



# Mark Scheme (Results) Summer 2014

IAL Chemistry (WCH04/01)  
General Principles of Chemistry I

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Summer 2014

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## General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.
- Mark schemes will indicate within the table where, and which strands of QWC, are being assessed. The strands are as follows:
  - i) ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear
  - ii) select and use a form and style of writing appropriate to purpose and to complex subject matter
  - iii) organise information clearly and coherently, using specialist vocabulary when appropriate

## Using the Mark Scheme

Examiners should look for qualities to reward rather than faults to penalise. This does NOT mean giving credit for incorrect or inadequate answers, but it does mean allowing candidates to be rewarded for answers showing correct application of principles and knowledge. Examiners should therefore read carefully and consider every response: even if it is not what is expected it may be worthy of credit.

The mark scheme gives examiners:

- an idea of the types of response expected
- how individual marks are to be awarded
- the total mark for each question
- examples of responses that should NOT receive credit.

/ means that the responses are alternatives and either answer should receive full credit.

( ) means that a phrase/word is not essential for the award of the mark, but helps the examiner to get the sense of the expected answer.

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

ecf/TE/cq (error carried forward) means that a wrong answer given in an earlier part of a question is used correctly in answer to a later part of the same question.

Candidates must make their meaning clear to the examiner to gain the mark. Make sure that the answer makes sense. Do not give credit for correct words/phrases which are put together in a meaningless manner. Answers must be in the correct context.

### Quality of Written Communication

Questions which involve the writing of continuous prose will expect candidates to:

- write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear
- select and use a form and style of writing appropriate to purpose and to complex subject matter
- organise information clearly and coherently, using specialist vocabulary when appropriate.

Full marks will be awarded if the candidate has demonstrated the above abilities.

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

**Section A (multiple choice)**

Question Number	Correct Answer	Reject	Mark
<b>1</b>	<b>D</b>		<b>1</b>

Question Number	Correct Answer	Reject	Mark
<b>2</b>	<b>A</b>		<b>1</b>

Question Number	Correct Answer	Reject	Mark
<b>3</b>	<b>D</b>		<b>1</b>

Question Number	Correct Answer	Reject	Mark
<b>4</b>	<b>D</b>		<b>1</b>

Question Number	Correct Answer	Reject	Mark
<b>5</b>	<b>C</b>		<b>1</b>

Question Number	Correct Answer	Reject	Mark
<b>6(a)</b>	<b>A</b>		<b>1</b>

Question Number	Correct Answer	Reject	Mark
<b>6 (b)</b>	<b>B</b>		<b>1</b>

Question Number	Correct Answer	Reject	Mark
<b>7(a)</b>	<b>D</b>		<b>1</b>

Question Number	Correct Answer	Reject	Mark
<b>7(b)</b>	<b>C</b>		<b>1</b>

Question Number	Correct Answer	Reject	Mark
<b>8</b>	<b>A</b>		<b>1</b>

Question Number	Correct Answer	Reject	Mark
<b>9</b>	<b>C</b>		<b>1</b>

Question Number	Correct Answer	Reject	Mark
<b>10</b>	<b>B</b>		<b>1</b>

Question Number	Correct Answer	Reject	Mark
<b>11</b>	<b>B</b>		<b>1</b>

Question Number	Correct Answer	Reject	Mark
<b>12</b>	<b>B</b>		<b>1</b>

Question Number	Correct Answer	Reject	Mark
<b>13</b>	<b>A</b>		<b>1</b>

Question Number	Correct Answer	Reject	Mark
<b>14</b>	<b>B</b>		<b>1</b>

Question Number	Correct Answer	Reject	Mark
<b>15 (a)</b>	<b>C</b>		<b>1</b>

Question Number	Correct Answer	Reject	Mark
<b>15(b)</b>	<b>A</b>		<b>1</b>

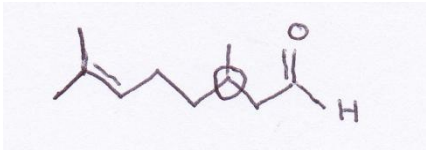
Question Number	Correct Answer	Reject	Mark
<b>16</b>	<b>C</b>		<b>1</b>

Question Number	Correct Answer	Reject	Mark
<b>17</b>	<b>B</b>		<b>1</b>


**Total for Section A = 20 marks**

## Section B

Question Number	Acceptable Answers	Reject	Mark
<b>18(a)</b>	$C_{10}H_{18}O$ <b>ALLOW</b> any order i.e. $C_{10} OH_{18} / H_{18} C_{10} O / H_{18} O C_{10} / OC_{10}H_{18} /$ $OH_{18} C_{10}$ <b>IGNORE</b> $C_9H_{17}CHO$ and other structural formulae as working <b>COMMENT</b> Allow numbers not as subscripts e.g. $C_{10}H_{18}O$ Structural formula without correct molecular formula will not score.	superscripts	<b>1</b>

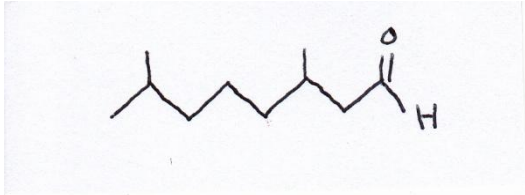
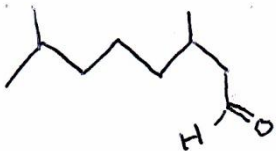
Question Number	Acceptable Answers	Reject	Mark
<b>18(b)</b>	 <p>Circle as shown  <b>ALLOW</b> * or any other clear indication of the correct carbon atom</p>	more than one carbon atom indicated	<b>1</b>

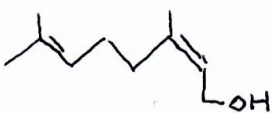
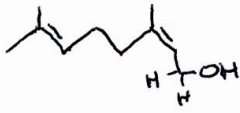
Question Number	Acceptable Answers	Reject	Mark
<b>18(c)(i)</b>	<p><b>Stand alone marks</b></p> <p><b>First mark</b> restricted / barrier to rotation around/due to C=C/<math>\pi</math> bond <b>ALLOW</b> no/lack of/inhibits (free) rotation around/due to C=C/<math>\pi</math> bond <b>(1)</b></p> <p><b>Second mark</b> two different atoms/groups attached to each C in C=C /each C in C=C must not have two groups the same attached to it <b>OR</b> 4 different atoms/groups attached to C=C <b>ALLOW</b> 2 highest priority/molecular mass/atomic number atoms/groups on opposite sides (of C=C) is the <i>E</i> isomer <b>ALLOW</b> 2 highest priority/molecular mass/atomic number atoms/groups on the same side (of C=C) is the <i>Z</i> isomer <b>ALLOW</b> correct diagrams to show any of these points <b>(1)</b></p>	<p>Just 'no rotation' without reference to C=C</p> <p>molecule does not rotate</p> <p>molecules/compounds attached to C atoms</p>	<b>2</b>

Question Number	Acceptable Answers	Reject	Mark
<b>18(c)(ii)</b>	<p>circle around double bond as shown</p>  <p><b>ALLOW</b> any clear indication of the correct double bond or a circle around <b>either</b> of the two carbon atoms in this bond.</p> <p><b>ALLOW</b> the circle being extended to the adjacent carbon atoms attached to the C=C.</p>	<p>both C=C bonds circled</p> <p>the circle extended to include the C=O and/or C-H bond(s) on the right</p>	<b>1</b>



Question Number	Acceptable Answers	Reject	Mark												
<b>18(d)</b>	<p>Any reagent and <b>matching</b> observation from <b>(1)</b> <b>(1)</b></p> <table border="1" data-bbox="336 409 1026 1375"> <thead> <tr> <th data-bbox="336 409 663 443">reagent</th> <th data-bbox="663 409 1026 443">observation</th> </tr> </thead> <tbody> <tr> <td data-bbox="336 443 663 589">Fehling's (solution and heat/boil)</td> <td data-bbox="663 443 1026 589">(blue solution) to red / red-brown/brown /orange <b>and</b> precipitate</td> </tr> <tr> <td data-bbox="336 589 663 734">Benedict's (solution and heat/boil)</td> <td data-bbox="663 589 1026 734">(blue solution) to red / red-brown/brown /orange <b>and</b> precipitate</td> </tr> <tr> <td data-bbox="336 734 663 880">Tollens' (reagent) /ammoniacal silver nitrate (and warm)</td> <td data-bbox="663 734 1026 880">silver mirror or grey/black/silver <b>and</b> ppt</td> </tr> <tr> <td data-bbox="336 880 663 1305"><b>ALLOW</b> potassium/sodium dichromate((VI)) <b>and</b> sulfuric acid (and warm) or acidified dichromate((VI) ions and warm) or acidified (potassium/sodium) dichromate((VI))</td> <td data-bbox="663 880 1026 1305">(orange) to green/blue</td> </tr> <tr> <td data-bbox="336 1305 663 1375"><b>ALLOW</b> Schiff's reagent</td> <td data-bbox="663 1305 1026 1375">pink/purple/magenta</td> </tr> </tbody> </table> <p><b>ALLOW</b> correct formulae/ names</p> <p><b>IGNORE</b> Brady's reagent/2,4- DNPH etc</p> <p><b>IGNORE</b> sodium hydroxide in Tollens' reagent</p>	reagent	observation	Fehling's (solution and heat/boil)	(blue solution) to red / red-brown/brown /orange <b>and</b> precipitate	Benedict's (solution and heat/boil)	(blue solution) to red / red-brown/brown /orange <b>and</b> precipitate	Tollens' (reagent) /ammoniacal silver nitrate (and warm)	silver mirror or grey/black/silver <b>and</b> ppt	<b>ALLOW</b> potassium/sodium dichromate((VI)) <b>and</b> sulfuric acid (and warm) or acidified dichromate((VI) ions and warm) or acidified (potassium/sodium) dichromate((VI))	(orange) to green/blue	<b>ALLOW</b> Schiff's reagent	pink/purple/magenta	Just an observation not linked to a reagent	<b>2</b>
reagent	observation														
Fehling's (solution and heat/boil)	(blue solution) to red / red-brown/brown /orange <b>and</b> precipitate														
Benedict's (solution and heat/boil)	(blue solution) to red / red-brown/brown /orange <b>and</b> precipitate														
Tollens' (reagent) /ammoniacal silver nitrate (and warm)	silver mirror or grey/black/silver <b>and</b> ppt														
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<b>ALLOW</b> Schiff's reagent	pink/purple/magenta														

Question Number	Acceptable Answers	Reject	Mark
<b>18(e)(i)</b>	<p>In (e)(i) and (e)(ii), penalise any structure other than skeletal only once, in the item where it appears first</p>  <p><b>OR</b></p>  <p><b>ALLOW</b> any unambiguous skeletal formula showing the aldehyde (with or without the H in CHO)</p>	any structure with an OH group	<b>1</b>

Question Number	Acceptable Answers	Reject	Mark
<b>18(e)(ii)</b>	<p>In (e)(i) and (e)(ii), penalise any structure other than skeletal only once, in the item where it appears first</p>  <p><b>ALLOW</b></p>  <p><b>ALLOW</b> O<sup>-</sup> for OH</p> <p><b>ALLOW</b> -O-H for OH</p> <p><b>ALLOW</b> the OH on either side of the structure</p> <p><b>ALLOW</b> just 1 H shown on the C with the OH attached</p> <p><b>ALLOW</b> any unambiguous skeletal formula showing the alcohol (with or without the 2Hs on end C)</p>	<p>any structure without both C=C</p> <p>the <i>E</i> isomer</p>	<b>1</b>

(Total for Question 18 = 9 marks)

Question Number	Acceptable Answers	Reject	Mark
<b>19(a)(i)</b>	<p><b>First marking point - Orders</b>  <math>\text{H}_2\text{O}_2</math> first/1st order/order 1  <math>\text{H}^+</math> zero/0 order/order 0  <b>both</b> correct (1)</p> <p><b>Explanations</b>  <b>Second marking point</b>  <math>\text{H}_2\text{O}_2</math> - as <math>[\text{H}_2\text{O}_2]</math> doubles  <b>and</b>  <math>[\text{H}^+]</math> and <math>[\text{I}^-]</math> stay the same/other concentrations stay the same/using experiments 1 and 2 (this could be shown on the table)  <b>and</b>  the rate doubles/working to show this</p> <p><b>ALLOW</b> reverse argument ie as <math>[\text{H}_2\text{O}_2]</math> halves <b>and</b>  <math>[\text{H}^+]</math> and <math>[\text{I}^-]</math> stay the same/other concentrations stay the same/using experiments 1 and 2 (this could be shown on the table) <b>and</b>  the rate halves/working to show this (1)</p> <p><b>Third marking point</b>  <math>\text{H}^+</math> - as <math>[\text{H}^+]</math> doubles/halves  <b>and</b>  <math>[\text{H}_2\text{O}_2]</math> and <math>[\text{I}^-]</math> stay the same/other concentrations stay the same/using experiments 1 and 3 (this could be shown on the table)  <b>Note</b> – do not penalise omission of this if it has been penalised in second marking point  <b>and</b>  the rate stays the same /working to show this</p> <p><b>OR</b>  As <math>[\text{H}^+]</math> doubles <b>and</b> <math>[\text{H}_2\text{O}_2]</math> halves <b>and</b>  <math>[\text{I}^-]</math> stays the same /using experiments 2 and 3 (this could be shown on the table)  (also see note above)  <b>and</b>  rate halves due to <math>[\text{H}_2\text{O}_2]</math> change so rate does not change due to <math>[\text{H}^+]</math>/working to show this  <b>ALLOW</b> reverse argument (1)</p>	Either/both explanations if inconsistent with order(s) stated above	<b>3</b>

Question Number	Acceptable Answers	Reject	Mark
<b>19(a)(ii)</b>	<p><b>First marking point</b> First/1st order /order 1 <b>(1)</b></p> <p><b>Second marking point-consequential on correct order</b></p> <p>graph shows rate is (directly) proportional to <math>[I^-]</math> <b>OR</b> as <math>[I^-]</math> increases, the rate increases proportionally <b>OR</b> as <math>[I^-]</math> doubles, the rate doubles</p> <p><b>ALLOW</b> graph (of rate against <math>[I^-]</math>) is a straight line (through the origin) /gradient is constant</p> <p><b>ALLOW</b> Increase in rate is constant <b>(1)</b></p>	<p>Any other order scores zero overall</p> <p>iodine/<math>I_2</math> Penalise once only in (ii) and (iii)</p>	<b>2</b>

Question Number	Acceptable Answers	Reject	Mark
<b>19(a)(iii)</b>	<p>rate/r/R = <math>k[H_2O_2][I^-]</math></p> <p><b>ALLOW</b> <math>[H_2O_2]^1[I^-]^1</math></p> <p><b>ALLOW</b> <math>[H^+]^0</math></p> <p><b>ALLOW</b> upper case K</p> <p><b>consequential</b> on their orders from (a)(i) and (ii)</p>	$[I_2]$	<b>1</b>

Question Number	Acceptable Answers	Reject	Mark
<b>19(a)(iv)</b>	<p><math>2.8 \times 10^{-5}</math> <b>(1)</b></p> <p><math>dm^3mol^{-1}s^{-1}</math> <b>(1)</b></p> <p><b>ALLOW</b> units in any order</p> <p><b>Note:</b> value and units are consequential on their rate equation from (a)(iii) and must be consistent Ignore SF unless 1.</p> <p><b>Comment</b> If zero order wrt <math>[I^-]</math>, <math>k = 1.4 \times 10^{-5} s^{-1}</math></p>		<b>2</b>

Question Number	Acceptable Answers	Reject	Mark
<b>19(b)(i)</b>	<p>(Rate determining step) Any balanced equation that has just <b>2NO<sub>2</sub></b> on the LHS <b>(1)</b></p> <p>(Step 2) Any balanced equation for which the two steps combine to the overall equation/double the overall equation <b>(1)</b></p> <p><b>Examples of matching pairs:</b>  <math>2\text{NO}_2 \rightarrow \text{N}_2\text{O}_4</math>  <math>\text{N}_2\text{O}_4 + \text{CO} \rightarrow \text{NO} + \text{NO}_2 + \text{CO}_2/</math>  <math>\text{N}_2\text{O}_4 + 2\text{CO} \rightarrow 2\text{NO} + 2\text{CO}_2</math>  <b>OR</b>  <math>2\text{NO}_2 \rightarrow 2\text{NO} + \text{O}_2</math>  <math>2\text{CO} + \text{O}_2 \rightarrow 2\text{CO}_2/\text{CO} + 1/2\text{O}_2 \rightarrow \text{CO}_2</math>  <b>OR</b>  <math>2\text{NO}_2 \rightarrow \text{N}_2 + 2\text{O}_2</math>  <math>\text{N}_2 + 2\text{O}_2 + \text{CO} \rightarrow \text{NO} + \text{NO}_2 + \text{CO}_2</math>  <b>OR</b>  <math>2\text{NO}_2 \rightarrow 2\text{NO} + 2\text{O}</math>  <math>\text{NO} + 2\text{O} + \text{CO} \rightarrow \text{NO}_2 + \text{CO}_2</math>  <b>OR</b>  <math>2\text{NO}_2 \rightarrow \text{NO} + \text{NO}_3</math>  <math>2\text{CO} + \text{NO}_3 \rightarrow 2\text{CO}_2 + \text{NO}</math></p> <p><b>ALLOW</b> NO<sub>2</sub> + NO<sub>2</sub> on LHS  <b>NOTE</b>  NO<sub>2</sub> → NO + 1/2O<sub>2</sub> then  CO + 1/2O<sub>2</sub> → CO<sub>2</sub>  Does not score the first mark but scores 1 for the consequential second equation</p> <p><b>IGNORE</b> state symbols even if incorrect</p>	NO <sub>2</sub> or any multiple other than 2 of NO <sub>2</sub> on LHS for first mark only	<b>2</b>

Question Number	Acceptable Answers	Reject	Mark
<b>19(b)(ii)</b>	<p>In (b)(ii) penalise incorrect/missing units but allow J/mol K and J/mol/K and lower case k</p> <p><b>FIRST CHECK THE FINAL ANSWER,</b>            If answer is <math>-13.3 \text{ J mol}^{-1} \text{ K}^{-1}</math>            or <math>-0.0133 \text{ kJ mol}^{-1} \text{ K}^{-1}</math>, award <b>2</b> marks</p> <p><math>13.3 \text{ J mol}^{-1} \text{ K}^{-1} / 0.0133 \text{ kJ mol}^{-1} \text{ K}^{-1}</math> (sign omitted) <b>(1)</b>  <math>-13.3 / -0.0133</math> (units omitted) <b>(1)</b></p> <p>If none of the above answers is given  <b>First mark</b> for correct data used <b>(1)</b></p> <p><b>Second mark</b> value, sign and units consequential on incorrect entropy value(s) used in the correct expression  <math>(\Delta S^{\circ}_{\text{system}} =) [210.7 + 213.6] - [197.6 + 240.0]</math> <b>(1)</b></p> <p><b>IGNORE</b> SF except 1SF</p>		<b>2</b>

Question Number	Acceptable Answers	Reject	Mark
<b>19(b)(iii)</b>	<p><b>FIRST CHECK THE FINAL ANSWER,</b>            If final answer is  <math>+0.75839 \text{ kJ mol}^{-1} \text{ K}^{-1}</math> <b>(2)</b>  <math>+758.39 \text{ J mol}^{-1} \text{ K}^{-1}</math> <b>(2)</b></p> <p><b>EITHER</b>  <math>(\Delta S^{\circ}_{\text{surroundings}} =) \frac{-\Delta H}{T} \text{ OR } -\frac{(-226)}{298}</math> <b>(1)</b>  <math>= 0.75839 \text{ kJ mol}^{-1} \text{ K}^{-1}</math> <b>(1)</b>            Second mark is for answer with correct unit</p> <p><b>OR</b>  <math>(\Delta S^{\circ}_{\text{surroundings}} =) \frac{-\Delta H}{T} \text{ OR } -\frac{(-226000)}{298}</math> <b>(1)</b>  <math>= 758.39 \text{ J mol}^{-1} \text{ K}^{-1}</math> <b>(1)</b>            Second mark is for answer with correct unit</p> <p><b>ALLOW</b>  <math>-0.75839 \text{ kJ mol}^{-1} \text{ K}^{-1} / -758.39 \text{ J mol}^{-1} \text{ K}^{-1}</math> <b>(1)</b></p> <p><b>IGNORE</b> SF except 1 SF</p>	$-0.75839 / -758.39$ with no units	<b>2</b>

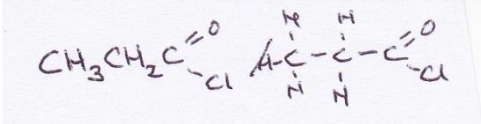
Question Number	Acceptable Answers	Reject	Mark
<b>19(b)(iv)</b>	<p><b>First marking point</b>  <math>(\Delta S^{\circ}_{\text{total}} = \Delta S^{\circ}_{\text{system}} + \Delta S^{\circ}_{\text{surroundings}})</math>  <math>(= -13.3 + 758.39) / (-0.0133 + 0.75839)</math>  <math>= (+)745.09 \text{ J K}^{-1} \text{ mol}^{-1} / (+)0.74509 \text{ kJ K}^{-1} \text{ mol}^{-1}</math>  <b>(1)</b></p> <p><b>TE</b> on (ii) and (iii) added together with the same units  <b>IGNORE</b> SF except 1 SF  <b>IGNORE</b> units, even if incorrect</p> <p><b>Second marking point</b>  (sign is positive so) reaction is  (thermodynamically) feasible / spontaneous  <b>(1)</b></p> <p><b>ALLOW</b>  feasible / will occur / reaction goes / it reacts (at 298 K) reactants thermodynamically unstable</p> <p><b>COMMENT</b>  If value for <math>\Delta S^{\circ}_{\text{total}}</math> is negative, then allow consequential mark for (sign is negative so) reaction is not feasible / not spontaneous / will not occur / reaction / it does not take place (at 298 K)</p>	(ii) and (iii) added together with different units for first mark only	<b>2</b>

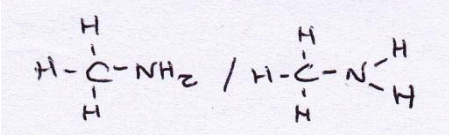
**(Total for Question 19 = 16 marks)**





Question Number	Acceptable Answers	Reject	Mark
<b>20(a)(ii)</b>	nucleophilic <b>(1)</b>  addition <b>(1)</b>  <b>Note</b> Do not allow 'addition' if S <sub>N</sub> 1/ S <sub>N</sub> 2 are included in the answer.  Words can be in either order		<b>2</b>

Question Number	Acceptable Answers	Reject	Mark
<b>20(b)(i)</b>	If name and formula given, both must be correct  CH <sub>3</sub> CH <sub>2</sub> COCl / propanoyl chloride /    <b>ALLOW</b> skeletal formula/any combination of displayed/structural formula <b>Ignore</b> C <sub>3</sub> H <sub>5</sub> OCl <b>Comment</b> Molecular formula without correct structural formula or name will not score.		<b>1</b>

Question Number	Acceptable Answers	Reject	Mark
<b>20(b)(ii)</b>	If name and formula given, both must be correct  methylamine / CH <sub>3</sub> NH <sub>2</sub> / NH <sub>2</sub> CH <sub>3</sub>    <b>Ignore</b> CH <sub>5</sub> N/ CNH <sub>5</sub>  <b>Note</b> Allow the mark if the answer to this item is written by Step 3 in the flow chart on page 19	methyl amide	<b>1</b>

Question Number	Acceptable Answers	Reject	Mark
<b>20(b)(iii)</b>	4/four (peaks)		<b>1</b>

Question Number	Acceptable Answers	Reject	Mark
<b>20(c)</b>	$\text{CH}_3\text{CH}_2\text{COOH} + \text{CH}_3\text{CH}(\text{OH})\text{CH}_3 \rightleftharpoons$ $\text{CH}_3\text{CH}_2\text{COOCH}(\text{CH}_3)_2 + \text{H}_2\text{O}$ <p style="text-align: right;"><b>(1)</b></p> <p>rest of equation correct including H<sub>2</sub>O, conditional on correct structure for ester <b>(1)</b></p> <p><b>ALLOW</b> full displayed formulae or a combination of structural and displayed formulae</p> <p><b>ALLOW</b> missing bracket around OH</p> <p><b>ALLOW</b> → instead of ⇌</p> <p><b>ALLOW</b> H<sup>+</sup> above the arrow or eqm sign OR on both sides of the equation.</p> <p><b>Note:</b> If candidate uses propan-1-ol/C<sub>3</sub>H<sub>7</sub>OH allow 1 mark for a completely correct equation</p> $\text{CH}_3\text{CH}_2\text{COOH} + \text{CH}_3\text{CH}_2\text{CH}_2\text{OH} \rightleftharpoons$ $\text{CH}_3\text{CH}_2\text{COOCH}_2\text{CH}_2\text{CH}_3 + \text{H}_2\text{O}$ <p><b>OR</b></p> $\text{CH}_3\text{CH}_2\text{COOH} + \text{C}_3\text{H}_7\text{OH} \rightleftharpoons$ $\text{CH}_3\text{CH}_2\text{COOCH}_2\text{CH}_2\text{CH}_3 + \text{H}_2\text{O}$	<p>molecular formulae</p> <p>penalise missing H once only</p> <p>any other alcohol or acid used for both marks</p>	<b>2</b>

Question Number	Acceptable Answers	Reject	Mark
<b>20(d)</b>	<p><b>First marking point</b> propan-1-ol/correct structural/displayed/skeletal formula/</p> <p><b>ALLOW</b> propanol <b>and</b> primary alcohol /1°/1<sup>y</sup> <b>ALLOW</b> C<sub>3</sub>H<sub>7</sub>OH <b>(1)</b></p> <p><b>Second marking point – stand alone</b> because the IR spectrum shows an absorption at 3750-3100 (cm<sup>-1</sup>) due to the OH bond/OH group /alcohol/hydroxy(l) <b>OR</b> no peak at around 1700 / 2700-2775 (cm<sup>-1</sup>) so it is not an aldehyde <b>(1)</b></p> <p><b>Note</b> – these could be shown on the spectrum as labelled peaks</p> <p><b>ALLOW</b> any wavenumber or range within the ranges given above</p> <p><b>IGNORE</b> any other peaks mentioned/references to bend/stretch/intensity</p>	hydroxide	<b>2</b>

**(Total for Question 20 = 13 marks)**

Question Number	Acceptable Answers	Reject	Mark
<b>21(a)(i)</b>	$(K_p =) \frac{P_{HI}^2}{P_{H_2} \times P_{I_2}}$ <p><b>ALLOW</b> <math>P_{HI}^2</math></p> <p><b>ALLOW</b> lower or upper case p /pp/curved brackets</p> <p><b>IGNORE</b> state symbols even if incorrect</p> <p><b>IGNORE</b> missing x</p>	<p>square brackets</p> <p>expressions without p/pp/P/PP to show partial pressure</p>	<b>1</b>

Question Number	Acceptable Answers	Reject	Mark																				
<b>21(a)* (ii)</b>	<table border="1"> <thead> <tr> <th></th> <th>H<sub>2</sub></th> <th>I<sub>2</sub></th> <th>2HI</th> </tr> </thead> <tbody> <tr> <td>initial mol</td> <td>1</td> <td>1</td> <td>0</td> </tr> <tr> <td>eqm mol</td> <td>0.21</td> <td>0.21</td> <td>1.58</td> </tr> <tr> <td>partial pressure</td> <td><math>\frac{0.21 \times 5}{2}</math> = 0.525</td> <td><math>\frac{0.21 \times 5}{2}</math> = 0.525</td> <td><math>\frac{1.58 \times 5}{2}</math> = 3.95</td> </tr> <tr> <td>K<sub>p</sub></td> <td colspan="3"><math>\frac{3.95^2}{0.525^2} = 56.6/57</math> no units</td> </tr> </tbody> </table>		H <sub>2</sub>	I <sub>2</sub>	2HI	initial mol	1	1	0	eqm mol	0.21	0.21	1.58	partial pressure	$\frac{0.21 \times 5}{2}$ = 0.525	$\frac{0.21 \times 5}{2}$ = 0.525	$\frac{1.58 \times 5}{2}$ = 3.95	K <sub>p</sub>	$\frac{3.95^2}{0.525^2} = 56.6/57$ no units				<b>5</b>
		H <sub>2</sub>	I <sub>2</sub>	2HI																			
	initial mol	1	1	0																			
	eqm mol	0.21	0.21	1.58																			
	partial pressure	$\frac{0.21 \times 5}{2}$ = 0.525	$\frac{0.21 \times 5}{2}$ = 0.525	$\frac{1.58 \times 5}{2}$ = 3.95																			
K <sub>p</sub>	$\frac{3.95^2}{0.525^2} = 56.6/57$ no units																						
<p><b>First mark</b> eqm mol of H<sub>2</sub> = 0.21 <b>(1)</b></p>																							
<p><b>Second mark</b> eqm mol of HI = 1.58 <b>(see note at end)</b> <b>(1)</b></p>																							
<p><b>Third mark</b> all 3 partial pressures, either working or answer <b>(1)</b> <b>consequential</b> on their equilibrium moles</p>																							
<p><b>Fourth mark</b> correct value (56.6/57) for K<sub>p</sub> with or without working <b>(1)</b> <b>consequential</b> on their partial pressures and their expression for K<sub>p</sub> in (a)(i)</p>																							
<p><b>Fifth mark</b> 'no units' stated / working to show that units cancel / statement that units cancel <b>ALLOW</b> - /atm<sup>0</sup> or similar indication of no units <b>ALLOW</b> units based on expression for K<sub>p</sub> in (i) or the expression they have used in the calculation in (ii) <b>(1)</b></p>																							
<p><b>Note</b> <b>Only award 5 marks if partial pressures are stated or working to show them</b> If 0.21 mol H<sub>2</sub> <b>(1)</b> and 0.79 mol HI<b>(0)</b>, then partial pressures H<sub>2</sub>/I<sub>2</sub> = 0.868 and HI = 3.264 <b>(1)</b> K<sub>p</sub> = 14/14.2 <b>(1)</b> no units <b>(1)</b></p> <p>If 0.21 mol H<sub>2</sub> <b>(1)</b> and 0.42 mol HI<b>(0)</b>, then partial pressures H<sub>2</sub>/I<sub>2</sub> = 1.25 and HI = 2.5 <b>(1)</b> K<sub>p</sub> = 4 <b>(1)</b> no units <b>(1)</b></p>																							
<p><b>Alternative method for marks 2 and 3</b> If initial P(H<sub>2</sub>) and P(I<sub>2</sub>) = 2.5 (atm) Eqm P(H<sub>2</sub>) and P(I<sub>2</sub>) = 2.5x0.21 = 0.525(atm) <b>(1)</b> P(HI) = 5-(2 x 0.525) = 3.95 <b>(1)</b> <b>IGNORE</b> SF except 1SF</p>																							

Question Number	Acceptable Answers	Reject	Mark
<b>21(b)</b>	No effect because (there are) equal numbers of (gas) mole(cule)s on each side of the equation	Just 'equal numbers of mole(cule)s'	<b>1</b>

Question Number	Acceptable Answers	Reject	Mark
<b>21(c)(i)</b>	<p><b>First mark</b>  <math>(\Delta H</math> is negative/exothermic so)  <math>-\Delta H/T</math> gets less positive  <b>ALLOW</b> decreases  <b>OR</b>  <math>(\Delta H</math> is negative/exothermic so)  <math>\Delta S_{\text{surroundings}}</math> gets less positive  <b>ALLOW</b> decreases <b>(1)</b></p> <p><b>Second mark</b>  (so, since <math>\Delta S_{\text{total}} = -\Delta H/T + \Delta S_{\text{system}}</math>) <b>(1)</b>  <math>\Delta S_{\text{total}}</math> decreases</p> <p>Mark independently</p> <p><b>No TE</b> on incorrect <math>\Delta S_{\text{surroundings}}</math></p> <p><b>Ignore</b> comments based on <math>K_p</math></p>		<b>2</b>

Question Number	Acceptable Answers	Reject	Mark
<b>21(c)* (ii)</b>	<p><b>First mark</b>  <math>\ln K = \Delta S_{\text{total}}/R</math>  <b>OR</b>  <math>K = e^{\Delta S_{\text{total}}/R}</math>  <b>OR</b>  <math>\Delta S_{\text{total}} = R \ln K</math>  <b>OR</b>  <math>\Delta S_{\text{total}}</math> is (directly) proportional to <math>\ln K</math> <b>(1)</b></p> <p><b>Second mark</b>  <math>K_p</math> decreases <b>and</b> yield (of HI) decreases <b>(1)</b></p> <p><b>consequential</b> on their <math>\Delta S_{\text{total}}</math> in (c)(i)</p> <p><b>Ignore</b> comments based on Le Chatelier's principle</p>	<p><math>\Delta S_{\text{total}}</math> is (directly) proportional to <math>K</math></p> <p>Just 'equilibrium position moves to the left' without reference to yield and <math>K_p</math></p>	<b>2</b>

(Total for Question 21 = 11 marks)

**TOTAL FOR SECTION B = 49 MARKS**

## Section C

Question Number	Acceptable Answers	Reject	Mark
<b>22(a)(i)</b>	Proton donor/donates protons <b>OR</b> H <sup>+</sup> ion donor/donates H <sup>+</sup> ions <b>Ignore</b> just releases H <sup>+</sup> ions or protons.		<b>1</b>

Question Number	Acceptable Answers	Reject	Mark
<b>22(a)(ii)</b>	$\text{CH}_3\text{CH}(\text{OH})\text{COOH} + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{CH}(\text{OH})\text{COO}^- + \text{H}_3\text{O}^+$ <b>OR</b> $\text{CH}_3\text{CH}(\text{OH})\text{CO}_2\text{H} + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{CH}(\text{OH})\text{CO}_2^- + \text{H}_3\text{O}^+$ <b>ALLOW</b> → for ⇌  <b>ALLOW</b> $\text{CH}_3\text{CH}(\text{OH})\text{COOH} \rightleftharpoons \text{CH}_3\text{CH}(\text{OH})\text{COO}^- + \text{H}^+$ <b>ALLOW</b> $\text{CH}_3\text{CH}(\text{OH})\text{CO}_2\text{H} \rightleftharpoons \text{CH}_3\text{CH}(\text{OH})\text{CO}_2^- + \text{H}^+$ <b>Ignore</b> state symbols even if incorrect <b>Ignore</b> missing bracket around OH	HA and A <sup>-</sup> once only in (a)(ii) and (a)(iii)  Penalise missing H once only in (a)(ii) and (a)(iii)	<b>1</b>

Question Number	Acceptable Answers	Reject	Mark
<b>22(a)(iii)</b>	(K <sub>a</sub> =) $\frac{[\text{CH}_3\text{CH}(\text{OH})\text{COO}^-][\text{H}_3\text{O}^+]}{[\text{CH}_3\text{CH}(\text{OH})\text{COOH}]}$ <b>OR</b> $\frac{[\text{CH}_3\text{CH}(\text{OH})\text{CO}_2^-][\text{H}_3\text{O}^+]}{[\text{CH}_3\text{CH}(\text{OH})\text{CO}_2\text{H}]}$ <b>OR</b> $\frac{[\text{CH}_3\text{CH}(\text{OH})\text{COO}^-][\text{H}^+]}{[\text{CH}_3\text{CH}(\text{OH})\text{COOH}]}$ <b>OR</b> $\frac{[\text{CH}_3\text{CH}(\text{OH})\text{CO}_2^-][\text{H}^+]}{[\text{CH}_3\text{CH}(\text{OH})\text{CO}_2\text{H}]}$ <b>Note</b> Allow any of these for the mark, even if a different equation using H <sup>+</sup> /H <sub>3</sub> O <sup>+</sup> has been given in (a)(ii)	H <sub>2</sub> O in expression  Lack of square brackets  HA and A <sup>-</sup> once only in (a)(ii) and (a)(iii)  Penalise missing H once only in (a)(ii) and (a)(iii)	<b>1</b>

Question Number	Acceptable Answers	Reject	Mark
<b>22(a)</b> <b>(iv)</b>	<p><b>Comment Allow</b> <math>[H_3O^+]</math>, <math>[HA]</math>, <math>[A^-]</math> as alternative formula throughout</p> <p><b>Calculation</b></p> <p><b>Ignore</b> sf, except 1 sf, throughout</p> <p><b>First</b> check the final answer  If pH = 2.34, award the first <b>3</b> marks  If pH <math>\neq</math> 2.34, award marks as follows</p> <p><b>ROUTE 1</b></p> $K_a = 10^{-3.86} = 1.3804 \times 10^{-4} (\text{mol dm}^{-3}) \quad (1)$ $[H^+] = \sqrt{K_a [CH_3CH(OH)COOH]}$ $= \sqrt{1.38 \times 10^{-4} \times 0.15}$ $= 4.5504 \times 10^{-3} (\text{mol dm}^{-3}) \quad (1)$ <p><b>TE</b> on their value for <math>K_a</math></p> $\text{pH} = -\log_{10}[H^+] = -\log_{10} 4.55 \times 10^{-3}$ $= 2.3420/2.34 \quad (1)$ <p><b>TE</b> on their value for <math>[H^+]</math> provided <math>\text{pH} &gt; 1</math> and <math>&lt; 7</math>  (pH = 0.12 if use 3.86 for <math>K_a</math>, scores 2)</p> <p><b>ROUTE 2</b></p> $[H^+] = \sqrt{K_a [CH_3CH(OH)COOH]}$ $\text{pH} = \frac{1}{2} \text{p}K_a - \frac{1}{2} \log [CH_3CH(OH)COOH] \quad (1)$ $= \frac{1}{2} 3.86 - \frac{1}{2} \log 0.15 \quad (1)$ $= 2.34 \quad (1)$ <p><b>TE</b> on not halving (4.68 is worth 1 mark)</p> <p><b>Assumption 1</b>  <math>[H^+] = [CH_3CH(OH)COO^-]</math>  <b>OR</b>  no <math>H^+</math> from the (ionization of) water/ionization of water is negligible  <b>OR</b>  <math>H^+</math> is (only) from the acid <span style="float:right">(1)</span></p> <p><b>Assumption 2</b>  Ionization/dissociation of the (weak) acid is negligible / very small / insignificant  <b>OR</b>  <math>[CH_3CH(OH)COOH]_{\text{initial}} = [CH_3CH(OH)COOH]_{\text{equilibrium}}</math>  <b>OR</b>  <math>[CH_3CH(OH)COOH]_{\text{equilibrium}} = 0.15 (\text{mol dm}^{-3})</math>  <b>OR</b>  <math>[H^+] / [CH_3CH(OH)COO^-] \ll [CH_3CH(OH)COOH]</math>  <b>OR</b>  <math>[CH_3CH(OH)COOH]</math>/acid concentration remains constant <span style="float:right">(1)</span></p>	<p>Incorrect units for <math>K_a</math> and/or <math>[H^+]</math>, max 2 for calculation</p> <p><math>[H^+]_{\text{initial}} = [H^+]_{\text{equilibrium}}</math>/</p>	<p><b>5</b></p>



	<p><b>ROUTE 3</b>  <b>First</b> check the final answer          If pH = 2.35, award the first <b>4</b> marks</p> <p>If pH <math>\neq</math> 2.35, award marks as follows</p> <p><math>K_a = 10^{-3.86} = 1.38 \times 10^{-4} \text{ (mol dm}^{-3}\text{)}</math> <b>(1)</b></p> <p><math>[\text{H}^+]^2 = K_a([\text{CH}_3\text{CH(OH)COOH}] - [\text{H}^+])</math>  <math>[\text{H}^+]^2 = 1.38 \times 10^{-4} \times (0.15 - [\text{H}^+])</math> <b>(1)</b></p> <p><math>[\text{H}^+] = 4.48 \times 10^{-3} \text{ (mol dm}^{-3}\text{)}</math> <b>(1)</b>  <b>ecf</b> on their value for <math>K_a</math></p> <p>pH = <math>-\log_{10}[\text{H}^+]</math>  <math>= -\log_{10} 4.48 \times 10^{-3}</math>  <math>= 2.35</math> <b>(1)</b>  <b>TE</b> on their value for <math>[\text{H}^+]</math></p> <p><b>Assumption</b>  <math>[\text{H}^+] = [\text{CH}_3\text{CH(OH)COO}^-]</math>  <b>OR</b>          no <math>\text{H}^+</math> from the (ionisation of) water  <b>OR</b>  <math>\text{H}^+</math> is (only) from the acid <b>(1)</b></p>	<p><math>[\text{H}^+]_{\text{initial}} =</math>  <math>[\text{H}^+]_{\text{equilibrium}}</math></p>	
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Question Number	Acceptable Answers	Reject	Mark
<b>22(b)(i)</b>	<p>If answer is 13.2, with or without working, award 2 marks (13/13.17 score 1 mark, answer not to 1 dp)</p> $[\text{H}^+] = \frac{1.0 \times 10^{-14}}{0.15}$ $= 6.67 \times 10^{-14} \text{ (mol dm}^{-3}\text{)} \quad \mathbf{(1)}$ <p>pH = <math>-\log_{10} 6.67 \times 10^{-14}</math>  = 13.176  = 13.2 <math>\mathbf{(1)}</math></p> <p><b>TE</b> on their <math>[\text{H}^+]</math>, provided pH &gt; 7 and &lt; 14</p> <p><b>OR</b></p> <p>pOH = 0.824 <math>\mathbf{(1)}</math>  pH = 14 - 0.824 = 13.176 = 13.2 <math>\mathbf{(1)}</math></p>	<p>Answer not given to 1 dp</p> <p>Answer not given to 1 dp</p>	<b>2</b>

Question Number	Acceptable Answers	Reject	Mark
<b>22(b)(ii)</b>	<p>Curve continues and finishes at any pH between 12 and 13.2</p> <p><b>ALLOW</b> this as standalone if they have no pH in (b)(i) or their pH is <math>\leq 10</math></p> <p><b>TE</b> on their pH in (b)(i) if it is &gt; 10</p>	<p>finishing at &gt;13.2 or &lt;12</p> <p>curves that 'dip' by more than 1 small square at the end</p> <p>stopping before 45 cm<sup>3</sup></p>	<b>1</b>

Question Number	Acceptable Answers	Reject	Mark
<b>22(b)(iii)</b>	<p><b>Indicator and colour change</b></p> <p>named indicator (1)            matching colour change (1)</p> <p>phenol red            yellow to red/pink  <b>OR</b>            thymol blue (base)            yellow to blue  <b>OR</b>            phenolphthalein            colourless to red/pink /magenta</p> <p><b>ALLOW</b>            bromothymol blue            yellow to blue</p> <p><b>ALLOW</b> thymolphthalein if they have continued to vertical section to at least 10.6 with colour change colourless to blue, for both marks</p> <p><b>ALLOW</b> correct colour change for thymolphthalein even if the vertical section does not continue to 10.6 for 1 mark.</p> <p><b>NO</b> TE for colour change from any other indicator</p> <p><b>Justification</b>            pH range (of indicator) lies (completely) in the vertical jump (on the titration curve)  <b>OR</b>            Indicator will change colour in the vertical section of the graph  <b>OR</b>            pH range of indicator and pH range of vertical section of the graph stated as long as they overlap</p> <p><b>ALLOW</b>  <math>pK_{in}</math> (<math>\pm 1</math>) is in the vertical jump  <b>OR</b>  <math>pK_{in}</math> is nearest to the pH at the end/equivalence point  <b>ALLOW</b>            Indicator will change colour at the end/equivalence point  <b>ALLOW</b>            (because it is a) titration of a weak acid with a strong base (1)</p>	Universal indicator loses all 3 marks	<b>3</b>



Question Number	Acceptable Answers	Reject	Mark
<p><b>22(b)*</b> <b>(v)</b></p>	<p><b>Comment Allow</b> [HA], [A<sup>-</sup>] as alternative formulae throughout</p> <p><b>First mark – statement or equations showing the buffer solution</b> buffer solution contains a large amount/reservoir /excess of a weak acid and its conjugate base/salt</p> <p><b>OR</b></p> <p>a large amount/reservoir /excess of lactic acid and lactate ions/formulae for lactic acid and lactate ions</p> <p><b>OR</b></p> <p>CH<sub>3</sub>CH(OH)COOH <math>\rightleftharpoons</math> CH<sub>3</sub>CH(OH)COO<sup>-</sup> + H<sup>+</sup> / CH<sub>3</sub>CH(OH)COOH + H<sub>2</sub>O <math>\rightleftharpoons</math> CH<sub>3</sub>CH(OH)COO<sup>-</sup> + H<sub>3</sub>O<sup>+</sup> <b>and</b> CH<sub>3</sub>CH(OH)COO<sup>(-)</sup>Na<sup>(+)</sup> <math>\rightarrow</math> CH<sub>3</sub>CH(OH)COO<sup>-</sup> + Na<sup>+</sup></p> <p><b>Ignore</b> definitions of a buffer solution <b>(1)</b></p> <p><b>Second mark – identifying which species react with the added acid and alkali</b> CH<sub>3</sub>CH(OH)COOH reacts with added alkali/OH<sup>-</sup> ions OR CH<sub>3</sub>CH(OH)COOH + OH<sup>-</sup> <math>\rightarrow</math> OR OH<sup>-</sup> ions react with H<sup>+</sup>/H<sub>3</sub>O<sup>+</sup> ions <b>and</b> CH<sub>3</sub>CH(OH)COO<sup>-</sup> reacts with added acid/H<sup>+</sup> ions / H<sub>3</sub>O<sup>+</sup> ions OR CH<sub>3</sub>CH(OH)COO<sup>-</sup> + H<sup>+</sup>/ H<sub>3</sub>O<sup>+</sup> <math>\rightarrow</math></p> <p><b>OR</b></p> <p>(pH=pK<sub>a</sub> + lg <math>\frac{[\text{salt}]}{[\text{acid}]}</math> )</p> <p>small additions of acid/alkali have little/no effect on lg <math>\frac{[\text{salt}]}{[\text{acid}]}</math> so pH hardly changes/no change</p> <p><b>ALLOW</b> Ratio [acid]:[salt]/[salt]:[acid] only changes a little so pH hardly changes/no change</p> <p><b>ALLOW</b> HA and A<sup>-</sup> in formulae/equations <b>(1)</b> <b>Comment</b> This mark may be given from the equations</p>	<p>Reservoir of H<sup>+</sup> ions</p> <p><math>\rightarrow</math> in equation</p> <p><math>\rightleftharpoons</math> in equation</p>	<p><b>4</b></p>

	<p><b>Third mark – ionic equation for OH<sup>-</sup></b>  <b>ALLOW</b> equations with reversible arrows  <math>\text{CH}_3\text{CH}(\text{OH})\text{COOH} + \text{OH}^- \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{COO}^- + \text{H}_2\text{O}</math>  <b>ALLOW</b>  <math>\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O} / \text{H}_3\text{O}^+ + \text{OH}^- \rightarrow 2\text{H}_2\text{O}</math> <b>(1)</b></p> <p><b>Fourth mark – ionic equation for H<sup>+</sup></b>  <math>\text{CH}_3\text{CH}(\text{OH})\text{COO}^- + \text{H}^+ \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{COOH}</math>  <b>OR</b>  <math>\text{CH}_3\text{CH}(\text{OH})\text{COO}^- + \text{H}_3\text{O}^+ \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{COOH} + \text{H}_2\text{O}</math> <b>(1)</b></p> <p><b>Note</b>  Only penalise non ionic equations e.g. using NaOH, HCl once only.</p> <p><b>Comment</b>  Two completely correct ionic equations scores marks 2,3 and 4</p>		
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Question Number	Acceptable Answers	Reject	Mark
<b>22(c)</b>	$\text{CH}_3\text{CH}(\text{OH})\text{COO}^- + \text{CH}_3\text{COOH}_2^+$ <b>both</b> needed for the mark  <b>ALLOW</b> $[\text{CH}_3\text{CH}(\text{OH})\text{COO}]^- + [\text{CH}_3\text{COOH}_2]^+$ <b>ALLOW</b> $[\text{CH}_3\text{COOHH}]^+ / \text{CH}_3\text{COOHH}^+$ for the ethanoic acid ion $\text{CH}_3\text{CH}(\text{OH})\text{CO}_2^-$ for the lactic acid ion		<b>1</b>

**(Total for Question 22 = 21 marks)**

**TOTAL FOR PAPER = 90 marks**

