Pearson
Edexcel

Mark Scheme (Results)

Summer 2019

Pearson Edexcel Advanced Level
In Chemistry (9CH0) Paper 03 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	Acceptable Answers	Additional Guidance	Mark
1(a)	• (a Brønsted-Lowry acid is a) proton donor	Allow donates / gives away protons / H^+ (ions) / hydrogen ions Allow releases / loses protons / H^+ / hydrogen ions Do not award ‘donates H_3O^+ (ions)’	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
1(b)	• correct acid-base pairs identified **and** linked	<u>Examples of acid-base pairs</u> CH_3COOH + $HCOOH$ → $CH_3COOH_2^+$ + $HCOO^-$ base 2/B2 acid 1/A1 acid 2/ A2 base 1/B1 **or** CH_3COOH + $HCOOH$ → $CH_3COOH_2^+$ + $HCOO^-$ base acid acid base **or** CH_3COOH + $HCOOH$ → $CH_3COOH_2^+$ + $HCOO^-$ base / B acid / A conjugate acid / CA conjugate base / CB Allow any clear identification of acid and base **and** connection between the correct pairs	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
1(c)	• (pH =) $-\log[H^+(aq)]$ **or** (pH =) $-\log[H_3O^+(aq)]$	Allow $\log_{10}$ / lg for log Ignore missing (aq) Do not award –log conc H^+ Do not award round brackets / no brackets for concentration but allow round brackets around the square brackets e.g. $-\log([H^+(aq)])$	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
1(d)	• calculation of $[H^+(aq)]$	<u>Example of calculation</u> $[H^+(aq)] = 10^{-pH} = 10^{-2.76}$ $= 1.7378 \times 10^{-3}$ / 1.738×10^{-3} / 1.74×10^{-3} / 1.7×10^{-3} / 0.0017378 / 0.001738 / 0.00174 / 0.0017 (mol dm^{-3}) Ignore units even if incorrect Correct answer to 2 or more SF with no working scores (1)	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
1(e)	An explanation that makes reference to the following points: • $[H^+]$/ $[H_3O^+]$/ concentration of hydrogen ions from water is $1(.0) \times 10^{-7}$ (mol dm^{-3}) **(1)** • so total $[H^+]$ is greater than $1(.0) \times 10^{-7}$ (mol dm^{-3}) / is 1.1×10^{-7} (mol dm^{-3}) **or** the pH cannot be more than 7 / alkaline (for an acid) **or** concentration of hydrogen ions from water is not negligible / cannot be ignored **or** 10^{-8} is only the concentration of ions from the acid, it doesn't include those from the water **(1)**	Penalise reference to nitric acid as a weak acid in M2 only Allow $[H^+]$ from water = $\sqrt{1(.00) \times 10^{-14}}$ / $\sqrt{K_w}$ Allow this shown as part of a calculation Allow $[H_3O^+]$/ concentration of hydrogen ions for $[H^+]$ Allow $[H^+]$ is greater than 1×10^{-8} (mol dm^{-3}) Allow $[H^+]$ cannot be less than $[OH^-]$ / $[OH^-]$ cannot be more than $[H^+]$ Allow the addition of nitric acid to water decreases pH by increasing $[H^+]$ Allow pH is 6.96 Allow pH 8 / >7 is alkaline Allow acid must have pH below 7 Do not award $10^{-14}/10^{-8} = 10^{-6}$ so pH = 6 for M2 only Allow water also dissociates to form H^+ ions	**(2)**

(Total for Question 1 = 6 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
2(a)(i)	• correct temperature **and** pressure	<u>Examples of values</u> Temperature: 298 K / 25°C Pressure: 1 atm / 1 bar 100 kPa/ 1 x 10^5 Pa / 101 kPa / 1.01 x 10^5 Pa / 1 x 10^5 Nm^{-2} / 1.01 x 10^5 Nm^{-2} Values **and** units are needed Ignore reference to concentration even if incorrect	**(1)**

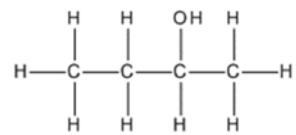
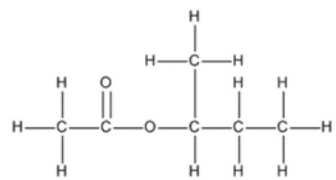
Question Number	Acceptable Answers	Additional Guidance	Mark
2(a)(ii)		The mistakes can be in any order Ignore any other errors Ignore reasons for replacements	(3)
	• ammeter / symbol for ammeter **and** replace with (high resistance) voltmeter / symbol for voltmeter **(1)**	Allow replace with potentiometer / Wheatstone bridge Do not award voltameter	
	• ethanoic acid **and** replace with solution that is 1.0 mol dm^{-3} with respect to $H^+(aq)$ **(1)**	Allow replace with (1.0 / 1.16-1.18 mol dm^{-3}) hydrochloric acid / HCl / nitric acid / HNO_3 **or** Allow 0.5 mol dm^{-3} sulfuric acid / H_2SO_4 Ignore just ‘replace with a strong acid’	
	• potassium chloride / chemical in salt bridge **and** replace with potassium nitrate / KNO_3 / sodium nitrate / $NaNO_3$ **(1)**	Allow replace chloride with a nitrate anion Ignore replace with a different anion that will not react with Ag^+	

Question Number	Acceptable Answers	Additional Guidance	Mark
2(b)	• substitution of correct values into expression **(1)** • calculation of In[Ag^+(aq)] **(1)** • calculation of [Ag^+(aq)] **(1)**	<u>Example of calculation</u> $0.72 = 0.80 + \frac{8.31 \times 293}{96500} \times \ln[Ag^+(aq)]$ $\ln[Ag^+(aq)] = (0.72 - 0.80) \times \frac{96500}{8.31 \times 293}$ $= -3.1707$ $[Ag^+(aq)] = e^{\ln[Ag+(aq)]}$ $= 0.041976$ / 4.1976×10^{-2} (mol dm^{-3}) TE on In[Ag^+(aq)] Ignore SF except 1 SF Correct answer with no working scores full marks Expression can be rearranged before substitution of values	**(3)**

(Total for Question 2 = 7 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
3(a)	A synthetic pathway that includes: **Conversion to alcohol** • (aqueous ethanolic) potassium / sodium hydroxide **(1)** • name or structure of propan-1-ol **(1)** **EITHER ROUTE 1** **Conversion to carboxylic acid** • (oxidise some of the propan-1-ol using) potassium dichromate((VI)) **and** (dilute) sulfuric acid **(1)** • name or structure of propanoic acid **(1)** **Formation of ester** • react propan-1-ol and propanoic acid together **and** using (concentrated) sulfuric acid (catalyst) **(1)** **PTO for ROUTE 2**	Allow names or formulae for reagents but if both are given, both must be correct Allow correct species in unbalanced equations Allow any combination of structural, displayed or skeletal formulae for the intermediates Penalise missing H once only Ignore conditions e.g. heat / reflux Allow hydroxide ions / OH^- Ignore concentration Do not award just ethanol / ethanolic Stand alone mark e.g. $CH_3CH_2CH_2OH$ Allow propanol if correct structure shown somewhere Allow acidified potassium dichromate((VI)) / $Cr_2O_7^{2-}$ **and** H^+ Allow acidified manganate((VII)) Ignore concentration of acid / formation of aldehyde Do not award hydrochloric acid / HCl Stand alone mark e.g. CH_3CH_2COOH Stand alone mark for C_3 compounds Allow (concentrated hydrochloric) acid / H^+ / H_3O^+ instead of sulfuric acid Ignore concentration of acid Ignore incorrect structure of ester e.g. with H or O missing	**(5)**

	OR ROUTE 2 **Conversion to acyl chloride** • (oxidise some of the propan-1-ol using) potassium dichromate((VI)) **and** (dilute) sulfuric acid **and** add phosphorus(V) chloride to propanoic acid **(1)** • name or structure of propanoyl chloride **(1)** **Formation of ester** • react propan-1-ol and propanoyl chloride together **(1)**	Allow acidified potassium dichromate((VI)) / $Cr_2O_7^{2-}$ **and** H^+ Allow acidified manganate((VII)) Ignore concentration of acid / formation of aldehyde Do not award hydrochloric acid / HCl Stand alone mark e.g. CH_3CH_2COCl Stand alone mark for C_3 compounds Ignore incorrect structure of ester e.g. with H or O missing	

Question Number	Acceptable Answers	Additional Guidance	Mark
3(b)	**Identifications** • structure of alcohol **B** **(1)** • structure of ester **A** **(1)** **Justification** • butan-2-ol / $CH_3CH_2CHOHCH_3$ is the **only** alcohol (with formula $C_4H_{10}O$) that (undergoes elimination and) produces (but-1-ene and) but-2-ene **(1)**	Allow any combination of structural, displayed or skeletal formulae / correct species in unbalanced equations Allow structures not labelled **A** and **B** Penalise missing H once only <u>Examples of identification</u> **(B)**  Ignore connectivity of the OH group unless horizontal **(A)**  Ignore incorrect name for **A** TE on incorrect alcohol Allow butan-2-ol can form a double bond either side of the C with OH / between the 1st and 2nd carbon atoms and the 2nd and 3rd carbon atoms – this can be shown on diagram / equation Allow OH must be on the 2nd carbon atom / secondary alcohol to form but-1-ene and but-2-ene Allow butan-1-ol gives but-1-ene **and** 2-methylpropan-1-ol / 2-methylpropan-2-ol gives (2-)methylpropene Allow the other alcohols (with formula $C_4H_{10}O$) do not give but-2-ene	**(3)**

(Total for Question 3 = 8 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
4(a)(i)	**Test 1** • (gas is) ammonia / NH_3 **(1)** • (cation is) ammonium / NH_4^+ **(1)** **Test 2** • (cation is) cobalt(II) / Co^{2+} / $[Co(H_2O)_6]^{2+}$ **(1)** • (complex ion is) $[CoCl_4]^{2-}$ **(1)** **Test 3** • (precipitate is) barium sulfate / $BaSO_4$ **(1)** • (anion is) sulfate((VI)) / SO_4^{2-} **(1)**	If name and formula are given, both must be correct Mark independently Do not award gas is ammonium / NH_4 Do not award cation is ammonia / NH_3^+ Oxidation number of cobalt is needed in the name but allow cobalt **with** Co^{2+} Charge is needed on the ion Allow +2 and −2 for the charges on the ions Allow brackets around Cl Ignore missing square brackets in complex ions Do not award $[CoCl_6]^{4-}$ **Note** If cation in Test 2 is identified as copper(II) / Cu^{2+}, do not award M3 but M4 can be awarded as TE for $[CuCl_4]^{2-}$ Oxidation number of sulfate is not needed but if given must be correct e.g. do not award sulfate(IV)	**(6)**

Question Number	Acceptable Answers	Additional Guidance	Mark
4(a)(ii)	• correct formula	Examples of correct formula $(NH_4)_2Co(SO_4)_2$ $(NH_4)_2SO_4.CoSO_4$ Allow NH_4, Co and SO_4 in any order Allow multiples Allow any combination of Co^{2+} / NH_4^+ / SO_4^{2-} that gives a neutral complex TE on the **three** ions identified in (a)(i) Ignore missing dot in second formula Ignore any amount of water of crystallisation	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
4(b)	• correct equation	Example of equation $NH_4^+ + OH^- \rightarrow NH_3 + H_2O$ Allow multiples Allow Na^+ on both sides if crossed through Ignore state symbols even if incorrect	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
4(c)	• ligand exchange	Allow ligand substitution / ligand replacement Ignore change in co-ordination number Do not award ligand change Do not award any other type of reaction in addition to correct answer e.g. reduction / acid-base / deprotonation	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
4(d)	An answer that makes reference to the following point: • to react with / remove any carbonate / sulfite / sulfate(IV) (ions)	Allow equation for the reaction with acid e.g. $2H^+ + CO_3^{2-} \rightarrow H_2O + CO_2$ Allow to prevent any other ions forming a precipitate (with barium ions / Ba^{2+}) Allow to rule out the possibility of carbonate / sulfite / sulfate(IV) ions giving a false result Ignore just 'to remove impurities / other (an)ions' / 'react with precipitates' Ignore to dissolve barium carbonate / sulfite Ignore reference to hydrogencarbonate	(1)

(Total for Question 4 = 10 marks)

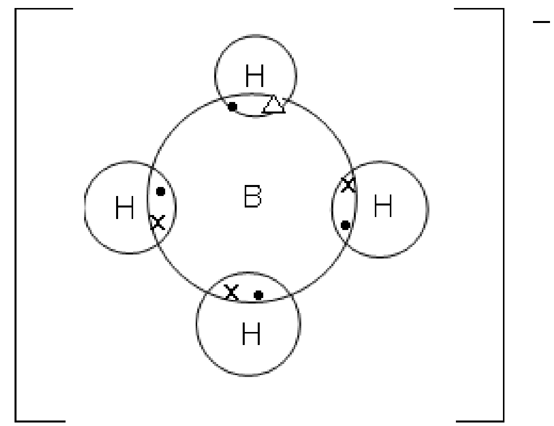
Question Number	Acceptable Answers	Additional Guidance	Mark
5(a)	• phosphate(III) (ion)	Name **and** oxidation number are required Allow gap between name and oxidation number Allow phosphate and +3 Ignore missing brackets around oxidation number Do not award phosphorus / trioxide / phosphite(III)	**(1)**

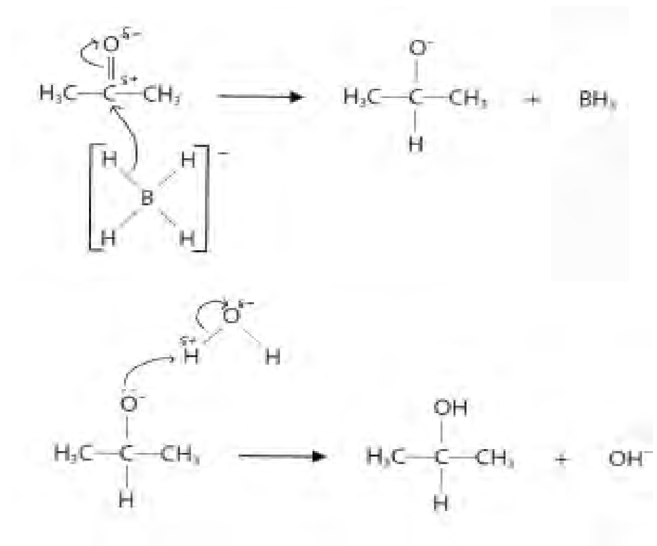
Question Number	Acceptable Answers	Additional Guidance	Mark
5(b)	• (a reducing agent) increases in oxidation number **and** loses electron(s)	Allow oxidation number becomes more positive / gets larger Allow donates / gives electrons / number of electrons decreases Ignore a reducing agent decreases the oxidation number of another substance	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
5(c)	• Na / sodium	Do not award Na^+	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
5(d)(i)	• MnO_2, MnO_4^-, OH^- and MnO_4^{2-} species correct in a single equation **(1)** • H_2O on right **and** balancing **(1)**	Example of equation $MnO_2 + 2MnO_4^- + 4OH^- \rightarrow 3MnO_4^{2-} + 2H_2O$ Ignore state symbols, even if incorrect Do not award M1 if H^+ is on the left Allow cancelled electrons Allow multiples	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
5(d)(ii)	An answer that makes reference to: • 2 different species are oxidised and reduced (to form the same species) **or** there is not 1 species that is being oxidised and reduced **or** 2 different oxidation states are not produced from one oxidation state **or** only 1 oxidation state / +6 is formed as a product **or** Mn changes from +4 and +7 to +6 (only)	This mark can be awarded even if (i) is incorrect Allow manganate(VI) / MnO_4^{2-} is oxidised and reduced in the reverse reaction Allow Mn in the same species is not being oxidised and reduced Ignore just 'Mn is not simultaneously oxidised and reduced' Ignore this is reverse disproportionation / comproportionation Do not award O / H is oxidised / reduced Do not award molecules / compounds for species	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
5(e)(i)	• dot-and-cross diagram	Example of diagram  Electrons must have the correct symbols i.e. 3 bonds with • and x and 1 bond with • and Δ Circles do not need to be shown Allow missing brackets but charge needs to be shown Allow charge anywhere on or close to diagram Ignore lines representing covalent bonds e.g. x • Ignore missing atom labels / inner shell of 2 electrons on B	(1)

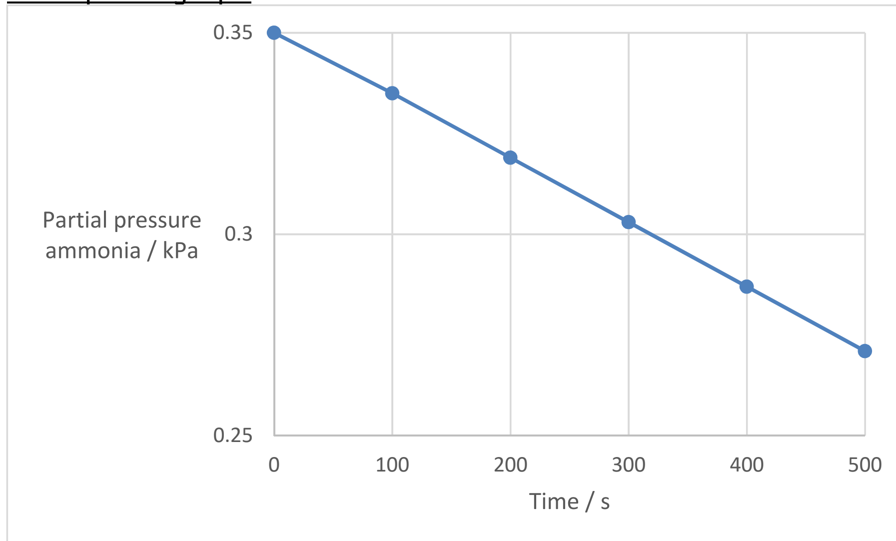
Question Number	Acceptable Answers	Additional Guidance	Mark
5(e)(ii)	• curly arrow from B-H bond to C of C=O Allow curly arrow from B-H bond to H **and** curly arrow from H to C **(1)** • dipole on C=O **and** curly arrow from C=O bond to or just beyond O **(1)** • lone pair on O^- **and** curly arrow from lone pair to H of H_2O **(1)** • curly arrow from O-H bond to O **and** dipole on H-O bond **(1)**	<u>Example of mechanism</u>  Allow curly arrow from any B-H bond Ignore lone pair on O in H_2O Penalise half-headed curly arrow once only	**(4)**

(Total for Question 5 = 11 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
6(a)(i)	• six / 6		**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
6(a)(ii)	• 1+ / +1	Allow + / one positive charge Ignore positive / plus	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
6(b)	Oxidation state: • Two ions of the **same metal** (iron or copper) with different oxidation states and the same ligands with appropriate colours **(1)** Ligands: • formula and colour of complex with first ligand **(1)** • formula and colour of complex with second ligand **(1)**	Ignore ions of metals other than iron or copper Ignore use of precipitates instead of complex ions Ignore names of complex ions, even if incorrect Penalise additional incorrect species / colours once only <u>Examples of ions</u> $[Fe(H_2O)_6]^{2+}$ is green **and** $[Fe(H_2O)_6]^{3+}$ is yellow / orange / red/ brown $[CuCl_4]^{2-}$ is yellow **and** $[CuCl_2]^{-}$ is colourless $[Cu(H_2O)_6]^{2+}$ is (pale) blue **and** $[CuCl_4]^{2-}$ is yellow $[Cu(H_2O)_6]^{2+}$ is (pale) blue **and** $[Cu(NH_3)_4]^{2+}$ / $[Cu(NH_3)_4(H_2O)_2]^{2+}$ / $[Cu(H_2O)_2(NH_3)_4]^{2+}$ is a **darker** blue than in the aqua ion $[CuCl_4]^{2-}$ is yellow and $[Cu(NH_3)_4]^{2+}$ / $[Cu(NH_3)_4(H_2O)_2]^{2+}$ / $[Cu(H_2O)_2(NH_3)_4]^{2+}$ is (deep / dark) blue Allow any correct example of the **same metal** in the same oxidation state with different ligands and their corresponding colours, including colourless – the metal can be different to that in M1 **Note** Formulae **and** colours must be correct but ignore missing square brackets e.g. Do not award mention of green for $[CuCl_4]^{2-}$ Do not award $[Cu(NH_3)_6]^{2+}$ Ignore qualifications of colour e.g. pale / dirty	**(3)**

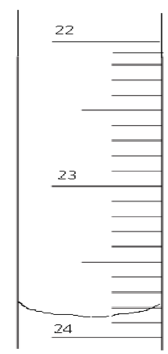
Question Number	Acceptable Answers	Additional Guidance	Mark
6(c)(i)	• axes with time on x axis **and** labelled, including units **and** suitable scale **(1)** • **all** points plotted correctly **and** best fit line **(1)**	<u>Example of graph</u>  Allow y axis labelled with partial pressure / pressure and unit Do not allow partial pressure axis starting at 0 Both axes must cover at least half the graph paper Allow ± ½ square M2 can be awarded if axes the wrong way around in M1	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
6(c)(ii)	• rate = k / rate = k x $p(NH_3)^0$ **(1)** • (zero / 0 order) because the rate is independent of the partial pressure of ammonia / rate is constant **or** because the graph is a straight line / linear **(1)**	Allow r for rate Allow −rate = k / rate = $k[NH_3]^0$ Ignore $[H_2]^0$ or $[N_2]^0$ Conditional on M1 Allow because the gradient is constant	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
6(c)(iii)	• calculation of gradient of graph / rate / rate constant **(1)** • corresponding units for rate constant **(1)**	<u>Example of calculation</u> $\frac{(0.271 - 0.350}{500} = (-)\frac{0.079)}{500}$ k= 1.58 x 10^{-4} / 0.000158 Allow any value in the range 1.50 to 1.65 x 10^{-4} 1.58 x 10^{-4} / 0.000158 kPa s^{-1} Allow 158 x 10^{-6} kPa s^{-1} / 0.158 Pa s^{-1} / 1.58 x 10^{-1} Pa s^{-1} Do not award units of mol dm^{-3} s^{-1} Ignore SF except 1 SF Ignore negative value for k Correct answer with corresponding units and no working scores (2)	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
6(c)(iv)	A description that makes reference to the following points: • adsorption of ammonia / reactant onto surface of tungsten / catalyst **(1)** • breaking bonds in ammonia / reactant **or** breaking N-H bonds **(1)** • desorption of nitrogen and hydrogen / products / gases from surface of tungsten / catalyst **(1)**	Ignore reference to heterogeneous / homogeneous / active sites Allow gas for ammonia Allow adsorb / adsorp for adsorption Ignore "stick" Do not award absorption Allow bonds weaken instead of break Ignore mention of atoms / radicals Allow products released / detached from catalyst surface Allow de-adsorbed / desorped for desorption Do not award desorption of ammonia	**(3)**

(Total for Question 6 = 14 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
7(a)(i)	• bottom of meniscus between 23.8 and 23.9 (cm^3) **(1)** • meniscus curved downwards **(1)**	<u>Example of diagram</u>  Ignore shading below the meniscus Do not award M2 if there is shading above the meniscus	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
7(a)(ii)	An explanation that makes reference to the following points: • 23.15 (cm^3) should be used as it is the mean of the concordant titres / titres 2 and 4 /23.10 and 23.20 (cm^3) **(1)** • 23.43 (cm^3) should not be used as it includes the inaccurate / non-concordant / rough values / titres 1 and 3 / 23.85 and 23.55 (cm^3) **(1)**	Allow other descriptions of concordant e.g. titres within 0.1 / 0.2 cm^3 Allow (23.1(0) + 23.2(0))/2 = 23.15 (cm^3) Allow only the concordant titres / titres 2 and 4 / 23.20 and 23.20 (cm^3) should be used / are used(in the mean) Allow the inaccurate / non-concordant / rough values / titres 1 and 3 / 23.85 and 23.55 (cm^3) should not be used / are used (in the mean)	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
7(a)(iii)	• calculation of percentage uncertainty	Example of calculation $\frac{2 \times 0.05}{23.20} \times 100$ = (±)0.431 / 0.43 / 0.4 (%) Ignore SF including 1 SF Correct answer with no working scores (1)	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
7(a)(iv)	• calculation of moles of MnO_4^- **(1)** • calculation of moles $C_2O_4^{2-}$ in 25.0 cm^3 **(1)** • calculation of moles $C_2O_4^{2-}$ in 1.00 dm^3 **(1)** • calculation of **y** to nearest whole number **(1)**	<u>Example of calculation</u> moles MnO_4^- = 23.15 x 0.0203/1000 = 0.00046995 / 4.6995 x 10^{-4} (mol) moles $C_2O_4^{2-}$ in 25.0 cm^3 = 4.6995 x 10^{-4} x 5/2 = 0.0011749 / 1.1749 x 10^{-3} (mol) TE on moles MnO_4^- moles $C_2O_4^{2-}$ in 1.00 dm^3 = 1.1749 x 10^{-3} x $\frac{1000}{25.0}$ = 0.046995 / 4.6995 x 10^{-2} (mol) TE on moles $C_2O_4^{2-}$ in 25.0 cm^3 Ratio moles salt : moles $C_2O_4^{2-}$ = 0.0235 : 0.046995 = 1 : 1.9998 **y** = 2 TE on moles $C_2O_4^{2-}$ in 1.00 dm^3 Alternative method for M3 and M4 moles salt in 25.0 cm^3 = 0.0235 x 25.0/1000 = 5.875 x 10^{-4} (1) Ratio moles salt : moles $C_2O_4^{2-}$ = 5.875 x 10^{-4} : 1.1749 x 10^{-3} = 1 : 1.9998 **y** = 2 TE on moles salt and $C_2O_4^{2-}$ in 25.0 cm^3 (1) Ignore SF in working except 1 SF Correct answer with no working scores (1) Allow M4 for correct answer using charges on ions	**(4)**

Question Number	Acceptable Answers	Additional Guidance	Mark
7(b)(i)	• calculation of mol of anhydrous salt **(1)** • calculation of mol H_2O **(1)** • calculation of ***z*** to nearest whole number **(1)**	<u>Example of calculation</u> mol anhydrous salt = 2.96/218.1 = 0.013572 / 1.3572×10^{-2} (mol) TE on M_r of anhydrous salt from value of **y** in (a)(iv) or an assumed value of ***y*** Allow 0.013578 from M_r 218 mol H_2O (= 0.45/18) = 0.025 / 2.5×10^{-2} (mol) Ratio mol salt : mol H_2O = 0.013572 : 0.025 = 1 : 1.842 **z** = 2 TE on moles anhydrous salt and moles H_2O Ignore SF in working except 1 SF Correct answer with some working scores (3) Penalise **y** and **z** not given to nearest whole number once only in (a)(iv) and (b)(i) Allow alternative correct methods	**(3)**

Question Number	Acceptable Answers	Additional Guidance	Mark
7(b)(ii)	An answer which includes the following points: Crystals jumped out of crucible • value of ***z*** increases **and** because it appears that more mass / mol / water is lost (than expected) **(1)** • (this can be prevented by) placing a lid on the crucible **or** heat more gently / carefully **(1)** Not all water of crystallisation lost • less mass / mol /water is lost (than expected) **(1)** • (this can be prevented by) heating to constant mass **or** description of heating to constant mass **(1)** • so this accounts for the lower value of ***z*** / value of ***z*** decreases **(1)**	Ignore just 'loss in mass / mol' Stand alone mark Allow just 'cover the crucible' Ignore use an electrical heater / larger crucible / evaporating basin / conical flask / test tube etc Do not award add anti-bumping granules Stand alone mark Ignore just 'heat for longer' Do not award the idea of repeating the experiment / using a drying agent Conditional on M3	**(5)**

(Total for Question 7 = 17 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
8(a)(i)	An answer that makes reference to the following points: • cool the mixture because the reaction (with concentrated sulfuric acid / H_2SO_4) is (very) exothermic / releases (a lot of) heat **(1)** • anti-bumping granules are added to prevent violent / sudden / localised boiling **or** to prevent superheating / large bubbles forming **or** to promote smooth / even / controlled boiling **or** to promote the formation of small bubbles **or** to provide nucleation centres / (rough) surface for bubble formation **(1)** • heating under reflux is used to prevent the loss of any volatile substances / volatile reactants / volatile products / organic compound / named organic compound **or** to make sure the vapour / gas condenses **or** to prevent vapour escaping **(1)**	Ignore reaction is violent / to prevent splashing / to slow down the reaction / to stop reactants evaporating Do not award to quench the reaction / reference to explosion Ignore to stop bumping / spitting / explosion / liquid splashing out / vigorous reaction / loss of reactants / to distribute heat more evenly / any reference to rate / to promote smooth heating Allow so that the reaction goes to completion Ignore just ‘to prevent gas escaping’ / just ‘to prevent loss of reactants / products’ / just ‘reactants / products are volatile’ / ‘because 1-bromobutane / butan-1-ol is flammable’ / to increase yield / reference to safety Do not award for reference to oxidation or reduction	**(3)**

Question Number	Acceptable Answers	Additional Guidance	Mark
8(a)(ii)	An answer that makes reference to the following points: • there is a gap between the condenser and the flask / seal the joint between the flask and condenser **and** so vapour / gas / reactants / products will escape **(1)** • the water is flowing the wrong way through the condenser / the water should go in at the bottom (and out at the top) **and** so it doesn't fill with water / is only part filled /there is an airlock **(1)** • there is a stopper on the condenser / there should not be a stopper on the condenser **and** so there will be a build-up of pressure (if the gap between condenser and flask is closed) **(1)**	Allow answers shown on annotated diagram e.g. gap circled Ignore any additional errors Ignore additional suggested modifications even if incorrect Do not award just 'the apparatus is not sealed' unless it is clear it means between the condenser and flask Allow so this will lower the yield of product / 1-bromobutane Ignore condenser is fitted the wrong way up Allow so there will be inefficient condensation / cooling Allow so the stopper will blow off / there will be an explosion / it will be dangerous	**(3)**

Question Number	Acceptable Answers	Additional Guidance	Mark
8(a)(iii)	An explanation that makes reference to the following points: • (brown vapour / it) is bromine / Br_2 **(1)** • bromide ions / Br^- / HBr oxidised (by concentrated sulfuric acid) **(1)**	Stand alone mark Do not award just 'Br' Do not award any other brown gas in addition to bromine Allow bromide ions / Br^- / HBr reduce sulfuric acid / act as a reducing agent Ignore sodium bromide / NaBr is oxidised Ignore just 'redox reaction' Do not award bromine is oxidised Do not award oxidation by anything other than sulfuric acid	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
8(b)(i)	An answer that makes reference to the following: • aqueous layer is on the top **and** because water / it has a lower density than 1-bromobutane	Allow 'it' for aqueous layer Allow because 1-bromobutane has a higher density than water Ignore reference to butanol unless in a third layer Do not award water is 'lighter' Do not award reference to three layers	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
8(b)(ii)	An answer that makes reference to the following points: Step **8** • (aqueous sodium hydrogencarbonate / $NaHCO_3$) reacts with / neutralises / removes the (hydrochloric) acid / H^+ (ions) in the mixture **(1)** Step **9** • (the tap is opened) to release the carbon dioxide / gas (formed) **or** to allow the carbon dioxide / gas to escape **or** to prevent the build-up of pressure **(1)** Step **10** • (anhydrous sodium sulfate is added) to remove / absorb water **(1)**	Do not award reacts with incorrect acid e.g. H_2SO_4 / HBr / ethanoic acid Ignore removes water Do not award an incorrect gas e.g. hydrogen Allow (anhydrous) sodium sulfate is a drying agent / added to dry the product Do not award dehydration / reacts with water	**(3)**

Question Number	Acceptable Answers	Additional Guidance	Mark
8(b)(iii)	• starting temperature 99 or 100 or 101 (°C) **and** final temperature 103 or 104 or 105 (°C)	Do not award just one value / 102 (°C) Do not award 102 (°C) with another temperature	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
8(b)(iv)	• calculation of mol of 1-bromobutane **(1)** • calculation of number of molecules **and** answer to 2/3 SF **(1)**	Example of calculation mol of 1-bromobutane = $\frac{12.0 \times 1.27}{136.9}$ = 0.11132 (mol) Do not award 0.1 number of molecules = $0.11132 \times 6.02 \times 10^{23}$ = 6.7×10^{22} / 6.70×10^{22} TE on a calculated mol 1-bromobutane using M_r Correct answer to 2 or 3 SF with no working scores (2)	**(2)**

(Total for Question 8 = 15 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
9(a)(i)	An explanation that makes reference to the following points: • glycinate ions / they do not contain a carbon atom with four different atoms / groups attached **or** the glycinate ion is superimposable on its mirror image **(1)** • so there will be no effect (on plane-polarised monochromatic light) **(1)**	An answer that states there will be an effect scores (0) Allow not chiral / achiral / has no enantiomers / has no asymmetric carbon atom Allow the carbon atom attached to NH_2 is only attached to 3 different atoms / groups / is not attached to 4 different atoms / groups Ignore glycinate ions are not optically active / do not exhibit optical isomerism Do not award it is a racemic mixture / there are equal amounts of the two isomers / four different molecules attached M2 is conditional on M1 Do not award the (monochromatic) light will not be polarised	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
9(a)(ii)	• correct formula of one of the copper species **(1)** • rest of equation correct **(1)**	<u>Example of equation</u> $(CH_3COO)_2Cu$ + 2 NH_2CH_2COOH → $(NH_2CH_2COO)_2Cu$ + 2CH_3COOH Allow $Cu(CH_3COO)_2$ / $Cu(NH_2CH_2COO)_2$ Allow both charges shown e.g. $(CH_3COO^-)_2Cu^{2+}$ Allow displayed / skeletal formulae for organic substances but not molecular formulae Ignore state symbols, even if incorrect Do not award M1 if covalent bond between Cu and O in any species but M2 can still score	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
9(a)(iii)	An answer that makes reference to any **four** of the following points: Student **1** / higher yield • the crystals were not dry / still damp when they were weighed **(1)** • there are impurities in the crystals **(1)** Student **2** / lower yield • reaction was incomplete **(1)** • not all of the copper(II) glycinate had crystallised / some is left in solution **(1)** • description of a specific handling loss **(1)**	Ignore reference to weighing errors for both students Allow the student did not subtract the mass of filter paper / product container Do not award the crystals contain water of crystallisation / are (partially) hydrated Allow a specific impurity e.g. glycine Allow the reaction reached equilibrium / side reactions occur / by-products form Ignore just 'the solution has not cooled enough' Allow any specific example e.g. some crystals left on the walls of the container / beaker / flask / lost during filtration / lost during transfer Ignore just 'transfer error' / lost when handling	**(4)**

Question Number	Acceptable Answers	Additional Guidance	Mark
9(b)	An explanation that makes reference to any **TWO** of the following points: • carbon monoxide replaces / takes the place of the oxygen molecule **(1)** • (and may be toxic because) it binds strongly to the Fe^{2+} (ion) **(1)** • effect on the body **(1)**	Allow carbon monoxide displaces the oxygen molecule Allow ligand substitution / exchange reaction between oxygen and carbon monoxide Allow carbon monoxide forms a stronger bond / binds more tightly to / has a stronger affinity for Fe^{2+} Allow reduces the amount of oxygen that can bind to Fe^{2+} Allow carbon monoxide binds (almost) irreversibly / permanently to Fe^{2+} Allow CO forms a more stable complex ion with Fe^{2+} / has a larger equilibrium constant / K Ignore CO bonds more easily to Fe^{2+} Ignore just 'CO bonds more strongly to haemoglobin' Allow prevents oxygen being carried to the cells / organs / around the body / blood Allow reduces the amount of oxygen that can be carried to the cells / organs / around the body / blood	**(2)**

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

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		
	• **IP1 - Reagents and conditions** magnesium **and** dry ether / dry ethoxyethane / dry $(CH_3CH_2)_2O$	This may be shown as part of any specific reaction. Ignore errors in an equation to make the Grignard.	
	• **IP2 - Hydrolysis of product** add dilute (hydrochloric) acid / $H^+(aq)$ /HCl(aq) (to hydrolyse the intermediate / protonate …O−)	This only needs to be mentioned once Do not award this point if acid is clearly added at the same time as magnesium / dry ether / a reactant	
	• **IP3 – Primary alcohol** react with methanal to form butan-1-ol / $CH_3CH_2CH_2CH_2OH$		
	• **IP4 – Secondary alcohol** react with ethanal to form pentan-2-ol / $CH_3CH_2CH_2CH(OH)CH_3$	Allow other specific aldehydes with corresponding product	
	• **IP5 – Tertiary alcohol** react with propanone to form 2-methylpentan-2-ol / $CH_3CH_2CH_2C(CH_3)(OH)CH_3$	Allow other specific ketones with corresponding product	
	• **IP6 – Carboxylic acid** react with carbon dioxide to form butanoic acid / $CH_3CH_2CH_2COOH$		

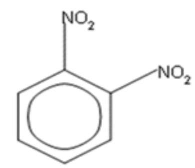
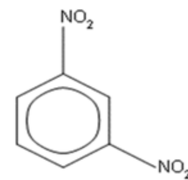
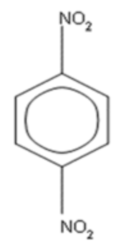
(Total for Question 9 = 16 mark)

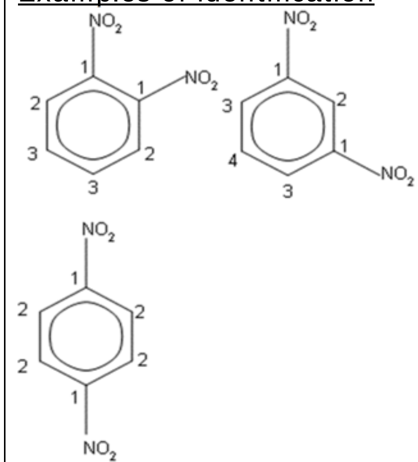
Question Number	Acceptable Answers	Additional Guidance	Mark
10(a)(i)	An explanation that makes reference to the following points: • (the increase in mass of) **X** will increase **and** (the increase in mass of) **Y** will stay the same **(1)** • because **X** will also absorb the water / moisture in the oxygen **(1)** • (**Y** stays the same) because the water / moisture has already been absorbed by **X** **(1)**	Allow greater change in mass for **X** if it is clear that it is an increase Allow **X** reacts with the water in oxygen Do not award **X** absorbs oxygen Allow because **Y** only absorbs carbon dioxide / CO_2 Allow because **Y** does not absorb water Allow because the amount of carbon dioxide / CO_2 does not change	**(3)**

Question Number	Acceptable Answers	Additional Guidance	Mark
10(a)(ii)	• calculation of mol C/ CO_2 **(1)**	<u>Example of calculation</u> mol CO_2 = 5.28/44 = 0.12 = mol C **or** mass C = 5.28 x 12/44 = 1.44 (g) mol C = 1.44/12 = 0.12	**(5)**
	• calculation of mol H **(1)**	mol H_2O = 0.72/18 = 0.04 mol H = 2 x mol H_2O = 0.08 **or** mass H = 0.72 x 2/18 = 0.08 mol H = 0.08 x 1 = 0.08	
	• calculation of mol N **(1)**	mol N_2 = 0.56/28 = 0.02 mol N = 2 x mol N_2 = 0.04 **or** mass N = 0.56 mol N = 0.56/14 = 0.04	
	• calculation of mol O **(1)**	mass O = 3.36 – (12 x 0.12 + 1 x 0.08 + 14 x 0.04) = 1.28 (g) mol O = 1.28/16 = 0.08 TE on masses of C, H and N	
	• empirical formula **(1)**	(0.12 C : 0.08 H : 0.04 N : 0.08 O) $C_3H_2NO_2$ Allow symbols in any order TE on incorrect moles but the ratio must be a whole number and include C, H, N and O if no O, only M1, M2 and M3 can be awarded Ignore use of O_2 / O / N_2 / N in the 'words' Correct empirical formula with some working at each stage scores (5) but correct empirical formula with no working scores M5 only	

Question Number	Acceptable Answers	Additional Guidance	Mark
10(b)	• molecular ion is at *m*/z = 168 **or** 168 is equal to the M_r of **D** / twice the empirical formula / 2 x 84 / 168÷2 = 84 / M_r of empirical formula is 84 **(1)** • (so the molecular formula is) $C_6H_4N_2O_4$ **(1)**	Allow 168 shown on spectrum along with the rest of the explanation Do not award M1 for any other value Stand alone mark Ignore structural / displayed / skeletal formula Do not award $C_6H_4N_2O_4^+$	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
10(c)(i)	• $C_6H_4^+$	Allow $H_4C_6^+$ Do not award just C_6H_4	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
10(c)(ii)	• 3 correct formulae **(2)**	Examples of formulae    Allow (1) for any 2 correct formulae Allow (2) for three disubstituted benzenes with incorrect substituents / (1) for any two disubstituted benzenes with incorrect substituents Allow incorrectly displayed formulae of NO_2 groups **In (c)(ii) and (iii):** Allow Kekule structures Allow hydrogen atoms shown on benzene Ignore connectivity of NO_2 groups Penalise missing circle in benzene once only	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
10(c)(iii)	• **D** identified as 1,3-dinitrobenzene **and** 4 different carbon environments labelled **(1)** • 3 different carbon environments labelled on 1,2-dinitrobenzene **(1)** • 2 different carbon environments labelled on 1,4-dinitrobenzene **(1)**	<u>Examples of identification</u>  These labels may be shown on the structures in (c)(ii) The identification of **D** can be assumed if it is the only structure with 4 carbon environments labelled Allow any form of identification of the carbon environments e.g. numbers, letters, equivalent carbon environments circled TE on disubstituted benzene substituents in (ii) Penalise only half the carbon environments labelled once only	**(3)**

(Total for Question 10 = 16 marks)