Mark Scheme (Results)

Summer 2017

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

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Summer 2017
Publications Code 9CH0_03_1706_MS

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)(i)	• All species and balancing correct **(1)** • All state symbols correct **(1)**	<u>Examples of equation</u> $Cr(OH)_3(s) + 3H_2O(l) + 3H^+(aq) \rightarrow [Cr(H_2O)_6]^{3+}(aq)$ **Or** $Cr(OH)_3(s) + 3H_3O^+(aq) \rightarrow [Cr(H_2O)_6]^{3+}(aq)$ **Or** $[Cr(OH)_3(H_2O)_3](s) + 3H^+(aq)$ on LHS as an alternative Allow correct equations for sequential protonation e.g. $[Cr(OH)_3(H_2O)_3](s) + H^+(aq) \rightarrow [Cr(H_2O)_4(OH)_2]^+(aq)$ M2 consequential on M1 being awarded, or a 'near-miss' e.g. Cl^- on both sides / one missing charge	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
1(a)(ii)	A description that makes reference to the following points: • green solid / grey-green solid **(1)** • forms green solution **(1)**	Allow ppt/precipitate for solid Allow purple /violet /ruby solution Do not award yellow-green / red / blue-green bubbles etc means MP2 should not be awarded Ignore adjectives to describe green e.g. pale	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
1(a)(iii)	• all species and balancing correct **(1)** • all state symbols correct **(1)**	<u>Examples of equation</u> $Cr(OH)_3(s) + 3OH^-(aq) \rightarrow [Cr(OH)_6]^{3-}(aq)$ **Or** $[Cr(OH)_3(H_2O)_3](s) + 3OH^-(aq) \rightarrow [Cr(OH)_6]^{3-}(aq) + 3H_2O(l)$ Allow $Cr(OH)_3(s) + OH^-(aq) \rightarrow [Cr(OH)_4]^-(aq)$ **Or** $[Cr(OH)_5(H_2O)]^{2-}(aq)$ as complex ion on RHS, with rest of equation correctly balanced M2 consequential on M1 being awarded, or a 'near-miss'	**(2)**

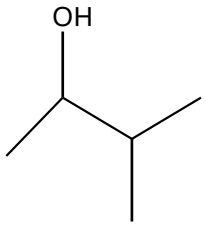
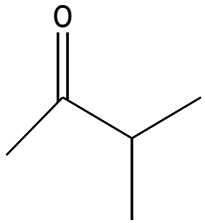
Question Number	Acceptable Answers	Additional Guidance	Mark
1(a)(iv)	An answer that makes reference to the following point: • green **and** solution	Ignore 'Qualifiers' for any colour (e.g. 'dark', 'deep', etc)	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
1(b)(i)	A description that makes reference to the following points: • (blue solution initially forms pale) blue precipitate **(1)** • (which dissolves to) form dark/deep/royal blue solution **(1)**	Allow 'solid' / 'ppt' for 'precipitate' Do not award for 'blue crystals' Do not allow dark blue ppt	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
1(b)(ii)	$[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4H_2O$ • LHS of equation correct **(1)** • RHS of equation correct **(1)**	Ignore state symbols even if incorrect Ignore balanced sulfate ions Do not award just Cu^{2+} on LHS Allow $[Cu(OH)_2(H_2O)_4] + 4NH_3 \rightarrow$ $[Cu(NH_3)_4(H_2O)_2]^{2+} + 2H_2O + 2OH^-$ Do not award for $[Cu(NH_3)_4]^{2+}$ / $[Cu(NH_3)_6]^{2+}$ on RHS	**(2)**

(Total for Question 1 = 11 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
2(a)	An answer that makes reference to the following points: • (First change) Adjust so that the flow of water goes in at the bottom of the condenser and out at the top of the condenser **(1)** • (Reason) Keeps condenser full of water / water removes (any) air in the condenser / allows more efficient / better cooling / prevents 'air-lock' **(1)** • (Second change) (Replace funnel and) seal with a thermometer or a stopper **(1)** • (Reason) Prevents vapour / gas / product / reactants escaping **(1)**	First and second change can be in either order Ignore prior refluxing Ignore water bath Allow just "water should enter the condenser at the bottom" OR Just "water should leave at the top" OR Just "swap the tubes around" Allow replacing the funnel with a tap / dropping funnel Ignore thermometers used to measure boiling temperatures	**(4)**

Question Number	Acceptable Answers	Additional Guidance	Mark
2(b)	 **(1)**  **(1)**	Do not penalise 'connectivity' to OH unless O-H-C Allow O-H for OH Penalise non-skeletal formulae once only	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
2(c)(i)	• 3-methylbutan-2-ol / secondary alcohols cannot be oxidised to a carboxylic acid OR • 3-methylbutanone / the product / ketones cannot be (further) oxidised	Allow only primary alcohols can be oxidised to carboxylic acids	**(1)**

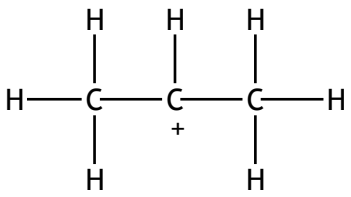
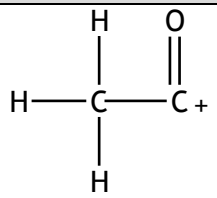
Question Number	Acceptable Answers	Additional Guidance	Mark
2(c)(ii)	• H_2SO_4	Ignore 'sulfuric acid'	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
2(c)(iii)	• all formulae correct **(1)** • all state symbols correct **(1)**	<u>Example of equation:</u> $Na_2CO_3(s) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + H_2O(l) + CO_2(g)$ OR $Na_2CO_3(s) + 2H^+(aq) \rightarrow 2Na^+(aq) + H_2O(l) + CO_2(g)$ OR $Na_2CO_3(s) + 2H_2SO_4(aq) \rightarrow 2NaHSO_4(aq) + H_2O(l) + CO_2(g)$ Use of $NaCO_3$ or H_2CO_3 scores zero Allow any acid. M2 consequential on M1 being awarded, or a 'near-miss'	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
2(d)(i)	An explanation that makes reference to the following points: • peak at 1720 (cm^{-1}) **(1)** • shows presence of a C=O bond / carbonyl **(1)**	Allow any absorbance between 1720 to 1700 (cm^{-1}) Marks cannot be awarded if ANY incorrect other peaks are identified e.g. peak due to C=C / peak due to O-H Ignore references to alkane C-H bonds / fingerprint region Do not award just 'ketone' for MP2	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
2(d)(ii)	An answer that makes reference to the following points: • peak between 3750 and 3200 (cm^{-1}) will disappear / will be absent from the spectrum OR Peak(s) above 3000(cm^{-1}) will disappear / will be absent from the spectrum **(1)** • (because) 3-methylbutan-2-ol / the alcohol / O-H has now been removed **(1)**	Allow any absorbance between 3750 to 3200 (cm^{-1}) Ignore references to fingerprint region	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
2(e)(i)	(identify the peak at the) highest/largest *m*/*z* value	Allow Peak (furthest) to the right/last peak on the spectrum Do not award the mark for "largest peak" / "highest peak" Ignore "parent ion" / molecular ion peak / References to *m*/*z* = 86	**(1)**

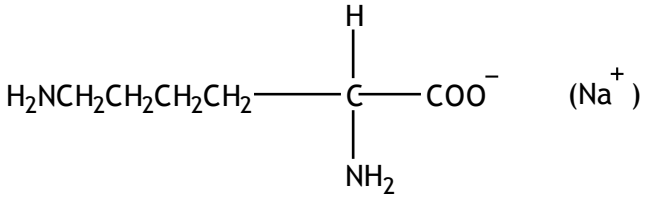
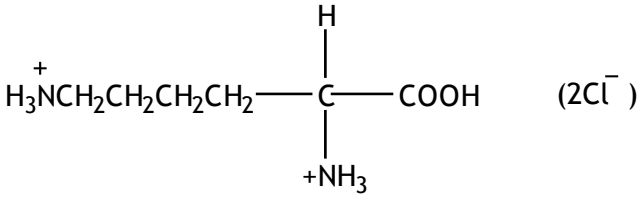
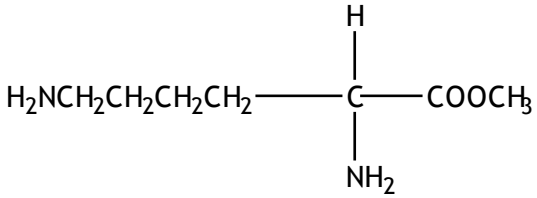
Question Number	Acceptable Answers	Additional Guidance	Mark
2(e)(ii)	 **(1)**  **(1)**	Allow positive charge anywhere on structure Ignore open bonds Penalise non-displayed formulae once only Ignore brackets around the structure Penalise missing charge once only	**(2)**

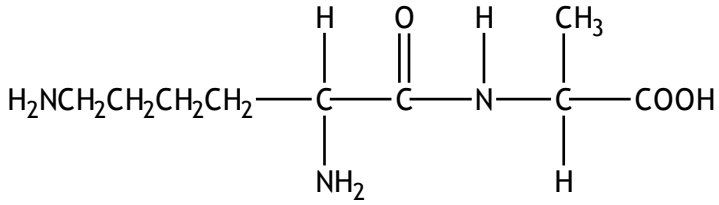
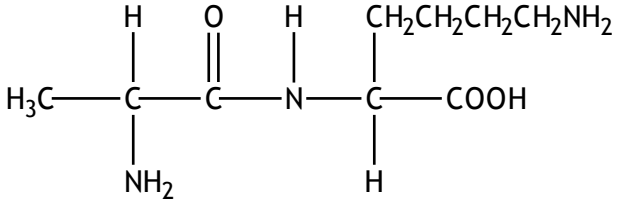
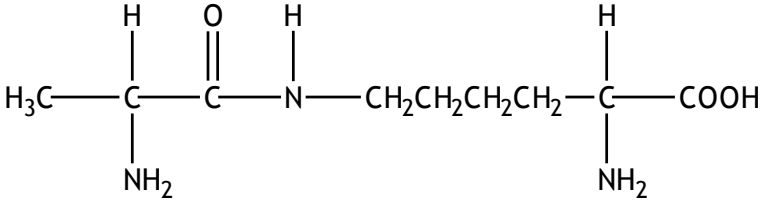
Question Number	Acceptable Answers	Additional Guidance	Mark
2(f)(i)	$C_5H_{12}O + [O] \rightarrow C_5H_{10}O + H_2O$ • left-hand side of equation correct **(1)** • right-hand side of equation correct **(1)**	**Molecular** formulae must be used throughout Allow [O] above the arrow Do not award for $C_5H_{11}OH$ as the alcohol Ignore state symbols if incorrect or conditions mentioned	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
2(f)(ii)	• calculation of moles of both of $C_5H_{10}O$ and $C_5H_{12}O$ **(1)** • calculation of mass of $C_5H_{12}O$ **(1)** OR • calculation of theoretical mass of $C_5H_{10}O$ **and** moles of $C_5H_{10}O$ **(1)** • calculation of mass of $C_5H_{12}O$ **(1)**	Example of calculation Moles $C_5H_{10}O = \frac{2.15}{86.0} = 0.025(0)$ (mol) **and** moles $C_5H_{12}O = \frac{0.025(0)}{62.5} \times 100 = 0.04(00)$ (So) mass of $C_5H_{12}O = 0.04(00) \times 88 = 3.52$ g Theoretical mass $C_5H_{10}O = \frac{2.15}{62.5} \times 100 = 3.44$ g **and** moles $C_5H_{10}O = \frac{3.44}{86.0} = 0.04(00) =$ mol $C_5H_{12}O$ (So) mass of $C_5H_{12}O = 0.04(00) \times 88 = 3.52$ g Correct answer with no working scores (2) Allow TE from MP1 Award 1 mark for 3.36 g, 1.375 g or 2.2 g	**(2)**

(Total for Question 2 = 21 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
3(a)	• 2,6-diaminohexanoic acid	Allow 2,6-diamin**e**hexanoic acid Ignore any additional commas or hyphens or spaces Do not award 2,6-dia**mm**inohexanoic acid	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
3(b)	• Deprotonated structure **(1)**  	Allow displayed /structural /condensed formulae Allow NH_2– Allow $–CO_2^-$ Allow –COONa but penalise if O–Na covalent bond is shown	**(3)**
	• Protonated structure **(1)**  	**Both** NH_2 groups must be protonated Allow NH_3^+– / ^+H_3N– Allow $–CO_2H$	
	• Ester structure **(1)**  	Allow CO_2CH_3 Allow NH_3^+– or NH_2– for each amine group Penalise wrong side chain only once If alanine used throughout then only MP3 can be awarded	

Question Number	Acceptable Answers	Additional Guidance	Mark
3(c)	Any one of:  OR  OR 	Must be the dipeptide and not the repeat unit Allow $-CO_2H$ Allow $-H_2N$ Allow –CONH– / -COHN- unless C-H-N Allow zwitterions or cyclic dipeptides Allow skeletal / part-skeletal formulae	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
3(d)	An explanation that makes reference to the following points: • (In acidic conditions) lysine (ion) has two positive charges (whereas alanine has only one) **(1)** • (So lysine ion has) has greater attraction for the stationary phase **(1)**	Ignore comments on retention time, solubility, polarity, dipoles or intermolecular forces Allow 'greater positive charge' Allow lysine has 2 NH_2 groups that can be protonated Allow 'greater affinity for stationary phase' 'adheres better to stationary phase' 'better a**d**sorption onto stationary phase' Allow 'polar phase' for 'stationary phase' Allow reverse argument for alanine Mark points M1 and M2 independently	**(2)**

(Total for Question 3 = 7 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
4(a)	• 1.60 **(1)** • (+) 42.5 **(1)**	Do not award MP1 for "1.6" (must be to 2 D.P.) Do not award MP2 for "42.50" (must be to 1 D.P.) Penalise D.P. error once only	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
4(b)	$CH_3OH(l) + 1.5O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$ • Balanced equation **(1)** • State symbols all correct **(1)**	Do not award multiples (enthalpy change is for the complete combustion of one mole) for MP1 MP2 depends on the award of MP1 or correct species	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
4(c)	• Calculation of energy change **(1)** • Calculation of moles of CH_3OH **(1)** • Calculation of energy ÷ moles CH_3OH **(1)** • ΔH final answer in kJ mol^{-1} **and** negative sign included **and** ΔH final answer to 2 or 3 S.F. **(1)**	Example of calculation (= $mc\Delta T$ = 150 x 4.18 x 42.5 =) 26647.5 (J) Moles CH_3OH = 1.60/32 (= 0.05(00)) $\frac{26647.5}{0.05(00)}$ = 532950 (J mol^{-1}) Ignore any signs at this stage **−**533 (kJ mol^{-1}) **Or** **−**530 (kJ mol^{-1}) Correct answer with no working gains full marks Penalise incorrect units for MP4 only Allow TE at each stage Allow correct rounding to 2SF or more at each stage	**(4)**

Question Number	Acceptable Answers	Additional Guidance	Mark
4(d)(i)	(±)0.7 (%)	Allow from 1 SF up to calculator value correctly rounded where (% uncertainty =) (±) $\frac{1}{150}$ x 100 = 0.66666…7 (%) . Allow 0.6 or $\frac{2}{3}$ Do not award 0.66/0.6	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
4(d)(ii)	An answer that makes reference to the following points: • Calculation of the % uncertainty using the 25 cm^3 measuring cylinder **(1)** **Then any two from:** • % uncertainty with use of 25 cm^3 measuring cylinder is greater **(1)** • Repeated use of the small measuring cylinder will lead to greater transfer losses **(1)** • Repeated use will take more time **(1)**	Needs to show combined error in using the 25 cm^3 six times is greater than using 250 cm^3 measuring cylinder once only Award MP1 EITHER if multiplies errors: 100 x (0.2 /25) x 6 = 4.8% OR If adds errors 100 x (1.2 /150) = 0.8% Do not award (0.2 / 25) x 100 = 0.8 % Do not award 'easier' to use larger measuring cylinder	**(3)**

Question Number	Acceptable Answers	Additional Guidance	Mark
4(d)(iii)	An answer that makes reference to any **three** of the following points: • heat/energy loss (to the surroundings) **(1)** • evaporation of methanol / water from the calorimeter **(1)** • incomplete combustion (of methanol) **(1)** • (specific) heat capacity of the calorimeter/apparatus has been ignored **(1)**	Ignore experiment carried out under non-standard conditions Ignore just 'no lid' Allow calorimeter has not been calibrated	**(3)**

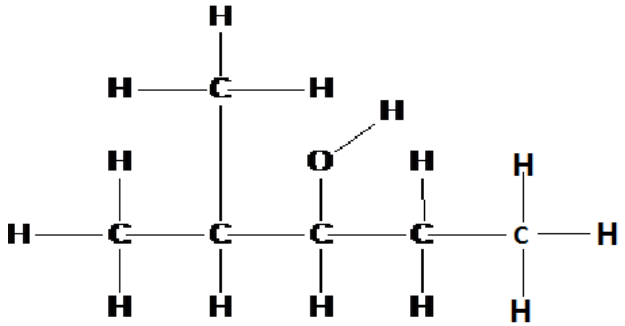
Question Number	Acceptable Answers	Additional Guidance	Mark
4(e)	An explanation that makes reference to the following points: • The second value will be less exothermic / less negative **(1)** • Some energy will be used to boil the water/boiling water is endothermic Water can only be heated to 100°C/ Temperature rise (measured) can only be (a maximum) of 40°C Greater heat losses in the 60°C to 100°C range **(1)**	Allow 'more positive' or 'smaller in magnitude' Do not accept 'greater' or 'smaller' for 'less negative' Do not award **just** "the water boils" Mark points M1 and M2 independently	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
4(f)	An explanation that makes reference to the following points: Either • student 2's value will be similar / the same **(1)** • (As) both the energy change **and** moles/mass (of methanol) burned will be higher/ Ratio of energy change to moles/mass (of methanol) burned will be the same/ The energy change is proportional to the moles/mass (of methanol) burned **(1)** Or • student 2's value will be less negative/ less exothermic **(1)** • greater heat loss because higher temperature/heated for longer **(1)**	Allow 'temperature change' for 'energy change' Allow 'more positive' or 'smaller in magnitude' or 'smaller' for 'less negative' Mark points MP1 and MP2 independently within each route	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
4(g)	An answer that makes reference to the following points: • (Calculated) value of moles (of methanol) burned will be less / too small **(1)** • The calculated value will be more exothermic / more negative **(1)**	Allow **both** marks for a calculation using M_r of 46.0 (instead of 32.0), giving a final ΔH value (approx.) of −766 (kJ mol^{-1}) Allow 'increase' or 'greater' for 'more negative' MP2 depends on MP1	**(2)**

(Total for Question 4 = 21 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
5(a)	C atom of C–Mg bond labelled as δ– **and** Mg labelled as δ+	Do not award full + or – charge Ignore δ- on Br	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
5(b)(i)		Ignore other structures Allow non-displayed formula	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
5(b)(ii)	• 2-methylpentan-3-ol	Allow 2-methyl-3-pentanol No TE on incorrect formula from 5(b)(i)	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
5(c)	• ✓ next to nucleophile **(1)** • ✓ next to reducing agent **(1)**	If more than two boxes ticked scores (0)	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
5(d)	• propane / C_3H_8	Accept name or formula or structural / skeletal / displayed formula Ignore additional inorganic products Do not award just 'alkane' If name and formula given then they both must be correct	**(1)**

(Total for Question 5 = 6 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
6(a)	• 23.15 **and** 23.55 **and** 23.20 completed in table **(1)** • ✓ beneath titres **1 and 3** **and** mean titre = 23.18 (cm^3) **(1)**	All three titres must be shown to 2 D.P. Allow 23.2 or 23.175 (cm^3)	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
6(b)	(From)(pale) pink/purple (to) colourless	**Both** colours needed for the mark Do not award mauve or magenta or violet for pink/purple Ignore references to 'clear'	**(1)**

Question Number	Acceptable Answers		Additional Guidance	Mark
6(c)			Example of calculation	**(5)**
	• calculation of moles of MnO_4^- in 25.0 cm^3	**(1)**	Moles MnO_4^- = $\frac{0.02(00) \times 25.0}{1000}$ = 5(.00) x 10^{-4} / 0.0005(00) (mol)	
	• calculation of moles of NO_2^- in mean titre	**(1)**	Moles NO_2^- in mean titre = 2.5 x moles MnO_4^- = 1.25 x 10^{-3} / 0.00125 (mol)	
	• calculation of moles of NO_2^- in 250 cm^3	**(1)**	Moles NO_2^- in 250 cm^3 = moles NO_2^- in mean titre x $\frac{250}{\text{mean titre from (a)}}$ = 1.25 x 10^{-3} x $\frac{250}{23.18}$ = 0.013481449 = 0.0135 (mol) Allow TE on mean titre from (a) Ignore SF except 1 SF	
	• calculation of molar mass	**(1)**	• Molar mass = 2 x $\frac{1.15}{0.0135}$ = 170.3703704 (g mol^{-1}) = 170.4 (g mol^{-1})	

	• calculation of ***x*** correctly to the nearest whole number: **(1)**	Allow TE • ***x*** = $\frac{170.4 - 116.3}{18(.0)}$ ***x*** = 3.005555556 ***x*** = 3 (**must** be to nearest whole number) Allow TE from molar mass calculated Allow alternative correct methods for MP4 and MP5 Correct value of ***x*** with no working scores (1)	

Question Number	Acceptable Answers	Additional Guidance	Mark
6(d)	$2MnO_4^- + 5NO_2^- + 6H^+ \rightarrow 2Mn^{2+} + 5NO_3^- + 3H_2O$ • evidence of multiplying 1st equation by 2 **and** 2nd equation by 5 **(1)** • overall equation correct with H^+ and H_2O and $e^{(-)}$ cancelled as appropriate **(1)**	Each of the following equations score **(1)** mark overall: $2MnO_4^- + 5NO_2^- + 16H^+ + 5H_2O \rightarrow 2Mn^{2+} + 5NO_3^- + 8H_2O + 10H^+$ OR $2MnO_4^- + 5NO_2^- + 6H^+ + 5H_2O \rightarrow 2Mn^{2+} + 5NO_3^- + 8H_2O$ OR $2MnO_4^- + 5NO_2^- + 16H^+ \rightarrow 2Mn^{2+} + 5NO_3^- + 10H^+ + 3H_2O$ Ignore state symbols, even if incorrect Allow multiples	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
6(e)	An explanation that makes reference to the following: **Either** • the (calculated) value of ***x*** would be too high **(1)** • The moles of $MgCO_3$ would be too low / the moles of $Mg(NO_2)_2 \cdot \boldsymbol{x}H_2O$ would be too low / the M_r of $Mg(NO_2)_2 \cdot \boldsymbol{x}H_2O$ would be too high **(1)** **Or** • (So) the (calculated) value of ***x*** would be unchanged (so this does not explain the discrepancy) **(1)** • Only a small amount/mass of $MgCO_3$ would dissolve because it is very slightly soluble **(1)**	Allow 'amount' or 'mass' for 'moles' MP2 depends on MP1 MP2 depends on MP1	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
6(f)	An answer that makes reference to the following points: • the $MgCO_3$ would decompose / the residue would contain $NaNO_2$ / the residue would contain (the excess) Na_2CO_3 **(1)** • (so) the (proposed) method is not valid / appropriate / suitable **(1)**	Ignore references to just 'impurities' M2 dependent on M1	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
6(g)	An answer that makes reference to the following point: • heat (the sample) to constant mass	 Allow repetition of heating and weighing until there is no change in mass (of the sample) Ignore references to 'brown gas' etc	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
6(h)	An answer that makes reference to the following points: • use a larger mass (of the hydrated salt) **(1)** • Use a balance that weighs to 3 D.P. (rather than 2 D.P.) **(1)**	 Ignore references to repeat measurements Allow statements such as 'use a balance that weighs to more decimal places' /'greater resolution' / ' a more precise/sensitive balance' Do not allow 'more accurate'	**(2)**

(Total for Question 6 = 17 marks)

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>*7(a)</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).

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

Reasoning marks may be subtracted for extra incorrect chemistry.</td>
<td>(6)</td>
</tr>
</table>

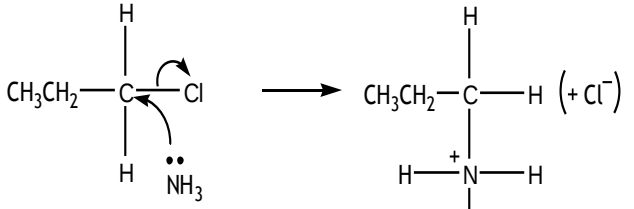
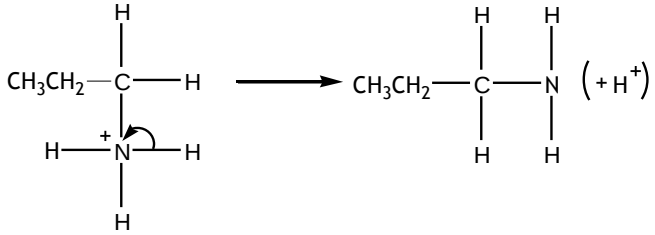
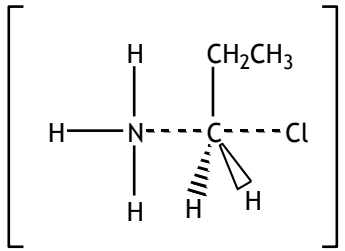
	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2
Answer is partially structured with some linkages and lines of reasoning.	1
Answer has no linkages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

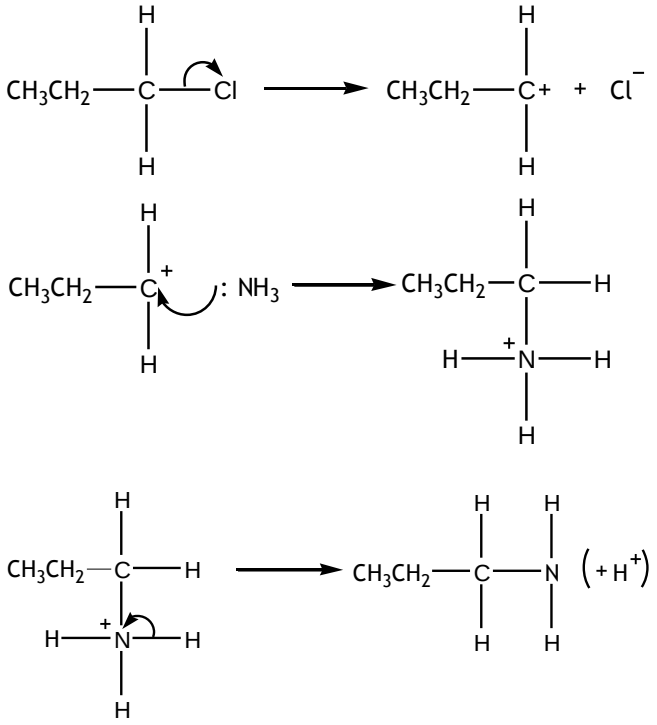
	Indicative content (IPs) **IP1:** • (transition metal) forms an **ion** with an incomplete *d* sub-shell **IP2:** • scandium **and** zinc are not transition metals **IP3:** • Sc^{3+} **and** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ **IP4:** • Zn^{2+} **and** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}$ **IP5:** • Sc^{3+} **and** *d* sub-shell empty / *d*-orbitals empty **IP6:** • Zn^{2+} **and** *d* sub-shell full / **ALL** *d*-orbitals are full	Allow 'partially-filled' for incomplete Allow *d*-orbital(s) Do not award "*d*-shell" Allow "*D*" for "*d*" throughout Allow if **only** Sc **and** Zn are used to illustrate *d*-block elements that are not transition metals Allow $4s^0$ and/or $3d^0$ Penalise use of [Ar] once only Allow "Sc^{3+} has no *d* sub-shell" Allow 'd orbital is full' if clarified by $3d^{10}$	

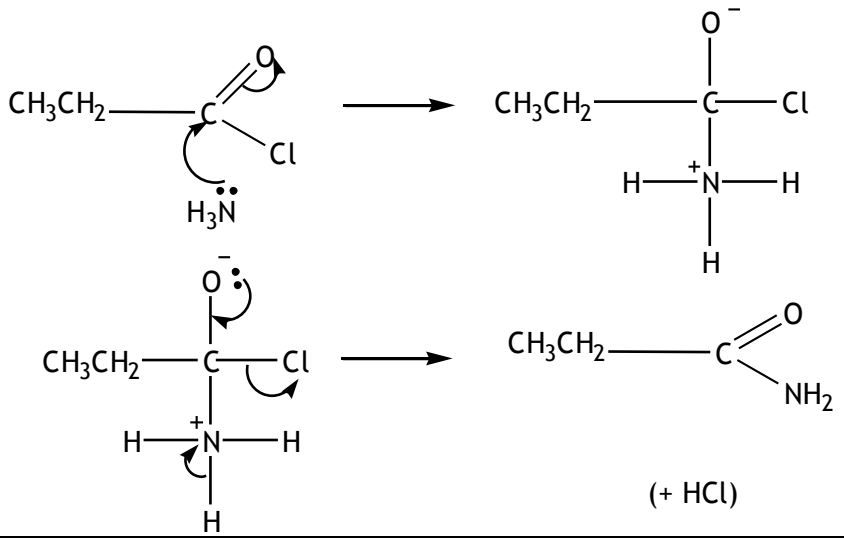
Question Number	Acceptable Answers	Additional Guidance	Mark
7(b)	• calculation of moles of $Cr_2O_7^{2-}$ **(1)** • calculation of moles of Mn^{2+} **(1)** • deduction of whole number mole ratio of $Cr_2O_7^{2-}$: Mn^{2+} **(1)** • deduction of total number of electrons lost by 3 mol of Mn^{2+} **(1)** • deduction of final oxidation state of manganese **(1)**	Example of calculation • moles of $Cr_2O_7^{2-}$ = $\frac{0.100 \times 20.0}{1000}$ = 2(.00) x 10^{-3} (mol) • moles of Mn^{2+} = $\frac{0.200 \times 30.0}{1000}$ = 6(.00) x 10^{-3} (mol) • mole ratio $Cr_2O_7^{2-}$: Mn^{2+} = 1 : 3 • 3 mol Mn^{2+} lose a total of $6e^-$ • each Mn^{2+} loses $2e^-$, so final oxidation state of Mn is (+)4 / IV /Mn^{4+} MP3 and MP4 may be awarded via alternative methods e.g. use of oxidation numbers / moles of electrons correct final oxidation state with no working scores M5 only	**(5)**

Question Number	Acceptable Answers	Additional Guidance	Mark
7(c)	• calculation of moles of Cr **(1)** **MP2, 3 & 4 are only available for answers using a 3:2 mole ratio** • deduction of mole ratio of **X** to Cr^{3+} **(1)** • calculation of moles of **X** **(1)** • calculation of molar mass / A_r of **X** **and** identification of **X** accordingly **(1)**	Example of calculation Moles Cr = $\frac{1.456}{52(.0)}$ = 0.028(0) **3** mol **X** : **2** mol Cr^{3+} / Cr Allow $2Cr^{3+} + 3\mathbf{X} \rightarrow 3\mathbf{X}^{2+} + 2Cr$ Moles **X** = 0.028(0) x 1.5 = 0.042(0) Correctly multiplying by 1.5 for MP3 implies MP2 $M_r = \frac{1.021}{0.042(0)}$ = 24.3 (g mol^{-1}) **and** (so) **X** is magnesium/Mg COMMENT: If transpose 3:2 ratio, **X** has M_r = 54.7 (g mol^{-1}) and **X =** Mn so scores M1, then M3 and M4 by TE (i.e. **(3)** marks overall)	**(4)**

(Total for Question 7 = 15 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
8(a)	• first two curly arrows and lone pair shown on the nitrogen **(1)** • structure of intermediate including positive charge **(1)** • third curly arrow and formation of final organic product **(1)**	Ignore correct dipoles Allow non-displayed NH_3^+ for MP2 Ignore involvement of Cl^- / NH_3 or wrong inorganic products for MP3 EITHER   Ignore depiction of transition state e.g. 	**(3)**

	OR • fission of C-Cl bond curly arrow **and** curly arrow from nitrogen in NH_3 with lone pair shown on N atom to correct carbocation **(1)** • structure of resulting nitrogen-containing intermediate including positive charge **(1)** • curly arrow resulting in breaking of an N-H bond and structure of the final organic product **(1)**	OR AWARD S_N1 mechanism 	

Question Number	Acceptable Answers	Additional Guidance	Mark
8(b)	• first two curly arrows and lone pair shown on the nitrogen **(1)** • structure of intermediate including both charges **(1)** • three curly arrows and structure of final organic product **(1)**		**(3)**

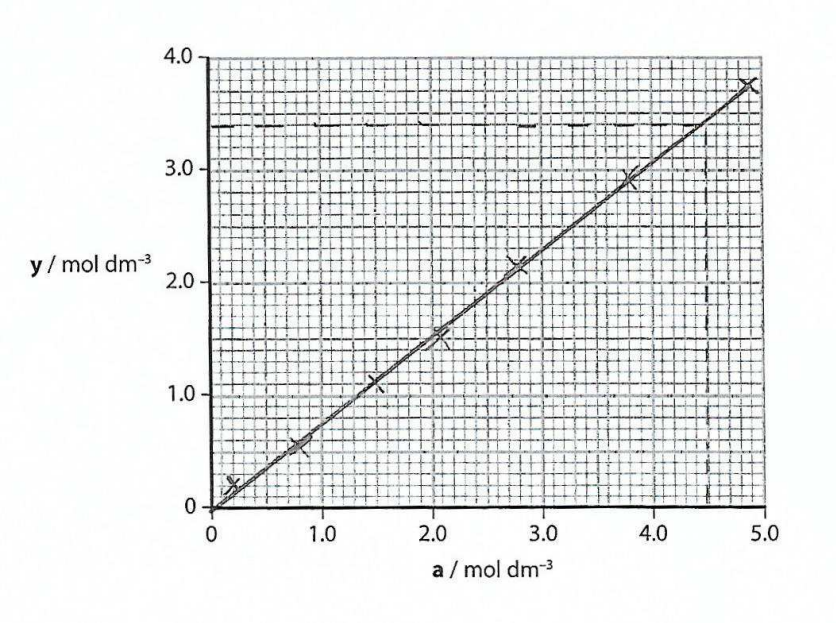
(Total for Question 8 = 6 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
9(a)(i)	$(K_c =) \dfrac{[HI(g)]^2}{[H_2(g)][I_2(g)]}$	Ignore missing state symbols or units Do not award round brackets	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
9(a)(ii)	$(K_c =) \dfrac{4y^2}{(a - y)^2}$ • Numerator term correct **(1)** • Denominator term correct **(1)**	Allow square brackets Allow $(2y)^2$ Allow $(a^2 - 2ay+y^2)$ or (a-y)(a-y)	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
9(b)(i)	• both values correct to 2 DP	1.13 2.93	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
9(b)(ii)	• All 7 points plotted correctly **(1)** • Appropriate straight line of best fit, drawn through the origin **(1)**	Allow TE for incorrect values from 9(b)(i) Do not allow all points above or below the line of best fit Allow line of best fit to intersect one square either side of the origin	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
9(b)(iii)	• co-ordinates correctly read off the line on graph **(1)**  • gradient correctly calculated **(1)**	At least 1 line must be shown on the graph to indicate selection of co-ordinates Example of calculation 3.40 – 0.00 = gradient of graph 4.50 – 0.00 Gradient = 0.76 Ignore SF except 1SF Do not allow units for the gradient Allow a value from 0.71 to 0.81 inclusive	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
9(b)(iv)	• $\frac{\sqrt{K_c}}{2 + \sqrt{K_c}}$ = gradient / $\frac{y}{a}$ **(1)** • re-arrangement of expression and calculation of K_c **(1)**	Example of calculation $\frac{\sqrt{K_c}}{2 + \sqrt{K_c}} = 0.76$ K_c = 40.1 /40 (no units) Allow TE on gradient from part (b)(iii) $K_c = [(2 \times \text{grad})/(1\text{-grad})]^2$ Correct answer with no working scores (2)	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
9(c)	• hydrogen is flammable / explosive	Allow iodine vapour damages eyes /toxic Allow hydrogen iodide is corrosive / acidic / irritant (if qualified) / lachrymator Ignore references to high pressure Ignore references to safety precautions	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
9(d)	• Faster rate of reaction / increased rate **(1)** • K_c unchanged **(1)**	Ignore references to shifting position of equilibrium	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
9(e)(i)	An explanation that makes reference to the following points: • (K_c is) smaller / decreases / gets less **(1)** • (forward) reaction is exothermic **(1)**	Allow reverse/backwards reaction is endothermic MP2 dependent on MP1	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
9(e)(ii)	• straight line drawn on the graph with a less steep gradient (and goes through the origin)	Do not allow if lines cross	**(1)**

(Total for Question 9 = 16 marks)

TOTAL FOR PAPER = 120 MARKS

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