Pearson Edexcel

Mark Scheme (Results)

Summer 2025

Pearson Edexcel GCE A Level
In Chemistry (9CH0)
Paper 02: Advanced Organic and Physical Chemistry

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Summer 2025
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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	Mark
1(a)	**The only correct answer is C** ($CH_2(OH)COOH$) ***A*** *is not correct because propanoic acid has a relative molecular mass of 74 and so would have a molecular ion peak with m/z = 74* ***B*** *is not correct because oxoethanoic acid has a relative molecular mass of 74 and so would have a molecular ion peak with m/z = 74* ***D*** *is not correct because methyl ethanoate has a relative molecular mass of 74 and so would have a molecular ion peak with m/z = 74*	**(1)**

Question Number	Answer	Mark
1(b)	**The only correct answer is B** (29) ***A*** *is not correct because both propanal and propanone could produce a CH_3^+ fragment with m/z = 15* ***C*** *is not correct because propanal could produce the fragment [CH_2CHO^+]and propanone could produce the fragment [CH_3CO^+] which both have m/z = 43* ***D*** *is not correct because both propanal and propanone have this $(M+1)^+$ peak which is not a fragment ion*	**(1)**

(Total for Question 1 = 2 marks)

Question Number	Answer	Mark
2(a)	**The only correct answer is A** ($(CH_3)_2CHCH_2C(CH_3)_3$) ***B*** *is not correct because this is not the most branched isomer as it only has two branches* ***C*** *is not correct because this is not the most branched isomer as it only has two branches* ***D*** *is not correct because this unbranched isomer will have the highest boiling temperature*	**(1)**

Question Number	Answer	Additional Guidance	Mark
2(b)	An explanation that makes reference to the following points: • (only) pentan-1-ol has hydrogen bonds **(1)** • (Intermolecular forces in pentan-1-ol) are stronger **and** require more **energy** to break (hence the lower volatility) **(1)**	Can be shown on a diagram for M1 Do not award reference to covalent bonding Accept answers referring to higher boiling temperature instead of lower volatility of pentan-1-ol Allow reverse argument: hexane only has London forces which are weaker than Hydrogen bonds and so require less energy to break scores 2 (Allow VdW/dispersion forces/instantaneous induced dipoles) Ignore references to permanent dipole-dipole forces	**(2)**

Question Number	Answer	Mark
2(c)	**The only correct answer is C** (London forces) ***A*** *is not correct because covalent bonds are not broken when iodine vaporises* ***B*** *is not correct because ionic bonds are not broken when iodine vaporises* ***D*** *is not correct because iodine does not have permanent dipole-dipole forces*	**(1)**

Question Number	Answer		Additional Guidance	Mark
2(d)	An explanation that makes reference to the following points:		Allow **3D** diagrams for M1 and M2	**(4)**
	• boron trichloride has a trigonal **planar** shape	**(1)**	Ignore references to VSEPR and lone pairs	
	• phosphorus trichloride has a **pyramidal** shape	**(1)**	If name and diagram given, both must be correct	
	• (because) in boron trichloride molecules the dipoles/vectors cancel / boron trichloride molecules have no dipole moment **and** Phosphorous trichloride is polar molecule/has an overall dipole	**(1)**	If diagram shown, net dipole must be clear for M3 Allow discussion about the difference in symmetry of the boron trichloride and phosphorus trichloride Do not award the charges cancel	
	• (which means) phosphorus trichloride has permanent dipole-dipole forces (between the molecules to give the higher boiling temperature)	**(1)**	Allow permanent dipole forces Ignore references to London forces	

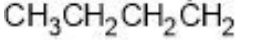
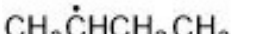
(Total for Question 2 = 8 marks)

Question Number	Answer	Mark
3(a)	**The only correct answer is C** (90.9 %) ***A*** *is not correct because this is the atom economy of one sodium stearate divided by stearin plus one sodium hydroxide which is then multiplied by 100* ***B*** *is not correct because this is the relative molecular mass of one sodium stearate divided by stearin and multiplied by 100* ***D*** *is not correct because this is the atom economy calculated for three sodium stearate molecules divided by stearin plus one sodium hydroxide*	**(1)**

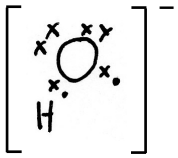
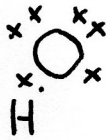
Question Number	Answer	Mark
3(b)	**The only correct answer is D** (propane-1,2,3-triol) ***A*** *is not correct because the functional group provides the suffix in the name* ***B*** *is not correct because the alcohol group positions need to be indicated by a number* ***C*** *is not correct because three alcohol or hydroxyl groups are all aggregated in the suffix 'ol' and numbered before the suffix*	**(1)**

(Total for Question 3 = 2 marks)

Question Number	Answer	Additional Guidance	Mark
4(a)(i)	• conversion of nanometres to metres **(1)** • calculation of energy of one photon **(1)** • calculation of energy per mol of photons **(1)** • comparison to Cl−Cl bond and C−H bond stating that Cl−Cl bond can be broken but not C−H bond **(1)**	Example of calculation $\lambda = 3.15 \times 10^{-7}$ m $E = ((6.626 \times 10^{-34} \times 3.00 \times 10^{8}) \div 3.15 \times 10^{-7})$ $= 6.3105 \times 10^{-19}$ (J) $E = 6.3105 \times 10^{-19} \times 6.02 \times 10^{23}$ = 379 890 (J mol^{-1}) / 379.890 (kJ mol^{-1}) TE for M1 to M3 413 > 379.890 (so) C−H (is not broken) but 379.890 > 243 (so) Cl−Cl (is broken) **Alternative approach for M3** Bond enthalpy for one C-H bond E = (413 x 1000) ÷ 6.02×10^{23} = 6.86 x 10^{-19} (J) Bond enthalpy for Cl-Cl bond E = (243 x 1000) ÷ 6.02×10^{23} = 4.04 x 10^{-19} (J)	**(4)**

Question Number	Answer	Additional Guidance	Mark
4(a)(ii)	An answer that makes reference to the following points: • primary butyl radical **(1)** • secondary butyl radical **(1)**	'dot' must be on the correct carbon atom  Allow $CH_3CH_2CH_2CH_2^{\bullet}$  Allow $CH_3CH^{\bullet}CH_2CH_3$ Penalise missing 'dot'/extra 'dot 'once only Do not allow charged ions Do not allow chlorinated radicals Allow displayed formulae	**(2)**

Question Number	Answer	Additional Guidance	Mark
4(a)(iii)	An explanation that makes reference to the following points: • 1-chlorobutane is produced from a primary radical **(1)** **and** 2-chlorobutane is produced from a secondary radical • a secondary (radical) which is more stable (than a primary (radical)) **(1)**	Penalise use of carbocation in M1 only Allow (because) of the positive inductive effect / electron-releasing effect of the two alkyl groups (rather than one), providing linked to stability Do not allow reference to stability of halogenoalkanes	**(2)**

Question Number	Answer	Additional Guidance	Mark
4(b)	An answer that makes reference to the following points: • dot-and-cross diagram of hydroxide ion **(1)** • dot-and-cross diagram of hydroxyl radical **(1)**	Example of diagrams  Allow missing brackets, but do not award omission of negative charge Allow all of the non-bonded electrons to be crosses so long as the shared pair is a dot and a cross  Allow dots and crosses to be given the 'other way around' Allow use of other symbols as long as clearly different. Allow (1) for two 'correct' diagrams with all dots or all crosses	**(2)**

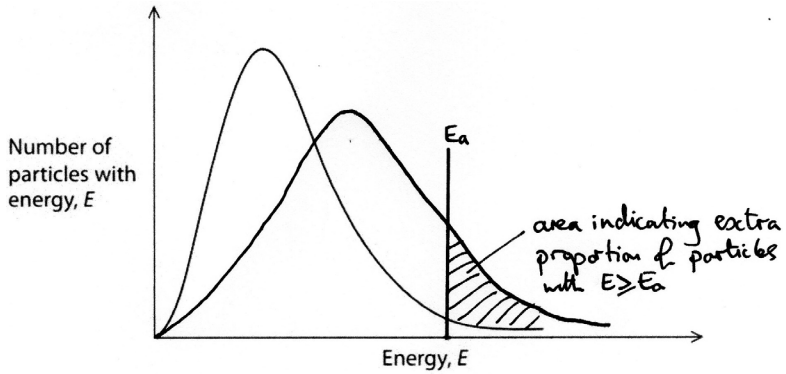
Question Number	Answer	Mark
4(c)	**The only correct answer is A** (the formation of the cyanide nucleophile from KCN) ***B*** *is not correct because the attack by the cyanide nucleophile to produce the nitrile does involve heterolytic fission of the C–Br bond* ***C*** *is not correct because the attack by the hydroxide nucleophile does involve heterolytic fission of the C–Br bond* ***D*** *is not correct because the attack by the water nucleophile does involve heterolytic fission of the C–I bond*	**(1)**

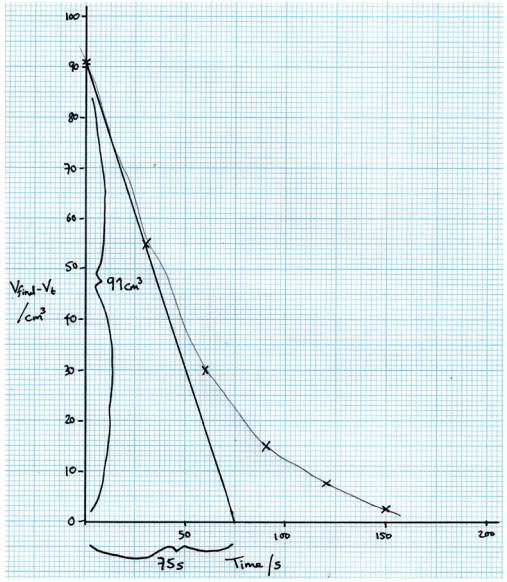
(Total for Question 4 = 11 marks)

Question Number	Answer	Additional Guidance	Mark
5(a)	• calculation of moles of calcium carbonate **(1)** • calculation of moles of hydrochloric acid **(1)** • calculation of dm^3 volume of hydrochloric acid **(1)** • conversion to cm^3 volume **and** 2/3 SF **(1)**	Example of calculation $n = (0.355 \div 100.1) = 0.0035465 / 3.5465 \times 10^{-3}$ (mol) allow use of 100 $n = (0.0035465 \times 2)$ $= 0.0070929 / 7.0929 \times 10^{-3}$ (mol) $V = (0.0070929 \div 0.100)$ $= 0.070929 / 7.0929 \times 10^{-2}$ (dm^3) $V = (0.070929 \times 1000)$ $= (70.929) = 71 / 70.9$ (cm^3) Do not award 71.0 if 100.1 has been used as M_r Ignore SF for M1 to M3 except 1 SF TE at each stage Correct answer with some (correct) working scores (4)	**(4)**

Question Number	Answer	Additional Guidance	Mark
5(b)	An answer that makes reference to the following point: • powdered carbonate has greater surface area	Allow SA for surface area Allow description of greater surface area	**(1)**

Question Number	Answer		Additional Guidance	Mark
5(c)(i)	• conversion of pressure and temperature	**(1)**	Example of calculation pressure = 1×10^5 Pa and temperature = 347.0 K	**(4)**
	• rearrangement of ideal gas equation	**(1)**	$V = \frac{nRT}{P}$ M2 may be subsumed in M3	
	• calculation of volume	**(1)**	$V = \frac{(4.19 \times 10^{-3} \times 8.31 \times 347.0)}{1 \times 10^5}$ $= 1.2082 \times 10^{-4}$ (m^3) / 121 (cm^3) Ignore units for M3, even if incorrect Ignore SF except 1 SF TE for M3	
	• Correct units for volume **and** a statement that this is not measurable as volume exceeds volume of the gas syringe	**(1)**	If no units given in M3, assume m^3 from the ideal gas equation TE on incorrect volume (< 5 cm^3) for M3, with correct units and reasonable suggestion as to why the apparatus would not give a measurable result	

Question Number	Answer	Additional Guidance	Mark
5(c)(ii)	An answer that makes reference to the following points: • line added to the right of the existing line **and** with a lower peak **(1)** • activation energy line added to the right of both line peaks **(1)** • shaded area(s) of particles $\geq E_a$, plus annotation or greater proportion of particles exceed the **activation energy** **(1)**	Do not award the line crossing the other line twice Do not award the curve crossing the x-axis Do not award a line which goes up on the right or that plateaus high above the x axis, Example of graph Note – Example below scores all three marks with no further explanation needed  Allow more molecules/particles have energy greater than the activation energy Do not award M3 if there is any reference to the activation energy decreasing/increasing Ignore 'more particles **have** the required activation energy' Ignore reference to just higher frequency of collisions	**(3)**

Question Number	Answer	Additional Guidance	Mark
5(d)	• tangent showing initial rate drawn on graph **(1)** **or** relevant working on graph • calculation of rate **with** units **(1)**	Example of graph and calculation  rate = (91 cm^3 ÷ 75 s) = 1.2133 / 1.213 / 1.21 / 1.2 cm^3 s^{-1} Allow range of 1.1 – 1.3 cm^3 s^{-1} Ignore SF except 1SF Ignore sign If no other marks awarded, allow TE from a tangent/gradient calculated at a point from any part of the curve	**(2)**

(Total for Question 5 = 14 marks)

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>*6(a)</td>
<td>
This question assesses the 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
<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained lines of reasoning</th></tr>
<tr><td>Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>
</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.

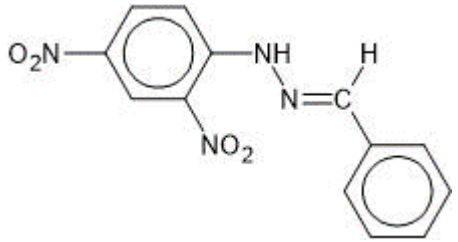
For example, a response with four indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).

If there were no linkages between the points, then the same indicative marking points would yield and overall score of 3 marks (3 marks for indicative content and zero marks for linkages).

More than one indicative marking point may be made within the same comment or explanation
</td>
<td>(6)</td>
</tr>
</table>

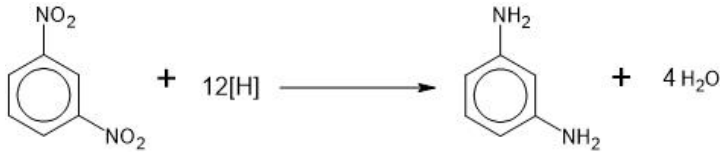
	Indicative content **For benzaldehyde** • **IP1** – Fehling's test or Benedict's test / Tollens' reagent/ acidified dichromate(VI) • **IP2 –** red **precipitate** / silver mirror/ green **For phenylethanone** • **IP3 –** Iodine and NaOH/alkaline iodine • **IP4 –** (pale) yellow **precipitate** **For benzoic acid** • **IP5** – any named carbonate/hydrogencarbonate (solution) • **IP6 –** effervescence / bubbles / fizzing	If more than one test given for a compound both/all must be correct for IP1, 3 and 5 The correct observation must match the test given for IP2, 4 and 6. The correct test must match the correct compound Allow silver precipitate/solid/mirror Allow IP2 for a 'near miss', i.e. missing 'acidified' for potassium dichromate and goes green Allow iodoform/haloform test Allow antiseptic smell Allow IP4 for 'near miss', i.e. missing alkaline or NaOH gives yellow ppt If formula given, must be correct Allow 'metal carbonate' Allow add a named alcohol (and acid) and warm (1) **and** fruity smell (1) for IP 5 and IP 6 Allow PCl_5 (1) **and** misty/steamy fumes (1) for IP 5 and IP 6 Allow IP6 for a 'near miss', i.e. add carbonate ions and bubbles of gas Ignore use of 2,4-DNP	

Question Number	Answer	Mark
6(b)(i)	**The only correct answer is B** (condensation) ***A*** *is not correct because water is not a product of an addition reaction* ***C*** *is not correct because hydrolysis involves water as a reactant and not as a product* ***D*** *is not correct because a polymer is not produced in this reaction*	**(1)**

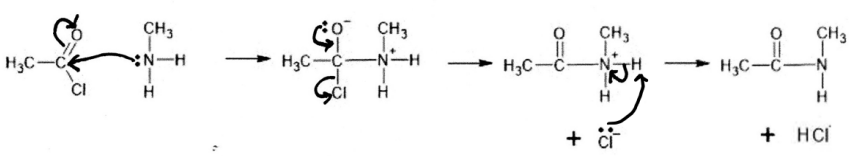
Question Number	Answer	Additional Guidance	Mark
6(b)(ii)	• structure	 Ignore connectivity of N-N bond Allow C_6H_5 for phenyl group Allow either cis or trans isomers	**(1)**

(Total for Question 6 = 8 marks)

Question Number	Answer	Additional Guidance	Mark
7(a)	An answer that makes reference to the following points: **butylamine from a halogenoalkane** • equation for making butylamine from a halogenoalkane **(1)** • (conditions of excess) ammonia **(1)** **and** alcoholic solvent and/or heat in a sealed tube • from the halogenoalkane the reaction is (nucleophilic) substitution **(1)** **butylamine from butanenitrile** • equation for making butylamine from butanenitrile **(1)** • $LiAlH_4$ **(1)** **and** (conditions of dry) ether • from the nitrile the reaction is reduction **And any one from:** • from the halogenoalkane secondary and tertiary amines will also be produced (so the yield is low) **(1)** • greater atom economy from the nitrile • only one product from the nitrile	Allow structural, displayed or skeletal throughout Reagent can be awarded from equations Penalise incorrect chain length once only **Example of equation** $C_4H_9Br + 2NH_3 \rightarrow C_4H_9NH_2 + NH_4Br$ Allow $C_4H_9Br + NH_3 \rightarrow C_4H_9NH_2 + HBr$ Accept heat under pressure Do not award reference to reflux Do not award electrophilic **Example of equation** $C_3H_7CN + 4[H] \rightarrow C_4H_9NH_2$ Accept hydrogen gas and Ni / Pd / Pt with $C_3H_7CN + 2H_2 \rightarrow C_4H_9NH_2$ Allow redox for reduction Allow hydrogenation Allow from the halogenoalkane heating in a sealed tube is difficult in practice Allow hard to exclude water when using $LiAlH_4$	**(7)**

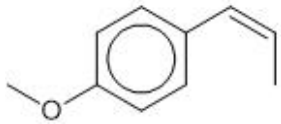
Question Number	Answer	Additional Guidance	Mark
7(b)(i)	An answer that makes reference to the following points: • correct organic species in equation **(1)** • remaining species and balancing of equation **(1)** (conditions) • tin / Sn **and** (concentrated) HCl **and** heat under reflux **(1)**	Example of equation  Allow Kekulé structures Allow $6H_2$ for 12[H] Do not allow molecular formulae for M1 Look for evidence of conditions in the equation Do not award dilute Ignore addition of NaOH to neutralise ammonium salt Allow heat or reflux Note allow other reducing reagents which would work, such as Zinc and HCl	**(3)**

Question Number	Answer	Additional Guidance	Mark
7(b)(ii)	An explanation that makes reference to the following points: • (a base) is a proton acceptor/is a lone pair donor **(1)** • propane-1,3-diamine has a lower pK_b and so is a stronger base **or** benzene-1,3-diamine has a higher pK_b so is a weaker base **(1)** • **Lone pair** of electrons on **Nitrogen** in benzene-1,3-diamine are delocalised (with the ring of electrons/ π system) **(1)** • So **lone pair** less readily available in benzene-1,3-diamine **(1)**	Ignore reference to the two amine groups Allow correct conversion to K_b with correct comment about base strength Allow Alkyl groups in propane-1,3-diamine are electron releasing. Do not award nitrogen lone pair donated into the benzene ring Penalise omission of 'lone pair' once only If no other mark scored then allow (1) for: Correct identification of the stronger base (1) **or** any reference to a (lone) pair of electrons on nitrogen atom (1) **or** availability of (lone) pair determines basicity scores (1)	**(4)**

Question Number	Answer	Additional Guidance	Mark
7(c)	An answer that makes reference to the following points: All 6 curly arrows correct scores (3) 4 or 5 curly arrows scores (2) 2 or 3 curly arrows scores (1)	<u>Example of curly arrows in mechanism</u>  Allow lone pair on chloride ion to attack either hydrogen (with the correct hydrogen removed) If dipoles given, must be correct Penalise half headed arrows once only If additional arrows added, subtract 1 for each incorrect arrow above the expected 6 arrows from the 'arrow total' before calculating score	**(3)**

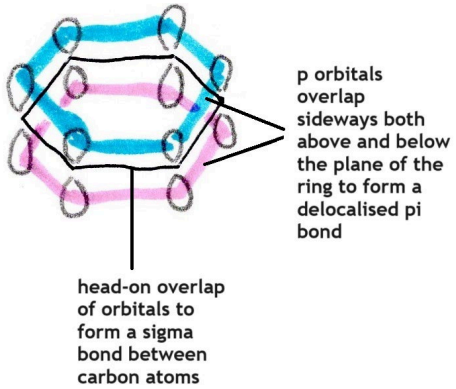
(Total for Question 7 = 17 marks)

Question Number	Answer	Additional Guidance	Mark
8(a)	• $C_{10}H_{12}O$	Accept atoms (and corresponding numbers) in any order Numbers must be sub scripts (and cannot be super scripts)	(1)

Question Number	Answer	Additional Guidance	Mark
8(b)	• structure	 Allow Kekulé structure Ignore bond lengths Do not award omission of benzene ring Accept displayed or skeletal formula	(1)

Question Number	Answer	Additional Guidance	Mark
8(c)	An answer that makes reference to the following point: • each carbon atom (in anethole) in the C=C group is bonded to two different substituents **or** one of the carbon atoms (in estragole) in the C=C group is bonded to two hydrogen atoms/same substituents	Allow both carbons of the C=C group do not have two different atoms / groups bonded to them Do not allow 'on the same side' Allow functional groups instead of substituents Ignore reference to restricted rotation about C=C	(1)

Question Number	Answer	Mark
8(d)	**The only correct answer is A** (acidified potassium manganate(VII)) ***B*** *is not correct because the nucleophilic hydroxide ions would be repelled by the C=C bond* ***C*** *is not correct because the nucleophilic hydroxide ions would be repelled by the C=C bond* ***D*** *is not correct because a diol is not formed by the addition of steam*	**(1)**

Question Number	Answer	Additional Guidance	Mark
8(e)(i)	A description that makes reference to the following points: **sigma bonds** • head on/direct overlap (between orbitals) from neighbouring carbon atoms to form a sigma bond **(1)** **π-bonds** • (perpendicular) p orbitals overlap sideways (to form the π-bonds) **(1)** • so (p orbital electrons) form a delocalised π system/ring system **(1)**	Evidence for all marking points may be given in an annotated diagram Allow sp^2 hybrid orbitals overlap to form a sigma bond <u>Example of diagram</u>  	**(3)**

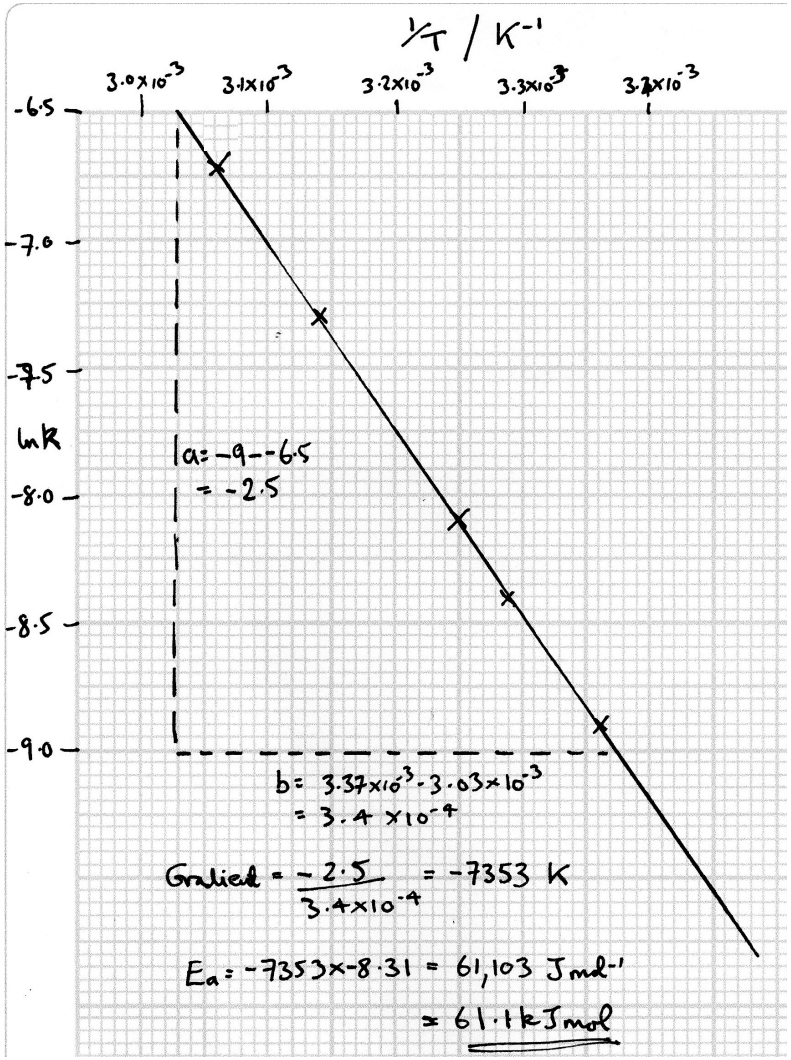
Question Number	Answer	Additional Guidance	Mark
8(e)(ii)	An explanation that makes reference to the following points: **Thermodynamic measurement** • the enthalpy of **hydrogenation** for the Kekulé structure would be (three times) greater than that of cyclohexene **(1)** **or** if values given (-208 $KJmol^{-1}$ for benzene and -360 $KJmol^{-1}$ for Kekulé) • (so) in the delocalised model it is more (energetically) stable/is more accurate **(1)** **Physical measurement** • (X-ray measurements would show that) **carbon-carbon** bond lengths are different in the Kekulé structure **(1)** • (but) in the delocalised model the bond lengths are all equivalent **(1)**	Allow use of enthalpy level diagrams for M1 and M2 Allow enthalpy of **combustion/hydrogenation** for Kekulé structure would be more exothermic than that of benzene Allow enthalpy of **formation** for Kekulé is more endothermic/less exothermic than of benzene Do not allow reference to less / smaller / lower M2 depends on M1 or near miss, i.e. use of less/smaller/lower Allow reference to forming a regular/perfect hexagon	**(4)**

Question Number	Answer	Additional Guidance	Mark
8(f)	An answer that makes reference to the following points: • anethole is soluble in ethanol **(1)** • anethole is less soluble/slightly soluble in water **(1)** And any one from: **(1)** • anethole is more attracted to the non-polar part/ethyl of the ethanol molecule than water • anethole forms greater intermolecular/London forces with ethanol than water • structures of anethole and ethanol are more similar (than anethole and water) • anethole forms hydrogen bonds with water less readily (than with ethanol)	Ignore reference to hydrogen bonds Allow anethole is more soluble in ethanol than in water scores M1 and M2 Allow anethole is insoluble in water Or reverse argument (ORA)	**(3)**

Question Number	Answer	Mark
8(g)	**The only correct answer is B** (6) ***A*** *is not correct because there are four non-equivalent carbon atoms in the ring and not three* ***C*** *is not correct because there are four non-equivalent carbon atoms in the ring and not five* ***D*** *is not correct because not all of the carbon atoms in the ring are non-equivalent*	**(1)**

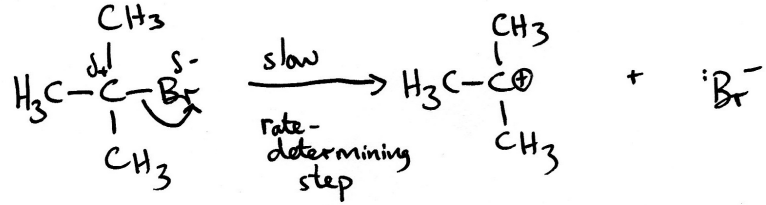
(Total for Question 8 = 15 marks)

Question Number	Answer	Additional Guidance	Mark
9(a)(i)	An answer that makes reference to the following points: • temperature value **(1)** • rate constant value **(1)**	 304 (K) 2.25×10^{-4} Penalise non-3SF values once only 303.95 and 2.2487×10^{-4} scores (1)	**(2)**

Question Number	Answer	Additional Guidance	Mark
9(a)(ii)		Example of suitable graph 	(5)

	• axes: correct way round and in the correct direction, labelled with units	**(1)**	Do not award 1/*t* for 1/*T*	
	• all points plotted correctly, with best-fit straight line and suitable scale	**(1)**	Allow ± ½ square Plotted points must cover at least ½ the graph paper on each axis	
	• calculation of gradient	**(1)**	Gradient = (−) 7353 Allow ± 400	
	• sign **and** units of gradient	**(1)**	− and *K* **Stand alone mark**	
	• use of gradient to calculate activation energy	**(1)**	E_a = − (−7353 × 8.31) ÷ 1000 = (+) 61.1 (kJ mol^{-1}) Allow ± 4 If no units, assume kJ mol^{-1}. Allow answer in J mol^{-1} providing units given Ignore SF except 1 SF TE on numerical value of gradient Do not award negative final value	

Question Number	Answer	Additional Guidance	Mark
9(a)(iii)	An explanation that makes reference to the following points: • rate ÷ *k* gives $mol^2\ dm^{-6}$ **(1)** • which is **units** of concentration squared (meaning second order) **(1)** Alternative approach • **units** of concentration squared (as a second order reaction) **(1)** • rate ÷ $[mol^1dm^{-3}]^2$ = k **(1)**		**(2)**

Question Number	Answer	Additional Guidance	Mark
9(b)(i)	(step 1) • dipole on C–Br bond and curly arrow from bond to, or just beyond the Br **(1)** • structure of carbocation intermediate and Br^- **(1)** (step 2) • curly arrow from lone pair on oxygen of hydroxide ion to the positively charged carbon of the intermediate **(1)**	Example of suitable mechanism  Allow structural/skeletal or combination If S_N2 given, award M1 only if correct dipole and curly arrow correct Ignore missing lone pair on Br^- Br^- can be shown in either the intermediate stage or the final products	**(3)**

Question Number	Answer	Additional Guidance	Mark
9(b)(ii) **Clip with (b)(i)**	An answer that makes reference to the following point: • step 1 identified as RDS **and** hydroxide ions do not appear in step 1	Note: Look at the mechanism in (b)(i) for evidence of the correct RDS, but must state hydroxide ions do not appear in step 1 Accept slow step	**(1)**

(Total for Question 9 = 13 marks)

TOTAL FOR PAPER = 90 MARKS

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