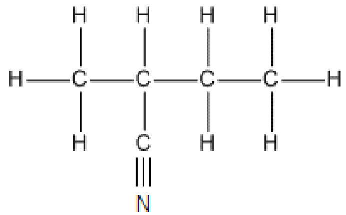
Question Number	Acceptable Answer	Additional Guidance	Mark
1(a)(i)	NH_3	Do not allow just the name ammonia	**1**

Question Number	Acceptable Answer	Additional Guidance	Mark
1(a)(ii)		Do not award skeletal/structural formulae or a combination of these	**1**

Question Number	Answer	Additional Guidance	Mark
1(b)	**A** (the C-Cl bond has a higher bond enthalpy than the C-Br bond)		**1**

Question Number	Acceptable Answer	Additional Guidance	Mark
1(c)(i)	An answer that makes reference to the following points: • hydroxide ions are nucleophiles as they donate a (lone) pair of electrons (to form a covalent bond) (1) • substitution because OH replaces the halogen atom (in the molecule) (1)		**2**

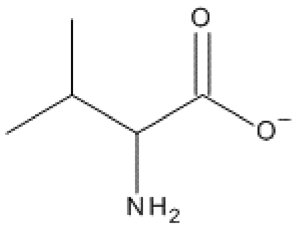
Question Number	Answer	Additional Guidance	Mark
1(c)(ii)	**D** (2-bromo-2-methylpropane, 2-bromobutane, 1-bromobutane)		**1**

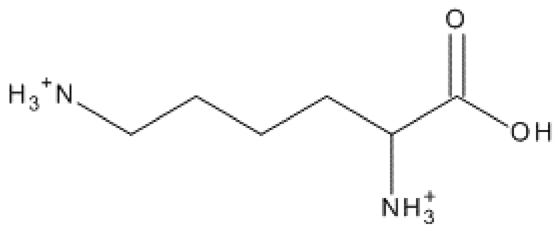
Question Number	Acceptable Answer	Additional Guidance	Mark
1(c)(iii)	An answer that makes reference to the following points: • rate = k[$(CH_3)_3CBr$] / rate = k[$(CH_3)_3CBr$]^1 (1) • only the reactants/$(CH_3)_3CBr$ in the slow/rate determining step appear in the rate equation (1)		**2**

(Total for Question 1 = 8 marks)

Question Number	Answer	Additional Guidance	Mark
2(a)	**B** (hydrolysis of butanenitrile with dilute hydrochloric acid)		**1**

Question Number	Answer	Additional Guidance	Mark
2(b)	**D** (CH_3COCl and $CH_3CH_2CH_2OH$)		**1**

Question Number	Acceptable Answer	Additional Guidance	Mark
2(c)(i)		Do not award displayed or structural formulae	**1**

Question Number	Acceptable Answer	Additional Guidance	Mark
2(c)(ii)	 **both** NH_2 groups must be protonated for the mark	Do not award displayed or structural formulae	**1**

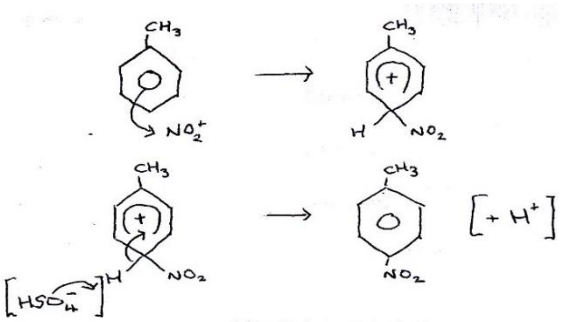
Question Number	Acceptable Answer	Additional Guidance	Mark
2(d)(i)	An answer that makes reference to the following points: • to separate (the esters)		**1**

Question Number	Acceptable Answer	Additional Guidance	Mark
2(d)(ii)	An answer that makes reference to the following points: • to identify (the esters) (by determining the M_r / measuring the molecular ion's *m*/*z* to 4 dp / by fragmentation)		**1**

(Total for Question 2 = 6 marks)

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>3(a)</td><td>An answer that makes reference to the following points:

• $HNO_3 + 2H_2SO_4 \rightarrow NO_2^+ + H_3O^+ + 2HSO_4^-$
OR
$HNO_3 + H_2SO_4 \rightarrow NO_2^+ + H_2O + HSO_4^-$
OR
$HNO_3 + H_2SO_4 \rightarrow H_2NO_3^+ + HSO_4^-$
and
$H_2NO_3^+ \rightarrow NO_2^+ + H_2O$ (1)



• curly arrow from on or within the circle to the N of NO_2^+ (1)

• intermediate structure including charge with horseshoe covering at least 3 carbon atoms and facing the tetrahedral carbon and some part of the positive charge must be within the horseshoe (1)

• curly arrow from C—H bond to anywhere in the hexagon, reforming the delocalized structure (1)</td><td>IGNORE state symbols, even if incorrect

Correct Kekulé structures score full marks

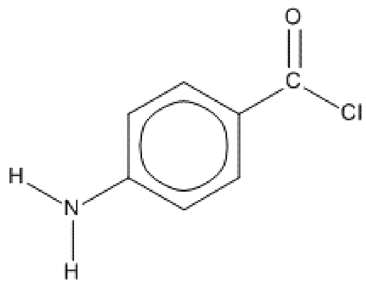
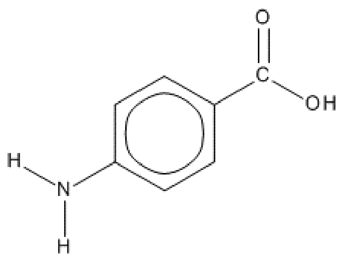
If final product is not 1-methyl-4-nitrobenzene, maximum 3 marks

Allow curly arrow from anywhere within the hexagon
Allow curly arrow to any part of the NO_2^+ including to the + charge

Ignore any involvement of HSO_4^- in the final step</td><td>4</td></tr>
</table>

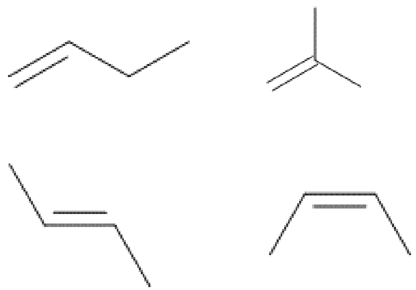
Question Number	Acceptable Answer	Additional Guidance	Mark
3(b)(i)	An explanation that makes reference to the following points: • the lone pair of electrons on the O overlap with the π/delocalised electrons in the benzene ring (1) • so (increased electron density) makes the ring more susceptible to electrophilic attack (1)	second mark is conditional on a reasonable explanation	**2**

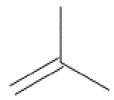
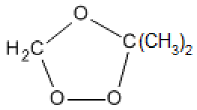
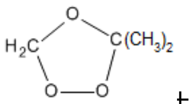
Question Number	Acceptable Answer	Additional Guidance	Mark
3(b)(ii)	An explanation that makes reference to the following points: • 2-nitrophenol forms intramolecular hydrogen bonding <u>and</u> 4-nitrophenol only forms intermolecular hydrogen bonding **(1)** • so the hydrogen in the 2-nitrophenol cannot form hydrogen bonds with water (so less soluble) **(1)**		**2**

Question Number	Acceptable Answer	Additional Guidance	Mark
3(c)	 **or** 	Allow skeletal formula Allow NH_2 Allow COOH / CO_2H / COCl Allow O-H	**1**

(Total for Question 3 = 9 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
4(a)	• calculates mol of CO_2 and H_2O / mol C and H (1) • deduces empirical formula (1) • calculates mol **J** (1) • calculates M_r of **J** and hence molecular formula (1)	<u>Example of calculation</u> mol CO_2 / mol C = 0.88/44 = 0.02 <u>and</u> mol H_2O = 0.36/18 = 0.02 / mol H = 0.04 ratio C : H = 1 : 2 <u>and</u> empirical formula is CH_2 n = pV/RT mol **J** = $101 \times 10^3 \times 123 \times 10^{-6}/(8.31 \times 298)$ = 5.0166×10^{-3} M_r of **J** = $0.28/5.0166 \times 10^{-3}$ = 55.8 so molecular formula is C_4H_8	**4**

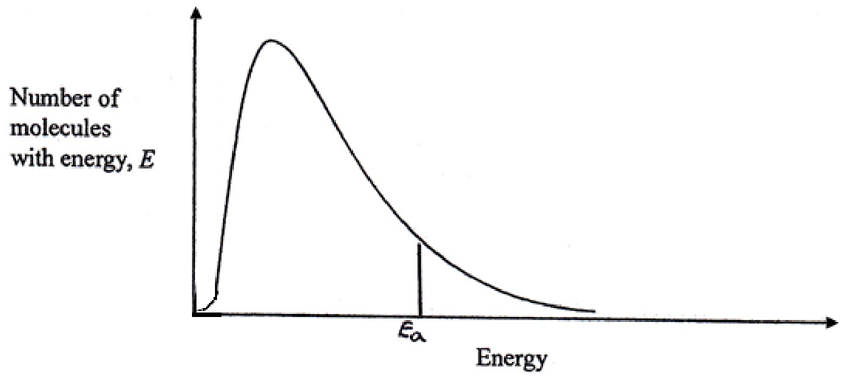
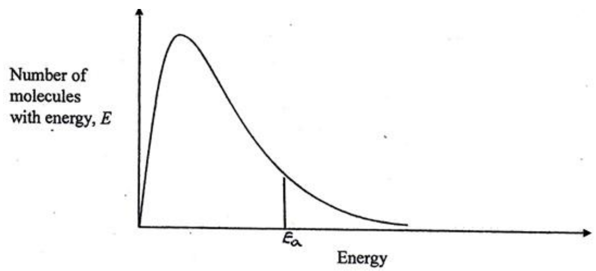
Question Number	Acceptable Answer	Additional Guidance	Mark
4(b)	 • all 4 correct (3) • any 3 correct (2) • any 2 correct (1)	Allow 2 marks for four correct structures that are not skeletal Do not award cycloalkanes	**3**

Question Number	Acceptable Answer	Additional Guidance	Mark
4(c)	An answer that makes reference to the following points: • **K** is HCHO/methanal because it is the (only) carbonyl with M_r 30 (1) • the M_r of **L** is 58 so it could be CH_3COCH_3/propanone or CH_3CH_2CHO/propanal **or** • a carbonyl compound with 3 carbon atoms (1) • 2 peaks on the ^{13}C NMR spectrum show 2 different carbon environments so it must be propanone (as propanal would have 3 different carbon environments (1) • **J** is methylpropene/$CH_2{=}C(CH_3)_2$ /  (1) • $CH_2{=}C(CH_3)_2 + O_3 \rightarrow$   + $H_2O \rightarrow HCHO + O{=}C(CH_3)_2 + H_2O_2$ **both** equations correct (1)		**5**

Question Number	Acceptable Answer	Additional Guidance	Mark
4(d)	• calculates number of mol of Br_2/mol of Br (1) • calculates volume of **J** (1) • calculates percentage of **J** (1)	Example of calculation mol Br_2 = 0.32/159.8 = 0.002 / mol Br = 0.32/79.9 = 0.004 (mol **J** = 0.002 so) vol **J** = 0.002 x 24 000 = 48 cm^3 percentage of **J** = $\frac{48}{120}$ x 100 = 40%	**3**

(Total for Question 4 = 15 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
5(a)	An answer that makes reference to the following point: • different phase	Allow different physical state	**1**

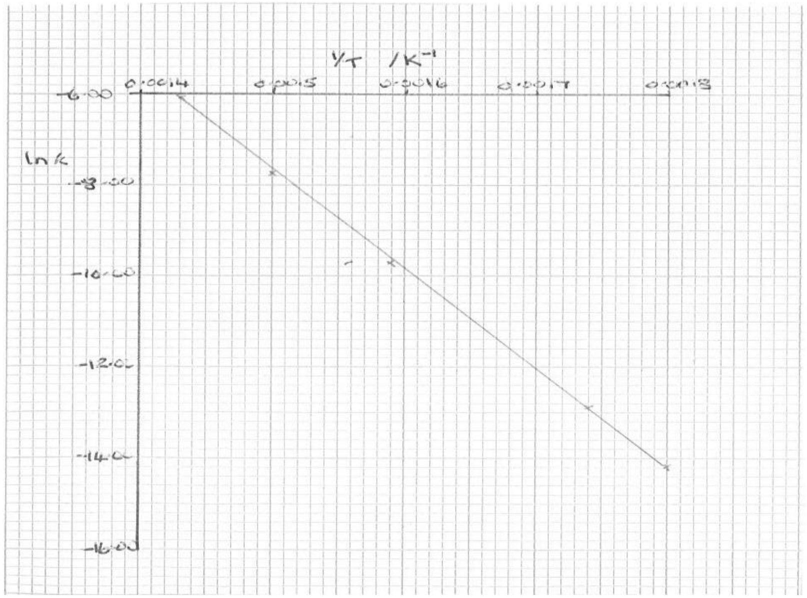
Question Number	Acceptable Answer	Additional Guidance	Mark
5(b)(i)	 • both axes labelled y axis = number/fraction of molecules (with energy, *E*) x axis = (kinetic) energy/*E* (1) • curve starting at or going towards origin, asymmetric, asymptotic to x axis and correct shape (1) • E_a shown (well to right of the peak) (1)	Allow 	**3**

Question Number	Acceptable Answer	Additional Guidance	Mark
5(b)(ii)	An explanation that makes reference to the following points: • E_a(cat) shown on graph at a lower energy than E_a or stated to be at a lower energy (1) • greater proportion/more of the molecules/collisions have energy greater than the activation energy with a catalyst **OR** shows this with labelled shading on the graph (1) • greater proportion/more of the collisions lead to a reaction (1)		**3**

Question Number	Acceptable Answer	Additional Guidance	Mark
5(c)	An answer that makes reference to the following points: • two half-lives measured and both about 2 min (1) • half-lives are constant so first order (1)		**2**

Question Number	Acceptable Answer	Additional Guidance	Mark
5(d)(i)	An answer that makes reference to the following points: • second order (1) • as the concentration of HI triples, the initial rate increases by a factor of 9 / 3^2 (1)		**2**

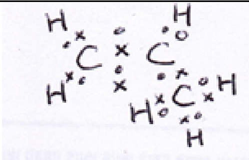
Question Number	Acceptable Answer	Additional Guidance	Mark
5(d)(ii)	Both marks TE on order in d(i) • rate equation (1) • calculate rate (1)	rate = k[HI]^2 rate = $7.040 \times 10^{-9} \times (0.5/0.1)^2$ = 1.76×10^{-7} (mol dm^{-3} s^{-1}) **or** k = rate/[HI]^2 = $7.040 \times 10^{-9}/(0.1)^2$ = 7.040×10^{-7} <u>and</u> rate = $7.040 \times 10^{-7} \times 0.5^2$ = 1.76×10^{-7} (mol dm^{-3} s^{-1})	**2**

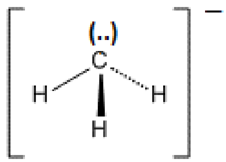
Question Number	Acceptable Answer	Additional Guidance	Mark
5(d)(iii)	 • axes labelled and correct unit (1) • points correct, ± half square <u>and</u> best fit straight line (1) • calculates gradient (1) • calculates E_a = -gradient x R (1) • E_a given to 2/3 SF <u>and</u> correct units for E_a to match answer given (1)	gradient = -21 892 (K) Allow -21 000 to -22 800 (K) E_a= - - 21 892 x 8.31 = (+)181 923 J mol^{-1} **or** =(+)181.923 kJ mol^{-1} E_a = (+)180 000 / (+)182 000 J mol^{-1} **or** (+)180/ (+)182 kJ mol^{-1} TE on value of gradient but do not allow the mark if E_a is negative	**5**

(Total for Question 5 = 18 marks)

Question Number	Answer	Additional Guidance	Mark
6(a)(i)	**C** (C_7H_{14})		**1**

Question Number	Answer	Additional Guidance	Mark
6(a)(ii)	**C** (C_7H_{12})		**1**

Question Number	Acceptable Answer	Additional Guidance	Mark
6(b)	 • 2 pairs of electrons between 2 carbon atoms and 1 pair of electrons between the other 2 carbon atoms (1) • rest of diagram correct (1)	Allow dots or crosses for any atoms or all dots or all crosses Allow diagrams with overlapping circles Ignore inner shell electrons shown on carbon atoms	**2**

Question Number	Acceptable Answer	Additional Guidance	Mark
6(c)	An answer that makes reference to the following points: • shape: (trigonal) pyramidal/ drawn as (trigonal) pyramidal (1) • bond angle: 107° (1) • justification: 4 pairs of electrons arranged as far apart as possible to minimise repulsion/maximum separation (1) • 1 pair of electrons is a lone pair and causes more repulsion than the bonding pairs (so the bond angle is less than a normal tetrahedral shape) (1)	Example of shape drawn:  Allow any bond angle in the range 105-108°	**4**

Question Number	Answer	Additional Guidance	Mark
6(d)(i)	**C** (homolytic fission)		**1**

Question Number	Acceptable Answer	Additional Guidance	Mark
6(d)(ii)	• $CH_3CH_2CH_3 + Cl\cdot \rightarrow CH_3CH\cdot CH_3 + HCl$ (1) • $CH_3CH\cdot CH_3 + Cl_2 \rightarrow CH_3CHClCH_3 + Cl\cdot$ (1)	Allow 1 mark for two correct equations forming 1-chloropropane Allow one mark for two correct equations using molecular formula of propane forming C_3H_7Cl	**2**

Question Number	Acceptable Answer	Additional Guidance	Mark
6(d)(iii)	An explanation that makes reference to the following points: • the chlorine radical can remove a hydrogen from anywhere in the propane molecule (1) • so a mixture of products is formed (1)	e.g. 1-chloropropane / 1,2-dichloropropane	**2**

(Total for Question 6 = 13 marks)

Question Number	Answer	Additional Guidance	Mark
7(a)(i)	**B** (alcohol **Q**)		**1**

Question Number	Answer	Additional Guidance	Mark
7(a)(ii)	**C** (alcohols **P, R** and **S** only)		**1**

Question Number	Answer	Additional Guidance	Mark
7(a)(iii)	**C** (alcohol **R**)		**1**

Question Number	Acceptable Answer	Additional Guidance	Mark
7(b)	• calculates mol of propan-1-ol (1) • calculates mol of 2-bromopropane produced (1) • calculates mass of 2-bromopropane (1)	<u>Example of calculation</u> mol propan-1-ol = 3.0/60 = 0.05 mol 2-bromopropane produced = 0.05 x 0.65 x 0.58 = 0.01885 mass of 2-bromopropane = 0.01885 x 122.9 = 2.317 (g) = 2.3 (g) ignore sf except 1 sf	**3**

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>7(c)*</td><td>This question assesses a student’s ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5–4</td><td>3</td></tr>
<tr><td>3–2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>

The following table shows how the marks should be awarded for structure and lines of reasoning.

<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr>
<tr><td>Answer shows a coherent and 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, 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></td></tr>
</table>

	Indicative content • convert some ethanol into bromoethane or iodoethane / CH_3CH_2Br / CH_3CH_2I • reagents and conditions: potassium bromide / KBr <u>and</u> concentrated sulfuric acid / H_2SO_4 or red phosphorus / P_4 <u>and</u> iodine / I_2 • convert bromoethane / iodoethane into ethylmagnesium bromide / iodide CH_3CH_2MgBr / CH_3CH_2MgI <u>and</u> using magnesium / Mg in dry ether • convert some ethanol into ethanal / CH_3CHO • reagents and conditions: potassium dichromate(VI) in dilute sulfuric acid and distil product immediately • react ethylmagnesium bromide / iodide with ethanal (in dry ether) and hydrolyse the product (with dilute acid)		**6**

(Total for Question 7 = 12 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
8(a)	An explanation that makes reference to the following points: • **A** no because the two substances have the same molecular formula/ relative molecular mass (1) • **B** yes because only 2-aminopropanal is chiral (1) • **C** no because both substances react with Fehling's solution (to produce a red precipitate) (1)	Allow no because 3-aminopropanal is not chiral and 2-aminopropanal could be a racemic mixture	**3**

<table>
<tr><th>Question Number</th><th>Acceptable Answer</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.
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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></td></tr>
</table>

	Indicative content • both have 4 different proton environments/ peaks will be at same chemical shift • peak areas are 1:1:2:3 in 2-aminopropanal • peak areas are 1:2:2:2 in 3-aminopropanal • explanation or use of the (n+1) rule for any splitting pattern • 2-aminopropanal has 1 singlet (N**H**$_2$), 2 doublets (C**H**O), and (C**H**$_3$), 1 pentuplet (C**H**) • 3-aminopropanal has 1 singlet (N**H**$_2$), 2 triplets (C**H**O), and (C**H**$_2$-NH$_2$), 1 quartet (C**H**$_2$)	Allow ratios in any order for the second and third marking points Only penalise use of peak heights instead of peak areas once	**6**

(Total for Question 8 = 9 marks)

TOTAL FOR PAPER = 90 MARKS