Mark Scheme (Results)

October 2020

Pearson Edexcel GCE
In Chemistry (9CH0)
Paper 2: Advanced Organic and Physical 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.

Using the Mark Scheme

Examiners should look for qualities to reward rather than faults to penalise. This does NOT mean giving credit for incorrect or inadequate answers, but it does mean allowing candidates to be rewarded for answers showing correct application of principles and knowledge. Examiners should therefore read carefully and consider every response: even if it is not what is expected it may be worthy of credit.

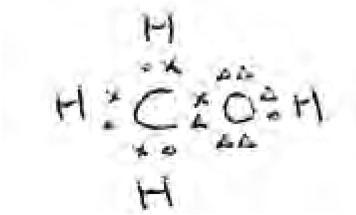
The mark scheme gives examiners:
- an idea of the types of response expected
- how individual marks are to be awarded
- the total mark for each question
- examples of responses that should NOT receive credit.

/ means that the responses are alternatives and either answer should receive full credit.
( ) means that a phrase/word is not essential for the award of the mark, but helps the examiner to get the sense of the expected answer.
Phrases/words in **bold** indicate that the meaning of the phrase or the actual word is **essential** to the answer.
ecf/TE/cq (error carried forward) means that a wrong answer given in an earlier part of a question is used correctly in answer to a later part of the same question.

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

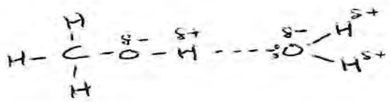
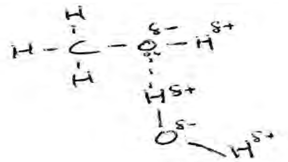
Quality of Written Communication
Questions which involve the writing of continuous prose will expect candidates to:
- write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear
- select and use a form and style of writing appropriate to purpose and to complex subject matter
- organise information clearly and coherently, using specialist vocabulary when appropriate.

Full marks will be awarded if the candidate has demonstrated the above abilities.
Questions where QWC is likely to be particularly important are indicated (QWC) in the mark scheme, but this does not preclude others.

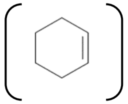
Question Number	Answer	Additional Guidance	Mark
1(a)	• all bonding pairs of electrons correct **(1)** • 2 lone pairs of electrons on oxygen **(1)**	<u>Example of diagram</u>  Allow any symbols for electrons, including all dots or all crosses Allow electrons either side of a line for a bond e.g. <u>x</u> • Electrons can be in overlapping circles, on the lines, inside the lines or in the gaps between the lines Non-bonding electrons on O can be shown as 2 pairs, all 4 together or as 3 and 1 Ignore inner shell electrons	**(2)**

Question Number	Answer	Additional Guidance	Mark
1(b)	• O–H	Allow this shown on diagram in (a) Allow OH Do not award –O–H	**(1)**

Question Number	Answer	Additional Guidance	Mark
1(c)(i)	• hydrogen bonding		**(1)**

Question Number	Answer	Additional Guidance	Mark
1(c)(ii)	• at least one lone pair shown on the oxygen atom in water or methanol **and** involved in the hydrogen bond **(1)** • hydrogen bond shown between an H in one molecule and an O on the other molecule **and** O–H---O / O---H–O bond angle at (about) 180° **(1)** • at least one δ+ shown on either H atom in water or attached to O in methanol **and** at least one δ– shown on any O atom **(1)**	<u>Examples of diagrams</u>   Any bond angle labelled as 180° must be between the correct bonds 180° must be drawn at about 180°, not just labelled Ignore all other bond angles Only 1 correct dipole needs to be shown No TE on c(i) If 2 hydrogen bonds shown, 1 with correct bond angle and 1 incorrect, do not award M2	**(3)**

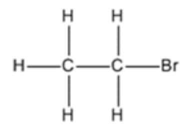
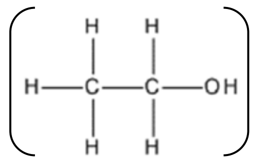
(Total for Question 1 = 7 marks)

Question number	Answer	Mark
2(a)	**The only correct answer is C**  *A is incorrect because this has molecular formula* C_6H_{12} *B is incorrect because this has molecular formula* C_6H_8 *D is incorrect because this has molecular formula* C_6H_8	**(1)**

Question number	Answer	Mark
2(b)	**The only correct answer is C** (2,3-dimethylbut-1-ene) *A is incorrect because the longest chain has 4 carbon atoms* *B is incorrect because the longest chain has 4 carbon atoms* *D is incorrect because the C=C should have the lowest number*	**(1)**

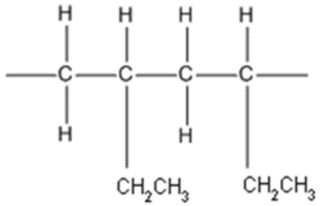
<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>2(c)</td><td>

product in Reaction 1 (1)
reagent in Reaction 2 (1)
condition in Reaction 2 (1)

</td><td>
<u>Example of table</u>
<table>
<tr><th>Reaction</th><th>Reagent and condition</th><th>Product</th></tr>
<tr><td>1</td><td>(HBr at
room temperature)</td><td></td></tr>
<tr><td>2</td><td>steam / $H_2O(g)$
and
acid / H^+</td><td></td></tr>
</table>
Allow structural / skeletal / molecular formula / name for (1-)bromoethane

Allow water / H_2O and heat instead of steam

Allow specific acid e.g. (concentrated) phosphoric acid / sulfuric acid
Ignore any specific temperature and pressure
Do not award acid if mention of any reagent other than steam / water e.g. acidified dichromate
</td><td>(3)</td></tr>
</table>

Question Number	Answer	Additional Guidance	Mark
2(d)(i)	• 2 repeat units with extension bonds	<u>Example of two repeat units</u>  The extension bonds can be solid / dotted / dashed Allow C_2H_5 for the side chains Allow ethyl groups on carbon atoms: 1 and 3, 2 and 4, 1 and 4 or 2 and 3 Allow skeletal formula / any combination of structural or displayed formulae Ignore brackets / n Ignore connectivity of vertical CH_2CH_3 groups	(1)

Question Number	Answer	Additional Guidance	Mark
2(d)(ii)	• calculation of moles of but-1-ene **(1)** • calculation of number of molecules of but-1-ene **(1)**	<u>Example of calculation</u> moles of but-1-ene = $\frac{70.0}{56.0}$ = 1.25 (mol) molecules of but-1-ene = 1.25 x 6.02 x10^{23} = 7.525 x 10^{23} TE on moles but-1-ene Ignore SF except 1 SF Do not award M2 for mass x 6.02 x10^{23} Correct answer with no working scores (2)	**(2)**

(Total for Question 2 = 8 marks)

Question Number	Answer	Additional Guidance	Mark
3(a)(i)	An explanation that makes reference to the following points: • oxidation numbers of Br identified as (+)5 for BrO_3^-, −1 for Br^- and 0 for Br_2 **(1)** • this is not disproportionation because: two different species of bromine / reactants are oxidised and reduced / not one species oxidised and reduced **or** only one species containing bromine is produced / two different species containing bromine in two different oxidation states are not produced **(1)**	These may be shown in the equation Allow 5+ / V / 1− / −I Do not award any change in oxidation numbers of oxygen and or hydrogen Allow bromine is oxidised and reduced in the reverse reaction Allow this is reverse disproportionation / comproportionation	**(2)**

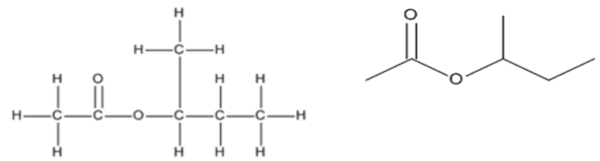
Question number	Answer	Mark
3(a)(ii)	**The only correct answer is D** (cannot tell from this information) *A is incorrect because there are 3 reactant species but the overall order of a reaction can only be determined by experiment* *B is incorrect because there is 1 bromate ion and 5 bromide ions but the overall order of a reaction can only be determined by experiment* *C is incorrect because there are 12 reactant particles but the overall order of a reaction can only be determined by experiment*	**(1)**

Question Number	Answer	Additional Guidance	Mark
3(b)	• calculation of moles of $KBrO_3$ **(1)** • calculation of moles of O_2 **(1)** • calculation of volume of O_2 **(1)**	Example of calculation moles of $KBrO_3 = \frac{5.20}{(39.1 + 79.9 + (3 \times 16.0))} = \frac{5.20}{167(.0)}$ $= 0.031138$ / 3.1138×10^{-2} (mol) moles of $O_2 = \frac{0.031138 \times 3}{2}$ $= 0.046707$ / 4.6707×10^{-2} (mol) TE on moles of $KBrO_3$ volume of $O_2 = 0.046707 \times 24$ $= 1.12096$ (dm^3) TE on moles of O_2 Do not award incorrect unit e.g. dm^{-3} Correct answer with no working scores (3) Ignore SF except 1 SF Ignore use of $pV = nRT$	**(3)**

(Total for Question 3 = 6 marks)

Question number	Answer	Mark
4(a)(i)	**The only correct answer is B** (Compound **Q**) *A is incorrect because this is not hydrolysed* *C is incorrect because this is hydrolysed to form phenol and ethanoic acid* *D is incorrect because this is not hydrolysed*	**(1)**

Question number	Answer	Mark
4(a)(ii)	**The only correct answer is A** (Compound **P**) *B is incorrect because it is an ester and does not react with sodium hydrogencarbonate* *C is incorrect because it is an ester and does not react with sodium hydrogencarbonate* *D is incorrect because it is not acidic enough to react with sodium hydrogencarbonate*	**(1)**

Question Number	Answer	Additional Guidance	Mark
4(b)	**Structures:** • **T**: structure of butan-2-ol **(1)** • **U**: structure of butanone **(1)** • **V**: structure of 1-methylpropyl ethanoate **(1)** **Justification:** • **U** is a ketone because it gives an orange precipitate with 2,4-dinitrophenylhydrazine **and** does not give a precipitate with Fehling's solution **(1)** • **T** is a secondary alcohol because it was oxidised to / formed a ketone **(1)** • **V** is an ester as alcohols react with acyl chlorides / ethanoyl chloride to form esters **(1)**	Examples of structures Ignore names, even if incorrect **T**: $CH_3CH_2CHOHCH_3$ Ignore connectivity of OH group in displayed formula **U**: $CH_3CH_2COCH_3$ **V**:  Allow skeletal formulae or any combination of displayed and structural formulae Do not award C_4H_9 from alcohol Allow butyl ethanoate if **T** is butan-1-ol Allow **U** is a carbonyl compound because it gives an orange precipitate with 2,4-dinitrophenylhydrazine **and** is not an aldehyde as it does not give a precipitate with Fehling's solution	**(6)**

(Total for Question 4 = 8 marks)

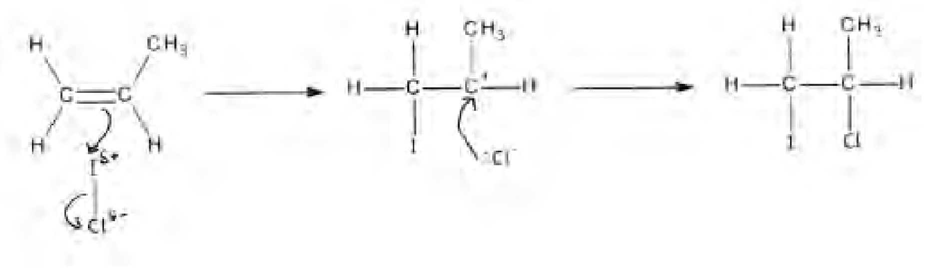
Question number	Answer	Mark
5(a)	**The only correct answer is D** (C_6H_{14}) *A is incorrect because this has general formula C_nH_n and non-cyclic, saturated hydrocarbons have the general formula C_nH_{2n+2}* *B is incorrect because this has general formula C_nH_{2n-2} and non-cyclic, saturated hydrocarbons have the general formula C_nH_{2n+2}* *C is incorrect because this has general formula C_nH_{2n} and non-cyclic, saturated hydrocarbons have the general formula C_nH_{2n+2}*	**(1)**

Question number	Answer	Mark
5(b)	**The only correct answer is B** (3) *A is incorrect because the structural isomers of C_5H_{12} are pentane, 2-methylbutane and 2,2-dimethylpropane* *C is incorrect because the structural isomers of C_5H_{12} are pentane, 2-methylbutane and 2,2-dimethylpropane* *D is incorrect because the structural isomers of C_5H_{12} are pentane, 2-methylbutane and 2,2-dimethylpropane*	**(1)**

Question number	Answer	Mark
5(c)	**The only correct answer is D** (16σ bonds and 1π bond) *A is incorrect because there are 10 σ C-H bonds, 6 C-C σ bonds and 1 C-C π bond* *B is incorrect because there are 10 σ C-H bonds, 6 C-C σ bonds and 1 C-C π bond* *C is incorrect because there are 10 σ C-H bonds, 6 C-C σ bonds and 1 C-C π bond*	**(1)**

Question Number	Answer	Mark
5(d)(i)	**The only correct answer is A** (50 cm^3) *B is incorrect because this is the increase in volume from 200 cm^3 of ethane* *C is incorrect because this is the volume of CO_2 formed* *D is incorrect because this is the total volume of CO_2 and H_2O formed*	**(1)**

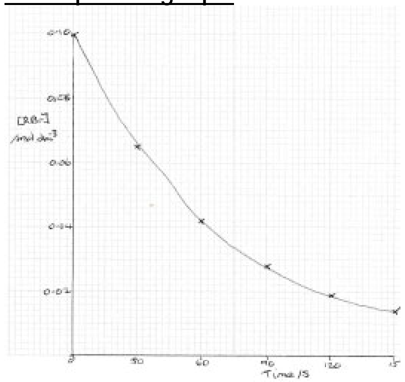
Question number	Answer	Additional Guidance	Mark
5(d)(ii)	• calculation of x **(1)** • calculation of y **(1)** • structure of cyclopentene **(1)**	<u>Example of calculation</u> (volume of CO_2 = 125 (cm^3) so x = 125/25) = 5 (25 + 25(5 + (y/4)) − 75 = 125) y = 8  Allow the skeletal formula of any cyclic C_5H_8 compound with C=C e.g. a methylcyclobutene TE on x and y for a cyclic hydrocarbon	**(3)**

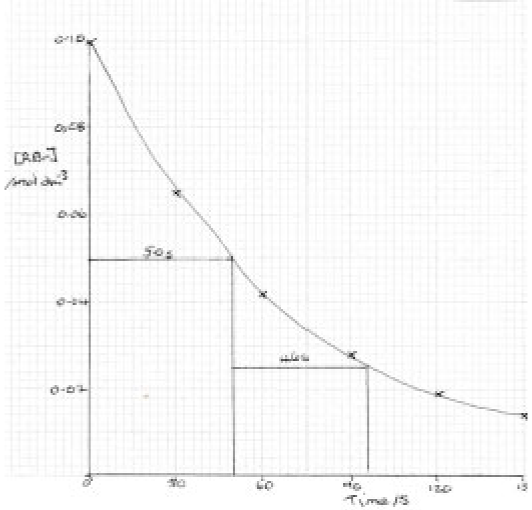
Question Number	Answer	Additional Guidance	Mark
5(e)	• dipole on I-Cl **and** correct major product **(1)** • curly arrow from C=C to I **and** curly arrow from I-Cl to, or just beyond, Cl **(1)** • intermediate **(1)** • lone pair on Cl^- **and** curly arrow from **lone pair** to C^+ **(1)**	<u>Example of mechanism</u>  Do not award $C^{\delta+}$ on intermediate Allow curly arrow from lone pair to $C^{\delta+}$ if penalised in M3 **Notes** If minor product formed, M2, M3 (with I on other carbon atom) and M4 can score If dipole shows $Cl^{\delta+}$ or no dipole shown and Cl joining first, M2 can score for curly arrow from C=C to Cl **and** curly arrow from Cl-I to, or just beyond, I and M4 can score for lone pair on I^- **and** curly arrow from lone pair to C^+	(4)

Question Number	Answer	Additional Guidance	Mark
5(f)	• calculation of moles of Br_2 **(1)** • calculation of moles of limonene **(1)** • calculation of mass of limonene **(1)** • calculation of percentage of limonene **and** answer given to 2 or 3 SF **(1)**	Example of calculation moles of $Br_2 = \frac{30.6 \times 0.200}{1000} = 0.00612$ / 6.12×10^{-3} moles of limonene = $\frac{0.00612}{2} = 0.00306$ / 3.06×10^{-3} TE on moles of Br_2 molar mass of limonene = 136 (g mol^{-1}) **and** mass of limonene in oil = 0.00306 x 136 = 0.41616 (g) TE on moles of Br_2 percentage of limonene = $\frac{0.41616}{0.500} \times 100$ (= 83.232(%)) = 83/83.2(%) TE on mass of limonene provided answer is less than 100% with 0.500 as denominator Correct answer with no working scores (4)	**(4)**

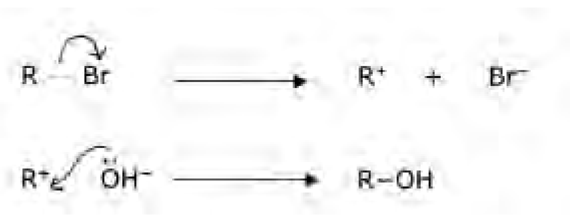
(Total for Question 5 = 15 marks)

Question Number	Answer	Additional Guidance	Mark
6(a)	An answer that makes reference to the following point: • (hydroxide ions in ethanol would give an) elimination reaction	Allow an alkene would form Ignore references to solubility in ethanol / ethanol is a (co-)solvent Ignore just 'causes another reaction'	**(1)**

Question Number	Answer	Additional Guidance	Mark
6(b)	• both axes labelled, including units **(1)** • suitable scales and points taking up at least half the graph paper in both directions **(1)** • points plotted correctly **and** smooth curve through the points **(1)**	<u>Example of graph</u>  Allow T / t for time with units Allow just 'concentration' with units Do not award RBr without square brackets Allow ± half square Do not award point-to-point straight lines	**(3)**

Question Number	Answer	Additional Guidance	Mark
6(c)	• first half-life 50 s **and** second half-life 50 s **(1)** • reaction is first order because the half-lives are (almost) the same **(1)**	<u>Example of working on graph</u>  Allow ± 6 s for both half-lives Do not award M1 if no working is shown on the graph Allow rate ∝ [RBr] / rate = k[RBr] for first order Conditional on 2 half-lives within 12 s **or** the second half-life is (about) twice the first half-life	**(2)**

Question Number	Answer	Additional Guidance	Mark
6(d)(i)	• zero (order0 / 0 (order)	Allow x = 0 / rate is proportional to $[OH^-]^0$ / rate = $k[R\text{-}Br][OH^-]^0$	**(1)**

Question Number	Answer	Additional Guidance	Mark
6(d)(ii)	• curly arrow from R-Br bond to, or just beyond, Br • **(1)** • R^+ **and** Br^- **(1)** • lone pair on O of OH^- **and** curly arrow from lone pair to R^+ **(1)**	<u>Example of mechanism</u>  Ignore dipole on RBr	**(3)**

Question Number	Answer	Additional Guidance	Mark
6(e)	An explanation that makes reference to the following points: • a racemic mixture / racemate is formed **or** equal amounts / an equimolar mixture of both optical isomers forms **(1)** • intermediate / carbocation is (trigonal) planar around the reaction site / C^+ / central carbon **(1)** • (equal probability of) attack (by nucleophile / hydroxide ions) from either side / above and below / both sides / opposite sides (of the plane) **(1)**	Allow enantiomers / D-L isomers / (+) and (-) isomers Allow the two isomers rotate the plane of plane-polarised light in opposite directions and cancel out Ignore just ‘mixture is not optically active’ / ‘mixture does not rotate the plane of plane-polarised light’ Allow the intermediate / carbocation is planar (around the reaction site) Do not award ‘the molecule is planar’	**(3)**

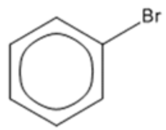
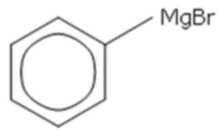
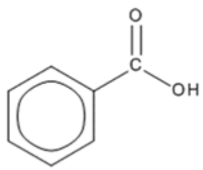
(Total for Question 6 = 13 marks)

Question Number	Answer	Additional Guidance	Mark
7(a)(i)	An answer that makes reference to the following point: • the hydride ion will not attack / will be repelled by regions of high electron density	Allow the reduction by $LiAlH_4$ is a nucleophilic addition / alkenes do not undergo nucleophilic reactions / H^- is a nucleophile Allow alkenes react with H^+ / $H^{\delta+}$ / H• Allow the hydride ion will not attack a pi-bond / C=C Allow like charges repel Ignore hydride ions cannot reduce alkenes Ignore hydride ions can only reduce carbonyl compounds	**(1)**

Question Number	Answer	Additional Guidance	Mark
7(a)(ii)	An answer that makes reference to the following points: • hydrogen / H_2 **(1)** • nickel / Ni **or** platinum / Pt / palladium / Pd **(1)**	Mark independently Ignore reference to temperature	**(2)**

Question Number	Answer	Additional Guidance	Mark
7(a)(iii)	• 1-bromobutane / $CH_3CH_2CH_2CH_2Br$	If name and formula are given, both must be correct Allow Cl or I instead of Br Allow skeletal or displayed formulae	**(1)**

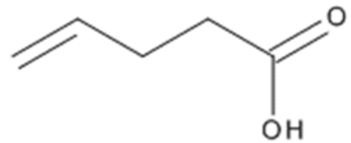
Question Number	Answer	Additional Guidance	Mark
7(a)(iv)	• hydrochloric acid / HCl / H^+	Allow any (dilute) strong acid Ignore concentration of acid Do not award any weak acid	**(1)**

Question Number	Answer	Additional Guidance	Mark
7(b)	**Step 1** • bromine **and** iron / iron(III) bromide **or** chlorine and aluminium chloride **(1)** •  **(1)** **Step 2** • magnesium **and** dry ether **(1)** •  **(1)** **Step 3** • carbon dioxide followed by a dilute acid **(1)** •  **(1)** **Step 4** • phosphorus(V) chloride / phosphorus pentachloride **(1)**	Allow names or formulae for reagents but if both are given, both must be correct Allow these drawn as a reaction scheme with reagents and conditions on arrows and intermediates in unbalanced equations The marks for the intermediate structures are stand-alone Allow carbon dioxide and dilute acid Ignore just carbon dioxide and water	**(7)**

(Total for Question 7 = 12 marks)

Question number	Answer	Mark
8(a)(i)	**The only correct answer is D** ($C_5H_8O_2$) *A is incorrect because C_7H_{16} has a molecular ion m / z = 100.1248* *B is incorrect because $C_6H_{12}O$ has a molecular ion m / z = 100.0885* *C is incorrect because $C_6H_{14}N$ has a molecular ion m / z = 100.1123*	**(1)**

Question Number	Answer	Additional Guidance	Mark
8(a)(ii)	• alkene / C=C **(1)** • carboxylic acid / COOH **(1)**	The functional groups can be in any order Ignore just 'double bond' Ignore just C=O and OH	**(2)**

Question Number	Answer	Additional Guidance	Mark
8(a)(iii)	• skeletal formula of **X**	<u>Example of skeletal formula</u>  Ignore bond lengths and bond angles	**(1)**

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>8(b)*</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><td>Number of indicative marking points seen in answer</td><td>Number of marks awarded for indicative marking points</td></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.

Comment:
Look for the indicative marking points first, then consider the mark for structure of answer and sustained line of reasoning

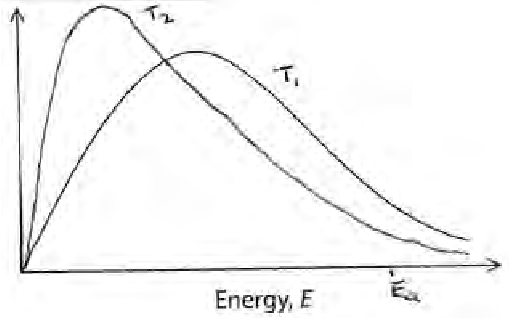
General points to note
If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).
e.g.
Mention of splitting on the ^{13}C spectra

Deduct 1 reasoning mark if the similarity in IP1 has not been explicitly mentioned

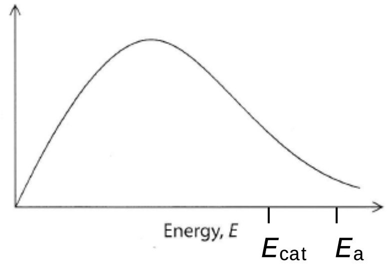
	Indicative content • **IP1 -** Similarity **both** ^{1}H NMR spectra have a peak (which is a singlet with relative peak area 1) for OH • **IP2 -** ^{13}C spectra 3 peaks for propan-1-ol **and** 2 peaks for propan-2-ol • **IP3 -** ^{1}H spectra number of peaks 4 peaks for propan-1-ol **and** 3 peaks for propan-2-ol • **IP4 -** ^{1}H spectra relative peak areas (relative) peak areas 3 : 2 : 2 : 1 for propan-1-ol, 6 : 1 : 1 for propan-2-ol • **IP5 -** ^{1}H splitting pattern for propan-1-ol 2 triplets, 1 sextet / split into 6 and 1 singlet • **IP6 -** ^{1}H splitting pattern for propan-2-ol 1 doublet, 1 septet / split into 7 and 1 singlet	All IP can be shown on clearly labelled diagrams of structures and/or spectra Allow carbon environments for peaks Ignore any reference to peak areas Allow 3 : 2 : 2 and 6 : 1 if peak areas for OH given in similarity Allow ratios in any order e.g. 1 : 2 : 2 :3 Allow hextet for sextet Ignore missing singlet if this has been given in similarity Allow heptet for septet Ignore missing singlet if this has been given in similarity	

(Total for Question 8 = 10 marks)

Question Number	Answer	Additional Guidance	Mark
9(a)(i)	• fraction / proportion / number of molecules / particles with energy, *E*	Allow fraction / proportion / number of molecules / particles Allow label written on y axis on diagram	(1)

Question Number	Answer	Additional Guidance	Mark
9(a)(ii)	• peak for T_2 to the left of T_1 **(1)** • peak for T_2 higher than T_1 **and** asymptote lower than T_1 line and not touching the x axis **(1)**	<u>Example of diagram</u>  Ignore missing label from added line Do not award M2 if added line curves upwards at the end	(2)

Question Number	Answer	Additional Guidance	Mark
9(a)(iii)	An explanation that makes reference to the following points: • (at a lower temperature the) molecules / particles / collisions have lower (kinetic) energy **(1)** • so fewer molecules / particles / collisions have energy greater than (or equal to) the activation energy / E_a **(1)**	Ignore molecules / particles move more slowly Allow fewer molecules / particles have (enough energy to overcome) the activation energy Allow this shown as labelled shading on the diagram Ignore just 'fewer successful collisions'	**(2)**

Question Number	Answer	Additional Guidance	Mark
9(a)(iv)	• E_{cat} labelled anywhere between the energy corresponding to the highest point of the peak and to the left of E_a	<u>Example of label</u>  Allow other clear labels for E_{cat}	**(1)**

Question Number	Answer	Additional Guidance	Mark
9(b)	• substitution of numbers into expression **(1)** • evaluation of k_2/k_1 or ln k_2/k_1 **and** $1/T_1 - 1/T_2$ **(1)** • rearrangement of expression **(1)** • evaluation of expression **(1)** • answer given to 2/3 SF **and** corresponding units **(1)**	Example of calculation $\ln \frac{4.87 \times 10^{-3}}{1.50 \times 10^{-3}} = \frac{-E_a}{8.31}\left(\frac{1}{338} - \frac{1}{328}\right)$ $k_2/k_1 = 3.2467$ or ln $k_2/k_1 = 1.1776$ Allow 487/150 for ln k_2/k_1 **and** $1/T_1 - 1/T_2 = (-)9.0201 \times 10^{-5}$ Allow (−)5/55432 for (−)9.0201×10^{-5} e.g. $E_a = \frac{1.1776 \times 8.31}{9.0201 \times 10^{-5}}$ or $\frac{E_a}{R} = \frac{1.1776}{9.0201 \times 10^{-5}}$ / = 13056 E_a = 108 493 TE on ln (k_2/k_1) and $1/T_1 - 1/T_2$ = (+)108 000 / 110 000 J mol^{-1} or (+)108 / 110 kJ mol^{-1} Do not award negative value Expression may be rearranged before any evaluation Correct answer to 2/3 SF and units with no working scores (5)	(5)

(Total for Question 9 = 11 marks)

Total for Paper = 90 Marks

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