



Mark Scheme (Results)

October 2023

Pearson Edexcel International Advanced Level
In Chemistry (WCH14)
Paper 01 Unit 4: Rates, Equilibria and Further
Organic Chemistry

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October 2023

Question Paper Log Number P75068A

Publications Code WCH14_01_MS_2310

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General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

Using the Mark Scheme

Examiners should look for qualities to reward rather than faults to penalise. This does NOT mean 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 understand the sense of the expected answer.

Phrases/words in **bold** indicate that the meaning of the phrase or the actual word is **essential** for the answer.

ecf/TE/cq (error carried forward) means that a wrong answer given in an earlier part of a question is carried forward 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 your 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 their writing 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.

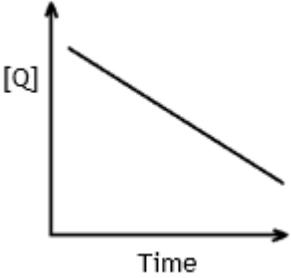
Questions where QWC is likely to be particularly important are indicated (QWC) in the mark scheme. This does not preclude others.

Section A (multiple choice)

Question Number	Answer	Mark
1(a)	<p>The only correct answer is B (measurement of change in volume)</p> <p><i>A is incorrect because none of the gases is coloured</i></p> <p><i>C is incorrect because there is no loss or gain of mass</i></p> <p><i>D is incorrect because there are no bases in the mixture</i></p>	(1)

Question Number	Answer	Mark
1(b)	<p>The only correct answer is D (quenching followed by titrating with acid)</p> <p><i>A is incorrect because nothing in the mixture is coloured</i></p> <p><i>B is incorrect because there is no change in volume</i></p> <p><i>C is incorrect because there is no loss or gain of mass</i></p>	(1)

Question Number	Answer	Mark
2	<p>The only correct answer is D (16)</p> <p><i>A is incorrect because doubling $[\text{BrO}_3^-]$ and $[\text{Br}^-]$ will both double the rate, doubling $[\text{H}^+]$ increases the rate by 2^2</i></p> <p><i>B is incorrect because doubling $[\text{BrO}_3^-]$ and $[\text{Br}^-]$ will both double the rate, doubling $[\text{H}^+]$ increases the rate by 2^2</i></p> <p><i>C is incorrect because doubling $[\text{BrO}_3^-]$ and $[\text{Br}^-]$ will both double the rate, doubling $[\text{H}^+]$ increases the rate by 2^2</i></p>	(1)

Question Number	Answer	Mark
3(a)	<p data-bbox="371 443 1189 483">The only correct answer is A ()</p>  <p data-bbox="371 651 1644 687"><i>B is incorrect because the graph shows a reaction where the rate decreases as concentration of Q increases</i></p> <p data-bbox="371 719 1525 756"><i>C is incorrect because the graph shown is correct when rate is plotted against concentration of Q</i></p> <p data-bbox="371 788 1644 825"><i>D is incorrect because the graph shows a reaction where the rate increases as concentration of Q increases</i></p>	(1)

Question Number	Answer	Mark
3(b)	<p data-bbox="371 965 857 1005">The only correct answer is B (20s)</p> <p data-bbox="371 1037 1211 1074"><i>A is incorrect because the half-life for a first order reaction is constant</i></p> <p data-bbox="371 1106 1211 1142"><i>C is incorrect because the half-life for a first order reaction is constant</i></p> <p data-bbox="371 1174 1211 1211"><i>D is incorrect because the half-life for a first order reaction is constant</i></p>	(1)

Question Number	Answer	Mark
4	<p>The only correct answer is C ($(-\text{gradient}) \times R$)</p> <p><i>A is incorrect because the gradient = $-E_a / R$</i></p> <p><i>B is incorrect because the gradient = $-E_a / R$</i></p> <p><i>D is incorrect because the gradient = $-E_a / R$</i></p>	(1)

Question Number	Answer	Mark
5 (a)	<p>The only correct answer is B (-364)</p> <p><i>A is incorrect because the value must be divided by 2 as there are 2 Cl^-</i></p> <p><i>C is incorrect because the signs are the wrong way round giving an endothermic value</i></p> <p><i>D is incorrect because the signs are the wrong way round giving an endothermic value and the value must be divided by 2 as there are 2 Cl^-</i></p>	(1)

Question Number	Answer	Mark
5(b)	<p>The only correct answer is C (magnesium ions have a higher charge density)</p> <p><i>A is incorrect because the radius of magnesium ions are smaller</i></p> <p><i>B is incorrect because this is true but it does not explain the hydration enthalpy</i></p> <p><i>D is incorrect because this is true but it does not explain the hydration enthalpy</i></p>	(1)

Question Number	Answer	Mark
6	<p>The only correct answer is D ($K_p = (p\text{NO}_2)^4 \times (p\text{O}_2)$)</p> <p><i>A is incorrect because solids are not included in the K_p expression and the value should be raised to the power not multiplied by the number from the equation</i></p> <p><i>B is incorrect because solids are not included in the K_p expression</i></p> <p><i>C is incorrect because the value should be raised to the power not multiplied by the number from the equation</i></p>	(1)

Question Number	Answer	Mark								
7	<p>The only correct answer is D (</p> <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>Acid 1</th> <th>Conjugate base of Acid 1</th> <th>Acid 2</th> <th>Conjugate base of Acid 2</th> </tr> </thead> <tbody> <tr> <td>HCl</td> <td>Cl^-</td> <td>HCOOH_2^+</td> <td>HCOOH</td> </tr> </tbody> </table> <p>)</p> <p><i>A is incorrect because the conjugate bases are the wrong way round</i></p> <p><i>B is incorrect because HCOOH_2^+ is an acid not a base and HCOOH is a base and not an acid in this reaction</i></p> <p><i>C is incorrect because HCOOH_2^+ is an acid not a base and so should be exchanged with HCOOH</i></p>	Acid 1	Conjugate base of Acid 1	Acid 2	Conjugate base of Acid 2	HCl	Cl^-	HCOOH_2^+	HCOOH	(1)
Acid 1	Conjugate base of Acid 1	Acid 2	Conjugate base of Acid 2							
HCl	Cl^-	HCOOH_2^+	HCOOH							

Question Number	Answer	Mark
8	<p>The only correct answer is C (the dissociation of water is endothermic, so the concentration of hydrogen ions is higher at 100°C than at 25°C)</p> <p><i>A is incorrect because at lower pH the concentration of hydrogen ions is higher</i></p> <p><i>B is incorrect because at lower pH the concentration of hydrogen ions is higher and the reaction is endothermic</i></p> <p><i>D is incorrect because the forward reaction is endothermic</i></p>	(1)

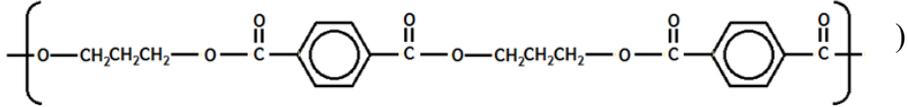
Question Number	Answer	Mark
9	<p>The only correct answer is D (4, 3, 1, 2)</p> <p><i>A is not correct because Beaker 4 has the highest pH</i></p> <p><i>B is not correct because Beaker 4 has the highest pH</i></p> <p><i>C is not correct because Beaker 4 has the highest pH</i></p>	(1)

Question Number	Answer	Mark
10(a)	<p>The only correct answer is D (lithium tetrahydridoaluminate(III))</p> <p><i>A is incorrect because these are the reagents for the reverse reaction</i></p> <p><i>B is incorrect because this will not reduce a carboxylic acid</i></p> <p><i>C is incorrect because this will not reduce the carboxylic acid to the primary alcohol</i></p>	(1)

Question Number	Answer	Mark
10(b)	<p>The only correct answer is D (8.80 g)</p> <p><i>A is incorrect because this answer comes from swapping the M_r values</i></p> <p><i>B is incorrect because this assumes that 90% of methylpropanoic acid is required to give this yield</i></p> <p><i>C is incorrect because this assumes the yield is 100%</i></p>	(1)

Question Number	Answer	Mark
10(c)	<p>The only correct answer is B (anhydrous)</p> <p><i>A is incorrect because the reaction requires no catalyst</i></p> <p><i>C is incorrect because the reaction works at room temperature.</i></p> <p><i>D is incorrect because ether solvent is required for use with $LiAlH_4$</i></p>	(1)

Question Number	Answer	Mark
10(d)	<p>The only correct answer is A (it can be carried out at room temperature)</p> <p><i>B is incorrect because a catalyst is not required</i></p> <p><i>C is incorrect because the atom economy is lower as HCl is formed rather than H_2O</i></p> <p><i>D is incorrect because the formation of toxic HCl is a disadvantage</i></p>	(1)

Question Number	Answer	Mark
11	<p>The only correct answer is D ()</p> <p><i>A is incorrect because it is a single repeat unit</i></p> <p><i>B is incorrect because it is missing a dicarboxylic acid group</i></p> <p><i>C is incorrect because the groups are reversed</i></p>	(1)

Question Number	Answer	Mark
12	<p>The only correct answer is D (44.0632 43.9898)</p> <p><i>A is not correct because 27.9949 is the mass of CO and 29.0395 is the mass of C₂H₅</i></p> <p><i>B is not correct because 27.9949 is the mass of CO and 29.0395 is the mass of C₂H₅</i></p> <p><i>C is not correct because 43.9898 is the mass of propane and 44.0632 is the mass of carbon dioxide</i></p>	(1)

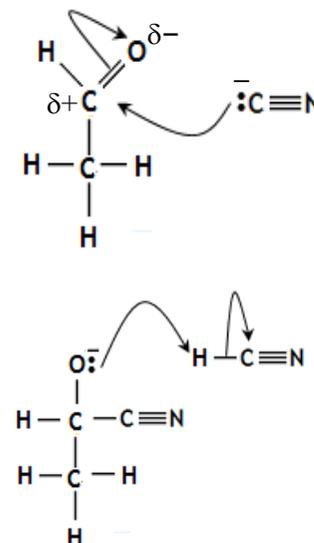
Question Number	Answer	Mark
13(a)	<p>The only correct answer is B (0.38)</p> <p><i>A is incorrect because this is the ratio of the spot to the top of the chromatogram slide</i></p> <p><i>C is incorrect because this is the ratio of the distanced travelled by X compared to Y</i></p> <p><i>D is incorrect because this is (1 – the correct answer)</i></p>	(1)

Question Number	Answer	Mark		
13(b)	<p>The only correct answer is C (<table border="1" data-bbox="840 662 1630 778"> <tr> <td data-bbox="840 662 1234 778">is weaker than the attraction between X and the stationary phase</td> <td data-bbox="1234 662 1630 778">is stronger than the attraction between X and the mobile phase</td> </tr> </table>)</p> <p><i>A is incorrect because a stronger attraction to the stationary phase means it will move more slowly</i></p> <p><i>B is incorrect because a stronger attraction to the stationary phase means it will move more slowly</i></p> <p><i>D is incorrect because a weaker attraction to the mobile phase means it will move more slowly</i></p>	is weaker than the attraction between X and the stationary phase	is stronger than the attraction between X and the mobile phase	(1)
is weaker than the attraction between X and the stationary phase	is stronger than the attraction between X and the mobile phase			

(Total for Section A = 20 marks)

Section B

Question Number	Answer	Additional Guidance	Mark
14(a)(i)	An answer that makes reference to the following point: <ul style="list-style-type: none"><li data-bbox="421 443 779 478">• 2-hydroxypropanenitrile	Allow 2-hydroxypropannitrile Allow 2-hydroxypropanitrile Do not award 2-hydroxo versions of allowable answers Do not award 2-hydroxyl versions of allowable answers Do not award Hydroxy-2-propanenitrile Do not award nitride versions of allowable answers Do not award additional numbers e.g. 2-hydroxypropane-2-nitrile Ignore additional spaces, omission of hyphen, use of comma instead of hyphen e.g. 2 hydroxy propanenitrile	(1)

Question Number	Answer	Additional Guidance	Mark
14(a)(ii)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> • structure of the intermediate carbanion including negative charge anywhere on the ion or outside a bracket around the ion <p>Step 1 mechanism</p> <ul style="list-style-type: none"> • lone pair of electrons on C of $C\equiv N^-$ • arrow from lone pair on C of $C\equiv N^-$ to C(δ^+) in ethanal • arrow from C=O bond to, or just beyond, O • dipole on C=O <p>Step 2 mechanism</p> <ul style="list-style-type: none"> • lone pair on O • arrow from lone pair on O of intermediate to H of $H-C\equiv N$ / HCN • arrow from H-C bond to C, or just beyond C, of $H-C\equiv N$ / HCN 	<p>Intermediate is stand alone and scores (1)</p> <p>Allow $-CH_3$ Allow $-CN$ Ignore absence of lone pair Triple bond does not need to be shown Do not award $C\equiv N-C$</p>  <p>Ignore dipole on HCN even if incorrect Do not award Step 2 point 2 for +ve charge on H For the mechanism all 7 points scores 3 marks 4, 5 or 6 points scores 2 marks 2 or 3 points scores 1 mark Only 1 step point scores 0 step marks</p>	(4)

Question Number	Answer	Additional Guidance	Mark
14(a)(iii)	<p>An answer that makes reference to the following points:</p> <p>This mark is for the description of nucleophilic attack</p> <ul style="list-style-type: none"> in the first step of the reaction the (negative) cyanide ion / $\text{C}\equiv\text{N}^-$ attacks a δ^+ centre / seeks out regions of low electron density <p>This mark is for the description of addition</p> <ul style="list-style-type: none"> two substances join together to make one 	<p>Mark independently</p> <p>Allow donates a pair of electrons Allow seeks out positive charge / centre Allow carbon (of the $\text{C}=\text{O}$) is positive (1) Ignore acts as a nucleophile Ignore general descriptions of nucleophile which are not specific to CN^- Do not award just CN (with no charge)</p> <p>(1) Allow CN^- is added onto the ethanal with nothing substituted / eliminated / with no other product formed. Allow there is only one product / no other molecule is formed Allow there are fewer products than reactants Allow hydrogen cyanide and ethanal join together Allow unsaturated compound becomes more saturated Allow a π (pi) bond is broken and (two) single bonds are made Allow HCN is joined/bonded onto ethanal Ignore just HCN / CN^- is added onto the ethanal Ignore added</p>	(2)

Question Number	Answer	Additional Guidance	Mark
14(b)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> • because the product is a racemic mixture / equal concentrations of both enantiomers are formed (1) • as the cyanide / nitrile ion attacks / approach from above and below the plane of the C=O bond equally (1) 	<p>Marks are standalone</p> <p>Allow two mirror images are formed in equal amounts / concentrations</p> <p>Accept can attack / approach equally from either side / both sides / opposite sides / top and bottom of the plane of the C=O bond</p> <p>Ignore 'both directions' or 'two directions' without 'opposite'</p> <p>Do not award from any sides</p>	(2)

(Total for Question 14 = 9 marks)

Question Number	Answer	Additional Guidance	Mark
15(a)(i)	<ul style="list-style-type: none"> <li data-bbox="416 384 898 456">• calculation of moles of oxygen at equilibrium (1) <li data-bbox="416 496 853 568">• calculation of moles of NO at equilibrium (1) <li data-bbox="416 647 864 719">• calculation of moles of NO₂ at equilibrium (1) 	<p data-bbox="1088 308 1391 339"><u>Example of calculation</u></p> <p data-bbox="1088 379 1603 411">= $7.000 \div 32 = 0.21875 / 0.219$ (mol)</p> <p data-bbox="1088 419 1234 451">Allow 7/32</p> <p data-bbox="1088 491 1675 523">= moles of oxygen x 2 = $0.4375 / 0.438$ (mol)</p> <p data-bbox="1088 531 1234 563">Allow 7/16</p> <p data-bbox="1088 643 1675 707">= total moles – moles of O₂ – moles of NO = $0.69625 - 0.21875 - 0.4375 = 0.0400$ (mol)</p> <p data-bbox="1088 715 1368 746">Allow TE throughout</p> <p data-bbox="1088 754 1211 786">Ignore SF</p>	(3)

Question Number	Answer	Additional Guidance	Mark
15(a)(ii)	<ul style="list-style-type: none"> <li data-bbox="416 379 925 483">• divides the moles of the three substances by 15 to find the concentrations <li data-bbox="416 563 775 600">• gives the formula for K_c <li data-bbox="416 754 925 823">• substitution of concentrations in the expression given in M2 <li data-bbox="416 1050 925 1118">• calculation of final value including units 	<p data-bbox="1111 304 1406 336"><u>Example of calculation</u></p> <p data-bbox="1111 371 1928 408">[NO₂] = 0.0400 ÷ 15 = 0.0026667 / 2.6667 × 10⁻³ (mol dm⁻³)</p> <p data-bbox="1111 408 1917 445">[NO] = 0.4375 ÷ 15 = 0.029167 / 2.9167 × 10⁻² (mol dm⁻³)</p> <p data-bbox="1111 445 1928 481">[O₂] = 0.21875 ÷ 15 = 0.014583 / 1.4583 × 10⁻² (mol dm⁻³)</p> <p data-bbox="1111 481 1592 518">Allow TE on incorrect values in (a)(i)</p> <p data-bbox="1037 448 1077 485">(1)</p> <p data-bbox="1037 560 1077 596">(1)</p> <p data-bbox="1111 560 1397 596">= [NO₂]² ÷ [NO]²[O₂]</p> <p data-bbox="1111 596 1872 633">Allow an expression showing moles ÷ V for each substance</p> <p data-bbox="1111 633 1480 670">Do not award round brackets</p> <p data-bbox="1111 670 1480 707">Do not award K_p expressions</p> <p data-bbox="1037 783 1077 820">(1)</p> <p data-bbox="1111 743 1693 780">$K_c = 0.0026667^2 \div (0.029167^2 \times 0.014583)$</p> <p data-bbox="1111 780 1816 817">$K_c = 7.1113 \times 10^{-6} \div (8.5071 \times 10^{-4} \times 1.4583 \times 10^{-2})$</p> <p data-bbox="1111 817 1957 853">Award M2 for the correct expression if no formula has been given</p> <p data-bbox="1111 853 1592 890">Allow TE on incorrect formula in M2</p> <p data-bbox="1111 890 1704 927">Allow TE on incorrect values calculated in M1</p> <p data-bbox="1111 927 1816 995">Allow TE on moles in (a)(i) used without converting to concentration</p> <p data-bbox="1111 1038 1733 1075">= 0.57320 / 5.7320 × 10⁻¹ dm³ mol⁻¹ / mol⁻¹ dm³</p> <p data-bbox="1037 1075 1077 1112">(1)</p> <p data-bbox="1111 1075 1592 1112">Allow TE on incorrect formula in M2</p> <p data-bbox="1111 1155 1637 1192">0.038213 dm³ mol⁻¹ (not ÷ 15) scores (3)</p> <p data-bbox="1111 1192 1693 1228">Correct answer with some working scores (4)</p> <p data-bbox="1111 1228 1592 1265">Ignore SF except 1 SF in final answer</p>	(4)

Question Number	Answer	Additional Guidance	Mark
15(b)	<ul style="list-style-type: none"> • rearrangement of $pV = nRT$ (1) • conversion of volume in dm^3 to m^3 and moles of gas = 0.69625 (1) • calculation of final value (1) 	<p><u>Example of calculation</u></p> <p>$T = pV \div nR$ Allow with values substituted in</p> <p>$15 \text{ dm}^3 = 0.015 / 1.5 \times 10^{-2} \text{ m}^3 / 15 \times 10^{-3} \text{ m}^3$</p> <p>$= (200,000 \times 0.015) \div (0.69625 \times 8.31)$ $= 518.51 / 519 \text{ (K)}$ Allow use of 8.314 rather than 8.31</p> <p>Allow conversion of pressure to kPa and use of dm^3 giving $= (200 \times 15) \div (0.69625 \times 8.31)$ $= 518.51 / 519 \text{ (K)}$ Allow 245.5(1) °C / 246 °C</p> <p>518510 / 519000 (no conversion) scores (2)</p> <p>If given in °C units must be given Allow TE on incorrect moles of gas and volume Do not award 518(K) or 519°C Correct answer with some working scores (3) Ignore SF except 1 SF</p>	(3)

Question Number	Answer	Additional Guidance	Mark
15(c)(i)	<p>An answer that makes reference to the following point:</p> <ul style="list-style-type: none"> the reactants / NO and O₂ are colourless but the product / NO₂ is reddish brown / coloured 	<p>Allow just NO / O₂ is colourless and NO₂ is brown Allow just nitrogen dioxide / product is reddish brown / coloured / dark colour Allow any combination of yellow, red, orange and brown for the colour of NO₂ Allow measure the time for the brown gas to form Allow the reaction goes from colourless to brown</p> <p>Ignore just 'there will be a colour change' / mixture will darken Ignore NO₂ is a different colour form NO and O₂ Do not award NO is coloured so there is a colour change Do not award NO is yellow / red / orange / brown</p>	(1)

Question Number	Answer	Additional Guidance	Mark
15(c)(ii)	<ul style="list-style-type: none"> rearrangement of rate equation expression and inserting values calculation of <i>k</i> and units 	<p><u>Example of calculation</u></p> $= 6.87 \times 10^{-4} \div ((6.50 \times 10^{-2})^2 \times 1.25 \times 10^{-2})$ $= 13.008 / 13.0 \text{ dm}^6 \text{ mol}^{-2} \text{ s}^{-1}$ <p>Correct answer with no working scores (2) Correct numerical answer with incorrect units scores (1) Allow units in any order Allow dm⁶/mol²s</p> <p>0.84554 / 0.846 dm³ mol⁻¹ s⁻¹ (not squaring 6.50 × 10⁻²) scores (1) for final value and units for M2 Ignore SF except 1SF</p>	(2)

Question Number	Answer	Additional Guidance	Mark
15(c)(iii)	An answer that makes reference to the following point <ul style="list-style-type: none"> a three particle collision is unlikely 	Accept it is unlikely that more than two molecules will collide / Allow hard / difficult / impossible instead of unlikely Allow there are three molecules involved in the reaction Ignore it is a third order reaction Do not award just three moles colliding / just three reactants colliding	(1)

Question Number	Answer	Additional Guidance	Mark
15(c)(iv)	An answer that makes reference to the following points: <ul style="list-style-type: none"> adding the two steps together gives the overall equation the steps do not match the rate equation because the slow step should be the second step 	<p>(1) Allow the two steps match the overall equation as the reactants and products are the same Allow N_2O_2 is formed then reacts / cancels out / is an intermediate Ignore just the overall equation is $2\text{NO} + \text{O}_2 \rightarrow 2\text{NO}_2$</p> <p>(1) Allow it does not match because there is no oxygen in the slow step / rate determining step / rds Allow because in this mechanism oxygen is zero order / is not first order Allow because with these steps the rate equation would be $\text{rate} = k[\text{NO}]^2$</p>	(2)

(Total for Question 15 = 16 marks)

Question Number	Answer	Additional Guidance	Mark
16(a)(i)	<ul style="list-style-type: none"> • calculation of the standard entropy of the reactants (1) • calculation of the standard entropy of the products (1) • calculation of the entropy change (products – reactants) (1) 	<p><u>Example of calculation</u></p> <p>Penalise units once only</p> <p>= $87.4 + (3 \times 197.6) = (680.2) \text{ (J K}^{-1} \text{ mol}^{-1}\text{)}$</p> <p>= $(2 \times 27.3) + (3 \times 213.6) = (695.4) \text{ (J K}^{-1} \text{ mol}^{-1}\text{)}$</p> <p>= $(695.4 - 680.2) = (+)15.2 \text{ (J K}^{-1} \text{ mol}^{-1}\text{)}$</p> <p>Ignore SF in final answer except 1 SF Correct answer with no working scores (3) Allow TE</p>	(3)

Question Number	Answer	Additional Guidance	Mark
16(a)(ii)	<ul style="list-style-type: none"> • calculation of the standard enthalpy of formation of the reactants (1) • calculation of the standard enthalpy of formation of the products (1) • calculation of the enthalpy change (products – reactants) (1) 	<p><u>Example of calculation</u></p> <p>= $-824 + (3 \times -111) = (-1157 \text{ (kJ mol}^{-1}\text{)})$</p> <p>= $3 \times -394 = (-1182) \text{ (kJ mol}^{-1}\text{)}$</p> <p>= $(-1182) - (-1157) = -25 \text{ (kJ mol}^{-1}\text{)}$</p> <p>-2339 (kJ mol⁻¹) scores M1 and M2 +25 (kJ mol⁻¹) scores M1 and M2 Ignore calculates the enthalpy change and then goes on to calculate $\Delta S_{\text{surroundings}}$ BUT allow the equations in (a)(iii) Ignore SF except 1 SF Correct answer with no working scores (3)</p>	(3)

Question Number	Answer	Additional Guidance	Mark
16(a)(iii)	<p>An answer that makes reference to the following points:</p> <p>Either (using entropy arguments)</p> <ul style="list-style-type: none"> • $\Delta S_{\text{total}} = \Delta S_{\text{system}} + \Delta S_{\text{surroundings}}$ and $\Delta S_{\text{surroundings}} = -\Delta H \div T$ (1) • (ΔH is negative so) $\Delta S_{\text{surroundings}}$ or $-\Delta H \div T$ is (always) positive and ΔS_{system} is positive (1) • ΔS_{total} is positive (at all temperatures) and so the reaction is feasible (at all temperatures) (1) <p>OR (using Gibbs free energy arguments)</p> <ul style="list-style-type: none"> • $\Delta G = \Delta H - T\Delta S$ (1) • (ΔS is positive so) $T\Delta S$ or ΔS is (always) positive and ΔH is negative (1) • ΔG is (always) negative and so the reaction is (always) feasible (1) 	<p>Candidates may use their values instead of symbols Penalise omission of Δ once only</p> <p>$\Delta S_{\text{total}} = \Delta S_{\text{system}} - \frac{\Delta H}{T}$ scores M1</p> <p>Allow either equation described in words</p> <p>Allow spontaneous</p> <p>Allow spontaneous Allow TE on values in (a)(i) and (a)(ii)</p>	(3)

Question Number	Answer	Additional Guidance	Mark
16(b)(i)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> • calculation of ΔS_{system} • calculation of ΔH • conversion of ΔS_{system} or ΔH so units match • rearrange $\Delta S_{\text{total}} = \Delta S_{\text{system}} + \Delta S_{\text{surroundings}}$ when $\Delta S_{\text{total}} = 0$ and calculation of T 	<p>(1) $= ((2 \times 28.3) + (3 \times 213.6)) - (50.9 + (3 \times 197.6))$ $= 697.4 - 643.7$ $= 53.7 \text{ (J K}^{-1} \text{ mol)}$</p> <p>(1) $= (3 \times -394) - (-1676 + (3 \times -111))$ $= -1182 + 2009$ $= 827 \text{ (kJ mol}^{-1}\text{)}$</p> <p>(1) $\Delta S = 0.0537 \text{ (kJ K}^{-1} \text{ mol)}$ or $\Delta H = 827000 \text{ (J mol}^{-1}\text{)}$</p> <p>$T = \Delta H \div \Delta S_{\text{system}}$</p> <p>(1) $= \frac{827000}{53.7} = 15400 / 1.5400 \times 10^4 \text{ (K)}$</p> <p>Correct answer scores (4) 15.4 (no M3) scores (3) Ignore incorrect units throughout except in final answer Allow TE throughout except for M4 for a negative temperature</p>	(4)

Question Number	Answer	Additional Guidance	Mark
16(b)(ii)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> because this temperature cannot be achieved in a Blast Furnace 	<p>Allow the temperature in the Blast Furnace is too low Allow the temperature required is too high Ignore temperature required is very high Ignore the energy needed is too high Ignore activation energy is too high Ignore cost</p>	(1)

(Total for Question 16 = 14 marks)

Question number	Answer	Additional guidance	Mark																				
*17a	<p>This question assesses the student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning.</p> <p>Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.</p> <p>The following table shows how the marks should be awarded for indicative content.</p> <table border="1" data-bbox="383 576 1218 823"> <thead> <tr> <th>Number of indicative marking points seen in answer</th> <th>Number of marks awarded for indicative marking points</th> </tr> </thead> <tbody> <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> </tbody> </table> <p>The following table shows how the marks should be awarded for structure and lines of reasoning</p> <table border="1" data-bbox="383 927 1240 1337"> <thead> <tr> <th></th> <th>Number of marks awarded for structure of answer and sustained lines of reasoning</th> </tr> </thead> <tbody> <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> </tbody> </table>	Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	6	4	5-4	3	3-2	2	1	1	0	0		Number of marks awarded for structure of answer and sustained lines of reasoning	Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2	Answer is partially structured with some linkages and lines of reasoning	1	Answer has no linkages between points and is unstructured	0	<p>Guidance on how the mark scheme should be applied.</p> <p>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).</p> <p>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).</p> <p>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 0 reasoning marks.</p> <p>If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).</p> <p>Comment: Look for the indicative marking points first, then consider the mark for the structure of the answer and sustained line of reasoning</p>	(6)
Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points																						
6	4																						
5-4	3																						
3-2	2																						
1	1																						
0	0																						
	Number of marks awarded for structure of answer and sustained lines of reasoning																						
Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2																						
Answer is partially structured with some linkages and lines of reasoning	1																						
Answer has no linkages between points and is unstructured	0																						

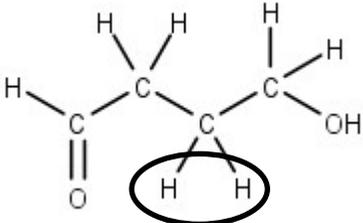
	<p>Indicative content</p> <ul style="list-style-type: none"> • IP1 sodium carbonate solution / sodium hydrogencarbonate solution gives fizzing (due to the formation of carbon dioxide) • IP2 identifies butanoic acid is the only (carboxylic) acid / compound with an acidic proton / only compound with -COOH • IP3 Tollens' reagent / ammoniacal silver nitrate gives a silver mirror • IP4 identifies 4-hydroxybutanal, which is the only aldehyde / only compound containing -CHO • IP5 iodine and sodium hydroxide (solution) gives a yellow precipitate / antiseptic smell • IP6 identifies 3-hydroxybutanone, which is the only compound with a $\text{CH}_3\text{CO-}$ group / only compound with a methyl ketone group 	<p>1 IP for each test and positive result, 1 IP for the compound and the functional group. Compound IP dependent on correct test or very near miss</p> <p>Allow react with alcohol and (conc) H_2SO_4 and fruity smell for IP1 BUT deduct one reasoning mark (as ethyl ethanoate also has a fruity smell) Allow reactive metal such as magnesium giving fizzing but do not award sodium / potassium Allow produces gas Ignore produces CO_2 / bubbling through limewater</p> <p>Allow butanoic acid is a carboxylic acid</p> <p>Accept Fehling's / Benedict's test gives a red precipitate</p> <p>Allow has a carbonyl group which can be oxidised Allow 4-hydroxybutanal is an aldehyde</p> <p>Allow 'use of the triiodomethane / iodoform test / iodoform reaction' / alkaline iodine</p> <p>Accept is the only compound with a secondary OH group attached to a methyl group</p> <p>If IP3 (and IP4) OR IP5 (and IP6) have been scored, Allow 2,4 DNP and red/orange ppt as an alternative to the other pair of IPs (IP3 & IP4 or IP5 & IP6) BUT deduct 1 reasoning mark Ignore Brady's reagent / 2,4 DNP other than as above</p>	
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		Ignore indicator / PCl_5 / hydrolysis of ethyl ethanoate / acidified potassium dichromate(VI) / ethyl ethanoate has a fruity / gluey smell	
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Question Number	Answer	Additional Guidance	Mark
17(b)(i)	<p>An answer that makes reference to the following point:</p> <ul style="list-style-type: none"> they / all (four isomers) have four carbon environment / produce four peaks 	<p>Allow they have the same number of peaks Allow they all have four carbons in different environments Allow they / all (four) have the same number of carbon environments / peaks Ignore just they all have four carbons Ignore they have the same molecular formula Ignore they have the same proton environments Ignore they all have five different proton environments Do not award they have the same peaks Do not award the wrong number of carbon atoms Do not award all have four different proton environments</p>	(1)

Question Number	Answer	Additional Guidance			Mark
17(b)(ii)	<ul style="list-style-type: none"> Two correct numbers of peaks (1) Third correct number of peaks (1) Fourth correct number of peaks (1) 				(3)
		Name	Skeletal structure	Number of peaks	
		butanoic acid		4	
		4-hydroxybutanal		5	
		ethyl ethanoate		3	
3-hydroxybutanone		4			

Question Number	Answer	Additional Guidance	Mark
17(b)(iii)	<p>An answer that makes reference to the following point:</p> <ul style="list-style-type: none"> • butanoic acid / CH₃CH₂CH₂COOH <p>and</p> <p>the hydrogen / proton in COOH</p>	<p>If both are given, both must be correct May be shown on a labelled diagram Allow any formula showing structure including skeletal formula to identify the acid</p> <p>Allow COOH to indicate the proton If name and formula are given both must be correct Do not award positive ions such as [COOH]⁺</p>	(1)

Question Number	Answer	Additional Guidance	Mark
17(b)(iv)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> • the quintet results from a hydrogen with four hydrogens on adjacent carbons / the hydrogen is split by four other hydrogens (1) • because 4-hydroxybutanal has (a carbon with) a hydrogen / two hydrogens with four hydrogens on adjacent carbons (1) 	<p>This marking point is to justify the quintet. This may be scored within M2 Ignore next to a carbon with 4 hydrogens attached?</p> <p>This marking point justifies 4-hydroxybutanal as the isomer. May be shown by a diagram indicating the either the hydrogens giving the signal or the hydrogens causing the quintet in some way for example</p> <div style="text-align: center;">  </div> <p>Do not award 4-hydroxybutanal and arguments related to having 5 hydrogen environments</p>	(2)

(Total for Question 17 = 13 marks)

(Total for Section B = 52 marks)

Question Number	Answer	Additional Guidance	Mark
18(a)(i)	<p>Route 1 – Solving the expression to find $[H^+]$</p> <ul style="list-style-type: none"> • M1 expression for K_a <p>Then Either</p> <ul style="list-style-type: none"> • M3 calculates pH <p>Or</p> <ul style="list-style-type: none"> • M3 calculates $[H^+]$ from given pH <p>Or</p> <ul style="list-style-type: none"> • M3 calculates $[C_4H_9COOH]$ <p>Or</p>	<p>Allow any alternative methods Ignore throughout $-\log_{10}0.00120 = 2.9$</p> <p>(1) $K_a = \frac{[C_4H_9COO^-][H^+]}{[C_4H_9COOH]}$</p> <p>Allow use of $[H^+]^2$ $[HA]$ and / or $[A^-]$ Allow correct rearranged expression</p> <p>(1) $= \sqrt{1.38 \times 10^{-5} \times 0.12}$ This also scores M1 $= 0.0012869 / 1.2869 \times 10^{-3} \text{ (mol dm}^{-3}\text{)}$</p> <p>(1) $= -\log_{10}0.0012869$ $= 2.8905 / 2.9$</p> <p>(1) $= 0.0012589 / 1.2589 \times 10^{-3}$</p> <p>(1) $= \frac{0.0012869^2}{1.38 \times 10^{-5}} = 0.12001$</p>	(3)

	<ul style="list-style-type: none"> M3 uses Henderson-Hasselbalch equation to find pH <p>Route 2 – Equating expression for $[H^+]$ to expression for pH</p> <ul style="list-style-type: none"> expression for K_a gives a mathematical expression relating pH and $[H^+]$ equates expression to calculate $[H^+]$ to 10^{-pH} <p>or</p> <ul style="list-style-type: none"> equates expression to calculate $[H^+]$ to pH 	<p>(1) $pH = pK_a + \log_{10}([CH_3COO^-] / [CH_3COOH])$ or $pH = -\log_{10}K_a + \log_{10} [CH_3COO^-] - \log_{10} [CH_3COOH]$ or $pH = -\log_{10}(0.0000138) + \log_{10}0.0012869 - \log_{10}0.12$ and $pH = 4.8601 + -2.8905 + 0.92082 = 2.8904$</p> <p>(1) $K_a = \frac{[C_4H_9COO^-][H^+]}{[C_4H_9COOH]}$</p> <p>(1) $pH = -\log_{10}[H^+]$ or $[H^+] = 10^{-pH}$</p> $10^{-2.9} = \sqrt{1.38 \times 10^{-5} \times 0.12}$ <p>or</p> <p>(1) $2.9 = -\log_{10}\sqrt{1.38 \times 10^{-5} \times 0.12}$</p> <p>Do not award a statement that $-\log_{10}0.00120 = 2.9$</p>	
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Question Number	Answer	Additional Guidance	Mark
18(a)(ii)	<p>An answer that makes reference to the following points:</p> <p style="text-align: center;">EITHER</p> <p>Route 1</p> <ul style="list-style-type: none"> • estimates concentration of H⁺ <p style="text-align: right;">(1)</p> <ul style="list-style-type: none"> • calculates pH and so pH must be less than 13 as concentration diluted (by pentanoic acid solution / by reaction with pentanoic acid) <p style="text-align: right;">(1)</p> <p style="text-align: center;">OR</p> <p>Route 2</p> <ul style="list-style-type: none"> • estimates pOH <p style="text-align: right;">(1)</p> <ul style="list-style-type: none"> • calculates pH and so pH must be less than 13 as concentration diluted (by pentanoic acid solution / by reaction with pentanoic acid) <p style="text-align: right;">(1)</p> <p style="text-align: center;">OR</p>	<p>Allow alternative methods Allow TE throughout as long as the final pH is less than 13 and greater than 9</p> <p>$K_w = [H^+][OH^-]$</p> <p>$[H^+] = 1.0 \times 10^{-14} \div 0.1 = 1.0 \times 10^{-13} \text{ (mol dm}^{-3}\text{)}$</p> <p>pH = 13</p> <p>Ignore incomplete dissociation of alkali</p> <p>$= -\log_{10}[OH^-] = 1$</p> <p>pH = 14 – pOH = 13</p> <p>Ignore incomplete dissociation of alkali</p>	(2)

	<p>Route 3</p> <ul style="list-style-type: none"> calculates the concentration of OH⁻ in 75 cm³ assuming none has reacted calculates pH of this concentration <p style="text-align: center;">OR</p> <p>Route 4</p> <ul style="list-style-type: none"> calculates concentration of OH⁻ after addition of 50 cm³ to the pentanoic acid calculates pH 	<p>(1) mol OH⁻ = $0.1 \times 50 \times 10^{-3} = 5 \times 10^{-3}$ (mol) [OH⁻] = $5 \times 10^{-3} \div 75 \times 10^{-3} = 0.066667$ (mol dm⁻³)</p> <p>(1) $-\log_{10}[\text{OH}^-] = 1.1761$ pH = $14 - 1.1761 = 12.824$ (which is less than 13) Or [H⁺] = $1.0 \times 10^{-14} \div 0.066667 = 1.5 \times 10^{-13}$ pH = $-\log_{10}[\text{H}^+] = 12.824$</p> <p>[OH⁻] = $\frac{\text{moles of OH}^- \text{ added} - \text{moles of pentanoic acid}}{\text{Volume of water}}$</p> <p>[OH⁻] = $\frac{0.00500 - 0.00300}{75 \div 1000} = 0.026667$ (mol dm⁻³)</p> <p>pOH = $-\log_{10}[\text{OH}^-] = 1.574$ pH = $14 - \text{pOH} = 14 - 1.574 = 12.426$ Or [H⁺] = $1.0 \times 10^{-14} \div 0.026667 = 3.75 \times 10^{-13}$ pH = $-\log_{10}[\text{H}^+] = 12.426$ (which is less than 13)</p>	
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Question Number	Answer	Additional Guidance	Mark
18(a)(iii)	<p>(Neutralisation should occur at 30 cm³ because)</p> <ul style="list-style-type: none"> • calculation of number of moles of pentanoic acid (1) <p>EITHER</p> <ul style="list-style-type: none"> • calculation of volume of potassium hydroxide <p>OR</p> <ul style="list-style-type: none"> • calculation of moles of potassium hydroxide assuming volume is 30 cm³ (1) 	<p><u>Example of calculation</u></p> $= 0.12 \times \frac{25}{1000} = 0.003 / 3.0 \times 10^{-3} \text{ (mol)}$ $= \frac{0.003}{0.1} \times 1000 = 30 \text{ (cm}^3\text{)}$ $= 0.100 \times \frac{30}{1000} = 0.003 / 3.0 \times 10^{-3} \text{ (mol)}$	(2)

Question Number	Answer	Additional Guidance	Mark
18(a)(iv)	<p>An answer that makes reference to the following point:</p> <ul style="list-style-type: none"> • the titration between a weak acid and a strong base (results in pH greater than 7 / alkaline pH at the equivalence point) 	<p>Accept the product of the neutralisation / the potassium pentanoate / the pentanoate ion / the salt of weak acid forms an alkaline solution when dissolved in water</p> <p>Allow $\text{C}_4\text{H}_9\text{COO}^- + \text{H}_2\text{O} \rightleftharpoons \text{C}_4\text{H}_9\text{COOH} + \text{OH}^-$ Allow some H⁺ (from water) will combine with C₄H₉COO⁻</p>	(1)

Question Number	Answer	Additional Guidance	Mark
18(a)(v)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> • at 15.0 cm³ the concentration of pentanoic acid and pentanoate ion are equal / the pentanoic acid has been half-neutralised / this is the half-neutralisation point • (at the half-neutralisation point) pH = pK_a and calculation of pH 	<p>Accept this is the half-equivalence point Allow numbers of moles of both = 0.0015 (mol) Allow concentration of both = 0.0375 (mol dm⁻³) This can be scored from a full buffer calculation</p> <p>= -log₁₀ 1.38 × 10⁻⁵ = 4.8601 / 4.9 The value of 4.9 from a full buffer calculation scores M2 Ignore pH = -log₁₀ 1.2589 × 10⁻⁵ = 4.9</p> <p>Ignore SF except 1SF</p> <p>Accept use of Henderson-Hasselbalch. All of the following would score M1 and the first half of M2 pH = pK_a + log₁₀$\frac{0.0375}{0.0375}$ pH = pK_a + log₁₀1 pH = pK_a + 0</p> <p>Common incorrect calculations give values of 2.82, 3.14 and 4.35. These will generally score (0) BUT look for both moles or both concentrations calculated to score M1</p>	(2)

Question Number	Answer	Additional Guidance	Mark
18(b)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> • because this region is a buffer / is the buffering region (1) • because there is a large reservoir of undissociated pentanoic acid (and pentanoate ions) in solution (1) <p>EITHER</p> <ul style="list-style-type: none"> • added OH⁻ reacts with H⁺ and pentanoic acid dissociates <p>and</p> <p>keeping the concentration of H⁺ (almost) constant</p> <p>OR</p> <p>pentanoic acid reacts with the small quantity of hydroxide ions added</p> <p>and</p> <p>keeping the concentration of H⁺ (almost) constant (1)</p>	<p>Do not award the addition of buffer</p> <p>Allow the concentration of pentanoic acid is high Ignore C₄H₉COOH and C₄H₉COO⁻ are both present in solution</p> <p>Allow equations $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$ $\text{C}_4\text{H}_9\text{COOH} \rightleftharpoons \text{C}_4\text{H}_9\text{COO}^- + \text{H}^+$ Allow descriptions using formulae</p> <p>Allow ratio of [C₄H₉COO⁻] to [C₄H₉COOH] hardly changes</p> <p>Allow balanced equation $\text{C}_4\text{H}_9\text{COOH} + \text{OH}^- \rightleftharpoons \text{C}_4\text{H}_9\text{COO}^- + \text{H}_2\text{O}$ Allow descriptions using formulae</p> <p>Allow ratio of [C₄H₉COO⁻] to [C₄H₉COOH] hardly changes</p> <p>Ignore just quoting the Henderson-Hasselbalch equation without explanation</p>	(3)

Question Number	Answer	Additional Guidance	Mark
18(c)(i)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> • at the start of the titration the solution will be red (1) • it will change to orange before key point 2 / in the buffering region / at pH 3.2 and remains orange in the buffering region / until about 25 cm³ of KOH is added / until the pH reaches 4.4 (1) • it will be yellow before the neutralisation point / before the vertical portion of the graph / before key point 3 / when pH is (about) 4.4 and is still yellow at key point 4 (1) 	<p>Allow answers describing colour at the pH values OR volumes of KOH(aq) added</p> <p>Allow it will be red at key point 1 Allow it will be red between key points 1 and 2 Allow at / before pH 3.2</p> <p>Allow it changes to orange after adding a small volume / a few cm³ of KOH and remains orange until just before key point 2 / until about 20cm³ are added Allow it gradually changes (from red) to orange around key point 2 / between and key points 1 and 2 / 3 Allow any volume of KOH up to 5cm³ for the change to orange and from 15-25 cm³ for change to yellow</p> <p>Allow it changes to yellow before key point 3 / at key point 3 and stays yellow Allow it will be yellow at key point 3 and stays yellow</p>	(3)

Question Number	Answer	Additional Guidance	Mark
18(c)(ii)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> • bromothymol blue (1) • (at the neutralisation point) there is a mixture of yellow and blue forms (of the indicator) so the solution appears green (1) 	<p>M2 dependent on M1 OR the selection of bromocresol green or bromocresol blue or bromophenol blue (which will not score M1)</p> <p>Allow indicator is yellow in acid and blue in alkali so green (at the neutralisation point) is observed Allow indicator is yellow below pH 6.0 and blue above pH 7.6 and green at the neutralisation point Allow green is between yellow in acid and blue in alkali</p>	(2)

(Total for Question 18 = 18 marks)

(Total for Section C = 18 marks)

Total for Paper = 90 marks

