



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)	<ul style="list-style-type: none"> all numbers for ^{35}Cl correct all numbers for $^{37}\text{Cl}^-$ correct 	<p><u>Example of table</u></p> <table border="1"> <thead> <tr> <th>Particle</th> <th>Protons</th> <th>Neutrons</th> <th>Electrons</th> </tr> </thead> <tbody> <tr> <td>^{35}Cl atom</td> <td>17</td> <td>18</td> <td>17</td> </tr> <tr> <td>$^{37}\text{Cl}^-$ ion</td> <td>17</td> <td>20</td> <td>18</td> </tr> </tbody> </table> <p>If no other mark is awarded, allow (1) for any four numbers correct</p>	Particle	Protons	Neutrons	Electrons	^{35}Cl atom	17	18	17	$^{37}\text{Cl}^-$ ion	17	20	18	(2)
Particle	Protons	Neutrons	Electrons												
^{35}Cl atom	17	18	17												
$^{37}\text{Cl}^-$ ion	17	20	18												

Question Number	Answer	Additional Guidance	Mark
1(a)(ii)	<ul style="list-style-type: none"> lines at 70 and 72 and 74 relative abundances 9:6:1 	<p><u>Example of spectrum</u></p> <p>Allow any abundances in an approximate 9:6:1 ratio e.g. 56:37-38:6 as %, or 75 : 50 : 8</p>	(2)

Question Number	Answer	Additional Guidance	Mark
1(b)	<ul style="list-style-type: none"> KClO₃ 	Allow K ⁺ ClO ₃ ⁻	(1)

Question Number	Answer	Additional Guidance	Mark
1(c)	<ul style="list-style-type: none"> equation state symbols 	<p>(1) <u>Example of equation</u> Cl(g) + e⁻ → Cl⁻(g) Allow just e for electron</p> <p>(1) Stand alone mark for species on both sides of equation Ignore state symbol for electron</p>	(2)

Question Number	Answer	Additional Guidance	Mark
1(d)(i)	<ul style="list-style-type: none"> identification of oxidising agent 	Either acidified (potassium) manganate(VII) / MnO ₄ ⁻ and H ⁺ Or acidified hydrogen peroxide / H ₂ O 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)	<ul style="list-style-type: none"> value of $E^{\ominus}_{\text{cell}}$ 	Either $E^{\ominus}_{\text{cell}} = (+)0.15$ (V) for acidified (potassium) manganate(VII) Or $E^{\ominus}_{\text{cell}} = (+)0.41$ (V) for acidified hydrogen peroxide No TE on any other reagent in (i)	(1)

(Total for Question 1 = 9 marks)


Question Number	Answer	Additional Guidance	Mark								
2(a)	<p>A description that makes reference to the following points:</p> <ul style="list-style-type: none"> • reagent • observation 	<p><u>Examples of reagents and observations</u></p> <table border="1" data-bbox="1128 341 1966 715"> <thead> <tr> <th data-bbox="1128 341 1464 379">Reagent</th> <th data-bbox="1464 341 1966 379">Observation</th> </tr> </thead> <tbody> <tr> <td data-bbox="1128 379 1464 491">any carbonate / NaHCO₃ / KHCO₃ (added to aqueous acid)</td> <td data-bbox="1464 379 1966 491">effervescence / fizzing / bubbles / gas evolved that turns limewater milky</td> </tr> <tr> <td data-bbox="1128 491 1464 603">magnesium (added to aqueous acid)</td> <td data-bbox="1464 491 1966 603">effervescence / fizzing / bubbles / gas evolved that gives a pop with a lighted splint</td> </tr> <tr> <td data-bbox="1128 603 1464 715">alcohol and (concentrated) H₂SO₄ / HCl / H⁺</td> <td data-bbox="1464 603 1966 715">characteristic smell (of an ester)</td> </tr> </tbody> </table> <p>Allow names or formulae for reagents but if both are given, both must be correct</p> <p>Ignore conditions e.g. heat</p> <p>Do not award PCl₅ / Na</p> <p>If more than one test is given, penalise any incorrect tests</p>	Reagent	Observation	any carbonate / NaHCO ₃ / KHCO ₃ (added to aqueous acid)	effervescence / fizzing / bubbles / gas evolved that turns limewater milky	magnesium (added to aqueous acid)	effervescence / fizzing / bubbles / gas evolved that gives a pop with a lighted splint	alcohol and (concentrated) H ₂ SO ₄ / HCl / H ⁺	characteristic smell (of an ester)	(2)
Reagent	Observation										
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alcohol and (concentrated) H ₂ SO ₄ / HCl / H ⁺	characteristic smell (of an ester)										

Question Number	Answer	Additional Guidance	Mark														
2(b)	<p>A description that makes reference to two of the following points:</p> <ul style="list-style-type: none"> • reagent (1) • corresponding observation (1) 	<p><u>Examples of reagents and observations</u></p> <table border="1" data-bbox="1128 339 1966 978"> <thead> <tr> <th data-bbox="1128 339 1547 379">Reagent</th> <th data-bbox="1547 339 1966 379">Observation</th> </tr> </thead> <tbody> <tr> <td data-bbox="1128 379 1547 528">bromine water Allow bromine (in an organic solvent)</td> <td data-bbox="1547 379 1966 528">orange / yellow / brown solution goes colourless Allow bromine water is decolourised</td> </tr> <tr> <td data-bbox="1128 528 1547 639">carboxylic acid and (concentrated) H₂SO₄ / HCl / H⁺</td> <td data-bbox="1547 528 1966 639">characteristic smell (of an ester)</td> </tr> <tr> <td data-bbox="1128 639 1547 751">acidified potassium manganate(VII) / permanganate</td> <td data-bbox="1547 639 1966 751">purple to colourless / decolourised</td> </tr> <tr> <td data-bbox="1128 751 1547 831">alkaline potassium manganate(VII)</td> <td data-bbox="1547 751 1966 831">purple to green</td> </tr> <tr> <td data-bbox="1128 831 1547 903">(neutral) potassium manganate(VII)</td> <td data-bbox="1547 831 1966 903">purple to brown ppt</td> </tr> <tr> <td data-bbox="1128 903 1547 978">acidified (potassium) dichromate(VI) (ions)</td> <td data-bbox="1547 903 1966 978">orange to green</td> </tr> </tbody> </table> <p>Allow names or formulae for reagents but if both are given, both must be correct</p> <p>Ignore conditions e.g. heat</p> <p>Do not award PCl₅ / Na</p> <p>If more than one test is given, penalise any incorrect tests</p>	Reagent	Observation	bromine water Allow bromine (in an organic solvent)	orange / yellow / brown solution goes colourless Allow bromine water is decolourised	carboxylic acid and (concentrated) H ₂ SO ₄ / HCl / H ⁺	characteristic smell (of an ester)	acidified potassium manganate(VII) / permanganate	purple to colourless / decolourised	alkaline potassium manganate(VII)	purple to green	(neutral) potassium manganate(VII)	purple to brown ppt	acidified (potassium) dichromate(VI) (ions)	orange to green	(2)
Reagent	Observation																
bromine water Allow bromine (in an organic solvent)	orange / yellow / brown solution goes colourless Allow bromine water is decolourised																
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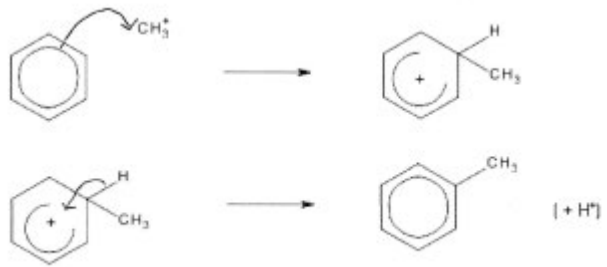
Question Number	Answer	Additional Guidance	Mark								
2(c)	<ul style="list-style-type: none"> • absorbance for A (1) • absorbance for B (1) • absorbance for C (1) 	<p><u>Example of table</u></p> <table border="1" data-bbox="1070 339 1912 834"> <thead> <tr> <th data-bbox="1070 339 1583 448">Absorbance</th> <th data-bbox="1583 339 1912 448">Wavenumber range / cm⁻¹</th> </tr> </thead> <tbody> <tr> <td data-bbox="1070 448 1583 572">Absorbance expected in infrared spectrum of A but not in B or C</td> <td data-bbox="1583 448 1912 572">1720 – 1700 Allow 1725 - 1700</td> </tr> <tr> <td data-bbox="1070 572 1583 697">Absorbance expected in infrared spectrum of B but not in A or C</td> <td data-bbox="1583 572 1912 697">1669 – 1645</td> </tr> <tr> <td data-bbox="1070 697 1583 834">Absorbance expected in infrared spectrum of C but not in A or B</td> <td data-bbox="1583 697 1912 834">1740 – 1725 Allow 1740 - 1720</td> </tr> </tbody> </table> <p>Allow values in reverse order e.g. 1700 – 1720 for A</p> <p>If single values are given instead of a range award (2) for 3 correct values within the ranges and (1) for 2 correct values</p> <p>Do not award a single value that occurs in two ranges i.e 1720-1725</p> <p>If no other mark is awarded, allow (1) for: A 3300-2500 and C 2900-2820 / 2775-2700</p>	Absorbance	Wavenumber range / cm ⁻¹	Absorbance expected in infrared spectrum of A but not in B or C	1720 – 1700 Allow 1725 - 1700	Absorbance expected in infrared spectrum of B but not in A or C	1669 – 1645	Absorbance expected in infrared spectrum of C but not in A or B	1740 – 1725 Allow 1740 - 1720	(3)
Absorbance	Wavenumber range / cm ⁻¹										
Absorbance expected in infrared spectrum of A but not in B or C	1720 – 1700 Allow 1725 - 1700										
Absorbance expected in infrared spectrum of B but not in A or C	1669 – 1645										
Absorbance expected in infrared spectrum of C but not in A or B	1740 – 1725 Allow 1740 - 1720										

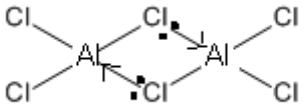
(Total for Question 2 = 7 marks)

Question Number	Answer	Additional Guidance	Mark
3(a)	<ul style="list-style-type: none"> $(1s^2)2s^22p^63s^23p^1$ 	<p>Allow numbers of electrons as subscripts or large numbers</p> <p>Allow p orbitals designated as x, y and z</p> <p>Ignore $1s^2$ repeated</p>	(1)

Question Number	Answer	Additional Guidance	Mark
3(b)(i)	<ul style="list-style-type: none"> dot-and-cross diagram 	<p><u>Example of diagram</u></p>  <p>Allow electrons in overlapping circles</p> <p>Allow all dots / all crosses</p> <p>Ignore inner shell electrons, even if incorrect</p> <p>Ignore lines as bonds e.g.</p> <p>\underline{x}</p> <p>•</p> <p>Do not award diagram with lone pair on Al</p>	(1)

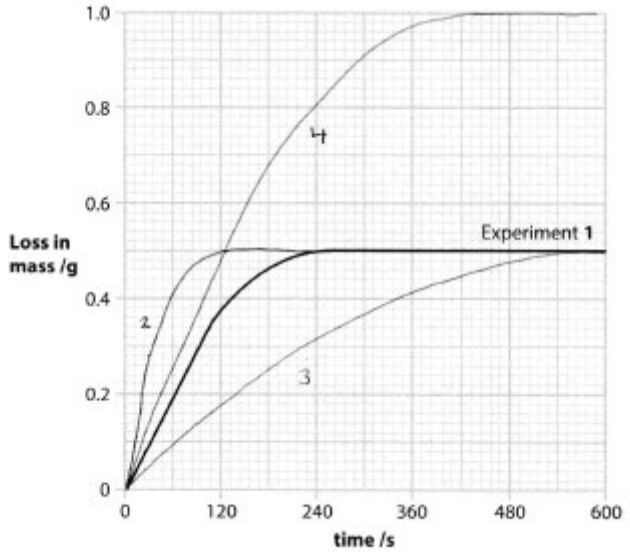
Question Number	Answer	Additional Guidance	Mark
3(b)(ii)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li data-bbox="365 347 1245 384">• shape – trigonal planar (1) <li data-bbox="365 459 1245 496">• bond angle - 120° (1) 	<p>Mark independently</p> <p>Both words needed Allow triangular for trigonal – but not just tri</p> <p>Allow marks for labelled diagram</p> <p>Note If shape is pyramidal, no mark for M1 but allow (1) for 107° No TE for any other shape</p>	(2)

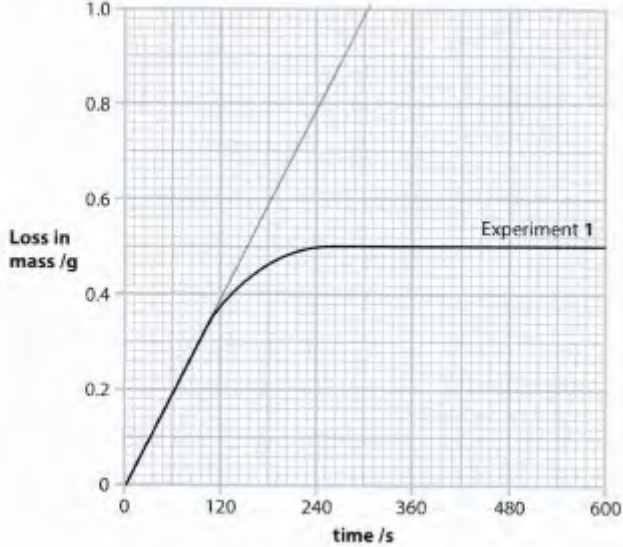
Question Number	Answer	Additional Guidance	Mark
3(b)(iii)	<ul style="list-style-type: none"> • equation for the formation of the electrophile (1) • curly arrow from on or within the circle to CH₃⁺ (1) • structure of intermediate including charge with some part of the charge within the horseshoe and horseshoe 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) 	<p><u>Example of mechanism</u></p> <p>CH₃Cl + AlCl₃ → CH₃⁺ + [AlCl₄]⁻</p>  <p>Allow AlCl₄⁻ / δ⁺CH₃-AlCl₄^{δ-} (1)</p> <p>Allow curly arrow from anywhere within the hexagon (1)</p> <p>Allow curly arrow to any part of CH₃⁺, including the + charge</p> <p>Do not award curly arrow from outside the hexagon</p> <p>Allow dotted / dashed lines for horseshoe</p> <p>Do not award dotted bonds to H and CH₃ unless clearly part of a 3D structure</p> <p>Ignore any involvement of AlCl₄⁻ in the final step /HCl</p> <p>Note</p> <p>Correct Kekulé structures score full marks</p>	(4)

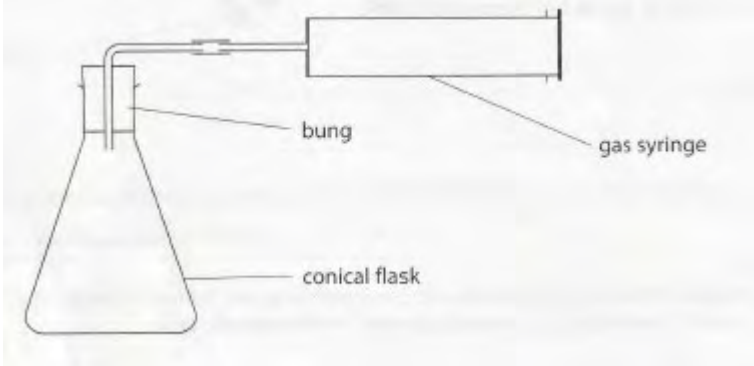
Question Number	Answer	Additional Guidance	Mark
3(c)(i)	<ul style="list-style-type: none"> diagram showing two AlCl_3 molecules joined through two chlorine atoms 	<p>Example of diagram</p>  <p>Allow dot-and-cross diagram</p> <p>Ignore missing arrows / direction of arrows</p> <p>Ignore missing lone pairs</p>	(1)

Question Number	Answer	Additional Guidance	Mark
3(c)(ii)	<ul style="list-style-type: none"> dative (covalent) bonds or coordinate bonds 	<p>Allow this labelled on diagram in (i)</p> <p>Do not award this mark if dative bonds shown as arrows starting from aluminium in (c)(i)</p>	(1)

(Total for Question 3 = 10 marks)

Question Number	Answer	Additional Guidance	Mark
4(a)	<ul style="list-style-type: none"> • curve for Experiment 2 steeper than Experiment 1 and Experiment 4 (1) and finishing at the same mass loss as Experiment 1 • curve for Experiment 3 shallower than Experiment 1 (1) and finishing at the same mass loss • curve for Experiment 4 steeper than Experiment 1 (1) and finishing at mass loss 1.0 g 	<p><u>Examples of curves</u></p>  <p>Allow curve for Experiment 4 steeper than Experiments 1 and 2 and finishing at mass loss 1.0 g</p>	(3)

Question Number	Answer	Additional Guidance	Mark
4(b)	<ul style="list-style-type: none"> <li data-bbox="367 826 965 970">• 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) <li data-bbox="367 1011 707 1050">• calculation of gradient (1) <li data-bbox="367 1203 479 1241">• units (1) 	<p data-bbox="1099 272 1357 304"><u>Example of tangent</u></p>  <p data-bbox="1099 1023 1868 1094">gradient = $\frac{1.0}{300} = 3.33 \times 10^{-3}$ Allow 3.13×10^{-3} to 3.53×10^{-3}</p> <p data-bbox="1099 1102 1951 1174">TE on tangent drawn or measurements from line on graph with no tangent</p> <p data-bbox="1099 1174 1420 1206">Ignore SF including 1SF</p> <p data-bbox="1099 1246 1323 1318">g s^{-1} or g/s stand alone mark</p>	(3)

Question Number	Answer	Additional Guidance	Mark
4(c)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> • 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) 	<p><u>Example of diagram</u></p>  <p>Ignore missing labels Ignore heat / water bath Do not award inclusion of a condenser Do not award test tube or beaker for collecting gas</p> <p>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</p> <p>Allow specified time intervals Allow collected in a specified time</p>	(4)

(Total for Question 4 = 10 marks)

Question Number	Answer	Additional Guidance	Mark
5(a)(i)	<ul style="list-style-type: none"> (The cation in X is) Fe²⁺ / iron(II) / Fe(II) (1) (The anion in X is) SO₄²⁻ / 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)	<ul style="list-style-type: none"> species and balancing (1) state symbols (1) 	<u>Examples of equation</u> Fe ²⁺ (aq) + 2OH ⁻ (aq) → Fe(OH) ₂ (s) or [Fe(H ₂ O) ₆] ²⁺ (aq) + 2OH ⁻ (aq) → Fe(OH) ₂ (s) + 6H ₂ O(l) or [Fe(H ₂ O) ₆] ²⁺ (aq) + 2OH ⁻ (aq) → Fe(OH) ₂ (H ₂ O) ₄ (s) + 2H ₂ O(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: <ul style="list-style-type: none"> Fe²⁺ is oxidised (to Fe³⁺) 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: <ul style="list-style-type: none"> 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)	<ul style="list-style-type: none"> $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$ 	Allow $[\text{Cu}(\text{NH}_3)_4]^{2+}$ Allow $[\text{Co}(\text{NH}_3)_6]^{2+}$ if Co^{2+} in (i) Ignore missing square brackets	(1)

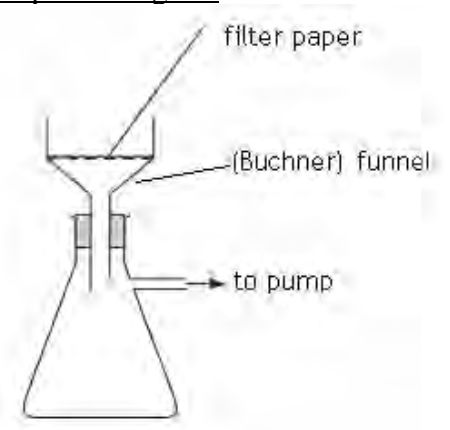
Question Number	Answer	Additional Guidance	Mark
5(b)(iii)	A description that makes reference to the following points: <ul style="list-style-type: none"> add dilute (aqueous) ammonia (and stir the mixture) the precipitate dissolves 	If Cl^- / chloride / chlorine ion: Allow add aqueous ammonia / $\text{NH}_3(\text{aq})$ 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)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> 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) 	<p>Allow lone pair (of electrons) on oxygen feeds into / donates into / interacts with the delocalised electrons / system Ignore electron pushing effect of OH</p>	(2)

Question Number	Answer	Additional Guidance	Mark
6(a)(ii)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> 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) 	<p>Allow M1 and M2 shown in diagrams Ignore reference to other specific types of intermolecular forces</p> <p>Allow 4-nitrophenol forms stronger intermolecular hydrogen bonds / forces / interactions</p> <p>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)</p>	(2)

Question Number	Answer	Additional Guidance	Mark
6(b)	<ul style="list-style-type: none"> 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)	<ul style="list-style-type: none"> 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) 	<p><u>Example of diagram</u></p>  <p>filter paper</p> <p>(Buchner) funnel</p> <p>to pump</p> <p>Ignore just 'suction'</p> <p>Allow funnel joined to flask with 'Quickfit' joint / no gap</p> <p>Do not award fluted filter paper / filter paper that extends up the sides of the funnel</p>	(3)

Question Number	Answer	Additional Guidance	Mark
6(c)(ii)	<p>A description that makes reference to the following points:</p> <ul style="list-style-type: none"> • 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) 	<p>Allow add / put for dissolve Do not award wash for dissolve</p> <p>Penalise use of incorrect solvent once only</p> <p>Allow M3 if hot is omitted and is mentioned in M2</p> <p>Do not award filter to remove soluble impurities</p> <p>Stand alone mark Allow other suitable methods of drying Do not award reference to crystals mixed with a drying agent</p>	(5)

Question Number	Answer	Additional Guidance	Mark
6(c)(iii)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> • melting temperature is lower (1) • it melts over a range of temperatures (1) or the melting temperature is not sharp 	<p>Allow a specified range of temperatures</p>	(2)

Question Number	Answer	Additional Guidance	Mark
6(d)(i)	<ul style="list-style-type: none"><li data-bbox="365 312 539 341">• C₈H₉NO₂	Allow the symbols, with subscripts, in any order e.g. C ₈ H ₉ O ₂ N Allow large numbers but not superscripts Ignore any other formulae as working	(1)

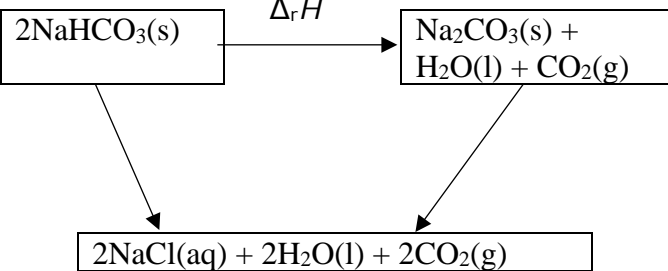
Question Number	Answer	Additional Guidance	Mark
6(d)(ii)	<ul style="list-style-type: none"> <li data-bbox="365 344 1249 384">• calculation of amount of Ce^{4+} (1) <li data-bbox="365 456 1249 496">• calculation of amount of paracetamol in 25.0 cm^3 (1) <li data-bbox="365 647 1249 687">• calculation of amount of paracetamol in 100.0 cm^3 (1) <li data-bbox="365 839 1249 943">• calculation of molar mass of paracetamol and mass of paracetamol in 1 tablet (1) <li data-bbox="365 1094 1249 1198">• calculation of percentage of paracetamol in 1 tablet and conclusion (1) 	<p data-bbox="1296 272 1599 296"><u>Example of calculation</u></p> <p data-bbox="1296 304 1845 416">amount Ce^{4+} used = $\frac{16.5 \times 0.100}{1000}$ $= 0.00165 / 1.65 \times 10^{-3} \text{ (mol)}$</p> <p data-bbox="1296 456 1845 568">amount paracetamol in $25.0 \text{ cm}^3 = \frac{0.00165}{2}$ $= 0.000825 / 8.25 \times 10^{-4} \text{ (mol)}$ TE on M1</p> <p data-bbox="1296 639 1845 751">amount paracetamol in 100.0 cm^3 $= 4 \times 0.000825$ $= 0.00330 / 3.30 \times 10^{-3} \text{ (mol)}$ TE on M2</p> <p data-bbox="1296 823 1845 1038">molar mass of paracetamol, $\text{C}_8\text{H}_9\text{NO}_2$ $= (8 \times 12) + (9 \times 1) + 14 + (2 \times 16) = 151$ and mass of paracetamol in 1 tablet $= 0.00330 \times 151 = 0.4983 \text{ g}$ TE on M3 and (d)(i)</p> <p data-bbox="1296 1086 1845 1190">percentage of paracetamol $= \frac{0.4983}{0.500} \times 100 = 99.66 \text{ (\%)}$</p> <p data-bbox="1296 1198 1845 1302">and the tablet was from Brand R TE on M4 provided $M4 < 0.500 \text{ g}$</p> <p data-bbox="1296 1342 1588 1366">Ignore SF except 1 SF</p>	(5)

(Total for Question 6 = 21 marks)

Question Number	Answer	Additional Guidance	Mark				
7(a)(i)	<ul style="list-style-type: none"> mass and temperature fall correct 	<table border="1"> <tr> <td>Mass of NaHCO₃ used / g</td> <td>5.62</td> </tr> <tr> <td>Temperature fall / °C</td> <td>(-)6.6</td> </tr> </table>	Mass of NaHCO ₃ used / g	5.62	Temperature fall / °C	(-)6.6	(1)
Mass of NaHCO ₃ used / g	5.62						
Temperature fall / °C	(-)6.6						

Question Number	Answer	Additional Guidance	Mark
7(a)(ii)	<ul style="list-style-type: none"> calculation of amount of NaHCO₃ and calculation of amount of hydrochloric acid <p style="text-align: right;">(1)</p> <ul style="list-style-type: none"> 0.0669 mol NaHCO₃ needs 0.0699 mol HCl for reaction so HCl is in excess <p style="text-align: right;">(1)</p>	<p>Example of calculation</p> $\text{amount NaHCO}_3 = \frac{5.62}{23 + 1 + 12 + (3 \times 16)}$ $= 0.0669 \text{ (mol)}$ <p>TE on mass of NaHCO₃ in (a)(i) and amount HCl = $\frac{50 \times 2.00}{1000} = 0.10 \text{ (mol)}$</p> <p>Ignore SF including 1SF</p> <p>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)</p>	(2)

Question Number	Answer	Additional Guidance	Mark
7(a)(iii)	<ul style="list-style-type: none"> <li data-bbox="365 347 1144 379">• calculation of heat absorbed (1) <li data-bbox="365 496 1144 528">• calculation of enthalpy change (1) <li data-bbox="365 794 1144 826">• positive sign and units (1) 	<p data-bbox="1184 272 1487 304"><u>Example of calculation</u></p> <p data-bbox="1184 344 1697 411">heat absorbed = $50.0 \times 4.18 \times 6.6$ = 1379.4 (J) / 1.3794 (kJ)</p> <p data-bbox="1184 419 1335 451">Ignore sign</p> <p data-bbox="1184 491 1615 595">enthalpy change = $\frac{1379.4}{0.0669}$ = 20619 (J mol⁻¹)</p> <p data-bbox="1184 603 1648 707">or = $\frac{1.3794}{0.0669}$ = 20.619 (kJ mol⁻¹)</p> <p data-bbox="1184 715 1850 746">TE on heat absorbed and amount NaHCO₃ in (a)(ii)</p> <p data-bbox="1184 786 1827 970">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⁻¹ / J mol⁻¹</p> <p data-bbox="1184 1010 1783 1082">Ignore SF except 1 SF Ignore incorrect / missing units in M1 and M2</p> <p data-bbox="1184 1121 1767 1153">Correct answer with sign and units scores (3)</p>	(3)

Question Number	Answer	Additional Guidance	Mark
7(b)(i)	<ul style="list-style-type: none"> <li data-bbox="367 643 1077 675">• correct species and balancing numbers in lower box (1) <li data-bbox="367 754 943 786">• both arrows pointing in correct directions (1) 	<p data-bbox="1294 272 1592 304"><u>Example of Hess cycle</u></p> <div style="text-align: center;">  </div> <p data-bbox="1294 647 1671 679">Ignore missing state symbols</p> <p data-bbox="1294 759 1877 823">Stand alone mark Ignore labels on arrows and inclusion of HCl</p>	(2)

Question Number	Answer	Additional Guidance	Mark
7(b)(ii)	<ul style="list-style-type: none"> <li data-bbox="365 309 1211 344">• expression for $\Delta_r H$ (1) <li data-bbox="365 384 1211 451">• substitution of values into expression with both values in same units (1) <li data-bbox="365 683 1211 863">• calculation of $\Delta_r H$ and sign and units (1) 	<p data-bbox="1256 272 1559 300"><u>Example of calculation</u></p> <p data-bbox="1256 309 1518 336">$\Delta_r H = 2 \times \Delta H_1 - \Delta H_2$</p> <p data-bbox="1256 379 1608 406">$\Delta_r H = 2 \times 20.619 - (-29.4)$</p> <p data-bbox="1256 421 1294 448">or</p> <p data-bbox="1256 456 1630 483">$\Delta_r H = 2 \times 20619 - (-29\ 400)$</p> <p data-bbox="1256 496 1951 563">M1 can be scored from values substituted into correct expression in M2</p> <p data-bbox="1256 568 1809 595">TE on ΔH_1 in (a)(iii) and expression in M1</p> <p data-bbox="1256 603 1711 630">No TE on incorrect arrows in cycle</p> <p data-bbox="1256 675 1563 702">$\Delta_r H = +70.638 \text{ kJ mol}^{-1}$</p> <p data-bbox="1256 716 1294 743">or</p> <p data-bbox="1256 751 1541 778">$\Delta_r H = +70638 \text{ J mol}^{-1}$</p> <p data-bbox="1256 786 1957 853">TE on ΔH_1 in (a)(iii) and expression in M1 provided it is a +ve answer</p> <p data-bbox="1256 898 1547 925">Ignore SF except 1 SF</p> <p data-bbox="1256 933 1839 960">Correct answer with sign and units scores (3)</p>	(3)

Question Number	Answer	Additional Guidance	Mark
7(c)(i)	<ul style="list-style-type: none"> calculation of percentage error 	<p><u>Example of calculation</u></p> <p>percentage error $= \frac{(90 - 74)}{90} \times 100 = 17.778 / 17.8 / 18(\%)$</p> <p>Allow 17.7 recurring</p> <p>Ignore SF except 1SF</p> <p>Do not award 17.7</p>	(1)

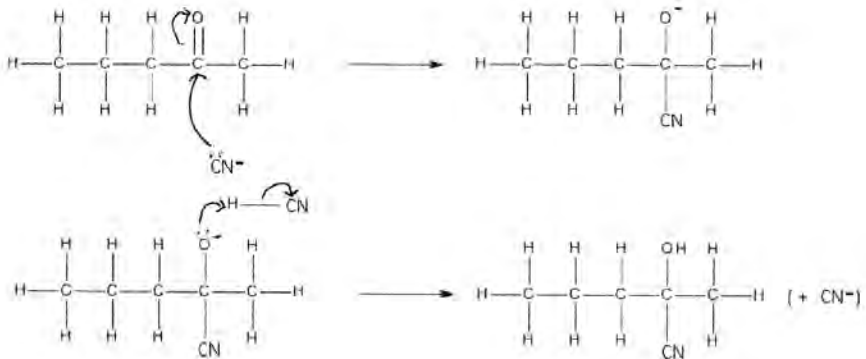
Question Number	Answer	Additional Guidance	Mark
7(c)(ii)	<ul style="list-style-type: none"> calculation of percentage uncertainty using measuring cylinder and burette 	<p><u>Example of calculation</u></p> <p>percentage uncertainty using measuring cylinder $= \frac{0.5 \times 100}{50} = 1(\%)$</p> <p>and</p> <p>percentage uncertainty using burette $= \frac{2 \times 0.05}{50} \times 100 = 0.2(\%)$</p> <p>Ignore SF / ±</p>	(1)

Question Number	Answer	Additional Guidance	Mark
7(c)(iii)	<p>An answer that makes reference to the following point</p> <ul style="list-style-type: none"> 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) 	<p>Allow the uncertainty using the burette is not significantly less than using the measuring cylinder</p> <p>Allow uncertainty represents a spread of values whereas the error is the difference of the true value and value obtained</p> <p>Allow just 'hydrochloric acid / HCl is in excess'</p> <p>Ignore heat loss</p>	(1)

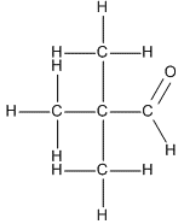
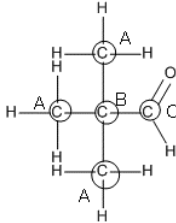
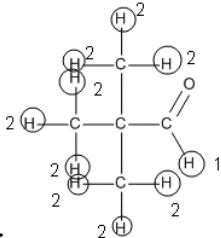
Question Number	Answer	Additional Guidance	Mark
7(c)(iv)	<p>A description that makes reference to the following points:</p> <ul style="list-style-type: none"> • measure the temperature of the (hydrochloric) acid every 30 s for 2½ minutes (1) • add the sodium carbonate / solid (at exactly 3 minutes) (1) • (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) 	<p>Allow different times in M1, M2 and M3 or measure the temperature at regular time intervals</p> <p>Allow use of a lid / additional insulation</p> <p>M4 & M5 can be awarded from a suitably labelled sketch graph</p>	(5)

(Total for Question 7 = 19 marks)

Question Number	Answer	Additional Guidance	Mark
8 (a)	<p>A description that makes reference to the following points:</p> <ul style="list-style-type: none"> • (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) 	<p>Allow names or formulae but if both are given, both must be correct</p> <p>Stand alone mark Allow antiseptic smell</p> <p>Ignore observation for pentan-3-one unless also stated that it gives a yellow precipitate</p>	(2)

Question Number	Answer	Additional Guidance	Mark
8(b)(i)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> • 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) 	<p>Example of mechanism:</p>  <p>Allow C₃H₇ and CH₃ for propyl and methyl groups</p> <p>Allow CN bond displayed</p> <p>Ignore correct dipoles, penalise an incorrect dipole once only</p> <p>Do not award M3 if C⁺ is shown on intermediate</p> <p>For M4, allow curly arrow from lone pair on O⁻ to H⁺ ion / H₂O molecule</p> <p>Penalise incorrect ketone once only in M3 intermediate</p> <p>Penalise curly arrow from -ve charge instead of lone pair once only</p>	(4)

Question Number	Answer	Additional Guidance	Mark
8(b)(ii)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li data-bbox="365 379 1245 451">• pentan-2-one / ketone is planar about the carbonyl carbon (1) <li data-bbox="365 643 1245 715">• so the CN⁻/ nucleophile attacks (equally) from above and below / either side (of the plane) (1) 	<p>Allow bonds about C=O are (trigonal) planar or the carbonyl carbon is (trigonal) planar</p> <p>Do not award planar molecule / reference to planar intermediate / ion</p> <p>Do not award multiple directions</p>	(2)

Question Number	Answer	Additional Guidance	Mark
8(c)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li data-bbox="367 384 1133 416">• displayed formula of aldehyde (1) <li data-bbox="367 644 1133 676">• three different carbon environments indicated (1) <li data-bbox="367 904 1133 936">• two different proton environments indicated (1) <li data-bbox="367 1203 1133 1275">• no splitting as there are no hydrogens on the adjacent carbon atom(s) (1) 	<p>Example of displayed formula:</p>  <p>Allow CH₃ groups but aldehyde group must be displayed</p> <p>Example of three carbon environments:</p>  <p>Example of two proton environments:</p>  <p>Stand alone mark</p>	(4)

Question Number	Acceptable Answers	Additional Guidance	Mark												
8(d)*	<p>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.</p> <p>Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.</p> <p>The following table shows how the marks should be awarded for indicative content.</p> <table border="1" data-bbox="320 635 835 978"> <thead> <tr> <th data-bbox="320 635 568 783">Number of indicative marking points seen in answer</th> <th data-bbox="568 635 835 783">Number of marks awarded for indicative marking points</th> </tr> </thead> <tbody> <tr> <td data-bbox="320 783 568 823">6</td> <td data-bbox="568 783 835 823">4</td> </tr> <tr> <td data-bbox="320 823 568 863">5-4</td> <td data-bbox="568 823 835 863">3</td> </tr> <tr> <td data-bbox="320 863 568 903">3-2</td> <td data-bbox="568 863 835 903">2</td> </tr> <tr> <td data-bbox="320 903 568 943">1</td> <td data-bbox="568 903 835 943">1</td> </tr> <tr> <td data-bbox="320 943 568 978">0</td> <td data-bbox="568 943 835 978">0</td> </tr> </tbody> </table> <p>The following table shows how the marks should be awarded for structure and lines of reasoning.</p>	Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	6	4	5-4	3	3-2	2	1	1	0	0	<p>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).</p>	(6)
Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points														
6	4														
5-4	3														
3-2	2														
1	1														
0	0														

		Number of marks awarded 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.	
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			
<p>Comment: Look for the indicative marking points first, then consider the mark for structure of answer and sustained line of reasoning</p>				

	<p>Indicative content</p> <ul style="list-style-type: none"> • 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 / $Ag(NH_3)^{2+}$ • IP2 Oxidation of aldehyde – structure of pentanoic acid • 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) • IP5 Reduction of aldehyde – structure of pentan-1-ol • IP6 Reduction of ketone – structure of pentan-3-ol 	<p>Reagents - Allow names or formulae but if both are given, both must be correct</p> <p>Products - Allow any combination of displayed and structural formulae / skeletal formulae Allow C_4H_9 / C_3H_7 for the alkyl groups</p> <p>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</p> <p>$CH_3CH_2CH_2CH_2COOH$</p> <p>Allow lithal Ignore hydrogen and platinum (catalyst) Ignore reference to heat</p> <p>$CH_3CH_2CH_2CH_2CH_2OH$</p> <p>$CH_3CH_2CH(OH)CH_2CH_3$</p>	
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(Total for Question 8 = 18 marks)

Question Number	Answer	Additional Guidance	Mark
9(a)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> there are fewer moles / molecules / particles of (gas) on the right (1) so (equilibrium) yield of ammonia increases (1) 	<p>Any reference to equilibrium constant changing scores (0) overall</p> <p>Allow 4 moles / molecules of gas on the left and 2 moles / molecules on right</p> <p>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</p> <p>Allow reverse argument</p>	(2)

Question Number	Answer	Additional Guidance	Mark
9(b)	<ul style="list-style-type: none"> rearrangement of formula (1) substitution of correct values (1) calculation of K_c (1) units (1) 	<p><u>Example of calculation</u></p> $K_c = K_p \times (RT)^{\Delta n}$ $K_c = 3.55 \times 10^{-2} \times (0.0821 \times 500)^2$ $K_c = 59.821$ <p>TE on Δn</p> <p>Stand alone mark $\text{dm}^6 \text{mol}^{-2}$ or $\text{mol}^{-2} \text{dm}^6$</p> <p>Correct value with units and no working scores (4)</p> <p>Ignore SF except 1 SF</p> <p>M1 and M2 can be in reverse order</p>	(4)

Question Number	Answer	Additional Guidance	Mark																				
9(c)	<ul style="list-style-type: none"> • 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 and answer to 1 / 2 SF (1) 	<p><u>Example of calculation</u></p> <table border="1" data-bbox="1057 341 1948 644"> <thead> <tr> <th></th> <th>N₂</th> <th>H₂</th> <th>NH₃</th> </tr> </thead> <tbody> <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>$\frac{0.85 \times P}{3.7}$</td> <td>$\frac{2.55 \times P}{3.7}$</td> <td>$\frac{0.30 \times P}{3.7}$</td> </tr> </tbody> </table> <p> $K_p = 7.76 \times 10^{-5} = \frac{\left(\frac{0.30 \times P}{3.7}\right)^2}{\left(\frac{0.85 \times P}{3.7}\right)\left(\frac{2.55 \times P}{3.7}\right)^3}$ $7.76 \times 10^{-5} = \frac{0.087419}{P^2}$ $P^2 = 1126.5 \text{ (atm}^2\text{)}$ $P = 33.564$ $= 34 / 30 \text{ (atm)}$ </p> <p>Allow any symbol for total pressure</p> <p>Allow TE throughout</p> <p>Correct answer to 1 or 2 SF with some working scores (5)</p> <p>Correct answer to 1 or 2 SF with no working scores (4)</p>		N ₂	H ₂	NH ₃	Initial mol	1.0	3.0	-	Eqm mol	1.0 - 0.15 = 0.85	3.0 - (3 x 0.15) = 2.55	0.30	Total mol at eqm	0.85 + 2.55 + 0.30 = 3.7			Partial pressure	$\frac{0.85 \times P}{3.7}$	$\frac{2.55 \times P}{3.7}$	$\frac{0.30 \times P}{3.7}$	(5)
	N ₂	H ₂	NH ₃																				
Initial mol	1.0	3.0	-																				
Eqm mol	1.0 - 0.15 = 0.85	3.0 - (3 x 0.15) = 2.55	0.30																				
Total mol at eqm	0.85 + 2.55 + 0.30 = 3.7																						
Partial pressure	$\frac{0.85 \times P}{3.7}$	$\frac{2.55 \times P}{3.7}$	$\frac{0.30 \times P}{3.7}$																				

Question Number	Answer	Additional Guidance	Mark
9(d)	<ul style="list-style-type: none"> • 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) 	<p><u>Example of calculation</u></p> $\ln\left(\frac{K_2}{6.76 \times 10^5}\right) = \left(\frac{-92400}{8.31}\right)\left(\frac{1}{298} - \frac{1}{310}\right)$ $\ln\left(\frac{K_2}{6.76 \times 10^5}\right) = -11119.1 \times 1.299 \times 10^{-4}$ $= -1.4444$ $K_2 = 6.76 \times 10^5 \times e^{-1.4444}$ <p>TE on M2</p> $K_2 = 1.59467 \times 10^5 / 159467(\text{atm}^{-2})$ <p>TE on M3</p> <p>Allow answer from earlier correct rounding to 2 or more SF</p> <p>Ignore SF except 1 SF</p> <p>Correct answer with no / some working scores (4)</p>	(4)

(Total for Question 9 = 15 marks)

