before Step 2	**(2)**

Question Number	Answer	Additional Guidance	Mark
10(c)(ii)	An explanation that makes reference to the following points: (The statement is not valid because) • one hydrogen ion is regenerated / reformed (so is acting as a catalyst) **(1)** • the other hydrogen ion is lost from the propanone (when replaced by iodine) / is a (by-)product of the reaction / is used to form HI **(1)**	Ignore reference to specific steps. Do not award M1 if candidate states that it is valid Ignore it is an autocatalyst	**(2)**

(Total for Question 10 = 12 marks)

TOTAL FOR PAPER = 120 MARKS

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