Mark Scheme (Results)

January 2025

Pearson Edexcel International Advanced Level
In Chemistry (WCH14)
Paper 01 Rates, Equilibria and Further Organic Chemistry

Edexcel and BTEC Qualifications

Edexcel and BTEC qualifications are awarded by Pearson, the UK's largest awarding body. We provide a wide range of qualifications including academic, vocational, occupational and specific programmes for employers. For further information visit our qualifications websites at www.edexcel.com or www.btec.co.uk. Alternatively, you can get in touch with us using the details on our contact us page at www.edexcel.com/contactus.

Pearson: helping people progress, everywhere

Pearson aspires to be the world's leading learning company. Our aim is to help everyone progress in their lives through education. We believe in every kind of learning, for all kinds of people, wherever they are in the world. We've been involved in education for over 150 years, and by working across 70 countries, in 100 languages, we have built an international reputation for our commitment to high standards and raising achievement through innovation in education. Find out more about how we can help you and your students at: www.pearson.com/uk

January 2025
Question Paper Log Number P78458RA
Publications Code WCH14_01_2501_MS

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.

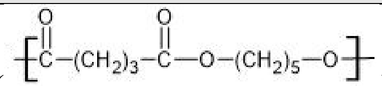
Quality of Written Communication

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.

Section A

Question Number	Answer	Mark
1	**The only correct answer is D** (lithium tetrahydridoaluminate(III) in dry ether) ***A*** *is incorrect because acidified potassium dichromate(VI) is an oxidising agent and not a reducing agent* ***B*** *is incorrect because concentrated sulfuric acid is used to catalyse the reaction of carboxylic acids with alcohols to form esters* ***C*** *is incorrect because this is the reducing agent for alkenes to alkanes*	**(1)**

Question Number	Answer	Mark
2	**The only correct answer is C** () ***A*** *is incorrect because there is an additional oxygen atom on the carboxyl end of the repeat unit* ***B*** *is incorrect because there is an additional oxygen atom on the carboxyl end of the repeat unit and the carboxyl part of the repeat unit is derived from heptanedioic acid* ***D*** *is incorrect because the carboxyl part of the repeat unit is derived from heptanedioic acid*	**(1)**

Question Number	Answer	Mark
3	**The only correct answer is D** (NH_4^+ and H_2O) ***A*** *is incorrect because the ammonium ion is also acting as a Brønsted-Lowry acid* ***B*** *is incorrect because these species are both acting as Brønsted-Lowry bases* ***C*** *is incorrect because the water molecule is also acting as a Brønsted-Lowry acid*	**(1)**

Question Number	Answer	Mark
4	**The only correct answer is B** (0.04) ***A*** *is incorrect because this is the difference in the concentration and not the pH* ***C*** *is incorrect because this is decrease in pH if the concentration becomes 0.110 instead of 0.0110* mol dm^{-3} ***D*** *is incorrect because this is not the decrease in pH but the pH of the 0.0110* mol dm^{-3} *solution*	**(1)**

Question Number	Answer	Mark
5(a)	**The only correct answer is A** (2.0×10^{12}) ***B*** *is incorrect because this value is determined by subtracting two from both the number 4 and its power* ***C*** *is incorrect because this value is determined by not including the power in the square root calculation* ***D*** *is incorrect because this value is* K_p *unchanged from equation 1*	**(1)**

Question Number	Answer	Mark
5(b)	**The only correct answer is D** (9.77×10^{25}) ***A*** *is incorrect because this value is determined by using* $\Delta n = +1$ *instead of* -1 ***B*** *is incorrect because this value is determined by using* $\Delta n = +1$ *instead of* -1 *and from using the temperature in °C instead of K* ***C*** *is incorrect because this value is determined from using the temperature in °C instead of K*	**(1)**

Question Number	Answer	Mark
6	**The only correct answer is A** ($\frac{1}{2}I_2(s) \rightarrow I(g)$) ***B*** *is incorrect because the standard state of iodine is solid* ***C*** *is incorrect because atomisation is for the formation of one mole of gaseous atoms* ***D*** *is incorrect because atomisation is for the formation of one mole of gaseous atoms and the standard state of iodine is solid*	**(1)**

Question Number	Answer	Mark
7	**The only correct answer is A** ($O^{-}(g) + e^{-} \rightarrow O^{2-}(g)$) ***B*** *is incorrect because this is the equation for the first and the second electron affinities of oxygen* ***C*** *is incorrect because this is the equation for the second ionisation energy of oxygen* ***D*** *is incorrect because this is the equation for the first and second ionisation energies of oxygen*	**(1)**

Question Number	Answer	Mark
8	**The only correct answer is D** (MgI_2) ***A*** *is incorrect because the calcium ion is larger than the magnesium ion so less polarising and the bromide ion is smaller than the iodide ion and less polarisable* ***B*** *is incorrect because the calcium ion is larger than the magnesium ion so less polarising* ***C*** *is incorrect because the bromide ion is smaller than the iodide ion and less polarisable*	**(1)**

Question Number	Answer	Mark
9	**The only correct answer is C** (positive negative) ***A*** *is incorrect because this pair of values will never be thermodynamically feasible* ***B*** *is incorrect because this pair of values is only thermodynamically feasible if the enthalpy change of reaction when divided by the temperature is greater in magnitude than the entropy change of the system* ***D*** *is incorrect because this pair of values is only thermodynamically feasible if the entropy change of the system is greater in magnitude than the value obtained from the enthalpy change of reaction divided by the temperature*	**(1)**

Question Number	Answer	Mark
10(a)	**The only correct answer is B** (the mixture becomes more purple) ***A*** *is incorrect because although there is no change in position of equilibrium the increase in pressure results in the purple iodine molecules being closer together so the colour becomes more intense* ***C*** *is incorrect because iodine vapour is not brown* ***D*** *is incorrect because iodine vapour is not brown*	**(1)**

Question Number	Answer	Mark
10(b)	**The only correct answer is B** (a decrease in temperature only) ***A*** *is incorrect because a change in pressure does not affect the value of* K_p ***C*** *is incorrect because only temperature has an effect on the value of* K_p *and an increase will result in* K_p *decreasing and not increasing* ***D*** *is incorrect because temperature does have an effect on the value of* K_p	**(1)**

Question Number	Answer	Mark
10(c)	**The only correct answer is A** (the equilibrium position has shifted towards the products) ***B*** *is incorrect because the increase in the value of* K_p *indicates a shift in the position of equilibrium to the products* ***C*** *is incorrect because the change in the value of* K_p *does indicate a shift in the extent of reaction* ***D*** *is incorrect because the change in the value of* K_p *is insufficient to result in almost complete conversion*	**(1)**

Question Number	Answer	Mark
11	**The only correct answer is B** (13.53) ***A*** *is incorrect because this is the pH determined using the value of* pK_w *at 298 K* ***C*** *is incorrect because this is the value of* pK_w *minus the concentration* ***D*** *is incorrect because this is the value of* pK_w	**(1)**

Question Number	Answer	Mark
12	**The only correct answer is D** (the dissociation of the carboxylic acid is almost complete) ***A*** *is incorrect because this is a valid assumption* ***B*** *is incorrect because this is a valid assumption* ***C*** *is incorrect because this is a valid assumption*	**(1)**

Question Number	Answer	Mark
13(a)	**The only correct answer is C** (5.07) ***A*** *is incorrect because this is the value from using [acid] ÷ [salt] instead of the other way around* ***B*** *is incorrect because this is the* pK_a *value* ***D*** *is incorrect because this is the value using the natural logarithm of salt divided by acid instead of logarithm to the base 10*	**(1)**

Question Number	Answer	Mark
13(b)	**The only correct answer is C** (to prevent deterioration by fungal activity) ***A*** *is incorrect because to prevent deterioration of the food which in the long run maintains the taste is not the same as improving the taste of food* ***B*** *is incorrect because this is not the reason for the addition of buffers to food* ***D*** *is incorrect because to prevent deterioration of the food which in the long run maintains the colour and appearance of food this is not the same as enhancing these qualities*	**(1)**

Question Number	Answer	Mark
13(c)	**The only correct answer is C** (the pH will decrease due to the equilibria shifting to the right) ***A*** *is incorrect because exercise produces CO_2 so the equilibria shift to the right* ***B*** *is incorrect because the increase in carbon dioxide produced will shift the equilibria to the right* ***D*** *is incorrect because the definition of buffers does not state that the pH is always kept constant but varies only slightly if small amounts of acid or base are added*	**(1)**

Question Number	Answer	Mark
14	**The only correct answer is D** (NO_2(g)) ***A*** *is incorrect because mercury has a metallic structure with some order that results in its entropy being lower than most gases* ***B*** *is incorrect because water has some order in its structure with hydrogen bonding and so its entropy is lower than most gases* ***C*** *is incorrect because it is a simpler gaseous molecule than* NO_2	**(1)**

Question Number	Answer	Mark
15	**The only correct answer is B** (132 minutes) ***A*** *is incorrect because this is the time taken for the concentration to reach* 5.5×10^{-3} *mol dm*$^{-3}$ *which is half-way between the starting concentration and the final concentration* ***C*** *is incorrect because this is half of the time shown on the graph* ***D*** *is incorrect because this is the time at the end of the graphical data*	**(1)**

Section B

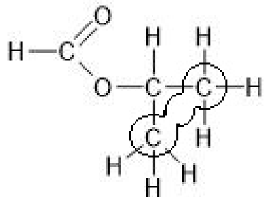
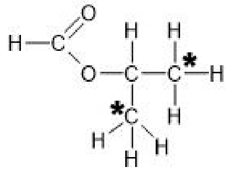
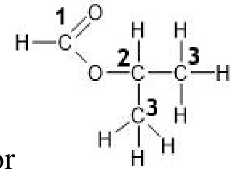
Question Number	Answer	Additional Guidance	Mark
16(a)	An explanation that makes reference to the following points: • pentan-2-one does not form hydrogen bonds (between molecules) **(1)** • hydrogen bonds require more **energy** to break (so pentan-2-one has a lower boiling temperature) **(1)**	Allow pentan-2-one (only) forms permanent dipole-dipole and London forces or (only) pentan-2-ol forms hydrogen bonds/ H-bonds Allow reference to hydrogen bonds in pentan-2-ol Ignore pentan-2-ol has stronger London forces Do not award 'more hydrogen bonds' Accept heat for energy Allow reverse argument that pentan-2-one requires less **energy** to break its intermolecular forces provided that hydrogen bonding is mentioned for M1 Allow reference to 'a lot of energy' if given in context of pentan-2-ol only having hydrogen bonds	**(2)**

Question Number	Answer		Additional Guidance	Mark
16(b)	An answer that makes reference to the following points: • iodine / I_2 **and** alkali / NaOH / KOH • yellow precipitate for pentan-2-one **and** no change for pentan-3-one	 **(1)** **(1)**	 Accept alkaline iodine Allow iodoform reaction/test/result or iodoform/CHI_3/ triiodomethane Allow solid/ppt/ppte for precipitate Allow antiseptic smell Allow only pentan-2-one forms a yellow precipitate Allow no result/no observation for no change M2 dependent on M1 but allow TE if alkali missing	**(2)**

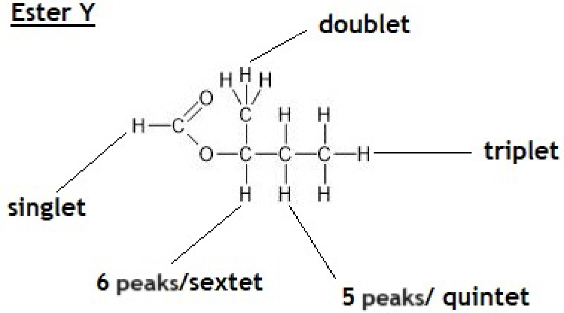
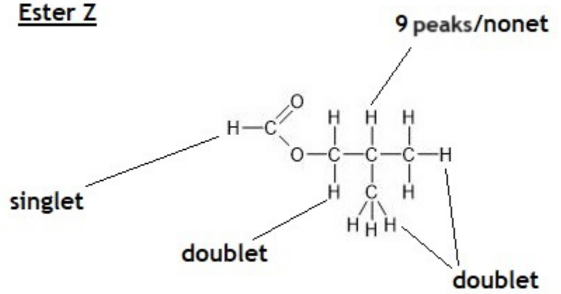
Question Number	Answer	Additional Guidance	Mark
16(c)	An answer that makes reference to the following points: • Fehling's/ Benedict's/ Tollens'/acidified dichromate((VI)) **(1)** • positive observation (for pentanal) which matches chosen test **and** no change (negative for pentan-2-one) **(1)**	Allow ammoniacal silver nitrate for Tollens' Allow $Cr_2O_7{}^{2-}$ and H^+ Ignore references to heat/reflux Do not award hydrochloric acid (Fehling's or Benedict's) brick-red/red/brownish red **and** ppt(from blue solution) (Tollens') silver mirror Allow black/grey ppt (acidified dichromate(VI))goes green/blue (from orange) Allow no result/no observation for no change M2 dependent on M1 but allow TE for minor errors such as omission of acid for the dichromate Allow (1) for addition of 2,4-DNPH and comparison of melting temperatures of products	**(2)**

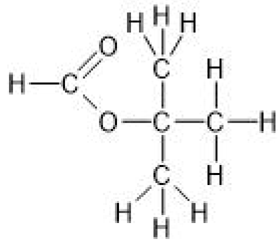
Question Number	Answer		Additional Guidance	Mark
16(d)	An explanation that makes reference to the following points: • 2,4-dinitrophenylhydrazine/ 2,4-DNPH	**(1)**	Allow lower case and minor misspellings such as 2,4-dinitrophen**o**lhydrazine Allow Brady's reagent Allow 2,4-DNP/2,4-dnp Ignore the colour given with the ppt	**(3)**
	• the solids need to be **re**crystallised	**(1)**	Accept suitable descriptions of recrystallisation Allow purified and crystalised for recrystallisation Ignore just crystallisation without some qualification	
	• their melting temperatures determined **and** compared with data/reference books	**(1)**	Do not award if the melting temperature is clearly stated to be that of pentan-2-one/ pentane-3-one /pentanal Do not award reference to boiling temperature(s)	

Question Number	Answer	Additional Guidance	Mark
16(e)	An explanation that makes reference to the following points: • the mechanism proceeds by nucleophilic/CN^- attack on the planar carbonyl group **(1)** • which is (equally/50:50 to) either side/ both sides/ above and below (and so results in a racemic mixture) **(1)** • pentan-2-one product has a chiral carbon/carbon with four different groups attached **and** (forms) two optical isomers **(1)** • pentan-3-one product is symmetrical/has two ethyl groups **and** so does not produce a product with a chiral carbon/optical isomer **(1)**	Marking points can be scored for correct labelled diagrams Allow flat for planar Do not award the molecule is planar Do not award planar intermediate/carbocation If pentan-3-one is stated to **not** react as per M1 and M2 then penalise 1 mark Reference to S_N1/S_N2 loses both M1 and M2 Allow pentan-2-one produces non-superimposable mirror image**s**/enantiomer**s** Allow product only has three different groups attached (on the third carbon) **and** so no chiral carbon/optical isomer Ignore reference to the rotation of the plane of plane-polarised light Ignore reference to racemic mixture because it is in the question	**(4)**

Question Number	Answer		Additional Guidance	Mark
17(a)	An explanation that makes reference to the following points: • ester S can be distinguished from the others with **three** peaks in its carbon-13 NMR spectrum • the other (three) esters have **four** peaks • labelling of the two equivalent carbon atoms in ester S	 (1) (1) (1)	Look at the formulae in the boxes for annotations Accept ester **S** has three carbon environments Accept the other (three) esters have four carbon environments Accept any suitable labelling such as  or  or  Allow the labelling of the carbon environments to include the hydrogen atoms but must not include non-equivalent carbon atoms	**(3)**

Question Number	Answer		Additional Guidance	Mark
17(b)(i)	An explanation that makes reference to the following points: • the peak for ester **W** has a chemical shift range of 2.8 – 4.2 (ppm) (due to H−C−O) • (whereas) the peak for ester **X** has a chemical shift range of 1.6 – 2.8 (ppm) (due to H−C−C=O)	 (1) (1)	Look at the formulae in the boxes for annotations Allow a range or a single value within these ranges for both M1 and M2 Accept ranges reversed such as 4.2 – 2.8 (ppm) Accept ranges reversed such as 2.8 – 1.6 (ppm) Standalone marks	**(2)**

Question Number	Answer	Additional Guidance	Mark
17(b)(ii)	An answer that makes reference to the following points: 9 correct labels scores 4 7 or 8 labels scores 3 4,5 and 6 scores 2 2 and 3 scores 1	Ester Y  Ester Z  Allow just numbers for the splitting patterns Allow pentuplet/pentet for 5 peaks Allow hextet/sixtet for 6 peaks Allow use of multiplet once only for sextet/quintet/nonet Allow no splits for singlet Allow labelling to include the carbon bonded to the respective hydrogen atoms and also any relevant oxygen atoms Allow "splits" for "peaks" Incorrect labelling of the two equivalent doublet methyl groups in ester Z loses one label only Ignore any additional information stated even if incorrect	**(4)**

Question Number	Answer	Additional Guidance	Mark
17(b)(iii)	• 	Allow structural/ skeletal/ /hybrid formulae e.g. $HCOOC(CH_3)_3$ Ignore connectivity to CH_3 Do not award $HCOOC_4H_9$ Do not award if hydrogen atom(s) missing	(1)

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>*18(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><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>
<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 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 were no linkages between the points, then the same indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).

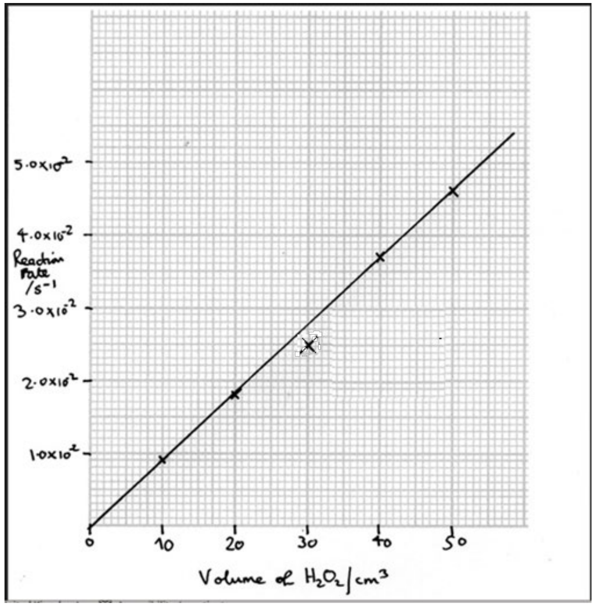
In general it would be expected that
5 or 6 indicative points would get 2 reasoning marks
3 or 4 indicative points would get 1 reasoning mark
0, 1 or 2 indicative points would get zero reasoning marks

If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).

Comment: Look for the indicative marking points first, then consider the mark for the structure of the answer and sustained line of reasoning</td><td>(6)</td></tr>
</table>

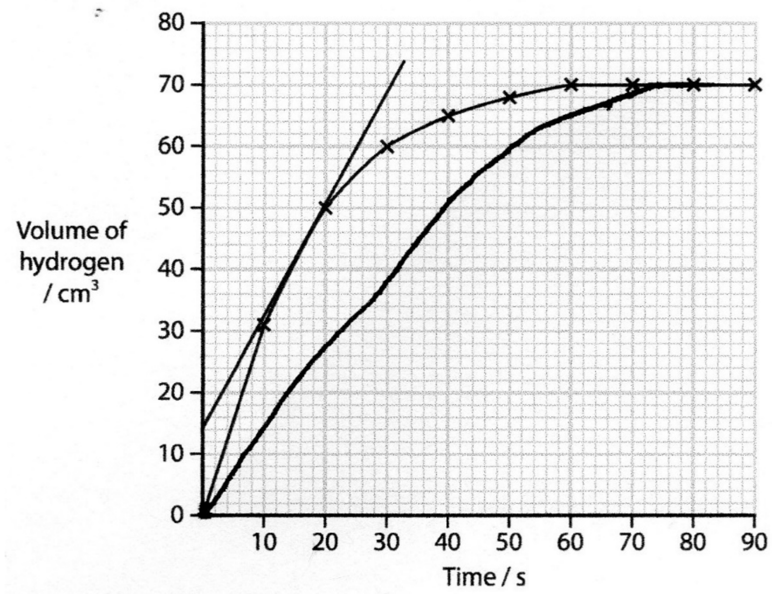
	Indicative content **IP1** only 1-bromobutane has the hydroxide ion in the rate equation /affecting the reaction rate/hydrolysis (giving evidence for the mechanism of each halogenoalkane)	Allow reference to primary halogenoalkanes for 1-bromobutane and to tertiary halogenoalkanes for 2-bromo-2-methylpropane Allow the rate/hydrolysis of 2-bromo-2-methylpropane is not affected by the hydroxide ion Allow rate with 1-bromobutane affected by two species Allow hydroxide to be referred to as a molecule Ignore reaction order references /rate equation re-drawn	
	IP2 1-bromobutane reacts by an S_N2 reaction mechanism **and** 2-bromo-2-methylpropane reacts by an S_N1 reaction mechanism		
	IP3 the hydroxide ion is only in the **rate determining step/ RDS/rds//slow** of the 1-bromobutane (reaction mechanism)	Allow two species in the **RDS** for 1-bromobutane/ only 2-bromo-2-methylpropane is in the **RDS** for its hydrolysis	
	IP4 1-bromobutane is reacts (in a single reaction step) via a transition state	Do not award intermediate for transition state	
	IP5 2-bromo-2-methylpropane forms a carbocation/intermediate (by the loss of a bromide ion) in the **slow** first step	Allow **RDS** for **slow** first step	
	IP6 the hydroxide ion (then) attacks the carbocation in a (fast) second step	Allow 1IP for IP5 and IP6 if **slow/RDS** absent Ignore references to differences in the rate or speed of hydrolysis between primary and tertiary halogenoalkanes Ignore references to optical activity	

Question Number	Answer	Additional Guidance	Mark
18(b)(i)	An answer that makes reference to the following point • from colourless **(1)** • to blue-black/blue/black **(1)**	Do not award clear Do not award if any colour is given Standalone mark Ignore shades Allow (1) for reversed answer i.e. black to colourless	**(2)**

Question Number	Answer	Additional Guidance	Mark
18(b)(ii)	• labelled axes with units **(1)** • plotting of points and straight line (±½ square) **(1)** • scale to ensure points cover over half the graph paper **(1)**	Allow just 'rate' and just 'volume' with appropriate units Allow $V(H_2O_2)$ for volume Allow small dots for plotted crosses Ignore absence of line to the origin Example of graph 	**(3)**

Question Number	Answer	Additional Guidance	Mark
18(b)(iii)	An answer that makes reference to the following point • first order/ one/ 1 **and** straight-line graph (passing through origin)	Allow rate is (directly) proportional volume (of H_2O_2) Allow rate doubles when volume doubles Allow graph has constant (positive) gradient Do not award if there is no graphical line No TE from incorrect graph	**(1)**

Question Number	Answer		Additional Guidance	Mark
18(c)(i)	• reaction rate value to 2 SF • units	**(1)** **(1)**	<u>Example of calculation</u> rate = (72 – 18) ÷ (32 − 2) = 1.8 Allow 1.9 $cm^3\ s^{-1}$ Allow cm^3 / s Standalone mark	**(2)**

Question Number	Answer	Additional Guidance	Mark
18(c)(ii)	An answer that makes reference to the following points: • line on the graph which is below the current line **and** (lower temperature means a) slower reaction rate **(1)** • plateaus at 70 cm^3 **and** concentration remains the same **(1)**	Allow ends at 70 for plateaus Allow reference to temperature not changing the yield Allow (1) for a correct line without justification / with incorrect justification if no other mark awarded Allow description of line and justification for either M1 or M2 but not both marks if no line drawn Exemplar graph 	**(2)**

Question Number	Answer	Additional Guidance	Mark
19(a)	An answer that makes reference to the following points: • a gas (and liquid products) are produced (from solids) **(1)** • more moles of products than reactants / increase in moles **(1)**	Ignore just carbon dioxide produced Ignore just change of state Do not award reference to two gases/H_2O gas Accept moles increase from 4 to 7 Allow reference to molecules / particles Do not award if numbers of moles incorrect Ignore references to exothermic / endothermic	**(2)**

Question Number	Answer	Additional Guidance	Mark
19(b)	An explanation that makes reference to the following points: • in solids the particles are fixed / in a lattice (so unable to move) **(1)** • so they cannot collide and react **(1)** • but when dissolved in water the particles are mobile **(1)**	Allow M2 if applied to the dissolved ions being able to collide and react Do not award reference to an increase in kinetic energy Allow when dissolved the ions are dissociated / spread out (in solution) Ignore references to entropy / energy changes / activation energy	**(3)**

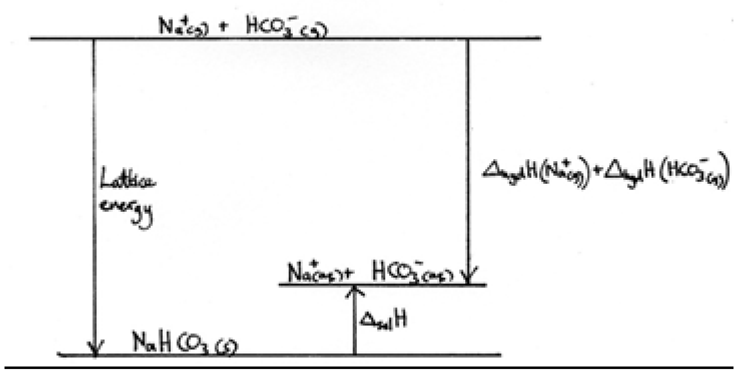
Question Number	Answer	Additional Guidance	Mark
19(c)	• calculation of enthalpy change value (1) • sign **and** units (1)	Example of calculation $\Delta H = (-\Delta S_{\text{surroundings}} \times T = - -234.9 \times 298 =)$ $\Delta H = +\ 70000.2\ /\ 70000\ /\ 7.0 \times 10^4\ \text{J mol}^{-1}$ or $\Delta H = +\ 70.002\ /\ 70\ /\ 7.0 \times 10^1\ \text{kJ mol}^{-1}$ Ignore SF Allow J / mol or kJ / mol for units If two answers are given then both must be correct Correct answer without working scores (2) Allow M2 for incorrect value provided the units match the value, e.g. use of 25 instead of 298 gives $+5872.5\ \text{J mol}^{-1}$ or $5.8725\ \text{kJ mol}^{-1}$	(2)

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>19(d)</td><td>

- enthalpy of solution labelled arrow shown to go up from solid $NaHCO_3$ **(1)**
- lattice energy gaseous species and labelled arrow to go down **(1)**
- enthalpy of hydration labelled arrow to go down and both aqueous ions species **(1)**

</td><td>

<u>Example of sketch</u>



Accept two labelled arrows if the hydration enthalpies for the ions are written separately
Allow just singular $\Delta_{hyd}H$ for hydration enthalpy of both ions

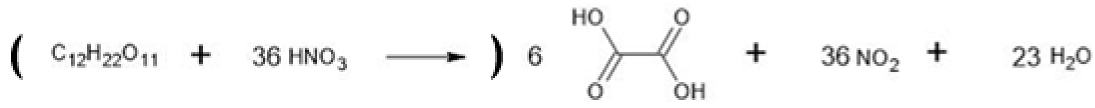
Accept +18.6 for $\Delta_{sol}H$
Allow ΔH_{hyd} for $\Delta_{hyd}H$ and ΔH_{sol} for $\Delta_{sol}H$
Allow any lengths of arrows

</td><td>(3)</td></tr>
</table>

Section C

Question Number	Answer		Additional Guidance	Mark
20(a)	• molar mass of ethanoic acid	(1)	$2 \times 12 + 2 \times 16 + 4 = 60$ Accept molar mass of 2-oxobutanedioic acid + water = 132 + 18 Allow 150 for the denominator	(2)
	• calculation of atom economy	(1)	Atom economy = $(90 \div 150 \times 100 =)$ 60 (%) Final answer without working scores (2) TE on incorrect molar mass e.g. use of 57 to give 61.2% scores (1)	

Question Number	Answer		Additional Guidance	Mark
20(b)	An answer that makes reference to the following points: • (reagents) potassium dichromate((VI))/ $K_2Cr_2O_7$ **and** sulfuric acid/ H_2SO_4	(1)	Accept sodium dichromate((VI))/ $Na_2Cr_2O_7$ Ignore [O] Allow $Cr_2O_7^{2-}$ **and** H^+ / acidified potassium dichromate((VI)) Ignore concentration if given If name and formula given then both must be correct Do not award hydrochloric acid Do not award M1 if any other reagents given	(2)
	• (heat under) reflux	(1)	Standalone mark	

Question Number	Answer	Additional Guidance	Mark
20(c)(i)	• one stoichiometric/molar value correct **(1)** • second and third stoichiometric/molar value correct **(1)**	Example of equation 	**(2)**

Question Number	Answer	Additional Guidance	Mark
20(c)(ii)	An answer that makes reference to the following point • brown fumes (of NO_2)	Allow reddish brown fumes Allow vapour/gas/smoke for fumes Ignore shades of brown Do not award brown with any other colours Allow steam/white solid dissolves Ignore effervescence/fizzing/bubbles/water forming Do not award incorrect observations such as precipitation	**(1)**

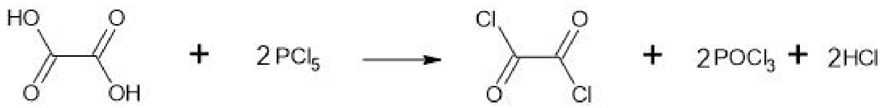
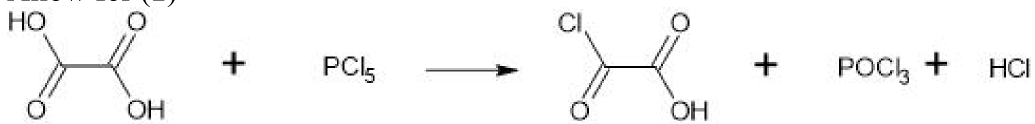
Question Number	Answer	Additional Guidance	Mark
20(d)(i)	An answer that makes reference to the following points: • first indicator **and** colour at the end point **(1)** • second indicator **and** colour at the end point **(1)**	Screened methyl orange **and** grey or methyl orange **and** orange or bromophenol blue **and** green phenol red **and** orange phenolphthalein **and** (pale) pink bromothymol blue **and** green Two correct indicators scores (1)	**(2)**

Question Number	Answer	Additional Guidance	Mark
20(d)(ii)	An answer that makes reference to the following point • difficult to see the colour change /colours will mix	Allow there is no correct second indicator Allow TE based on the colours stated in part (i)	**(1)**

Question Number	Answer		Additional Guidance	Mark
20(d)(iii)	An answer that makes reference to the following points:			(5)
	• use of volumes from graph at 12.5 cm^3 **and** 37.5 cm^3	(1)	Working **must** be shown on graph	
	• use of curve to determine the pH at 12.5 cm^3 **and** 37.5 cm^3	(1)	At 12.5 cm^3 pH = 1.3 Allow range 1.2 – 1.4 At 37.5 cm^3 pH = 5.5 Allow range 5.4 – 5.6 Accept pK_a for pH Allow (1) for M1 and M2 if no working on graph Allow (1) for M1 and M2 if only one correct volume used to determine pH Allow TE for M3 through M5	
	• 10^{-pK_a}	(1)	This may be subsumed in the calculation for M4 and M5	
	• first K_a value	(1)	K_{a1} = 0.050119/ 5.0119 x 10^{-2} (mol dm^{-3}) Allow range 0.039811 to 0.063096 (mol dm^{-3})	
	• second K_a value	(1)	K_{a2} = 0.0000031623/ 3.1623 x 10^{-6} (mol dm^{-3}) Allow range 2.5119 x 10^{-6} to 3.9811 x 10^{-6} (mol dm^{-3}) Ignore SF except 1SF but penalise once only	

Question Number	Answer	Additional Guidance	Mark
20(e)(i)	An answer that makes reference to the following point • (use the pure oxalic acid to) find the retention time	Ignore retention factor / R_f	**(1)**

Question Number	Answer		Additional Guidance	Mark
20(e)(ii)	(Method 1) • calculation of concentration of oxalic acid in g dm^{-3} • calculation of mass of oxalic acid needed in 500 cm^3 • calculation of mass of spinach needed (Method 2) • calculation of moles of oxalic acid needed in 500 cm^3 • calculation of mass of oxalic acid needed • calculation of mass of spinach needed	 **(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	<u>Example of calculation</u> c = (0.558 x 90 =) 50.22 (g dm^{-3}) m = (50.22 x 0.5 =) 25.11 (g) m = ((25.11 ÷ 0.700) x 100 =) 3587.1/3587/3590 (g) n = (0.558 ÷ 2 =) 0.279 (mol) m = (0.279 x 90 =) 25.11 (g) /25110 (mg) m = ((25110 ÷ 700) x 100 =) 3587.1/3587/3590 (g) Accept final mass in kilograms e.g. 3.59 kg TE at each stage Ignore SF except 1 SF Final answer without working scores (3)	**(3)**

Question Number	Answer	Additional Guidance	Mark
20(f)	• acyl chloride product **(1)** • balanced equation **(1)**	Accept skeletal/structural/displayed formulae or combination thereof Examples of equation  $HOOCCOOH + 2PCl_5 \rightarrow ClOCCOCl + 2POCl_3 + 2HCl$ Allow $COOHCOOH + 2PCl_5 \rightarrow COClCOCl + 2POCl_3 + 2HCl$ Penalise molecular formulae $C_2H_2O_4$ / $C_2O_2Cl_2$ once only Allow for **(1)** 	**(2)**

Pearson Education Limited. Registered company number 872828
with its registered office at 80 Strand, London, WC2R 0RL, United Kingdom