



Pearson

Mark Scheme (Results)

Summer 2017

Pearson Edexcel GCE 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)(i)	<ul style="list-style-type: none"> All species and balancing correct (1) All state symbols correct (1) 	<p>Examples of equation</p> $\text{Cr(OH)}_3(\text{s}) + 3\text{H}_2\text{O}(\text{l}) + 3\text{H}^+(\text{aq}) \rightarrow [\text{Cr}(\text{H}_2\text{O})_6]^{3+}(\text{aq})$ <p>Or</p> $\text{Cr(OH)}_3(\text{s}) + 3\text{H}_3\text{O}^+(\text{aq}) \rightarrow [\text{Cr}(\text{H}_2\text{O})_6]^{3+}(\text{aq})$ <p>Or</p> <p>$[\text{Cr}(\text{OH})_3(\text{H}_2\text{O})_3](\text{s}) + 3\text{H}^+(\text{aq})$ on LHS as an alternative</p> <p>Allow correct equations for sequential protonation e.g.</p> $[\text{Cr}(\text{OH})_3(\text{H}_2\text{O})_3](\text{s}) + \text{H}^+(\text{aq}) \rightarrow [\text{Cr}(\text{H}_2\text{O})_4(\text{OH})_2]^+(\text{aq})$ <p>M2 consequential on M1 being awarded, or a 'near-miss' e.g. Cl^- on both sides / one missing charge</p>	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
1(a)(ii)	<p>A description that makes reference to the following points:</p> <ul style="list-style-type: none"> green solid / grey-green solid (1) forms green solution (1) 	<p>Allow ppt/precipitate for solid</p> <p>Allow purple /violet /ruby solution</p> <p>Do not award yellow-green / red / blue-green bubbles etc means MP2 should not be awarded</p> <p>Ignore adjectives to describe green e.g. pale</p>	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
1(a)(iii)	<ul style="list-style-type: none"> all species and balancing correct (1) all state symbols correct (1) 	<p><u>Examples of equation</u></p> $\text{Cr(OH)}_3(\text{s}) + 3\text{OH}^-(\text{aq}) \rightarrow [\text{Cr(OH)}_6]^{3-}(\text{aq})$ <p>Or</p> $[\text{Cr(OH)}_3(\text{H}_2\text{O})_3](\text{s}) + 3\text{OH}^-(\text{aq}) \rightarrow [\text{Cr(OH)}_6]^{3-}(\text{aq}) + 3\text{H}_2\text{O}(\text{l})$ <p>Allow $\text{Cr(OH)}_3(\text{s}) + \text{OH}^-(\text{aq}) \rightarrow [\text{Cr(OH)}_4]^{-}(\text{aq})$</p> <p>Or</p> <p>$[\text{Cr(OH)}_5(\text{H}_2\text{O})]^{2-}(\text{aq})$ as complex ion on RHS, with rest of equation correctly balanced</p> <p>M2 consequential on M1 being awarded, or a 'near-miss'</p>	(2)

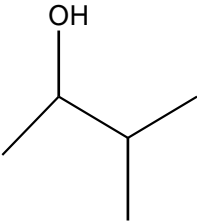
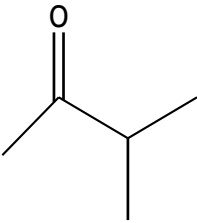
Question Number	Acceptable Answers	Additional Guidance	Mark
1(a)(iv)	<p>An answer that makes reference to the following point:</p> <ul style="list-style-type: none"> green and solution 	<p>Ignore 'Qualifiers' for any colour (e.g. 'dark', 'deep', etc)</p>	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
1(b)(i)	<p>A description that makes reference to the following points:</p> <ul style="list-style-type: none"> (blue solution initially forms pale) blue precipitate (1) (which dissolves to) form dark/deep/royal blue solution (1) 	<p>Allow 'solid' / 'ppt' for 'precipitate'</p> <p>Do not award for 'blue crystals'</p> <p>Do not allow dark blue ppt</p>	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
1(b)(ii)	$[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{NH}_3 \rightarrow [\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+} + 4\text{H}_2\text{O}$ <ul style="list-style-type: none"> • LHS of equation correct • RHS of equation correct 	Ignore state symbols even if incorrect Ignore balanced sulfate ions (1) Do not award just Cu^{2+} on LHS Allow $[\text{Cu}(\text{OH})_2(\text{H}_2\text{O})_4] + 4\text{NH}_3 \rightarrow [\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+} + 2\text{H}_2\text{O} + 2\text{OH}^-$ Do not award for $[\text{Cu}(\text{NH}_3)_4]^{2+}$ / $[\text{Cu}(\text{NH}_3)_6]^{2+}$ on RHS	(2)

(Total for Question 1 = 11 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
2(a)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> • (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) 	<p>First and second change can be in either order Ignore prior refluxing Ignore water bath</p> <p>Allow just "water should enter the condenser at the bottom" OR Just "water should leave at the top" OR Just "swap the tubes around"</p> <p>Allow replacing the funnel with a tap / dropping funnel</p> <p>Ignore thermometers used to measure boiling temperatures</p>	(4)

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

Question Number	Acceptable Answers	Additional Guidance	Mark
2(c)(i)	<ul style="list-style-type: none"> 3-methylbutan-2-ol / secondary alcohols cannot be oxidised to a carboxylic acid OR 3-methylbutanone / the product / ketones cannot be (further) oxidised 	<p>Allow only primary alcohols can be oxidised to carboxylic acids</p>	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
2(c)(ii)	<ul style="list-style-type: none"> H₂SO₄ 	<p>Ignore 'sulfuric acid'</p>	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
2(c)(iii)	<ul style="list-style-type: none"> all formulae correct (1) all state symbols correct (1) 	<p>Example of equation:</p> $\text{Na}_2\text{CO}_3(\text{s}) + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow \text{Na}_2\text{SO}_4(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$ <p>OR</p> $\text{Na}_2\text{CO}_3(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow 2\text{Na}^+(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$ <p>OR</p> $\text{Na}_2\text{CO}_3(\text{s}) + 2\text{H}_2\text{SO}_4(\text{aq}) \rightarrow 2\text{NaHSO}_4(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$ <p>Use of NaCO_3 or H_2CO_3 scores zero</p> <p>Allow any acid.</p> <p>M2 consequential on M1 being awarded, or a 'near-miss'</p>	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
2(d)(i)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> peak at $1720 \text{ (cm}^{-1}\text{)}$ (1) shows presence of a C=O bond / carbonyl (1) 	<p>Allow any absorbance between 1720 to $1700 \text{ (cm}^{-1}\text{)}$</p> <p>Marks cannot be awarded if ANY incorrect other peaks are identified e.g. peak due to C=C / peak due to O-H</p> <p>Ignore references to alkane C-H bonds / fingerprint region</p> <p>Do not award just 'ketone' for MP2</p>	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
2(d)(ii)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> • 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) 	<p>Allow any absorbance between 3750 to 3200 (cm^{-1})</p> <p>Ignore references to fingerprint region</p>	(2)

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

Question Number	Acceptable Answers	Additional Guidance	Mark
2(e)(ii)	<div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;"> $\begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{H} \\ \quad \quad \\ \text{H} \quad \quad \text{H} \\ \text{+} \end{array}$ <p>(1)</p> </div> <div style="text-align: center;"> $\begin{array}{c} \text{H} \quad \text{O} \\ \quad \\ \text{H}-\text{C}-\text{C}^+ \\ \\ \text{H} \end{array}$ <p>(1)</p> </div> </div>	<p>Allow positive charge anywhere on structure</p> <p>Ignore open bonds</p> <p>Penalise non-displayed formulae once only</p> <p>Ignore brackets around the structure</p> <p>Penalise missing charge once only</p>	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
2(f)(i)	$\text{C}_5\text{H}_{12}\text{O} + [\text{O}] \rightarrow \text{C}_5\text{H}_{10}\text{O} + \text{H}_2\text{O}$ <ul style="list-style-type: none"> • left-hand side of equation correct • right-hand side of equation correct 	<p>Molecular formulae must be used throughout</p> <p>Allow [O] above the arrow</p> <p>Do not award for C₅H₁₁OH as the alcohol</p> <p>Ignore state symbols if incorrect or conditions mentioned</p>	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
2(f)(ii)	<ul style="list-style-type: none"> • calculation of moles of both of C₅H₁₀O and C₅H₁₂O (1) • calculation of mass of C₅H₁₂O (1) <p>OR</p> <ul style="list-style-type: none"> • calculation of theoretical mass of C₅H₁₀O and moles of C₅H₁₀O (1) • calculation of mass of C₅H₁₂O (1) 	<p><u>Example of calculation</u></p> <p>Moles C₅H₁₀O = $\frac{2.15}{86.0} = 0.025(0)$ (mol)</p> <p>and</p> <p>moles C₅H₁₂O = $\frac{0.025(0)}{62.5} \times 100 = 0.04(00)$</p> <p>(So) mass of C₅H₁₂O = 0.04(00) x 88 = 3.52 g</p> <p>Theoretical mass C₅H₁₀O = $\frac{2.15}{62.5} \times 100 = 3.44$ g</p> <p>and</p> <p>moles C₅H₁₀O = $\frac{3.44}{86.0} = 0.04(00) = \text{mol C}_5\text{H}_{12}\text{O}$</p> <p>(So) mass of C₅H₁₂O = 0.04(00) x 88 = 3.52 g</p> <p>Correct answer with no working scores (2)</p> <p>Allow TE from MP1 Award 1 mark for 3.36 g, 1.375 g or 2.2 g</p>	(2)

(Total for Question 2 = 21 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
3(a)	<ul style="list-style-type: none">2,6-diaminohexanoic acid	Allow 2,6-diaminehexanoic acid Ignore any additional commas or hyphens or spaces Do not award 2,6-diamminohexanoic acid	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
3(b)	<ul style="list-style-type: none"> <li data-bbox="369 279 763 311">• Deprotonated structure <div style="text-align: center; margin: 10px 0;"> $\text{H}_2\text{NCH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{---}\overset{\text{H}}{\underset{\text{NH}_2}{\text{C}}}\text{---COO}^- \quad (\text{Na}^+)$ </div> <li data-bbox="369 582 674 614">• Protonated structure <div style="text-align: center; margin: 10px 0;"> $\overset{+}{\text{H}_3\text{N}}\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{---}\overset{\text{H}}{\underset{+\text{NH}_3}{\text{C}}}\text{---COOH} \quad (2\text{Cl}^-)$ </div> <li data-bbox="369 885 591 917">• Ester structure <div style="text-align: center; margin: 10px 0;"> $\text{H}_2\text{NCH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{---}\overset{\text{H}}{\underset{\text{NH}_2}{\text{C}}}\text{---COOCH}_3$ </div> 	<p data-bbox="1227 279 1800 343">(1) Allow displayed /structural /condensed formulae</p> <p data-bbox="1227 383 1899 518">Allow $\text{NH}_2\text{---}$ Allow ---CO_2^- Allow ---COONa but penalise if O-Na covalent bond is shown</p> <p data-bbox="1144 614 1783 742">(1) Both NH_2 groups must be protonated Allow $\text{NH}_3^+\text{---}$ / $^+\text{H}_3\text{N---}$ Allow $\text{---CO}_2\text{H}$</p> <p data-bbox="1144 917 1859 989">(1) Allow CO_2CH_3 Allow $\text{NH}_3^+\text{---}$ or $\text{NH}_2\text{---}$ for each amine group</p> <p data-bbox="1227 1029 1904 1133">Penalise wrong side chain only once If alanine used throughout then only MP3 can be awarded</p>	(3)

Question Number	Acceptable Answers	Additional Guidance	Mark
3(c)	<p>Any one of:</p> $\text{H}_2\text{NCH}_2\text{CH}_2\text{CH}_2\text{CH}_2-\overset{\text{H}}{\underset{\text{NH}_2}{\text{C}}}-\overset{\text{O}}{\parallel}{\text{C}}-\overset{\text{H}}{\text{N}}-\overset{\text{CH}_3}{\underset{\text{H}}{\text{C}}}-\text{COOH}$ <p>OR</p> $\text{H}_3\text{C}-\overset{\text{H}}{\underset{\text{NH}_2}{\text{C}}}-\overset{\text{O}}{\parallel}{\text{C}}-\overset{\text{H}}{\text{N}}-\overset{\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2}{\underset{\text{H}}{\text{C}}}-\text{COOH}$ <p>OR</p> $\text{H}_3\text{C}-\overset{\text{H}}{\underset{\text{NH}_2}{\text{C}}}-\overset{\text{O}}{\parallel}{\text{C}}-\overset{\text{H}}{\text{N}}-\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2-\overset{\text{H}}{\underset{\text{NH}_2}{\text{C}}}-\text{COOH}$	<p>Must be the dipeptide and not the repeat unit Allow $-\text{CO}_2\text{H}$ Allow $-\text{H}_2\text{N}$ Allow $-\text{CONH}-$ / $-\text{COHN}-$ unless C-H-N Allow zwitterions or cyclic dipeptides Allow skeletal / part-skeletal formulae</p>	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
3(d)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> • (In acidic conditions) lysine (ion) has two positive charges (whereas alanine has only one) • (So lysine ion has) has greater attraction for the stationary phase 	<p>Ignore comments on retention time, solubility, polarity, dipoles or intermolecular forces</p> <p>(1) Allow 'greater positive charge' Allow lysine has 2 NH₂ groups that can be protonated</p> <p>(1) Allow 'greater affinity for stationary phase' 'adheres better to stationary phase' 'better adsorption onto stationary phase'</p> <p>Allow 'polar phase' for 'stationary phase'</p> <p>Allow reverse argument for alanine</p> <p>Mark points M1 and M2 independently</p>	(2)

(Total for Question 3 = 7 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
4(a)	<ul style="list-style-type: none"> 1.60 (+) 42.5 	<p>(1) Do not award MP1 for "1.6" (must be to 2 D.P.)</p> <p>(1) Do not award MP2 for "42.50" (must be to 1 D.P.)</p> <p>Penalise D.P. error once only</p>	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
4(b)	$\text{CH}_3\text{OH}(\text{l}) + 1.5\text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l})$ <ul style="list-style-type: none"> Balanced equation State symbols all correct 	<p>(1) Do not award multiples (enthalpy change is for the complete combustion of one mole) for MP1</p> <p>(1) MP2 depends on the award of MP1 or correct species</p>	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
4(c)	<ul style="list-style-type: none"> <li data-bbox="322 336 1048 400">• Calculation of energy change (1) <li data-bbox="322 480 1048 544">• Calculation of moles of CH₃OH (1) <li data-bbox="322 624 1048 687">• Calculation of energy ÷ moles CH₃OH (1) <li data-bbox="322 799 1048 943">• ΔH final answer in kJ mol⁻¹ and negative sign included and ΔH final answer to 2 or 3 S.F. (1) 	<p data-bbox="1158 264 1491 296"><u>Example of calculation</u></p> <p data-bbox="1158 336 1644 400">($= mc\Delta T = 150 \times 4.18 \times 42.5 =$) 26647.5 (J)</p> <p data-bbox="1158 480 1715 512">Moles CH₃OH = $1.60/32 (= 0.05(00))$</p> <p data-bbox="1158 624 1637 687">$\frac{26647.5}{0.05(00)} = 532950$ (J mol⁻¹)</p> <p data-bbox="1158 695 1599 727">Ignore any signs at this stage</p> <p data-bbox="1158 799 1397 831">-533 (kJ mol⁻¹)</p> <p data-bbox="1158 839 1196 871">Or</p> <p data-bbox="1158 871 1397 903">-530 (kJ mol⁻¹)</p> <p data-bbox="1158 983 1872 1015">Correct answer with no working gains full marks</p> <p data-bbox="1158 1023 1693 1054">Penalise incorrect units for MP4 only</p> <p data-bbox="1158 1054 1491 1086">Allow TE at each stage</p> <p data-bbox="1158 1094 1928 1126">Allow correct rounding to 2SF or more at each stage</p>	(4)

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

Question Number	Acceptable Answers	Additional Guidance	Mark
4(d)(ii)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> • Calculation of the % uncertainty using the 25 cm³ measuring cylinder (1) <p>Then any two from:</p> <ul style="list-style-type: none"> • % uncertainty with use of 25 cm³ 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) 	<p>Needs to show combined error in using the 25 cm³ six times is greater than using 250 cm³ measuring cylinder once only</p> <p>Award MP1 EITHER if multiplies errors: $100 \times (0.2 / 25) \times 6 = 4.8\%$ OR If adds errors $100 \times (1.2 / 150) = 0.8\%$ Do not award $(0.2 / 25) \times 100 = 0.8 \%$</p> <p>Do not award 'easier' to use larger measuring cylinder</p>	(3)

Question Number	Acceptable Answers	Additional Guidance	Mark
4(d)(iii)	<p>An answer that makes reference to any three of the following points:</p> <ul style="list-style-type: none"> • 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) 	<p>Ignore experiment carried out under non-standard conditions Ignore just 'no lid'</p> <p>Allow calorimeter has not been calibrated</p>	(3)

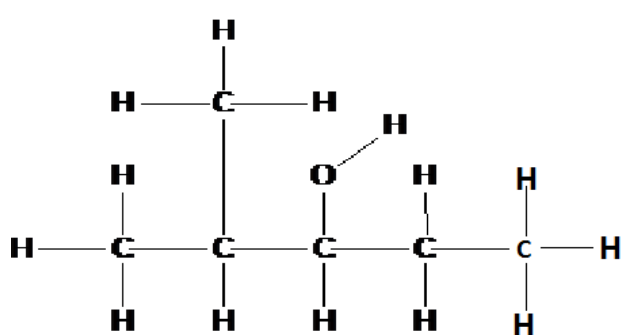
Question Number	Acceptable Answers	Additional Guidance	Mark
4(e)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> • The second value will be less exothermic / less negative (1) • Some energy will be used to boil the water/boiling water is endothermic 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) 	<p>Allow 'more positive' or 'smaller in magnitude' Do not accept 'greater' or 'smaller' for 'less negative'</p> <p>Do not award just "the water boils"</p> <p>Mark points M1 and M2 independently</p>	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
4(f)	<p>An explanation that makes reference to the following points:</p> <p>Either</p> <ul style="list-style-type: none"> • 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) <p>Or</p> <ul style="list-style-type: none"> • student 2's value will be less negative/ less exothermic (1) • greater heat loss because higher temperature/heated for longer (1) 	<p>Allow 'temperature change' for 'energy change'</p> <p>Allow 'more positive' or 'smaller in magnitude' or 'smaller' for 'less negative'</p> <p>Mark points MP1 and MP2 independently within each route</p>	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
4(g)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li data-bbox="322 336 1198 443">• (Calculated) value of moles (of methanol) burned will be less / too small (1) <li data-bbox="322 517 1198 587">• The calculated value will be more exothermic / more negative (1) 	<p>Allow both marks for a calculation using M_r of 46.0 (instead of 32.0), giving a final ΔH value (approx.) of $-766 \text{ (kJ mol}^{-1}\text{)}$</p> <p>Allow 'increase' or 'greater' for 'more negative'</p> <p>MP2 depends on MP1</p>	(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)	<ul style="list-style-type: none"> 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)	<ul style="list-style-type: none"> ✓ 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)	<ul style="list-style-type: none"> propane / C₃H₈ 	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)	<ul style="list-style-type: none"> 23.15 and 23.55 and 23.20 completed in table 	All three titres must be shown to 2 D.P.	(2)
	<ul style="list-style-type: none"> ✓ beneath titres 1 and 3 and mean titre = 23.18 (cm³) 	Allow 23.2 or 23.175 (cm ³)	

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

Question Number	Acceptable Answers	Additional Guidance	Mark
6(c)	<ul style="list-style-type: none"> <li data-bbox="322 331 987 368">• calculation of moles of MnO_4^- in 25.0 cm^3 <li data-bbox="322 512 987 549">• calculation of moles of NO_2^- in mean titre <li data-bbox="322 692 987 729">• calculation of moles of NO_2^- in 250 cm^3 <li data-bbox="322 1155 748 1192">• calculation of molar mass 	<p data-bbox="1225 266 1561 293"><u>Example of calculation</u></p> <p data-bbox="1225 331 1928 475">(1) Moles $\text{MnO}_4^- = \frac{0.02(00) \times 25.0}{1000}$ $= 5(.00) \times 10^{-4} / 0.0005(00)$ (mol)</p> <p data-bbox="1225 512 1877 651">(1) Moles $\text{NO}_2^- = 2.5 \times$ moles MnO_4^- in mean titre $= 1.25 \times 10^{-3} / 0.00125$ (mol)</p> <p data-bbox="1225 692 1928 1007">(1) Moles NO_2^- in $250 \text{ cm}^3 =$ moles NO_2^- in mean titre $\times \frac{250}{\text{mean titre from (a)}}$ $= 1.25 \times 10^{-3} \times \frac{250}{23.18}$ $= 0.013481449$ $= 0.0135$ (mol)</p> <p data-bbox="1225 1050 1697 1114">Allow TE on mean titre from (a) Ignore SF except 1 SF</p> <p data-bbox="1225 1155 1697 1326">(1) • Molar mass $= 2 \times \frac{1.15}{0.0135}$ $= 170.3703704$ (g mol^{-1}) $= 170.4$ (g mol^{-1})</p>	(5)

	<ul style="list-style-type: none"> calculation of x correctly to the nearest whole number: (1) 	<p>Allow TE</p> <ul style="list-style-type: none"> $x = \frac{170.4 - 116.3}{18(.0)}$ $x = 3.005555556$ $x = 3$ (must be to nearest whole number) <p>Allow TE from molar mass calculated Allow alternative correct methods for MP4 and MP5 Correct value of x with no working scores (1)</p>	
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Question Number	Acceptable Answers	Additional Guidance	Mark
6(d)	$2\text{MnO}_4^- + 5\text{NO}_2^- + 6\text{H}^+ \rightarrow 2\text{Mn}^{2+} + 5\text{NO}_3^- + 3\text{H}_2\text{O}$ <ul style="list-style-type: none"> evidence of multiplying 1st equation by 2 and 2nd equation by 5 overall equation correct with H^+ and H_2O and $e^{(-)}$ cancelled as appropriate 	<p>Each of the following equations score (1) mark overall:</p> $2\text{MnO}_4^- + 5\text{NO}_2^- + 16\text{H}^+ + 5\text{H}_2\text{O} \rightarrow 2\text{Mn}^{2+} + 5\text{NO}_3^- + 8\text{H}_2\text{O} + 10\text{H}^+$ <p>OR</p> $2\text{MnO}_4^- + 5\text{NO}_2^- + 6\text{H}^+ + 5\text{H}_2\text{O} \rightarrow 2\text{Mn}^{2+} + 5\text{NO}_3^- + 8\text{H}_2\text{O}$ <p>OR</p> $2\text{MnO}_4^- + 5\text{NO}_2^- + 16\text{H}^+ \rightarrow 2\text{Mn}^{2+} + 5\text{NO}_3^- + 10\text{H}^+ + 3\text{H}_2\text{O}$ <p>Ignore state symbols, even if incorrect</p> <p>Allow multiples</p>	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
6(e)	<p>An explanation that makes reference to the following:</p> <p>Either</p> <ul style="list-style-type: none"> the (calculated) value of x would be too high (1) The moles of MgCO_3 would be too low / the moles of $\text{Mg}(\text{NO}_2)_2 \cdot x\text{H}_2\text{O}$ would be too low / the M_r of $\text{Mg}(\text{NO}_2)_2 \cdot x\text{H}_2\text{O}$ would be too high (1) <p>Or</p> <ul style="list-style-type: none"> (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) 	<p>Allow 'amount' or 'mass' for 'moles'</p> <p>MP2 depends on MP1</p> <p>MP2 depends on MP1</p>	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
6(f)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> 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) 	<p>Ignore references to just 'impurities'</p> <p>M2 dependent on M1</p>	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
6(g)	An answer that makes reference to the following point: <ul style="list-style-type: none"> 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: <ul style="list-style-type: none"> 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)

Question Number	Acceptable Answers	Additional Guidance	Mark												
*7(a)	<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="322 651 779 1056"> <thead> <tr> <th data-bbox="322 651 533 871">Number of indicative marking points seen in answer</th> <th data-bbox="533 651 779 871">Number of marks awarded for indicative marking points</th> </tr> </thead> <tbody> <tr> <td data-bbox="322 871 533 906">6</td> <td data-bbox="533 871 779 906">4</td> </tr> <tr> <td data-bbox="322 906 533 941">5-4</td> <td data-bbox="533 906 779 941">3</td> </tr> <tr> <td data-bbox="322 941 533 976">3-2</td> <td data-bbox="533 941 779 976">2</td> </tr> <tr> <td data-bbox="322 976 533 1011">1</td> <td data-bbox="533 976 779 1011">1</td> </tr> <tr> <td data-bbox="322 1011 533 1056">0</td> <td data-bbox="533 1011 779 1056">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> <p>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.</p> <p>Reasoning marks may be subtracted for extra incorrect chemistry.</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			
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>Indicative content (IPs)</p> <p>IP1:</p> <ul style="list-style-type: none"> (transition metal) forms an ion with an incomplete <i>d</i> sub-shell <p>IP2:</p> <ul style="list-style-type: none"> scandium and zinc are not transition metals <p>IP3:</p> <ul style="list-style-type: none"> Sc³⁺ and 1s² 2s² 2p⁶ 3s² 3p⁶ <p>IP4:</p> <ul style="list-style-type: none"> Zn²⁺ and 1s² 2s² 2p⁶ 3s² 3p⁶ 3d¹⁰ <p>IP5:</p> <ul style="list-style-type: none"> Sc³⁺ and <i>d</i> sub-shell empty / <i>d</i>-orbitals empty <p>IP6:</p> <ul style="list-style-type: none"> Zn²⁺ and <i>d</i> sub-shell full / ALL <i>d</i>-orbitals are full 	<p>Allow 'partially-filled' for incomplete Allow <i>d</i>-orbital(s) Do not award "<i>d</i>-shell" Allow "<i>D</i>" for "<i>d</i>" throughout</p> <p>Allow if only Sc and Zn are used to illustrate <i>d</i>-block elements that are not transition metals</p> <p>Allow 4s⁰ and/or 3d⁰ Penalise use of [Ar] once only</p> <p>Allow "Sc³⁺ has no <i>d</i> sub-shell"</p> <p>Allow 'd orbital is full' if clarified by 3d¹⁰</p>	
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Question Number	Acceptable Answers	Additional Guidance	Mark
7(b)	<ul style="list-style-type: none"> • calculation of moles of $\text{Cr}_2\text{O}_7^{2-}$ (1) • calculation of moles of Mn^{2+} (1) • deduction of whole number mole ratio of $\text{Cr}_2\text{O}_7^{2-} : \text{Mn}^{2+}$ (1) • deduction of total number of electrons lost by 3 mol of Mn^{2+} (1) • deduction of final oxidation state of manganese (1) 	<p>Example of calculation</p> <ul style="list-style-type: none"> • moles of $\text{Cr}_2\text{O}_7^{2-} = \frac{0.100 \times 20.0}{1000}$ $= 2(.00) \times 10^{-3}$ (mol) • moles of $\text{Mn}^{2+} = \frac{0.200 \times 30.0}{1000}$ $= 6(.00) \times 10^{-3}$ (mol) • mole ratio $\text{Cr}_2\text{O}_7^{2-} : \text{Mn}^{2+}$ $= \quad \quad \quad 1 \quad : \quad 3$ • 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+} <p>MP3 and MP4 may be awarded via alternative methods e.g. use of oxidation numbers / moles of electrons</p> <p>correct final oxidation state with no working scores M5 only</p>	(5)

Question Number	Acceptable Answers	Additional Guidance	Mark
7(c)	<ul style="list-style-type: none"> • calculation of moles of Cr <p style="text-align: right;">(1)</p> <p>MP2, 3 & 4 are only available for answers using a 3:2 mole ratio</p> <ul style="list-style-type: none"> • deduction of mole ratio of X to Cr³⁺ <p style="text-align: right;">(1)</p> <ul style="list-style-type: none"> • calculation of moles of X <p style="text-align: right;">(1)</p> <ul style="list-style-type: none"> • calculation of molar mass / A_r of X and identification of X accordingly <p style="text-align: right;">(1)</p>	<p><u>Example of calculation</u></p> <p>Moles Cr = $\frac{1.456}{52(.0)} = 0.028(0)$</p> <p>3 mol X : 2 mol Cr³⁺ / Cr</p> <p>Allow $2\text{Cr}^{3+} + 3\text{X} \rightarrow 3\text{X}^{2+} + 2\text{Cr}$</p> <p>Moles X = $0.028(0) \times 1.5$ = $0.042(0)$</p> <p>Correctly multiplying by 1.5 for MP3 implies MP2</p> <p>$M_r = \frac{1.021}{0.042(0)}$ = $24.3 \text{ (g mol}^{-1}\text{)}$</p> <p>and (so) X is magnesium/Mg COMMENT: If transpose 3:2 ratio, X has $M_r = 54.7 \text{ (g mol}^{-1}\text{)}$ and X = Mn so scores M1, then M3 and M4 by TE (i.e. (3) marks overall)</p>	(4)

(Total for Question 7 = 15 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
8(a)	<ul style="list-style-type: none"> • first two curly arrows and lone pair shown on the nitrogen • structure of intermediate including positive charge • third curly arrow and formation of final organic product 	<p>Ignore correct dipoles Allow non-displayed NH₃⁺ for MP2 Ignore involvement of Cl⁻ / NH₃ or wrong inorganic products for MP3</p> <p>EITHER</p> <p>(1)</p> $\begin{array}{c} \text{H} \\ \\ \text{CH}_3\text{CH}_2-\text{C}-\text{Cl} \\ \\ \text{H} \end{array} \begin{array}{c} \curvearrowright \\ \curvearrowright \\ \text{NH}_3 \end{array} \longrightarrow \begin{array}{c} \text{H} \\ \\ \text{CH}_3\text{CH}_2-\text{C}-\text{H} \\ \\ \text{H}-\text{N}^+-\text{H} \\ \\ \text{H} \end{array} (+\text{Cl}^-)$ <p>(1)</p> $\begin{array}{c} \text{H} \\ \\ \text{CH}_3\text{CH}_2-\text{C}-\text{H} \\ \\ \text{H}-\text{N}^+-\text{H} \\ \\ \text{H} \end{array} \begin{array}{c} \curvearrowright \end{array} \longrightarrow \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{CH}_3\text{CH}_2-\text{C}-\text{N} \\ \quad \\ \text{H} \quad \text{H} \end{array} (+\text{H}^+)$ <p>Ignore depiction of transition state e.g.</p> $\left[\begin{array}{c} \text{H} \quad \text{CH}_2\text{CH}_3 \\ \quad \\ \text{H}-\text{N} \cdots \text{C} \cdots \text{Cl} \\ \quad / \quad \backslash \\ \text{H} \quad \text{H} \quad \text{H} \end{array} \right]$	(3)

OR

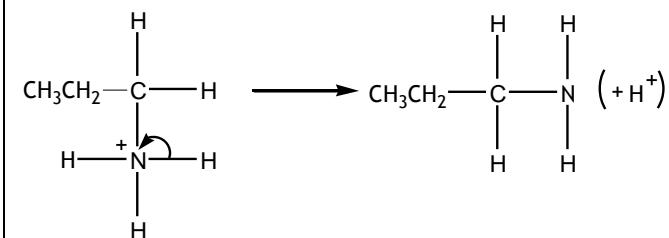
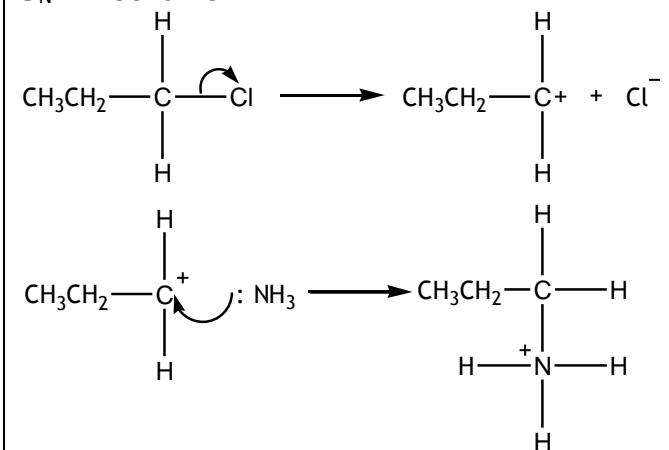
- fission of C-Cl bond curly arrow **and** curly arrow from nitrogen in NH₃ with lone pair shown on N atom to correct carbocation
- structure of resulting nitrogen-containing intermediate including positive charge
- curly arrow resulting in breaking of an N-H bond and structure of the final organic product

(1)

(1)

(1)

OR AWARD
S_N1 mechanism



Question Number	Acceptable Answers	Additional Guidance	Mark
8(b)	<ul style="list-style-type: none"> • 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) 	<p style="text-align: center;">(+ HCl)</p>	(3)

(Total for Question 8 = 6 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
9(a)(i)	$(K_c =) \frac{[\text{HI}(\text{g})]^2}{[\text{H}_2(\text{g})][\text{I}_2(\text{g})]}$	Ignore missing state symbols or units Do not award round brackets	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
9(a)(ii)	$(K_c =) \frac{4y^2}{(a - y)^2}$ <ul style="list-style-type: none"> Numerator term correct Denominator term correct 	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)	<ul style="list-style-type: none"> both values correct to 2 DP 	1.13 2.93	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
9(b)(ii)	<ul style="list-style-type: none"> All 7 points plotted correctly Appropriate straight line of best fit, drawn through the origin 	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)	<ul style="list-style-type: none"> <li data-bbox="371 268 1128 300">co-ordinates correctly read off the line on graph <div data-bbox="448 379 1205 922" style="text-align: center;"> </div> <ul style="list-style-type: none"> <li data-bbox="371 965 837 997">gradient correctly calculated 	<p data-bbox="1205 300 1256 336">(1)</p> <p data-bbox="1283 268 1924 336">At least 1 line must be shown on the graph to indicate selection of co-ordinates</p> <p data-bbox="1205 1002 1256 1038">(1)</p> <p data-bbox="1283 981 1615 1018"><u>Example of calculation</u></p> $\frac{3.40 - 0.00}{4.50 - 0.00} = \text{gradient of graph}$ <p data-bbox="1283 1161 1525 1198">Gradient = 0.76</p> <p data-bbox="1283 1233 1890 1334">Ignore SF except 1SF Do not allow units for the gradient Allow a value from 0.71 to 0.81 inclusive</p>	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
9(b)(iv)	<ul style="list-style-type: none"> $\frac{\sqrt{K_c}}{2 + \sqrt{K_c}} = \text{gradient} / \frac{y}{a}$ re-arrangement of expression and calculation of K_c 	<p>Example of calculation</p> $\frac{\sqrt{K_c}}{2 + \sqrt{K_c}} = 0.76$ <p>$K_c = 40.1 / 40$ (no units)</p> <p>Allow TE on gradient from part (b)(iii) $K_c = [(2 \times \text{grad}) / (1 - \text{grad})]^2$</p> <p>Correct answer with no working scores (2)</p>	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
9(c)	<ul style="list-style-type: none"> hydrogen is flammable / explosive 	<p>Allow iodine vapour damages eyes /toxic</p> <p>Allow hydrogen iodide is corrosive / acidic / irritant (if qualified) / lachrymator</p> <p>Ignore references to high pressure</p> <p>Ignore references to safety precautions</p>	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
9(d)	<ul style="list-style-type: none"> Faster rate of reaction / increased rate K_c unchanged 	<p>Ignore references to shifting position of equilibrium</p>	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
9(e)(i)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> (K_c is) smaller / decreases / gets less (1) (forward) reaction is exothermic (1) 	<p>Allow reverse/backwards reaction is endothermic</p> <p>MP2 dependent on MP1</p>	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
9(e)(ii)	<ul style="list-style-type: none"> 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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