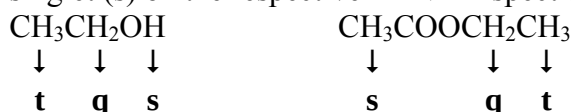


Suggested Answers

VCE Chemistry 2011 Year 12 Trial Exam Unit 3

SECTION A – Multiple Choice Answers

- Q1 B** Because the spectrum shows peak splitting it is a **high resolution ^1H NMR spectrum**. Three different peaks indicate that there are three different hydrogen environments. Ethanol, $\text{CH}_3\text{CH}_2\text{OH}$, and ethyl ethanoate, $\text{CH}_3\text{COOCH}_2\text{CH}_3$, both have three different hydrogen environments and both produce a quartet (q), a triplet (t) and a singlet (s) on the respective ^1H NMR spectra.

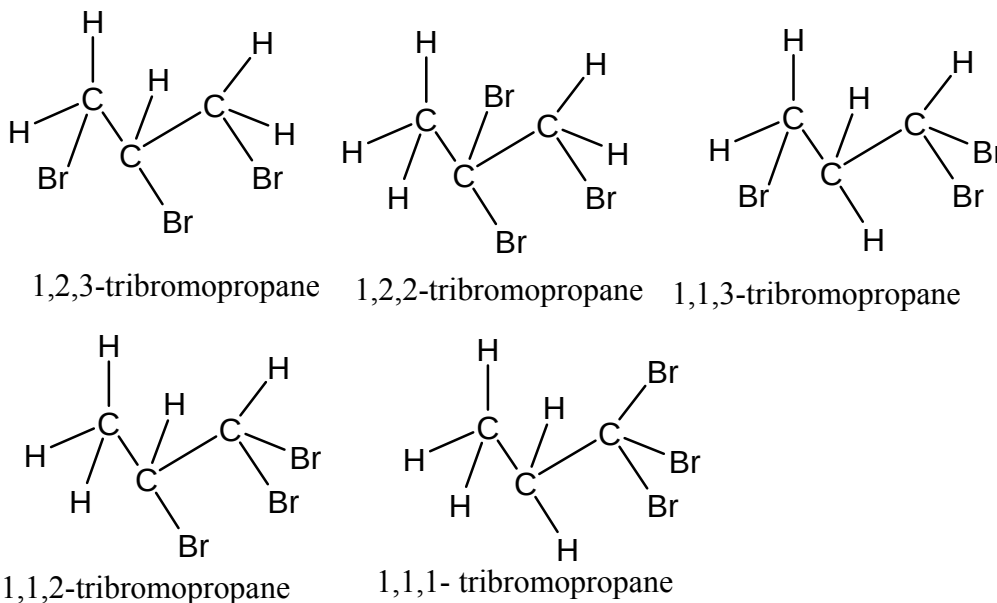


The **peak area ratio q : t : s** should be **2 : 3 : 1** for $\text{CH}_3\text{CH}_2\text{OH}$ but **2 : 3 : 3** for $\text{CH}_3\text{COOCH}_2\text{CH}_3$. Hence the **small peak area for the singlet** suggests that the spectrum is that of **ethanol**.

That the spectrum is **not** that of $\text{CH}_3\text{COOCH}_2\text{CH}_3$ is also supported by chemical shift data, $\delta(\text{s}) = 2.6$, $\delta(\text{q}) = 3.7$, $\delta(\text{t}) = 1.3$.

- Q2 B** The process of mass spectroscopy involves the following sequence:
1. A gaseous sample is injected into a mass spectrometer.
 2. Individual molecules / atoms assume a positive charge as they pass through the **ionising source** - an electron is knocked off each particle by a high speed electron beam.
 3. The positive ions are **accelerated** through an electric field.
 4. The ions are separated in a magnetic field where they follow curved paths as they are **deflected**, the extent of which depends on their mass to charge (m/e) ratios.

- Q3 C**

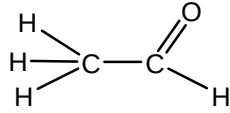


- Q4 A** Since alcohols can be produced from chloroalkanes, the first step is the conversion of propene into **2-chloropropane** by an addition reaction with HCl and second step is the conversion of 2-chloropropane to 2-propanol by a substitution reaction with OH⁻
- $$\text{CH}_3\text{CH}=\text{CH}_2 + \text{HCl} \rightarrow \text{CH}_3\text{CHClCH}_3$$
- $$\text{CH}_3\text{CHClCH}_3 + \text{OH}^- \rightarrow \text{CH}_3\text{CHOHCH}_3 + \text{Cl}^-$$
- Pathway is $\text{CH}_3\text{CH}=\text{CH}_2 \rightarrow \text{CH}_3\text{CHClCH}_3 \rightarrow \text{CH}_3\text{CHOHCH}_3$
- Q5 D** According to the calibration curve, the absorbance of 0.18 indicates that the concentration of K (as K⁺) in the 250 mL of diluted solution was 0.075 mg L⁻¹. To get this diluted solution 5.00 mL of the original solution (200.0 mL) containing the K from 0.20 g banana had been diluted by a factor of 50 (5 mL to 250 mL).
- $$c(\text{K}) \text{ in original solution} = 50 \times 0.075 = 3.75 \text{ mg L}^{-1}$$
- $$m(\text{K}) \text{ in original 200 mL solution} = 0.200 \text{ L} \times 3.75 \text{ mg L}^{-1} = 0.75 \text{ mg}$$
- All 0.75 mg K in the original 200 mL of solution came from 0.20 g of banana.
- $$\therefore m(\text{K}) \text{ in 100 g banana} = (0.75 / 0.20) \times 100 = 375 \text{ mg}$$
- $c(\text{K}) \text{ in banana} = \mathbf{375 \text{ mg K per 100 g banana}}$.
- Hence the closest value is 380 mg K per 100 g.
- Q6 B** Iodine, I₂, reacts with but-2-ene, CH₃CH=CHCH₃, in an addition reaction according to
- $$\text{CH}_3\text{CH}=\text{CHCH}_3 + \text{I}_2 \rightarrow \text{CH}_3\text{CHICHICH}_3 \text{ (2,3-diiodobutane)}$$
- Q7 C** According to Infrared absorption data supplied in the Data Book: With respect to the IR spectrum data, the major peak centred at 1715 cm⁻¹ is characteristic of **C=O** whilst the short narrow peak centred at 3100 cm⁻¹ is characteristic of **C-H**.
- The mass spectrum fragment at $m/e^- = 29$ could be due to **CH₃CH₂⁺** or **COH⁺**
- The ¹H NMR peak at $\delta = 4.1$ ppm is characteristic of **H atoms bonded to a C which is bonded to the singly bonded O of an ester group, RCOOCH₂R**
- Consider the alternatives
- A. The only possible structure for CH₃CHO is shown
- It has the empirical formula C₂H₄O.

It will produce C=O and C-H peaks on its IR spectrum.

It can produce a fragment at $m/e^- = 29$ (CHO⁺).

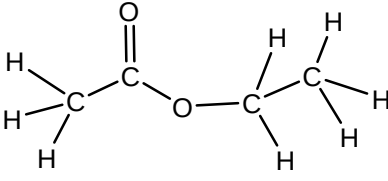
It will **not** produce a ¹H NMR peak at $\delta = 4.1$ ppm.


- B. CH₃COOH → **empirical formula CH₂O**
- C. The structure for CH₃COOCH₂CH₃ is shown
- It has the **empirical formula C₂H₄O**.

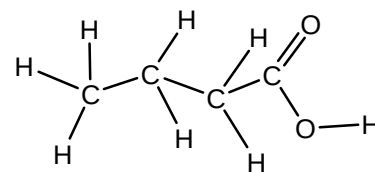
It will produce **C=O and C-H peaks** on its IR spectrum.

It can produce a **fragment at $m/e^- = 29$ (CH₃CH₂⁺)**.

It will produce a **¹H NMR peak at $\delta = 4.1$ ppm** (CH₃COOCH₂CH₃).



- D. The structure for $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$ is shown
 It has the empirical formula $\text{C}_2\text{H}_4\text{O}$.
 It will produce $\text{C}=\text{O}$ and $\text{C}-\text{H}$ peaks on its IR spectrum.
 It can produce a fragment at $m/e^- = 29$ (CH_3CH_2^+).
 It will **not** produce a ^1H NMR peak at $\delta = 4.1$ ppm



- Q8 B** When a mixture is distilled, the components of the mixture boil off and are collected in order of increasing boiling temperature.
 The reaction occurring (showing boiling temperatures) is
 $\text{CH}_3\text{OH} (65^\circ\text{C}) + \text{CH}_3\text{CH}_2\text{COOH} (141^\circ\text{C}) \rightarrow \text{CH}_3\text{COOCH}_2\text{CH}_3 (80^\circ\text{C}) + \text{H}_2\text{O} (100^\circ\text{C})$
 $\downarrow \qquad \qquad \downarrow \qquad \qquad \downarrow \qquad \qquad \downarrow$
 Beaker 1 Beaker 4 Beaker 2 Beaker 3
- Q9 D** Assume a 100 g sample of limestone
 $m(\text{Ca})$ present = 30 g
 $n(\text{Ca})$ present = $30 \text{ g} / 40.1 \text{ g mol}^{-1}$
 $= 0.75 \text{ mol}$
 Since the chemical formula for calcium carbonate is CaCO_3
 $n(\text{CaCO}_3)$ in sample = 0.75 mol
 $m(\text{CaCO}_3)$ in sample = $0.75 \text{ mol} \times 100.1 \text{ g mol}^{-1}$
 $= 75 \text{ g}$
 75 g CaCO_3 in 100 g limestone $\rightarrow$ %, by mass, $\text{CaCO}_3 = 75 \%$
- Q10 C** Since citric acid is triprotic then **1 mol $\text{C}_6\text{H}_8\text{O}_7$ reacts with 3 mol NaOH**
 $n(\text{NaOH})$ reacting = $0.350 \text{ mol L}^{-1} \times 37.09 \times 10^{-3} \text{ L}$
 $= 1.30 \times 10^{-2} \text{ mol}$
 $n(\text{C}_6\text{H}_8\text{O}_7)$ reacting = $n(\text{NaOH}) / 3$
 $= 1.30 \times 10^{-2} / 3$
 $= 4.33 \times 10^{-3} \text{ mol}$
 $m(\text{C}_6\text{H}_8\text{O}_7)$ in 20.0 ml = $4.33 \times 10^{-3} \text{ mol} \times 192.0 \text{ g mol}^{-1}$
 $= 0.831 \text{ g}$
 $c(\text{C}_6\text{H}_8\text{O}_7)$ in $\text{g L}^{-1} = (0.831 / 20.0) \times 1000$
 $= 41.5 \text{ g L}^{-1}$
- Q11 B** $\text{Fe}_2\text{O}_3(\text{s}) + 3\text{C}(\text{s}) \rightarrow 3\text{CO}(\text{g}) + 2\text{Fe}(\text{s})$
640 g 130 g
 $n(\text{Fe}_2\text{O}_3) = 640 \text{ g} / 159.8 \text{ g mol}^{-1}$
 $= 4.01 \text{ mol}$
 $n(\text{C}) = 130 \text{ g} / 12.0 \text{ g mol}^{-1}$
 $= 10.8 \text{ mol}$
 Since, according to the equation 4.01 mol Fe_2O_3 requires $3 \times 4.01 = 12.03 \text{ mol C}$ for complete reaction, and there is only 10.8 mol C available, then C is the limiting reactant.
 $n(\text{Fe})$ produced = $2 \times n(\text{C}) / 3$
 $= 2 \times 10.8 / 3$
 $= 7.22 \text{ mol}$
 $m(\text{Fe})$ produced = $7.22 \text{ mol} \times 55.9 \text{ g mol}^{-1}$
 $= 404 \text{ g}$

Q12 C Since the concentration is to be in mol L⁻¹, assume a one litre solution.

$V(\text{solution}) = \text{one litre}$

$m(\text{solution}) = d \times V$

$$= 1.038 \text{ g mL}^{-1} \times 1000 \text{ mL}$$

$$= 1038 \text{ g}$$

$m(\text{KI}) \text{ in solution} = 5 \% \text{ of } 1038 \text{ g}$

$$= (5/100) \times 1038$$

$$= 51.9 \text{ g}$$

$n(\text{KI}) \text{ in solution} = 51.9 \text{ g} / 166.0 \text{ g mol}^{-1}$

$$= 0.313 \text{ mol}$$

Since $\text{KI}(\text{aq}) \rightarrow \text{K}^+(\text{aq}) + \text{I}^-(\text{aq})$

$c(\text{I}^-) = c(\text{KI}) = \mathbf{0.313 \text{ mol L}^{-1}}$

Q13 B $\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + \text{HNO}_2(\text{aq}) + \text{H}^+(\text{aq}) \rightarrow \text{Cr}^{3+}(\text{aq}) + \text{NO}_3^-(\text{aq}) + \text{H}_2\text{O}(\text{l})$

Oxidation number changes - Cr decreased from +6 to +3 and N increased from +3 to +5 – indicate that $\text{Cr}_2\text{O}_7^{2-}(\text{aq})$ is reduced to $\text{Cr}^{3+}(\text{aq})$ and $\text{HNO}_2(\text{aq})$ is oxidised to $\text{NO}_3^-(\text{aq})$.

Write the half-equations, using the standard balancing technique of ‘atoms other than O and H’ followed by ‘O’, then ‘H’ and then ‘electrons’.

Oxidation: $\text{HNO}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{NO}_3^-(\text{aq}) + 3\text{H}^+(\text{aq}) + 2\text{e}^-$

Reduction: $\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 14\text{H}^+(\text{aq}) + 6\text{e}^- \rightarrow 2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\text{l})$

To get the overall redox equation, the oxidation half-equation must be multiplied by 3 to equalise the electrons.

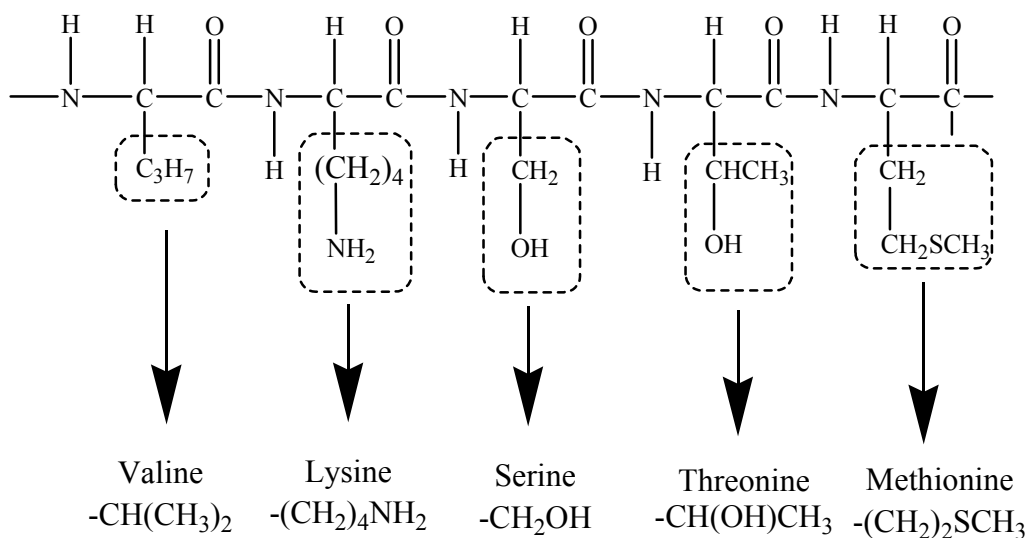
This leads to $3\text{H}_2\text{O}$ on the reactants side in oxidation which, when added to the $7\text{H}_2\text{O}$ on the products side in reduction leads to $4\text{H}_2\text{O}$ on the products side in the overall redox equation.

The overall equation is

$\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 3\text{HNO}_2(\text{aq}) + 5\text{H}^+(\text{aq}) \rightarrow 2\text{Cr}^{3+}(\text{aq}) + 3\text{NO}_3^-(\text{aq}) + 4\text{H}_2\text{O}(\text{l})$

Q14 A During hydrolysis, water reacts across the peptide groups to form amino and carboxyl groups and releases the amino acids.

So it is a matter of using the Data Book to identify the amino acids from the side-groups.



Q15 B The sections of spectra shown are from IR spectra, so it is a matter of using the absorption bands corresponding to the peaks to deduce structural information.

Spectrum A

The broad band centred near 3000 cm^{-1} is indicative of **O-H (acids)**.

The peak centred near 1700 cm^{-1} is indicative of **C=O**

So A is most likely a **carboxylic acid**.

Spectrum B

The narrow shallow band centred near 3000 cm^{-1} is indicative of **C-H**, there is no evidence of O-H on this spectrum.

The peak centred near 1700 cm^{-1} is indicative of **C=O**

So B is most likely an **ester**.

Spectrum C

The broad band centred near 3300 cm^{-1} is indicative of **O-H (alcohols)**.

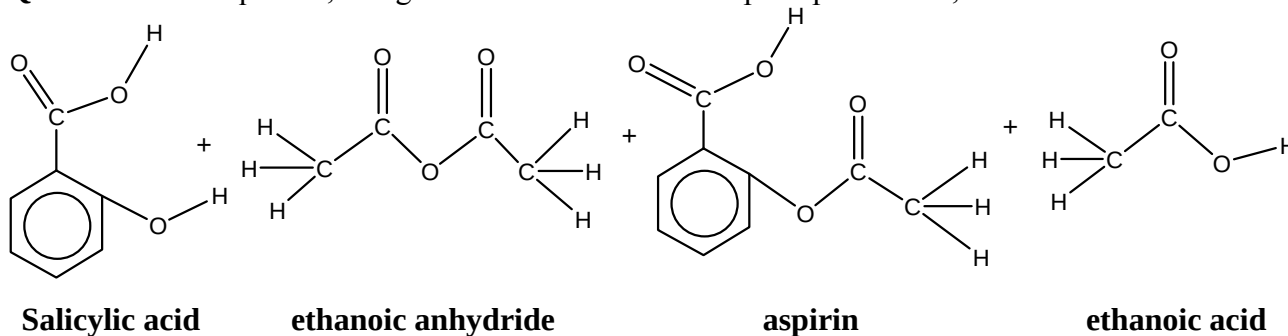
So C is most likely an **alcohol**.

Since the pathway starts with $\text{CH}_2=\text{CH}_2$, the logical order is **C then A then B** consistent with



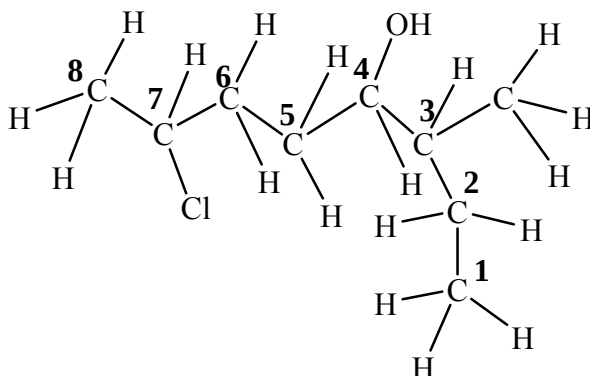
The reaction types are, in order, addition, oxidation, esterification (condensation).

Q16 B The equation, using structural formulae for aspirin production, is



The other structure which appeared in alternative C was that of salicyl alcohol which is an intermediate in the production of salicylic acid from salicin.

Q17 D Since the compound is an **alcohol**, number the longest unbranched chain of C atoms from the end that will assign the lowest number to the hydroxyl (-OH) group.

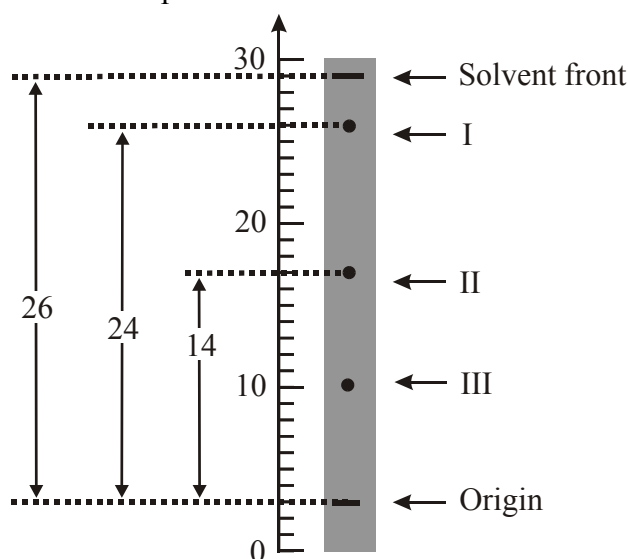


The longest unbranched chain contains 8 C atoms and the hydroxyl (-OH) group is on C-4 hence 4-octanol.

There is a methyl (-CH₃) substituent on C-3 and a chloro (-Cl) functional group on C-7. Since substituents are arranged alphabetically in systematic nomenclature, the systematic name of the compound is **7-chloro-3-methyl-4-octanol**.

- Q18 C** On the titration curve the pH at the start of the titration is 1. This is consistent with a 0.1 M solution of a strong monoprotic acid, i.e. HCl(aq) or $\text{HNO}_3\text{(aq)}$.
The pH levels of around 9 are consistent with a solution of a weak base, suggesting that the titration was of a strong acid with a weak base. $\text{NH}_3\text{(aq)}$ is a weak base.
The titration curve shows that the endpoint of the titration occurs between pH 4.5 and 7 and so would be most accurately picked up using methyl red (pH range 4.2-6.3).
Consider the alternatives
- A. Initial pH is too low for 0.1 M $\text{CH}_3\text{COOH(aq)}$ – a weak acid, and the pH at which the curve levels off is too low for KOH(aq) – a strong base.
 - B. The pH at which the curve levels off is too low for NaOH(aq) – a strong base, and the indicator would change colour before the endpoint.
 - C. Correct Answer
 - D. Because $\text{H}_2\text{SO}_4\text{(aq)}$ is a diprotic acid, the 20 mL of 0.1 M $\text{NH}_3\text{(aq)}$ would be required to reach the endpoint. Also phenolphthalein would change colour after the endpoint.

- Q19 A** Since component **I** moves the greatest distance along the chromatogram, it is less strongly attracted to the stationary phase than component **III** and would therefore be expected to have smaller molecules. Since component **III** moves the least distance along the chromatogram, its molecules are **less strongly attracted to the mobile phase** than the molecules of component **I**.



R_F = distance moved by component from origin / distance moved by solvent front from origin

$$R_F(\text{I}) = 24 / 26$$

$$= 0.92$$

$$R_F(\text{II}) = 14 / 26$$

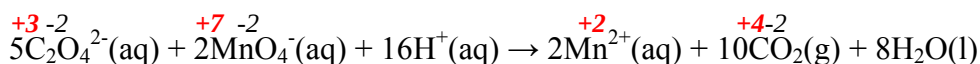
$$= \mathbf{0.54}$$

- Q20 D** $n(\text{C}_{12}\text{H}_{22}\text{O}_{11}) = 100 \times 10^6 \text{ g} / 342.0 \text{ g mol}^{-1}$
- $$= 2.92 \times 10^5 \text{ mol}$$
- $$n(\text{C}_{12}\text{H}_{22}\text{O}_{11}) \text{ in each chocolate} = 2.92 \times 10^5 / 50 \times 10^6$$
- $$= 5.85 \times 10^{-3} \text{ mol}$$
- $$N(\text{C}_{12}\text{H}_{22}\text{O}_{11}) \text{ in each chocolate} = 5.85 \times 10^{-3} \times 6.02 \times 10^{23}$$
- $$= \mathbf{3.5 \times 10^{21}}$$

SECTION B – Short Answer (Answers)

Question 1

- a. The reaction is a redox reaction because there are changes in oxidation numbers during the reaction



The **oxidation number of C increases from +3 to +4** as $\text{C}_2\text{O}_4^{2-}(\text{aq})$ is oxidised to $\text{CO}_2(\text{g})$ ❶

The **oxidation number of Mn decreases from +7 to +2** as $\text{MnO}_4^{-}(\text{aq})$ is reduced to $\text{Mn}^{2+}(\text{aq})$ ❶

The **oxidant $\text{MnO}_4^{-}(\text{aq})$** causes oxidation and is itself reduced; the **reductant $\text{C}_2\text{O}_4^{2-}(\text{aq})$** causes reduction and is itself oxidised. ❶

- b. $\text{C}_2\text{O}_4^{2-}(\text{aq})$ is oxidised to $\text{CO}_2(\text{g})$
 $\text{C}_2\text{O}_4^{2-}(\text{aq}) \rightarrow 2\text{CO}_2(\text{g}) + 2\text{e}^{-}$ ❶

- c. Concordant titres are with 0.1 mL of each other, so there are three concordant titres – 17.98, 18.07 and 18.16 mL
Average titre = $(17.98 + 18.07 + 18.16) / 3$
= **18.07 mL** ❶

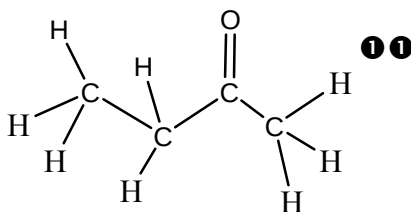
- d. $n(\text{Na}_2\text{C}_2\text{O}_4)$ in 500.0 mL flask = $0.2734 \text{ g} / 134.0 \text{ g mol}^{-1}$
= $2.040 \times 10^{-3} \text{ mol}$ ❶
 $n(\text{C}_2\text{O}_4^{2-})$ in 20.00 mL aliquot = $(2.040 \times 10^{-3} / 500) \times 20$
= $8.161 \times 10^{-5} \text{ mol}$ ❶
 $n(\text{MnO}_4^{-})$ in average titre = $2 \times n(\text{C}_2\text{O}_4^{2-}) / 5$
= $2 \times 8.161 \times 10^{-5} / 5$
= **$3.264 \times 10^{-5} \text{ mol}$** ❶

- e. Calculate the concentration of the potassium permanganate solution as a % (m/V).
 $n(\text{KMnO}_4)$ in average titre = $3.264 \times 10^{-5} \text{ mol}$
 $m(\text{KMnO}_4)$ in average titre = $3.264 \times 10^{-5} \text{ mol} \times 197.1 \text{ g mol}^{-1}$
= 0.06434 g ❶
% (m/V) KMnO_4 = $m(\text{KMnO}_4) / V(\text{average titre}) \times 100$
= $(0.06434 / 18.07) \times 100$
= **0.3561 %** ❶

- f. **Sodium hydroxide** ❶
Sodium hydroxide is deliquescent, i.e. it **absorbs water from the atmosphere**.
As a base it also **reacts with atmospheric carbon dioxide** which is an acidic oxide.
❶
As a consequence of these properties A sample of NaOH left exposed to the atmosphere will contain H_2O and NaHCO_3 .

Question 2

- a. Spectrum 1. ^{13}C NMR spectrum
 Spectrum 2. **High resolution ^1H NMR spectrum**
 Spectrum 3. **Infrared (IR) spectrum**
 Spectrum 4. **Mass spectrum**
- 1 1** for all four correct, **1** for two or three correct
- b. The molecules have **four different carbon environments**. **1**
 Can also deduce the presence of CH_3 – peak at 9 ppm, and CH_2 – peak at 30 ppm
- c. **Ethyl group (CH_3CH_2)** **1**
 The high resolution ^1H NMR spectrum shows a **quartet and a triplet**. The quartet indicates that the H atoms causing that peak have **3 neighbouring equivalent H atoms** ($n+1$ rule). The triplet indicates that the H atoms causing that peak have **2 neighbouring equivalent H atoms**. This is characteristic of the CH_3CH_2 group. **1**
- d. **O** is involved in a **double covalent bond with C**, i.e. in the **$\text{C}=\text{O}$** group. **1**
 The **strong peak just above 1700 cm^{-1}** **1** Table 7 in the Data Book indicates that $\text{C}=\text{O}$ produces an absorption peak in the range $1670\text{--}1750\text{ cm}^{-1}$.
- e. **72** **1**
 The highest m/e ratio on the mass spectrum usually corresponds to the relative molecular mass of the molecular ion.
- f. i. $\text{CH}_3\text{CH}_2\text{COCH}_3$



Relative mass of CH_3CH_2 is 29

Relative mass of $\text{C}=\text{O}$ is 28

Relative molecular mass = 72

So the remainder of the molecule has a relative mass of $72 - (29+28) = 15$.

Since the molecule has 4 C atoms, the rest must be a CH_3 group.

ii. **$[\text{CH}_3\text{CO}]^+$** **1**

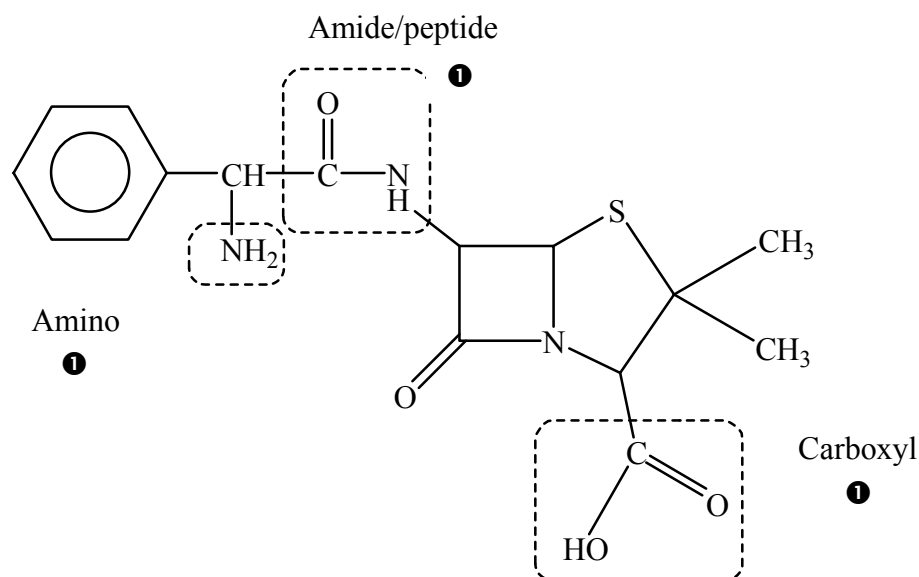
m/e of 43 is 29 less than the relative molecular mass of 72. This suggests a CH_3CH_2 has been chopped off the molecule, leaving behind the charged fragment, according to



In mass spectrometer only the charged species are detected and produce a peak.

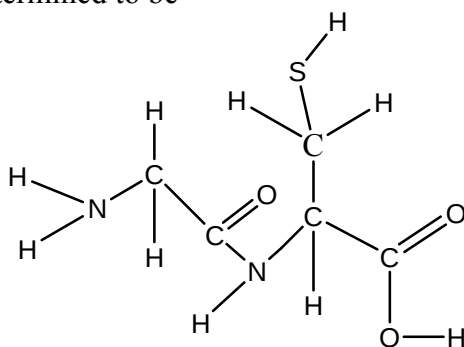
Question 3

a.

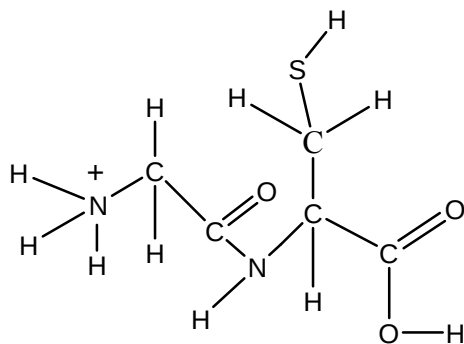


1 mark for each correct combination of highlighted functional group and name.

- b. A dipeptide is formed when two amino acids react together, hence **glycylcysteine** is a dipeptide formed when the -COOH group on glycine reacts with the -NH_2 group on cysteine to produce a linking peptide -CONH- group. Since the structures of glycine and cysteine are given in the Data Book, the structure of glycylcysteine may be determined to be

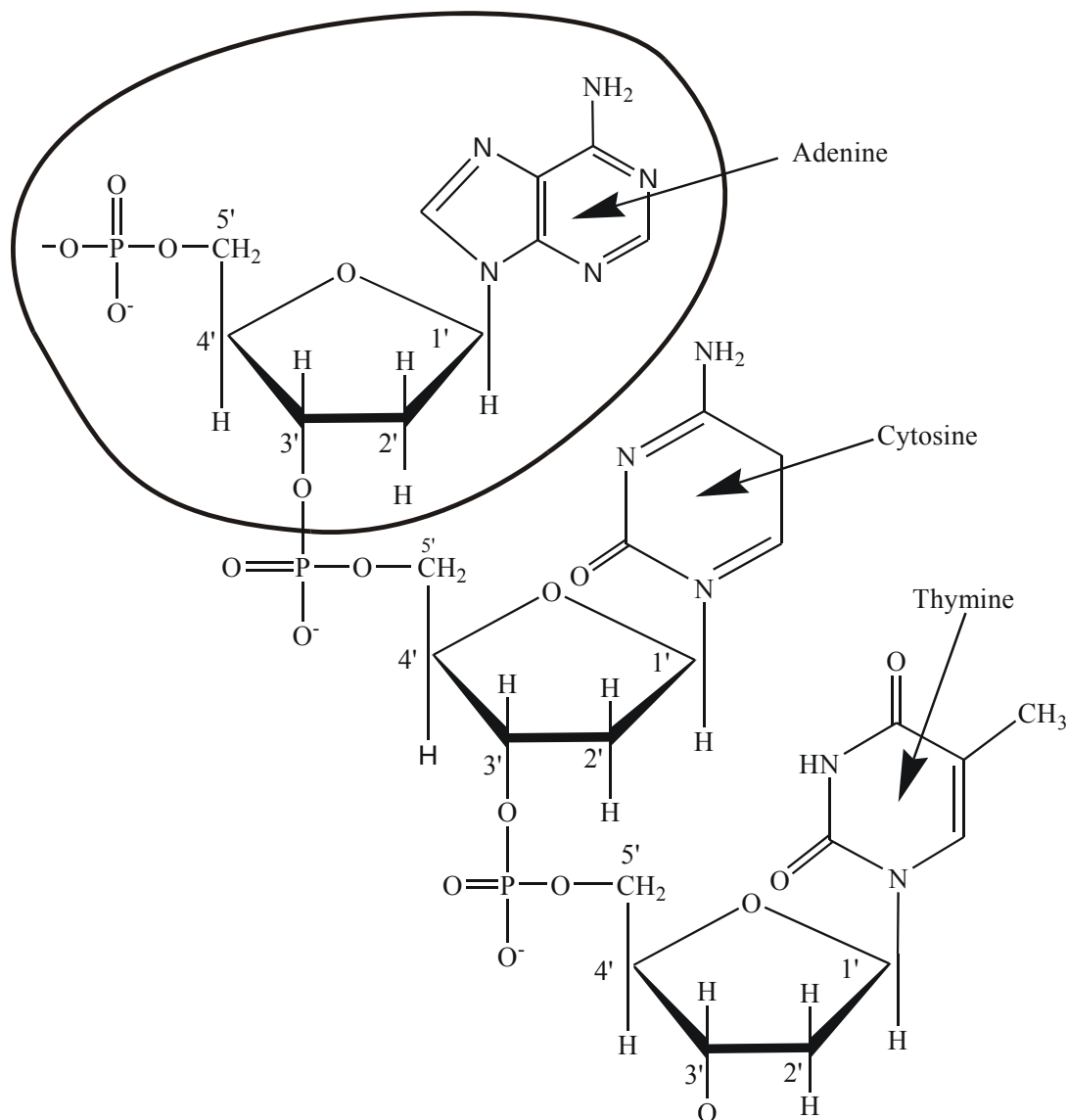


- i. However at pH 3, i.e. in an acidic environment, the amino, -NH_2 , group will be protonated so the structure at pH 3 will be



11 - one mark for the correct amino acids, one mark for the correct overall structure.

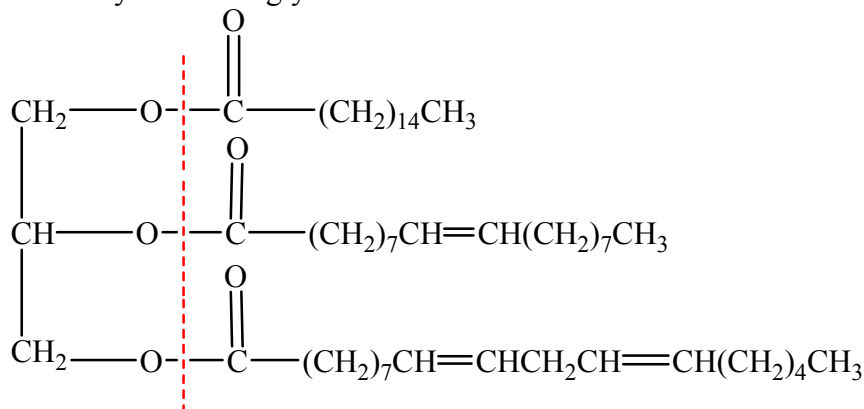
- ii. Since enzymes are proteins also produced from amino acids, then the **structures of enzymes and the dipeptide both contain the peptide group -CONH-** . 1



- c.
- See diagram ❶
 - Read the nitrogen base sequence from the top, using the Data Book to identify the nitrogen bases ❶
 - Hydrogen bonding ❶** between complementary bases, i.e. between Guanine (G) and Cytosine (C) and between Adenine (A) and Thymine (T) on adjacent strands.
The hydrogen in the G-C base pair is stronger than the hydrogen bonding in the A-T base pair because there are **three sites on each guanine and each cytosine molecule where hydrogen bonds can occur, but only two sites on adenine and thymine molecules**. So the **higher the proportion of G-C base pairs in DNA, the stronger the hydrogen bonding in the secondary structure. ❶**
- d. **Marker proteins. ❶**

Question 4

- a. i. The three fatty acids can be identified by recalling that the fat was formed by reaction between one of the hydroxyl, -OH, groups on glycerol and the carboxyl, -COOH group on each of the fatty acids. With an ester group formed in each case. During hydrolysis H_2O reacts across the ester groups releasing the fatty acids and glycerol.



Hence the three fatty acids are

$\text{CH}_3(\text{CH}_2)_{14}\text{COOH} \rightarrow \text{C}_{15}\text{H}_{31}\text{COOH}$ – **palmitic acid** ①

$\text{CH}_3(\text{CH}_2)_7\text{CH}=\text{CH}(\text{CH}_2)_7\text{COOH} \rightarrow \text{C}_{17}\text{H}_{33}\text{COOH}$ – **oleic acid** ①

$\text{CH}_3(\text{CH}_2)_7\text{CH}=\text{CHCH}_2\text{CH}=\text{CH}(\text{CH}_2)_4\text{COOH} \rightarrow \text{C}_{19}\text{H}_{31}\text{COOH}$ – **linoleic acid** ①

- ii. $\text{C}_{15}\text{H}_{31}\text{COOH(l)} + \text{CH}_3\text{OH(l)} \rightarrow \text{C}_{15}\text{H}_{31}\text{COOCH}_3\text{(l)} + \text{H}_2\text{O(l)}$ ①①

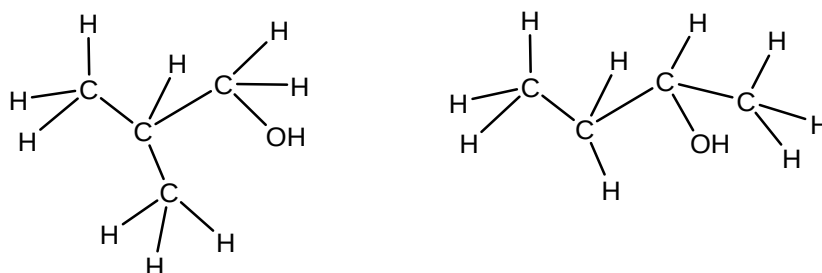
- b. i. Molecular formula of dodecane is $\text{C}_{12}\text{H}_{26}$
 $\text{C}_{12}\text{H}_{26}\text{(l)} + 18.5\text{O}_2\text{(g)} \rightarrow 12\text{CO}_2\text{(g)} + 13\text{H}_2\text{O(g or l)}$ or
 $2\text{C}_{12}\text{H}_{26}\text{(l)} + 37\text{O}_2\text{(g)} \rightarrow 24\text{CO}_2\text{(g)} + 26\text{H}_2\text{O(g or l)}$
One mark for all reactants and products correct. ①
One mark for correct balancing and correct states. ①

- ii. In fractional distillation, the fractions with smaller molecules are collected at lower temperatures so, on average, **petrol contains smaller lower molecular mass molecules** than jet fuel. ①
 The **temperature in a fractionating tower decreases moving up the column.** ① As the mixture rises up the tower the **jet fuel fraction** which has larger molecule compounds with **higher boiling temperatures, liquefies out before the petrol fraction because the temperature drops below their boiling temperatures first.** ① The petrol fraction of smaller molecule compounds continues to rise until the temperature drops below their boiling temperatures.

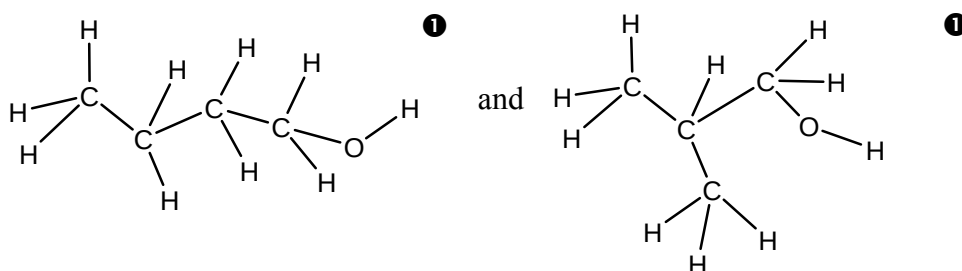
- c. i. **Fermentation** ①
 ii. Ethanol, $\text{CH}_3\text{CH}_2\text{OH}$, molecules have a polar region, -OH, and a non-polar region, CH_3CH_2 . ①
 This enables $\text{CH}_3\text{CH}_2\text{OH}$ to
 - **dissolve in petrol via dispersion force attraction with the non-polar molecules** ① in petrol
 - **dissolve in water via hydrogen bonding with the polar H_2O molecules** ①

Question 5

- 2-butanol** was most strongly attracted to the stationary because it has the **largest the retention time.** ①
- Ethanol has a unique retention time.** ① and so the amount present can be determined without it being affected by the amounts of the other substances present.
- To work out the amount of ethanol in an analysed sample, we need to calculate the **relationship between the area under the ethanol peak and ethanol concentration.** ① This can be obtained by measuring the peak area for standards of known ethanol concentration.
- $\text{CH}_3\text{CHOHCH}_3 \rightarrow \text{CH}_3\text{COCH}_3 + 2\text{H}^+ + 2\text{e}^-$** ①
- 2-methyl-2-propanol, $(\text{CH}_3)_3\text{COH}$ - peak 6, and 2-butanol, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$ – peak 8, are structural isomers with molecular formula $\text{C}_4\text{H}_{10}\text{O}$. The structures of these two isomers are represented below.



The structures of the **other two isomers showing all bonds** are



The names of these two isomers are **1-butanol** and **2-methyl-1-propanol** ①

- Since the ester has 4 C atoms but only 3 peaks on its ^{13}C NMR spectrum, two of the C atoms must be in the same bonding environment.
The ester is produced from an acid (produced from one of the alcohols) and an alcohol so the possible C atom combinations in the ester are
- 2 from the acid and 2 from the alcohol – ethanoic acid CH_3COOH and ethanol $\text{CH}_3\text{CH}_2\text{OH}$
- 3 from the acid and 1 from the alcohol – propanoic acid $\text{CH}_3\text{CH}_2\text{COOH}$ and methanol CH_3COOH
- 1 from the acid and 3 from the alcohol – methanoic acid HCOOH and either 1-propanol $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$ or 2-propanol $\text{CH}_3\text{CHOHCH}_3$.
Since only 2-propanol molecules have 2 carbon atoms in the same bonding environment, the compounds used to produce the ester are **methanol** (CH_3OH) ① from which methanoic acid is produced in the intermediate reaction, and **2-propanol** ($(\text{CH}_3)_2\text{CHOH}$) ①
 - 2-propyl methanoate, $\text{HCOOCH}(\text{CH}_3)_2$** ①

Question 6

a. i. $m(\text{H}) = m(\text{sample}) - [m(\text{C}) + m(\text{N}) + m(\text{O})]$
 $= 1.7321 - [0.2747 + 0.3205 + 1.0988]$
 $= 1.7321 - 1.694$
 $= \mathbf{0.0381 \text{ g} \text{ ①}}$

ii.	C	:	H	:	N	:	O	
mass ratio	0.2747	:	0.0381	:	0.3205	:	1.0988	g
mole ratio	0.2747/12.0	:	0.0381/1.0	:	0.3205/14.0	:	1.0988/16.0	
	0.0229	:	0.0381	:	0.0229	:	0.0687	mol ①
simplest ratio	0.0229/0.0229	:	0.0381/0.0229	:	0.0229/0.0229	:	0.0687/0.0229	
		:	9	:	9	:		
	1	:	1.67	:	1	:	3	①
	1	:	1 ² / ₃	:	1	:	3	
	1	:	5/3	:	1	:	3	
	3	:	5	:	3	:	9	

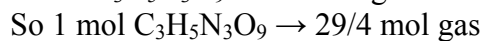
Empirical formula: $\mathbf{C_3H_5N_3O_9 \text{ ①}}$

iii. Empirical Formula mass - EFM $= 3 \times 12 + 5 \times 1 + 3 \times 14 + 9 \times 16$
 $= 277$

Molecular Formula $= [M_r / \text{EFM}] \times \text{Empirical Formula}$
 $= [227 / 277] \times \text{C}_3\text{H}_5\text{N}_3\text{O}_9$
 $= \mathbf{C_3H_5N_3O_9 \text{ ①}}$

b. $n(\text{C}_3\text{H}_5\text{N}_3\text{O}_9) = 50.1 \text{ g} / 227 \text{ g mol}^{-1}$
 $= 0.221 \text{ mol}$

According to the equation



$n(\text{gas}) = 29/4 \times n(\text{C}_3\text{H}_5\text{N}_3\text{O}_9)$
 $= 29/4 \times 0.221$
 $= 1.60 \text{ mol} \text{ ①}$

$p(\text{gas}) = n(\text{gas}) \times RT / V$
 $= 1.60 \times 8.31 \times (227+273) / 800 \times 10^{-3} \text{ ①}$
 $= 8.31 \times 10^3 \text{ kPa}$
 $= 8.31 \text{ MPa} \text{ ①}$

End of Suggested Answers