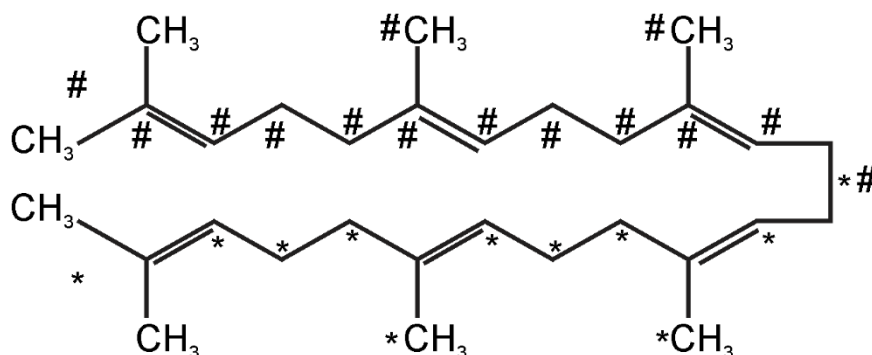


VCE Chemistry 2018 Year 12 Trial Exam Units 3/4

Q1. C The semi-structural formula of squalene is
 $(\text{CH}_3)_2\text{C}=\text{CHCH}_2\text{CH}_2\text{C}(\text{CH}_3)=\text{CHCH}_2\text{CH}_2\text{C}(\text{CH}_3)=\underset{\begin{array}{c} | \\ \text{CH}_2\text{CH}_2\text{C}(\text{CH}_3)=\text{CHCH}_2 \end{array}}{\text{CHCH}_2}$

The are no C atoms bonded to four different atom groups, hence **no chiral carbons**.

Squalene molecules are symmetrical as emphasised by the skeletal structure.

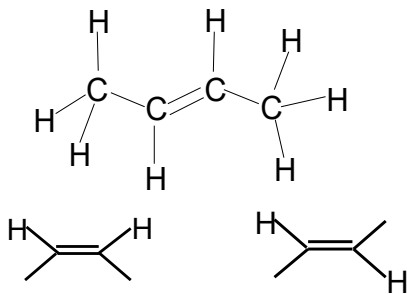


Squalene molecules have **14 carbon environments** – indicated by # on the skeletal structure.

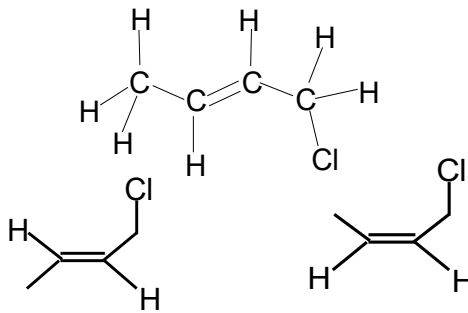
Q3. C The induced fit model of enzyme activity refers to the situation when **exposure to a substrate (reactant) causes the active site of the enzyme to change to a shape complementary to that of the substrate** to allow the interaction necessary for reaction to occur.

Q4. D

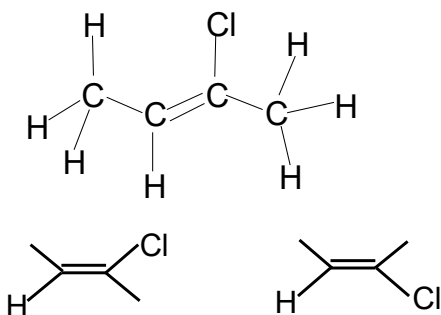
But-2-ene



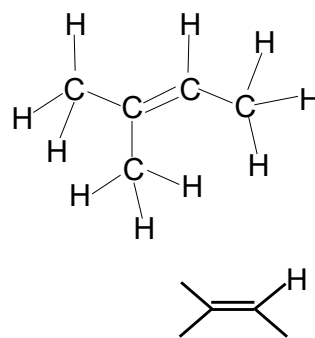
1-chlorobut-2-ene



2-chlorobut-2-ene



2-methylbut-2-ene



Q5. A Energy released during combustion = $4.18 \text{ J g}^{-1}\text{°C}^{-1} \times 200 \text{ g} \times 28.7\text{°C}$
 $= 2.40 \times 10^4 \text{ J}$
 $= 24.0 \text{ kJ}$

$$\begin{aligned} n(\text{hydrocarbon}) \text{ burnt} &= 24.2 \text{ kJ} / 2058 \text{ kJ mol}^{-1} \\ &= 0.0117 \text{ mol} \end{aligned}$$

$$M(\text{hydrocarbon}) = m / n = 0.49 / 0.0117 = 42 \text{ g mol}^{-1}$$

Relative molecular mass = 42

Q6. C The key piece of information is the direction of movement of the anion, $\text{NO}_3^-(\text{aq})$. In all electrochemical cells, anions move towards the anode which, in galvanic cells, is the **negative** electrode.

In all cells, the anode is the site of oxidation of the reductant which, in the $Y^+(aq) / Y(s)$ half-cell, is $Y(s)$.

The half-equation at the negative electrode is $\text{Y(s)} \rightarrow \text{Y}^+(\text{aq}) + \text{e}^-$

Q7. A. The amino acid is most likely to be the one with the greatest proportion of nitrogen atoms. Visual inspection of amino acid structures from the *VCE Chemistry Data Book (Table 17)* suggest **arginine**.

$$\text{Proportions by mass of N} = [m(\text{N}) / M(\text{amino acid})] \times 100$$

Arginine – $(56/174) \times 100 = 32 \%$

Asparagine – $(28/132) \times 100 = 21 \%$

Histidine – $(42/155) \times 100 = 27 \%$

Lysine – $(28/146) \times 100 = 19 \%$

Q8. D According to electrochemical series in *Table 2 of the VCE Chemistry Data Book*.

$$E^\circ (\text{Ag}^+/\text{Ag}) = 0.80 \text{ V}$$

$$E^\circ (\text{Pb}^{2+}/\text{Pb}) = -0.13 \text{ V}$$

$$E (\text{Ag}^+/\text{Ag} // \text{Pb}^{2+}/\text{Pb}) = 0.80 - (-0.13) = 0.93 \text{ V}$$

According to the information in the question we can deduce

$$E (\text{Ag}^+/\text{Ag} // \text{Y}^{3+}/\text{Y}) = 0.93 + 2.24 = 3.17 \text{ V}$$

Since $E^\circ (\text{Ag}^+/\text{Ag}) = 0.80 \text{ V}$, then $E^\circ (\text{Y}^{3+}/\text{Y})$ must be either $3.17 + 0.80$ i.e. 3.87 which would place it above $\text{F}_2(\text{g})/\text{F}^-(\text{aq})$ on the table of electrode potentials, or $0.80 - 3.17 = -2.37 \text{ V}$.

$$\begin{aligned} E^\circ (\text{Y}^{3+}/\text{Y}) &= E^\circ (\text{Ag}^+/\text{Ag}) - E(\text{cell}) = 0.80 - 3.17 \\ &= -2.37 \text{ V} \end{aligned}$$

So, expand the electrochemical series to

$$E^\circ (\text{Ag}^+/\text{Ag}) = 0.80 \text{ V}$$

$$E^\circ (\text{Pb}^{2+}/\text{Pb}) = -0.13 \text{ V}$$

$$E^\circ (\text{Y}^{3+}/\text{Y}) = -2.37 \text{ V}$$

$$\begin{aligned} E^\circ (\text{Pb}^{2+}(\text{aq})/\text{Pb}(\text{s}) // \text{Y}^{3+}(\text{aq})/\text{Y}(\text{s})) &= -0.13 - (-2.37) \\ &= 2.24 \text{ V} \end{aligned}$$

$$\begin{aligned} E(\text{Tl}^+(\text{aq})/\text{Tl}(\text{s}) // \text{Y}^{3+}(\text{aq})/\text{Y}(\text{s})) &= 2.24 - 0.21 \text{ V} \\ &= 2.03 \text{ V} \end{aligned}$$

$E^\circ (\text{Tl}^+/\text{Tl})$ is either 2.03 more or 2.03 less than $E^\circ (\text{Y}^{3+}/\text{Y})$, i.e. -0.34 V or -4.40 V . The latter is unlikely since it would place $\text{Tl}^+(\text{aq})/\text{Tl}(\text{s})$ below $\text{Li}^+(\text{aq})/\text{Li}(\text{s})$.

So, $E^\circ (\text{Tl}^+/\text{Tl}) = -0.34$.

Electrochemical series becomes

$$E^\circ (\text{Ag}^+/\text{Ag}) = 0.80 \text{ V}$$

$$E^\circ (\text{Pb}^{2+}/\text{Pb}) = -0.13 \text{ V}$$

$$E^\circ (\text{Tl}^+/\text{Tl}) = -0.34 \text{ V}$$

$$E^\circ (\text{Y}^{3+}/\text{Y}) = -2.37 \text{ V}$$

Strongest reductant is Y

Q9. B $c(\text{ethanol})$ in dilute mixture = $0.430 \text{ \% (m/V)}$

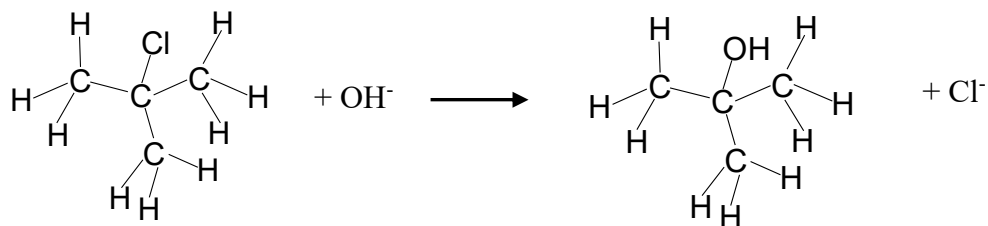
$$\begin{aligned} c(\text{ethanol}) \text{ in original fermentation mixture} &= (500/20) \times 0.430 \\ &= 10.8 \text{ \% (m/V)} \end{aligned}$$

$$= 10.8 \text{ g in } 100 \text{ mL}$$

$$\begin{aligned} m(\text{CH}_3\text{CH}_2\text{OH}) \text{ in } 100 \text{ mL} &= 10.8 \text{ g} / 46.0 \text{ g mol}^{-1} \\ &= 0.234 \text{ mol} \end{aligned}$$

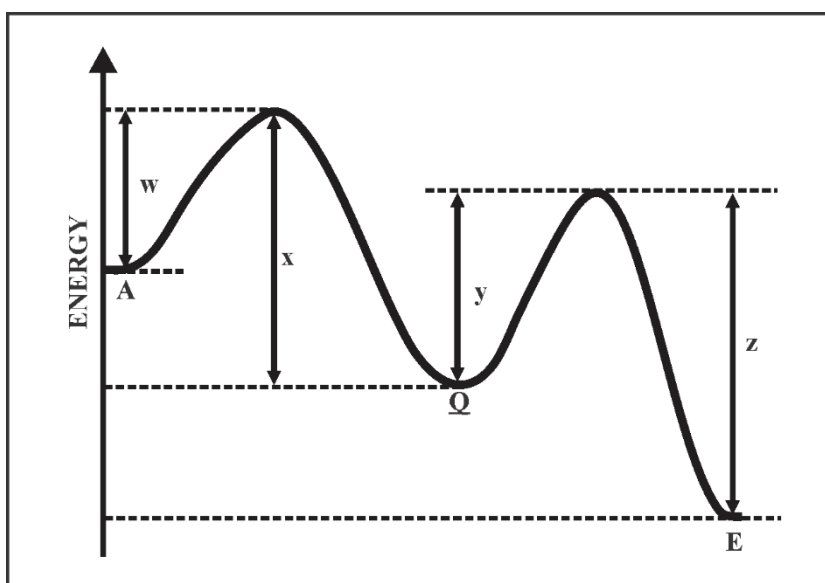
$$c(\text{CH}_3\text{CH}_2\text{OH}) = 2.34 \text{ mol L}^{-1}$$

Q10. A In NaOH(aq), 2-chloromethylpropane will be converted to methylpropan-2-ol



As the $[\text{OH}^-]$ decreases due to the reaction, the **pH will decrease.**

Q11. B Consider the two stages of the conversion of A to E.



Energy change $A \rightarrow Q = \mathbf{x} - \mathbf{w}$

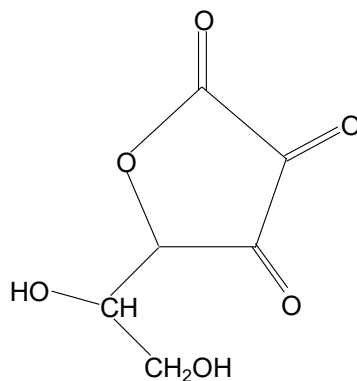
Energy change $Q \rightarrow E = \mathbf{z} - \mathbf{y}$

Total energy change $A \rightarrow E$ $= x - w + z - y$
 $= \underline{x + z - w - y}$

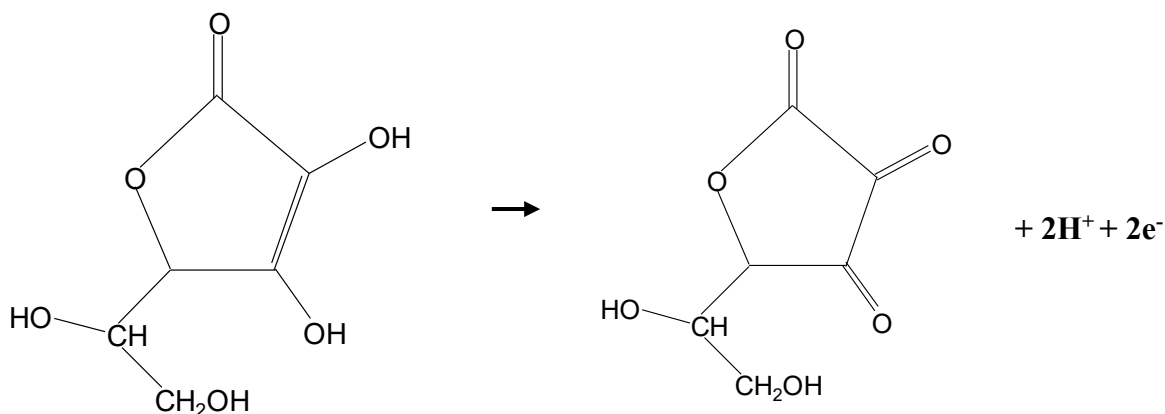
Q12. B The structure of ascorbic acid is given in the *Table 17 of the VCE Chemistry Data Book*.

The loss of hydrogen in the oxidation to dehydroascorbic acid indicates that H^+ ions will be released during the oxidation. In the oxidation half-equation, the charge on the H^+ ions will be balanced by electrons so the overall charge on ascorbic acid remains zero.

The only structure consistent with the half-equation will be

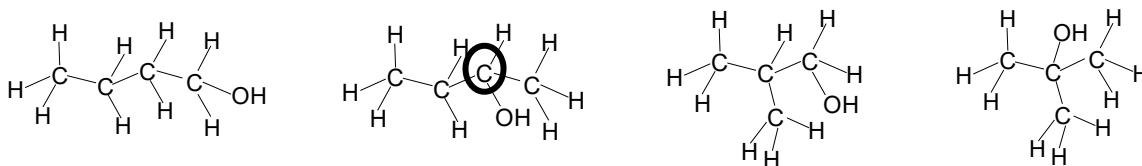


The half-equation for the oxidation is

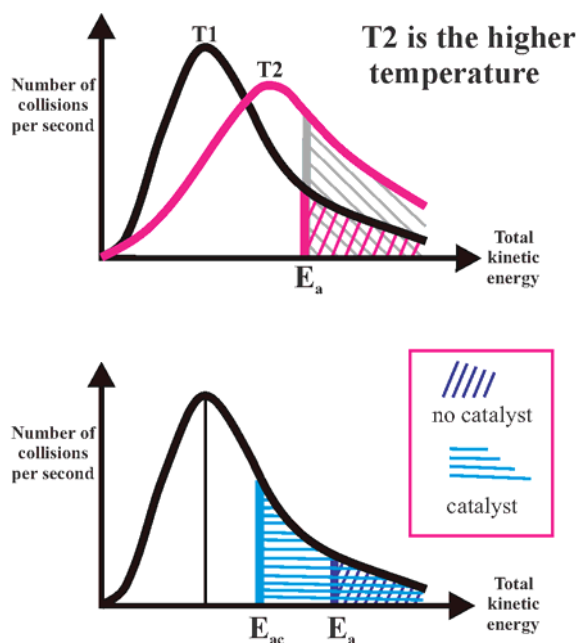


Q13. B To exist as a racemic mixture the substance must have two stereo isomers resulting from one chiral centre.

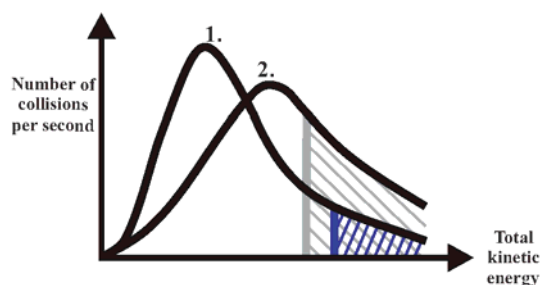
Only butan-2-ol has a chiral centre, i.e. a carbon bonded to four different atoms or groups of atoms.



- Q14. C** The effect of an increase in temperature on reaction rate and a catalyst on reaction is represented in the Maxwell-Boltzmann distribution curves shown below.



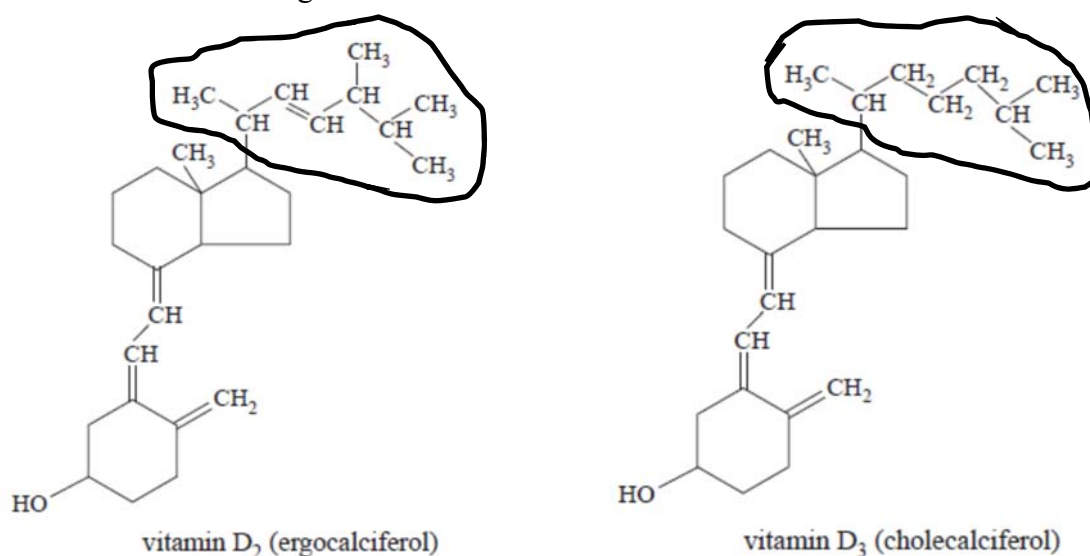
These curves are combined in the curves for conditions 1. and 2., i.e.



So, the conditions at 2. involve a **higher temperature and the presence of a catalyst**.

- Q15. A** Equation for titration reaction
 $\text{CH}_3(\text{OH})\text{COOH}(\text{aq}) + \text{NaOH}(\text{aq}) \rightarrow \text{CH}_3(\text{OH})\text{COONa}(\text{aq}) + \text{H}_2\text{O}(\text{l})$
 $n(\text{NaOH}) \text{ used} = 0.150 \text{ mol L}^{-1} \times 13.2 \times 10^{-3} \text{ L}$
 $= 1.98 \times 10^{-3} \text{ mol}$
 $m(\text{lactic acid}) = 1.98 \times 10^{-3} \text{ mol} \times 90.0 \text{ g mol}^{-1}$
 $= 0.178 \text{ g}$
 $m(\text{milk}) = 25.0 \text{ mL} \times 1.03 \text{ g mL}^{-1}$
 $= 25.8 \text{ g}$
 $\% \text{ lactic acid} = (0.178 / 25.8) \times 100$
 $= 0.692 \% \text{ (m/m)}$

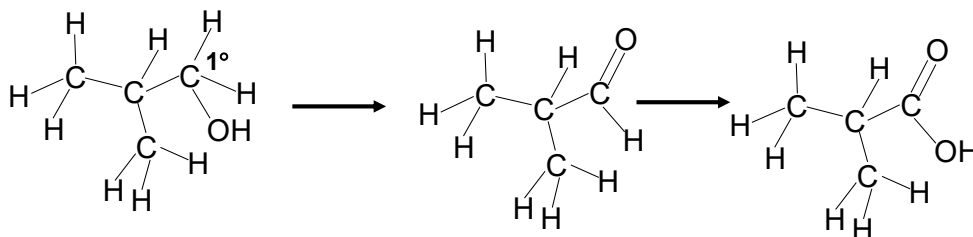
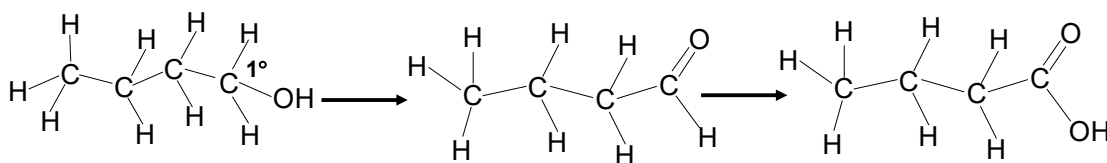
- Q16. D** The structures of vitamin D₂ and vitamin D₃ are shown in Table 10 in the **VCE Chemistry Data Book**. The difference between structures is in the hydrocarbon chains attached to the ring structure.



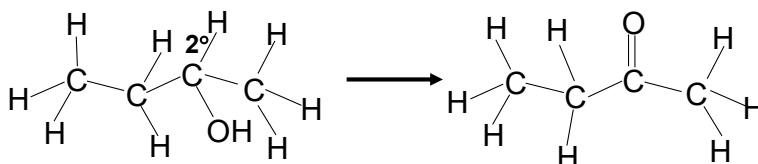
The formulae of the respective side chains are **C₉H₁₇** and **C₈H₁₇**.
 The extra carbon atom in vitamin D₂ means that its intermolecular dispersion force attraction will be stronger and its melting temperature higher.

- Q17. B** The chemical shift of a H or C atom in a molecule on a ¹H or ¹³C NMR spectrum is determined by the relative strength of the external magnetic field experienced by the atoms. Exposure to the magnetic field is reduced by the shielding effect of electrons surrounding the atom in the bonded state. This shielding effect is reduced by the presence of more electronegative atoms in the molecule which means the nuclei are exposed to a stronger magnetic field. Consequently, the **energy gap between the two nuclear spins states increases and so does the chemical shift.**

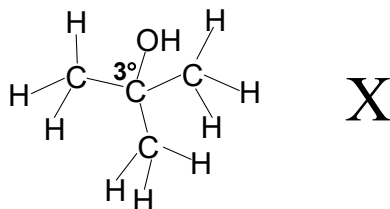
- Q18. D** In the presence of acidified dichromate,
- primary alcohols – **propan-1-ol** and **methylpropan-1-ol** – are oxidised to **aldehydes** and carboxylic acids



- secondary alcohols – **propan-2-ol** – are oxidised to ketones



- tertiary alcohols – **methylpropan-2-ol** – are not oxidised



Hence methylpropan-2-ol will require the least amount of acidified dichromate.

Q19. B $\text{H}_2 + \text{CO} \rightarrow \text{C}_n\text{H}_{2n+2} + \text{H}_2\text{O}$

$\text{H}_2 + n \text{CO} \rightarrow \text{C}_n\text{H}_{2n+2} + \text{H}_2\text{O}$

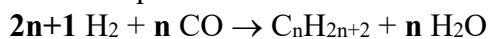
$\text{H}_2 + n \text{CO} \rightarrow \text{C}_n\text{H}_{2n+2} + n \text{H}_2\text{O}$

Total number of H atoms on right = $2n+2 + 2n$
= $4n+2$

Number of H atoms required on left = $4n + 2$

Number of H₂ molecules required on left = $(4n+2) / 2$
= $2n+1$

Overall equation



Q20. B The accuracy of the determined $c(\text{CH}_3\text{COOH})$ depends on how close it is to the true value.
 The precision depends on the reproducibility of the data collected under the same conditions.
 It **cannot be claimed** that the result is **accurate** because there may be a flaw in the technique or a significant systematic error.
 However, **multiple repetition** of the same experimental technique under the same conditions should eliminate any random error and provide **results that are close together, i.e. precise**.

Q21. A The equation for the reaction is
 $\text{Na}_2\text{CO}_3(\text{aq}) + 2\text{HCl}(\text{aq}) \rightarrow 2\text{NaCl}(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
 The $c(\text{HCl})$ is determined via the calculation sequence
 $V(\text{Na}_2\text{CO}_3) \times c(\text{Na}_2\text{CO}_3) \rightarrow n(\text{Na}_2\text{CO}_3) \times 2 \rightarrow n(\text{HCl}) \div V(\text{HCl}) \rightarrow c(\text{HCl})$
 Rinsing the pipette with water only, rather than with water followed by sodium carbonate solution – the correct technique - will mean that the calculated $n(\text{Na}_2\text{CO}_3)$ will be higher than the true value because of dilution by residual water in the pipette. This means the calculated $n(\text{HCl})$ and subsequently $c(\text{HCl})$ will be too high.
 Alternatively, the lower concentration of Na_2CO_3 in the pipette will lead to a smaller $V(\text{HCl})$ in the titre which leads to a higher calculated $c(\text{HCl})$.
 This means Megan's calculated value of the $c(\text{HCl})$ will be higher than Harry's calculated value.
 Since the $V(\text{HCl})$ reacting is determined by subtracting the initial burette reading from the final burette reading, it cannot be determined how reading from the top rather than the bottom of the meniscus -the preferred technique - impacted on Harry's calculated result.

Q22. D. The glycaemic index of a food effectively represents the rate of hydrolysis of carbohydrates in food to glucose since it is a scale which ranks foods according to their effect on blood sugar levels over a 2-hour period after consumption.
 However, the glycaemic index does not take into account the variation in relative amount of carbohydrate in each food in a meal.
 The actual amount of carbohydrate in each food in the meal has been added to the table as shown below.

Food	Carbohydrate content g / 100 g	Actual amount of carbohydrate g	Glycaemic index
Wholemeal bread – 84 g	47	39.5	59
Avocado – 50 g	4	2.0	10
Omelette – 200 g	0	0	-
Chips – 100 g	20.1	20.1	85
Watermelon – 150 g	4	6	76

Although the 'chips' have the highest glycaemic index it does not have the greatest impact on blood sugar levels in **that** meal because there is almost twice as much carbohydrate available from the wholemeal bread. This, considered in conjunction with the relative glycaemic indices, shows that wholemeal bread has the highest glycaemic load in the meal.

Glycaemic load (GL) of a food stuff can be calculated via

$$\text{GL} = (\text{GI} \times \text{amount of carbohydrate}) / 100$$

$$\text{Wholemeal bread} = 59 \times 39.5 / 100 = 23$$

$$\text{Avocado} = 10 \times 2.0 / 100 = 0.20$$

$$\text{Chips} = 85 \times 20.1 / 100 = 17$$

$$\text{Watermelon} = 76 \times 6 / 100 = 4.6$$

Q23. C Use the composition data to determine the empirical formula of the compound

$$\begin{aligned}
 m(\text{O}) &= m(\text{sample}) - [m(\text{C}) + m(\text{H})] \\
 &= 0.886 - [0.0402 \times 12.0 + 0.0806 \times 1.0] \\
 &= 0.886 - [0.483 + 0.0806] \\
 &= 0.322 \text{ g} \\
 n(\text{O}) &= 0.322 / 16.0 \\
 &= 0.0201 \text{ mol}
 \end{aligned}$$

Mole ratio

C	:	H	:	O
0.0402	:	0.0806	:	0.0201
2	:	4	:	1

Empirical formula C₂H₄O

Molecules of all the alternatives

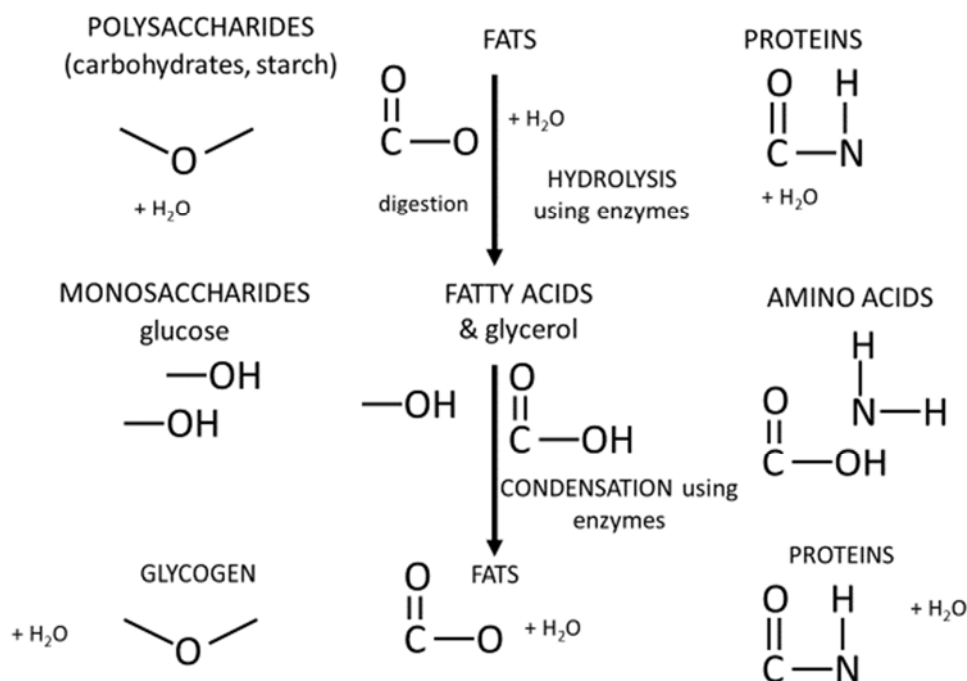
- butanoic acid (CH₃CH₂CH₂COOH),
- methyl propanal [(CH₃)₂CHCHO],
- methyl propanoate (CH₃CH₂COOCH₃) and
- butan-2-one (CH₃CH₂COCH₃)

all contain 4 carbon atoms, so the **molecular formula of the compound is C₄H₈O₂**

This is consistent with only **butanoic acid** and **methyl propanoate**.

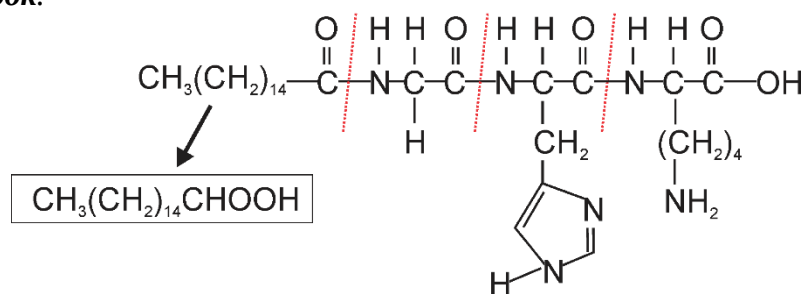
IR spectrum does not show a peak in the absorption band 2500-3500 cm⁻¹ for OH(acid). It does show a peak in the absorption band 1720-1840 cm⁻¹ for C=O esters. Compound is **methyl propanoate**.

Q24. B A more detailed version of the summary diagram showing functional group changes is given below

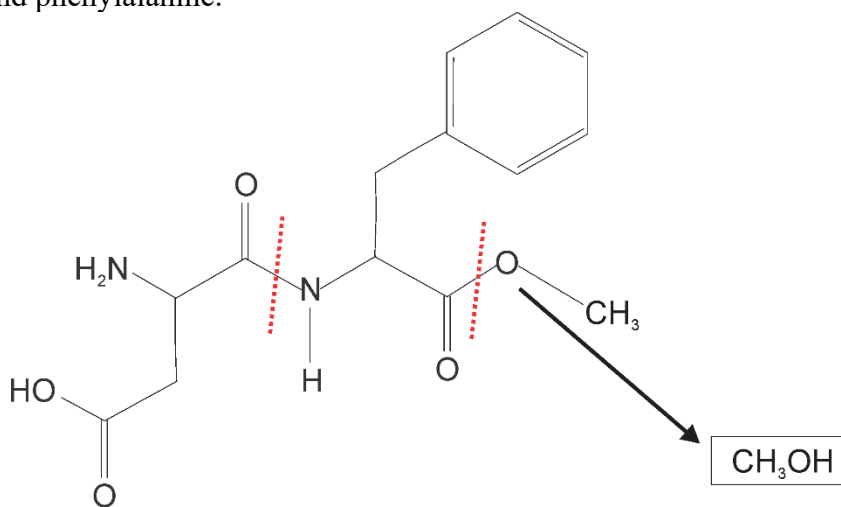


There are total of **six** functional groups involved – hydroxyl, ether(glycoside), ester, carboxyl, amide (peptide) and amino.

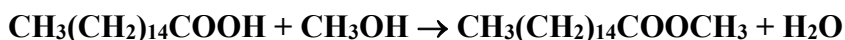
- Q25. C** Hydrolysis of **Palmitoyl-GHK** will release **palmitic acid**, $\text{CH}_3(\text{CH}_2)_{14}\text{COOH}$ and **three amino acids** – glycine, histidine and lysine - identified from Table 17 in **VCE Chemistry Data Book**.



Hydrolysis of **Aspartame** will release **methanol**, CH_3OH , and **two amino acids** – aspartic acid and phenylalanine.

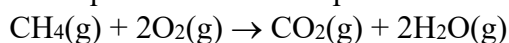


Under appropriate conditions, **palmitic acid** can react with **methanol** to produce methyl palmitate – a **biodiesel**.



In alkaline conditions **palmitoyl-GHK** and **Aspartame** will assume a charge of **-1** as **both have a single carboxyl group that can be deprotonated**, but no acid side chains on their amino acid side chains.

- Q26. D** The equation for the complete combustion of methane is



Since 1 mol CH_4 reacts with 2 mol $\text{O}_2(\text{g})$ to give 1 mol $\text{CO}_2(\text{g})$ and 2 mol $\text{H}_2\text{O}(\text{g})$, then since all volumes are measured at the same temperature and pressure the volume ratio for reaction is the same as the mole ratio in the equation.

So, 120 mL CH_4 reacts with 240 mL O_2 to give 120 mL CO_2 and 240 mL H_2O

CH_4 , CO_2 and H_2O are all greenhouse gases.

Initial volume greenhouse gases = $V(\text{CH}_4)$

$$= 120 \text{ mL}$$

Final volume greenhouse gases = $V(\text{CO}_2) + V(\text{H}_2\text{O})$

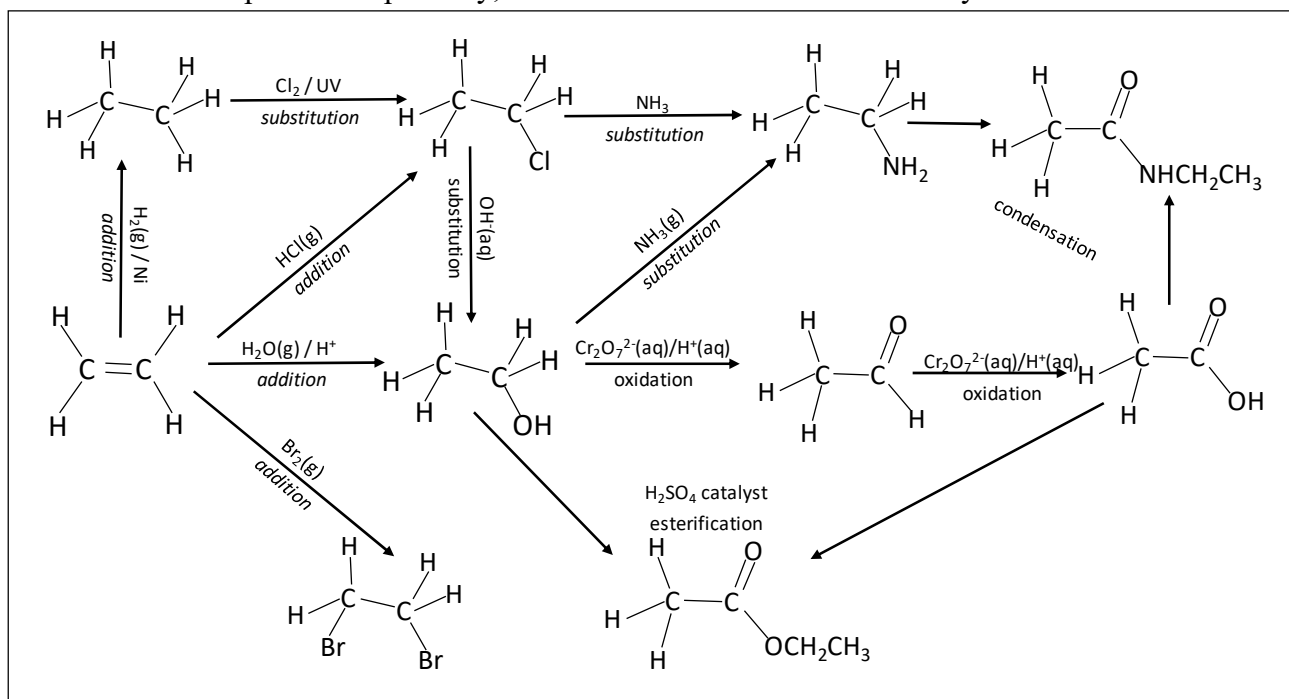
$$= 120 \text{ mL} + 240 \text{ mL}$$

$$= 360 \text{ mL}$$

Change in volume of greenhouse gases is an **increase of 240 mL**.

- Q27. C** According to Table 11 of the *VCE Chemistry Data Book*, the heats of combustion of the compounds in M15 are
 Methanol 22.7 kJ g^{-1}
 Octane 47.9 kJ g^{-1}
 M15 is 15 % methanol and 85 % octane
 $V(\text{CH}_3\text{OH})$ in 50 L M15 = $0.15 \times 50 = 7.5 \text{ L}$
 $m(\text{CH}_3\text{OH}) = d \times V = 792 \text{ g L}^{-1} \times 7.5 \text{ L}$
 $= 5940 \text{ g}$
 $V(\text{C}_8\text{H}_{18})$ in 50 L M15 = $0.85 \times 50 = 42.5 \text{ L}$
 $m(\text{C}_8\text{H}_{18}) = d \times V = 703 \text{ g L}^{-1} \times 42.5 \text{ L}$
 $= 2.99 \times 10^4 \text{ g}$
 Total energy contained = $5940 \text{ g} \times 22.7 \text{ kJ g}^{-1} + 2.99 \times 10^4 \text{ g} \times 47.9 \text{ kJ g}^{-1}$
 $= 1.35 \times 10^5 \text{ kJ} + 1.43 \times 10^6 \text{ kJ}$
 $= 1.6 \times 10^6 \text{ kJ}$

- Q28. B** HBr is not part of the pathway, as indicated in the detailed summary below.



Q29. C

$$Q = It$$

$$I = 85.6 \mu\text{A} = 85.6 \times 10^{-6} \text{ A}$$

$$t = 10.0 \text{ years}$$

$$= 10.0 \times 365 \times 24 \times 60 \times 60 \text{ seconds}$$

$$= 3.15 \times 10^8 \text{ s}$$

$$Q = 3.15 \times 10^8 \times 85.6 \times 10^{-6}$$

$$= 2.70 \times 10^4 \text{ C}$$

$$n(e^-) = Q / F = 2.70 \times 10^4 / 96500$$

$$= 0.280 \text{ mol}$$

Oxidation half-equation $\text{Li} \rightarrow \text{Li}^+ + e^-$

$$n(\text{Li}) = 0.280 \text{ mol}$$

$$m(\text{Li}) = 0.280 \text{ mol} \times 6.9 \text{ g mol}^{-1}$$

$$= \mathbf{1.93 \text{ g}}$$

Q30. B Species present in an aqueous solution of sodium chloride are $\text{Na}^+(\text{aq})$, $\text{Cl}^-(\text{aq})$ and $\text{H}_2\text{O}(\text{l})$. According to the power supply notation, **electrode A** is (-) and **electrode B** is (+). The products of the electrolysis of $\text{NaCl}(\text{aq})$ can be deduced from the electrochemical series

$\text{Cl}_2(\text{g}) + 2e^- \rightarrow 2\text{Cl}^-(\text{aq})$	1.36 V
$\text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4e^- \rightarrow 2\text{H}_2\text{O}(\text{l})$	1.23 V
$2\text{H}_2\text{O}(\text{l}) + 2e^- \rightarrow \text{H}_2(\text{g}) + 2\text{OH}^-(\text{aq})$	-0.83 V
$\text{Na}^+(\text{aq}) + e^- \rightarrow \text{Na}(\text{s})$	-2.71 V

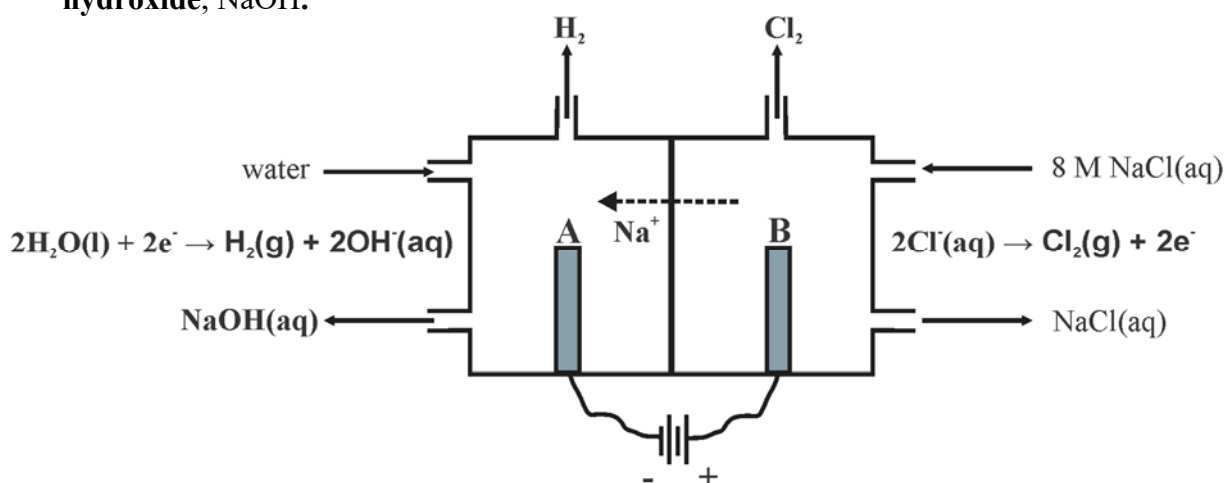
$\text{H}_2\text{O}(\text{l})$ will be reduced at the cathode, which is the negative electrode in electrolysis. At the anode – the positive electrode - depending on the $c(\text{Cl}^-)$, $\text{H}_2\text{O}(\text{l})$ and/or $\text{Cl}^-(\text{aq})$ will be oxidised. Under standard conditions, $\text{O}_2(\text{g})$ will be produced, at high $c(\text{Cl}^-)$, $\text{Cl}_2(\text{g})$ will be produced. This reflects the relative similarities in the reducing strengths of $\text{H}_2\text{O}(\text{l})$ and $\text{Cl}^-(\text{aq})$.

Half-equations for the electrolysis of 8 M $\text{NaCl}(\text{aq})$ are

(+) electrode: $2\text{Cl}^-(\text{aq}) \rightarrow \text{Cl}_2(\text{g}) + 2e^-$

(-) electrode: $2\text{H}_2\text{O}(\text{l}) + 2e^- \rightarrow \text{H}_2(\text{g}) + 2\text{OH}^-(\text{aq})$

So, the compound extracted from the half of the cell containing the (-) electrode is **sodium hydroxide**, NaOH .



SECTION B – Short Answer (Answers)

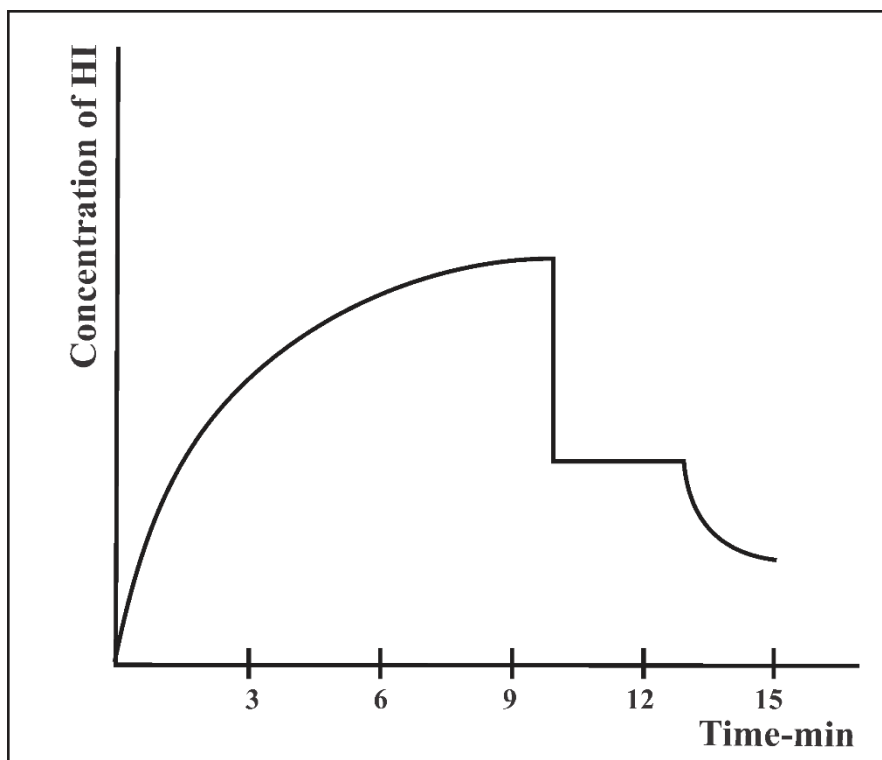
Question 1 (11 marks)

- a. Mass of spirit of burner before heating the water & mass of spirit burner after heating water for all four alcohols. ❶
Temperature change of the water in the can. ❶
- b. Molecular mass / molar mass of the alcohols. ❶
The independent variable is the one varied during the investigation and the different alcohols have different have different molar masses / molecular sizes.
- c. One of. ❶
Volume (mass) of water being heated.
Distance between burner and water container.
Length of wick extended from burner.
Amount of stirring of water.
Controlled variables are factors which are kept as constant as possible to ensure the best outcome of the relationship between the dependent variable – heat of combustion – and independent variable – molecule size – is produced.
- d. Energy absorbed by water = $4.18 \text{ J g}^{-1} \text{ }^{\circ}\text{C}^{-1} \times 200 \text{ g} \times 21.2 \text{ }^{\circ}\text{C}$
 $= 1.77 \times 10^4 \text{ J}$ ❶
 $n(\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}) = 0.936 \text{ g} / 60.0 \text{ g mol}^{-1}$
 $= 1.56 \times 10^{-2} \text{ mol}$
Molar heat of combustion = $1.77 \times 10^4 \text{ J} / 1.56 \times 10^{-2} \text{ mol}$
 $= 1.14 \times 10^6 \text{ J mol}^{-1}$
 $= 1.14 \times 10^3 \text{ kJ mol}^{-1}$ ❶
- e. During the combustion of the alcohols the **total energy released depends on the total number of C-C and C-H bonds which are broken and the total number of C=O and O-H bonds formed**. The energy released reflects the difference between the energy released when C=O and O-H bonds are formed and the energy used in breaking C-C and C-H bonds. ❶ The larger the alcohol molecules, the greater the numbers of C-C and C-H bonds broken and C=O and O-H bonds formed and the larger the amount of energy released in the combustion of one mole of the alcohol. ❶
- f. The equipment set up does not maximise the transfer of energy released by combustion of the alcohol to the water, hence the calculated energy absorbed by the water is less than the energy released during combustion.
Possible modifications could be
- **putting a lid on the container** to reduce heat loss from the water *or*
- adding a protective shield around the burner to **reduce heat loss to the surroundings**. ❶
- g. % efficiency = [(calculated heat of combustion) / (actual* heat of combustion)] $\times 100$
 $= (871 / 1360) \times 100$
 $= 64.0 \%$ ❶
(* - from *VCE Chemistry Data Book*)
- h. The calorimeter incorporates energy absorbed by the reaction bomb material, the stirrer and thermometer. This is not accounted for in the experimental technique used. ❶

Question 2 (10 marks)

- a. $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g})$ ①
- b. The concentrations of H_2 and I_2 decrease and the concentration of HI increases until there is no change after 9.0 minutes. The data also shows that the rate of the forward reaction decreases with time since the changes in amounts of amount of H_2 and I_2 reacting, and HI produced, become increasingly smaller. ① This is consistent with the decreasing number of reactant collisions as the $[\text{H}_2]$ and $[\text{I}_2]$ are decreasing. However, as the $[\text{HI}]$ is increasing, the rate of the reverse reaction is increasing until the point is reached, around 9.0 minutes, when the rates of the forward and reverse reactions are equal and there is no further change in amounts of reactants or product as the system has reached equilibrium. ①
- c. $K = \frac{[\text{HI}]^2}{[\text{H}_2][\text{I}_2]}$ ①
 $= \frac{(n(\text{HI})/V)^2}{\{ (n(\text{H}_2)/V) \times (n(\text{I}_2)/V) \}}$
 $= \frac{n(\text{HI})^2}{\{n(\text{H}_2) \times n(\text{I}_2)\}}$
 $= 1.56^2 / (0.22 \times 0.22)$
 $= 50.3$ ①
- There are the same number of particles on both sides of the equilibrium, so*
- i. the actual volume of the container is not needed to calculate K_c since V effectively cancels out.
- ii. K does not have any units.
- d. The volume increase would cause all concentrations to decrease and decrease the total pressure. However, because there are the same number of particles on both sides of the equilibrium it cannot shift to compensate for these changes, hence the amounts of reactants and products present do not change. ①
- The decrease in temperature would cause the system to compensate by favouring the exothermic reaction. According to the data changes following the temperature decrease, this was the reverse reaction. ①

e.

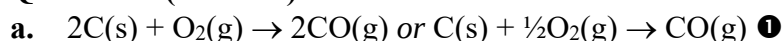


The $[HI]$ starts at zero and increases as the system heads to equilibrium at the 9 minute mark. The rate of increase falls as the $[H_2]$ and $[I_2]$ decrease. $[HI]$ is constant between 9 and 10 minutes. ❶

At the 10-minute mark the $[HI]$ halves due to the volume doubling and remains at that new level up to the 13-minute mark. ❶

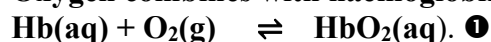
Between 13 minutes and 15 minutes the $[HI]$ decreases as the reverse reaction is favoured by the temperature decrease. ❶

Question 3 (5 marks)

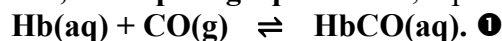


- b. Exposure to CO can affect the capacity of haemoglobin in the blood to carry O_2 to cells in the body.

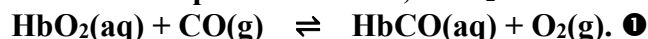
Oxygen combines with haemoglobin via an equilibrium represented by the equation:



However, haemoglobin combines more readily with CO than O_2 and so in the presence of CO, a competing equilibrium, represented by the equation below, is set up.

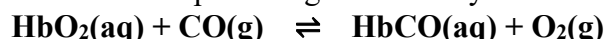


The Hb/CO equilibrium has a much higher equilibrium constant than the Hb/ O_2 equilibrium and so in the presence of CO, HbO_2 is forced to release its O_2 , according to



Consequently, CO is carried to the cells by haemoglobin rather than the necessary O_2 .

- c. Non-fatal CO poisoning is treated by breathing pure oxygen, which causes the equilibrium



to shift to the left and the carriage of O_2 to the by Hb is enhanced. ❶

Question 4 (13 marks)

- a. Both **α -linolenic** and **γ -linolenic** acids are polyunsaturated fatty acids with 3 C=C double bonds. The key structural difference is the **location of the 3 C=C double bonds (or the 3 CH=CHCH₂ moieties) in the hydrocarbon chain**. The **omega classification** is dependent on **location of the C=C double bond furthest from the carboxyl group**. ❶

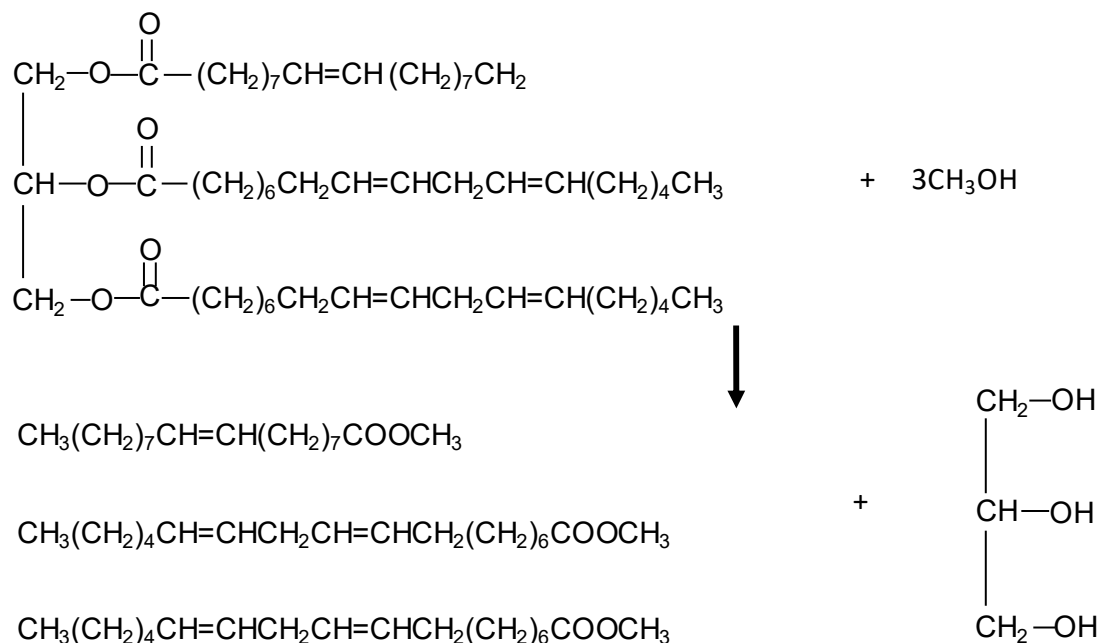
α -linolenic acid –

CH₃CH₂CH=CHCH₂CH=CHCH₂CH=CHCH₂CH₂CH₂CH₂CH₂CH₂COOH is **Omega-3 (ω -3)**

γ -linolenic acid –

CH₃CH₂CH₂CH₂CH₂CH=CHCH₂CH=CHCH₂CH=CHCH₂CH₂CH₂CH₂COOH is **Omega-6 (ω -6)**

b.



- ❶ for correct fat structure
 ❶ for correct number of methanol molecules.
 ❶ for three correct methyl ester formulae.
- c. **No.** CO₂ is produced from the combustion of both the biodiesel and petrodiesel components of the blended fuel used in the flight. However, **the biodiesel produced from mustard seed oil is effectively sourced from plants and the CO₂ emissions from its combustion are offset by the CO₂ absorbed from the atmosphere during photosynthesis in the growth of the mustard plant**. ❶ However, for **petrodiesel**, a fossil fuel oil, there is **no offset for CO₂ emissions during its combustion**. ❶ So, using biodiesel as an alternative to petrodiesel does not result in additional CO₂ being added to the atmosphere.
- d. i. The surfactant molecules must have a polar region – to bond with the polar water molecules, and a non-polar region – to bond with the non-polar petrodiesel molecules. ❶
- ii. **Biodiesel** molecules each have a **polar ester group to which water molecules can bond**. So, the **more biodiesel molecules present the greater the amount of water that can be present**. ❶
- e. The **production of the biofuel has no effect on land available for food production and is produced more cheaply due to lower water costs, and the offset effect of income from the sale of leftover material as animal feed**. ❶

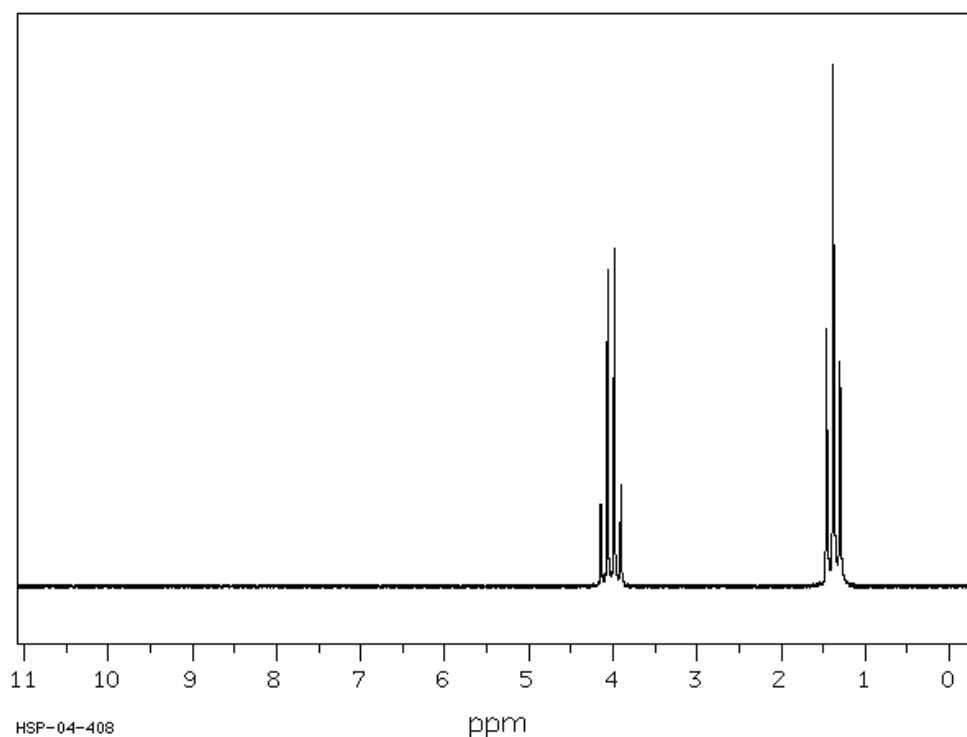
- f. The CFPP reflects the attraction between fuel molecules. So, the stronger the intermolecular attraction, the higher the CFPP. **B100**, which is pure biodiesel, will have the **higher CFPP** because due to the presence of the **polar ester group** in each molecule it has **stronger intermolecular attraction** than petrodiesel. ❶
- g. $m(\text{petrodiesel}) = 500 \text{ L} \times 832 \text{ g L}^{-1}$
 $= 4.16 \times 10^5 \text{ g}$
 Energy released from petrodiesel $= 4.16 \times 10^5 \text{ g} \times 45 \text{ kJ g}^{-1}$
 $= 1.87 \times 10^7 \text{ kJ}$ ❶
 $m(\text{B100}) = 1.87 \times 10^7 \text{ kJ} / 39 \text{ kJ g}^{-1}$
 $= 4.80 \times 10^5 \text{ g}$
 $= 0.48 \text{ t}$ ❶
- h. **Brassicic acid** has the higher melting temperature.
 Both acids have the same molecular formula and one carboxyl functional group. So, the **determining factor in the intermolecular attraction is the arrangement around the C=C double bond**. **Erucic acid has a cis arrangement and brassicic acid has a trans arrangement**. The kink caused by the *cis* arrangement in erucic acid prevents its molecules packing together as effectively or as strongly as brassicic acid molecules. ❶

Question 5 (9 marks)

- a. Since the compounds prevent free radical damage they act as **antioxidants**. ❶
- b. The fuel would be the biodiesel methyl oleate, **$\text{C}_{17}\text{H}_{33}\text{COOCH}_3$** . ❶
 Combustion equation.
 $\text{C}_{17}\text{H}_{33}\text{COOCH}_3(\text{l}) + 27\text{O}_2(\text{g}) \rightarrow 19\text{CO}_2(\text{g}) + 18\text{H}_2\text{O}(\text{g} / \text{l})$ ❶
- c. Much of the carbohydrate in avocados must be cellulose, and other dietary fibre which is not digested due to lack of appropriate enzymes. ❶
- d. i. Ubiquinol contains **two hydroxyl groups** which in ubiquinone has been **converted to two carbonyl groups**.
 Ubiquinol in the diet can **act as an antioxidant** as the (C)-OH is oxidised to C=O. ❶
- ii. **Fat soluble due to the long non-polar hydrocarbon tail** which enables significant dispersion force attraction with non-polar fat molecules. ❶
- e. Many enzymes **are proteins which need some temporary modification of their tertiary structure** to show enzyme action. ❶ **Coenzymes interact with the active site modifying it to enable the substrate to bond to it so that the bond breaking necessary for reaction is activated.** ❶
- f. Enzymes are proteins. For enzyme activity to occur, the **substrate molecule(s) must be able to interact with the active site**. The active site is determined by the **tertiary structure** of the protein. ❶

Question 6 (12 marks)

- a. $\text{CH}_3\text{CH}_2\text{OH}(\text{aq}) \rightarrow \text{CH}_3\text{CHO}(\text{aq}) + 2\text{H}^+(\text{aq}) + 2\text{e}^-$ ❶
The oxidation of ethanol involves the loss of hydrogen, consistent with the '*alcohol dehydrogenase*' name of the enzyme. ❶
- b. NAD^+ acts as the **oxidant** ❶ and is reduced – gaining hydrogen - according to $\text{NAD}^+(\text{aq}) + \text{H}^+(\text{aq}) + \text{e}^- \rightarrow \text{NADH}(\text{aq})$ ❶
- c. $\text{CH}_3\text{CO}\bullet$ ❶
-
- d. $\text{C}_{10}\text{H}_{20}\text{N}_2\text{S}_4$ from $(\text{CH}_3\text{CH}_2)_2\text{NS}_4\text{N}(\text{CH}_2\text{CH}_3)_2$ ❶
- e. Disulfiram is a symmetrical molecule with four equivalent CH_3CH_2- groups. The ^1H NMR spectrum will contain **two sets of signals** split into a **triplet** (H on CH_3) ❶ and a **quartet** (H on CH_2) ❶ according to the n+1 rule.



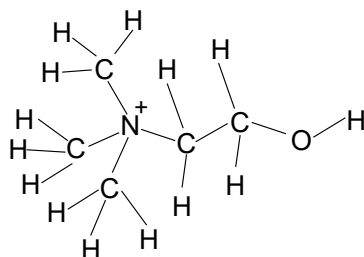
- f. $V(\text{ethanol})$ in 190 mL glass of wine $= (14.5/100) \times 190$
 $= 27.6 \text{ mL}$
 $m(\text{ethanol})$ in 190 mL glass of wine $= V(\text{ethanol}) \times d(\text{ethanol})$
 $= 27.6 \text{ mL} \times 0.785 \text{ g mL}^{-1}$
 $= 21.6 \text{ g}$ ❶
 Time to process ethanol in 190 mL glass of wine $= 21.6 \text{ g} / 10.0 \text{ g per hour}$
 $= 2.16 \text{ hours}$ ❶
- g. $\text{C}_6\text{H}_{12}\text{O}_6(\text{aq}) \rightarrow \text{CH}_3\text{CH}_2\text{OH}(\text{aq}) + 2\text{CO}_2(\text{g})$ ❶
Fermentation is an exothermic reaction and if the heat produced cannot dissipate the catalyst may become ineffective since **catalyse is an enzyme and enzymes, like all proteins, can denature at high temperatures**, and in the presence of ethanol, **causing the active site to be less effective.** ❶

Question 7 (11 marks)

- a. $m(\text{CO})$ produced in gasification = $0.50 \text{ mol} \times 28.0 \text{ g mol}^{-1}$
= 14 g
Energy required = $14 \text{ g} \times 3.1 \text{ kJ g}^{-1}$
= 43.4 kJ ①
Brown coal - $10 \text{ MJ kg}^{-1} \rightarrow 10 \times 10^3 \text{ kJ in } 1000 \text{ g} \rightarrow 10 \text{ kJ g}^{-1}$
 $m(\text{brown coal})$ needed = $43.4 \text{ kJ} / 10 \text{ kJ g}^{-1}$
= 4.4 g ①
- b. Overall equation for the process, obtained by adding together equations 1., 2., and 3. is
 $2\text{C(s)} + \text{O}_2(\text{g}) + 2\text{H}_2\text{O(g)} \rightarrow 2\text{H}_2(\text{g}) + 2\text{CO}_2(\text{g})$.
The **CO₂ produced** in the process is a **greenhouse gas** which if possible should not be released into atmosphere. ①
For CCS to be feasible
- a **suitable storage location for this CO₂ must be identified** (deep geological formations deep underground).
- since **CO₂ would be stored under pressure the location must be remain leakproof** under this pressure.
- the **location must not be subject to natural phenomena which could lead to release of CO₂**. ①
- c. 1. **Hydrogen is flammable** – must be stored in an airtight container away from any possible ignition sources. ①
2. **Hydrogen is a gas** – must be stored under pressure in well maintained pressurised containers. ①
- d. Negative electrode is the site of oxidation of the fuel, H₂(g), in an alkaline environment.
 $\text{H}_2(\text{g}) + 2\text{OH}^-(\text{aq}) \rightarrow 2\text{H}_2\text{O(l)} + 2\text{e}^-$ ①
- e. i. Electrolysis requires electrolytic and electronic conduction. **The lack of ions, other than minimal amounts of H⁺(aq) and OH⁻(aq) in pure water minimises electrolytic conduction.** ①
ii. **Use electrical energy obtained from solar cells to drive the electrolysis of a dilute aqueous solution of sodium chloride.** ①
Cathode reaction: $2\text{H}_2\text{O(l)} + 2\text{e}^-(\text{aq}) \rightarrow \text{H}_2(\text{g}) + 2\text{OH}^-(\text{aq})$ ①
- f. In a coal fired power station, energy is lost at each energy transformation so that only about 30 per cent of the chemical energy is converted to usable electric energy. Fuel cells are far more efficient because the direct conversion of chemical energy to electrical energy occurs in a single step. ①

Question 8 (9 marks)

a. i. $(\text{CH}_3)_3\text{N}^+\text{CH}_2\text{CH}_2\text{OH}$ ❶

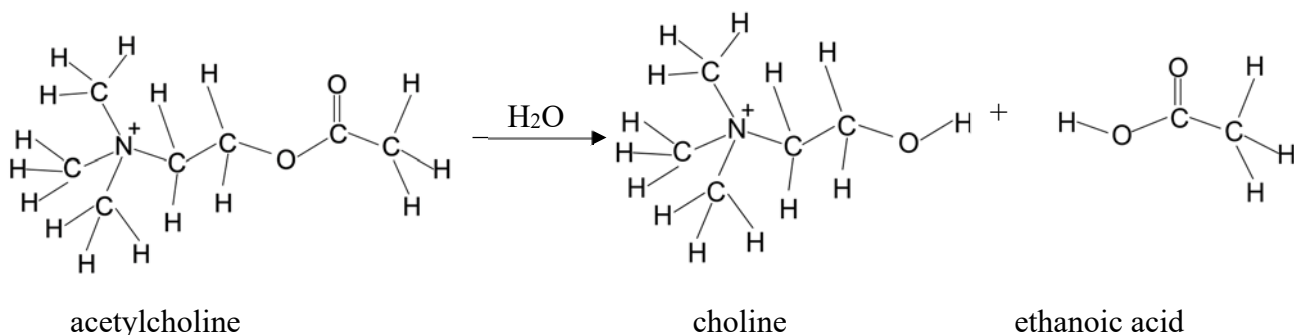


Products of hydrolysis were $(\text{CH}_3)_3\text{N}^+\text{CH}_2\text{CH}_2\text{OH}$ and CH_3COOH , i.e. the ester group in acetylcholine was converted to a hydroxyl and a carboxyl group.

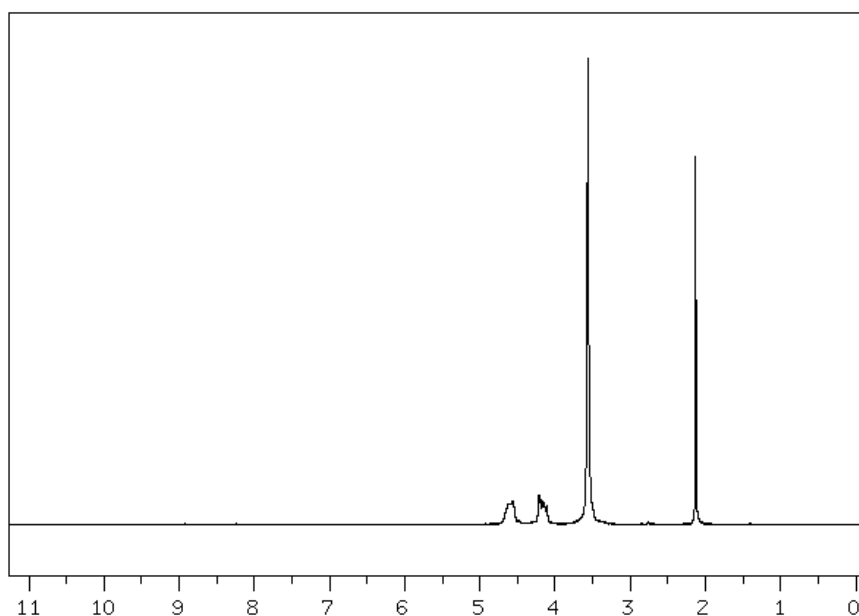
ii. **Quaternary** reflects the fact the **nitrogen atom is bonded to four different carbon atoms**, just as in the ammonium ion, the nitrogen atom is bonded to four hydrogen atoms.

The in-course context was the **quaternary structure of proteins**. ❶ The quaternary structure refers to the combination of two or more protein chains linked together and is present in complex proteins such as haemoglobin.

b. The hydrolysis of acetylcholine occurs according to the chemical equation.

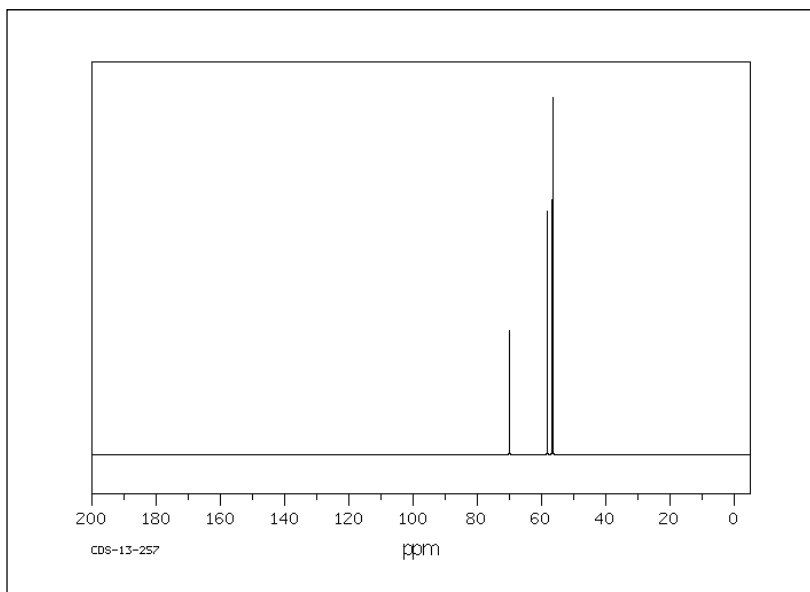


i. **Spectrum 1.**



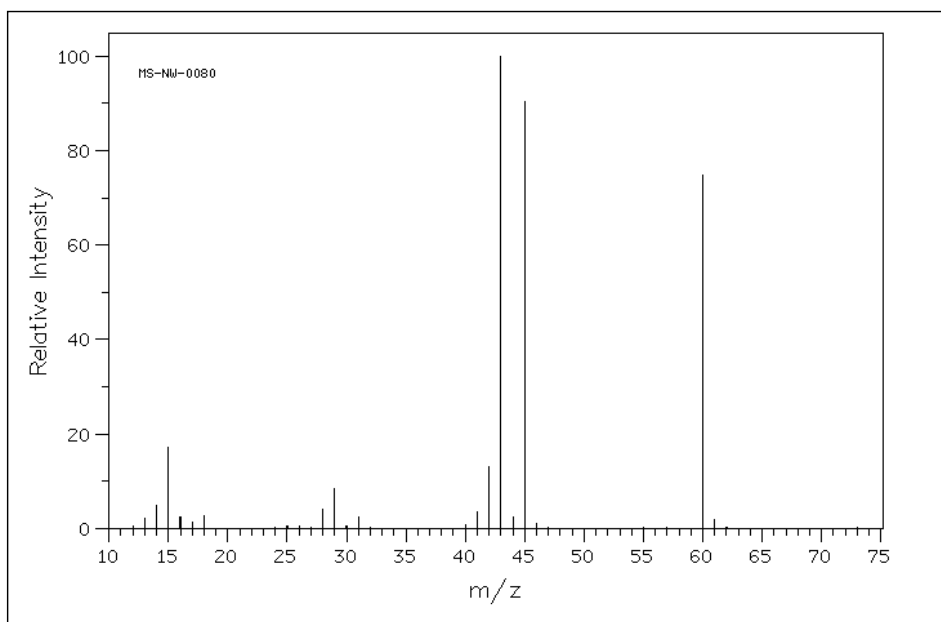
This is the ^1H NMR spectrum of acetylcholine – it is only species with **four different hydrogen environments**. ❶

Spectrum 2.



This is the ^{13}C NMR spectrum of choline – it is only species with **three different carbon environments**. ❶

Spectrum 3.



This is the mass spectrum of ethanoic acid (acetic acid) – the parent peak at $m/z = 60$ corresponds with the molecular mass of CH_3COOH . ❶

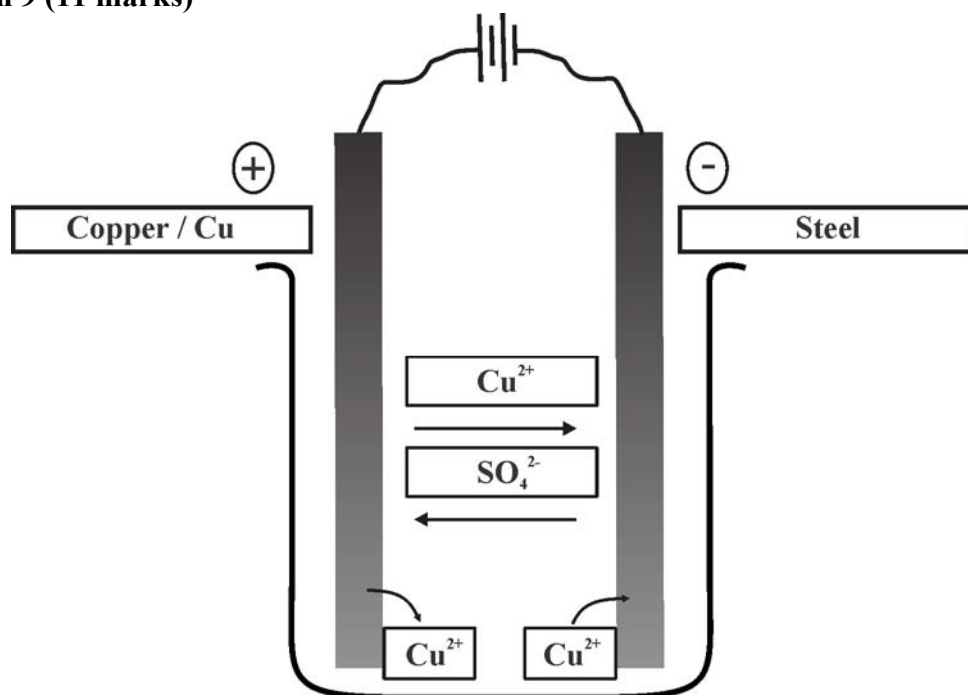
- ii. The peak with relative intensity at $m/z = 43$ is the **base peak** and is associated with the **most abundant species** resulting from fragmentation in the mass spectrometer.

Species formula – $[\text{CH}_3\text{CO}]^+$ ❶

- c. **Compounds in nerve agents binding to serine in acetylcholinesterase would disrupt its tertiary structure and so interfere with the active site on the enzyme.** ❶
This would reduce the ability of the enzyme to break down acetylcholine.
- d. Pralidoxime chloride: $C_7H_9N_2OCl$
 $m(C_7H_9N_2OCl)$ required in 20 minutes = $30 \text{ mg kg}^{-1} \times 82.5 \text{ kg}$
 $= 2.5 \times 10^3 \text{ mg} = 2.5 \text{ g}$
 $n(C_7H_9N_2OCl)$ required in 20 minutes = $2.5 \text{ g} / 172.5 \text{ g mol}^{-1}$
 $= 1.4 \times 10^{-2} \text{ mol}$ ❶
 $n(C_7H_9N_2OCl)$ required in 60 minutes = $1.4 \times 10^{-2} \text{ mol} \times 3$
 $= 4.3 \times 10^{-2} \text{ mol}$
 Rate administered = $4.3 \times 10^{-2} \text{ mol / hour}$ ❶

Question 9 (11 marks)

a.



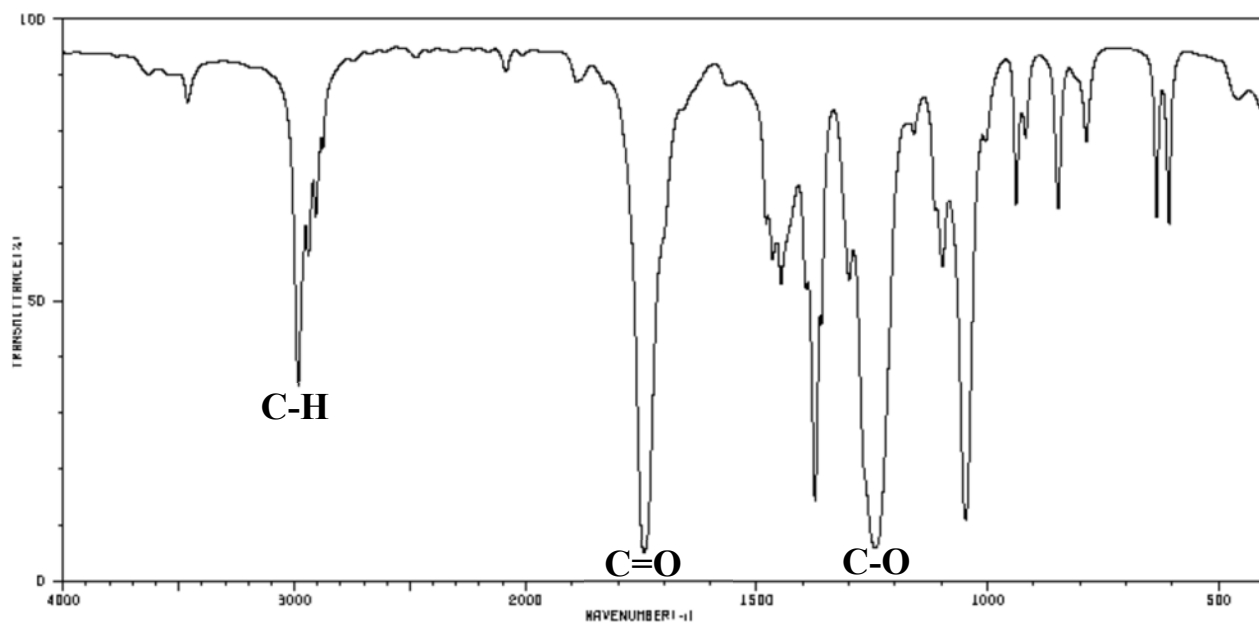
- ❶ for correct electrode signs.
 ❶ for correct labelling of electrodes.
 ❶ for correct species identification in electrolyte.
- b. Independent variable – **current**.
 Dependent variable – **mass of Cu deposited** / change in mass of plate. ❶
- c. Three from
 Electrolyte concentration, electrode surface area, distance between electrodes, voltage, temperature and time. ❶
- d. % efficiency = $[\text{actual } m(\text{Cu}) \text{ deposited} / \text{theoretical } m(\text{Cu}) \text{ deposited}] \times 100$
 Reduction half-equation = $\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cu}(\text{s})$
 Clarisse: Actual $m(\text{Cu})$ deposited = 0.395 g
 $Q = It = 1.45 \times 15 \times 60 = 1.3 \times 10^3 \text{ C}$
 $n(\text{e}^-) = Q/F = 1.3 \times 10^3 / 96500 = 0.014 \text{ mol}$ ❶
 Theoretical $m(\text{Cu})$ deposited = $\frac{1}{2} \times 0.014 \times 63.5$
 $= 0.43 \text{ g}$ ❶
 % efficiency = $(\text{actual mass} / \text{theoretical mass}) \times 100$
 $= (0.395 / 0.43) \times 100$
 $= 92 \%$ ❶

- e. Possible reasons.
- Masud did not dry the copper plated electrode prior to weighing. ❶
 - Clarisse accidentally removed some of the deposited copper when drying the copper plated electrode.
 - Some of the copper deposited on Masud's electrode was oxidised during drying.
- f. $\text{Cu}^{2+}(\text{aq})$ is simultaneously produced at the anode and consumed at the cathode. ❶
- g. In the original analysis, some of copper produced at the steel electrode may not stick to the electrode or may be accidentally removed during drying, making the recorded change in the electrode mass lower than the mass of copper oxidised from the anode. Whilst this would be less of an issue if the copper anode was weighed before and after the electrolysis the **results obtained would not be a true experimental outcome.** ❶

Question 10 (9 marks)

- a. During the discharge the strongest oxidant is reacting with the strongest reductant. Since $\text{Ce}^{3+}(\text{aq})$ is a weaker reductant than $\text{Zn}(\text{s})$ then $\text{Ce}^{4+}(\text{aq})$ must be a stronger oxidant than $\text{Zn}^{2+}(\text{aq})$.
During discharge $\text{Zn}(\text{s})$ is oxidised at the (-) electrode – **Zn**, whilst $\text{Ce}^{4+}(\text{aq})$ is reduced at the (+) electrode – **graphene oxide – graphite composite**. So **$\text{Zn}^{2+}(\text{aq})$ is pumped over the (-) electrode and $\text{Ce}^{4+}(\text{aq})/\text{Ce}^{3+}(\text{aq})$ is pumped over the (+) electrode.** ❶
- (-) $\text{Zn}(\text{s}) \rightarrow \text{Zn}^{2+}(\text{aq}) + 2\text{e}^-$
(+) $\text{Ce}^{4+}(\text{aq}) + \text{e}^- \rightarrow \text{Ce}^{3+}(\text{aq})$ ❶
- b. **During recharging $\text{Zn}(\text{s})$ is deposited on the (-) electrode** due to
 $\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Zn}(\text{s})$ ❶
- c. $2.20 \text{ V} = E^\circ(\text{oxidant half-cell}) - E^\circ(\text{reductant half-cell}) = E^\circ(\text{Ce}^{4+}/\text{Ce}^{3+}) - E^\circ(\text{Zn}^{2+}/\text{Zn})$
 $= E^\circ(\text{Ce}^{4+}/\text{Ce}^{3+}) - (-0.76) - \text{from Table 2 of the VCE Chemistry Data Book}$
 $= E^\circ(\text{Ce}^{4+}/\text{Ce}^{3+}) + 0.76$
 $E^\circ(\text{Ce}^{4+}/\text{Ce}^{3+}) = 2.20 - 0.76$
 $= 1.44 \text{ V}$ ❶
- d. In a conventional rechargeable battery all the reactants are within the cell. However, in the **redox flow battery the reactants are stored outside the cell and pumped in as required as happens in fuel cells.** However, **electrical recharging is not characteristic of fuel cells.** ❶
- e. i. General reaction pathway from $\text{CH}_3\text{CH}_2\text{Cl}$ with no other organic compounds involved is
 $\text{CH}_3\text{CH}_2\text{Cl} \rightarrow \text{CH}_3\text{CH}_2\text{OH} \rightarrow \text{CH}_3\text{CHO} \rightarrow \text{CH}_3\text{COOH} \rightarrow \text{CH}_3\text{COOCH}_2\text{CH}_3$
The mass spectrum shows **parent ion peak at $m/z = 88.0$ and base peak at $m/z = 43.0$.** ❶
The ^1H NMR spectrum shows **three hydrogen environments** with a **quartet, singlet, triplet** splitting pattern.
This data is consistent with the ester **ethyl ethanoate $\text{CH}_3\text{COOCH}_2\text{CH}_3$** ❶
 $M_r(\text{CH}_3\text{COOCH}_2\text{CH}_3) = 88.0$
- $m/z = 43.0$ is consistent with **CH_3CO^+ fragment**
- **three different hydrogen environments**
- **quartet, triplet** is consistent with **$-\text{CH}_2\text{CH}_3$** ❶
Also, signal at $\delta = 2.0$ ppm is consistent with CH_3COOR ,
signal at $\delta = 4.0$ ppm is consistent with RCOOCH_2R .

- ii. Use **Table 14 in the VCE Chemistry Data Book** to identify peaks for C-H, C-O and C=O(esters) bonds.



① for all 3 correct

End of Suggested Answers