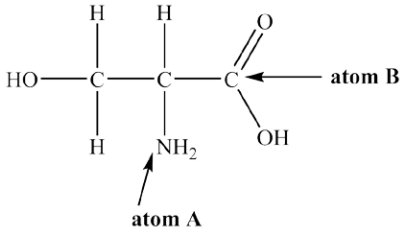
1. How many stereoisomers are there of $CH_3CH = CHCH(OH)CH_2CH = CH_2$?

A. 2
B. 4
C. 6
D. 8

Your answer ☐

[1]

2(a). Serine, shown below, is an amino acid.



i.

Use electron repulsion theory to predict the shape of the bonds around atoms **A** and **B**.

Give relevant bond angles around atoms **A** and **B**.

Give reasons for your answers.

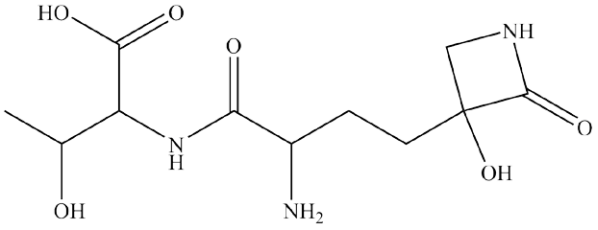
[4]

ii. A student adds an excess of aqueous sodium hydroxide to a sample of solid serine.
The student then purifies the resulting reaction mixture to obtain a pure sample of an ionic organic product.

- Draw the structure of the ionic organic compound obtained.
- Outline the steps that the student could carry out to obtain a pure sample of the organic product from the reaction mixture.

[3]

(b). Tabtoxin is a poisonous substance produced by bacteria found in lilac trees.



tabtoxin

i. Identify the chiral centres present in a molecule of tabtoxin.

On the structure above, mark each chiral centre with an asterisk, *.

[1]

ii. Tabtoxin can be broken down by alkaline hydrolysis.

Draw the structures of **all** the organic products of the alkaline hydrolysis of tabtoxin.

[4]

3. In basic conditions, α-amino acids form anions with the general formula, $RCH(NH_2)COO^-$. These anions can act as bidentate ligands.

Copper(II) ions can form a square planar complex with anions of the amino acid glycine (R = H). There are two stereoisomers of this complex, **B** and **C**.

i. Draw the **skeletal** formula of the anion of glycine.

[1]

ii. Draw diagrams of stereoisomers **B** and **C**.

In your structures, show the ligands as skeletal formulae.

[2]

iii. Anion ligands of the amino acid alanine (R = CH_3) would be expected to form more than two square planar stereoisomers with copper(II) ions.

Explain this statement.

[1]

4(a). Compound **F** has the molecular formula C_4H_8.

Compound **F** is reacted with steam in the presence of an acid catalyst, to form a mixture of three alcohols, **G**, **H** and **I**.

Compound **G** is oxidised with acidified potassium dichromate(VI) to form compound **J**.

Compound **J** reacts with Tollens' reagent to form compound **K**.

Compounds **H** and **I** are optical isomers.

Draw the structures of the compounds **F**, **G**, **H**, **I**, **J** and **K**.

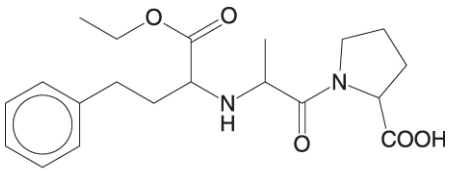
[6]

(b). Explain, with reference to a suitable chemical test, how compound **J** could be identified.

Your answer should **not** include spectroscopy.

[3]

5. Enalapril is a drug used in the treatment of high blood pressure.



enalapril

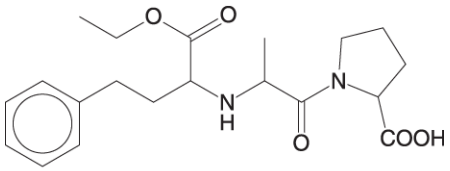
i. **On the structure above**, mark each chiral centre with an asterisk (*).

[1]

ii. Suggest **two** benefits of using single stereoisomers in the synthesis of drugs such as enalapril.

[2]

iii. Enalapril is broken down in the body by acid hydrolysis.



enalapril

Draw the structures of the **three** organic products of the **acid hydrolysis** of enalapril.

[4]

iv. A scientist hydrolysed enalapril in the laboratory. The scientist then analysed the mixture of products using GC–MS.

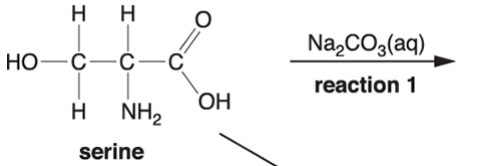
Explain how GC–MS enables the products to be identified.

[1]

6(a). Many α-amino acids have several functional groups.

Serine, shown below, is a naturally occurring α-amino acid.

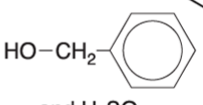
i. In the boxes below, draw the structure of the organic compounds formed by each reaction.



$Na_2CO_3(aq)$

reaction 1

reaction 2



and H_2SO_4

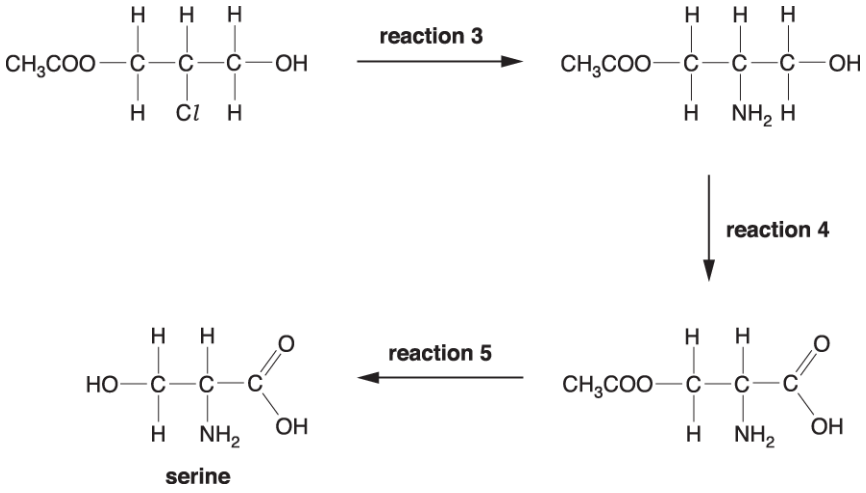
[3]

ii. Suggest a use for the organic compound formed by **reaction 2**.

[1]

iii. Serine is commonly used in organic synthesis.

One possible method of synthesising serine is shown below.



Complete the following:

Reagent and conditions used for **reaction 3**.

Type of reaction for:

reaction 4 .....

reaction 5 .....

[3]

(b). Compound **E**, C_4H_7NO, is one of two optical isomers. It can be oxidised by Tollens' reagent to an α-amino acid, **F**.

The α-amino acid **F** forms two different polymers, **G** and **H**.
Polymer **G** has the empirical formula $C_4H_7NO_2$.
Polymer **H** has the empirical formula C_4H_5NO.

- Suggest structures for compound **E** and compound **F**.
- Draw repeat units of polymer **G** and polymer **H**.
- Describe how **F** forms **G** and **H**.

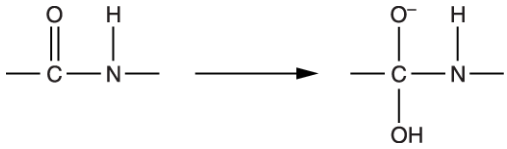
[6]

7(a). The building blocks of peptides and proteins are α-amino acids.

A tripeptide is hydrolysed to form a mixture of three different α-amino acids.

The first step of an incomplete mechanism for the alkaline hydrolysis of the tripeptide is shown below.

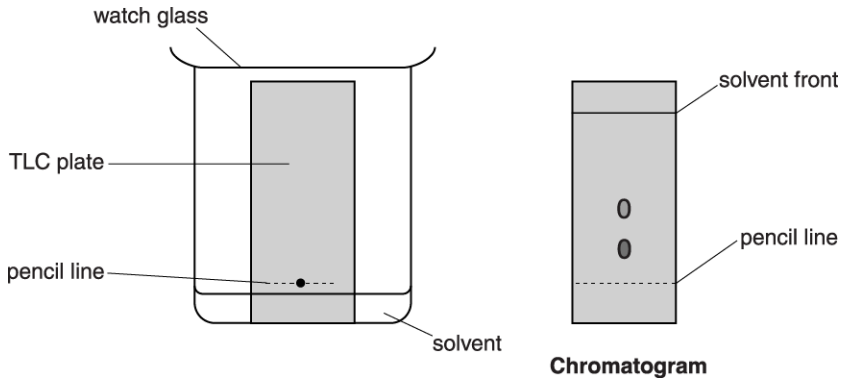
Add curly arrows and relevant dipoles to the diagram to suggest how the hydroxide ion takes part in the first step of this mechanism.



[2]

(b). The tripeptide is hydrolysed and the resulting mixture containing the three amino acids is neutralised.

A student tries to separate and identify the three amino acids in the mixture using thin-layer chromatography (TLC). The diagram below shows the apparatus for the experiment and the chromatogram produced.



Explain how the chromatogram can be used to identify amino acids.
The student thinks that there should be three spots on the chromatogram.

Suggest why there are only two spots.

[3]

(c). The three α-amino acids in the tripeptide are aspartic acid, glycine and isoleucine.

The general formula for an α-amino acid is $RCH(NH_2)COOH$.

α-amino acid	R-group
aspartic acid	$–CH_2COOH$
glycine	–H
isoleucine	$–CH(CH_3)CH_2CH_3$

i. Aspartic acid has an isoelectric point of 2.77.

What is meant by the term *isoelectric point*?

In your answer you should use the appropriate technical terms spelled correctly.

[1]

ii. Draw the structure of aspartic acid when it is dissolved in a solution with a high pH.

[1]

iii. Suggest a structure for the tripeptide.

On your structure, mark each chiral centre with an asterisk (*).

[2]

8(a). A chemistry teacher carries out an experiment to synthesise 2-aminopropan-1-ol, $CH_3CH(NH_2)CH_2OH$.

The teacher asks a university chemistry department to test the 2-aminopropan-1-ol using proton NMR spectroscopy and mass spectrometry.

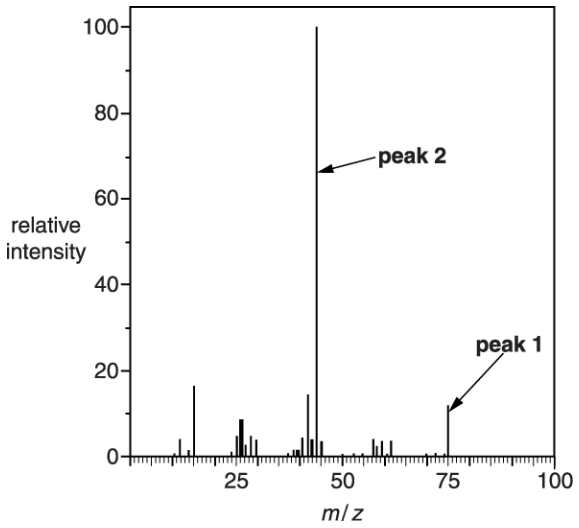
i. For the ^1H NMR analysis, the sample was dissolved in D_2O.

Complete the table to predict the ^1H NMR spectrum of $CH_3CH(NH_2)CH_2OH$ after dissolving in D_2O.

^1H NMR spectrum for $CH_3CH(NH_2)CH_2OH$, dissolved in D_2O		
Chemical shift, δ/ ppm	**Relative peak area**	**Splitting pattern**

[3]

ii. The mass spectrum for $CH_3CH(NH_2)CH_2OH$ is shown below.



Give the formulae for the species responsible for **peak 1** and **peak 2** in the mass spectrum.

peak 1

peak 2

[2]

(b). The teacher synthesises 2-aminopropan-1-ol, $CH_3CH(NH_2)CH_2OH$, from 2-chloropropan-1-ol, $CH_3CHClCH_2OH$.

i. State the reagents and conditions required for this synthesis.

[1]

ii. The sample prepared by the teacher from 2-chloropropan-1-ol is not pure. It also contains compound **D**.

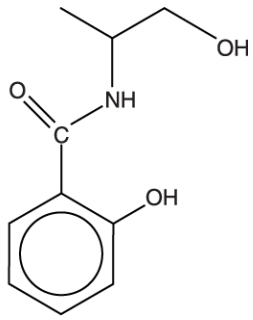
Compound **D** has a molecular formula of $C_6H_{15}NO_2$.

Suggest the structure of compound **D**.

Compound **D**

[1]

(c). In a separate experiment, the chemistry teacher prepares compound **E** from 2-aminopropan-1-ol.



compound E

i. One of the functional groups in compound **E** is a phenol.

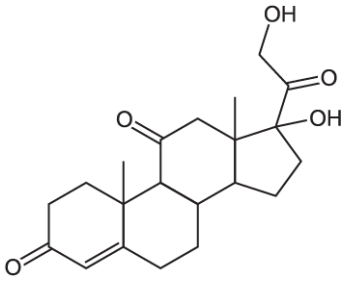
Name the other functional groups in compound **E**.

[1]

ii. Draw the structures of the **two** organic products formed when compound **E** is heated under reflux with dilute hydrochloric acid.

[2]

9. What is the number of chiral centres in the molecule below?



A 4
B 5
C 6
D 7

Your answer ☐

[1]

10(a). This question is about α-amino acids.

Serine, $H_2NCH(CH_2OH)COOH$, is a naturally occurring α-amino acid.

i. Serine has two optical isomers.

Explain what is meant by the term *optical isomers*, and draw the two optical isomers of serine.

[3]

ii. Serine can react with the α-amino acid glycine, H_2NCH_2COOH, to form **three** different organic products, each with the molecular formula $C_5H_{10}N_2O_4$.

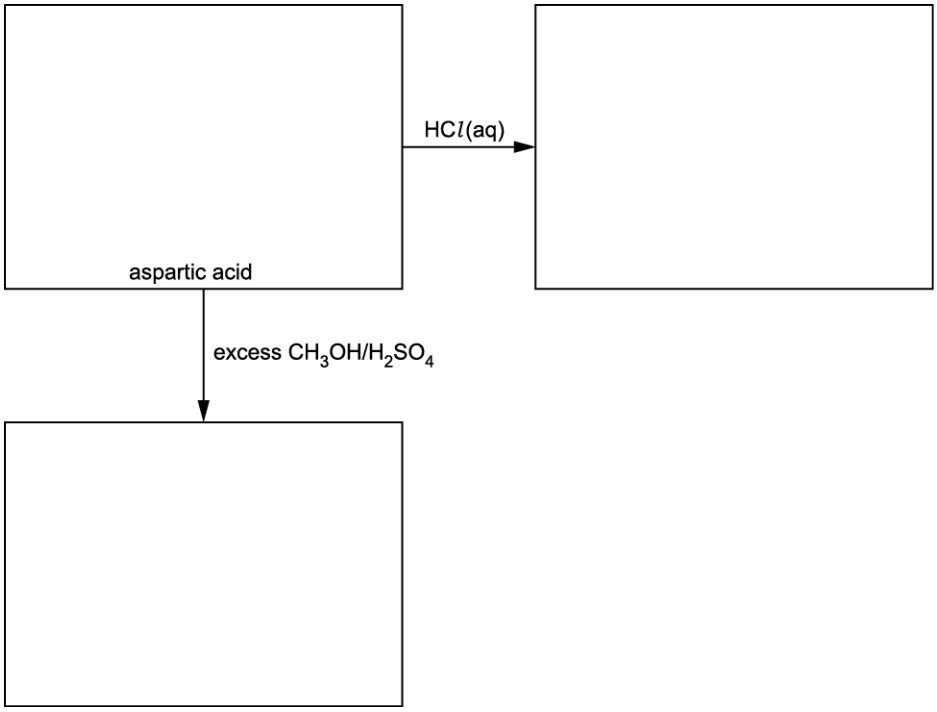
Draw the structures of the **three** organic products that can be formed by the reaction of serine with glycine.

[3]

(b). The general formula of an α-amino acid is $RCH(NH_2)COOH$.

i. Aspartic acid (R = CH_2COOH) is reacted as shown in the flowchart below.

Draw the structures of aspartic acid and the missing organic products in the boxes.



[4]

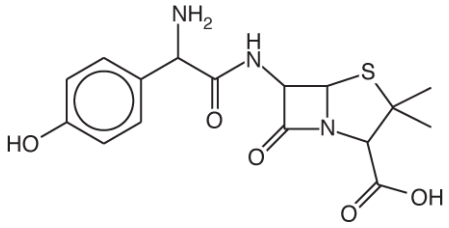
ii. Compound **G** is an α-amino acid with a **branched** R group.

0.0300 mol of **G** has a mass of 3.51 g.

Determine the molar mass of α-amino acid **G** and suggest its structure.

[2]

11. What is the number of chiral centres in the molecule below?



A 2
B 3
C 4
D 5

Your answer ☐ **[1]**

12. This question is about weak acids.

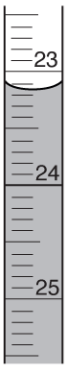
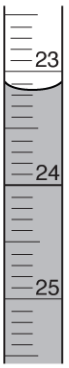
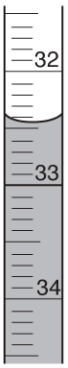
Compound **A** is a weak monobasic acid.

A student is supplied with a 250.0 cm^3 solution prepared from 2.495 g of **A**.

The student titrates 25.0 cm^3 samples of this solution with 0.0840 mol dm^{-3} NaOH in the burette.

The student carries out a trial, followed by the three further titrations. The diagrams show the initial burette readings and the final burette readings for the student's three **further** titrations.

All burette readings are measured to the nearest 0.05 cm^3.

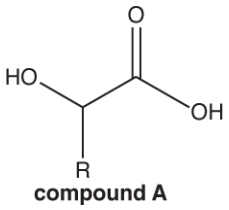
Titration 1		Titration 2		Titration 3	
Initial reading	Final reading	Initial reading	Final reading	Initial reading	Final reading
					

i. Record the student's readings and the titres in an appropriate format.

Calculate the mean titre that the student should use for analysing the results.

mean titre = _____ cm^3 **[4]**

ii. The structure of compound **A** is shown below.



compound A

Compound **A** has four optical isomers.

Using this information and the student's results, answer the following.

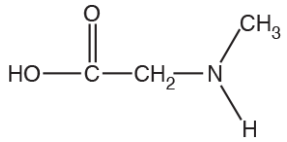
- Determine the molar mass of **A** and the formula of the alkyl group R.
- Draw the structure of compound **A** and label any chiral carbon atoms with an asterisk*.

Show all your working.

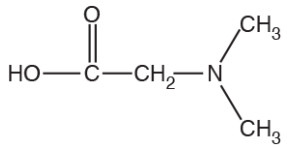
[6]

13. Which compound is a secondary amide?

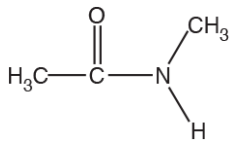
A



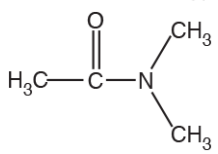
B



C



D



Your answer [1]

14. How many straight-chain structural isomers of $C_7H_{15}Cl$ contain a chiral carbon atom?

A 1
B 2
C 3
D 4

Your answer [1]

15(a). The general formula of an α-amino acid is $RCH(NH_2)COOH$.

The α-amino acid cysteine ($R = CH_2SH$) shows optical isomerism.

Draw 3-D diagrams to show the optical isomers of cysteine.

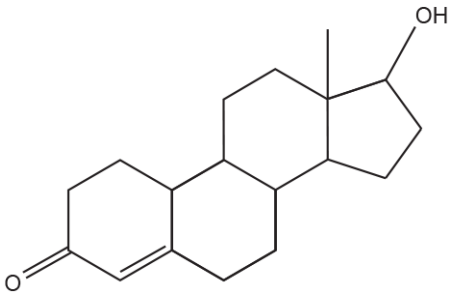
[2]

(b). The α-amino acid lysine ($R = (CH_2)_4NH_2$) reacts with an excess of dilute hydrochloric acid to form a salt.

Draw the structure of the salt formed in this reaction.

[2]

16. What is the number of chiral carbon atoms in the steroid molecule below?



A 5
B 6
C 7
D 8

Your answer ☐ **[1]**

17. $(CH_3)_3CCHBrCH_3$ has stereoisomers.

i. Explain the term stereoisomers and name this type of stereoisomerism.

Explanation:

Type of stereoisomerism: ---------- **[1]**

ii. Draw 3D diagrams for the stereoisomers of $(CH_3)_3CCHBrCH_3$.

[2]

18. Which type(s) of stereoisomerism is/are shown by 2,4-dimethylhex-2-ene?

A *E* / *Z* isomerism only.
B Optical isomerism only.
C Both *E* / *Z* isomerism and optical isomerism.
D Neither E / Z isomerism nor optical isomerism.

Your answer ☐ **[1]**

19(a). This question is about organic acids.

Table 18.1 shows the R groups in four amino acids.

Amino acid	R group
alanine	CH_3–
valine	$(CH_3)_2CH$–
threonine	$CH_3CH(OH)$–
lysine	$H_2N(CH_2)_4$–

Table 18.1

Most amino acids show optical isomerism.

i. Explain the term **optical isomerism**.

[1]

ii. Draw 3-D diagrams to show the optical isomers of alanine.

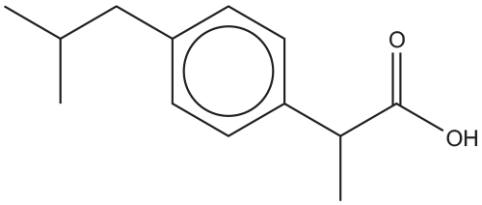
[2]

iii. How many optical isomers does threonine have?

.....

[1]

(b). Ibuprofen, shown below, is used as a painkiller.



ibuprofen

i. What is the molecular formula of ibuprofen?

.....

[1]

ii. One ibuprofen tablet contains 400 mg of ibuprofen.

Calculate the number of ibuprofen molecules in one ibuprofen tablet.

Give your answer to **3** significant figures.

number of ibuprofen molecules = ... **[3]**

(c). Tablets based on ibuprofen and lysine are now available from pharmacies.

These tablets are claimed to act faster than ibuprofen by being absorbed into the body more quickly than ibuprofen alone.

One type of these tablets contains a salt of ibuprofen and the amino acid lysine (R = $–(CH_2)_4NH_2$) in a 1:1 molar proportion.

i. Suggest the structure of each ion in this lysine salt of ibuprofen, including the position of any charges.

– ion	+ ion

[2]

ii. Suggest why tablets based on a salt of ibuprofen should act faster in the body than ibuprofen.

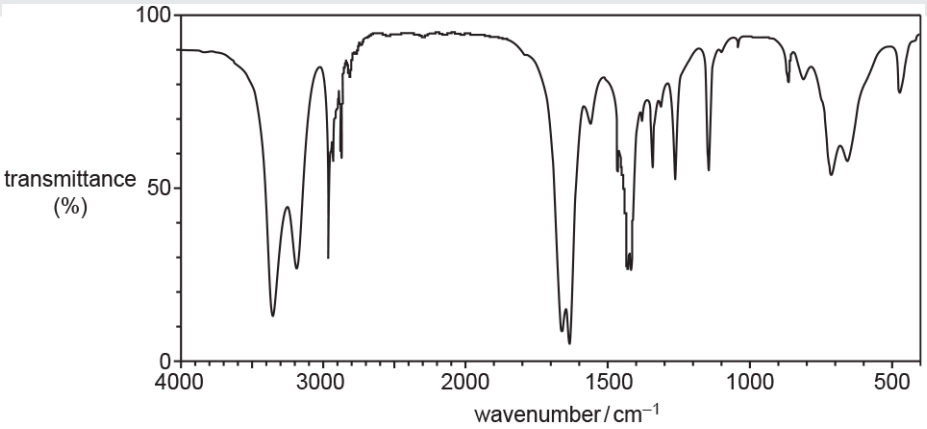
[1]

20. This question is about two reactions of ammonia.

Reaction 1
Excess ammonia is reacted with 4.77 g of copper(II) oxide. The reaction produces 3.81 g of solid **E**, liquid **F** and 0.560 g of gas **G**, which has a volume of 480 cm^3 at RTP.

Reaction 2
Ammonia reacts with compound **H** to form compound **I**, C_2H_5NO, and chloride salt **J**.

The IR spectrum of **I** is shown below.



Identify **E**, **F**, **G**, **H**, **I** and **J**, and write equations for the **two** reactions.

Show your reasoning.

[6]

21. Glycine, H_2NCH_2COOH, is an α-amino acid.

i. Glycine reacts with NaOH to form the salt H_2NCH_2COONa.

Glycine reacts with HCl to form the salt $HOOCCH_2NH_3Cl$.

The salts have different H-N-H bond angles.

State the different H-N-H bond angles and explain why they are different.

H_2NCH_2COONa H-N-H bond angle = ... °

$HOOCCH_2NH_3Cl$ H-N-H bond angle = ... °

explanation

[3]

ii. Glycine reacts with aqueous copper(II) ethanoate to form copper(II) glycinate, $Cu(H_2NCH_2COO)_2$, and ethanoic acid. Copper(II) glycinate is a complex which exists as two square planar isomers.

Write an equation for this reaction and draw the structures of the two square planar isomers of the complex $Cu(H_2NCH_2COO)_2$.

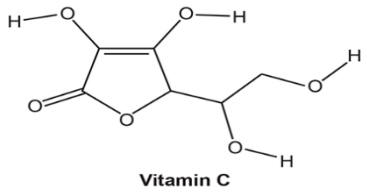
equation

structures

[3]

22(a). A student carries out an investigation on vitamin C, $C_6H_8O_6$.

The structure of vitamin C is shown below. Vitamin C is an optical isomer.



Vitamin C

What is the total number of optical isomers with the structure of vitamin C?

total number of optical isomers = ... **[1]**

(b). Vitamin C is extremely soluble in water. This means that vitamin C is removed rapidly from the body. 'Vitamin C ester' is available in tablet form as a less soluble source of vitamin C which stays in the body for longer.

i. Suggest why vitamin C is extremely soluble in water.

[1]

ii. A 'vitamin C ester' tablet contains an ester with the molecular formula $C_{22}H_{38}O_7$.

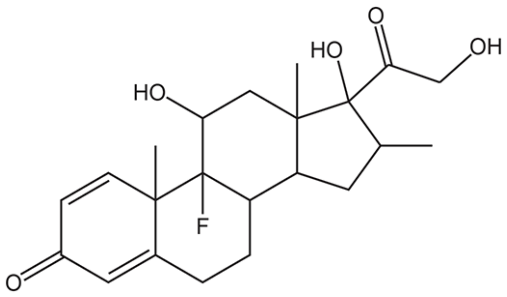
This ester can be prepared by reacting vitamin C with a long chain carboxylic acid, C_xH_yCOOH, in the presence of an acid catalyst.

Vitamin C and the long chain carboxylic acid react in a 1:1 molar ratio.

Determine *x* and *y* in the formula of this carboxylic acid.

x = ... *y* = ... **[2]**

23. The structure of a drug is shown below:



How many chiral carbon atoms are there in a molecule of the drug?

A 5
B 6
C 7
D 8

Your answer ☐ **[1]**

24. This question is about unsaturated hydrocarbons.

Compounds **B** and **C** are **branched** hydrocarbons that are structural isomers of C_6H_{12}.

Compounds **B** and **C** both have stereoisomers.

• Compound **B** has *cis* and *trans* isomers but does **not** have optical isomers.

• Compound **C** has optical isomers but does **not** have *cis* and *trans* isomers.

i. What is meant by the term **structural isomers**?

[1]

ii. What is meant by the term **stereoisomers**?

[1]

iii. Draw structures for the *cis* and *trans* isomers of the branched hydrocarbon **B**.

***cis* isomer**	***trans* isomer**

[2]

iv. Draw 3D structures for the optical isomers of compound **C**.

Optical isomers	

[2]

v. Compounds **D** and **E** are two more structural isomers of C_6H_{12}.

Compounds **D** and **E** do **not** show stereoisomerism.

Table 16.1 shows NMR and infrared (IR) spectral data for **D** and **E**.

	Number of peaks in ^{1}H NMR spectrum	Number of peaks in ^{13}C NMR spectrum	IR peak at 1620–1680 cm^{-1}
D	1	1	No
E	1	2	Yes

Table 16.1

Draw the structures of **D** and **E** and explain how the spectral data in **Table 16.1** provides evidence for the structures.

D	**E**

[4]

25. This question is about an analysis of an unknown organic **Compound X**.

Some properties of **Compound X** are shown in the table.

Molecular formula	Functional groups	Chirality
$C_xH_yF_6O$	C–F C–O–C	1 chiral carbon

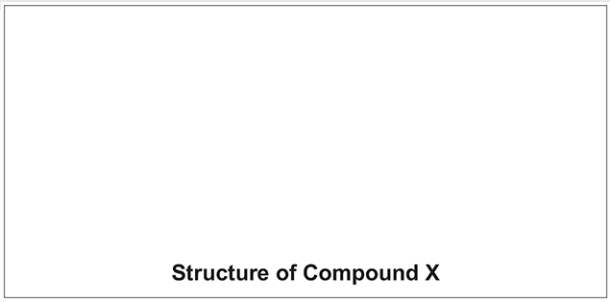
At a pressure of 1.07×10^5Pa at 30 °C, 1.327 g of **Compound X** is a gas with a volume of 186 cm^3.

Determine the molar mass of **Compound X** and its molecular formula.

Draw a possible structure for a molecule of **Compound X**.

molar mass ..... gmol $^{-1}$

molecular formula .....



Structure of Compound X

[6]

26. This question is about compounds that contain the carboxylic acid functional group.

Carboxylic acids react with alkalis, metals and carbonates to form salts.

Write full equations for the following **three** reactions. Show structures for organic compounds.

- the reaction of propanoic acid with aqueous potassium hydroxide:
- the reaction of aqueous methanoic acid with magnesium:
- the reaction of the α−amino acid, aspartic acid (R=CH_2COOH), with an excess of aqueous sodium carbonate, Na_2CO_3:

[4]

27(a). This question is about α-amino acids.

The general formula of an α-amino acid is $RCH(NH_2)COOH$.

Most α-amino acids show optical isomerism.

Explain the term **optical isomerism**.

[1]

(b). The α-amino acid valine has the R group of $–CH(CH_3)_2$.

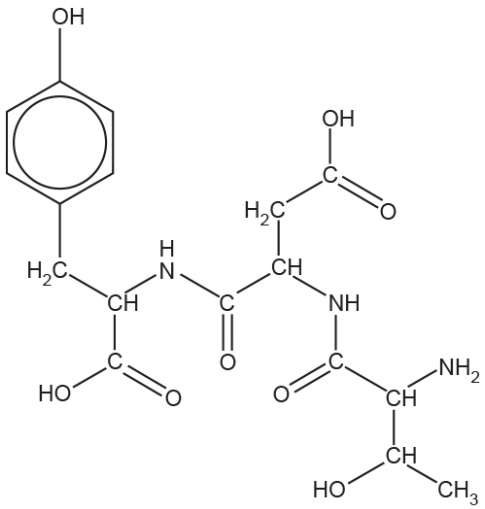
i. What is the systematic name of valine?

[1]

ii. Draw diagrams to show 3D structures of the optical isomers of valine.

[2]

(c). Three α-amino acids can react together to form compound **E**, shown below.



Compound E

i. How many optical isomers are possible for compound **E**?

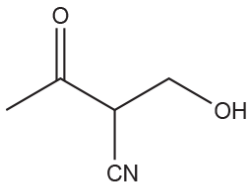
[1]

ii. A student hydrolyses compound **E** with dilute hydrochloric acid, HCl (aq).

Draw the structures of the organic products formed by this hydrolysis.

[4]

28. A chemist is investigating compound **A**, shown below, as a potential organic intermediate.



Compound A

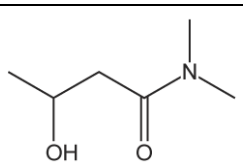
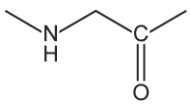
Describe the type of stereoisomerism shown by compound **A** and suggest three reactions of compound **A**, one for each of the **three** functional groups using reagents of your choice.

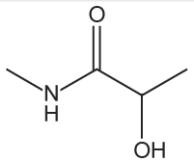
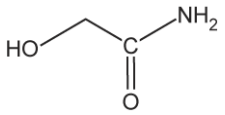
In your answer, show stereoisomers of compound **A**, your chosen reactants and conditions, and the structures for the organic products produced.

Mechanisms and equations are **not** required.

[6]

29. Which compound is a secondary amide?

A	
B	

C	
D	

Your answer ☐ **[1]**

30. α-Amino acids have the general formula $RCH(NH_2)COOH$.

The R group in an α-amino acid contains C and H only.

This R group has a molar mass of 91 g mol^{-1}.

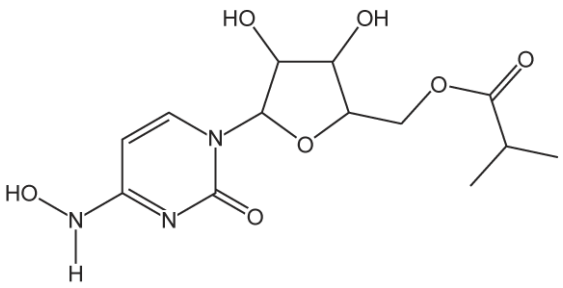
A polymer is formed from 500 molecules of this α-amino acid.

Determine the molar mass of this polymer.

Give your answer to the nearest whole number.

molar mass of polymer = ... g mol^{-1} **[3]**

31. Compound **B**, shown below, is an antiviral medicine



compound B

i. What is the molecular formula of compound **B**

---

[1]

ii. How many chiral carbon atoms are there in one molecule of compound **B**?

[1]

iii. A research chemist synthesises two related compounds, compound **C** and compound **D**, from compound **B**.

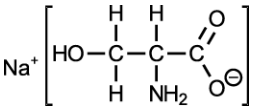
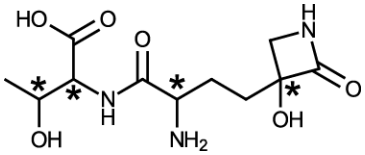
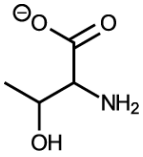
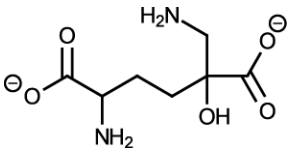
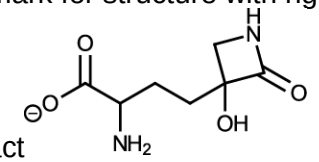
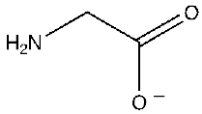
- In compound **C**, the N atoms in compound **B** had been replaced by P atoms.
- In compound **D**, the O atoms in compound **B** had been replaced by S atoms.

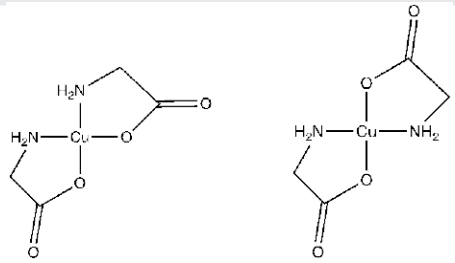
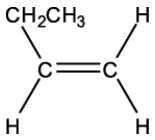
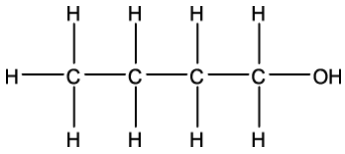
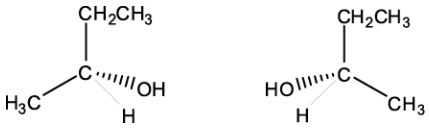
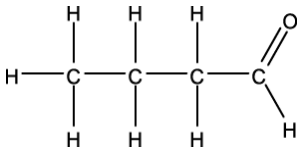
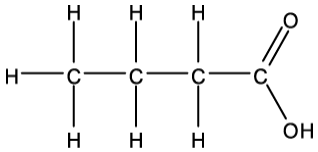
What is the difference between the relative molecular masses of compound **C** and compound **D**?

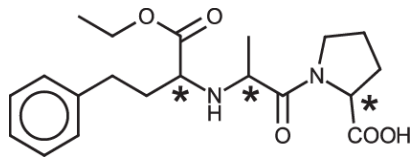
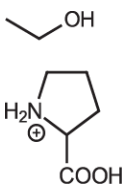
difference = ... **[2]**

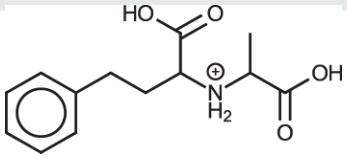
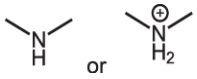
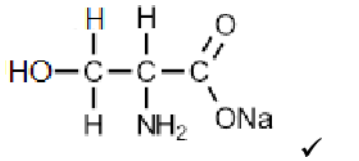
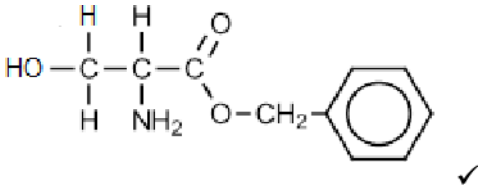
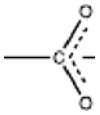
END OF QUESTION PAPER

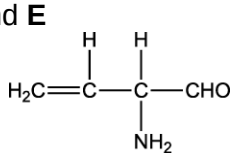
Mark scheme

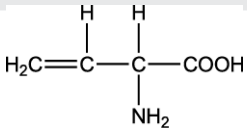
Question			Answer/Indicative content	Marks	Guidance
1			B	1	
			Total	**1**	
2	a	i	Atom **A**: 3 bonding pairs **AND** 1 lone pair (therefore) pyramidal **AND** 107° Atom **B**: 3 bonding centres (and 0 lone pairs) (therefore) trigonal planar **AND** 120°	4	**ALLOW** 106–108° **ALLOW** 4 bonding pairs but with 1 double / π− bond (therefore 3 bonding centres)
		ii	 filter solution recrystallise	3	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous.
	b	i	 for all four	1	
		ii	***Left-hand fragment***  **OR** structure with COOH rather than COO^- ***Right-hand fragment***  **OR** structure with COOH rather than COO^- Two **OR** three COO^- shown	4	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **ALLOW** 1 mark for structure with right-hand ring still intact 
			Total	**12**	
3		i		1	Must be skeletal formula

		ii		2	**IGNORE** charges **ALLOW** Cs and Hs labelled on structures *Marks are for correct connectivity*
		iii	Alanine has a chiral C atom / centre	1	
			Total	**4**	
4	a		**F–K** clearly identified	6	**ANNOTATE ANSWER WITH TICKS AND CROSSES**
			Compound F: 		**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous
			Compound G: 		**IGNORE** names
			Compounds H and I: 		**H** and **I** can be identified either way round
			Compound J: 		
			Compound K: 		
	b		(Add) 2,4-dinitrophenylhydrazine **AND** orange/yellow/red precipitate	3	**NOTE: (b)** is marked completely independently of **(a)** ALLOW errors in spelling **ALLOW** 2,4(−)DNP **OR** 2,4(−)DNPH

					ALLOW Brady's reagent or Brady's Test **ALLOW** solid **OR** crystals **OR** ppt as alternatives for precipitate
			Take melting point of crystals Compare to known values		**Mark second and third points independently of response for first marking point** **DO NOT ALLOW** 2nd and 3rd marks for taking and comparing boiling points **OR** chromatograms
			Total	**9**	
5		i		1	**ALL** correct for one mark **Examiner's Comments** This part was answered well by many candidates. Some missed the chiral centre on the proline moiety or added an asterisk to a carbonyl carbon.
		ii	*any **two** from:* no / fewer side effects increases the (pharmacological) activity / effectiveness Reduces / stops the need for / cost / difficulty in separating stereoisomers / optical isomers ✓✓	2	**IGNORE** toxic / harmful **IGNORE** a response that implies a reduced dose **IGNORE** "it takes (less) time to separate" **Examiner's Comments** Most candidates gained this mark by stating that the use of a single stereoisomer results in fewer side effects and increased pharmacological activity. Vague answers and comments about a reduced dose did not score marks.
		iii	 ✓ one mark for ethanol ✓ one mark for proline with NH **OR** NH_2^+	4	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** combination of above as long as unambiguous **ALLOW** + charge on H of NH_2 groups, *i.e.* NH_2^+ **IGNORE** negative (counter) ions

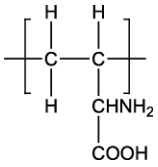
			 ✓ one mark for remaining fragment with  or **Fourth** mark for structure of ✓ **both** ions shown correctly with NH_2^+		**Examiner's Comments** This question discriminated well. Most candidates were able to score one mark for the formula of ethanol. Only a small number of able candidates scored full marks for including the correct formulae for the protonated amine groups formed during acid hydrolysis.
		iv	idea of separating (the components / compounds) **AND** idea of (identifying compounds by) comparison with a (spectral) database ✓	1	**ALLOW** (identifies compounds) using fragmentation (patterns) / fragment ions (but **IGNORE** molecular ions) **IGNORE** retention times **Examiner's Comments** To get the mark for this question candidates had to include points about the separation of the mixture and identification of the compounds. Answers based on identification using retention times or measurement of molar mass did not score the mark.
			Total	**8**	
6	a	i	 ✓  ✓ $—NH_3^+$ in second product ✓	3	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **ALLOW** $—O^-Na^+$ **OR** $—O^-$ (cation not required) **DO NOT ALLOW** —O—Na (covalent bond) **DO NOT ALLOW** —O (without the sodium) **ALLOW** delocalised carboxylate  **Examiner's Comments** The majority scored two marks here. The question had a three mark total for drawing two structures and this may have prompted some candidates to incorrectly form a salt with the alcohol group in **reaction 1**. Many

					were able to draw a correct structure for the ester formed in **reaction 2**, but very few protonated the amine group in acidic conditions. The protonation of hydrolysis products has been well represented in recent papers.
		ii	perfume / fragrance / flavouring ✓	1	**IGNORE** solvent **OR** food additive **Examiner's Comments** Well answered with most of the correct responses referring to perfumes and flavourings which are the uses listed in the specification. Common responses marked as incorrect were suggestions that this ester could be used for making dyes, polymers or textiles.
		iii	Reaction 3: (hot) ethanolic ammonia ✓ Reaction 4: oxidation ✓ Reaction 5: hydrolysis ✓	3	**ALLOW** NH_3 (dissolved) in ethanol **IGNORE** other conditions **ALLOW** oxidisation / oxidised **DO NOT ALLOW** redox **ALLOW** nucleophilic addition-elimination **DO NOT ALLOW** nucleophilic substitution **IGNORE** acid / base **Examiner's Comments** Most candidates were able to score at least one mark here, usually for correctly identifying **reaction 4** as an oxidation reaction. Although the use of excess reagent was not required for **reaction 3**, some missed ethanol as an essential solvent and **reaction 5** was occasionally described as a reduction.
	b		**M1** Compound **E**  ✓ **M2** Compound **F**	6	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous Labels are not required for compound E, F, G or H **IGNORE** labels for **M1**, **M2**, **M3** and **M4** CH_2=CH must be shown in **E** **ALLOW** C_2H_3 **OR** $CHCH_2$ for $CH=CH_2$ in **F**



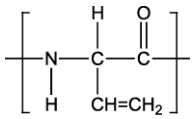
✓

M3 Compound **G**



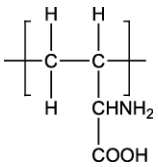
✓

M4 Compound **H**



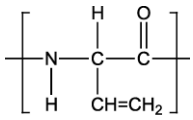
✓

M5 Compound **G**
OR



Is an addition polymer ✓

M6 Compound **H**
OR



is a condensation polymer ✓

ALLOW ECF from error in structure of aldehyde E

ALLOW multiple repeat units but must be full repeat units
ALLOW end bonds shown as .....

DO NOT ALLOW if structures have no end bonds
IGNORE brackets unless they are used to pick out the repeat unit from a polymer chain
IGNORE n

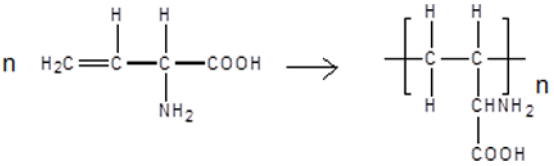
ALLOW $C_2H_4NO_2$ for $CH(NH_2)COOH$ in polymer **G**

ALLOW C_2H_3 **OR** $CHCH_2$ for $CH=CH_2$ in polymer **H**

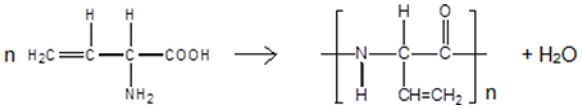
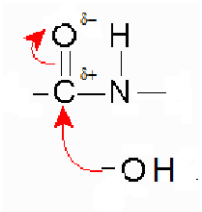
ALLOW ECF from $NH_2CH_2CH=CHCOOH$ for the formation of compound G or compound H

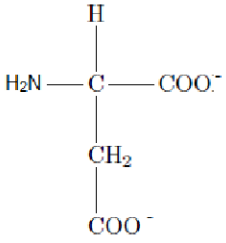
ALLOW alkene forms addition polymer / polymer with same empirical formula as monomer

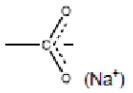
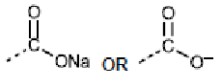
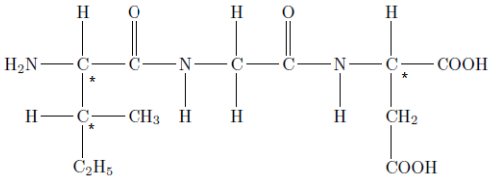
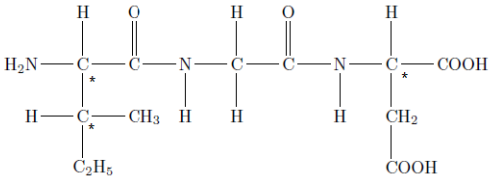
ALLOW equation for reaction



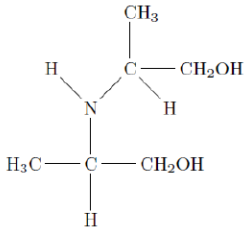
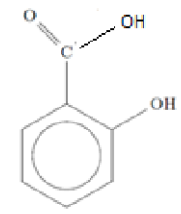
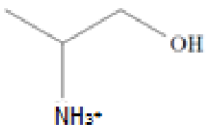
ALLOW amino acid forms condensation polymer

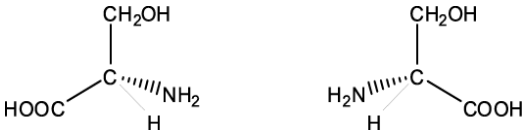
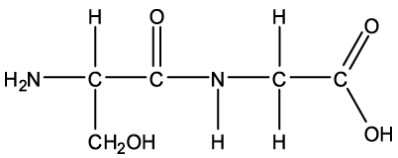
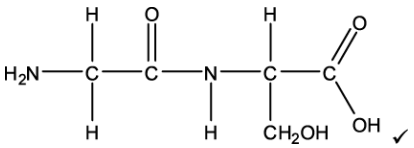
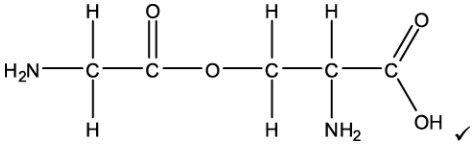
					OR (molecules of) compound **F** join / bond / add / react / form polymer and water / small molecule **ALLOW** equation for reaction  **Examiner's Comments** This question discriminated well and many well organised and well-presented answers were seen. Candidates were usually able to identify the aldehyde structure in compound **E** and those who failed to include a chiral centre in compound **E** had possibly missed essential information in the stem of the question. However, they could still score marks for the polymer structures by the application of error carried forward. Some candidates correctly identified the four structures but then missed the last two marks for a description of how the polymers are formed. Although labels were not required to score marks for the four structures, the description of the formation of the polymers had to be linked to the correct structure or the correctly labelled compound and some candidates lost marks here because their description was linked to the wrong polymer.
			Total	**13**	
7	a		 Curly arrow from OH^- to C(δ+) ✓ Dipole correct **AND** curly arrow from C=O bond to O(δ−) ✓	2	First curly arrow must come from either a lone pair on O or negative charge on O **Examiner's Comments** Some candidates lost a mark for the incorrect positioning of the curly arrow from

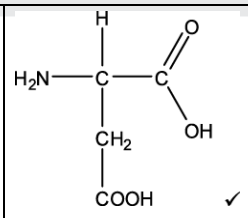
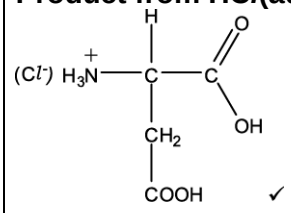
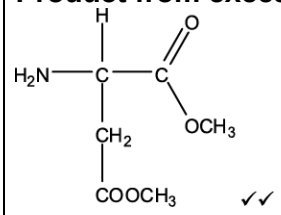
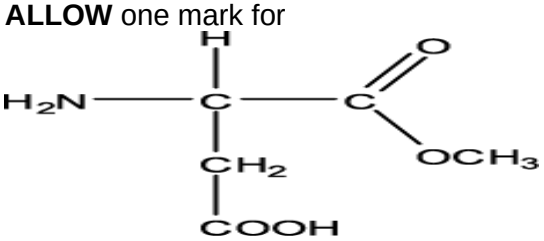
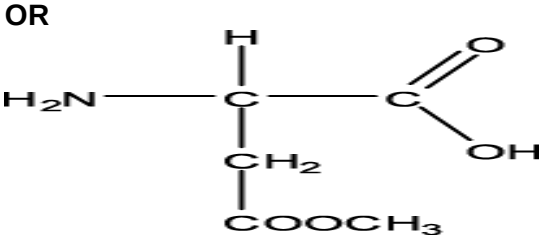
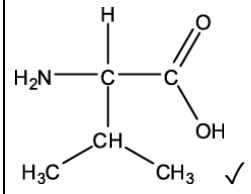
					the hydroxide ion. The mark scheme specifies that it should start at either the lone pair on the oxygen atom or the negative change on the oxygen atom.
	b		Measure distance moved by spot/distance moved by solvent ✓	2	**ALLOW** attempt at calculation of R_f value using distances measured on the chromatogram **IGNORE** explanation of how chromatography works
			Compare (R_f) value with data book values/known values ✓ Two amino acids have the same/similar R_f value **OR** similar adsorption **OR** move the same/similar distance ✓	1	**ALLOW** One spot contains two amino acids **ALLOW** Two amino acids have not separated **IGNORE** relative solubility **ALLOW** two of the amino acids have similar structures **Examiner's Comments** This question discriminated well with relatively few candidates able to score all three marks. Some candidates attempted to explain how the technique separates components between a mobile phase and a stationary phase which was not required by the question. There was some confusion with gas chromatography and retention times. Vague answers about all amino acids having similar structures did not score the final marking point to explain why only two spots appeared on the chromatogram.
	c	i	The **pH** at which the amino acid exists as a zwitterion ✓ **QWC**: **zwitterion** spelled correctly in the correct context	1	**DO NOT ALLOW** PH/ph **ALLOW** zwitter ion **Examiner's Comments** This definition had been learned by the majority of candidates.
		ii		1	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** combination of above as long as unambiguous **Two** COO^- groups are required in the structure **ALLOW** $–COO^-Na^+$ **OR** –COONa

					 **ALLOW** delocalised carboxylate **ALLOW**  **DO NOT ALLOW** -COO-Na **OR** -O-Na (covalent bond) **Examiner's Comments** Generally well answered but structures with only one carboxylate group were quite common and some candidates showed aspartic acid being protonated at high pH.
		iii	**M1** structure  ✓ **M2** correct structure has three chiral centres  ✓	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **ALLOW** tripeptide with the 3 amino acids in any order **ALLOW** cyclic tripeptide Isoleucine has two chiral centres, aspartic acid has one chiral centre and glycine has none. **ALL three** correct for one mark **ALLOW** chiral centres correctly identified if the three amino acids are part of a polypeptide chain **Examiner's Comments** A more challenging question with relatively few candidates able to show the position of all three chiral centres on a correct tripeptide structure. Most candidates identified the chiral centres in the amino acid backbone of aspartic acid and isoleucine and realised that glycine was not

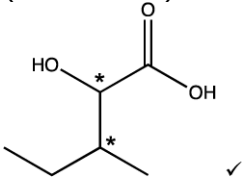
					chiral, but many missed the second chiral centre in isoleucine.
			Total	**9**	
8	a	i	^{1}H NMR spectrum for 2-aminopropan-1-ol Chemical shift, δ/ppm / Relative peak area / Splitting pattern 0.8 – 2.0 / 3 / doublet 2.3 – 3.0 / 1 / multiplet 3.3 – 4.2 / 2 / doublet ✓✓✓	3	One mark for each correct row **ALLOW** δ values as a range or a value within the specified range. **ALLOW** δ values +/− 0.2 ppm. **ALLOW** a response that implies a splitting into two for a doublet etc. **ALLOW** sextet/hextet/six (or more than 5) as alternative to multiplet Relative peak area = CH /3H etc. penalise once **Examiner's Comments** Although it could be argued that this question tested the same skill three times, the full range of marks was awarded and errors were seen in the chemical shift, relative peak area and splitting pattern. Fully correct responses included either a chemical shift value within the range specified on the data sheet or a range that matched the one given on the data sheet.
		ii	M^+ peak at 75 (peak 1) $CH_3CH(NH_2)CH_2OH^+/C_3H_9NO^+$ ✓ Fragment peak at 44 (peak 2) $CH_3CH(NH_2)^+/C_2H_6N^+$ ✓	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous Positive charge is essential but **ALLOW** maximum of one mark if both formulae are correct **AND** neither species has a positive charge **Examiner's Comments** Although peak 2 was often correct, the species responsible for the M+ peak was often missing a positive charge. Possibly students have learned that the particles become charged as part of the fragmentation process and don't realise that only charged particles can be detected by a mass spectrometer.

	b	i	Ethanolic ammonia **OR** ammonia/NH_3 **AND** ethanol ✓	1	**ALLOW** ammonia in a sealed tube **ALLOW** dilute ethanolic ammonia/NH_3 **IGNORE** heat **ALLOW** alcohol for ethanol **DO NOT ALLOW** any reference to water or hydroxide ions **Examiner's Comments** A well answered question. Some candidates forgot to use a solvent or suggested the use of aqueous ammonia.
		ii	(compound D)  ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **Examiner's Comments** This question discriminated well. Although there were very few blank pages, many incorrect structures were seen.
	c	i	Alcohol **AND** Amide/peptide ✓	1	**IGNORE** phenol **IGNORE** hydroxyl/hydroxy **IGNORE** attempts to classify alcohol or amide as primary, secondary or tertiary **DO NOT ALLOW** hydroxide **Examiner's Comments** Generally well answered but incorrect functional groups included carbonyl and amine.
		ii	 	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** combination of above as long as unambiguous **ALLOW** + on N or H i.e. $^+NH_3$ or NH_3 $^+$**ALLOW** $NH_3{}^+Cl^-$

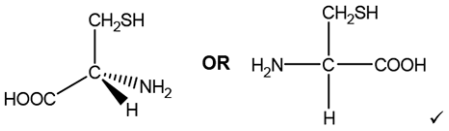
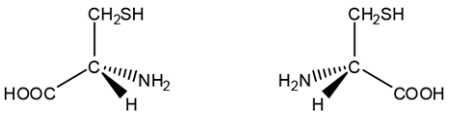
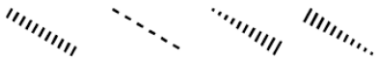
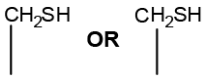
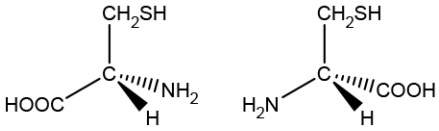
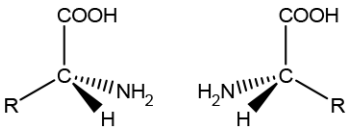
					Examiner's Comments Many candidates were able to score one mark for this question but the amine group was often not protonated and it was surprisingly common to see the amine group as NH_2^+.
			Total	**10**	
9			**C**	1	
			Total	**1**	
10	a	i	(optical isomers are) non-super imposable mirror images ✓ Two 3D structures of serine that are mirror images irrespective of connectivity ✓  Correct connectivity in both structures ✓	3	
		ii	Dipeptide Ser-Gly  Dipeptide Gly-Ser  Esterification of OH on Ser 	3	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** structures in any order
	b	i	**Structure of aspartic acid**	4	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous

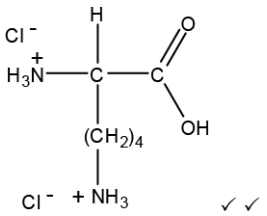
			 ✓ **Product from HC*l*(aq)**  ✓ **Product from excess CH_3OH/H_2SO_4**  ✓✓		**Note:** the amine group could be shown as either NH_2 or NH_3^+*(acidic conditions)* **ALLOW** one mark for  **OR** 
		ii	Molar mass of **G** = $\frac{3.51}{0.0300}$ = 117(.0) (g mol^{-1}) ✓ **Structure of G**  ✓	6	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** R (group of **G**) is −$CH(CH_3)_2$ if structure of amino acid is not given
			Total	**12**	
11			C	1	**ALLOW** 4 (This is the number of chiral centres)

					Examiner Comments This question was answered well. The correct answer C, was provided by just over 60% of candidates. Where incorrect responses were seen, it was frequently due to the candidate missing one of the chiral centres, typically the one nearest to the sulfur atom within the ring.
			Total	**1**	
12		i	***Burette readings*** Final (reading) /cm^3 23.15 45.95 32.45 Initial (reading) /cm^3 0.60 23.15 10.00 ✓ • Correct titration results recorded with initial and final readings, clearly labeled **AND** all readings recorded to two decimal places with last figure either 0 or 5 ***Titres*** Titre / cm^3 22.55 22.80 22.45 ✓ • Correct subtractions to obtain final titres to 2 DP ***Units*** • Units of cm^3 for initial, final and titres ✓ ***Mean titre*** • mean titre = $\frac{22.55 + 22.45}{2}$ = 22.50 **OR** 22.5 cm^3 ✓ *i.e. using concordant (consistent) titres*	**4**	Table **not** required **ALLOW** initial reading before final reading **ALLOW ECF** **ALLOW** units with each value **ALLOW** brackets for units, i.e. (cm^3) **ALLOW ECF** from incorrect concordant titres **Examiner's Comment:** This question should have been four straightforward marks, but it was actually found very challenging by candidates. Most read the scales correctly but then did not present their findings clearly, often

					scattering unlabelled numbers around, omitting units with absence of any heading linking them to the burettes. 0.60 was very often shown as 0.6 and 22.80 as 22.8. Candidates were expected to take the mean of their closest titres but a significant number took an average of all three titres instead. The mark scheme allowed for a mean titre obtained from incorrect titres. Candidates need to appreciate the importance of communicating their results in a clear and comprehensive way with headings and units, and showing numerical values to the accuracy of the apparatus used.
		ii	**ALLOW 3SF** or more throughout **IGNORE** trailing zeroes, e.g. **ALLOW** 0.084 for 0.0840 ..... $n(\text{NaOH}) = 0.0840 \times \frac{22.50}{1000} = 1.89 \times 10^{-3}$ (mol) ✓ n(**A**) in 250 cm^3 = 10 × 1.89 × 10^{-3} = 1.89 × 10^{-2} (mol) ✓ $M(\text{A}) = \frac{2.495}{1.89 \times 10^{-2}} = 132$ (g mol^{-1}) ✓ M(alkyl group) (= 132 – 75) = 57 ✓ R = C_4H_9 ✓ **ALLOW** alkyl group in drawn structure with straight chain or branch (es) in wrong position, e.g. for R = C_4H_9, $CH_3CH_2CH_2CH_2$ **OR** $(CH_3)_3C$ Structure with chiral carbon atoms identified (see * below)  ✓	**6**	**ALLOW ECF** from incorrect mean titre in **4a(i)** e.g. From 22.60 cm^3 (mean of all 3 titres in **(i)**, n(NaOH) = 1.8984 × 10^{-3} (mol) **ALLOW ECF** from incorrect n(NaOH) **ALLOW ECF** from incorrect n(**A**) **ALLOW ECF** from incorrect M(**A**) – 75 **ALLOW ECF** for alkyl group closest to calculated M(alkyl group), e.g. for M = 45, **ALLOW** C_3H_7 (43) **ALLOW** correct structural **OR** skeletal **OR** displayed formula **OR** mixture of the above as long as non-ambiguous **IGNORE** poor connectivity to OH groups *Given in question* ..... **Common error for 4 marks max**

					25.00 instead of 22.50 and scaling by × 10 $2.10 \times 10^{-3} \rightarrow 2.10 \times 10^{-2}$ ✓ → 118.81 ✓ → 43.81 ✓ → C_3H_7 ✓ *25.00 instead of 22.50 and scaling by* $\times \frac{250}{22.50}$ $2.10 \times 10^{-3} \rightarrow 2.33 \times 10^{-2}$ ✓ → 106.93 ✓ → 31.93 ✓ → C_2H_5 ✓ No structure with 2 chiral centres possible . **Examiner's Comment:** Most candidates made some headway with this problem. Candidates were expected to process their mean titre from 4(a)(i) in a conventional titration calculation to arrive at a molar mass of 132 g mol^{-1}. From there, candidates could determine a C_4H_9 alkyl group and draw the structure of compound A with two chiral carbon atoms. Most candidates scored some marks but processing beyond the molar mass proved to be difficult for weaker candidates. Some candidates showed a structure with a linear C_4H_9 group which contains one chiral carbon atom. A common error was use of 25.0 cm^3, instead of the titre, as the volume of NaOH, obtaining an initial value of 2.10×10^{-3} mol. The mark scheme allowed processing of this value to be credited using error carried forwards. Some candidates omitted to scale their initial value by a factor of ×10, obtaining a molar mass of over 1000 g mol^{-1}, e.g. 1320 instead of 132. A large range of marks was seen and the question discriminated extremely well.
			Total	**10**	
13			**C**	**1**	**Examiner's Comments** The majority of candidates identified C as the secondary amide.
			Total	**1**	
14			**B**	**1**	**ALLOW** 2 (This is the number of straight chain isomers with a chiral C atom)

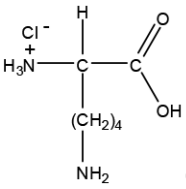
					Examiner's Comments This question proved difficult. Candidates who drew out the different isomers of chloroheptane were able to identify B as the correct response.
			Total	**1**	
15	a		Correct groups attached to chiral C of cysteine seen **once** e.g.  ✓ Two **3D structures** of cysteine that are mirror images with correct connectivity in both ✓  	**2**	Each structure must have four central bonds with **at least two wedges**. For bond into paper accept:  **ALLOW** bond to any part of the CH_2 of the CH_2SH group e.g. **ALLOW**  **ALLOW** two 3D structures with 2 groups swapped e.g.  **IF** CH_2SH is shown as 'R' **ALLOW** 1 mark for two 3D structures with correct connectivity that are mirror images e.g.  **Examiner's Comments** Candidates were well prepared to tackle this question and consequently most candidates scored both marks.
	b		Correct salt of lysine with both amine groups protonated	**2**	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **Note:** Cl^- is required *(question asks for salt)*



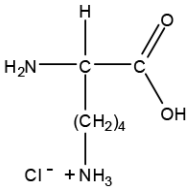
✓✓

ALLOW NH_3Cl *i.e* charges **not** required

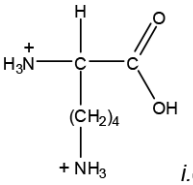
ALLOW 1 mark for



OR

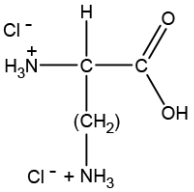


OR



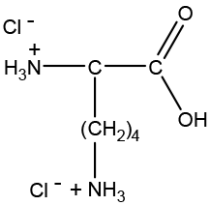
i.e. no Cl^-

IF there is a small slip in the structure **ALLOW 1 mark** for diammonium salt e.g



(incorrect number of CH_2 in R group)

OR

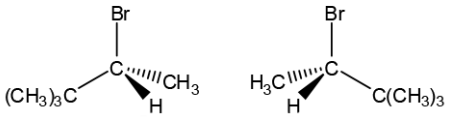
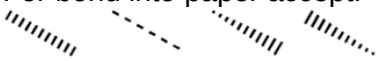
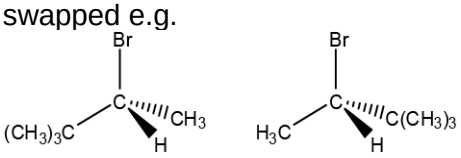
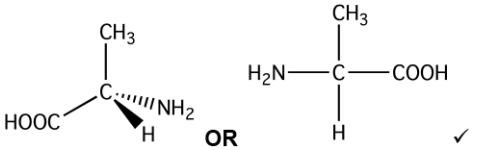
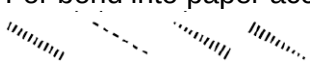
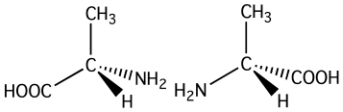


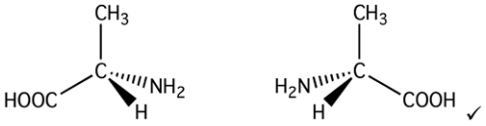
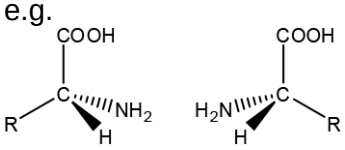
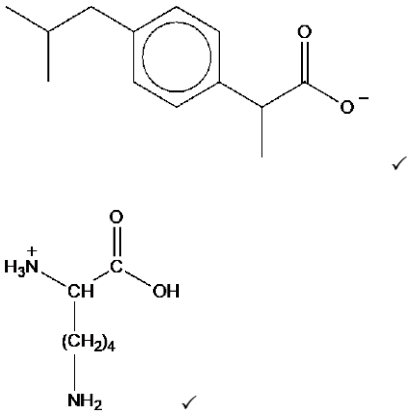
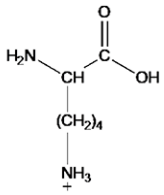
(H missing from α C atom)

Examiner's Comments

In contrast to part (a) this question proved difficult and discriminated well. The higher ability candidates correctly identified the dichloride salt produced by the reaction of lysine with excess acid. Some candidates formed ammonium ions on both nitrogen atoms but omitted the chloride ions. Others only formed a monochloride salt, leaving the R group unchanged. These two approaches scored one mark.

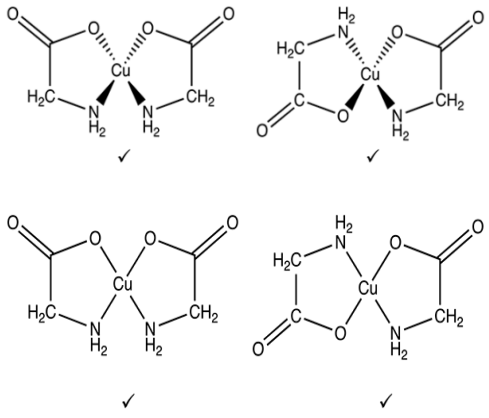
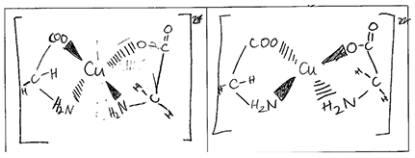
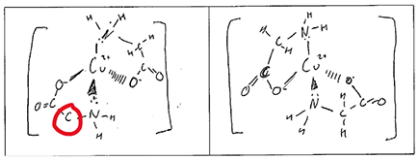
			Total	**4**	

16			**B**	1 (AO 1.2)	**ALLOW** 6 (This is the number of chiral centres)
			Total	**1**	
17		i	**Stereoisomers** Same structural formula **AND** Different arrangement (of atoms) in space **OR** different spatial arrangement (of atoms) **AND** **Type:** Optical ✓	1 (AO1.2)	**ALLOW** structure/displayed/skeletal formula **DO NOT ALLOW** same empirical formula **OR** same general formula **IGNORE** same molecular formula **IGNORE** references to chiral molecules/compounds
		ii	One 3D structure with correct groups attached to the chiral C ✓ Two 3D structures of (CH3)3CCHBrCH3 that are mirror images **AND** correct connectivity in both ✓ 	2 (AO2.5) (AO1.2)	**ALLOW** small slip in one of the groups OR use of C4H9 3D structures must have four central bonds with **at least two wedges**. For bond into paper accept:  **ALLOW** two 3D structures with 2 groups swapped e.g. 
			Total	**3**	
18			**B**	1 (AO1.2)	
			Total	**1**	
19	a	i	Non-superimposable mirror images (about a chiral centre) ✓	1 (AO1.1)	
		ii	Correct groups attached to chiral C of alanine seen once e.g.  **OR** ✓ Two **3D structures** of alanine that are mirror images **AND** correct connectivity in both	2 (AO2.1× 2)	Each structure must have four central bonds with **at least two wedges**. For bond into paper accept:  **ALLOW** two 3D structures with 2 groups swapped e.g.  **IF** CH_3 is shown as 'R' **ALLOW** 1 mark for two 3D structures with correct connectivity

			i.e.  ✓		that are mirror images e.g. 
		iii	4 ✓	1 (AO2.2)	
	b	i	$C_{13}H_{18}O_2$ ✓	1 (AO2.1)	**ALLOW** C, H and O in any order
		ii	**FIRST CHECK ANSWER ON THE ANSWER LINE** **If answer = $1.17 \times 10_{21}$ award 3 marks** *M*(ibuprofen) = 206 ✓ *n*(ibuprofen) = $\frac{400 \div 1000}{206}$ = 1.94×10^{-3} (mol) ✓ Number of molecules = $1.94 \times 10^{-3} \times 6.02 \times 10^{23}$ = 1.17×10^{21} to **3 SF** ✓	3 (AO2.2×3)	**ALLOW ECF** from **(c)(i)** Calculator: $1.941747573 \times 10^{-3}$ **ALLOW ECF** from *n*(ibuprofen) **3 SF** essential
	c	i	 ✓	2 (AO3.2×2)	**IGNORE** small slip in carbon chains **ALLOW** 
		ii	More soluble in water ✓	1 (AO3.1)	**Answer must be a comparison** **ALLOW** dissolve faster/quicker **IGNORE** absorbed more quickly (given in question)
			Total	**11**	
20			**Level 3 (5–6 marks)** Reaches a comprehensive conclusion to determine the correct formulae of **almost all** of **E**, **F**, **G**, **H**, **I** and **J** *There is a well-developed line of reasoning which is clear and logically structured.* *The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Reaches a sound conclusion to determine the correct formulae of **at least half** of **E**, **F**,	6 (AO3.1×2) (AO3.2×4)	**Indicative scientific points may include:** **Identify of E, F, G, H, I and J** • **E** Cu/copper • F: H_2O/water • **G**: N_2/nitrogen • **H**: CH_3COCl **OR** $ClCH_2CHO$ **OR** C_2H_3OCl • **I**: CH_3CONH_2 **OR** H_2NCH_2CHO • **J**: NH_4Cl/ammonium chloride

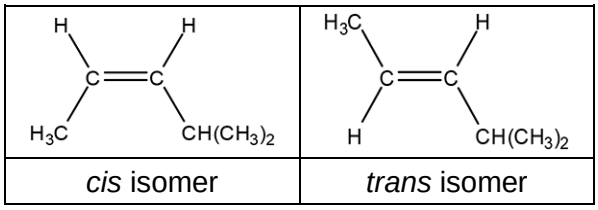
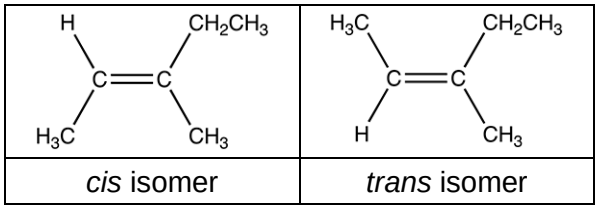
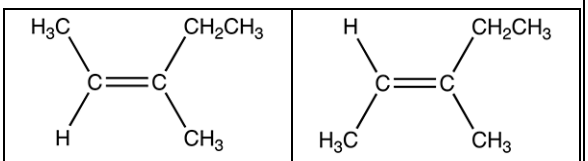
			G, **H**, **I** and **J** *There is a line of reasoning presented with some structure.* *The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Reaches a simple conclusion to determine the correct formulae of **some** of **E**, **F**, **G**, **H**, **I** and **J** *There is an attempt at a logical structure with a line of reasoning.* *The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*		Examples of reasoning **Working** $n(CuO) = \frac{4.77}{(63.5 + 16)} = 0.06$ (mol) M(**E**) = 3.81 ÷ 0.06 = 63.5 n(**G**) = $\frac{480}{24000} = 0.02$ M(**G**) = $\frac{0.560}{0.02}$ = 28 (g mol^{-1}) **Infrared spectrum** I contains • C=O (~1700 cm^{-1}) • NH_2 (~3200–3400 cm^{-1}) **Equations** $3CuO + 2NH_3 \rightarrow 3Cu + 3H_2O + N_2$ $CH_3COCl + 2NH_3 \rightarrow CH_3CONH_2 + NH_4Cl$ **OR** $ClCH_2CHO + 2NH_3 \rightarrow H_2NCH_2CHO + NH_4Cl$ **Examiner's Comments** Candidates were supplied with information about two reactions, supported by numerical data and an IR spectrum. The reactions were novel, meaning that candidates needed to apply their knowledge and understanding to unfamiliar contexts. This is an area in which many candidates have difficulty. Candidates were required to identify six unknown substances, with Levels being determined from the number identified. The communication mark in each level was given on the clarity of the analysis of the evidence. Overall, candidates found this question difficult. For reaction 1, many identified **F** and **G** as H_2 and N_2 respectively. Identification of **E** as Cu proved to be more problematic, with $Cu(OH)_2$ and copper(II) complexes with ammonia being seen often. This was despite the mass of **E** in the supplied data being less than the mass of copper(II) oxide. For reaction 2, many identified the N–H and C=O peaks in the IR spectrum but candidates often listed all the possible peaks from the Data Sheet. The supplied

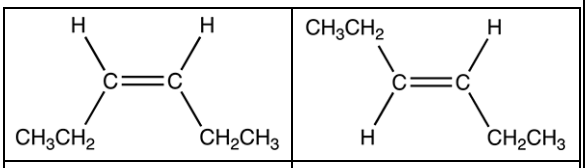
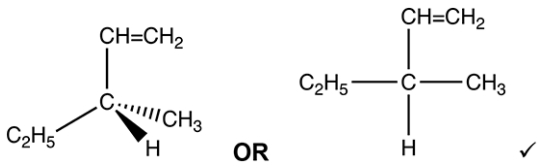
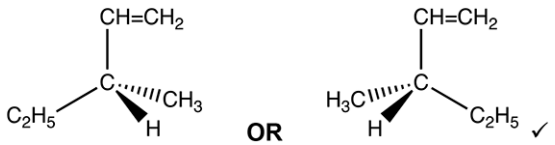
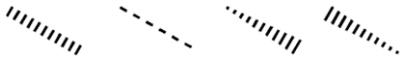
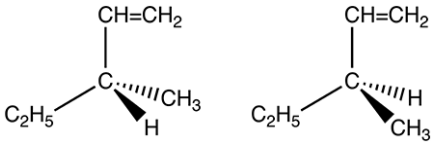
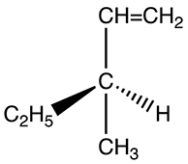
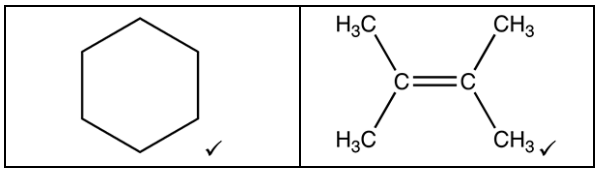
					clues showed that **H**, **I** and **J** were linked by the reaction of an acyl chloride with ammonia. The chloride salt **J** as NH_4Cl was seen very rarely. There were attempts at constructing equations. The equation for reaction 1 was seen by high-attaining candidates, mostly those achieving Level 3.
			Total	**6**	
21		i	***Bond angles*** H_2NCH_2COONa, bond angle = 107° **AND** $HOOCCH_2NH_3Cl$, bond angle = 109.5° ✓ ***Number of electron pairs*** ***Mark independently of angles*** In NaOH/107°, (NH_2 has) **3** bonded pairs ***/*** **3** bonds **AND** **1** lone pair ✓ In HCl/109.5°, (NH_3^+ has) **4** bonded pairs / **4** bonds ✓	3 (3 ×AO1.2)	**ALLOW** 107 ± 0.5 **ALLOW** 109 **OR** 110° **ALLOW** NH_2 has **4** pairs, one of which is a lone pair **For bonded pairs/bonds** **ALLOW bonded** groups, atoms, elements, regions ***Bonded*** *essential* **IGNORE** electron region **OR** electron density **IGNORE** NH_3 has no lone pairs **IGNORE** lone pairs repel more (than bonded pairs) **IGNORE** shapes, even if wrong **ALLOW** bp for bonded pair and lp for lone pair **Examiner's Comments** 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. 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. 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:** **2** $H_2NCH_2COOH + Cu(CH_3COO)_2 \rightarrow Cu(H_2NCH_2COO)_2 +$ **2** CH_3COOH ✓ **Structures**  ✓ ✓ ✓ ✓ Ligands **must** shown as bidentate rings **IGNORE** connectivity for NH_2 **BUT** connectivity **must** be to O of COO	3 (AO2.6) (2 ×AO2.5)	**ALLOW** molecular formulae or mixture, e.g. $2C_2H_5NO_2 + CuC_4H_6O_4 \rightarrow CuC_4H_8N_2O_4 + 2C_2H_4O_2$ **IGNORE** charges **i.e. IGNORE** wrong or missing charges in ionic compounds if formula is correct/ e.g. **ALLOW** $Cu(CH_3COO^-)_2$, $Cu^+(CH_3COO^-)_2$ **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **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 formulae for ethanol or propanoic acid were also often seen for ethanoic acid. Candidates are advised to check all formulae and then to check balancing, the golden rules for successfully constructing all equations.
			Total	**6**	
22	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.
	b	i	Hydrogen bonding **AND** **Many** OH/hydroxyl / hydroxy / alcohol ✓	1 (AO2.1)	**ALLOW** 4 OH **DO NOT ALLOW** OH^- **Examiner's Comments** 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 (2 ×AO3.2)	**Examiner's Comments** More successful responses determined that x = 15 and y = 31. 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 → $C_{16}H_{32}O_2$ → $C_{15}H_{31}COOH$. 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**	
23			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**	
24		i	Same **molecular** formula **AND** Different **structural** formulae ✓ **OR**	1 (AO1.1)	Same formula is **not** sufficient *(no reference to molecular)* Different arrangement of atoms is **not** sufficient

			Both have the **molecular** formula C_6H_{12} **AND** Different **structural** formulae ✓		*(no reference to structure/structural)* For 'structural formulae', **ALLOW** structure/displayed/skeletal formulae/functional groups **DO NOT ALLOW** any reference to spatial/space
		ii	Same structural formula **AND** Different arrangement (of atoms) in **space** **OR** different **spatial** arrangement (of atoms) ✓	1 (AO1.1)	**ALLOW** structure/displayed/skeletal formula **DO NOT ALLOW** same empirical formula **OR** same general formula **IGNORE** same molecular formula Reference to *E/Z* isomerism or optical isomerism is **not** sufficient
		iii	Correct identification of *cis* **AND** *trans* isomers of 4-methylpent-2-ene ✓✓  *cis* isomer | *trans* isomer **OR** Identification of 3-methylpent-2-ene as *cis* **AND** *trans* isomers ✓✓  *cis* isomer | *trans* isomer	2 (AO1.2) (AO2.5)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous C_3H_7 is **not** sufficient (could be unbranched) **ALLOW** one mark if *cis* **AND** *trans* isomers of 4-methylpent-2-ene are in the wrong boxes **ALLOW** the isomers of 3-methylpent-2-ene in either box  *cis* isomer | *trans* isomer *Ambiguity with cis/trans identification system* **ALLOW** one mark for correct identification

					of *cis* **AND** *trans* isomers of unbranched C_6H_{12} e.g.  *cis* isomer | *trans* isomer
		iv	Correct groups attached to chiral carbon of compound C seen **once** e.g.  Two **3D structures** of compound C that are mirror images with correct connectivity in both 	2 (AO2.5×2)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous For C_2H_5–, ALLOW CH_3CH_2– For –CH=CH_2, ALLOW –C_2H_3 OR –$CHCH_2$ For bond into paper accept:  **ALLOW** two 3D structures with 2 groups swapped e.g.  **DO NOT ALLOW** a bond angle of 180° e.g. 
		v		4 (AO2.5×2) (AO2.2×2)	**ALLOW** 1 mark for structures if shown in wrong boxes.

			<table><tr><th>D</th><th>E</th></tr></table> Two of the following for **D** ✓ • All H are equivalent/in the same chemical environment/ the same type • All C are equivalent/ in the same chemical environment/ the same type • No C=C present Two of the following for **E** ✓ • All H are equivalent/ in the same chemical environment/ the same type • 2 C environments • C=C present		**CHECK** table 16.1 for annotations that may be worthy of credit **Examiner's Comments** The majority of candidates were able to correctly define a structural isomer. This definition was well known by candidates with the majority of responses given the mark. Some candidates omitted the reference to structural formula. 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. 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. 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**	
25			**FIRST CHECK ANSWER LINES** **If M=168(.0) Award 4 marks for calculation providing unit conversions are correct**	6 (AO1.2×1) (AO2.4×3) (AO2.5×2)	**ALLOW ECF throughout** **ALLOW** calculator value of 167.968115 (using 8.314) for M

Use of ideal gas equation

$pV = nRT$ **OR** $n = \frac{pV}{RT}$ ✓

SI Unit conversions AND substitution into $n = \frac{pV}{RT}$:

- $R = 8.314$ ***OR*** 8.31
- $V = 186 \times 10^{-6}$
- *T in K: 303 K*

e.g.

$$\frac{1.07 \times 10^5 \times 186 \times 10^{-6}}{8.314 \times 303}$$ ✓

Calculation of n

$n = 7.90 \times 10^{-3}$ (mol) ✓

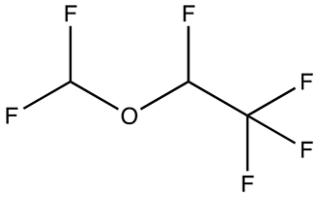
Calculation of M

$$M = \frac{1.327}{7.90 \times 10^{-3}} = 168(.0)$$ ✓

Molecular formula

$C_3H_2F_6O$ ✓

Structure



ALLOW calculator value of 167.8873033 (using 8.31) for M

Calculator value of *n*:

from $8.314 = 7.900308915 \times 10^{-3}$

from $8.31 = 7.904111711 \times 10^{-3}$

ALLOW ECF that matches M but the formula
MUST contain F_6O

Use of 24 dm^3:
e.g.

$$n = \frac{186.0}{24000} = 7.75 \times 10^{-3}$$

No mark

(calculation much simpler)

$$M = \frac{1.327}{7.75 \times 10^{-3}} = 171(.2)$$ ✓

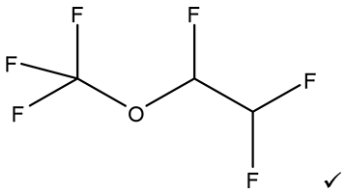
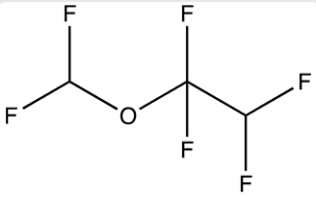
ECF

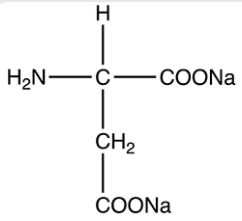
$C_3H_5F_6O$ ✓

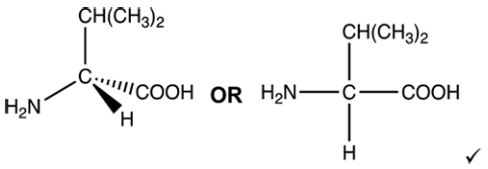
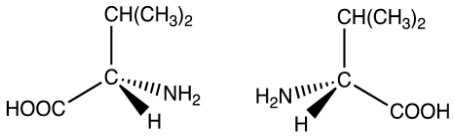
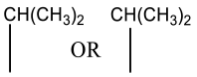
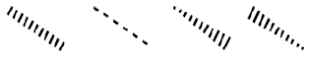
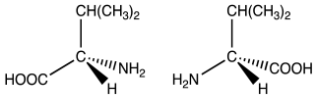
ECF

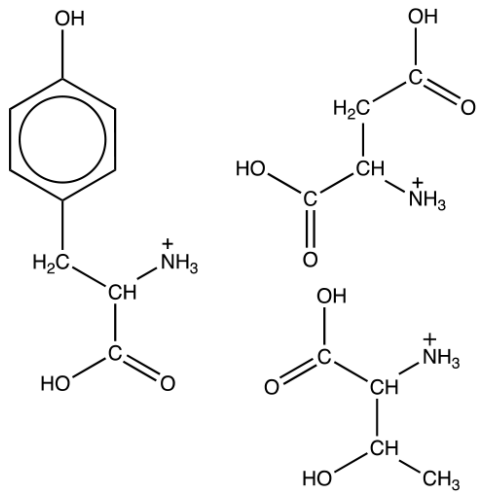
ALLOW ECF for a feasibile chemical structure that matches M **AND** contains F_6O **AND** has a chiral carbon

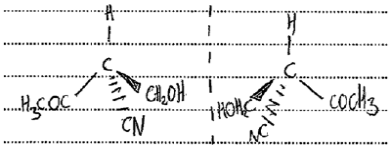
DO NOT ALLOW

			OR  ✓		 *no chiral carbon* **Examiner's Comments** 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**	
26			$C_2H_5COOH + KOH \rightarrow C_2H_5COOK + H_2O$ ✓ $2HCOOH + Mg \rightarrow (HCOO)_2Mg + H_2$ ✓ H_2O **AND** CO_2 ✓	4 (AO2.6×4)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** state symbols and use of equilibrium sign **ALLOW** KC_2H_5COO **DO NOT ALLOW** a missing charge (e.g. $C_2H_5COO^-K$) the 1st time seen but **IGNORE** for next equations. For salts, **ALLOW** $C_2H_5COO^-K^+$ **OR** $C_2H_5COO^- + K^+$ **DO NOT ALLOW** –COO–K (covalent bond) the 1st time seen but **IGNORE** for next equations. **FOR** $CO_2 + H_2O$ **ALLOW** H_2CO_3

			 ✓ Correct formula of salt:		**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**	
27	a		Non-superimposable mirror images (about a chiral centre) ✓	1 (AO1.1)	**IGNORE** definition of stereoisomers **Examiner's Comments** 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 **OR** 3-methyl-2-aminobutanoic acid ✓	1 (AO1.2)	**IGNORE** lack of hyphens, extra hyphens, or addition of commas **DO NOT ALLOW** the following for methyl: methy, meth, methly **DO NOT ALLOW** the following for amino: amine, amin **Examiner's Comments** 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** e.g.  ✓ Two **3D structures** of valine that are mirror images with correct connectivity in both ✓  	2 (AO1.1) (AO1.2)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** connectivity for the first marking point but must be correct for the second mark. **ALLOW** bond to any part of the CH of the $CH(CH_3)_2$ group e.g. **ALLOW**  Each structure must have four central bonds with **at least two wedges.** For bond into paper accept:  **ALLOW** two 3D structures with 2 groups swapped e.g.  **ALLOW** R or C_3H_7 to be shown for $CH(CH_3)_2$ for second mark only. **ALLOW ECF** for second mark for small slips such as missing H e.g. $C(CH_3)_2$ **<u>Examiner's Comments</u>**

					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 (AO2.6)	**Examiner's Comments** This question was challenging for even the most able candidates with very few obtaining the correct answer of 16. Many 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		4 (AO2.5 ×4)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** connectivity **ALLOW** + charge on H of NH_3 group, i.e. NH_3^+ If structures are shown with NH_3 groups

			1 mark for each **correct** structure with • **Either** NH_3^+ **OR** NH_2 ✓✓✓ **1 mark** for • **all 3 correct** structures with NH_3^+ ✓		(without the + charge) **OR** as NH_2^+ groups allow **ECF** for subsequent use. **ALLOW** structures shown as correctly balanced salts, e.g NH_3Cl **OR** $NH_3^+Cl^-$ all marks can be awarded. **Examiner's Comments** 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 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**	
28			**Level 3 (5–6 marks)** Suggests **ALL** of the following • Reagents and conditions for **3** functional groups • Products for **3** functional groups • Optical isomerism with description and 3D optical isomers shown *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Suggests **two** of the following • Reagents and conditions for **2** functional groups	6 (AO 3.1 ×3) (AO 3.2 ×3)	**CHECK TOP OF QUESTION FOR RESPONSES** --- *Indicative scientific points may include:* **Stereoisomerism** • Optical isomerism identified with description: e.g. chiral centre /non-superimposable mirror images • 3D Optical isomers drawn, e.g.  *Description is subsumed in 3D diagrams*

- Products for **2** functional groups
- Optical isomerism with description **OR** an attempt to show 3D optical isomers

There is a line of reasoning presented with some structure.
The information presented is relevant and supported by some evidence.

Level 1 (1–2 marks)
Suggests **two** of the following

- 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.

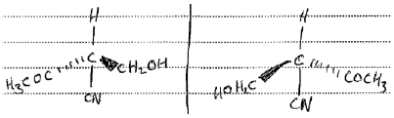
0 mark *No response or no response worthy of credit.*

Key points to check

CHECK TOP OF QUESTION for responses
IGNORE CONNECTIVITY

in 3D isomer structures

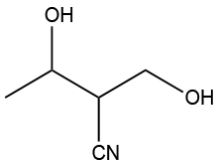
- *IGNORE bond angles*
- *Wedges needed*
- *ALLOW*



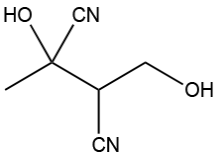
Some responses will not fit into this exact pattern and a best-fit match may be needed

Clear communication
Focus on

Reactions of ketone/carbonyl e.g.
$NaBH_4$

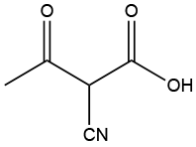


HCN **OR** CN^-/H^+ (e.g. $NaCN/H^+$)

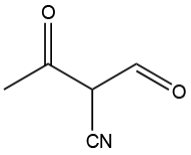


Reactions of –OH, e.g.

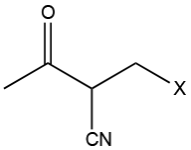
$H^+/Cr_2O_7^{2-}$ **OR** $H_2SO_4/K_2Cr_2O_7$ reflux



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

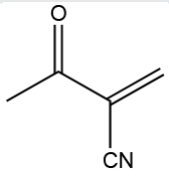
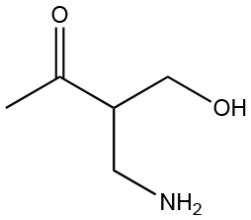
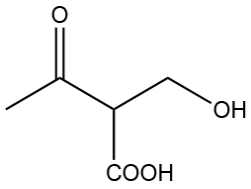


$NaBr/KBr/Br^-$ **AND** $acid/H^+$ **OR** HBr



X = halogen

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

			• 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** • 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 • You need to judge the extent of any slip based on the whole response. Remember that each candidate		 **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)  **OTHER REAGENTS, CONDITIONS AND PRODUCTS** **e.g. $LiAlH_4$ as reagent** **Check with Team Leader** **Examiner's Comments** 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. To achieve the highest level of response, a description of optical isomerism should be accompanied by 3D diagrams of the optical isomers. 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.

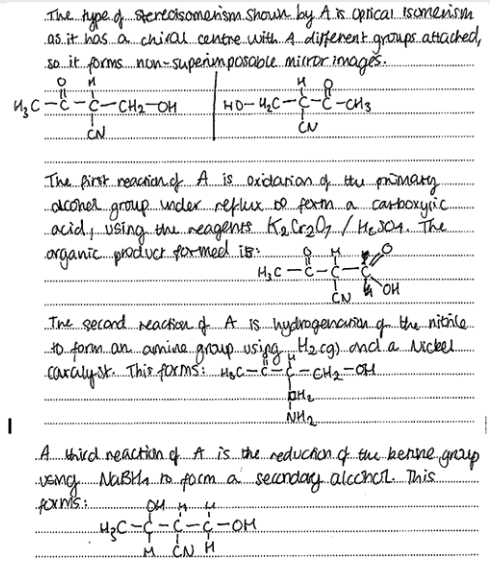
Most candidates showed good knowledge and understanding of reactions for the three functional groups.

- 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)
- For the ketone, most chose $NaBH_4$ (→ secondary alcohol)
- For the nitrile, most chose either H_2/Ni (→ amine) or H^+(aq) (→ carboxylic acid).

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.

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.

Exemplar 2

					 The type of stereoisomerism shown by A is optical isomerism as it has a chiral centre with 4 different groups attached, so it forms non-superimposable mirror images. The first reaction of A is oxidation of the primary alcohol group under reflux to form a carboxylic acid, using the reagents $K_2Cr_2O_7$ / H_2SO_4. The organic product formed is: The second reaction of A is hydrogenation of the nitrile to form an amine group using $H_2(g)$ and a Nickel catalyst. This forms: A third reaction of A is the reduction of the ketone group using $NaBH_4$ to form a secondary alcohol. This forms: 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. The absence of 3D structures limits the response to Level 2 and 4 marks have been awarded for choosing correct and relevant reagents and conditions, and for the clear communication of the structures.
			Total	**6**	
29			**C**	1	**Examiner's Comments** 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**	
30			**IF** answer on answer line = 73518 **AWARD** 3 marks **IF** answer on answer line = 73500 **AWARD** 2 marks ----------	3	**ALLOW ECF** from incorrect M_r of amino acid **Alternative method:** Mr of repeat unit = 147 ✓

			---------- M_r of amino acid = 165 ✓ M_r of 500 molecules = 500 × 165 = 82500 ✓ M_r of polymer = 82500 – (499 × 18) = 73518 ✓ *(final answer must be given to nearest whole number)*		147 x 500 = 73500 ✓ 73500 + 18 = 73518 ✓ **Common error for 2 marks** 36518 Use of Mr 91 82500 Not shown 165 in working **Common error for 1 mark** 45500 Use of Mr 91 **Examiner's Comments** 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. 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 number,e.g. rounding 73518 to 74000 or 82500 to 80000.
			Total	**3**	
31		i	$C_{13}H_{19}N_3O_7$ ✓	1	**ALLOW** elements in formula in any order e.g. $C_{13}H_{19}O_7N_3$ **Examiner's Comments** 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** This question was answered well with the

					correct answer of 4 being seen on most scripts, reflecting good understanding of chiral carbon centres. 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** **IF difference = 61.7, award 2 marks** --- M_r of **C** = 380 **OR** M_r of **D** = 441.7 ✓ Correct difference = 441.7 - 380 = **61.7** ✓ **AWARD** mark for **correct answer of 61.7 only**	2	**ALLOW** other approaches based on different atoms in **C** and **D**, e.g. Difference = 7 × (32.1 - 16) - 3 × (31 - 14) = 112.7 - 51 = **61.7** ✓ **Check answer from 2c(i) at top of response for ECF** **ALLOW ECF** from incorrect formula from **2c(i)** e.g. From $C_{12}H_{16}N_3O_6$ M_r of **C** = 349 **OR** M_r of **D** = 394.6 ✓ **ECF** difference = 394.6 - 349 = **45.6** ✓ **ECF** **Examiner's Comments** This question was answered extremely well with about three-quarters of candidates securing both marks. Most candidates calculated the molecular 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**). ECF was applied to any incorrect molecular formulae from Question 2 (c) (i) from which both marks could be obtained
			Total	**4**	