Mark Scheme (Results)

November 2021

Pearson Edexcel GCE
In Chemistry (9CH0)
Paper 3: General and Practical Principles in Chemistry

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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.

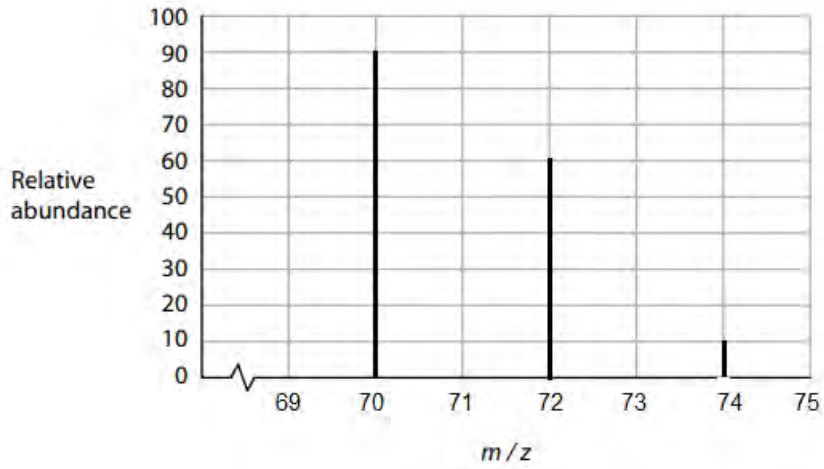
Candidates must make their meaning clear to the examiner to gain the mark. Make sure that the answer makes sense. Do not give credit for correct words/phrases which are put together in a meaningless manner. Answers must be in the correct context.

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)(i)	• all numbers for ^{35}Cl correct **(1)** • all numbers for $^{37}Cl^-$ correct **(1)**	Example of table Particle / Protons / Neutrons / Electrons ^{35}Cl atom: 17 / 18 / 17 $^{37}Cl^-$ ion: 17 / 20 / 18 If no other mark is awarded, allow (1) for any four numbers correct	**(2)**

Question Number	Answer	Additional Guidance	Mark
1(a)(ii)	• lines at 70 and 72 and 74 **(1)** • relative abundances 9:6:1 **(1)**	Example of spectrum  Allow any abundances in an approximate 9:6:1 ratio e.g. 56:37-38:6 as %, or 75 : 50 : 8	**(2)**

Question Number	Answer	Additional Guidance	Mark
1(b)	• $KClO_3$	Allow $K^+ClO_3^-$	(1)

Question Number	Answer	Additional Guidance	Mark
1(c)	• equation **(1)** • state symbols **(1)**	Example of equation $Cl(g) + e^- \rightarrow Cl^-(g)$ Allow just e for electron Stand alone mark for species on both sides of equation Ignore state symbol for electron	(2)

Question Number	Answer	Additional Guidance	Mark
1(d)(i)	• identification of oxidising agent	Either acidified (potassium) manganate(VII) / MnO_4^- and H^+ Or acidified hydrogen peroxide / H_2O_2 and H^+ Allow H^+ shown in equation in (i) or (ii) If the acid is specified it must be sulfuric acid	(1)

Question Number	Answer	Additional Guidance	Mark
1(d)(ii)	• value of $E^{\ominus}_{cell}$	Either $E^{\ominus}_{cell}$ = (+)0.15 (V) for acidified (potassium) manganate(VII) Or $E^{\ominus}_{cell}$ = (+)0.41 (V) for acidified hydrogen peroxide No TE on any other reagent in (i)	(1)

(Total for Question 1 = 9 marks)

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>2(a)</td>
<td>A description that makes reference to the following points:

• reagent (1)

• observation (1)</td>
<td><u>Examples of reagents and observations</u>

<table>
<tr><th>Reagent</th><th>Observation</th></tr>
<tr><td>any carbonate / $NaHCO_3$ / $KHCO_3$ (added to aqueous acid)</td><td>effervescence / fizzing / bubbles / gas evolved that turns limewater milky</td></tr>
<tr><td>magnesium (added to aqueous acid)</td><td>effervescence / fizzing / bubbles / gas evolved that gives a pop with a lighted splint</td></tr>
<tr><td>alcohol and (concentrated) H_2SO_4 / HCl / H^+</td><td>characteristic smell (of an ester)</td></tr>
</table>

Allow names or formulae for reagents but if both are given, both must be correct

Ignore conditions e.g. heat

Do not award PCl_5 / Na

If more than one test is given, penalise any incorrect tests</td>
<td>(2)</td>
</tr>
</table>

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>2(b)</td><td>A description that makes reference to two of the following points:

• reagent (1)

• corresponding observation (1)</td><td><u>Examples of reagents and observations</u>

<table>
<tr><th>Reagent</th><th>Observation</th></tr>
<tr><td>bromine water
Allow bromine (in an organic solvent)</td><td>orange / yellow / brown solution goes colourless
Allow bromine water is decolourised</td></tr>
<tr><td>carboxylic acid and (concentrated) H_2SO_4 / HCl / H^+</td><td>characteristic smell (of an ester)</td></tr>
<tr><td>acidified potassium manganate(VII) / permanganate</td><td>purple to colourless / decolourised</td></tr>
<tr><td>alkaline potassium manganate(VII)</td><td>purple to green</td></tr>
<tr><td>(neutral) potassium manganate(VII)</td><td>purple to brown ppt</td></tr>
<tr><td>acidified (potassium) dichromate((VI)) (ions)</td><td>orange to green</td></tr>
</table>

Allow names or formulae for reagents but if both are given, both must be correct

Ignore conditions e.g. heat

Do not award PCl_5 / Na

If more than one test is given, penalise any incorrect tests</td><td>(2)</td></tr>
</table>

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>2(c)</td><td>

- absorbance for **A** **(1)**
- absorbance for **B** **(1)**
- absorbance for **C** **(1)**

</td><td>
<u>Example of table</u>
<table>
<tr><th>Absorbance</th><th>Wavenumber range / cm^{-1}</th></tr>
<tr><td>Absorbance expected in infrared spectrum of A but not in B or C</td><td>1720 – 1700
Allow 1725 - 1700</td></tr>
<tr><td>Absorbance expected in infrared spectrum of B but not in A or C</td><td>1669 – 1645</td></tr>
<tr><td>Absorbance expected in infrared spectrum of C but not in A or B</td><td>1740 – 1725
Allow 1740 - 1720</td></tr>
</table>
Allow values in reverse order e.g. 1700 – 1720 for A

If single values are given instead of a range award (2) for 3 correct values within the ranges and (1) for 2 correct values

Do not award a single value that occurs in two ranges i.e 1720-1725

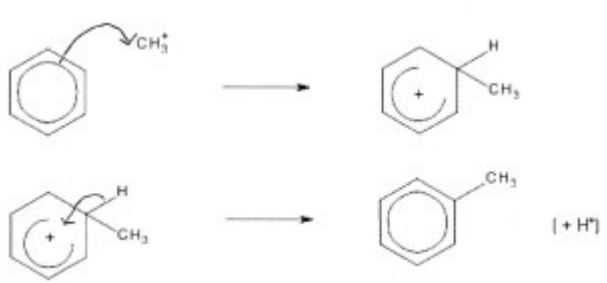
If no other mark is awarded, allow (1) for:
A 3300-2500 and C 2900-2820 / 2775-2700
</td><td>(3)</td></tr>
</table>

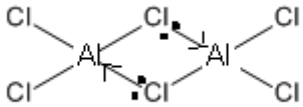
(Total for Question 2 = 7 marks)

Question Number	Answer	Additional Guidance	Mark
3(a)	• $(1s^2)2s^2 2p^6 3s^2 3p^1$	Allow numbers of electrons as subscripts or large numbers Allow p orbitals designated as x, y and z Ignore $1s^2$ repeated	(1)

Question Number	Answer	Additional Guidance	Mark
3(b)(i)	• dot-and-cross diagram	<u>Example of diagram</u>  Allow electrons in overlapping circles Allow all dots / all crosses Ignore inner shell electrons, even if incorrect Ignore lines as bonds e.g. <u>x</u> • Do not award diagram with lone pair on Al	(1)

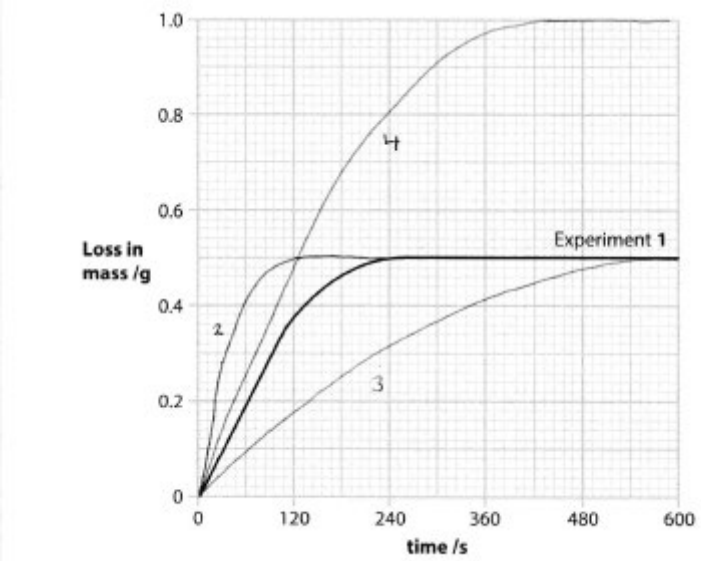
Question Number	Answer	Additional Guidance	Mark
3(b)(ii)	An answer that makes reference to the following points: • shape – trigonal planar **(1)** • bond angle - 120° **(1)**	Mark independently Both words needed Allow triangular for trigonal – but not just tri Allow marks for labelled diagram **Note** If shape is pyramidal, no mark for M1 but allow (1) for 107° No TE for any other shape	**(2)**

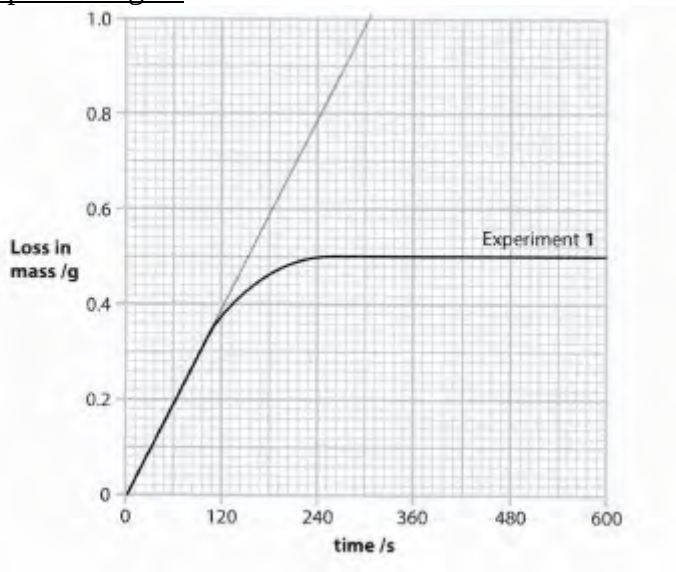
Question Number	Answer	Additional Guidance	Mark
3(b)(iii)	• equation for the formation of the electrophile **(1)** • curly arrow from on or within the circle to CH_3^+ **(1)** • structure of intermediate including charge with some part of the charge within the horseshoe **and** horseshoe covering at least 3 carbon atoms **and** facing the tetrahedral carbon **(1)** • curly arrow from C-H bond to anywhere in the hexagon reforming the delocalised structure **(1)**	Example of mechanism $CH_3Cl + AlCl_3 \rightarrow CH_3^+ + [AlCl_4]^-$  Allow $AlCl_4^-$ / $^{\delta+}CH_3\text{-}AlCl_4^{\delta-}$ Allow curly arrow from anywhere within the hexagon Allow curly arrow to any part of CH_3^+, including the + charge Do not award curly arrow from outside the hexagon Allow dotted / dashed lines for horseshoe Do not award dotted bonds to H and CH_3 unless clearly part of a 3D structure Ignore any involvement of $AlCl_4^-$ in the final step /HCl **Note** Correct Kekulé structures score full marks	**(4)**

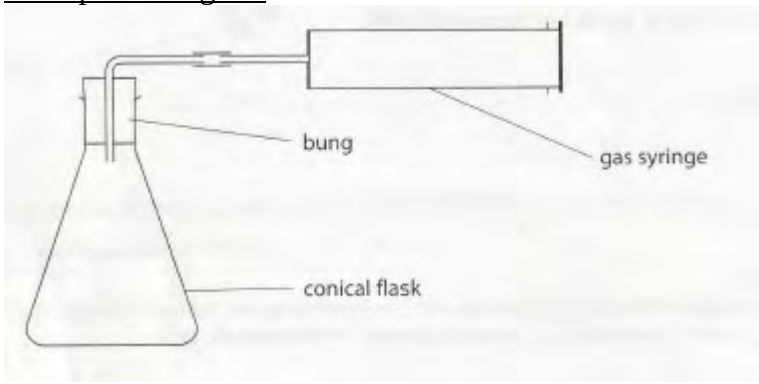
Question Number	Answer	Additional Guidance	Mark
3(c)(i)	• diagram showing two $AlCl_3$ molecules joined through two chlorine atoms	Example of diagram  Allow dot-and-cross diagram Ignore missing arrows / direction of arrows Ignore missing lone pairs	(1)

Question Number	Answer	Additional Guidance	Mark
3(c)(ii)	• dative (covalent) bonds **or** coordinate bonds	Allow this labelled on diagram in (i) Do not award this mark if dative bonds shown as arrows starting from aluminium in (c)(i)	(1)

(Total for Question 3 = 10 marks)

Question Number	Answer	Additional Guidance	Mark
4(a)	• curve for Experiment **2** steeper than Experiment **1** and Experiment **4** **and** finishing at the same mass loss as Experiment **1** **(1)** • curve for Experiment **3** shallower than Experiment **1** **and** finishing at the same mass loss **(1)** • curve for Experiment **4** steeper than Experiment **1** **and** finishing at mass loss 1.0 g **(1)**	<u>Examples of curves</u>  Allow curve for Experiment **4** steeper than Experiments **1** and **2** and finishing at mass loss 1.0 g	**(3)**

Question Number	Answer	Additional Guidance	Mark
4(b)	• tangent drawn to curve when time = 0 tangent must touch curve for at least first 3 small squares on x axis and extend to at least 120 s **(1)** • calculation of gradient **(1)** • units **(1)**	Example of tangent  gradient = $\frac{1.0}{300}$ = 3.33×10^{-3} Allow 3.13×10^{-3} to 3.53×10^{-3} TE on tangent drawn or measurements from line on graph with no tangent Ignore SF including 1SF g s^{-1} or g/s stand alone mark	**(3)**

Question Number	Answer	Additional Guidance	Mark
4(c)	An answer that makes reference to the following points: • a diagram showing (calcium carbonate in a conical) flask attached to a gas syringe / a delivery tube passing into a container of water with an upturned measuring cylinder **(1)** • add the hydrochloric acid and (immediately) stopper the flask **(1)** • record the volume of gas **(1)** • collected at regular time intervals **(1)**	<u>Example of diagram</u>  Ignore missing labels Ignore heat / water bath Do not award inclusion of a condenser Do not award test tube or beaker for collecting gas Allow carbonate added to acid and stopper the flask Allow acid in a tube / beaker in the flask and tip the flask for them to mix Allow specified time intervals Allow collected in a specified time	**(4)**

(Total for Question 4 = 10 marks)

Question Number	Answer	Additional Guidance	Mark
5(a)(i)	• (The cation in **X** is) Fe^{2+} / iron(II) / Fe(II) **(1)** • (The anion in **X** is) SO_4^{2-} / sulfate(VI) **(1)**	Allow Fe^{+2} Allow sulfate / SO_4^{-2} Do not award sulfite / sulfate(IV)	**(2)**

Question Number	Answer	Additional Guidance	Mark
5(a)(ii)	• species and balancing **(1)** • state symbols **(1)**	<u>Examples of equation</u> $Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$ **or** $[Fe(H_2O)_6]^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s) + 6H_2O(l)$ **or** $[Fe(H_2O)_6]^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(H_2O)_4(s) + 2H_2O(l)$ Ignore missing square brackets TE on cation that forms an insoluble hydroxide in **Test 1** State symbols conditional on correct species or 'near miss' / non-ionic equation	**(2)**

Question Number	Answer	Additional Guidance	Mark
5(a)(iii)	An answer that makes reference to the following point: • Fe^{2+} is oxidised (to Fe^{3+}) by oxygen / air	Allow iron(III) hydroxide / iron(III) (ions) are formed by reaction with oxygen / air TE on cation in **Test 1** Allow just 'the precipitate / it is oxidised by oxygen / air'	**(1)**

Question Number	Answer	Additional Guidance	Mark
5(a)(iv)	An answer that makes reference to the following point: • to react with / remove any carbonate / sulfite / sulfate(IV) ions **or** to eliminate the possibility of carbonate / sulfite / sulfate(IV) ions	Allow to prevent any other ions forming a precipitate with barium ions / Ba^{2+}	**(1)**

Question Number	Answer		Additional Guidance	Mark
5(b)(i)	• (The cation in **Y** is) Cu^{2+} / copper(II)	**(1)**	Allow Cu^{+2} Ignore water ligands Do not award just copper / Cu	**(2)**
	• (The anion in **Y** is) Cl^- / chloride	**(1)**	Do not award just 'chlorine' / Cl	

Question Number	Answer	Additional Guidance	Mark
5(b)(ii)	• $[Cu(NH_3)_4(H_2O)_2]^{2+}$	Allow $[Cu(NH_3)_4]^{2+}$ Allow $[Co(NH_3)_6]^{2+}$ if Co^{2+} in (i) Ignore missing square brackets	**(1)**

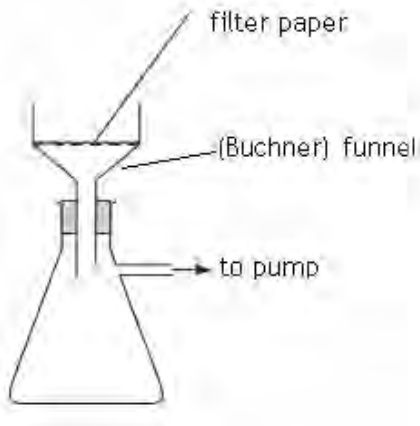
Question Number	Answer	Additional Guidance	Mark
5(b)(iii)	A description that makes reference to the following points: • add dilute (aqueous) ammonia (and stir the mixture) **(1)** • the precipitate dissolves **(1)**	If Cl^- / chloride / chlorine ion: Allow add aqueous ammonia / $NH_3(aq)$ Do not award concentrated ammonia Conditional on use of ammonia Ignore colourless solution If Br^- / bromide / bromine ion identified in Test 4: precipitate is insoluble in dilute ammonia (1) but soluble in concentrated ammonia (1) If I^- / iodide / iodine ion identified in test 4: precipitate is insoluble (1) in dilute and concentrated ammonia (1) Do not award addition of concentrated sulfuric acid	**(2)**

(Total for Question 5 = 11 marks)

Question Number	Answer	Additional Guidance	Mark
6(a)(i)	An explanation that makes reference to the following points: • the electron density of the (benzene) ring is greater in phenol (than in benzene) **(1)** • because the lone pair (of electrons) on oxygen **and** overlaps with the pi cloud / delocalised electrons / delocalised system **(1)**	Allow lone pair (of electrons) on oxygen feeds into / donates into / interacts with the delocalised electrons / system Ignore electron pushing effect of OH	**(2)**

Question Number	Answer	Additional Guidance	Mark
6(a)(ii)	An explanation that makes reference to the following points: • they both form hydrogen bonds **(1)** • in 4-nitrophenol the hydrogen bonds join molecules in a straight chain / at both ends / at opposite ends (of the molecule so are stronger) **or** 2-nitrophenol forms intramolecular hydrogen bonds / forces / interactions (so fewer intermolecular hydrogen bonds) **(1)**	Allow M1 and M2 shown in diagrams Ignore reference to other specific types of intermolecular forces Allow 4-nitrophenol forms stronger intermolecular hydrogen bonds / forces / interactions Allow in 2-nitrophenol the hydrogen bonds join 2 molecules together / form a dimer (so there are fewer / weaker hydrogen bonds) Allow in 2-nitrophenol the hydrogen bonds are on the same side (of the molecule)	**(2)**

Question Number	Answer	Additional Guidance	Mark
6(b)	• reducing agent / reductant	Ignore tin and concentrated hydrochloric acid Do not award any other named reducing agent	(1)

Question Number	Answer	Additional Guidance	Mark
6(c)(i)	• side-arm flask with label 'to pump' / drawing of pump **(1)** • (Buchner) funnel with perforations **and** bung around neck of funnel **(1)** • **flat** filter paper (over perforations) **(1)**	<u>Example of diagram</u>  Ignore just 'suction' Allow funnel joined to flask with 'Quickfit' joint / no gap Do not award fluted filter paper / filter paper that extends up the sides of the funnel	(3)

Question Number	Answer	Additional Guidance	Mark
6(c)(ii)	A description that makes reference to the following points: • dissolve crystals in the **minimum** (amount / volume) **(1)** • of hot water / solvent **(1)** • filter hot **and** allow to cool **(1)** • filter **and** wash with a small amount of (cold) solvent **(1)** • dry crystals between filter papers / in a desiccator / in a warm oven **(1)**	Allow add / put for dissolve Do not award wash for dissolve Penalise use of incorrect solvent once only Allow M3 if hot is omitted and is mentioned in M2 Do not award filter to remove soluble impurities Stand alone mark Allow other suitable methods of drying Do not award reference to crystals mixed with a drying agent	**(5)**

Question Number	Answer	Additional Guidance	Mark
6(c)(iii)	An answer that makes reference to the following points: • melting temperature is lower **(1)** • it melts over a range of temperatures **or** the melting temperature is not sharp **(1)**	Allow a specified range of temperatures	**(2)**

Question Number	Answer	Additional Guidance	Mark
6(d)(i)	• $C_8H_9NO_2$	Allow the symbols, with subscripts, in any order e.g. $C_8H_9O_2N$ Allow large numbers but not superscripts Ignore any other formulae as working	**(1)**

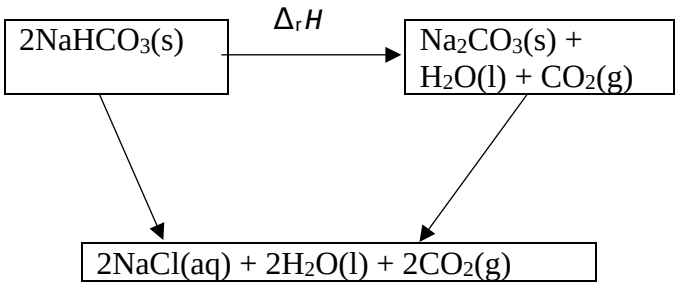
Question Number	Answer		Additional Guidance	Mark
6(d)(ii)	• calculation of amount of Ce^{4+}	**(1)**	Example of calculation amount Ce^{4+} used = $\frac{16.5 \times 0.100}{1000}$ $= 0.00165 / 1.65 \times 10^{-3}$ (mol)	**(5)**
	• calculation of amount of paracetamol in 25.0 cm^3	**(1)**	amount paracetamol in 25.0 cm^3 = $\frac{0.00165}{2}$ $= 0.000825 / 8.25 \times 10^{-4}$ (mol) TE on M1	
	• calculation of amount of paracetamol in 100.0 cm^3	**(1)**	amount paracetamol in 100.0 cm^3 $= 4 \times 0.000825$ $= 0.00330 / 3.30 \times 10^{-3}$ (mol) TE on M2	
	• calculation of molar mass of paracetamol **and** mass of paracetamol in 1 tablet	**(1)**	molar mass of paracetamol, $C_8H_9NO_2$ $= (8 \times 12) + (9 \times 1) + 14 + (2 \times 16) = 151$ **and** mass of paracetamol in 1 tablet $= 0.00330 \times 151 = 0.4983$ g TE on M3 and (d)(i)	
	• calculation of percentage of paracetamol in 1 tablet **and** conclusion	**(1)**	percentage of paracetamol $= \frac{0.4983}{0.500} \times 100 = 99.66$ (%) **and** the tablet was from Brand **R** TE on M4 provided M4 < 0.500 g Ignore SF except 1 SF	

(Total for Question 6 = 21 marks)

Question Number	Answer	Additional Guidance	Mark
7(a)(i)	• mass **and** temperature fall correct	<table><tr><td>Mass of $NaHCO_3$ used / g</td><td>5.62</td></tr><tr><td>Temperature fall / °C</td><td>(−)6.6</td></tr></table>	**(1)**

Question Number	Answer	Additional Guidance	Mark
7(a)(ii)	• calculation of amount of $NaHCO_3$ **and** calculation of amount of hydrochloric acid **(1)** • 0.0669 mol $NaHCO_3$ needs 0.0699 mol HCl for reaction so HCl is in excess **(1)**	Example of calculation amount $NaHCO_3$ = $\frac{5.62}{23 + 1 + 12 + (3 \times 16)}$ = 0.0669 (mol) TE on mass of $NaHCO_3$ in (a)(i) **and** amount HCl = $\frac{50 \times 2.00}{1000}$ = 0.10 (mol) Ignore SF including 1SF Allow mol ratio = 1 : 1 so HCl is in excess Allow just more moles of HCl used Allow 0.10 > 0.0669 (mol) Allow HCl is in excess by 0.033 (mol)	**(2)**

Question Number	Answer	Additional Guidance	Mark
7(a)(iii)	• calculation of heat absorbed **(1)** • calculation of enthalpy change **(1)** • positive sign **and** units **(1)**	Example of calculation heat absorbed = 50.0 x 4.18 x 6.6 = 1379.4 (J) / 1.3794 (kJ) Ignore sign enthalpy change = $\frac{1379.4}{0.0669}$ = 20619 (J mol^{-1}) **or** = $\frac{1.3794}{0.0669}$ = 20.619 (kJ mol^{-1}) TE on heat absorbed and amount $NaHCO_3$ in (a)(ii) Final answer +20.6(19) kJ mol^{-1} **or** +20619 J mol^{-1} TE on enthalpy change Allow +19.7(06) kJ mol^{-1} from 0.07 mol in (a)(ii) Allow kJ mol^{-} / J mol^{-} Ignore SF except 1 SF Ignore incorrect / missing units in M1 and M2 Correct answer with sign and units scores (3)	**(3)**

Question Number	Answer	Additional Guidance	Mark
7(b)(i)	• correct species and balancing numbers in lower box **(1)** • both arrows pointing in correct directions **(1)**	Example of Hess cycle  Ignore missing state symbols Stand alone mark Ignore labels on arrows and inclusion of HCl	**(2)**

Question Number	Answer		Additional Guidance	Mark
7(b)(ii)	• expression for $\Delta_r H$	**(1)**	<u>Example of calculation</u> $\Delta_r H = 2x\Delta H_1 - \Delta H_2$	**(3)**
	• substitution of values into expression with both values in same units	**(1)**	$\Delta_r H = 2 \times 20.619 - (-29.4)$ **or** $\Delta_r H = 2 \times 20619 - (-29\ 400)$ M1 can be scored from values substituted into correct expression in M2 TE on ΔH_1 in (a)(iii) and expression in M1 No TE on incorrect arrows in cycle	
	• calculation of $\Delta_r H$ **and** sign **and** units	**(1)**	$\Delta_r H = +70.638$ kJ mol^{-1} **or** $\Delta_r H = +70638$ J mol^{-1} TE on ΔH_1 in (a)(iii) and expression in M1 provided it is a +ve answer Ignore SF except 1 SF Correct answer with sign and units scores (3)	

Question Number	Answer	Additional Guidance	Mark
7(c)(i)	• calculation of percentage error	Example of calculation percentage error $= \frac{(90 - 74)}{90} \times 100 = 17.778 / 17.8 / 18(\%)$ Allow 17.7 recurring Ignore SF except 1SF Do not award 17.7	**(1)**

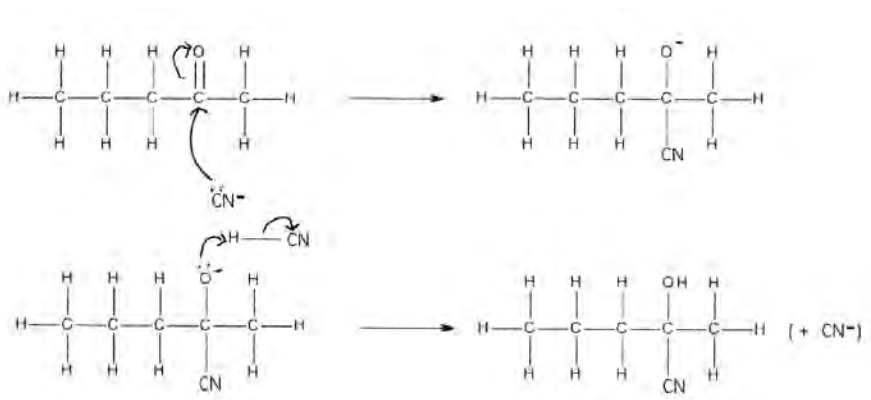
Question Number	Answer	Additional Guidance	Mark
7(c)(ii)	• calculation of percentage uncertainty using measuring cylinder **and** burette	Example of calculation percentage uncertainty using measuring cylinder $= \frac{0.5 \times 100}{50} = 1(\%)$ **and** percentage uncertainty using burette $= \frac{2 \times 0.05}{50} \times 100 = 0.2(\%)$ Ignore SF / ±	**(1)**

Question Number	Answer	Additional Guidance	Mark
7(c)(iii)	An answer that makes reference to the following point • the difference in the uncertainty in using the burette compared with the measuring cylinder is very much smaller than the % error in the value obtained (so other factors are more significant)	Allow the uncertainty using the burette is not **significantly** less than using the measuring cylinder Allow uncertainty represents a spread of values whereas the error is the difference of the true value and value obtained Allow just ‘hydrochloric acid / HCl is in excess‘ Ignore heat loss	**(1)**

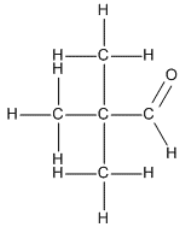
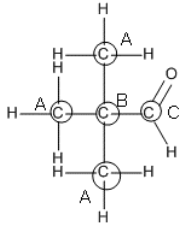
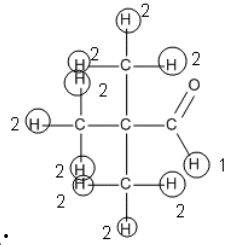
Question Number	Answer	Additional Guidance	Mark
7(c)(iv)	A description that makes reference to the following points: • measure the temperature of the (hydrochloric) acid every 30 s for 2½ minutes **(1)** • add the sodium carbonate / solid (at exactly 3 minutes) **(1)** • (stir and) measure the temperature (of the mixture) every 30 s for another 5 minutes **(1)** • plot a graph of temperature against time **(1)** • (join the two sets of points with 2 best fit straight lines and) extrapolate the lines to the time of mixing **and** determine the maximum temperature change / rise at that time **(1)**	Allow different times in M1, M2 and M3 or measure the temperature at regular time intervals Allow use of a lid / additional insulation M4 & M5 can be awarded from a suitably labelled sketch graph	**(5)**

(Total for Question 7 = 19 marks)

Question Number	Answer	Additional Guidance	Mark
8 (a)	A description that makes reference to the following points: • (add a solution of) iodine and alkali / sodium hydroxide / potassium hydroxide / hydroxide ions (and warm) **(1)** **or** (add a solution of) potassium iodide in sodium chlorate(I) (and warm) • (only) pentan-2-one give a (pale) yellow precipitate / ppt(e) / solid **(1)**	Allow names or formulae but if both are given, both must be correct Stand alone mark Allow antiseptic smell Ignore observation for pentan-3-one unless also stated that it gives a yellow precipitate	**(2)**

Question Number	Answer	Additional Guidance	Mark
8(b)(i)	An answer that makes reference to the following points: • curly arrow from lone pair on C of CN^- to C of ketone group **(1)** • curly arrow from C=O to, or just beyond, O **(1)** • intermediate **(1)** • curly arrow from lone pair on O^- to H and curly arrow from H-CN bond to anywhere on CN **(1)**	Example of mechanism:  Allow C_3H_7 and CH_3 for propyl and methyl groups Allow CN bond displayed Ignore correct dipoles, penalise an incorrect dipole once only Do not award M3 if C^+ is shown on intermediate For M4, allow curly arrow from lone pair on O^- to H^+ ion / H_2O molecule Penalise incorrect ketone once only in M3 intermediate Penalise curly arrow from -ve charge instead of lone pair once only	**(4)**

Question Number	Answer	Additional Guidance	Mark
8(b)(ii)	An explanation that makes reference to the following points: • pentan-2-one / ketone is planar about the carbonyl carbon **(1)** • so the CN^- / nucleophile attacks (equally) from above and below / either side (of the plane) **(1)**	Allow bonds about C=O are (trigonal) planar **or** the carbonyl carbon is (trigonal) planar Do not award planar molecule / reference to planar intermediate / ion Do not award multiple directions	**(2)**

Question Number	Answer		Additional Guidance	Mark
8(c)	An answer that makes reference to the following points:		Example of displayed formula: 	**(4)**
	• displayed formula of aldehyde	**(1)**	Allow CH_3 groups but aldehyde group must be displayed	
	• three different carbon environments indicated	**(1)**	Example of three carbon environments: 	
	• two different proton environments indicated	**(1)**	Example of two proton environments: 	
	• no splitting as there are no hydrogens on the adjacent carbon atom(s)	**(1)**	Stand alone mark	

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>8(d)*</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 4 marks (3 marks for indicative content and 1 mark 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.

	Indicative content	Reagents - Allow names or formulae but if both are given, both must be correct Products - Allow any combination of displayed and structural formulae / skeletal formulae Allow C_4H_9 / C_3H_7 for the alkyl groups	
	• **IP1 Reagents and conditions for oxidation** – acidified potassium dichromate((VI)) / $K_2Cr_2O_7$ **and** H^+/H_2SO_4 **or** acidified sodium dichromate((VI)) / $Na_2Cr_2O_7$ **and** H^+/H_2SO_4 **or** Fehling's solution / Benedict's solution **or** Tollens' reagent / ammoniacal silver nitrate / $Ag(NH_3)^{2+}$	Allow acidified dichromate((VI)) ions / $Cr_2O_7^{2-}$ **and** H^+/H_2SO_4 Allow acidified manganate((VII)) ions / MnO_4^- **and** H^+/H_2SO_4 Ignore reference to heat Do not award just Cu^{2+} for Fehling's / Benedict's	
	• **IP2 Oxidation of aldehyde** – structure of pentanoic acid	$CH_3CH_2CH_2CH_2COOH$	
	• **IP3 Oxidation of ketone**–pentan-3-one / ketone is not (easily) oxidised		
	• **IP4 Reagents and conditions for reduction** – lithium tetrahydridoaluminate((III)) / lithium aluminium hydride **and** dry ether /ethoxyethane (followed by a dilute acid) **or** sodium tetrahydridoborate((III)) / sodium borohydride **and** aqueous / methanol solution (followed by a dilute acid)	Allow lithal Ignore hydrogen and platinum (catalyst) Ignore reference to heat	
	• **IP5 Reduction of aldehyde** – structure of pentan-1-ol	$CH_3CH_2CH_2CH_2CH_2OH$	
	• **IP6 Reduction of ketone** – structure of pentan-3-ol	$CH_3CH_2\,CH(OH)CH_2CH_3$	

(Total for Question 8 = 18 marks)

Question Number	Answer	Additional Guidance	Mark
9(a)	An explanation that makes reference to the following points: • there are fewer moles / molecules / particles of (gas) on the right **(1)** • so (equilibrium) yield of ammonia increases **(1)**	Any reference to equilibrium constant changing scores (0) overall Allow 4 moles / molecules of gas on the left **and** 2 moles / molecules on right Allow 'equilibrium shifts to the right' M2 is conditional on M1 or the idea of fewer particles on the right / increasing the value of the quotient / Q Allow reverse argument	**(2)**

Question Number	Answer	Additional Guidance	Mark
9(b)	• rearrangement of formula **(1)** • substitution of correct values **(1)** • calculation of K_c **(1)** • units **(1)**	<u>Example of calculation</u> $K_c = K_p \times (RT)^{\Delta n}$ $K_c = 3.55 \times 10^{-2} \times (0.0821 \times 500)^2$ $K_c = 59.821$ TE on Δn Stand alone mark $dm^6\ mol^{-2}$ or $mol^{-2}\ dm^6$ Correct value with units and no working scores (4) Ignore SF except 1 SF M1 and M2 can be in reverse order	**(4)**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>9(c)</td><td>

- calculation of eqm moles **(1)**
- expressions for 3 partial pressures **(1)**
- substitution of values into K_p expression **(1)**
- rearrangement of K_p expression **(1)**
- calculation of total pressure **(1)**
  and
  answer to 1 / 2 SF

</td><td>

Example of calculation

<table>
<tr><td></td><td>N_2</td><td>H_2</td><td>NH_3</td></tr>
<tr><td>Initial mol</td><td>1.0</td><td>3.0</td><td>-</td></tr>
<tr><td>Eqm mol</td><td>1.0 − 0.15 =0.85</td><td>3.0 – (3 x 0.15) = 2.55</td><td>0.30</td></tr>
<tr><td>Total mol at eqm</td><td colspan="3">0.85 + 2.55 + 0.30 = 3.7</td></tr>
<tr><td>Partial pressure</td><td>$\frac{0.85}{3.7} \times P$</td><td>$\frac{2.55}{3.7} \times P$</td><td>$\frac{0.30}{3.7} \times P$</td></tr>
</table>

$K_p = 7.76 \times 10^{-5} = \dfrac{\left(\frac{0.30 \times P}{3.7}\right)^2}{\left(\frac{0.85 \times P}{3.7}\right)\left(\frac{2.55 \times P}{3.7}\right)^3}$

$7.76 \times 10^{-5} = \dfrac{0.087419}{P^2}$

$P^2 = 1126.5$ (atm^2)

$P = 33.564$
$= 34 / 30$ (atm)

Allow any symbol for total pressure

Allow TE throughout

Correct answer to 1 or 2 SF with some working scores (5)

Correct answer to 1 or 2 SF with no working scores (4)

</td><td>(5)</td></tr>
</table>

Question Number	Answer	Additional Guidance	Mark
9(d)	• substitution of numbers into expression **(1)** • evaluation of $\Delta H/R$ **and** $1/T_1 - 1/T_2$ **(1)** • rearrangement of expression **(1)** • evaluation of expression **(1)**	Example of calculation $\ln\left(\frac{K_2}{6.76 \times 10^5}\right) = \left(\frac{-92400}{8.31}\right)\left(\frac{1}{298} - \frac{1}{310}\right)$ $\ln\left(\frac{K_2}{6.76 \times 10^5}\right) = -11119.1 \times 1.299 \times 10^{-4}$ $= -1.4444$ $K_2 = 6.76 \times 10^5 \times e^{-1.4444}$ TE on M2 $K_2 = 1.59467 \times 10^5$ / 159467(atm^{-2}) TE on M3 Allow answer from earlier correct rounding to 2 or more SF Ignore SF except 1 SF Correct answer with no / some working scores (4)	**(4)**

(Total for Question 9 = 15 marks)