VICTORIAN CERTIFICATE OF EDUCATION

CHEMISTRY – SAC 4 - 2025

Analysis of Secondary data

Reading time: 5 minutes

Writing time: 65 minutes

Student's Name: Solutions

Teacher: ______________________________

Structure of booklet

Section	Number of Questions	Number of questions to be answered	Marks
Short Answer	6	6	52
		Total:	**52**

Directions to students

Materials

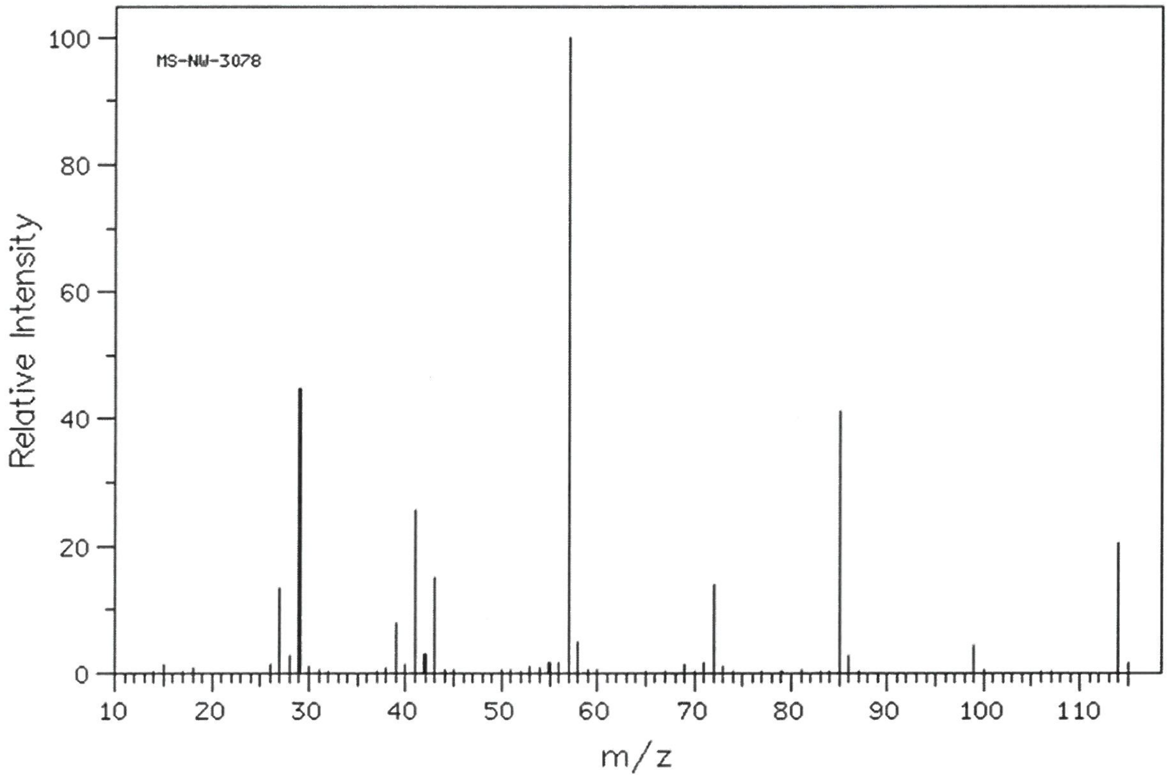
- Students **are permitted** to bring into the examination room: pens/pencils, highlighters, erasers, sharpeners, rulers, and an approved scientific calculator.
- Students are **NOT permitted** to bring into the examination room: white out liquid/tape, phones or electronic devices, including smart watches.
- Students are provided with the following: Question and answer book of **14** pages and VCAA Data booklet.

The task

- Please ensure that you write your name and teacher's name on this booklet. This paper consists of short answer questions.
- There are a total of **52** marks available.
- Be sure to include states with all chemical equations.
- All numerical answers need to be quoted to the correct number of significant figures.
- All working out must be shown in the space provided.

Question 1

Compound X has a molecular formula of $C_7H_{14}O$. The mass spectrum of compound X is shown below.



Data: National Institute of Advanced Industrial Science and Technology SDBS web http://sdbs.db.aist.go.jp

a. i. Give the formula of the particle that formed the peak at m/z 114.

1 mark

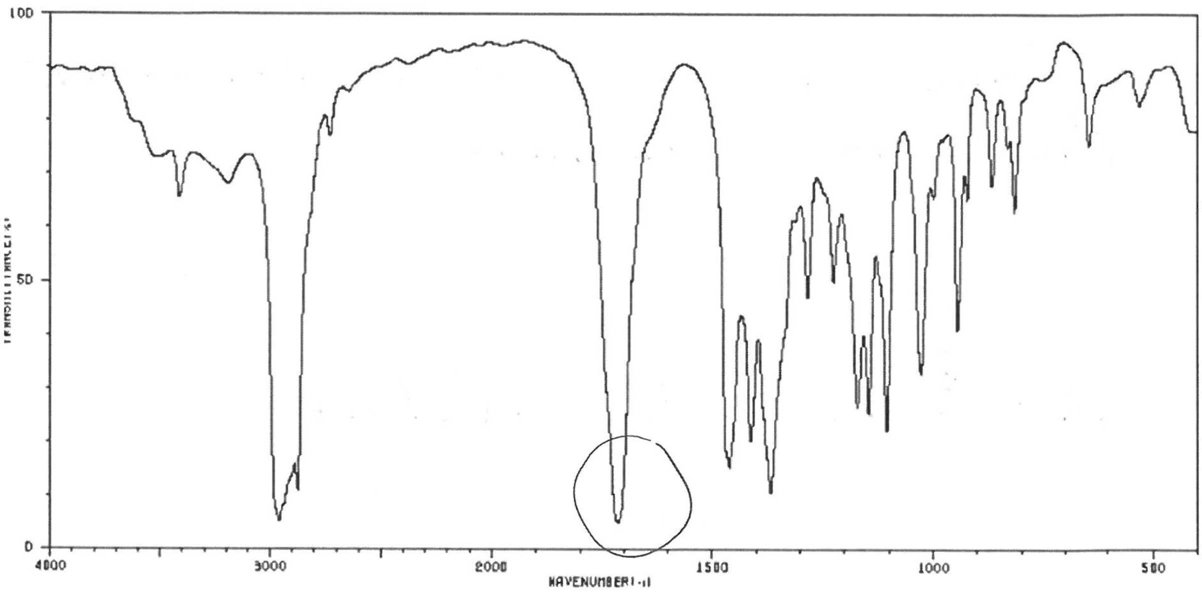
$C_7H_{14}O^+$

ii. Given that the Mr is 114, suggest why there is a very small peak at m/z = 115

1 mark

Presence of ^{13}C in the parent ion ($C_7H_{14}O^+$)

The IR spectrum of compound X is shown below.



Data: ***National Institute of Advanced Industrial Science and Technology SDBS web*** http://sdbs.db.aist.go.jp

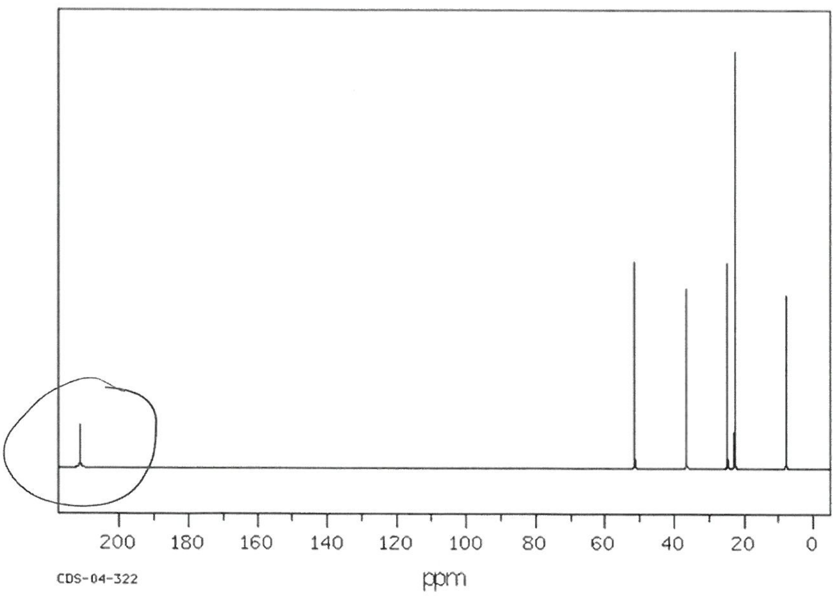
b. Suggest **four** bond types that might have created the peak that is circled above.

C=O (ketone) C=O (acid) 2 marks

C=O (aldehyde)

C=O (ester)

The ^{13}C NMR spectrum for compound X is shown below.



Data: ***National Institute of Advanced Industrial Science and Technology SDBS web*** http://sdbs.db.aist.go.jp

c. **i.** Given that the compound has seven carbons in the molecular formula, explain why there are only six peaks in the ^{13}C NMR Spectrum.

1 mark

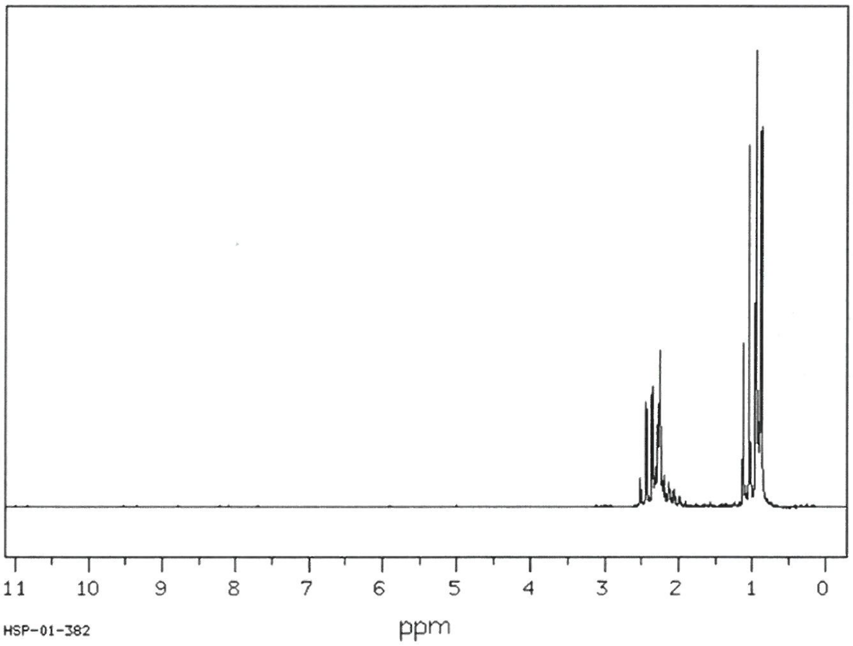
* There are 2 Carbon environments that are equivalent

ii. Use item 23 of the data book and the circled peak left of 200 ppm to identify the class of compounds this compound belongs to.

1 mark

$R-\overset{O}{\overset{\|}{C}}-R \Rightarrow$ Ketone

The high-resolution ^{1}H NMR spectrum for compound X is shown below.



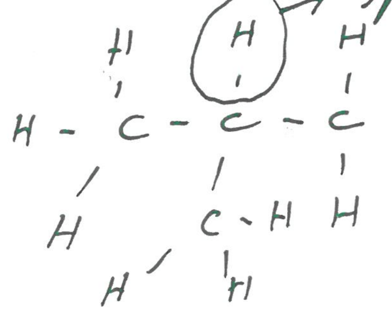
Data: National Institute of Advanced Industrial Science and Technology SDBS web http://sdbs.db.aist.go.jp

The H-NMR data is summarised in the table below.

Chemical shift	Relative peak area	Peak splitting
0.95	3	triplet
1.13	2	quartet
2.13	1	nonet (9)
2.38	6	doublet
2.27	2	doublet

d. **i**. Draw **part** of the structure of the molecule to represent the chemical shift that occurs at 2.13. Be sure your structure matches the relative peak area and peak splitting that occurs.

splits in 9.



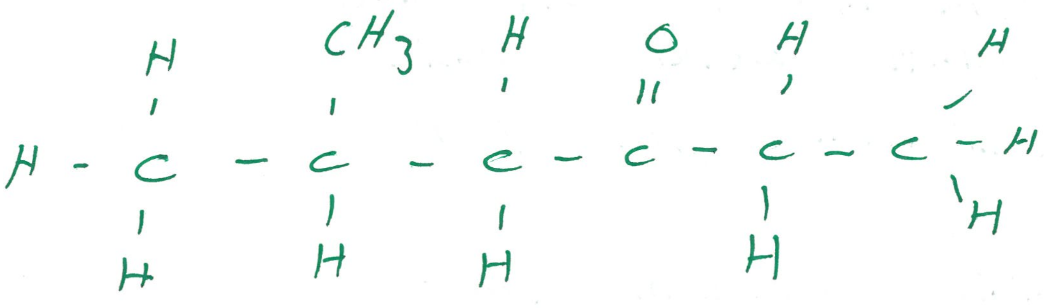
1 mark

ii. The ^1H NMR spectrum shows a peak at 2.27 ppm that is twice as large (integration) as the peak at 2.13 ppm. What does the size of an integration peak represent?

1 mark

The relative no. of equivalent hydrogens in an environment

iii. Based on all the information provided in parts **a-d** of Question **1**, draw the structure of compound X showing all bonds.



2 marks

Question 2

The bite from bull ants contains formic acid. Industrial Chemist Verco is asked to use titration to determine the concentration of formic acid in the sting from a bull ant. To find out the actual concentration of the acid, he diluted 2.00 mL of the ant bite to 150.00 mL in a volumetric flask. He then titrated 20.0 mL aliquots of the diluted ant bite against barium hydroxide solution of concentration 0.0357 M. The mean titre was found to be 19.50 mL. The equation for the reaction is:

$$2\ HCOOH_{(aq)} + Ba(OH)_{2\ (aq)} \rightarrow Ba(HCOO)_{2\ (aq)} + 2\ H_2O_{\ (l)}$$

a. Calculate the amount of $Ba(OH)_2$ required to react with the HCOOH in the aliquot.

$n(Ba(OH)_2) = C.V = 0.0357 \times 0.01950$

$= 6.96 \times 10^{-4}$ mol

1 mark

b. Calculate the concentration of the **diluted** HCOOH in mol/L.

$n(HCOOH) = 2n(Ba(OH)_2)$

$= 0.00139$ mol

$[HCOOH]_{diluted} = n/V = \frac{0.00139}{0.02} = 0.0696M$

2 marks

d. Calculate the concentration of methanoic acid in the **original** bull ant sting sample in mol/L.

$[HCOOH] = 150/2 \times 0.0696$

$= 5.22$ M.

1 mark

e. Why did Chemist Verco dilute the ant sting sample before he performed the titration?

* Minimise waste
* minimise cost
* To improve accuracy.

1 mark

f. Which indicator should be chosen for this titration. Explain your choice.

Phenolphalein
=> Weak acid + strong base
=> products weakly basic
=> equivalence point > 7

2 marks

g. Why did Chemist Verco make sure he had 3 concordant titres before finishing?

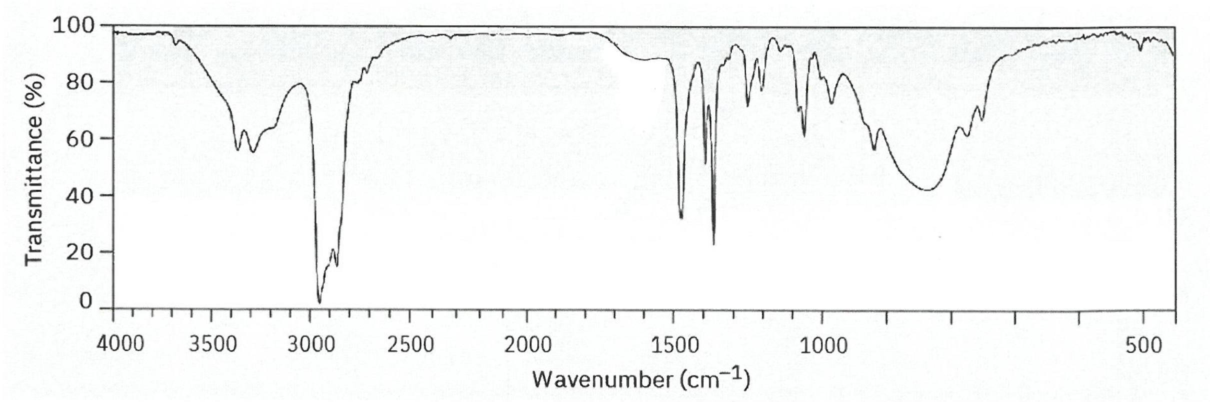
* Minimise random error
* ↑ precision
*

1 mark

Question 3

A research team at RMIT University were trying to isolate new organic compounds from plants, to be used as medicines. One of the chemists, Razman, isolated an organic compound from a plant, *Bongardia chrysogonum*.

An infrared spectrum of the compound is shown below.



a. Scientist, Razman, decided that based on the IR spectra, this compound cannot be an *alcohol* or *carboxylic acid*. Explain with reference to the **IR spectra** why he is **either** correct or incorrect **and** what the most likely family this molecule belongs to is.

* Not an alcohol or acid as there is no wide peak (2500 - 3500 cm^{-1}) for an acid or smooth peak (3200 - 3600 cm^{-1}) for an alcohol.

=> Most likely amine (3300 - 3500 cm^{-1})

(Also forked appearance)

3 marks

b. Razman wanted to determine the purity of a sample of *Bongardia chrysogonum (Bc)*. Explain how Razman could use the spectrum of *Bongardia chrysogonum (Bc)* from proton NMR to determine whether the sample was pure or impure.

Run sample through NMR spectrometer & compare spectrum to pure sample spectrum. - 1

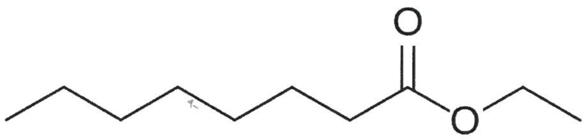
2 marks

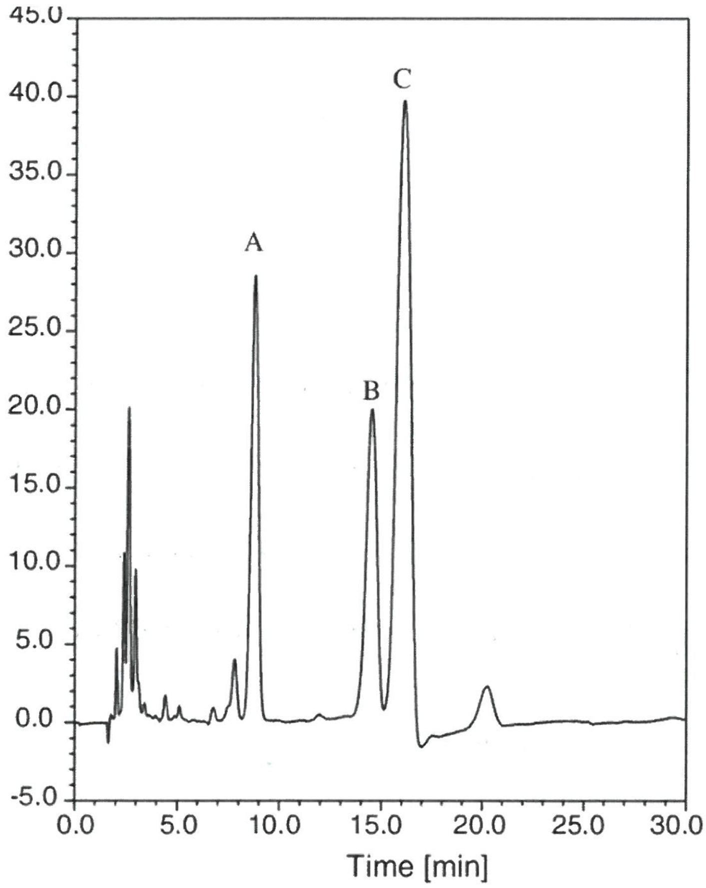
Any additional responses or larger responses => Impure sample.

- 1

Question 4

A HPLC printout is shown below from the laboratory, where senior professors Akers and Reilly are testing wine from the Yarra Valley. Wine contains many chemicals, such as ethanol, glucose and ethyl octanoate (structure shown below). In their testing, they injected a fraction from the sample of wine; the solvent used was non-polar and the stationary phase was polar. The early peak on the left side of the printout was produced by the solvent, not the sample.





1 mark ⇒ Polarity

1 mark ⇒ Phase attractions

1 mark ⇒ R_T comparison.

a. Identify the substances forming the peaks labelled as A, B and C.

A: ethyl octanoate B: ethanol C: Glucose

1 mark

b. Explain why substance A has a shorter retention time than substance C. You must refer to both substances in your response.

A = non-polar ⇒ stronger attraction to mobile phase ⇒ shorter R_T

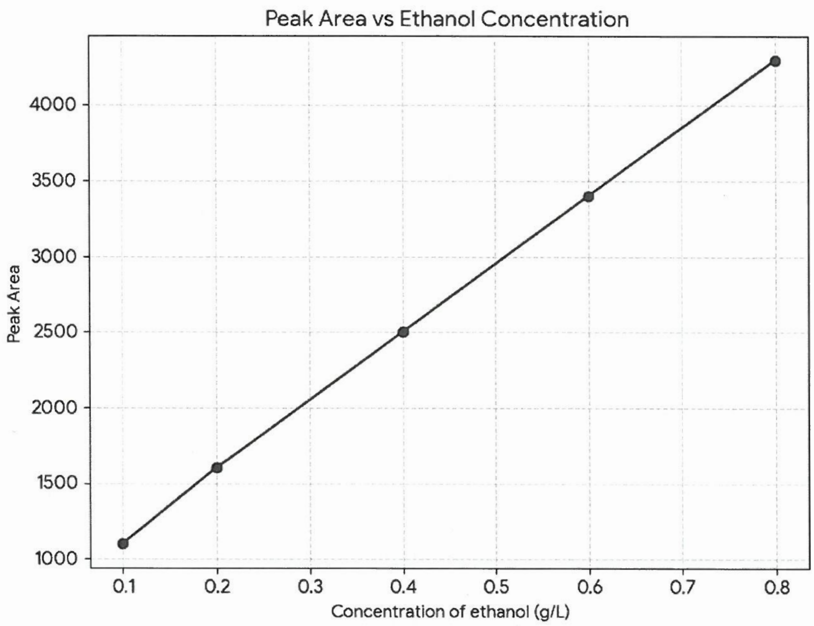
C = polar ⇒ stronger attraction to stationary phase ⇒ ↑ R_T.

polar

3 marks

High-performance liquid chromatography (HPLC) was used to determine the ethanol concentration in a sample taken from the wine.

Akers made up standard solutions using pure ethanol and deionised water. A 1 mL sample of each standard solution was injected into the HPLC column and its peak area was recorded and a calibration curve was produced (see below).



Reilly then took a 4.5mL sample of the wine and diluted it to 150.0mL in a volumetric flask. He transferred a 40.0 mL aliquot of this solution to a 250 mL volumetric flask and filled up to the calibration mark using deionised water. A sample of this solution was injected into the HPLC column. The peak area of the sample solution at the same retention time, and under the same conditions as those used to determine the calibration line, was found to be 2500.

e. Determine the ethanol content of the **diluted** wine sample tested in the HPLC, in grams per litre.

0.4 g/L

1 mark

f. Calculate the percentage mass/volume (% m/v) of ethanol in the original 4.5mL sample of wine. Be sure your answer is to the correct number of significant figures.

$$0.4 \times \frac{250}{40} \times \frac{150}{4.5} = 83.3 \text{ g/L}$$

$\Rightarrow$ 8.3 g/100 ml

= 8 % m/v

(1 s.f).

3 marks

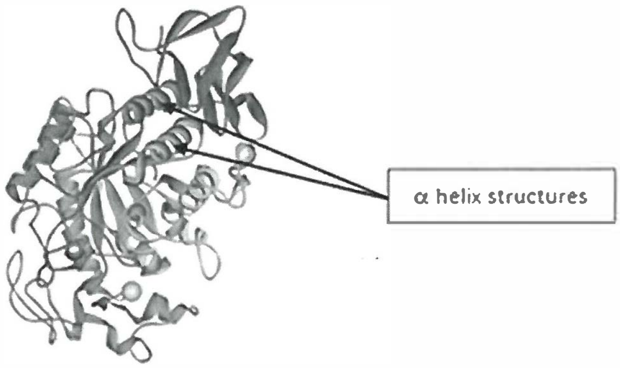
g. Reilly and Akers compared what the wine maker claimed the ethanol content to be and found their result for the ethanol concentration was significantly below the winemakers claim. Give one valid reason for this discrepancy.

Ethanol had oxidised to CH_3COOH
$\Rightarrow$ ↓ ethanol content.

1 mark

Question 5

α-amylase, shown in the diagram below, is a protein enzyme found in saliva. Its role in the body is to catalyse the hydrolysis of starch, ultimately increasing blood glucose levels. To help people with type 2 diabetes, scientists are looking for new compounds that may inhibit the function of the enzyme, so that blood glucose levels can be lowered.



a. The structure of the α-amylase enzyme is highly folded, including many α-helix segments. Name the bonding responsible for the formation of an α-helix in a protein. 1 mark

Hydrogen bonding

must talk about disruption of 3° structure

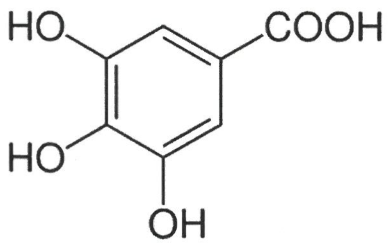
b. Human α-amylase is stable over a wide range of pH values (6.0 to 9.5). With reference to functional groups and bonds, explain why the enzyme may become compromised at pH levels below this range. 2 marks

Low pH $\Rightarrow$ Disruption of salt bridge
$\Rightarrow$ disruption of tertiary structure — 1
(Denatured)
(Loss of ionic interaction between
COO^- & $^+NH_3$ salt bridge)
$\Rightarrow$ change in shape of active
site $\Rightarrow$ enzyme inactive — 1

c. α-amylase contains the amino acid aspartic acid. Draw a structure of this amino acid in a pH of 13. 1 mark

$CH_2-COO^{\ominus}$
$|$
$H_2N-CH-COO^{\ominus}$ ⇒ $\boxed{2-}$ charge.

d. Scientists are investigating the use of gallic acid as a medicinal compound for people with type 2 diabetes. Gallic acid is an organic compound that can be extracted from fruits and medicinal plants. It has been found to inhibit the action of α-amylase. The structure of gallic acid is shown below.



e. Describe the mechanism by which gallic acid acts as a competitive inhibitor of the α-amylase enzyme.

Gallic acid will compete with starch for the active site of α-amylase
⇒ preventing the breakdown of starch into glucose.

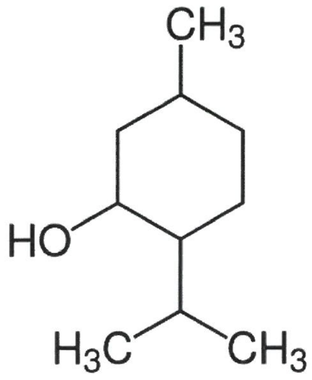
2 marks

f. Gallic acid does not contain any chiral centres. Explain why this is important when considering it for use as a safe and effective medicinal compound.

No chiral centres ⇒ no optical isomers exist ⇒ only one spatial arrangement of atoms in gallic acid
⇒ Gallic acid will not have any problem

2 marks

Another molecule found in medicinal plants is menthol. It's structure is shown below.



g. How many chiral centres does menthol have? 3

1 mark

h. Solvent extraction is used to remove menthol from plants it is found in. Name what type of solvent would be used in this process with a reason why.

A non-polar solvent, ideally one that is more volatile than menthol. The non-polar solvent will form dispersion forces with the non-polar menthol => extracting it from the plant.

2 marks

i. The anti-inflammatory drug naproxen has been around since 1970. It is effective at reducing pain and fever. Pain is caused by the release of prostaglandins, resulting in inflammation. It works by inhibiting the COX enzyme that produces prostaglandins. There are 2 enantiomers of naproxen, S-naproxen and r-naproxen. Only the S-naproxen enantiomer is effective at reducing pain. Explain why only the S-naproxen enantiomer is effective at reducing pain.

S-naproxen has the correct spatial arrangement of its atoms that are complementary to the COX enzyme (lock + key) - 1
whilst ~~the~~ r-naproxen has a different spacial arrangement of atoms => will not match the active site of COX ensyme. - 1
=> won't prevent prostaglandins & won't ↓ pain.

2 marks

Question 6

A group of Year 12 Chemistry students was provided with four **unknown** organic compounds. Their teacher asked the group to identify each one using common laboratory analysis techniques. Three hints were given to the students:

- Each compound contains five carbon atoms.
- No compounds contain methyl or ethyl branches.

The students completed the following tests for each organic compound:

- Test 1 – Reaction with sodium carbonate (Na_2CO_3).
- Test 2 – Reaction with 2% bromine water (brown colour).
- Test 3 – Reaction with ethanoic acid, using a sulfuric acid catalyst and gentle heating using a hot plate.
- Test 4 – Use of a pH meter to determine the pH of each compound.
- The students compiled the following results table based on their tests.
- All tests were performed at SLC.

	Test 1 (reaction with Na_2CO_3) Observations	**Test 2** (reaction with 2% bromine water) Observations	**Test 3** (reaction with ethanoic acid) Observations	**Test 4** (pH) Observations
Unknown Compound A	No observable reaction	Bromine water becomes colourless	No change in smell observed	Not tested
Unknown Compound B	No observable reaction	Bromine water stays brown	Pleasant odour observed	6.98
Unknown Compound C	No observable reaction	Bromine water stays brown	Pleasant odour observed	6.99
Unknown Compound D	Bubbles of gas observed	Bromine water stays brown	No change in smell observed	not tested

a. Based on the results obtained by the students, suggest a IUPAC systematic name for '**Unknown Compound A**'. 1 mark

~~But-1-ene~~ or ~~But-2-ene~~ pent-1-ene or pent-2-ene

bi. Based on the results obtained by the students, suggest the IUPAC systematic name of the compound that could be '**Unknown Compound D**'. 1 mark

Pentanoic acid

bii. Describe one source of evidence from the results table that support your response to Question 1bi. 1 mark

Acid + Na_2CO_3 → CO_2

⇒ Bubbles of gas = CO_2.

biii. Describe **another** test and the result that could be performed to provide further evidence in support of your response to Question **1bi**. 1 mark

Litmus => Blue Litmus turns red

or react with alcohol & fruity smell will be evident.

c. After analysing the results of each test, the group of students could not identify Unknown Compounds B and C. Their teacher gave them one further piece of information:

- One is a primary alcohol, and the other is a secondary alcohol.

Describe a test **and** the results that the students could perform and explain how it distinguishes between the two alcohols.

① React both alcohols with acidified MnO_4^- & gently heat. (Both will turn colour purple to clear)

① —

② Test both chemicals with Litmus paper

② —

=> the chemical that turns blue litmus red = carboxylic acid => must originally be a 1° alcohol

③ —

& chemical = ketone => originally secondary alcohol.

3 marks

END of SAC