Mark Scheme (Results)

Pearson Edexcel Advanced Level In Chemistry (9CH0) Paper 02 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.
- 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	Answer	Mark
1(a)(i)	**The only correct answer is B** (2-methylpentan-2-ol) **A** *is not correct because it is a secondary alcohol* **C** *is not correct because it is a secondary alcohol* **D** *is not correct because it is a secondary alcohol*	**(1)**

Question Number	Answer	Mark
1(a)(ii)	**The only correct answer is A** (hexan-2-ol) **B** *is not correct because it is a tertiary alcohol* **C** *is not correct because it does not contain a* CH_3CHOH *group* **D** *is not correct because it does not contain a* CH_3CHOH *group*	**(1)**

Question Number	Answer	Mark
1(b)	**The only correct answer is A** (red phosphorus) **B** *is not correct because it will not form iodoalkanes with iodine and alcohols* **C** *is not correct because it will not form iodoalkanes with iodine and alcohols* **D** *is not correct because it will not form iodoalkanes with iodine and alcohols*	**(1)**

(Total Question 1 = 3 marks)

Question Number	Answer	Mark
2(a)	**The only correct answer is A** (4-ethyloctane) *B is incorrect because the position of the ethyl group should be shown by counting in the direction that gives the lowest possible number* *C is incorrect because the longest carbon chain has 8 carbons* *D is incorrect because the longest carbon chain has 8 carbons and because the position of the alkyl group should be shown by counting in the direction that gives the lowest possible number*	**(1)**

Question Number	Answer	Mark
2(b)	**The only correct answer is D** (cracking) *A is incorrect because substitution would exchange atoms/groups in the reactant for other atoms/groups* *B is incorrect because reforming would produce branched/cyclic alkanes* *C is incorrect because fractional distillation would separate a mixture of alkanes*	**(1)**

Question Number	Answer	Mark
2(c)(i)	**The only correct answer is C (homolytic bond fission to form free radicals)** *A is incorrect because such bond fission would produce ions* *B is incorrect because the first step of the reaction produces free radicals by homolytic fission* *D is incorrect because the first step of the reaction produces free radicals*	**(1)**

Question Number	Answer	Additional Guidance	Mark
2(c)(ii)	122.9æ(122.9 + 80.9) x 100 **or** 122.9æ(44.0 + (2 x 79.9)) x 100 **or** (122.9æ203.8) x 100 (1) = 60.304% (1)	Allow 123æ(123+81) = 60.29% Award M1 only if final answer given as decimal 0.603 rather than % Allow TE for M2 for only one incorrect A_r value Ignore SF Correct answer with or without working scores (2)	**(2)**

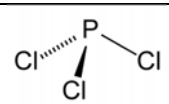
Question Number	Answer	Mark
2(c)(iii)	**The only correct answer is D** (the reaction produces a mixture of organic products) *A is incorrect because bromine is very reactive* *B is incorrect because gaseous reactants do not necessarily give a poor yield* *C is incorrect because the kinetics of the reaction do not affect the yield*	**(1)**

Question Number	Answer	Additional Guidance	Mark
2(c)(iv)	Amount of 1-bromopropane (1) So moles of propane required (1) So volume of propane required to 2 or 3 SF (1) **Alternative route** Target mass of 1-bromopropane required to produce 14.7 g (with a 31.0% yield) (1) Moles of propane required to produce the required mass of 1-bromopropane (1) So volume of propane required to 2 or 3 SF (1)	14.7/122.9 = 0.11961 (mol) (0.11961/31) x 100 = 0.38584 (mol) = 0.38584 x 24.0 = 9.2601 (dm^3) = 9.3 / 9.26 (dm^3) Allow 14.7/123 = 0.11951 (mol) (0.11951/31) x 100 = 0.38552 (mol) = 0.38552 x 24.0 = 9.2526 (dm^3) = 9.3 / 9.25 (dm^3) 14.7 x $\frac{100}{31.0}$ = 47.4 g $\frac{47.4}{122.9}$ = 0.3857 (mol) 0.3857 x 24.0 = 9.3 / 9.26 (dm^3) Award (2) for a final answer of 0.890 / 0.89 (dm^3) (incorrect use of 31.0%) Answer assuming 100% yield scores (2) for final answer of 2.87 / 2.9 (dm^3) Penalise incorrect units in M3 Do not award M3 if Ideal Gas Eqtn used for propane volume Penalise incorrect rounding once only **Correct answer to 2 or 3 SF with or without working scores (3)**	**(3)**

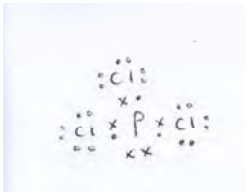
(Total Question 2 = 9 marks)

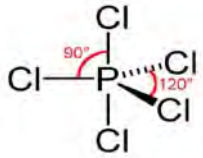
Question Number	Answer	Additional Guidance	Mark
3(a)(i)	An explanation that makes reference to • **M1** PCl_3 is (trigonal) pyramidal (1) • **M2** has 3 bond pairs and 1 lone pair (around central P atom) (1) • **M3** electron pairs repel to positions of minimum repulsion / maximum separation (1)	Marking points 1 and 2 may be shown on diagrams (see below) Award M1 for correct name of shape even if diagram(s) incorrect Ignore lone pair – bond pair repulsions > bond pair – bond pair repulsions Answer must state or imply somewhere that (electron) pairs repel Do not award if specifically stated that 'bonds repel' or 'atoms repel' Ignore any references to bond angles even if incorrect	**(3)**

Example of diagram for award of M1 (a lone pair may also be shown on the P atom)



Example of diagram for award of M2
(must show 3 bond pairs and 1 lone pair)



Question Number	Answer	Additional Guidance	Mark
3(a)(ii)	• **M1** Diagram showing trigonal bipyramidal shape, with 3D emphasised by use of two wedges or one hatch and one wedge in the central plane (1) • **M2** 90˚ and 120˚ angles labelled (1) • **M3** trigonal bipyramidal (1)	 M2 dependent on correct M1 Ignore 180° Do not award M2 if any incorrect bond angle is shown M3 stand alone mark Both words required Award “trigonal bipyramid”	(3)

Question Number	Answer	Additional Guidance	Mark
3(a)(iii)	An answer that makes reference to the following points: • phosphorus can expand its octet / can expand its (outer) shell / can accommodate more than 8 electrons / can accommodate 10 electrons / has available (3d-) orbitals (for promotion of electrons) (1) • nitrogen does not have (2)d-orbitals / can only accommodate eight electrons (in its outer shell) (1)	**Comment** Award reference to P accommodating 18 electrons Ignore comparisons of size / radius of P and N atoms	(2)

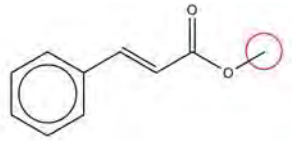
Question Number	Answer	Additional Guidance	Mark
3(b)	An explanation that makes reference to the following points: • **M1** London forces are greater in NCl_3 (1) • **M2** as NCl_3 has more electrons / as Cl (atom) has more electrons (than F atom) (1) • **M3 (**permanent) dipole-dipole forces / "permanent dipoles" / "dipole forces" stronger in NF_3 (than NCl_3) (1) • **M4** as F is more electronegative than Cl (1) • **M5** **either** London forces predominate / London forces are more significant **or** more (heat) energy needed to overcome the intermolecular forces between NCl_3 molecules (than NF_3 molecules) (1)	Allow reverse arguments Award van der Waals' / induced dipole etc Award NCl_3 has 58 electrons whereas NF_3 has 34 electrons Ignore comparisons of M_r Do not award M2 if comparison of "**ionic** radii" Award for M3 (permanent) dipole-dipole forces only in NF_3 Electronegativity difference 1.0 between N and F / No electronegativity difference between N and Cl / N-F is a more polar bond than N-Cl Award (0) for M5 if any mention of: Ionic bonds breaking in either NF_3 or NCl_3 **Breaking of** N-F and / or N-Cl covalent bonds scores (0) for M5 Note If hydrogen bonding mentioned, can only award M1, M2 and M5 max Ignore polarisation of ions	**(5)**

Question Number	Answer	Mark
3(c)	**The only correct answer is B** (propan-1-ol) **A** *is not correct because it does not give hydrogen chloride when PCl_5 is added* **C** *is not correct because it does not give hydrogen chloride when PCl_5 is added* **D** *is not correct because it does not give hydrogen chloride when PCl_5 is added*	**(1)**

(Total Question 3 = 14 marks)

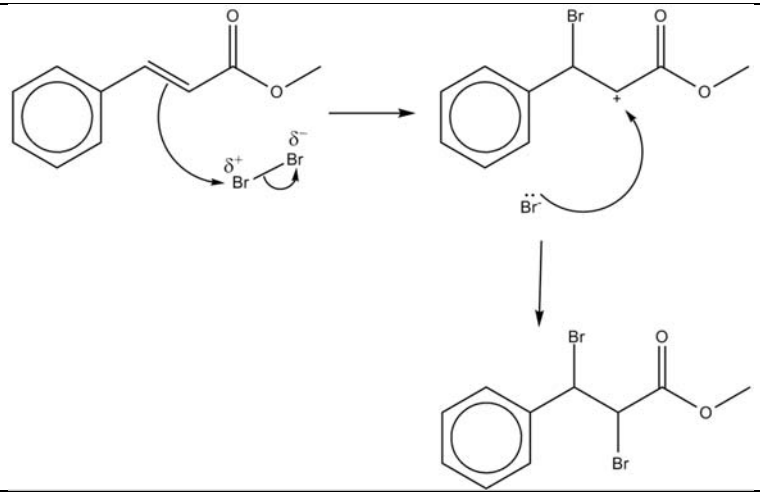
Question Number	Answer	Additional Guidance	Mark
4(a)	• calculation of molar mass of methyl cinnamate (1) • calculation of mass of carbon (1)	Example of calculation molar mass = 162 (g mol^{-1}) 2.34 x (120/162) = 1.73333 = 1.73 (g) TE on incorrect molar mass for M2 **Correct answer with no working scores 2 marks** Ignore SF except 1	**(2)**

Question Number	Answer	Additional Guidance	Mark
4(b)(i)	An answer that makes reference to the following points: • peak due to tetramethylsilane (1) • so (chemical) shifts (due to other hydrogen atoms) can be compared (1)	Allow TMS / $Si(CH_3)_4$ Name must be correct if given Allow "a reference" / "a standard" "calibration" Ignore "to allow other molecules to be compared"	**(2)**

Question Number	Answer	Additional Guidance	Mark
4(b)(ii)	An answer that makes reference to the following points: • **M1** circle around $-CH_3$ group in $-OCH_3$ (1) • **M2** singlet as no neighbouring hydrogen atoms (1) • **M3** peak area of 3 means there are 3 hydrogen atoms in this environment (1)	Allow 'protons' for hydrogen atoms  Award whole $-OCH_3$ circled Do not award if C=O included in circle M1 is a stand alone mark Award "has no adjacent hydrogen atoms" Award "no hydrogens on adjacent carbon" Ignore "there is no adjacent C atom" Award "(relative) peak area of three for a $-CH_3$ group" For M3 must relate to (relative) peak area / integral Ignore references to chemical shift value for ester δ = 3.0 to 4.0 (ppm) Ignore references to relative heights of peaks **Comment** M2 and / or M3 dependent on $-CH_3$ group being included in the circled group	**(3)**

Question Number	Answer	Additional Guidance	Mark
4(c)(i)	• **M1** arrow from double bond to (δ+)Br in Br_2 (1) • **M2** arrow from bond in Br_2 to $Br^{\delta-}$ (1) • **M3** structure of carbocation (1) • **M4** arrow from **lone pair** on Br^- to C^+ in carbocation **and** final product (1)	Example of mechanism **See below** Penalise lack of dipole only once in M1 and M2 Award C^+ in intermediate on either C from the double bond Do not award M3 if four bonds are shown on carbocation Br atoms can be shown either upwards or downwards in final product Award (0) if just electrophilic substitution mechanism given. If **both** electrophilic substitution and addition shown allow 2 max Penalise errors in structure of methyl cinnamate once only in either M3 or M4 Do not award **M4** if the two Br atoms have been added to the same carbon atom in the addition product Penalise use of half arrows once only	**(4)**

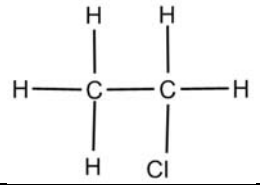
Example of mechanism

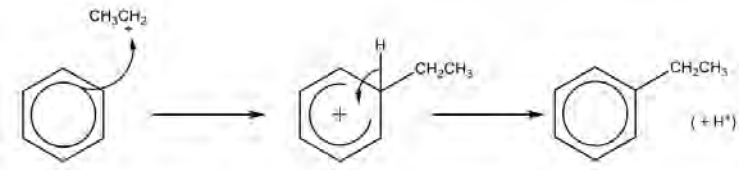


Question Number	Answer	Mark
4(c)(ii)	**The only correct answer is C** (4) **A** *is not correct because 2 chiral centres form in reaction, so 4 possible combinations of +/- forms* **B** *is not correct because 2 chiral centres form in reaction, so 4 possible combinations of +/- forms* **D** *is not correct because 2 chiral centres form in reaction, so 4 possible combinations of +/- forms*	**(1)**

Question Number	Answer	Mark
4(c)(iii)	**The only correct answer is D** (rotated) **A** *is not correct because diffracted is the wrong term* **B** *is not correct because reflected is the wrong term* **C** *is not correct because refracted is the wrong term*	**(1)**

(Total Question 4 = 13 marks)

Question Number	Answer	Additional Guidance	Mark
5(a)(i)		Do not award skeletal or structural formulae	(1)

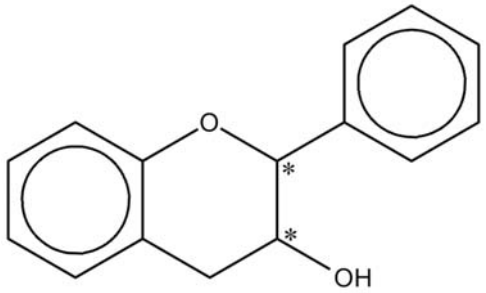
Question Number	Answer	Additional Guidance	Mark
5(a)(ii)	• **M1 equation** to show formation of electrophile (1) • **M2** curly arrow from anywhere on the central ring to positive carbon (1) • **M3** structure of intermediate (1) • **M4** curly arrow from C-H bond to reform the ring (1) • **M5 equation** showing regeneration of catalyst (1)	Example of mechanism Penalise incorrect halogenoalkane in (a)(i) only $CH_3CH_2Cl + AlCl_3 \rightarrow CH_3CH_2^+ + AlCl_4^-$ Ignore any curly arrows given in the equation Allow curly arrow from anywhere within the hexagon Do not award if curly arrow to CH_3 carbon in $CH_3CH_2^+$ Do not award if curly arrow to $C_2H_5^+$ Horseshoe facing the tetrahedral carbon and covering at least three carbon atoms Some part of the positive charge in the horseshoe Do not award dotted lines unless clearly part of a 3D structure $AlCl_4^- + H^+ \rightarrow AlCl_3 + HCl$ Ignore regeneration step if part of the mechanism **Mechanism**  Allow TE from (a)(i)	(5)

Question Number	Answer	Additional Guidance	Mark
5(a)(iii)	An explanation that makes reference to the following points: Phenol is likely to be more reactive because • **M1 lone pair** on **oxygen** (atom of –OH group) delocalises / is incorporated into the (benzene) ring / donated to the ring (1) • **M2** which increases the electron density (of the ring) (1) • **M3** making the ring / phenol more susceptible to electrophilic attack (1)	Do not award M2 if mention of "charge density" / "electronegativity" Ignore references to "the ring becomes more negative" Award "making the ring more nucleophilic" / "making the ring more susceptible to attack by a positive ion" Ignore references to "activation of the ring "	**(3)**

Question Number	Answer	Additional Guidance	Mark
5(b)	• **M1** conversion of pressure and temperature (1) • **M2** conversion of volume units (1) • **M3** rearrangement of gas equation and calculation of *n* (1) • **M4** calculation of the molar mass with the final answer given to **2 or 3 SF** (1)	Example of calculation 118 000 (Nm^{-2}) and 438 (K) 70.5×10^{-6} / 7.05×10^{-5} (m^3) $n = \frac{pV}{RT}$ $n = \frac{(118000 \times 70.5 \times 10^{-6})}{(8.31 \times 438)}$ $n = 2.2855777 \times 10^{-3}$ (mol) $\frac{0.271}{2.2855777 \times 10^{-3}}$ = 118.5696 = 119 / 120 (g mol^{-1}) If use $M_r = \frac{mRT}{pV}$ (since $n = \frac{m}{M_r}$) can score both **M3 and M4** $M_r = \frac{0.271 \times 8.31 \times 438}{118\,000 \times 70.5 \times 10^{-6}}$ M_r = 118.5695 M_r = 119 / 120 (g mol^{-1}) Award TE at each stage Ignore units even incorrect	**(4)**

Question Number	Answer	Additional Guidance	Mark
5(c)	An explanation that makes reference to the following points: EITHER • retention time depends on the polarity **or** attraction / affinity / solubility / of the component for the stationary phase (1) • The greater attraction / affinity / solubility / of the component for the stationary phase the greater the retention time (1) OR • retention time depends on the boiling temperature of the compound (1) • higher boiling temperature compounds spend less time in the gas phase / mobile phase so have longer retention time (1)	Allow 'solid phase' or 'liquid phase' for 'stationary phase' Allow 'retention time depends interaction with stationary phase' Ignore attractions to the mobile / gas phase Ignore comments related to mass of compounds	**(2)**

(Total Question 5 = 15 marks)

Question Number	Answer	Additional Guidance	Mark
6(a)			**(1)**

Question Number	Answer	Additional Guidance	Mark
6(b)	$C_{15}H_{14}O_2$	Allow symbols in any order e.g. $H_{14}O_2C_{15}$	**(1)**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>*6(c)</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><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
<table>
<tr><td></td><td>Number of marks awarded for structure of answer and sustained lines of reasoning</td></tr>
<tr><td>Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</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).

Typically

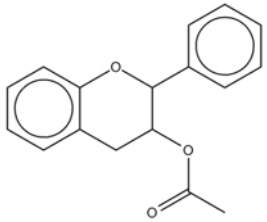
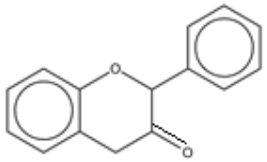
Number of IPs Reasoning mark

6 or 5 scores 2

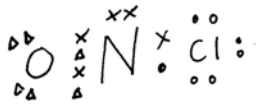
4 or 3 scores 1

2 or 1 or 0 scores 0
</td>
<td>(6)</td>
</tr>
</table>

	Answer is partially structured with some linkages and lines of reasoning	1		
	Answer has no linkages between points and is unstructured	0		

	Indicative content • **IP1** any mention of **oxidation** of ethanol **or oxidation** of flavan-3-ol (by oxygen in the air) • **IP2** for formation of **either** ethanoic acid **or** ethanal (from ethanol) • **IP3** for formation of ethyl ethanoate (from the reaction between ethanol and ethanoic acid) • **IP4** for structure / name of flavan-3-one • **IP5** for (-OH group on) flavan-3-ol forms an ester with ethanoic acid • **IP6** correct structure of the ester formed between flavan-3-ol and ethanoic acid  **This is the structure of the ester formed between flavan-3-ol and ethanoic acid**	Allow names or formulae **but** if both are given **both** must be correct  **Comment** For correct structure of the ester formed between flavan-3-ol and ethanoic acid award both **IP5** and **IP6** Do not award IP4 if the product is described as an aldehyde	

(Total Question 6 = 8 marks)

Question Number	Answer	Additional Guidance	Mark
7(a)	• electrons for double bond, single bond and lone pair around N (1) • rest of electrons on Cl and O (1)	Example of dot-and-cross diagram  Allow any combination of dots/crosses/triangles for electrons Allow bond pairs in double bond shown horizontally Ignore lines drawn between atoms to show covalent bonds	**(2)**

Question Number	Answer	Additional Guidance	Mark
7(b)(i)	• concentration of NO in experiment 2 (1) • concentration of Cl_2 in experiment 3 (1)	Example of calculation 0.244 0.121 Do not award 0.1205 **Both** values must be to **3SF**	**(2)**

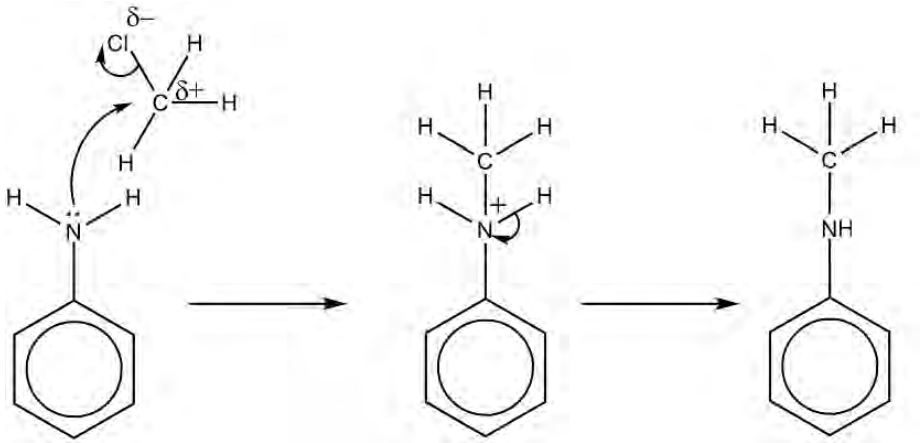
Question Number	Answer	Additional Guidance	Mark
7(b)(ii)	• **M1** rearrangement of rate equation to find *k* (1) • **M2** calculation of *k* (1) • **M3** correct units for *k* (1)	Example of calculation *k* = rate / $[NO]^2[Cl_2]$ 1.09×10^{-2} / $(0.122 \times 0.122 \times 0.241)$ =3.03871 = 3.04 Ignore SF Correct numerical answer for *k* scores both M1 and M2 $dm^6\ mol^{-2}\ s^{-1}$ Allow units in any order M3 stand alone mark	**(3)**

Question Number	Answer	Additional Guidance	Mark
7(b)(iii)	An explanation that makes reference to the following points: *k* increases because • the catalyst provides an alternative pathway of lower activation energy (1) • so a greater proportion of molecules / more molecules have energy greater than the activation energy (so faster reaction) (1)	Award 'particles' instead of 'molecules' Do not award "atoms" instead of 'molecules'	**(2)**

Question Number	Answer	Additional Guidance	Mark
7(b)(iv)	An explanation that makes reference to the following points: Catalysts will be less effective because • **M1** impurities **ad**sorb onto (catalyst) surface **or** impurities occupy active sites **or** impurities bond / bind to (catalyst) surface (1) • **M2** impurities prevent bond weakening in the reactants **or** less surface area (of catalyst) / fewer active sites available for reaction (1) • **M3** impurities form strong bonds (to surface) **or** impurities less likely to desorb (from surface) (1)	Do not award "**<u>ab</u>**sorb" for M1 Ignore impurities "react" Allow 'no active sites available' Allow 'impurities remain on surface'	**(3)**

(Total Question 7 = 12 marks)

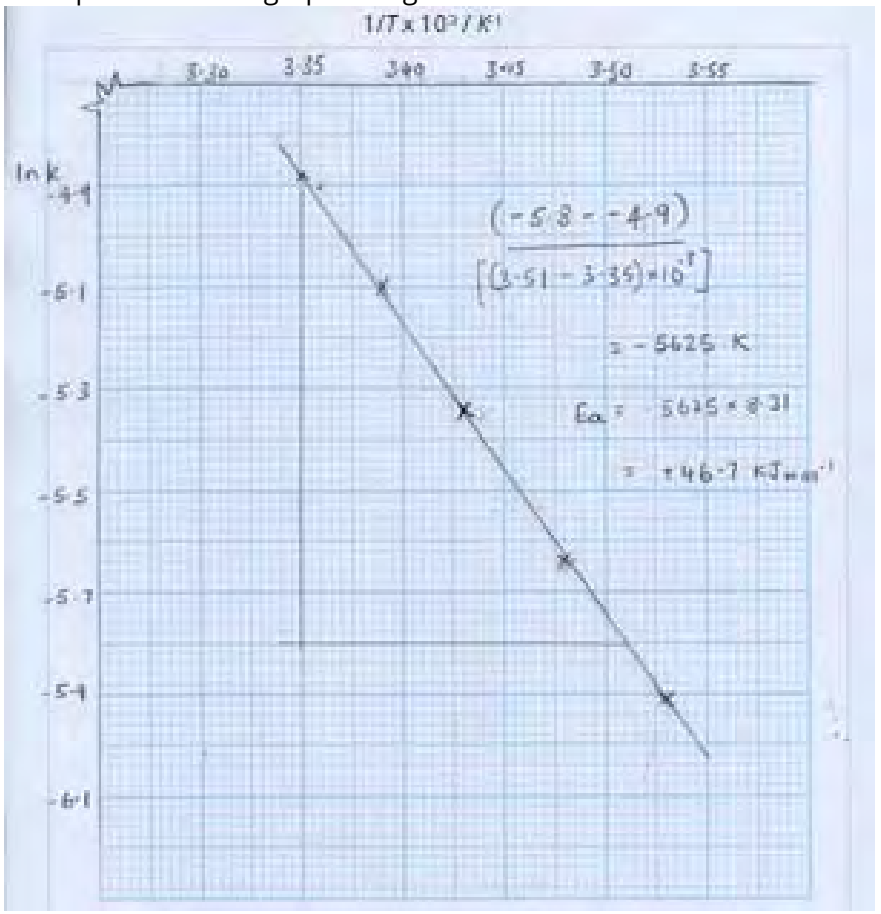
Question Number	Answer	Mark
8(ai)	**The only correct answer is D** (nucleophilic substitution) **A** *is not correct because it is not electrophilic or addition* **B** *is not correct because it is not electrophilic* **C** *is not correct because it is not addition*	**(1)**

Question Number	Answer	Additional Guidance	Mark
8(a)(ii)	• **M1** arrow from lone pair on nitrogen atom to carbon atom (1) • **M2** dipole shown **and** arrow from C–Cl bond to Cl or just beyond (1) • **M3** formula of intermediate including the **+** charge on the N atom (1) • **M4** arrow from N-H bond to N^+ and formula of organic product (1)	<u>Example of mechanism</u>  (+ H^+ / HCl) **Comment** M2 is a stand alone mark Allow access to full marks for correct use of other halogenomethanes Ignore any SN2 transition states Ignore use of a second molecule of phenylamine behaving as a base	**(4)**

Question Number	Answer	Additional Guidance	Mark
8(a)(iii)	An answer that makes reference to the following points: • **M1** dissolve (impure product) in a **minimum** volume of **hot** solvent (1) • **M2** cool (in ice) **or** leave to recrystallise (1) • **M3** filter using vacuum filtration / Buchner filtration / filter under suction (1) • **M4** dry solid in desiccator / between filter papers (1)	Allow any named solvent Ignore hot filtration after M1 Allow dry in a **warm** oven Ignore references to rinsing Do not award M4 if drying agent added to the crystals / solution	**(4)**

Question Number	Answer	Additional Guidance	Mark
8(b)(i)	• calculation of missing 1/*T* value **and** calculation of missing ln *k* value	<u>Example of calculation</u> 3.43×10^{-3} -5.64 Ignore SF	**(1)**

Question Number	Answer	Additional Guidance	Mark
8(b)(ii)	• **M1** axes correct way round and labelled with units on *x*-axis (1) • **M2** suitable scale, must be uniform (1) • **M3** all points plotted correctly, with straight line of best fit (1) • **M4** calculation of gradient, including minus sign (1) • **M5** units of gradient (1) • **M6** calculation of activation energy with units (1) **Comment** If ln*k* plotted with most negative value at the top or -ln*k*, then all marks can still be scored, but gradient should still be negative	<u>Example of calculation and graph</u> award 1/T x 10^3 / K^{-1} **or** 1/T / 10^{-3} K^{-1} or 1/T / K^{-1} (10^{-3}) Do not award 1/T x 10^{-3} / K^{-1} Do not award **M1** if units given for ln *k* on *y*-axis Do not award small "t" for "T" Points must cover at least half the graph paper in each direction -5775 (± 400) Award gradient value between -5375 to -6175 **K** (+)48.0 / (+)48 kJ mol^{-1} ; allow TE for gradient outside range Award E_a values (+)44.7 to (+)51.3 kJ mol^{-1} Award E_a if correct in J mol^{-1} Do not award M6 if given in just "kJ" or "J" Ignore SF Do not award M6 if final answer is a negative E_a value See next page for graph **Comment** If 1/*T* (*y*-axis) plotted against ln *k* (*x*-axis) Can only award **M2, M3** and TE for **M4** If either or both variables incorrect, then only **M2** can be scored	**(6)**

		Example of suitable graph and gradient  	

(Total Question 8 = 16 marks)
TOTAL FOR PAPER = 90 MARKS

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