

A-level

# Chemistry

Paper 2 (7405/2): Organic and Physical Chemistry  
Mark scheme

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7405  
Specimen paper

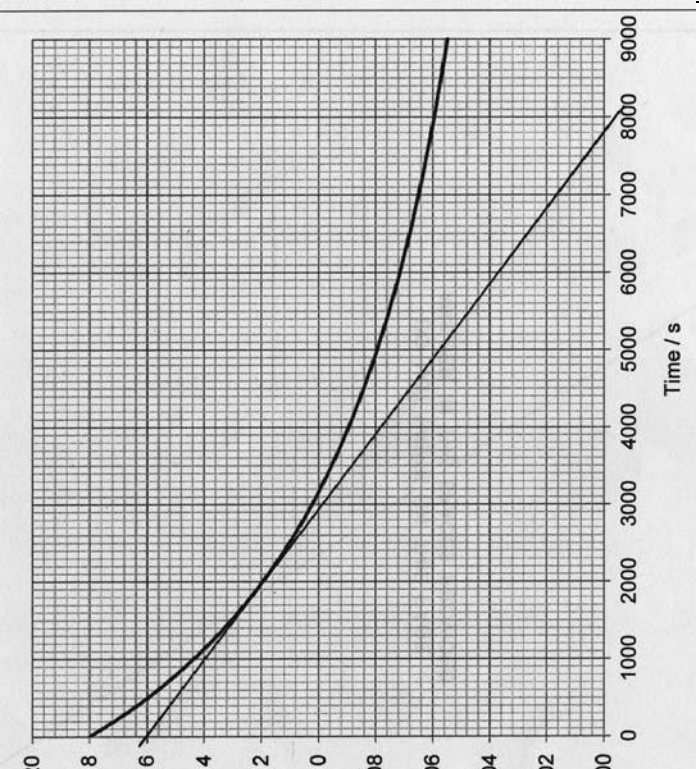
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Version 0.5

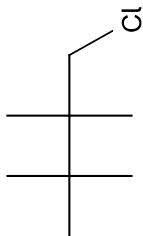
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Question	Marking guidance	Mark	AO	Comments
01.1	<p>Consider experiments 1 and 2: [B constant]                      [A] increases x 3: rate increases by <math>3^2</math> therefore 2nd order with respect to A</p> <p>Consider experiments 2 and 3:                      [A] increases x 2: rate should increase x <math>2^2</math> but only increases x 2                      Therefore, halving [B] halves rate and so 1st order with respect to B</p> <p>Rate equation: <math>\text{rate} = k[\text{A}]^2[\text{B}]</math></p>	<p>1</p> <p>1</p> <p>1</p>	<p>AO3 1a</p> <p>AO3 1a</p> <p>AO3 1b</p>	
01.2	<p>rate = <math>k [\text{C}]^2[\text{D}]</math> therefore <math>k = \text{rate} / [\text{C}]^2[\text{D}]</math></p> <p><math>k = \frac{7.2 \times 10^{-4}}{(1.9 \times 10^{-2})^2 \times (3.5 \times 10^{-2})} = 57.0</math></p> <p><math>\text{mol}^{-2} \text{dm}^+6 \text{s}^{-1}</math></p>	<p>1</p> <p>1</p> <p>1</p>	<p>AO2h</p> <p>AO2h</p> <p>AO2h</p>	<p>Allow consequential marking on incorrect transcription</p> <p>Any order</p>
01.3	<p>rate = <math>57.0 \times (3.6 \times 10^{-2})^2 \times 5.4 \times 10^{-2} = 3.99 \times 10^{-3} \text{ (mol dm}^{-3} \text{ s}^{-1}\text{)}</math></p> <p><b>OR</b></p> <p>Their <math>k \times (3.6 \times 10^{-2})^2 \times 5.4 \times 10^{-2}</math></p>	<p>1</p>	<p>AO2h</p>	

01.4	Reaction occurs when molecules have $E \geq E_a$ Doubling T causes <u>many</u> more molecules to have this $E$ Whereas doubling $[E]$ only doubles the number with this $E$	1 1 1	AO1a AO1a AO1a	
01.5	$E_a = RT(\ln A - \ln k)/1000$ $E_a = 8.31 \times 300 (23.97 - (-5.03))/1000 = 72.3 \text{ (kJ mol}^{-1}\text{)}$	1 1	AO1b AO1b	Mark is for rearrangement of equation and factor of 1000 used correctly to convert J into kJ

Question	Marking guidance	Mark	AO	Comments
02.1	Gradient drawn on graph 	1	AO3 1a	Line must touch the curve at 0.012 but must not cross the curve.

02.2	<p>Stage 1: Rate of reaction when concentration = <math>0.0120 \text{ mol dm}^{-3}</math>                      From the tangent                      Change in [butadiene] = <math>-0.0160 - 0</math> and change in time = <math>7800 - 0</math>                      Gradient = <math>-(0.0160 - 0)/(7800 - 0) = -2.05 \times 10^{-6}</math>                      Rate = <math>2.05 \times 10^{-6} \text{ (mol dm}^{-3} \text{ s}^{-1})</math></p> <p>Stage 2: Comparison of rates and concentrations                      Initial rate/rate at <math>0.0120 = (4.57 \times 10^{-6})/(2.05 \times 10^{-6}) = 2.23</math>                      Initial concentration/concentration at point where tangent drawn =  <math>0.018/0.012 = 1.5</math></p> <p>Stage 3: Deduction of order                      If order is 2, rate should increase by factor of <math>(1.5)^2 = 2.25</math> this is approximately equal to 2.23 therefore order is 2nd with respect to butadiene</p>	<p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p>	<p>AO3 1a</p> <p>AO3 1a</p> <p>AO3 1a</p> <p>AO3 1a</p> <p>AO3 1b</p>	<p>Extended response</p> <p>Marking points in stage 2 can be in either order</p>
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Question	Marking guidance	Mark	AO	Comments
03.1	2,2,4-trimethylpentane	1	AO1a	
03.2	5	1	AO2b	
03.3	$C_{20}H_{42} \longrightarrow C_8H_{18} + 2C_3H_6 + 3C_2H_4$	1	AO2b	
03.4	Mainly alkenes formed	1	AO1b	
03.5	4 (monochloro isomers) $  \begin{array}{ccccccc}  & & CH_3 & H & & CH_3 & \\  & &   &   & &   & \\  CH_3 & - & C & - & C & - & C & - & CH_3 \\  & &   &   & &   & \\  & & H & & & Cl & Cl & & CH_3  \end{array}  $	1  1	AO2b  AO2a	
03.6		1	AO2a	

	Both required	AO1b	1		1
03.7  $\text{C}_8\text{H}_{17}^{35}\text{Cl} = 96.0 + 17.0 + 35.0 = 148.0$ $\text{and } \text{C}_8\text{H}_{17}^{37}\text{Cl} = 96.0 + 17.0 + 37.0 = 150.0$ $M_r \text{ of this } \text{C}_8\text{H}_{17}\text{Cl} = \frac{1.5 \times 148.0}{2.5} + \frac{(1.0 \times 150.0)}{2.5} = 148.8$		AO1b	1		
03.8  $\frac{24.6}{12} \quad \frac{2.56}{1} \quad \frac{72.8}{35.5} = 2.05 : 2.56 : 2.05$ $\text{Simplest ratio} = \frac{2.05}{2.05} : \frac{2.56}{2.05} : \frac{2.05}{2.05}$ $= 1 : 1.25 : 1$ $\text{Whole number ratio } (\times 4) = 4 : 5 : 4$ $\text{MF} = \text{C}_8\text{H}_{10}\text{Cl}_8$		AO2b	1		

Question	Marking guidance	Mark	AO	Comments
04.1	3-methylbutan-2-ol	1	AO1a	
04.2	$  \begin{array}{c}  \text{CH}_3 \\    \\  \text{H}_3\text{C}-\text{C}-\text{C}-\text{CH}_3 \\    \quad    \\  \text{H} \quad \text{O}  \end{array}  $	1	AO2g	Allow $(\text{CH}_3)_2\text{CHCOCH}_3$
04.3	Elimination	1	AO1a	
04.4	$  \begin{array}{c}  \text{CH}_3 \\    \\  \text{H}_3\text{C}-\text{C}=\text{C}-\text{CH}_3 \\    \\  \text{H}  \end{array}  $	1	AO2g	Allow $(\text{CH}_3)_2\text{C}=\text{CHCH}_3$
	$  \begin{array}{c}  \text{CH}_3 \\    \\  \text{H}_3\text{C}-\text{C}-\text{C}=\text{CH}_2 \\    \quad   \\  \text{H} \quad \text{H}  \end{array}  $	1	AO2g	Allow $(\text{CH}_3)_2\text{CHCH}=\text{CH}_2$



04.5	Position	1	AO1a	
04.6	C B A	1	AO3 1b	
04.7	$\begin{array}{c} \text{CH}_3 \\   \\ \text{H}_3\text{C}-\text{C}-\text{CH}_2\text{CH}_3 \\   \\ \text{OH} \end{array}$	1	AO2g	Allow $(\text{CH}_3)_2\text{C}(\text{OH})\text{CH}_2\text{CH}_3$
04.8	$\begin{array}{c} \text{CH}_3 \\   \\ \text{H}_3\text{C}-\text{C}-\text{CH}_2\text{OH} \\   \\ \text{CH}_3 \end{array}$	1	AO2e	Allow $(\text{CH}_3)_3\text{CCH}_2\text{OH}$

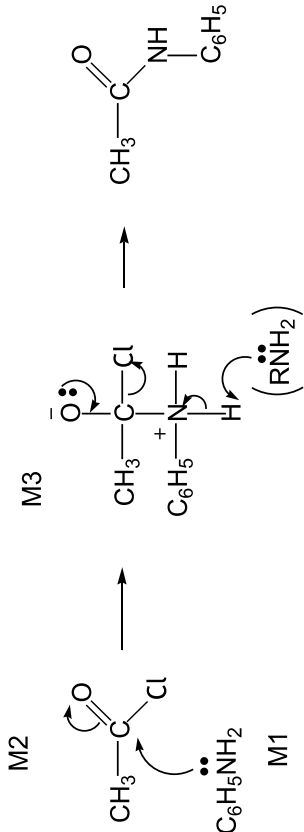
Question	Marking guidance	Mark	AO	Comments
05.1	Secondary	1	AO1a	
05.2	Nitrogen and oxygen are very electronegative Therefore, C=O and N–H are polar Which results in the formation of a hydrogen bond between O and H In which a lone pair of electrons on an oxygen atom is strongly attracted to the $\delta^+$ H	1 1 1 1	AO1a AO1a AO1a AO1a	

Question	Marking guidance	Mark	AO	Comments
06.1	<p>threonine</p> <p>glycine</p> <p>lysine</p>	1	AO2a	
06.2		1	AO2a	
06.3	<p>(Br<sup>-</sup>)</p>	1	AO2a	Allow (CH <sub>3</sub> ) <sub>3</sub> N <sup>+</sup> —CH <sub>2</sub> —COOH (Br <sup>-</sup> )
06.4	2-amino-3-hydroxybutanoic acid	1	AO2a	

06.5	$  \begin{array}{c}  \text{NH}_3^+ \\    \\  (\text{CH}_2)_4 \\    \\  \text{H}_3\text{N}^+ - \text{C} - \text{COOH} \\    \\  \text{H}  \end{array}  $	1	AO2a	
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Question	Marking guidance	Mark	AO	Comments
07.1	$  \begin{array}{c}  \text{H} \quad \text{CH}_3 \\    \quad   \\  \text{C}=\text{C} \\    \quad   \\  \text{CH}_3 \quad \text{Cl}  \end{array}  $ Addition	1	AO1a	
07.2	$  \begin{array}{c}  \text{H} \quad \text{H} \\    \quad   \\  \text{HO}-\text{C}-\text{C}-\text{OH} \\    \quad   \\  \text{CH}_3 \quad \text{CH}_3  \end{array}  $ $  \begin{array}{c}  \text{O} \quad \text{CH}_3 \quad \text{H} \quad \text{O} \\     \quad   \quad   \quad    \\  \text{HO}-\text{C}-\text{C}-\text{C}-\text{C}-\text{OH} \\    \quad   \quad   \\  \text{CH}_3 \quad \text{H} \quad \text{Cl}  \end{array}  $ OR $  \begin{array}{c}  \text{O} \quad \text{CH}_3 \quad \text{H} \quad \text{O} \\     \quad   \quad   \quad    \\  \text{Cl}-\text{C}-\text{C}-\text{C}-\text{C}-\text{Cl} \\    \quad   \quad   \\  \text{CH}_3 \quad \text{H} \quad \text{H}  \end{array}  $	1	AO2e	
07.3	<b>Q</b> is biodegradable Polar C=O group or $\delta^+$ C in <b>Q</b> (but not in <b>P</b> ) Therefore, can be attacked by nucleophiles (leading to breakdown)	1 1 1	AO2g AO2c AO2c	

Question	Marking guidance	Mark	AO	Comments
08.1	2-deoxyribose	1	AO1a	
08.2	Base A Top N–H forms hydrogen bonds to lone pair on O of guanine The lone pair of electrons on N bonds to H–N of guanine A lone pair of electrons on O bonds to lower H–N of guanine	1 1 1 1	AO3 1b AO2a AO2a AO2a	If Base B stated, allow 1 mark only for response including hydrogen bonding  Allow all 4 marks for a correct diagram showing the hydrogen bonding  Students could also answer this question using labels on the diagram
08.3	Allow either of the nitrogen atoms with a lone pair NOT involved in bonding to cytosine	1	AO2a	
08.4	Use in very small amounts / target the application to the tumour	1	AO2e	

Question	Marking guidance	Mark	AO	Comments
09.1	<p>(nucleophilic) addition-elimination</p>  <p>M4 for 3 arrows and lp</p>	1	AO1a	<p>Not electrophilic addition-elimination</p> <p>Allow C<sub>6</sub>H<sub>5</sub> or benzene ring</p> <p>Allow attack by :NH<sub>2</sub>C<sub>6</sub>H<sub>5</sub></p> <p>M2 not allowed independent of M1, but allow M1 for correct attack on C+</p> <p>M3 for correct structure <u>with charges</u> but lone pair on O is part of M4</p> <p>M4 (for three arrows and lone pair) can be shown in more than one structure</p>
		4	AO2a	

09.2	<p><b>The minimum quantity of hot water was used:</b> To ensure the hot solution would be saturated / crystals would form on cooling</p> <p><b>The flask was left to cool before crystals were filtered off:</b> Yield lower if warm / solubility higher if warm</p> <p><b>The crystals were compressed in the funnel:</b> Air passes through the sample not just round it</p> <p><b>A little cold water was poured through the crystals:</b> To wash away soluble impurities</p>	1 1 1 1	AO1b AO1b AO1b AO1b	Allow better drying but not water squeezed out
09.3	Water Press the sample of crystals between filter papers	1 1	AO3 1b AO3 2b	Do not allow unreacted reagents Allow give the sample time to dry in air
09.4	$M_r$ product = 135.0 Expected mass = $5.05 \times \frac{135.0}{93.0} = 7.33 \text{ g}$ Percentage yield = $\frac{4.82}{7.33} \times 100 = 65.75 = 65.8(\%)$	1 1 1	AO2h AO2h AO1b	Answer must be given to this precision



09.5	 <p>OR</p> $\text{C}_6\text{H}_5\text{NHCOCH}_3 + \text{NO}_2^+ \rightarrow \text{C}_6\text{H}_4(\text{NHCOCH}_3)\text{NO}_2 + \text{H}^+$	1	AO2c	
09.6	Electrophilic substitution	1	AO1a	
09.7	Hydrolysis	1	AO3 1a	
09.8	Sn/HCl	1	AO1b	Ignore acid concentration; allow Fe/HCl

Question	Marking guidance	Mark	AO	Comments
10	<p><b>IR</b></p> <p>M1 Absorption at <math>3360\text{ cm}^{-1}</math> shows OH alcohol present</p> <p><b>NMR</b></p> <p>M2 There are 4 peaks which indicates 4 different environments of hydrogen</p> <p>M3 The integration ratio = 1.6 : 0.4 : 1.2 : 2.4 The simplest whole number ratio is 4 : 1 : 3 : 6</p> <p>M4 The singlet (integ 1) must be caused by H in OH alcohol</p> <p>M5 The singlet (integ 3) must be due to a <math>\text{CH}_3</math> group with no adjacent H</p> <p>M6 Quartet + triplet suggest <math>\text{CH}_2\text{CH}_3</math> group</p> <p>M7 Integration 4 and integration 6 indicates two equivalent <math>\text{CH}_2\text{CH}_3</math> groups</p> <p>M8</p> <div style="text-align: center;"> <math display="block">\begin{array}{c} \text{CH}_2\text{CH}_3 \\   \\ \text{H}_3\text{C}-\text{C}-\text{OH} \\   \\ \text{CH}_2\text{CH}_3 \end{array}</math> </div>	<p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p>	<p>AO3 1a</p> <p>AO3 1a</p> <p>AO3 1a</p> <p>AO3 1a</p> <p>AO3 1b</p> <p>AO3 1b</p> <p>AO3 1b</p> <p>AO3 1b</p>	<p>Extended response</p> <p>Deduction of correct structure without explanation scores maximum of 4 marks as this does not show a clear, coherent line of reasoning.</p> <p>Maximum of 6 marks if no structure given OR if coherent logic not displayed in the explanations of how two of OH, <math>\text{CH}_3</math> and <math>\text{CH}_2\text{CH}_3</math> are identified.</p>

Question	Marking guidance	Mark	AO	Comments
11.1	$\text{CH}_3\text{CH}_2\text{COCH}_3 + 2[\text{H}] \longrightarrow \text{CH}_3\text{CH}_2\text{CH}(\text{OH})\text{CH}_3$	1	AO1b	
11.2	<p>This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.</p> <p><b>Level 3</b> 5–6 marks All stages are covered and the explanation of each stage is generally correct and virtually complete. Answer is communicated coherently and shows a logical progression from stage 1 to stage 2 then stage 3.</p> <p><b>Level 2</b> 3–4 marks All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete. Answer is mainly coherent and shows progression from stage 1 to stage 3.</p> <p><b>Level 1</b> 1–2 marks Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, OR only one stage is covered but the explanation is generally correct and virtually complete. Answer includes isolated statements but these are not presented in a logical order or show confused reasoning.</p> <p><b>Level 0</b> 0 marks Insufficient correct chemistry to gain a mark.</p>	6	1 AO1a  5 AO2a	<p><b>Indicative Chemistry content</b></p> <p><b>Stage 1:</b> Formation of product</p> <ul style="list-style-type: none"> <li>Nucleophilic attack</li> <li>Planar carbonyl group</li> <li>H<sup>-</sup> attacks from either side (stated or drawn)</li> </ul> <p><b>Stage 2:</b> Nature of product</p> <ul style="list-style-type: none"> <li>Product of step 1 shown</li> <li>This exists in two chiral forms (stated or drawn)</li> <li>Equal amounts of each enantiomer/racemic mixture formed</li> </ul> <p><b>Stage 3:</b> Optical activity</p> <ul style="list-style-type: none"> <li>Optical isomers/enantiomers rotate the plane of polarised light equally in opposite directions</li> <li>With a racemic/equal mixture the effects cancel</li> </ul>

Question	Marking guidance	Mark	AO	Comments
12.1	HBr OR HCl OR H <sub>2</sub> SO <sub>4</sub>	1	AO1b	Allow HI or HY
12.2	<p>Electrophilic addition</p> <p>The diagram shows the following steps:              1. 1-butene (CH<sub>2</sub>=CH-CH<sub>2</sub>-CH<sub>3</sub>) reacts with HBr. Curly arrows show the pi bond attacking the H of HBr, and the H-Br bond breaking to form Br<sup>-</sup>.              2. A secondary carbocation intermediate is formed: CH<sub>3</sub>-CH<sup>+</sup>(CH<sub>2</sub>CH<sub>3</sub>)-CH<sub>2</sub>-CH<sub>3</sub>.              3. The Br<sup>-</sup> ion attacks the carbocation carbon, forming the final product: CH<sub>3</sub>-CH(Br)-CH<sub>2</sub>-CH<sub>3</sub>.</p>	1 4	AO1a AO2a	Allow consequential marking on acid in 12.1 and allow use of HY
12.3	<p>The major product exists as a pair of enantiomers                      The third isomer is 1-bromobutane (minor product)                      Because it is obtained via primary carbocation</p>	1 1 1	AO2a AO2a AO2a	