Trial Exam

Unit 3/4 VCE

Chemistry

Student name _____

Question and answer book

Reading time 15 minutes

Writing time: 2 hours and 30 minutes

Structure of book

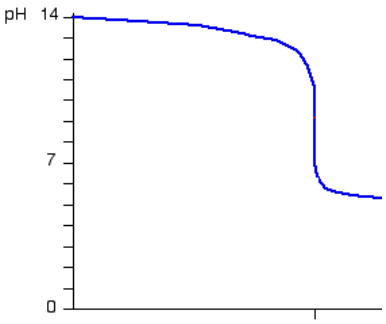
Section	Number of questions	Number of marks
A	30	30
B	12	159

ANSWER SHEET PART A: **NAME**_____

1.	●	B	C	D	**16.**	●	B	C	D
2.	A	B	C	●	**17.**	A	B	C	●
3.	●	B	C	D	**18.**	A	●	C	D
4.	●	B	C	D	**19.**	A	B	●	D
5.	A	●	C	D	**20.**	A	B	C	●
6.	A	●	C	D	**21.**	A	B	●	D
7.	A	●	C	D	**22.**	A	B	C	●
8.	●	B	C	D	**23.**	A	B	●	D
9.	A	B	C	●	**24.**	A	B	●	D
10.	●	B	C	D	**25.**	A	●	C	D
11.	A	B	●	D	**26.**	A	B	●	D
12.	A	B	C	●	**27.**	A	B	C	●
13.	A	B	C	●	**28.**	A	●	C	D
14.	A	B	C	●	**29.**	A	●	C	D
15.	●	B	C	D	**30.**	●	B	C	D

Circle the correct response to each question on the answer sheet.

1) A solution was analysed by titration. The pH curve is shown on the right. Which one of the following comments is most likely correct?
   a) A solution of strong base is titrated against a weak acid.
   b) A concentrated solution of hydrochloric acid is titrated against a weak base.
   c) A solution of NaOH is titrated against a 4.5M HCl solution.
   d) A concentrated solution of NaOH is titrated against a dilute solution of NaOH.



2) Which indicator should be used for this titration?
   a) Phenol red.
   b) Bromophenol blue
   c) Methyl orange
   d) Phenolphthalein

3) 1.50 grams of thymine ($C_5H_6N_2O_2$) would contain:
   a) 0.333 grams of nitrogen
   b) 0.33 grams of nitrogen
   c) 0.300 grams of oxygen
   d) 0.3 grams of oxygen

4) Serotonin is a compound that conducts nerve impulses in the brain and muscles. Each molecule has 12 hydrogen atoms and contains 6.82% hydrogen by mass. Its formula mass is:
   a) 176;
   b) 233;
   c) 156;
   d) Cannot be calculated from the information given.

5) Consider the following chemical equation that illustrates a transformation of a carbohydrate:

$$C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$$

   Which of the following statements best aligns with the principles of green chemistry and sustainability in relation to this reaction?
   a) The reaction is unsustainable because it produces carbon dioxide, a known greenhouse gas.
   b) This reaction promotes sustainability by utilizing renewable resources and generating a biofuel.
   c) The reaction does not adhere to green chemistry principles due to its low percent atom economy, which is below 30%.
   d) The reaction is considered sustainable as it produces only a small amount of carbon dioxide

6) Ethene burns in oxygen according to the equation below.

$2C_2H_4(g) + 6O_2(g) \Rightarrow 4CO_2(g) + 4H_2O(l)$ $\Delta H = -2822$ kJ

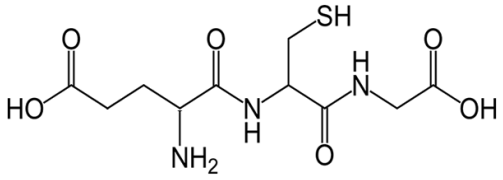
If a 30.0 litre sample of ethene is mixed with 70.0 litres of oxygen gas and ignited at SLC, which comment below is true?

a) 10 L of ethene remain unreacted and 200 kJ of energy is released.
b) 6.9 L of ethene remain unreacted and 1.3 X 10^3 kJ of energy is released.
c) 6.9 L of ethene remain unreacted and 130 kJ of energy is released.
d) 0.24 mol of oxygen remain unreacted and 2220 kJ of energy is released.

7) A small peptide is shown on the right.

What amino acids formed it?

a) Alanine, threonine, cysteine, glycine.
b) Glutamic acid, cysteine, glycine.
c) Alanine, glutamic acid, cysteine, glycine.
d) Alanine, threonine, cysteine.

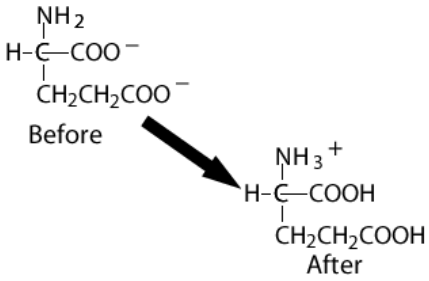


8) What option best describes the process by which proteins are digested in the digestive system?

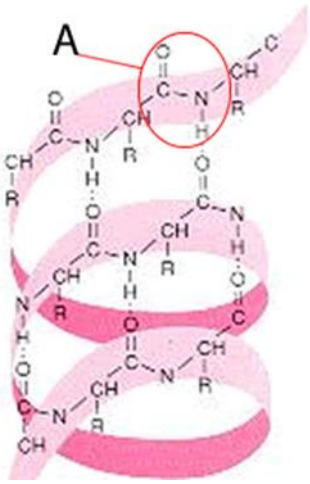
a) Hydrolysis
b) Esterification polymerisation
c) Oxidation
d) Condensation polymerisation

9) Glutamic acid exists as a zwitterion at a pH of 3.2. It is placed in a solution of unknown pH. The pH of the solution is then changed and the structure of glutamic acid determined by analysis. The structure of glutamic acid before the change in pH and after is shown on the right. The original solution of glutamic acid is most likely:

a) a at a pH of 10 and changes to a pH of 7.
b) at a pH of 10 and changes to a pH of 14.
c) at a pH of 4 and changes to a pH of 7.
d) at a pH of 6 and changes to a pH of 3.



Questions 10 and 11 refer to the structure shown on below.



10) The image represents:
    a) the secondary structure of a polypeptide brought about by hydrogen bonding;
    b) the primary structure of a protein chain brought about by covalent bonding and dispersion forces;
    c) the tertiary structure of a protein chain brought about by disulphide links;
    d) the tertiary structure of a polypeptide brought about by ionic, covalent and hydrogen bonding.

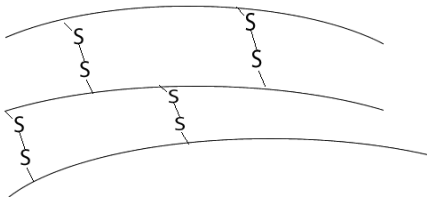
11) The functional group labelled “A” is known as:
    a) an ether link produced by a carboxyl and an amine functional group;
    b) an ester link produced by a hydroxyl and a carboxyl functional group;
    c) an amide link produced by an amino and carboxyl functional groups;
    d) an ether link produced by a two hydroxyl functional groups.

12) An enzyme operates optimally at 37°C, facilitating the breakdown of a specific fat. However, when heated to 50°C, the enzyme loses its functionality. What is the most likely reason for this loss of activity?

    a) The ionic and covalent bonds maintaining the helical and sheet structures of the enzyme have been disrupted.
    b) Covalent bonds have been disrupted, damaging the secondary structure of the enzyme.
    c) Covalent bonds have been disrupted, affecting the primary structure of the enzyme.
    d) The relatively weak forces of attraction stabilizing the secondary and tertiary structures of the enzyme have been disrupted.

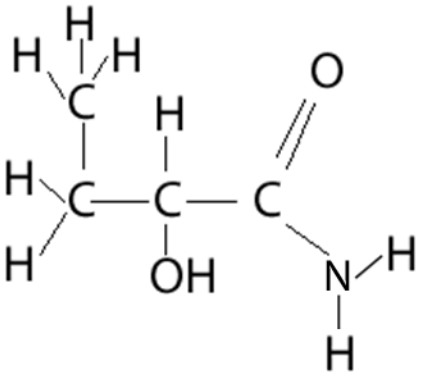
13) An enzyme in the body is made up of 100 amino acids and its structure is shown below. How many (CONH) functional groups are present in the enzyme?

a) 100
b) 97
c) 99
d) 50



14) What is the correct systematic name of the compound shown below.

a) 3-methyl-2-hydroxypropanamide
b) 1-amino-2- hydroxybutanal
c) 1-amido-2-methylpropan-2-ol
d) 2-hydroxybutanamide



15) Which one of the following analytical techniques can be used to isolate, identify and determine the concentration of an organic compound?

a) High pressure liquid chromatography.
b) IR spectroscopy
c) ^{1}H NMR
d) Mass spectroscopy

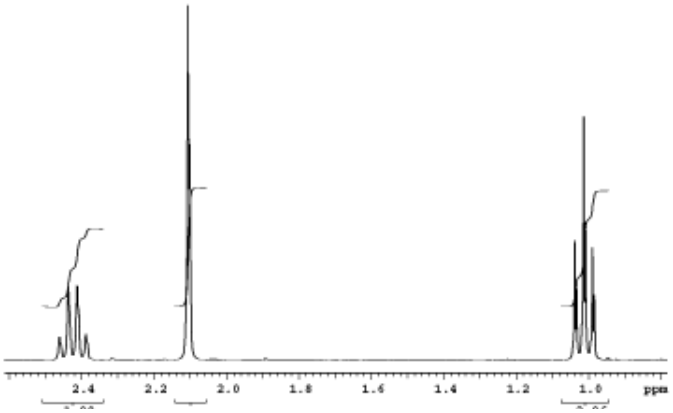
16) Which one of the following is least useful in investigating the molecular structure of a complex organic molecule?

a) HPLC
b) Mass spectroscopy
c) ^{1}H NMR
d) ^{13}C NMR

17) For analysis, a hydrocarbon is placed in a strong magnetic field and irradiated with electromagnetic radiation in the radio wave frequency. This is most likely to:

a) cause ionisation and fragmentation of the parent molecule;
b) cause electrons to become excited and jump to higher energy levels;
c) increase the bond vibration of the molecule;
d) cause a change in the energy state of nucleons.

18) The ^{1}H NMR spectrum of an organic molecule is shown below.



Which one fo the following options represents the semistructural formula of the molecule?

a) $CH_3CHOHCH_3$
b) $CH_3COCH_2CH_3$
c) $CH_3COOCHCH_2$
d) $(CH_3)_2CH_2$

19) Which of the following techniques can be used to obtain the ratio of U^{235} and U^{238} isotopes in a sample of uranium ore?

a) ^{1}H NMR
b) IR spectroscopy
c) Mass spectrometry
d) HPLC

The following information is to be used to answer question 20-21

Hydrogen gas is formed via steam reformation according to the reaction shown below.

$$CH_4(g) + H_2O(g) \rightarrow 3H_2(g) + CO(g)$$

A mass of 3.20 grams of methane gas completely reacted with steam to produce 0.85 grams of hydrogen gas.

20) What is the percent yield of the reaction?

a) Exactly 50%
b) Closer to 32%
c) Exactly 65%
d) Closer to 71%

21) The percent atom economy for the reaction is

a) 34%
b) 6 %
c) 18%
d) 83%

22) A student was given colourless liquids that were labelled A, B, C and D. They were known to be ethanol, ethanoic acid, pentane and hexene, but the exact identity of each liquid was unknown.

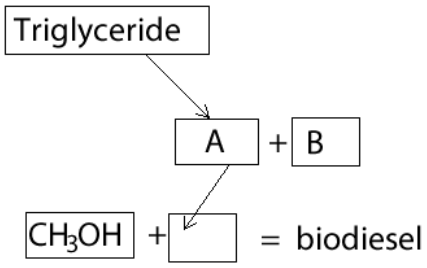
The student tested the properties of three of the liquids and obtained the results shown below. Identify each of the liquids.

	A	B	C
Solubility in water	insoluble	soluble	soluble
Addition of brown Br_2 solution	Br_2 solution turns clear	No reaction	No reaction
Reaction with Na_2CO_3 powder.	No reaction	Gas evolved	No reaction
Reaction with orange acidified $Cr_2O_7^{2-}(aq)$	No reaction	No reaction	Turns the orange solution green.

a) A is hexene, B is ethanoic acid and C is ethanol
b) A is hexene, B is ethanol and C is ethanoic acid
c) A is ethanoic acid, B is pentane and C is ethanol
d) A is ethanoic acid, B is ethanol and C is pentane

23) The formation of biodiesel is summarised in the diagram below. Which comment is true?

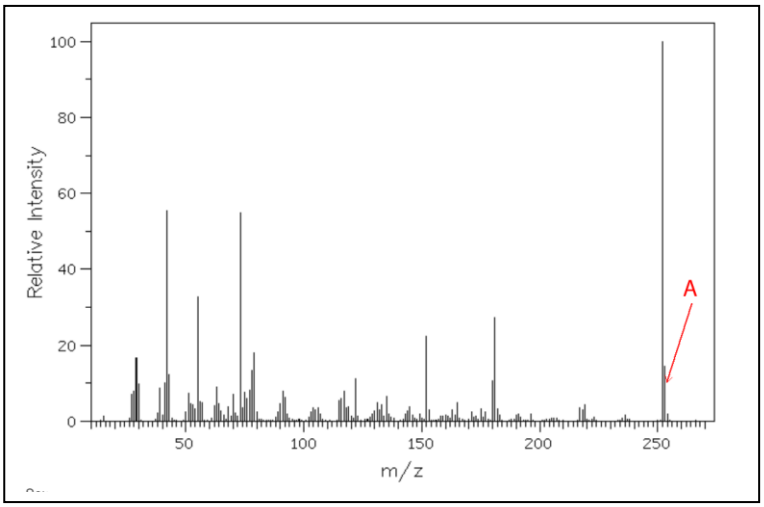
a) A is most likely glycerol.
b) B is most likely an ester.
c) The reaction to form A and B from a triglyceride is known as a hydrolysis reaction.
d) The reaction that produces biodiesel is an oxidation reaction.



24) An ether link is most likely found in:

a) carbohydrates and is formed between two carboxyl functional groups.
b) proteins and is formed in an esterification reaction .
c) carbohydrates and is formed in a condensation reaction.
d) proteins and is formed in an oxidation reaction.

The following information is to be used to answer questions 25- 26
A compound was analysed and was found to contain the following composition by mass. Carbon 47.62%, hydrogen 4.76%, nitrogen 22.22% and oxygen 25.40%. The mass spectrum of this compound is shown below.



25) This compound has the molecular formula:

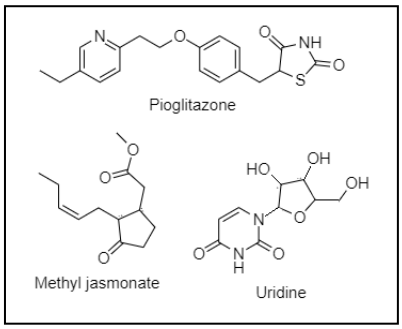
a) $C_{10}H_{12}N_4O_4$;
b) $C_5H_6N_2O_2$;
c) $C_{10}H_{20}N_4O_2$;
d) $C_{10}H_{10}N_4O_6$.

26) Peak A, pointed to by the arrow in the MS, is due to the:

a) ^{14}N isotope
b) ^{18}O isotope.
c) ^{13}C isotope
d) ^{1}H isotope.

27) Consider the molecular structures of the three molecules shown on the right. Which one statement is correct?

a) Uridine has two optical isomers.
b) Pioglitazone has no optical isomers.
c) Uridine has 1 chiral centre.
d) Methyl jasmonate has 4 optical isomers.



28) At a given temperature, the reaction quotient (Q) for the equilibrium shown below has a value of 4.9 M^2.

$$Co(H_2O)_6^{2+}(aq) + 4Cl^-(aq) \rightleftharpoons CoCl_4^{2-}(aq) + 6H_2O(l)$$

Given no temperature change which of the following options is most likely correct?

a) The equilibrium constant (K_c) for the equilibrium below is closest to 0.042 M^{-2}

$$2CoCl_4^{2-}(aq) + 12\,H_2O(l) \rightleftharpoons 2\,Co(H_2O)_6^{2+}(aq) + 8Cl^-(aq)$$

b) The reaction quotient for the equilibrium below is closest to 0.2 M^2

$$CoCl_4^{2-}(aq) + 6\,H_2O(l) \rightleftharpoons Co(H_2O)_6^{2+}(aq) + 4Cl^-(aq)$$

c) The addition of NaCl(aq) to the equilibrium mixture will give a value for K_c (equilibrium constant) greater than 4.9 M^{-2}

d) Dilution of the equilibrium mixture by the addition of water would immediately increase the value of Q but will eventually return to an equilibrium position with the same K_c value.

The following information is to be used to answer questions 29-30.

Cobalt (II) chloride, when dissolved in water, forms an equilibrium between a hydrated form and dehydrated form.

$$Co(H_2O)_6^{2+}(aq) + 4Cl^-(aq) \rightleftharpoons CoCl_4^{2-}(aq) + 6H_2O(l) \quad \Delta H>0$$

$Co(H_2O)_6^{2+}(aq)$ is pink whilst $CoCl_4^{2-}(aq)$ is blue.

29) Which one of the following options will drive the equilibrium system to the left and make the solution turn from a blue to a pink colour?

a) Addition of NaCl(s) to the equilibrium mixture.
b) Addition of $AgNO_3$ (s) to the equilibrium mixture.
c) Heating the solution over a Bunsen flame.
d) Adding KNO_3 (s) to the equilibrium mixture.

30) $Co(NO_3)_2$ is added and the system is allowed to reach equilibrium once more. Once at equilibrium the:

a) $[Cl^-]$ will be lower than before $Co(NO_3)_2$ was added;
b) $[Co(H_2O)_6^{2+}]$ will be lower than before $Co(NO_3)_2$ was added;
c) $[Cl^-]$ will be higher than $[Co(H_2O)_6^{2+}]$;
d) $[Cl^-]$ will be higher than $[CoCl^{2-}]$.

SECTION B –Short answer questions

Question 1

The amount of vitamin C (176.14 g/mol) in a brand of orange juice can be determined by titration with a standard iodine solution. Iodine reacts with vitamin C according to the equation below.

$$C_6H_8O_6\ (aq) + I_2(aq) \Rightarrow C_6H_6O_6\ (aq) + 2H^+(aq) + 2I^-(aq)$$

A 25.00 mL sample of juice is placed in a 250 mL volumetric flask and made to the mark with distilled water. Four 20.00 mL aliquots are each placed in four 100mL conical flasks and titrated against a standard 1.45 X 10^{-3} mol/L I_2 solution. Four trials are carried out and the results recorded in the table below.

	1	2	3	4
Titre (mL)	10.95	11.00	18.99	17.01

a) Write a balanced half equation for the oxidation of vitamin C, states included..

_____ *$C_6H_8O_6(aq) \rightarrow C_6H_6O_6(aq) + 2H^+(aq) + 2e^-$*

--- 1 mark for balanced half equation

--- 1 mark for states

b) Calculate the average titre?

Average titre= (11.00 +10.95) / 2 =10.98mL

c) Calculate the amount, in mol, of vitamin C present in the 20.00 mL aliquot.

Step 1 - Calculate mol of I_2 using the standard iodine concentration

Moles of I_2 = 0.01098 L × 1.45×10^{-3} mol/L =1.591×10^{-5} mol ---- 1 mark

Step 2 - Calculate mol of Vitamin C in the 20.00 mL aliquot (1:1 mol ratio with I_2)

Moles of Vitamin C =1.59×10^{-5} mol --- 1 mark

2 marks

d) Calculate the amount, in mol, of vitamin C in the original orange 25.00 mL sample.

Step 1 – 1.59 X 10^{-5} X 250/20 = 1.99 X 10^{-4}

--- 1 mark correct working out

--- 1 mark two sig figs.

e) Calculate the concentration, in %w/v, of vitamin C in the original juice, to the right number of significant figures.

Step 1 Find the mass of Vit C in 25 mL of orange juice.
=> 1.99 X 10^{-4} X 176.14 g/mol = 0.0351g ---- 1 mark

Step 2 Calculate %m/v
=> (0.0351 / 1000) X 100 = 0.00351% m/v

f) A student carried out the titration rinsing the burette with distilled water before performing the titration. All four trials were carried out without refilling the burette.

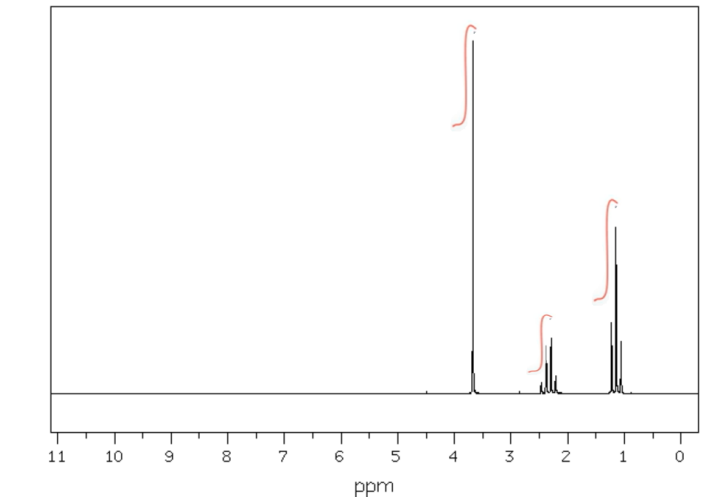
i. How would this impact the average titre achieved? Explain your reasoning.
Dilution of the titrant ---- 1 mark
will cause a larger volume of to be delivered as the titre, hence the average titre will be greater --- 1 mark

ii. Would this introduce a **systematic error,** or a **random error** or no error, in the titration? Justify your reasoning.
A systematic error since all trials were conducted with the same diluted titrant --- 1 mark
consistently skews all measurements (trials) by the same amount and direction. --- 1 mark

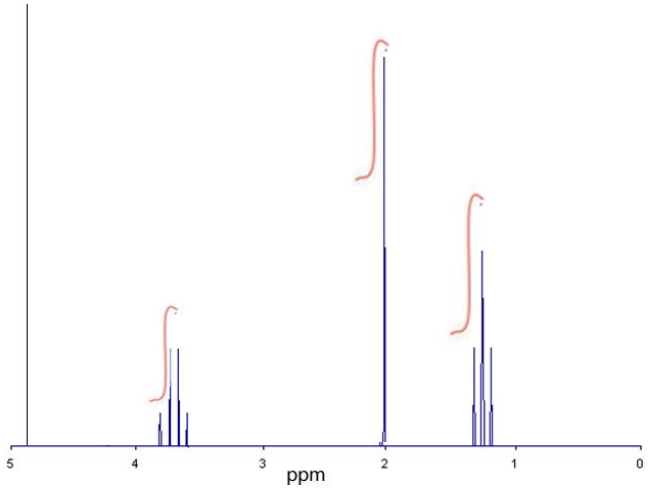
Question 2

Three different isomers A, B and C with the formula $C_4H_8O_2$ are analysed using different techniques.

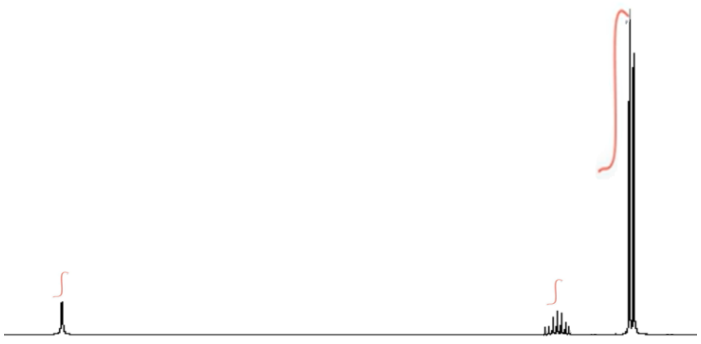
^1H NMR spectra of selected isomers are shown below.



^1H NMR spectrum for isomer C



^1H NMR spectrum for isomer B

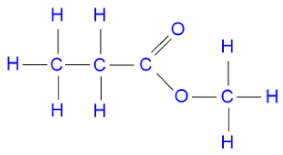


^1H NMR spectrum of isomer A.

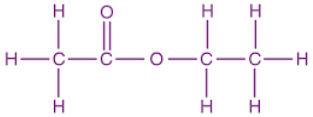
Consists of a doublet, septet and a singlet

a) Given that isomer "A" reacts with Na_2CO_3 to produce carbon dioxide while isomers "B" and "C" are products of a reaction between a primary alcohol and a carboxylic acid, draw a possible structural formula for each of the three isomers.

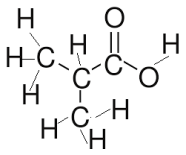
Isomer C



Isomer B



Isomer A



2+2+2= 6 marks

b) Consider the ^1H NMR spectrum of A.

i) What number of chemically equivalent hydrogens is represented by the septet?

_____1_____1 mark

ii) Explain how the signal was split into a septet.

Six equivalent neighbouring protons exist ----- 1 mark

the signal splits according to the n+1 rule, thus producing 7 (6 + 1) peaks, producing a septet. ---- 1 mark

c) Define *chemical shift* and *nuclear shielding* and use the terms to discuss why the splitting patterns in the ^1H NMR spectrum of isomers B and C are identical but arranged in a different unique order relative to the TMS signal at 0 ppm. You may redraw the structural formulae of each isomer in order to add clarity to your explanation.

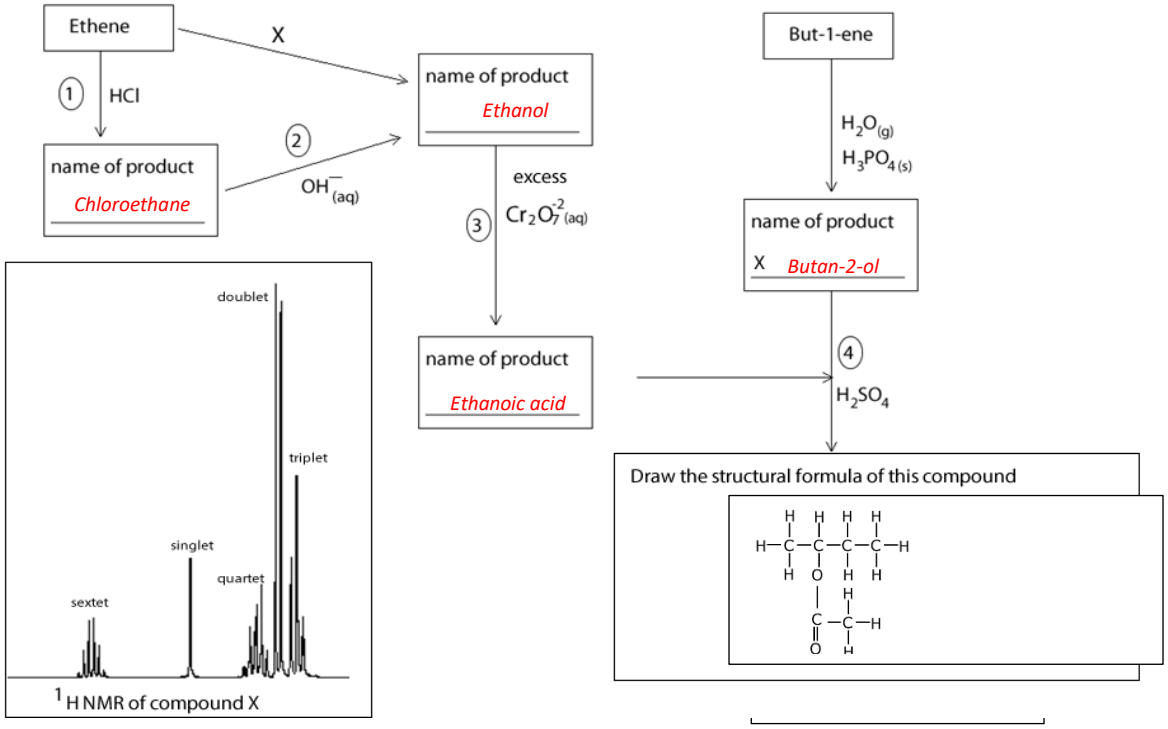
Chemical shift is the measure of how far a signal appears to the left of the TMS reference peak at 0 ppm in an NMR spectrum. This shift depends on the proximity of the protons responsible for the signal to electronegative atoms, such as oxygen. ----1 mark

Electrons surrounding a proton nucleus act to shield the nucleus from the applied magnetic field. This is known as nuclear shielding. Electronegative atoms, however, pull electrons away from neighbouring protons, causing the nuclear shielding to be less effective and increases the proton's sensitivity to the magnetic field, meaning a lower magnetic field strength is needed to excite the nucleus. -------1 mark

In isomer B (ethyl ethanoate, $CH_3COOCH_2CH_3$) the CH_2 protons adjacent to the oxygen atom are more deshielded due to the electronegativity of the oxygen. Therefore, this quartet signal will appear further downfield (higher chemical shift). ------1 mark

In isomer C (methyl propanoate, $CH_3CH_2COOCH_3$) the CH_2 protons are next to a carbon of a carbonyl group, which is less electronegative than an oxygen atom. This results in a smaller chemical shift for the CH_2 quartet signal compared to isomer B, -------1 mark

Question 3



a) Fill in the boxes on the diagram above.

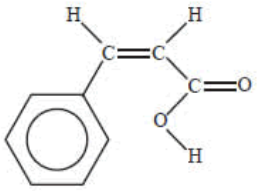
b) Identify the type of reaction represented by

1) _____*Addition*_____
2) _____ *Substitution* _____
3) _____ *Oxidation* _____
4) _____ *Esterification or condensation* _____

c) Identify the reagents and conditions represented by X

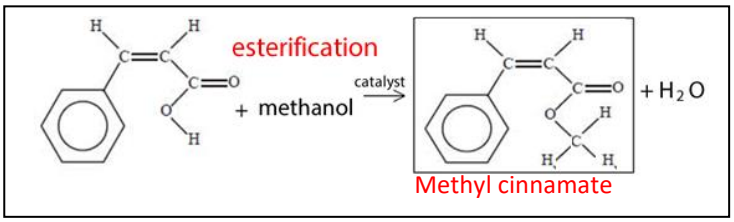
_____*H_3PO_4(s) ,300 ^{0}C, H_2O*_____ 1 mark

d) Cinnamic acid is an organic acid that contributes to the flavour of cinnamon. Its structure is shown on the right. Draw structural formulae of the product molecule formed in the following reactions and name the type of reaction of each.

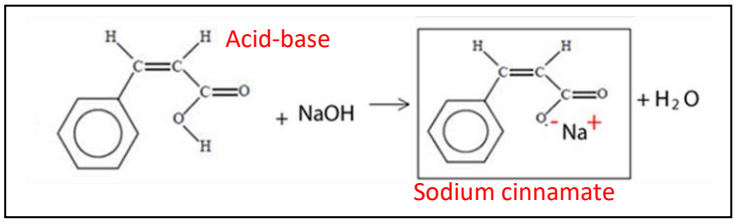


Cinnamic acid

i)



ii)



2+2=4marks

e) The degree of unsaturation is a measure of the number of ring structures and multiple bonds (double or triple) in a molecule. Each degree of unsaturation represents the loss of two hydrogen atoms from the fully saturated formula of a compound. This includes:

i) A molecule with the formula C_6H_{10} has a ring structure and
Two carbon-carbon double bonds --- 1 mark (must state carbon-carbon double bonds)

ii) What is the degree of unsaturation for cinnamic acid?
1 for the ring structure +
3 for the carbon to carbon double bonds in benzene+
1 for the carbon to carbon double bond outside the ring structure +
1 for the carbonyl group. ---- 1 mark

iii) Two unbranched hydrocarbons with six carbons are tested. Hydrocarbon A is saturated and Hydrocarbon B has a degree of unsaturation of 3. Compare their melting temperatures and justify your answer with reference to structure and bonding.

Hydrocarbon A has a higher melting temperature ---- 1 mark
*Saturated Hydrocarbon **A** has a straight, flexible structure that allows for efficient, close packing in the solid state where van der Waals interactions between molecules is more effective hence a greater amount of energy is needed to disrupt the intermolecular bonding, raising the melting temperature. ----- 1 mark (must state that a greater amount of energy is needed)*
*Unsaturated Hydrocarbon **B** has multiple double or triple bonds that introduce kinks along the carbon chain. Bending of the carbon chain prevents close packing, weakening intermolecular van der Waals forces and resulting in less energy needed to disrupt intermolecular bonds hence a lower melting temperature. ----- 1 mark*

Question 4

Palm tree oil is used to manufacture biodiesel.

a) What is meant by the term renewable?
A renewable resource is one that can be replenished or regenerated by natural means, in a timely manner so that it never runs out. ---- 1 mark

b) What is meant by the term sustainable practices?

Sustainable practices meet current needs without compromising the ability of future generations to meet their own needs, be they social, environmental, social or economic ----- 1 mark

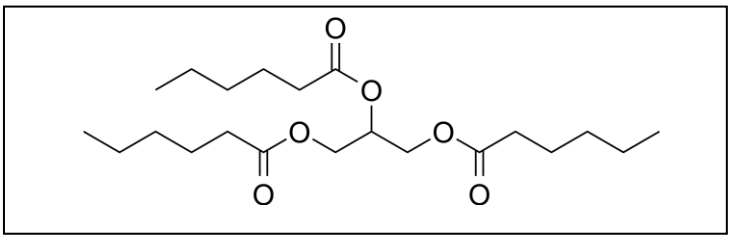
c) Give an example of how biodiesel can be renewable but not sustainable. Provide a clear and concise explanation to justify your answer.

Biodiesel from palm tree oil is renewable as it can be extracted from palm trees, in a timely manner whilst the palm tree are regrown relatively quickly. This ensure it never runs out. ---- 1 mark

This requires large areas of natural forest to be cleared for the planting of palm trees which contributes to deforestation and its negative impact on biodiversity, ecosystems and reduces land for the growth of food crops. ---- 1 mark

d) The triglyceride **tricaproin** consists of three fatty acid chains derived from **caproic acid** ($C_6H_{12}O_2$, 116 g/mol), a straight-chain fatty acid.

i. Draw the skeletal structure of tricaproin in the space provided below



----- 1 mark correct structure of caproic acid
----- 1 mark correct structure of glycerol
----- 1 mark clear structure of three ester bonds

ii. Give the IUPAC name for caproic acid

_____*Hexanoic acid*_____ 1 mark

e) Tricaproin is used to form biodiesel. A simplified pathway is show in fig. 1 below.

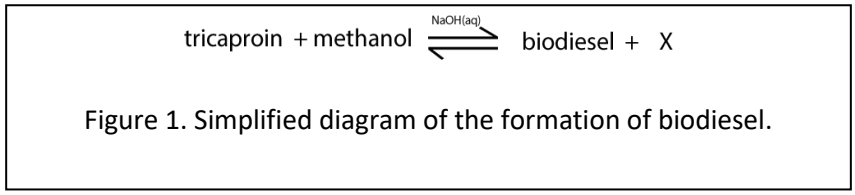


Figure 1. Simplified diagram of the formation of biodiesel.

i. Give the name of the molecule that forms the major component of the biodiesel.

_____*methyl hexanoate*_____ 1 mark

ii. Give the IUPAC name of compound X

_____*propan-1,2,3-triol*_____ 1 mark

iii. Give the balanced chemical equation for the complete combustion, at SLC, of the biodiesel, given as the answer to question i. above. Use chemical formulas and states.

_____*$2C_7H_{14}O_2$ (l) + 19 O_2(g) → 14CO_2 (g) + 14H_2O (l)*
----- 1 mark for correct states (water is a liquid as SLC)
----- 1 mark balanced equation
----- 1 mark correct products

iv. Given that the molar heat of combustion of the biodiesel, mentioned above, is 3997 kJ/mol, calculate the useful heat energy, in kJ, obtained from burning 11.6 grams of the diesel, assume no energy is lost to the environment.

Step 1 calculate the molar mass of the biodiesel
=> 7 X 12 + 14 X 1 + 2 X 16 = 130 --- 1 mark
Step 2 calculate the mol of biodiesel
=> 11.6/130 = 0.0892 --- 1 mark
Step 3 calculate the energy released
=> 0.0892mol X 3997 kJ / mol = 357 kJ ---- 1 mark correct value and 3 sig figs.

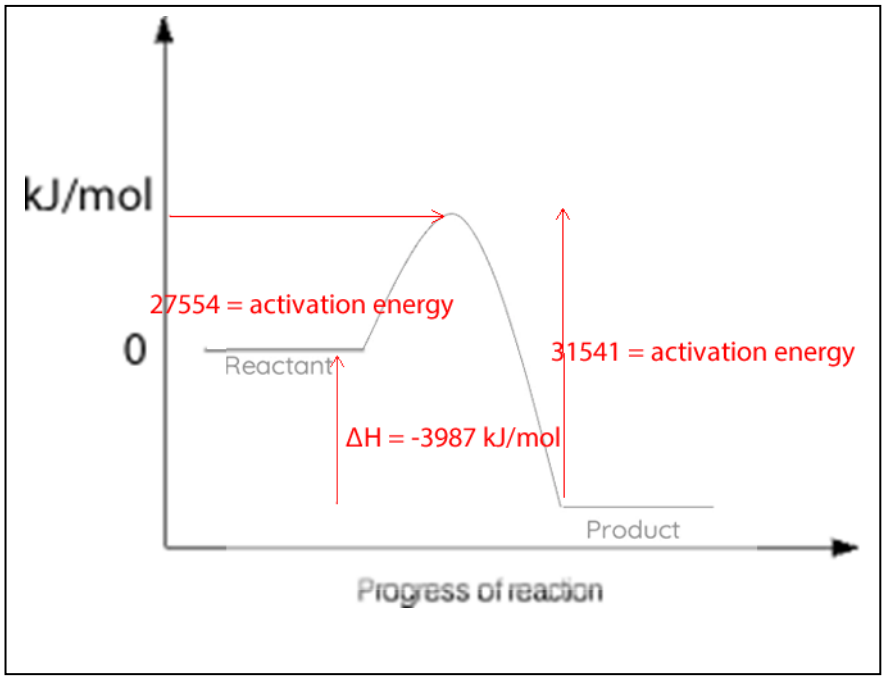
f) Given that the biodiesel molecule contains the following bonds 5 X C-C, 14 X C-H, 1 X C=O and 2 X C-O

i. Calculate the activation energy in kJ/mol. Show all working out in the space provided.

Bond enthalpies from the data booklet
C–C bonds: 10×346=1730 kJ/mol
C–H bonds: 28×414=5796 kJ/mol
C=O bond: 2×799=804 kJ/mol
C–O bonds: 4×358=716 kJ/mol
O=O bonds: 19X498 = 9462kJ/mol
Total bond breaking energy per mol = 27554 kJ/mol

----- 1 mark for the correct bond enthalpies
---- 1 mark for correct multiplication and addition of bond energies

ii. Complete the energy profile shown below,



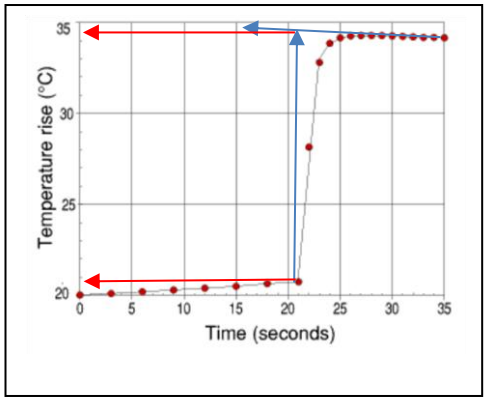
On the set of axes, shown above, clearly draw the energy profile of the reaction, showing the position and value of the following:

Activation energy correct value ---- 1 mark
ΔH = -3987 kJ/mol correct value and sign ---- 1 mark
Activation energy of the reverse reaction correct value ---- 1 mark

-----1 mark for correct shape for exothermic

Question 5

A bomb calorimeter, containing 50.0 mL of water at 20.6 °C was calibrated by passing a current of 6.11 A at 2.76 V for 2.50 minutes through the heating coil. The temperature was recorded periodically and the data recorded on a temperature vs time graph shown on the right.



a) Calculate the calibration factor (C_f) for the calorimeter.

Step 1 Calculate the energy delivered to the 50 mL of water.

=> E = Vit = 2.76 X 6.11 X 2.50 X 60 = 2.53 kJ *---- 1 mark*

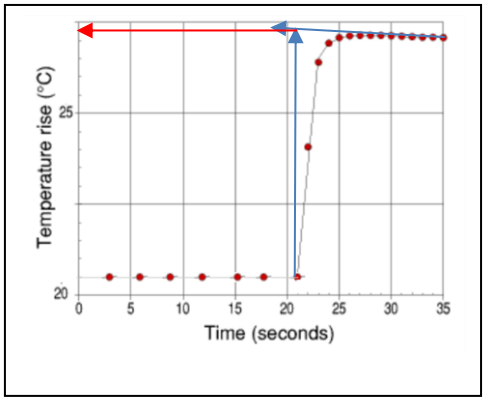
Step 2 Form the graph obtain the ΔT

=> 34.5 - 20.08 approximately 13.7 °C *---- 1 mark*

Step 3 Calculate the C_f

=> 2.53 kJ / 13.7 = 0.185 kJ/°C *---- 1 mark*

b) 0.0280 grams of liquid butane was placed in the bomb calorimeter with excess oxygen and ignited. The temperature was recorded and shown on the graph below.



i. Calculate the molar heat of combustion for butane using the information given above and your answer to question a).

Step 1 Calculate the mol of butane

=> 0.02800 / 58.0 = 4.83 X 10^{-3} mol *--- 1 mark*

Step 2 Calculate the energy released

=> 0.185 X 6.75 = 8.00 kJ *--- 1 mark*

Step 3 calculate the molar heat of combustion

=> 8.00 kJ/4.83 X 10^{-3} = -1656 kJ/mol *--- 1 mark (correct sign and value)*

ii. Write a balanced thermochemical equation for the combustion of butane using your answer to question i. above.

$2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(l)$ *ΔH = - 3312 kJ/mol*

---- 1 mark for balnced,---- 1 mark for correct states at SLC, ----- 1 mark for correct ΔH

c) Consider the information used to determine the calibration factor (C_f) for this calorimeter.

i. Will the molar heat of combustion calculated in question b part i. provide an

underestimation, accurate estimation, or overestimation?

Circle the correct response.

ii. Justify your choice.

When calibrating the calorimeter the total energy must come from the energy source provided, in this case, electrical energy.
Since the temperature was still rising when the current was applied indicates a secondary source of energy is present.
Thus the temperature rise would be greater whilst the energy input (E=Vit) would still be calculated using voltage, time and current hence C_f would be lower ---- 1 mark
A lower value for C_f would lead to an underestimation of the molar heat of combustion ---- 1 mark

d) When conducting the experiment to find the molar heat of combustion of butane, the analyst placed 100 mL of water in the calorimeter instead of 50 mL. Assuming that the specific heat capacity of water (4.18 J/g°C) does not change, the analyst concluded that using a different volume would not affect the calculated molar heat of combustion. Is this assumption accurate? Justify your answer.

Although the specific heat of water remains the same, using more water effectively increases the amount of heat the water in the calorimeter can absorb before increasing by 1°C . That means now, with 100 g of water, the system will require twice as much energy to achieve the same temperature change, than with 50 g of water. ---- 1 mark

The molar heat of combustion would be underestimated by approximately half.--- 1 mark

Question 6

Potassium permanganate ($KMnO_4$) is a strong oxidant. In a certain reaction 5.78 grams of chromium(II) sulphate reacted exactly with 37.60 mL of 0.265 M $KMnO_4$. During this reaction the Cr^{2+} ions were oxidised to Cr^{3+}.

a) What oxidation state was Mn in $KMnO_4$ reduced to?

The number of electrons given up by the reductant, $Cr^{3+}$is equal to the number of electrons taken up by the oxidant Mn^{7+}.

The oxidation reaction is as follows.

$Cr^{2+}(aq) => Cr^{3+}(aq) + e^-$

Mol of electrons = mol of Cr^{2+} ions. = 5.78/148= 0.03715 ---- 1 mark

Now the mol of Mn^{7+} ions = C X V = 0.247 X 0.03760 = 0.00996 mol

So the ratio of Mn^{7+} : electrons

= 0.00996 : 0.0391

= 1: 4 ---- 1 mark

So for every one mol of Mn^{7+} we need four mol of electrons.

$Mn^{7+}(aq) + 4e => Mn^{+3}(aq)$ ---- 1 mark

b) MnO_4^- is used as an oxidant to convert propan-1-ol to propanoic acid and in the process forming Mn^{2+} ions.

i) Give the oxidation half-equation for this reaction, states not included.

_____ *$H_2O + C_3H_8O \rightarrow C_3H_6O_2 + 4H^+ + 4e^-$*

---- 1 mark for correct formulae

---- 1 mark balanced for charge

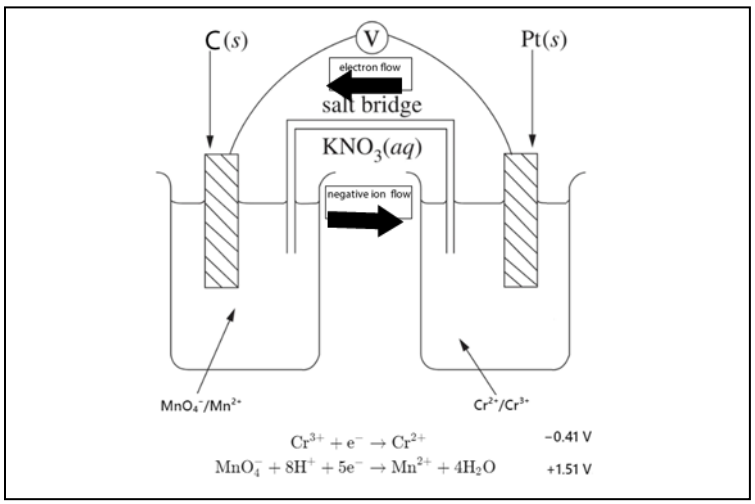
ii) Give the reduction half-equation for this reaction, states not included.

_____ *$5e^- + 8H^+ + MnO_4^- + \rightarrow 4H_2O + Mn^{2+}$* _____ 2 marks

---- 1 mark for correct formulae

---- 1 mark balanced for charge

c) The galvanic cell, shown below, was set up and operated at standard conditions.



i. Identify the:

Reductant _____*$Cr^{2+}(aq)$*_____;

Oxidant _____*$MnO_4^-(aq)$* _____.

2+2=4 marks

ii. Give the overall equation taking place in the cell . States required.

$MnO_4^-(aq) + 8H^+(aq) + 5Cr^{2+}(aq) \rightarrow 5Cr^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(l)$

---- 1 mark balanced for element

---- 1 mark balanced for charge and states shown.

iii. Indicate the direction of electron flow and negative ion flow by placing an arrow in the respective boxes provided. 2 marks

iv. Give the cell EMF. _____*1.92V*_____ 1 mark

v. Describe two changes that would occur in a galvanic cell if the carbon electrode is replaced with a zinc metal electrode: one chemical change and one energy transformation. Provide a concise explanation for why each change takes place.

Chemical change

The zinc metal would dissolve as the Zn metal now becomes the strongest reductant present reacting with the strongest oxidant ($MnO_4^-(aq)$)

Energy transformation change

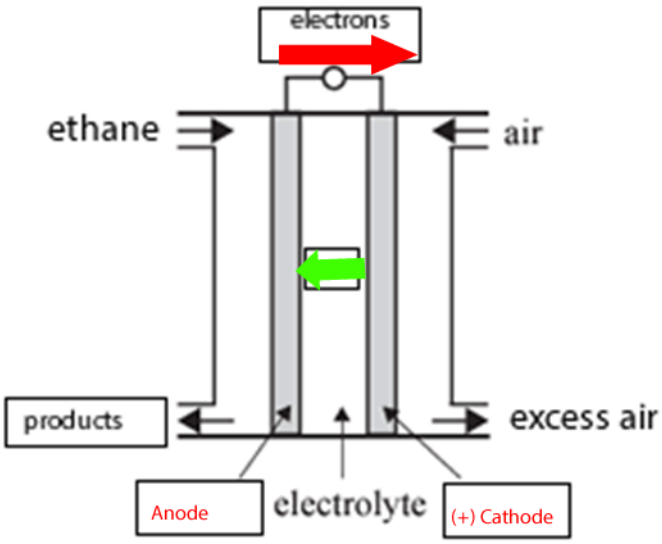
Since the strongest oxidant and strongest reductant are in direct contact with each other ---- 1 mark

the energy conversion is chemical → heat ---- 1 mark

Question 7

A solid oxide fuel cell (SOFC) is shown below. Ethane undergoes partial oxidation when reacted with atmospheric oxygen to produce carbon dioxide and hydrogen gas according to the equation below.

$$C_2H_6(g) + 2O_{2(g)} \rightarrow 2CO_2(g) + 3H_2(g)$$



Combustion of ethane in a solid oxide fuel cell

a) In the diagram above, label the following:
   i. Direction of electron flow. --- *1 mark*
   ii. Anode and cathode and its polarity --- *1 mark*
   iii. Direction of ion flow through the electrolyte. --- *1 mark*

b) The electrolyte allows for the flow of ions from one electrode to the other.
   i. Identify the ions that flow through the solid electrolyte.

   _____ O^{2-} _____1 mark

   ii. Indicate, by placing an arrow in the box provided in the diagram above, the direction of ion flow through the electrolyte 1 mark

c) Give the balanced half equations, states not included, that take place at the:
   i. Anode $C_2H_6 + 4O^{2-} \rightarrow 2CO_2 + 3H_2 + 8e^-$
   ---- 1 mark balanced
   ---- 1 mark and clearly showing electrons as products (oxidation)
   ii. Cathode _____ $O_2(g) + 4e^- \rightarrow 2O^{2-}$

   ---- 1 mark balanced
   ---- 1 mark and clearly showing electrons as reactants (reduction)

d) The fuel cell consumes 0.496 L of ethane per hour, at SLC, what is the current produced if the cell runs at 60.0% efficiency.

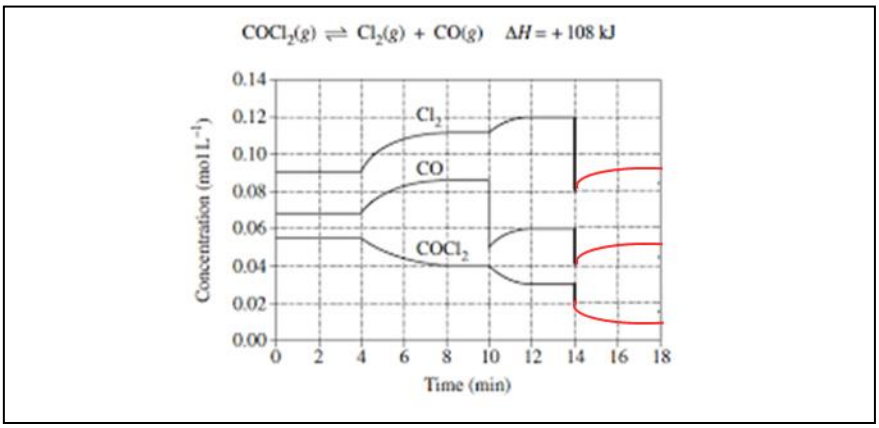
Step 1 Calculate the mol of ethane at SLC
=> 0.496 / 24.8 = 0.0200 mol *--- 1 mark*
Step 2 calculate the mol of electrons
=> $C_2H_6 + 4O^{2-} \rightarrow 2CO_2 + 3H_2 + 8e^-$
=> 0.0200 X 8 = 0.160 mol *--- 1 mark*
Step 3 calculate the current at 100% efficiency
=> Q =It
=> Q / t =I
=> 96500 X 0.160 / (60 X 60) = 4.29 amps *--- 1 mark*
Step 4 calculate the current at 60% efficiency
=> 4.29 X 0.600 = 2.57 amps. *(3 sig figs)* *--- 1 mark*

e) Is a solid oxide fuel cell running on ethane an example of a circular or linear economy? Explain your reasoning

linear economy ---- 1 mark
The use of a fossil fuel such ethane follows a "take-make-dispose" model, where resources are extracted, used to create energy, and the waste (CO_2) discarded.
---- 1 mark

Question 8

One mol of phosgene gas ($COCl_2$) is placed in a sealed 1.0 L reaction vessel and allowed to decompose to form Cl_2 and CO gases. Equilibrium is quickly achieved in under one minute. The concentration of the different species over time is shown below.



a) At the one minute mark 0.085 mol of Cl_2 was present. Calculate the value, with appropriate units, of the equilibrium constant (K_c) at the 2 minute mark.

$Kc = (0.085)^2/(1.00 - 0.085)$ M
=> 7.9 X 10^{-3}M
--- 1 mark for correct expression
--- 1 mark for correct values and calculation
--- 1 mark sig figs 2

b) How has the value of K_c and the rates of both the forward and backward reactions changed at t_8 as compared to the K_c and the rates at t_2? Circle the appropriate responses from the options below.

K_c	*increases*	decreases	unchanged
Rates	*increase*	decrease	unchanged

c) Justify your response to question b) above.

The stress at t8 is most likely a temperature change. Judging by the response of the endothermic system in moving to the right, temperature was increased yield is increased. ----- 1 mark
Due to a greater kinetic energy in the system both rates will also increase. ----- 1 mark

d) Suggest a likely stress imposed on the system at t_{14} and comment on how the K_c value at t_{14} differs from the K_c value at t_{12}. Justify your suggestion.

volume was increased by a third ---- 1 mark
No change in Kc ---- 1 mark
Kc changes only with temperature change not volume change ---- 1 mark

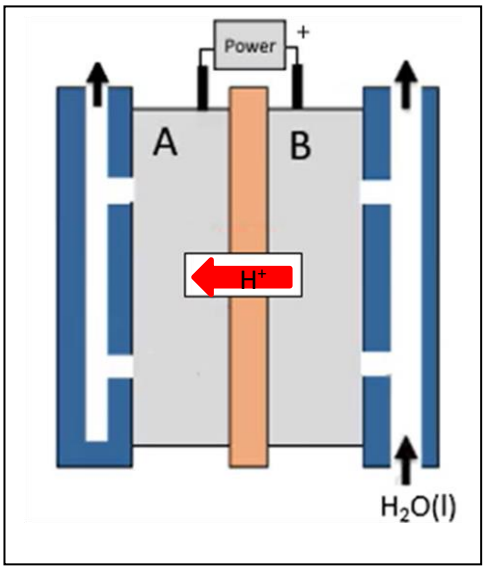
e) Complete the graph, above, indicating how the system responds to the stress at t_{14}.

---- 1 mark correct response

---- 1 mark correct proportional responses

Question 9

Consider the proton exchange membrane electrolyser shown below.



a) Which electrode is the anode?

_____*B*_____ 1 mark

b) Give the balanced chemical equation for the reaction taking place at each electrode. States not required

A _____ $4H^+ + 4e^- \rightarrow 2H_2$ _____ 1 mark

B _____ $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$ _____ 1 mark

c) Clearly identify the ions travelling through the electrolyte and their direction of travel in the box provided.

d) Identify the following species

Y _____ O_2 _____ 1 mark

X _____ H_2 _____ 1 mark

e) Suggest one requirement, when operating this electrolyser, that is necessary for the production of Green hydrogen. Justify your suggestion.

Use of renewable energy sources, such as solar or wind, to power the electrolyser. --- 1 mark

Production of green hydrogen, involves renewable and sustainable energy sources without the production of CO_2 --- 1 mark

Question 10

A rechargeable nickel-cadmium battery has the following overall reaction taking place when discharging.

$$Cd(s)+2NiO(OH)(s)+2H_2O(l)\rightarrow Cd(OH)_2(s)+2Ni(OH)_2(s)$$

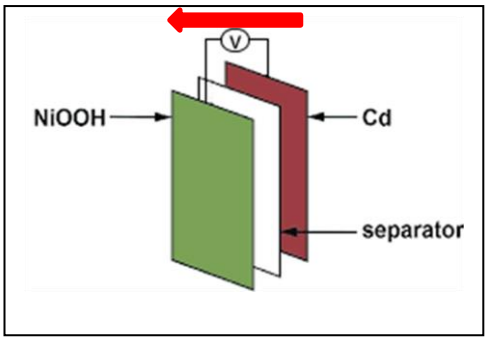
a) Write the half reaction taking place at the negative electrode during **discharge**. States included.

_____ *$Cd((s) + 2H_2O(l) \rightarrow 2e^- + 2H^+(aq) + Cd(OH)_2\ (s)$*
--- 1 mark correct formulae and balanced for element and charge.
--- 1 mark correct states

b) Write the half reaction taking place at the positive electrode during **recharge**. States included.

_____ *$Ni(OH)_2\ (s) + H_2O(l) \rightarrow 3e^- + 3H^+(aq) + NiO(OH)\ (s)$*
--- 1 mark correct formulae and balanced for element and charge.
--- 1 mark correct states

c) A simple schematic of the battery is shown below.



i. What is the polarity of the Cd electrode during discharge?
_____*negative --- 1 mark*

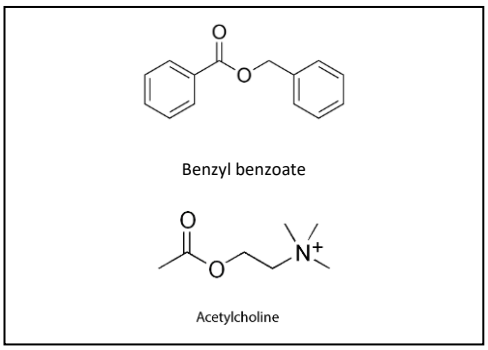
ii. How does the polarity of the Cd electrode change during recharge?
_____*no change ----1 mark*

d) Based on the half reactions taking place at each electrode, explain why the battery is rechargeable.

- *Products at both electrodes are solids ---- 1 mark*
- *Solid products adhere to the electrode ---- 1 mark*

Question 11

Acetylcholine is a neurotransmitter that transmits signals from nerves to muscles and other organs. The enzyme acetylcholinesterase is responsible for breaking down acetylcholine after it has been released to terminate the signal. Benzyl benzoate acts as a competitive inhibitor of acetylcholinesterase, competing with acetylcholine for binding to the enzyme's active site and thereby prolonging the effects of acetylcholine at the synapse.



a) Given the chemical structures of benzyl benzoate and acetylcholine, shown above:

i. What functional group do both of these molecules share.

_____*Ester*_____1 mark

ii. What type of reaction does the enzyme facilitate in order to break down this functional group and hence degrade acetyl choline?

_____*hydrolysis*_____ 1 mark

b) A mixture of benzyl benzoate and acetylcholine is to be separated into its pure components using HPLC. The HPLC column is filled with beads coated with methyl groups (CH_3).

i. The operator dissolves the mixture in a polar solvent before injecting it into the column. She expects benzyl benzoate to elute from the column first, ahead of acetylcholine. Do you agree? Provide a clear explanation based on your chemical knowledge.

No ---- 1 mark

- Benzyl benzoate is a relatively non-polar compound, so it will have a greater interaction with the non-polar stationary phase than the polar acetylcholine molecule. ----1 mark

- Benzyl benzoate with therefore have the highest retention time of the two compounds. ---- 1 mark

ii. Give a clear explanation of how HPLC can be used to identify the presence of both acetylcholine, and benzyl benzoate and to discount the possibility of potential contamination with an unknown organic substance.

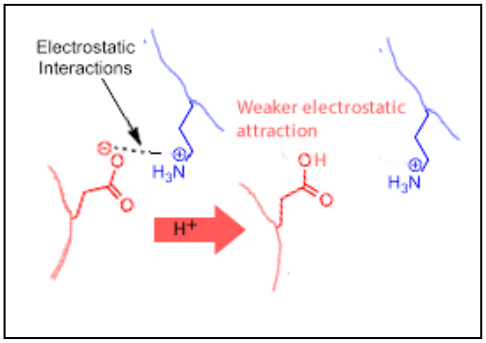
By running pure standards of acetylcholine and benzyl benzoate separately to determine their exact retention times under the same HPLC conditions. ----- 1 mark
When the mixture is run, peaks at these retention times indicate the presence of acetylcholine and benzyl benzoate. ---- 1 mark
Any unknown organic compound with a different polarity or structure would have a different retention time, producing additional peaks in the chromatogram. --- 1 mark
Additional peaks, therefore, provide evidence that the mixture is contaminated with unknown compounds. ---- 1 mark

c) Describe a way that a pure sample of benzyl benzoate and acetylcholine can be obtained from the mixture using a more simple technique, such as solvent extraction with water as the solvent. Provide a brief summary of the procedure detailing how each component will be separated from the mixture given the density of benzyl benzoate is 1.118 g/mL.

Dissolve the mixture in water, acetylcholine is polar and highly soluble in water whilst Benzyl benzoate is nonpolar and insoluble in water. ---- 1 mark
Place the mixture in a separating funnel and shake, allowing the aqueous layer and benzyl benzoate to separate. The benzyl benzoate will separate out as a distinct layer and settle at the bottom of the water layer since it is more dense than water.. ---- 1 mark.
Carefully drain the bottom layer (benzyl benzoate) into a clean container to obtain the pure benzyl benzoate. ---- 1 mark
The top layer, containing acetylcholine, can then be collected separately and with gentle heating, the water can evaporate leaving pure acetylcholine. --- 1 mark

d) The buildup of lactic acid during intense exercise contributes to muscle cramps through its effects on muscle pH, which can impair the function of acetylcholinesterase. This impairment can lead to prolonged acetylcholine activity, causing excessive muscle contraction known as cramps. Explain in terms of protein structure and bonding how lactic acid build up in muscle tissue impacts on the ability of acetylcholinesterase to degrade acetylcholine. You may use a diagram to enhance your explanation.

Acetylcholinesterase has a specific three-dimensional tertiary structure, on which lies a small section at the surface with a unique shape for binding acetylcholine, called the active site.
------ 1 mark (appropriate use of terms such as, tertiary structure, active site)
Increase in [H^+] due to lactic acid build up protonates amino acid sidechains which are involved in ionic bonds (salt bridges) --- 1 mark
Protonation of these side chains weakens the electrostatic attraction of ionic bonds (salt bridges) and distorts the tertiary structure and makes the active site less able to bind acetylcholine and catalyse its breakdown ---- 1 mark



--- 1 mark

Question 12

Below is an investigation conducted by a chemist in a scientific laboratory.

Practical Investigation: Determining the Concentration of Vitamin C in Orange Juice

Aim:

To determine the concentration of vitamin C (ascorbic acid) in different varieties of orange juice using an iodine titration method.

Materials:

A mass of 0.5 kg of different varieties of oranges (e.g., Navel, Valencia, Blood Orange)
100 mL freshly squeezed orange juice from each variety
0.005 M iodine solution
1% starch indicator solution
1 X 50 mL burette
3 X Pipette (10 mL)
4 X Conical flask (100 mL)
Distilled water
Standard vitamin C solutions 5mg/100mL, 20 mg/100mL, 40 mg/100mL, 60 mg/100mL for calibration
White tile (for colour contrast during titration)

Method:

1. Squeeze the juice from each variety of orange and filter to remove pulp.
2. Using new, clean, 10mL pipette deliver a 10 mL of aliquot of orange juice into each of the three conical flasks.
3. Add 2 mL of starch indicator solution.
4. Titrate the juice with the iodine solution, carefully adding iodine from the burette until the solution remains a blue-black colour for 30 seconds. Record the volume of iodine used.
5. Repeat steps 1 -4 three more times.
6. Repeat steps 1 – 5 for each orange juice sample.
7. Perform titration with the standard vitamin C solutions.
8. Plot the graph of iodine volume vs vitamin C concentration to create a calibration curve.
9. Use the calibration curve to determine the concentration of vitamin C in each of the three orange juice samples.

Results:

Orange Variety	**Volume of Iodine Used (mL)**	**Average Volume (mL)**	**Vitamin C Concentration (mg/100 mL)**
Navel Orange	15.20, 15.27, 15.30, 15.25	15.23	45.0
Valencia Orange	14.80, 14.95, 14.74, 15.15	14.77	43.5
Blood Orange	12.00, 12.15, 12.30, 12.15	12.15	36.5

a) Give the variables in this investigation

i. Independent variable _____*type of orange ----- 1 mark*

ii. Dependent variable ____*volume of titre or concentration of Vit C --- 1 mark*
As volume of titre will ultimately be used to find the [vit C] for each type of orange

iii. Two controlled variables
Any plausible variable such as
- temperature as this could impact on the rate of the reaction.
- volume of aliquot from juice sample.
- concentration of standard solution.

b) The results from which type of orange were most repeatable? Justify your choice.
Navel orange ---- 1 mark
All four results were within a very narrow range (0.100mL) and was the narrowest range of three varieties of orange. ---- 1 mark

c) The results from which type of orange were impacted by random errors? Justify your choice.
Valencia Orange ---- 1 mark
Results show the greatest variation amongst the three orange types, greatest variation amongst the results was between (14.74, and 15.15 mL). This inconsistency in repeated measurements under the same conditions is commonly attributed to random errors. – 1 mark

d) Aside from vitamin C, orange juice contains a variety of antioxidants, such as flavonoids and phenolic compounds, which may also react with iodine.

i. Given this information and the results derived from the Navel orange trials, discuss if the results are valid and reproduceable.
The results are less valid, as the iodine titration method is not specific to vitamin C alone and other antioxidants in the orange juice, may overestimate the actual concentration of vitamin C ---- 1 mark
Since no other group conducted this investigation under the same conditions we can not comment on the reproducibility of these results. ---- 1 mark

ii. What type of error does the presence of other antioxidants in orange juice pose for this investigation? Explain.
Systematic error ---- 1 mark
These compounds react with iodine alongside vitamin C in a consistent and predictable manner, leading to an identical overestimation of vitamin C concentration in each trial of a particular brand of orange. ------ 1 mark

iii. In a well-equipped laboratory, a chemist wants to determine the exact concentration of vitamin C in different brands of orange juice. Due to the presence of other antioxidants like flavonoids and phenolic compounds, she resorts to using HPLC. Suggest how this method would specifically measure vitamin C concentration.

HPLC separates compounds based on differences in chemical structure and polarity ---- 1 mark

Vitamin C will have a specific retention time on the HPLC column, allowing it to be identified distinctively from other antioxidants like flavonoids and phenolic compounds. ---- 1 mark

The area under the peak corresponding to vitamin C can then be measured and compared to a calibration curve to determine its concentration ---- 1 mark (reference to a calibration curve must be mentioned)

iv. Discuss how the used of HPLC would improve the validity of the investigation compared to an iodine titration, and how it may or may not improve, the accuracy of the results.

HPLC improves the validity of the results by specifically isolating and measuring vitamin C ---- 1 mark
Accuracy, however, depends on many other factors such as ,correct calibration, sample handling (eg the solvent used), and precision of the instrument and as such accuracy may not improve. ----- 1 mark

e) Write a relevant conclusion for this investigation.

The investigation successfully measured the concentration of vitamin C in different varieties of orange juice using iodine titration. Navel Orange juice had the highest and most precise concentration, with an average of 45.0 mg/100 mL ---- 1 mark
However, due to the potential reaction of iodine with other antioxidants, the results may overestimate the vitamin C content, impacting the validity. ---- 1 mark