# Mark scheme

| Question | | | Answer/Indicative content | Marks | Guidance |
|---|---|---|---|---|---|
| 1 | | i | $C_{13}H_{19}N_3O_7$ ✓ | 1 | **ALLOW** elements in formula in any order e.g. $C_{13}H_{19}O_7N_3$<br><br>**Examiner's Comments**<br><br>Most candidates made a good attempt at working out the molecular formula of the structure as being $C_{13}H_{19}N_3O_7$. N and O were usually correct with mistakes most common with carbon (especially 12) and hydrogen (especially 17-20). |
| | | ii | 4 ✓ | 1 | **Examiner's Comments**<br><br>This question was answered well with the correct answer of 4 being seen on most scripts, reflecting good understanding of chiral carbon centres.<br><br>The commonest incorrect response was 5, presumably by including the C atom on the bottom right of the structure within the -**C**H$(CH_3)_2$ group. |
| | | iii | **FIRST, CHECK THE ANSWER ON ANSWER LINE**<br>**IF difference = 61.7, award 2 marks**<br>---<br><br>$M_r$ of **C** = 380 **OR** $M_r$ of **D** = 441.7 ✓<br><br>Correct difference = 441.7 - 380 = **61.7** ✓<br><br>**AWARD** mark for **correct answer of 61.7 only** | 2 | **ALLOW** other approaches based on different atoms in **C** and **D**,<br>e.g. Difference = 7 × (32.1 - 16) - 3 × (31 - 14)<br>= 112.7 - 51 = **61.7** ✓<br><br>**Check answer from 2c(i) at top of response for ECF**<br>**ALLOW ECF** from incorrect formula from **2c(i)**<br>e.g. From $C_{12}H_{16}N_3O_6$<br><br>$M_r$ of **C** = 349 **OR** $M_r$ of **D** = 394.6 ✓ **ECF**<br>difference = 394.6 - 349 = **45.6** ✓ **ECF**<br><br>**Examiner's Comments**<br><br>This question was answered extremely well with about three-quarters of candidates securing both marks. Most candidates calculated the molecular |

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| | | | | | masses of compounds **C** and **D** as 380 and 441.7 respectively, to obtain a difference of 61.7. Some candidates adopted a simpler different approach which gives the same correct answer, working out the difference between the masses of nitrogen and phosphorus (for **C**) and oxygen and sulfur (for **D**).<br><br>ECF was applied to any incorrect molecular formulae from Question 2 (c) (i) from which both marks could be obtained |
| | | | **Total** | **4** | |
| 2 | | | **IF** answer on answer line = 73518<br>**AWARD** 3 marks<br>**IF** answer on answer line = 73500<br>**AWARD** 2 marks<br>---<br>$M_r$ of amino acid = 165 ✓<br><br>$M_r$ of 500 molecules = 500 × 165 = 82500 ✓<br><br>$M_r$ of polymer = 82500 – (499 × 18) = 73518 ✓<br>*(final answer must be given to nearest whole number)* | 3 | **ALLOW ECF** from incorrect $M_r$ of amino acid<br><br>**Alternative method:**<br>Mr of repeat unit = 147 ✓<br>147 x 500 = 73500 ✓<br>73500 + 18 = 73518 ✓<br><br>**Common error for 2 marks**<br>36518 Use of Mr 91<br>82500 Not shown 165 in working<br><br>**Common error for 1 mark**<br>45500 Use of Mr 91<br><br>**Examiner's Comments**<br><br>Most candidates managed to score at least one mark here, either for correctly determining the molar mass of the monomer, the repeat unit in the polymer or alternatively they multiplied a molar mass by500. Many candidates gained 2 marks for either 73500 or 82500 but then struggled to account for thewater lost.<br><br>Some candidates lost marks due to errors in calculating the molar mass of the monomer or some tried toincorporate the use of Avogadro's constant into the calculation. Many misunderstood what atoms wouldbe lost during polymerisation. For example, a common incorrect response seen was found by subtracting2 from the correct molar mass giving 163, followed by multiplication by 500 to give 81500 and finallyadding of 2 to give 81502. Some struggled to understand what was meant by nearest whole |

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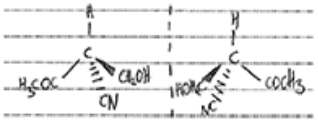
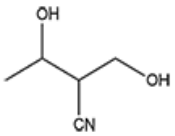
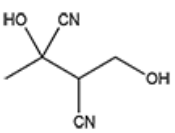
| | | | | | number,e.g. rounding 73518 to 74000 or 82500 to 80000. |
| | | | **Total** | **3** | |
| 3 | | | **C** | 1 | **Examiner's Comments**<br><br>More than three quarters of candidates were able to identify C as being the secondary amide, with many annotating each structure with the correct functional group. Some gave B, i.e. a secondary amine not amide, and a few gave A, i.e. tertiary amide not secondary. |
| | | | **Total** | **1** | |
| 4 | | | **Level 3 (5–6 marks)**<br>Suggests **ALL** of the following<br><br>• Reagents and conditions for **3** functional groups<br>• Products for **3** functional groups<br>• Optical isomerism with description and 3D optical isomers shown<br><br>*There is a well-developed line of reasoning which is clear and logically structured.*<br>*The information presented is relevant and substantiated.*<br><br>**Level 2 (3–4 marks)**<br>Suggests **two** of the following<br><br>• Reagents and conditions for **2** functional groups<br>• Products for **2** functional groups<br>• Optical isomerism with description<br>**OR** an attempt to show 3D optical isomers<br><br>*There is a line of reasoning presented with some structure.*<br>*The information presented is relevant and supported by some evidence.*<br><br>**Level 1 (1–2 marks)**<br>Suggests **two** of the following | 6<br>(AO 3.1 ×3)<br>(AO 3.2 ×3) | **CHECK TOP OF QUESTION FOR RESPONSES**<br>---<br>*Indicative scientific points may include:*<br>**Stereoisomerism**<br><br>• Optical isomerism identified with description: e.g. chiral centre /non-superimposable mirror images<br>• 3D Optical isomers drawn, e.g.<br><br>  <br><br>*Description is subsumed in 3D diagrams*<br><br>**Reactions of ketone/carbonyl e.g.**<br>$NaBH_4$<br><br>  <br><br>HCN **OR** $CN^-/H^+$ (e.g. $NaCN/H^+$)<br><br>  |

- Reagents and conditions for **1** functional group
- Products for **1** functional group
- Identifies optical isomerism with description
  **OR** an attempt to show 3D optical isomers

*There is an attempt at a logical structure with a line of reasoning.*
*The information is in the most part relevant.*

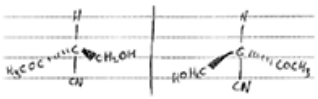
**0 mark** *No response or no response worthy of credit.*

**Key points to check**

*CHECK TOP OF QUESTION for responses*
*IGNORE CONNECTIVITY*

*in 3D isomer structures*

- *IGNORE bond angles*
- *Wedges needed*
- *ALLOW*



Some responses will not fit into this exact pattern and a best-fit match may be needed

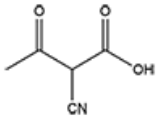
**Clear communication**
Focus on

- Clear diagrams of 3D optical isomers
- Diagrams of unambiguour structures
- Reagents and functional group formed are linked
- Communication is more a general feel for the quality of theresponses.

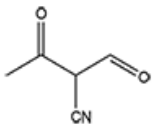
**Slips and minor errors in structures**

**Reactions of –OH, e.g.**

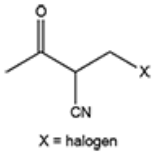
$H^+/Cr_2O_7^{2-}$ **OR** $H_2SO_4/K_2Cr_2O_7$ reflux



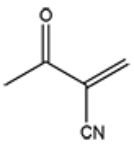

$H^+/Cr_2O_7^{2-}$ **OR** $H_2SO_4/K_2Cr_2O_7$ distil




NaBr/KBr/$Br^-$ **AND** acid/$H^+$ **OR** HBr

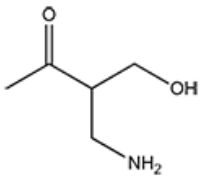



Acid/$H^+$ (catalyst) (e.g. $H_2SO_4$)




**Reactions of C–CN, e.g.**

$H_2$ **AND** metal catalyst e.g. Ni, Pt, Pd




$H^+/H_2O$ e.g. HCl(aq) or $H_2SO_4$(aq)

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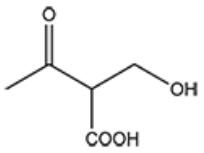
| | | | • Do not penalise the odd slip or omission, e.g. An extra C in a chain; a C short in a chain, C shown instead of $CH_2$ or skeletal<br>• You need to judge the extent of any slip based on the whole response. Remember that each candidate | |  <br><br><br>**OTHER REAGENTS, CONDITIONS AND PRODUCTS**<br>**e.g. $LiAlH_4$ as reagent**<br><br>**Check with Team Leader**<br><br>**Examiner's Comments**<br><br>Overall, candidates performed well when answering this question. They were required to identify that compound **A** shows optical isomerism and to choose a reaction for each of the three functional groups. Candidates were also expected to use structures for the organic products.<br><br>To achieve the highest level of response, a description of optical isomerism should be accompanied by 3D diagrams of the optical isomers.<br><br>Optical isomerism was usually identified, with associated diagrams with almost all candidates identifying the chiral centre. Most attempted 3D diagrams but candidates do need to take care that the groups attached to the chiral C atom are those in compound A and that no parts of chains are omitted. Optical isomers do also require use bold and dashed wedges to be used.<br><br>Most candidates showed good knowledge and understanding of reactions for the three functional groups.<br><br>• For the primary alcohol, most chose $H^+/Cr_2O_7^{2-}$, with distil (→ aldehyde) or reflux (→ carboxylic acid); a significant number chose a concentrated acid (→ alkene) or Br–-/H+ (→ haloalkane)<br>• For the ketone, most chose $NaBH_4$ (→ secondary alcohol) |

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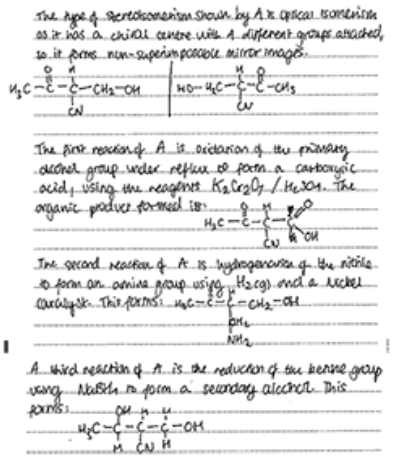
| | | | | | • For the nitrile, most chose either $H_2$/Ni (→ amine) or $H^+$(aq) (→ carboxylic acid).<br><br>Clear diagrams of the products were usually seen although many omitted a $CH_2$ from the amine branch for hydrolysis of the nitrile or an extra $CH_2$ in the aldehyde or carboxylic acid branch from oxidation of the primary alcohol.<br><br>Some candidates chose 2,4-DNP for a reaction of the ketone and treated the question as one requiring tests, and then proving that the compound was a ketone from no reaction with Tollens' reagent. The question asked for the organic product and the 2,4- DNP product is beyond the demands of this specification (although this was seen very rarely). Candidates adopting this reaction were limiting the extent of their response and candidate should have considered this requirement before selecting 2.4-DNP.<br><br>Exemplar 2<br><br>  <br><br><br>This exemplar shows a good response that lacks 3D diagrams for the optical isomers. The candidate has clearly given reagents and conditions and has shown the organic products. In the response, you can see that the candidate initially showed an extra $CH_2$ in the –COOH branch, and a mistake in the amine branch.<br><br>The absence of 3D structures limits the response to Level 2 and 4 marks have |

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| | | | | | been awarded for choosing correct and relevant reagents and conditions, and for the clear communication of the structures. |
| | | | **Total** | **6** | |
| 5 | a | | Non-superimposable mirror images (about a chiral centre) ✓ | 1 (AO1.1) | **IGNORE** definition of stereoisomers<br><br>**Examiner's Comments**<br><br>The majority of candidates were able to explain the term optical isomerism. However, it was still common to see incomplete responses such as 'mirror images' without reference to 'non-superimposable' or 'nonsuperimposable images' with no reference to 'mirror'. Lots gave the definitions for stereoisomerism or an explanation for how a chiral centre arises. |
| | b | i | 2-amino-3-methylbutanoic acid<br>**OR**<br>3-methyl-2-aminobutanoic acid ✓ | 1 (AO1.2) | **IGNORE** lack of hyphens, extra hyphens, or addition of commas<br><br>**DO NOT ALLOW** the following for methyl: methy, meth, methly<br><br>**DO NOT ALLOW** the following for amino: amine, amin<br><br>**Examiner's Comments**<br><br>Over half of candidates were unable to give the systematic name of valine, despite many being able to draw out a structure in the following question. A minority of candidates did not attempt the question. The best strategy was to use displayed formula, find the longest chain which included the COOH and label this as C number 1 to make sure of correct numbering. Common errors included 2-amino-3,3- dimethylpropanoic acid or 3-amino-2-methylbutanoic acid. Many candidates did not know how to name the amine functional group with errors including, amine, N-, nitro-, nitrile, etc. Some simply attempted to name the R group alone, e.g. '2-methylethyl- or 'dimethyl'. |
| | | ii | Correct groups attached to chiral C of valine seen **once**<br>e.g. | 2 (AO1.1) (AO1.2) | **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous |

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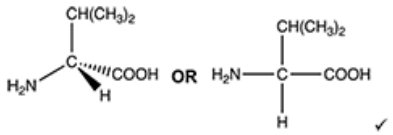
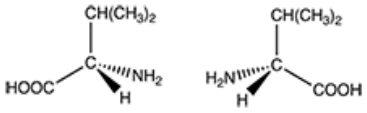
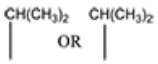
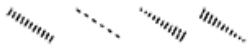
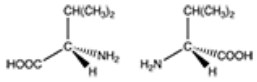
| | | |  ✓<br><br>Two **3D structures** of valine that are mirror images with correct connectivity in both ✓<br><br>  | | **IGNORE** connectivity for the first marking point but must be correct for the second mark.<br>**ALLOW** bond to any part of the CH of the $CH(CH_3)_2$ group<br>e.g. **ALLOW**<br>  <br>Each structure must have four central bonds with **at least two wedges.**<br>For bond into paper accept:<br>  <br>**ALLOW** two 3D structures with 2 groups swapped<br>e.g.<br>  <br>**ALLOW** R or $C_3H_7$ to be shown for $CH(CH_3)_2$ for second mark only.<br>**ALLOW ECF** for second mark for small slips such as missing H e.g. $C(CH_3)_2$<br><br>**Examiner's Comments**<br><br>Most candidates (more than half) were able to score both marks here, on what was a well-practised question from previous examination series. Most were able to identify the correct chiral carbon, with four different groups attached, and draw a 3-D representation of the two optical isomers with correct connectivity. Some candidates inadvertently drew the same structure (e.g. switched groups and gave a mirror image) so if not drawn in a standard way it needed extra checking. Some lost the second mark due to incorrect connectivity or use of $C_3H_7$. Some attempted to write formulae out as literal mirror images, e.g. $_2(_3HC)C$ and need to be told that this isn't necessary as can sometime lead to connectivity errors. |
| | c | i | 16 ✓ | 1<br>(AO2.6) | **Examiner's Comments**<br><br>This question was challenging for even the most able candidates with very few obtaining the correct answer of 16. Many |

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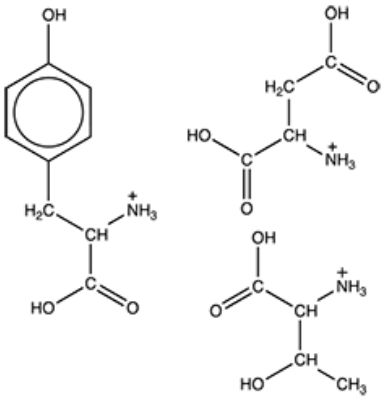
| | | | | | identified the four chiral centres in compound E, often labelling these with an asterisk. However, only a small proportion were able to predict that there would be 16 possible optical isomers. Most provided an answer of four corresponding to the number of chiral centres or eight considering that each chiral centre would result in two optical isomers. They struggled to see that they needed $2^n$ in this case where n represents the number of chiral centres. Candidates have probably seen very few, if any, examples of chiral compounds with more than two chiral centres. |
| | | ii |  <br>**1 mark** for each **correct** structure with<br>• **Either** $NH_3^+$ **OR** $NH_2$ ✓✓✓<br>**1 mark** for<br>• **all 3 correct** structures with $NH_3^+$ ✓ | 4 (AO2.5 ×4) | **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous<br>**IGNORE** connectivity<br>**ALLOW** + charge on H of $NH_3$ group, i.e. $NH_3^+$<br>If structures are shown with $NH_3$ groups (without the + charge) **OR** as $NH_2^+$ groups allow **ECF** for subsequent use.<br>**ALLOW** structures shown as correctly balanced salts, e.g $NH_3Cl$ **OR** $NH_3^+Cl^-$ all marks can be awarded.<br>**Examiner's Comments**<br>A significant number of candidates did not attempt this question despite similar questions appearing in previous exam series. However, approximately a quarter of candidates scored all 4 marks. Some lost the final mark for not protonating the amine groups as required as under acidic conditions. A very common error was to hydrolyse the amides to give acyl chlorides or even aldehydes rather than carboxylic acids. Lower scoring candidates often had incomplete hydrolysis or no hydrolysis at all with just |

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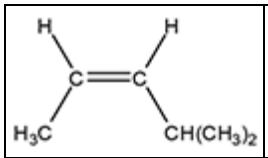
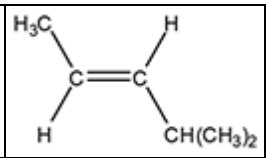
| | | | | | changes to acid/amine/phenol functional groups, e.g. protonation of amine to form salts or swapping or OH groups for Cl. Candidates need to check their answers carefully for missing or extra Hs as this lost marks. It was much easier to mark candidates' work presented with structures with a similar arrangement to compound E. |
| | | | **Total** | **9** | |
| 6 | | i | Same **molecular** formula<br>**AND**<br>Different **structural** formulae ✓<br><br>**OR**<br><br>Both have the **molecular** formula $C_6H_{12}$<br>**AND**<br>Different **structural** formulae ✓ | 1<br>(AO1.1) | Same formula is **not** sufficient<br><br>*(no reference to molecular)*<br>Different arrangement of atoms is **not** sufficient<br><br>*(no reference to structure/structural)*<br><br>For 'structural formulae',<br>**ALLOW** structure/displayed/skeletal formulae/functional groups<br><br>**DO NOT ALLOW** any reference to spatial/space |
| | | ii | Same structural formula<br>**AND**<br>Different arrangement (of atoms) in **space**<br>**OR** different **spatial** arrangement (of atoms) ✓ | 1<br>(AO1.1) | **ALLOW** structure/displayed/skeletal formula<br><br>**DO NOT ALLOW** same empirical formula **OR** same general formula<br><br>**IGNORE** same molecular formula<br><br>Reference to *E/Z* isomerism or optical isomerism is **not** sufficient |
| | | iii | Correct identification of *cis* **AND** *trans* isomers of 4-methylpent-2-ene ✓✓<br><br>  <br>*cis* isomer<br><br>  <br>*trans* isomer<br><br>**OR** | 2<br>(AO1.2)<br>(AO2.5) | **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous<br><br>$C_3H_7$ is **not** sufficient (could be unbranched)<br><br>**ALLOW** one mark if *cis* **AND** *trans* isomers of 4-methylpent-2-ene are in the wrong boxes |

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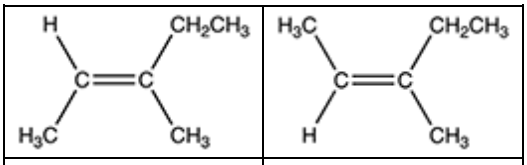
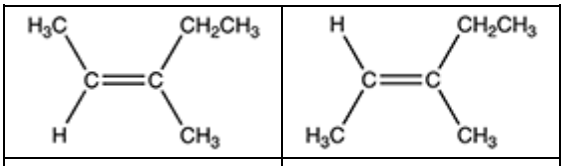
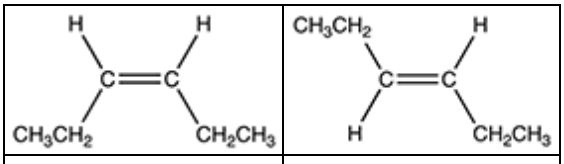
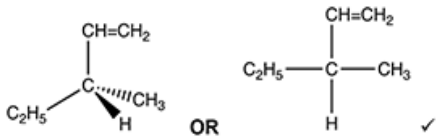
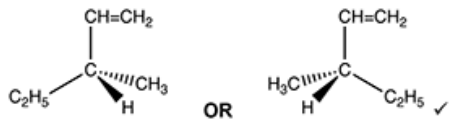
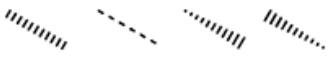
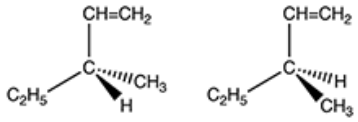
| | | | Identification of 3-methylpent-2-ene as *cis* **AND** *trans* isomers ✓✓<br>  <br>*cis* isomer \| *trans* isomer | | **ALLOW** the isomers of 3-methylpent-2-ene in either box<br>  <br>*cis* isomer \| *trans* isomer<br><br>*Ambiguity with cis/trans identification system*<br><br>**ALLOW** one mark for correct identification of *cis*<br>**AND** *trans* isomers of unbranched $C_6H_{12}$<br>e.g.<br>  <br>*cis* isomer \| *trans* isomer |
| | | iv | Correct groups attached to chiral carbon of compound C seen **once** e.g.<br>  <br>Two **3D structures** of compound C that are mirror images with correct connectivity in both<br>  | 2<br>(AO2.5×2) | **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous<br><br>For $C_2H_5$–, ALLOW $CH_3CH_2$–<br>For –CH=$CH_2$, ALLOW –$C_2H_3$ OR –$CHCH_2$<br><br>For bond into paper accept:<br>  <br><br>**ALLOW** two 3D structures with 2 groups swapped<br>e.g.<br>  |

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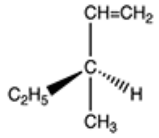
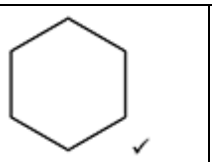
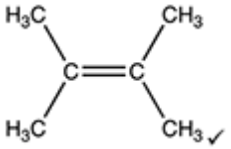
| | | | | | **DO NOT ALLOW** a bond angle of 180° e.g.<br>  <br> |
| | | v |  ✓  <br> ✓<br>**D** **E**<br><br>Two of the following for **D** ✓<br>• All H are equivalent/in the same chemical environment/ the same type<br>• All C are equivalent/ in the same chemical environment/ the same type<br>• No C=C present<br><br>Two of the following for **E** ✓<br>• All H are equivalent/ in the same chemical environment/ the same type<br>• 2 C environments<br>• C=C present | 4<br>(AO2.5×2)<br>(AO2.2×2) | **ALLOW** 1 mark for structures if shown in wrong boxes.<br><br>**CHECK** table 16.1 for annotations that may be worthy of credit<br><br>**Examiner's Comments**<br><br>The majority of candidates were able to correctly define a structural isomer.<br><br>This definition was well known by candidates with the majority of responses given the mark. Some candidates omitted the reference to structural formula.<br><br>This question required candidates to link their knowledge of *cis* and *trans* isomers with branched hydrocarbons. Higher ability candidates were able to do this. The majority of candidates scored 1 mark for correctly drawing *cis* and *trans* isomers of an unbranched hydrocarbon.<br><br>This question discriminated well. Candidates were required to identify the groups around a chiral carbon This question discriminated well. Candidates were required to identify the groups around a chiral carbon and then draw the two corresponding optical isomers. Incorrect responses frequently had incorrect connectivity around the chiral carbon, bond angles of 180° or 2D structures. |

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| | | | | | Most candidates were able to correctly draw the structure of D and E. Many candidates did not explain their answers in terms of the number of different hydrogen and carbon environments or the presence/absence of a carbon-carbon double bond. |
| | | | **Total** | **10** | |
| 7 | | | **FIRST CHECK ANSWER LINES**<br>**If M=168(.0) Award 4 marks for calculation providing unit conversions are correct**<br>**----------**<br>***Use of ideal gas equation***<br>$pV = nRT$ ***OR*** $n = \frac{pV}{RT}$ ✓<br>***SI Unit conversions AND substitution into*** $n = \frac{pV}{RT}$:<br>• *R = 8.314* ***OR*** *8.31*<br>• $V = 186 \times 10^{-6}$<br>• *T in K: 303 K*<br>*e.g.*<br>$\frac{1.07 \times 10^5 \times 186 \times 10^{-6}}{8.314 \times 303}$ ✓<br>***Calculation of n***<br>$n = 7.90 \times 10^{-3}$ (mol) ✓<br>***Calculation of M***<br>$M = \frac{1.327}{7.90 \times 10^{-3}} = 168(.0)$ ✓<br>***Molecular formula***<br>$C_3H_2F_6O$ ✓ | 6<br>(AO1.2×1)<br>(AO2.4×3)<br>(AO2.5×2) | **ALLOW ECF throughout**<br>**ALLOW** calculator value of 167.968115 (using 8.314) for M<br>**ALLOW** calculator value of 167.8873033 (using 8.31) for M<br>Calculator value of *n*:<br>from 8.314 = $7.900308915 \times 10^{-3}$<br>from 8.31 = $7.904111711 \times 10^{-3}$<br>**ALLOW** ECF that matches M but the formula MUST contain $F_6O$<br>**----------**<br>**Use of 24 dm$^3$**:<br>e.g.<br>$n = \frac{186.0}{24000} = 7.75 \times 10^{-3}$<br>**No mark**<br>*(calculation much simpler)*<br>$M = \frac{1.327}{7.75 \times 10^{-3}} = 171(.2)$ ✓<br>**ECF**<br>$C_3H_5F_6O$ ✓<br>**ECF** |

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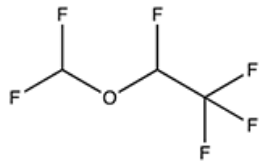
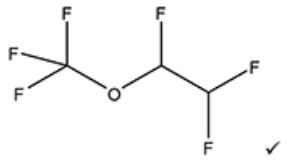
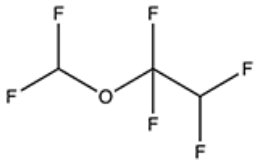
| | | | ***Structure***<br>  <br>**OR**<br>  <br>✓ | | **ALLOW** ECF for a feasibile chemical structure that matches M **AND** contains $F_6O$ **AND** has a chiral carbon<br><br>**DO NOT ALLOW**<br>  <br>*no chiral carbon*<br><br>**Examiner's Comments**<br><br>This question proved difficult and discriminated well. Higher ability candidates correctly used SI units and showed each step of their calculation and then using this to correctly identify a structure of compound X. Candidates frequently used the wrong interconversions and gave structures that lacked a chiral centre. A small number of candidates used molar gas volume rather than PV=nRT for their calculation. |
| | | | **Total** | **6** | |
| 8 | | | $C_2H_5COOH + KOH \rightarrow C_2H_5COOK + H_2O$ ✓<br><br>$2HCOOH + Mg \rightarrow (HCOO)_2Mg + H_2$ ✓<br><br>$H_2O$ **AND** $CO_2$ ✓ | 4<br>(AO2.6×4) | **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous<br><br>**IGNORE** state symbols and use of equilibrium sign<br><br>**ALLOW** $KC_2H_5COO$<br><br>**DO NOT ALLOW** a missing charge (e.g. $C_2H_5COO^-K$) the 1st time seen but **IGNORE** for next equations.<br><br>For salts,<br>**ALLOW** $C_2H_5COO^-K^+$ **OR** $C_2H_5COO^- + K^+$<br><br>**DO NOT ALLOW** –COO–K (covalent bond) the 1st time seen but **IGNORE** for next equations. |

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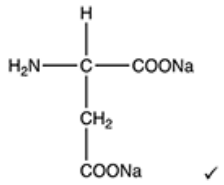
| | | |  Correct formula of salt: | | **FOR** $CO_2 + H_2O$ **ALLOW** $H_2CO_3$ **Examiner's Comments** This question proved challenging for candidates. The first equation was often answered correctly, although some candidates used sodium hydroxide rather than potassium hydroxide in their response. The second equation was frequently incorrect. Candidates frequently missed a hydrogen from the structure for methanolic acid or did not recognise that hydrogen was a product. Many candidates did not account for magnesium having a 2+ charge when working out the product. For the third equation, the majority of candidates identified that carbon dioxide and water would be produced but were unable to give the correct formula of the salt as they did not interpret the information given regarding the R group. |
| | | | **Total** | **4** | |
| 9 | | | D | 1 (AO1.2) | **ALLOW** 8 (correct number of chiral centres) **Examiner's Comments** Many candidates correctly answered D, with those selecting the correct response showing annotations on the given structure to identify the chiral carbons. C proved a good distractor. |
| | | | **Total** | **1** | |
| 10 | a | | Number of optical isomers = 4 ✓ | 1 (AO2.1) | **Examiner's Comments** Most candidates added two asterisks to the diagram of vitamin C for the possible chiral centres. More successful responses usually realised that two chiral centres would give rise to $2^2 = 4$ optical isomers, with 2 optical isomers being the commonest error. |

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| | b | i | Hydrogen bonding<br>**AND**<br>**Many** OH/hydroxyl / hydroxy / alcohol ✓ | 1<br>(AO2.1) | **ALLOW** 4 OH<br>**DO NOT ALLOW** $OH^-$<br><br>**Examiner's Comments**<br><br>Most candidates realise that hydrogen bonds would be formed from the OH groups in vitamin C to water. Candidates are advised to read the question carefully as the word 'extremely' was a hint that 'many' OH groups would be needed in the explanation. The most successful responses quoted that hydrogen bonds would form between the 4 OH groups in vitamin C and water. Some candidates stated that O atoms in vitamin C would be involved. This was not given marks as not all O atoms in vitamin C are a part of OH groups and capable of hydrogen bonding. |
| | | ii | x = 15 ✓ y = 31 ✓ | 1<br>(2 ×AO3.2) | **Examiner's Comments**<br><br>More successful responses determined that *x* = 15 and *y* = 31.<br><br>The key to success here was to subtract the formula of vitamin C from the formula of the ester and to add the formula of water: $C_{22}H_{38}O_7 - C_6H_8O_6 + H_2O \rightarrow C_{16}H_{32}O_2 \rightarrow C_{15}H_{31}COOH$.<br><br>A significant number of candidates did obtain one of these values, with 15/16 and 29/30/32 being common incorrect answers. Omitting part(s) of sequence above would result in these incorrect numbers. |
| | | | **Total** | **4** | |
| 11 | | i | ***Bond angles***<br>$H_2NCH_2COONa$, bond angle = 107°<br>**AND**<br>$HOOCCH_2NH_3Cl$, bond angle = 109.5° ✓<br>***Number of electron pairs***<br>***Mark independently of angles***<br><br>In NaOH/107°, ($NH_2$ has) **3** bonded pairs **/ 3** bonds<br>**AND**<br>**1** lone pair ✓ | 3<br>(3 ×AO1.2) | **ALLOW** 107 ± 0.5<br><br>**ALLOW** 109 **OR** 110°<br><br>**ALLOW** $NH_2$ has **4** pairs, one of which is a lone pair<br><br>**For bonded pairs/bonds**<br>**ALLOW bonded** groups, atoms, elements, regions<br>***Bonded** essential*<br><br>**IGNORE** electron region **OR** electron |

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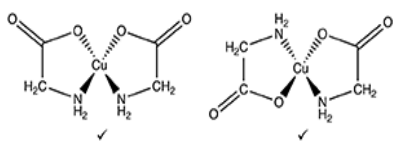
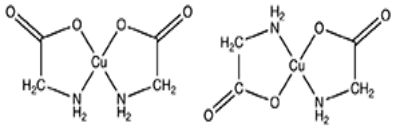
| | | | In HCl/109.5°, ($NH_3^+$ has) **4** bonded pairs / **4** bonds ✓ | | density<br><br>**IGNORE** $NH_3$ has no lone pairs<br><br>**IGNORE** lone pairs repel more (than bonded pairs)<br><br>**IGNORE** shapes, even if wrong<br><br>**ALLOW** bp for bonded pair and lp for lone pair<br><br>**Examiner's Comments**<br><br>This question required candidates to apply their knowledge and understanding of bond angles and electron pair repulsion of $NH_3$ and $NH_4^+$ to amino acid salts. The best candidates rose to this challenge and secured all 3 marks for correct bond angles and explanations in terms of the numbers of bonded and lone pairs around the N atoms.<br><br>Overall, candidates found this question quite difficult. Many different bond angles were predicted, with 120° being the commonest incorrect H-N-H bond angle in $H_2NCH_2COONa$. The explanation for 120° was in terms of three bonding pairs and no lone pairs. 104.5° was also seen, presumably relating $H_2N$ to $H_2O$. The 109.5° bond angle was correct more often, as was its explanation in terms of 4 bonding pairs.<br><br>Many successful responses showed working on diagrams in which bonded and lone pairs had been included. This strategy will have helped candidates in their conclusions. |
| | | ii | **Equation:**<br>**2** $H_2NCH_2COOH + Cu(CH_3COO)_2 \rightarrow Cu(H_2NCH_2COO)_2 +$ **2** $CH_3COOH$ ✓<br><br>**Structures**<br>  | 3<br>(AO2.6)<br>(2 ×AO2.5) | **ALLOW** molecular formulae or mixture, e.g. $2C_2H_5NO_2 + CuC_4H_6O_4 \rightarrow CuC_4H_8N_2O_4 + 2C_2H_4O_2$<br>**IGNORE** charges<br>**i.e. IGNORE** wrong or missing charges in ionic compounds if formula is correct/ e.g. **ALLOW** $Cu(CH_3COO^-)_2$, $Cu^+(CH_3COO^-)_2$<br><br>**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous |



✓ ✓

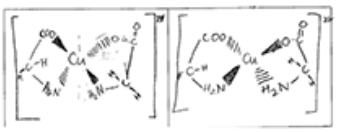
Ligands **must** shown as bidentate rings

**IGNORE** connectivity for $NH_2$
**BUT** connectivity **must** be to O of COO

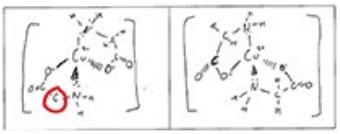
**IGNORE** charges

**ALLOW** arc to represent $-CH_2-$ between: C of C=O and $NH_2$

**ALLOW** 1 mark for 2 'correct' structures shown as tetrahedral e.g.



**IGNORE** missing Hs on C, e.g.



**Examiner's Comments**

Candidates were asked to predict an unfamiliar equation from provided information and to draw structures of square planar complexes containing an amino acid. Candidates found the structures easier than the equation, with many drawing 3D structures with 2 out-wedges and 2 in-wedges and attaching the $NH_2$ and COO groups correctly. It was also common to see a 'criss-cross' orientation, looking down on the complex, which is easier to draw. Many candidates connected the $NH_2$ and COO groups next to, and across from, each another in the isomers. A common error was for candidates to rotate their first structure, to produce a second drawing of the first structure. Less successful responses often tried to attach $NH_2$ and COO groups but with no $CH_2$ between the groups to produce a cyclic attachment. A minority of candidates ignored 'square planar' and drew tetrahedral structures instead.

The equation proved to be very difficult, the commonest error being omission of the '2' balancing numbers for $H_2NCH_2COOH$ and $CH_3COOH$. The

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| | | | | | formulae for ethanol or propanoic acid were also often seen for ethanoic acid.<br><br>Candidates are advised to check all formulae and then to check balancing, the golden rules for successfully constructing all equations. |
| | | | **Total** | **6** | |