Amino Acids, Amides and Chirality

1. $(CH_3)_3CCHBrCH_3$ 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]

2(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]

3. This question is about weak acids.

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

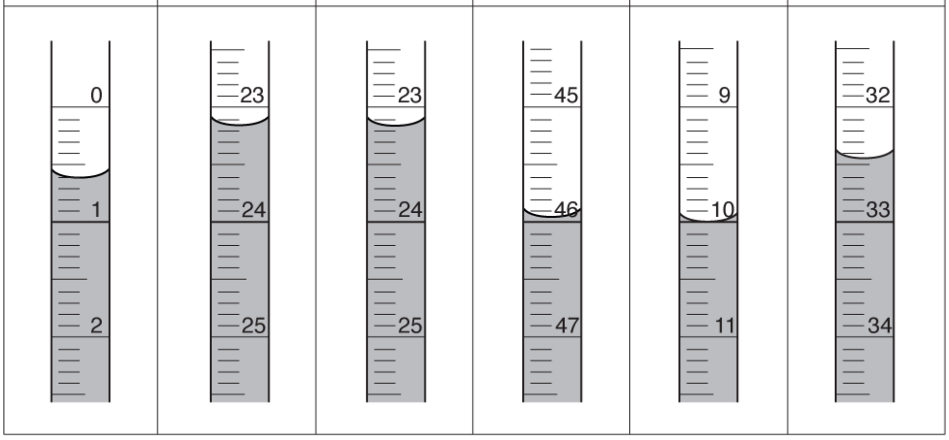
A student is supplied with a 250.0 cm^3 solution prepared from 2.495 g of **A**.

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

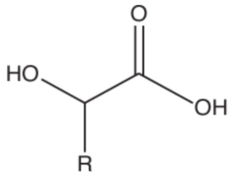


i. Record the student's readings and the titres in an appropriate format.

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]

4(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 $C_5H_{10}N_2O_4$.

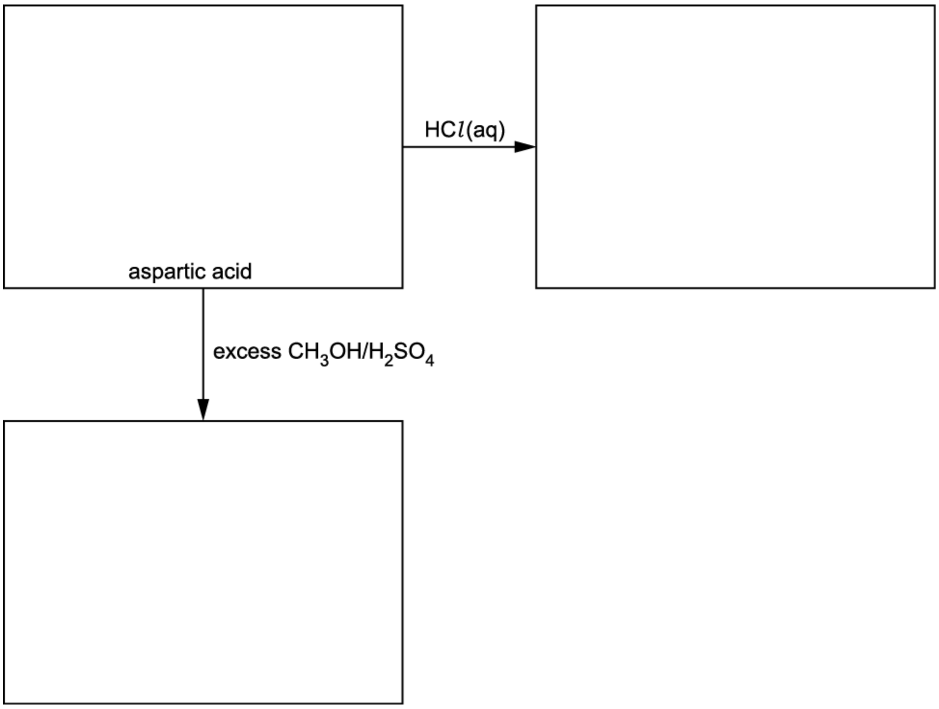
Draw the structures of the **three** organic products that can be formed by the reaction of serine with glycine.

[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]

5(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.

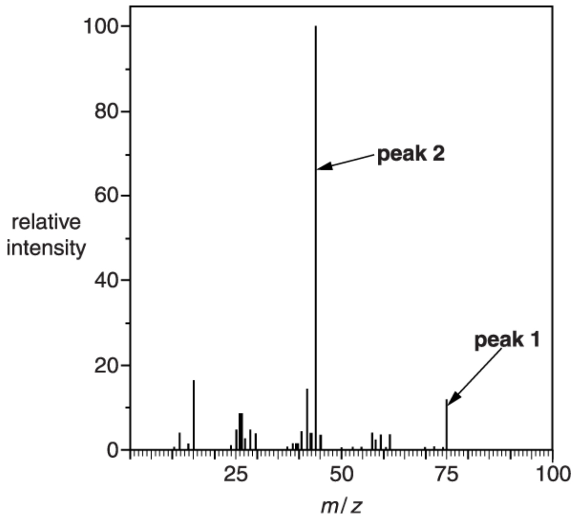
i. For the ^1H NMR analysis, the sample was dissolved in D_2O.

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, $CH_3CHCl\,CH_2OH$.

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**.

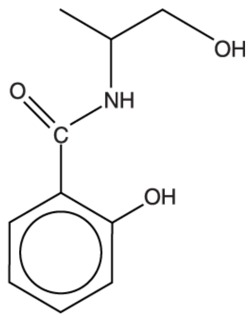
Compound **D** has a molecular formula of $C_6H_{15}NO_2$.

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.

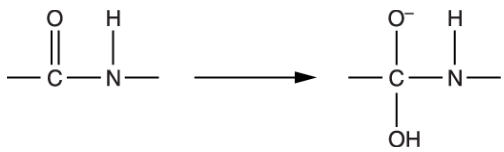
[2]

6(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.

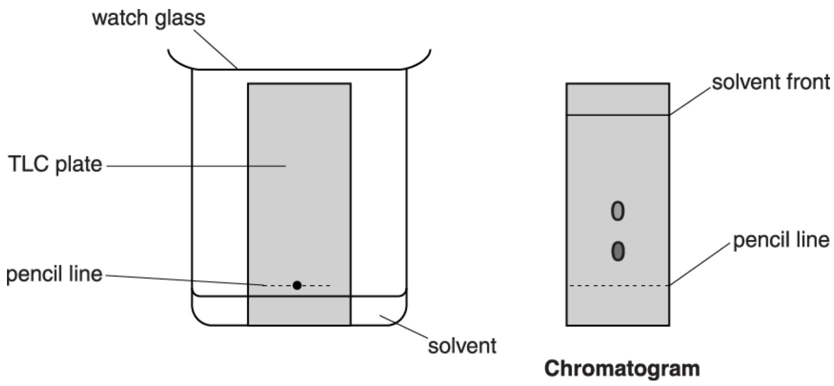
Add curly arrows and relevant dipoles to the diagram to suggest how the hydroxide ion takes part in the first step of this mechanism.



[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.

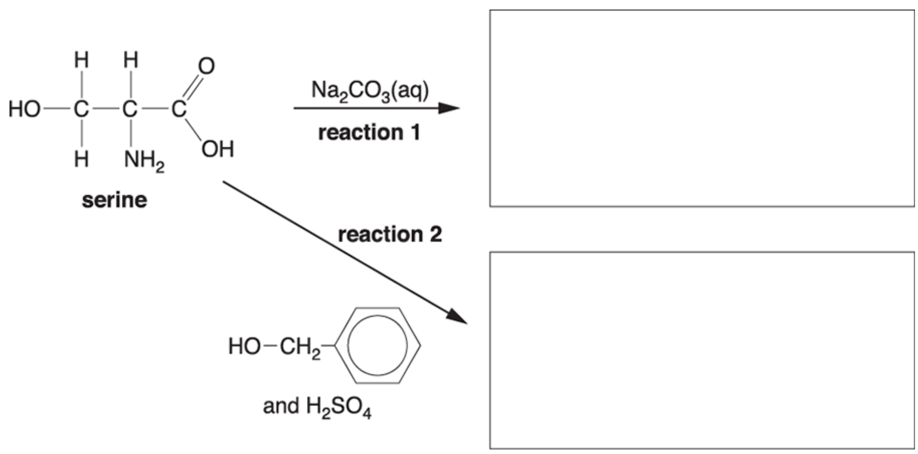
On your structure, mark each chiral centre with an asterisk (*).

[2]

7(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.



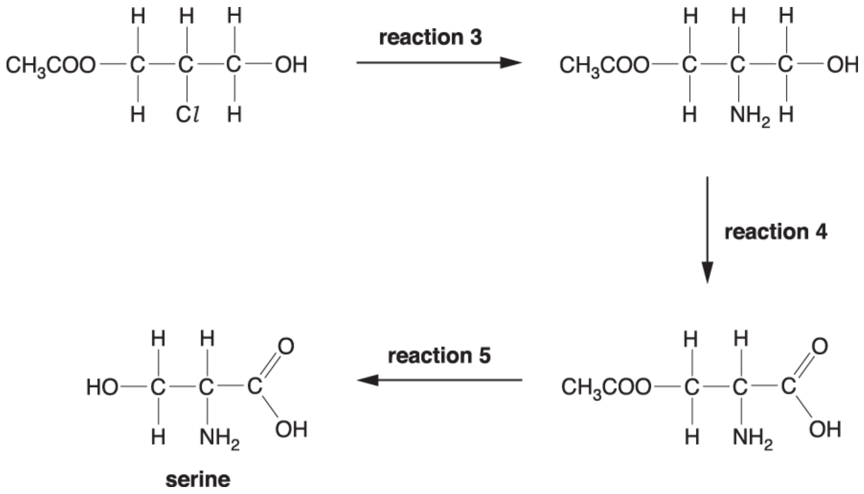
[3]

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]

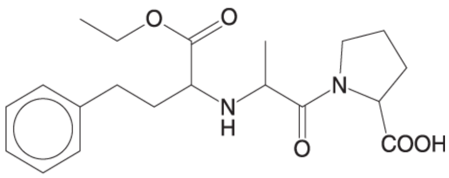
(b). Compound **E**, C_4H_7NO, is one of two optical isomers. It can be oxidised by Tollens' reagent to an α-amino acid, **F**.

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]

8. 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.

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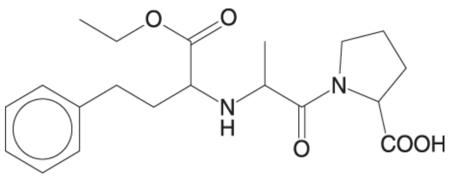
____ **[2]**

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–

Explain how GC– enables the products to be identified.

-- **[1]**

9. 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.

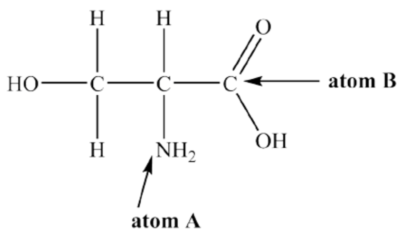
[2]

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]**

10(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**.

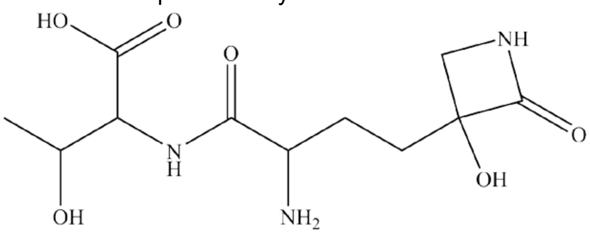
Give reasons for your answers.

---**[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]

END OF QUESTION PAPER