



VCE CHEMISTRY 2012

YEAR 12 TRIAL EXAM UNIT 3

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Time allowed: 90 Minutes

Total marks: 77

Section A

Contains 20 Multiple Choice Questions

20 marks, 27 minutes

Section B

Contains 6 Short Answer Questions

57 marks, 63 minutes

To download the Chemistry Data Book please visit the VCAA website:

http://www.vcaa.vic.edu.au/vce/studies/chemistry/chem1_sample_2008.pdf Page 20

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Student Name.....

VCE Chemistry 2012 Year 12 Trial Exam Unit 3

Student Answer Sheet

Instructions for completing test. Use only a 2B pencil. If you make a mistake erase and enter the correct answer. Marks will not be deducted for incorrect answers.

Write your answers to the Short Answer Section in the space provided directly below the question. There are 20 Multiple Choice questions to be answered by circling the correct letter in the table below.

Question 1 A B C D

Question 3 A B C D

Question 5 A B C D

Question 7 A B C D

Question 9 A B C D

Question 11 A B C D

Question 13 A B C D

Question 15 A B C D

Question 17 A B C D

Question 19 A B C D

Question 2 A B C D

Question 4 A B C D

Question 6 A B C D

Question 8 A B C D

Question 10 A B C D

Question 12 A B C D

Question 14 A B C D

Question 16 A B C D

Question 18 A B C D

Question 20 A B C D

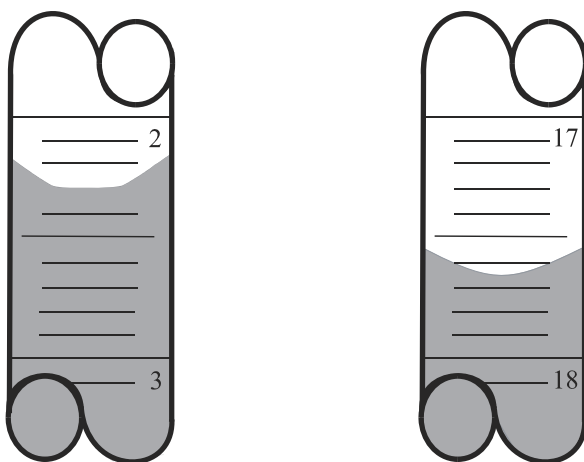
VCE Chemistry 2012 Year 12 Trial Exam Unit 3

SECTION A – Multiple Choice Section

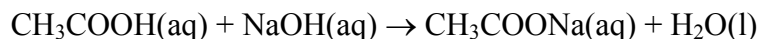
*Section A consists of 20 multiple-choice questions.
Section A is worth approximately 24 per cent of the marks available.
Choose the response that is correct or best answers the question.
Indicate your choice on the answer sheet provided.*

Question 1

Diagrams shown below provide an image of liquid levels in a burette at the start and at the endpoint of titration of 20.0 mL of vinegar with 0.500 M NaOH(aq).



The reaction occurring during the titration is represented by the equation



According to this information the concentration of ethanoic acid present in the vinegar was

- A. 0.366 mol L⁻¹
- B. 0.384 mol L⁻¹
- C. 0.433 mol L⁻¹
- D. 0.651 mol L⁻¹

Question 2

1-propylamine may be produced by a reaction between 1-chloropropane and one other molecular compound. When 2.17 g of 1-chloropropane is completely converted to 1-propylamine, what mass of the other compound would be expected to react?

- A. 0.407 g
- B. 0.470 g
- C. 0.940 g
- D. 1.01 g

Question 3

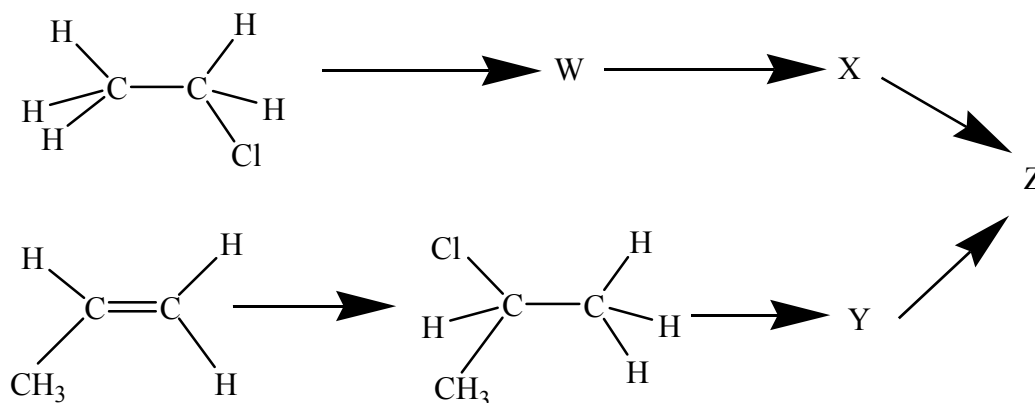
When metals hydrides, such as potassium hydride, KH, react with water, bubbles of gas are released and when phenolphthalein is added to the solution it turns red.

According to these observations, it is most likely that

- A. when the $\text{H}^-(\text{aq})$ ion reacts with water it acts as a base.
- B. when the $\text{H}^-(\text{aq})$ ion reacts with water it acts as an oxidant.
- C. when the $\text{H}^-(\text{aq})$ ion reacts with water it acts as a reductant and base.
- D. when the $\text{H}^-(\text{aq})$ ion reacts with water it acts as an oxidant and an acid.

Questions 4, 5, and 6 are based on the following information.

The diagram below shows part of a possible reaction pathway for producing a compound which has a distinctly fruity odour.



Question 4

Compounds X and Y are

- A. ethanoic acid and 1-propanol.
- B. ethanamine and 1-propylamine.
- C. ethanol and propanoic acid.
- D. ethanoic acid and 2-propanol.

Question 5

Compound Z would be expected to

- A. produce five peaks on its ^{13}C NMR spectrum.
- B. produce three peaks on its low resolution ^1H NMR spectrum.
- C. produce a peak at $m/z = 112$ on its mass spectrum.
- D. show a broad absorption band in the range $2500\text{--}3300\text{ cm}^{-1}$ on its IR spectrum.

Question 6

Which of the inorganic reagents listed below would be **not** be expected to be part of this pathway?

- A. Potassium dichromate.
- B. Sulfuric acid.
- C. Chlorine.
- D. Sodium hydroxide.

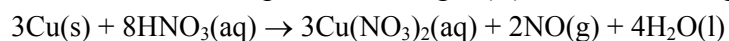
Question 7

Ammonia can act as a reductant. Which of the following substances is least likely to be produced when ammonia is involved in a redox reaction?

- A. Sodium nitrate.
- B. Nitric acid.
- C. Ammonium sulfate.
- D. Nitrogen.

Question 8

Copper reacts with dilute nitric acid to produce nitrogen(II) oxide according to the equation



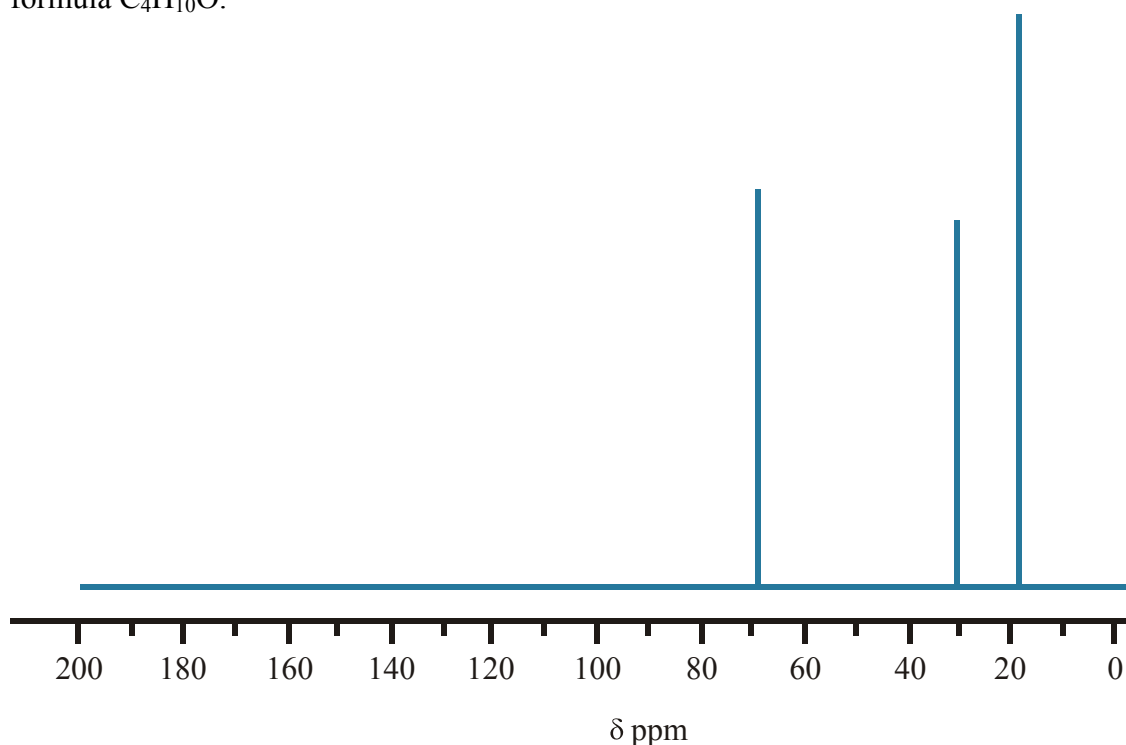
When 6.75 g of Cu is added to 200 mL of 1.00 M HNO₃ and the reaction allowed to proceed to completion, 630 mL of NO is collected at STP.

Which of the following is closest to the percentage of the NO produced in the reaction that was actually collected?

- A. 27
- B. 40
- C. 56
- D. 60

Question 9

Shown below is a representation of the ¹³C NMR spectrum of a compound with molecular formula C₄H₁₀O.



This is the ¹³C NMR spectrum of

- A. 2-propanol.
- B. 2-butanol.
- C. methyl-1-propanol.
- D. methyl-2-propanol.

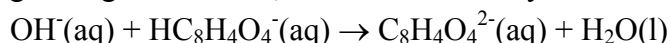
Question 10

The most significant difference in the infrared spectra for the structural isomers, ethanoic acid and methyl methanoate, will be evident in the peaks due to

- A. O-H bond stretching.
- B. C=O bond stretching.
- C. C-H bond stretching.
- D. C-O bond stretching.

Question 11

Potassium hydrogen phthalate $\text{K}(\text{HC}_8\text{H}_4\text{O}_4)$, a primary standard, is used to determine the concentration of an aqueous solution of calcium hydroxide, $\text{Ca}(\text{OH})_2$, by volumetric analysis. The reaction occurring during the titration, can be described by the ionic equation



In a particular standardisation procedure, 0.864 g of $\text{KHC}_8\text{H}_4\text{O}_4$ was weighed out and dissolved in water to produce a total volume of 200.0 mL.

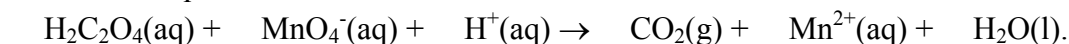
19.25 mL of this solution was required to neutralise 20.0 mL of $\text{Ca}(\text{OH})_2(\text{aq})$ solution.

The molar concentration of the $\text{Ca}(\text{OH})_2$ solution was

- A. 0.000407 M.
- B. 0.00509 M.
- C. 0.0102 M.
- D. 0.0126 M.

Question 12

Oxalic acid, $\text{H}_2\text{C}_2\text{O}_4$, is found in many vegetables, including rhubarb. It also has a diverse range of uses, including waste water treatment where it is used to precipitate calcium ions. Oxalic acid is a reductant and reacts with potassium permanganate, KMnO_4 according to the unbalanced ionic equation.

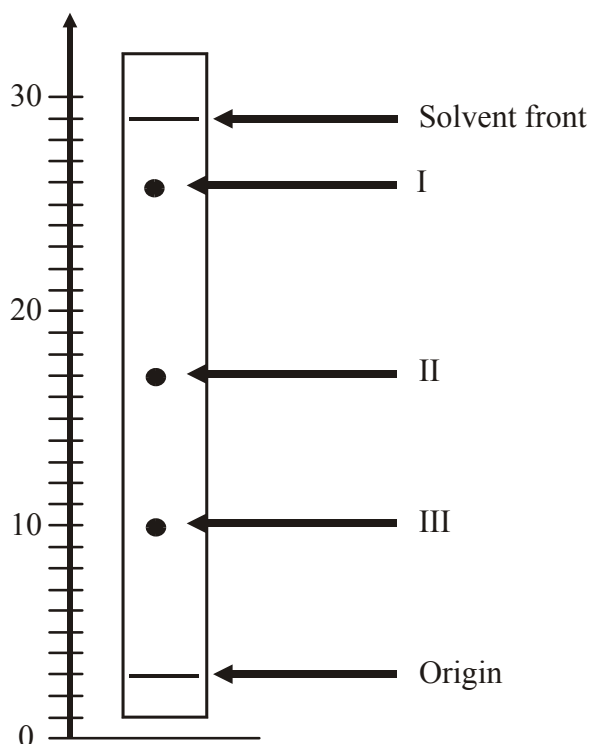


If two mole of $\text{MnO}_4^-(\text{aq})$ is consumed in this reaction, the amount of oxalic acid reacting will be

- A. one mole.
- B. two mole.
- C. five mole.
- D. ten mole.

Question 13

Thin Layer Chromatography is used as part of the analysis of a substance known to contain different compounds. When a **single** chromatogram is produced, using a non-polar stationary phase, three distinct regions, I, II and III, appear on the chromatogram, which is represented below.



Which of the following statements **cannot** be conclusively deduced from this chromatogram?

- A. The molecules in region I are least strongly attracted to the stationary phase.
- B. If the solvent front had moved a smaller distance from the origin, the R_f values for I, II and III would be larger.
- C. The molecules in region III are most strongly adsorbed to the stationary phase.
- D. There are only three different compounds in the substance.

Question 14

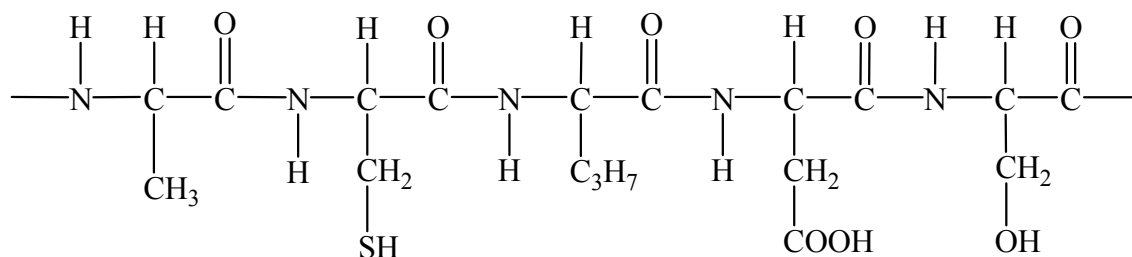
The amount of copper present in an aqueous solution of copper(II) sulfate that is contaminated with other substances can be determined by both atomic absorption spectroscopy and UV-Visible spectroscopy.

Which of the following steps in the analytical procedure is associated with one of these techniques but not the other?

- A. Determine a wavelength which is strongly absorbed by $\text{Cu}^{2+}(\text{aq})$ ions but is not absorbed by any of the other substances in the solution.
- B. Make up a set of standards of known copper concentration and measure their absorbances.
- C. Establish a calibration curve to determine the relationship between absorbance and copper concentration.
- D. If the measured absorbance of the copper(II) sulfate solution is above the range of the calibration curve, dilute it so that absorbance falls within the range of the curve.

Questions 15 and 16 refer to the following information.

Part of a protein chain is represented by the structure below.



Question 15

The solubility of a protein in aqueous solutions depends on the distribution of hydrophilic and hydrophobic patches on the protein's surface. Proteins that have hydrophobic amino acid side chains on the surface will be less soluble in aqueous solutions.

The amino acid present in the section of protein chain that would provide the greatest contribution to hydrophobic regions is

- A. alanine.
- B. phenylalanine.
- C. valine.
- D. serine.

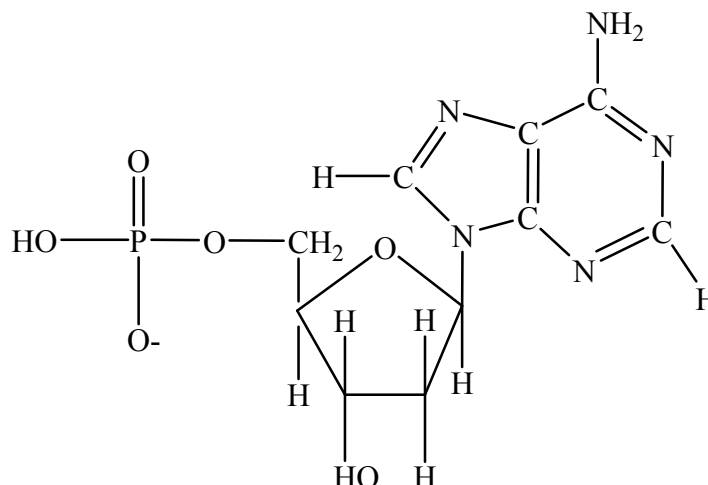
Question 16

Which of the amino acids in this section of the protein chain has a side chain that would enable the formation of covalent bonds in the tertiary structure of the protein?

- A. Cysteine.
- B. Valine.
- C. Aspartic acid.
- D. Serine.

Question 17

The structure below represents a nucleotide involved in the formation of DNA.

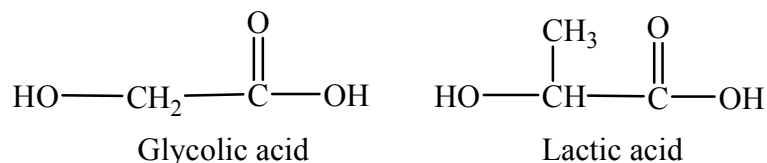


A chemical reaction that occurs during the formation of the nucleotide is

- A. a redox reaction between phosphoric acid and ribose.
- B. an esterification reaction between cytosine and ribose.
- C. an acid-base reaction between deoxyribose and phosphoric acid.
- D. a condensation reaction between deoxyribose and adenine.

Question 18

Some polyesters have been used in applications such as sutures and drug delivery systems. One polyester which slowly hydrolyses and dissolves is a copolymer of lactic acid and glycolic acid, which are represented by the diagrams below



If 500 molecules of glycolic acid and 500 molecules of lactic acid combine to form a polyester chain, the relative molecular mass of the polyester chain will be

- A. equal to the sum of the relative molecular masses of lactic acid and glycolic acid.
- B. 9000 lower than the sum of the relative molecular masses of lactic acid and glycolic acid.
- C. 17982 lower than the sum of the relative molecular masses of lactic acid and glycolic acid.
- D. 18000 lower than the sum of the relative molecular masses of lactic acid and glycolic acid.

Question 19

Instructions for the production of a useful chemical, accompanied by appropriate safety warnings, included

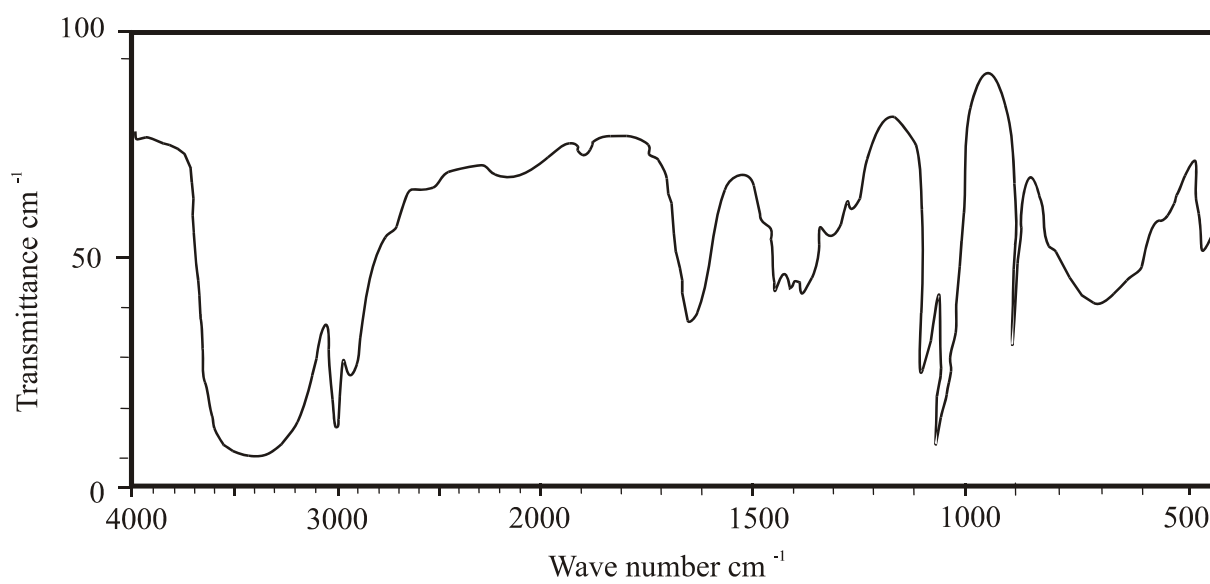
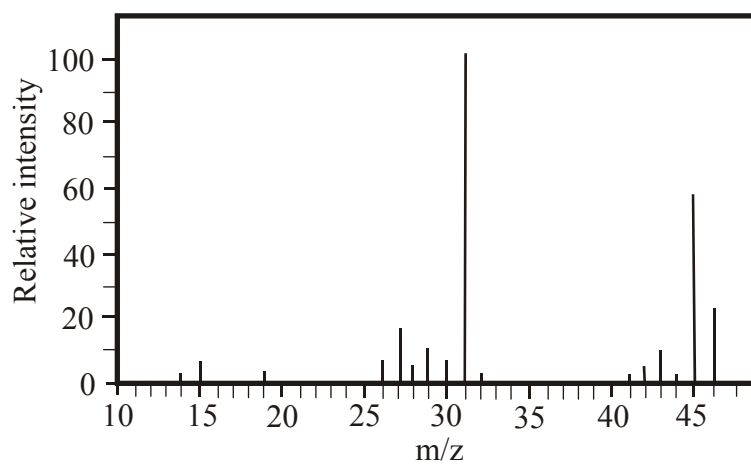
1. Take one litre of cooking oil, 3.5 grams of sodium hydroxide and 200 mL of methanol.
2. Pour the methanol into a blender.
3. Add the 3.5 g of sodium hydroxide and blend until the sodium hydroxide has completely dissolved.
4. Add the one litre of cooking oil and continue blending until the liquid separates into two layers.

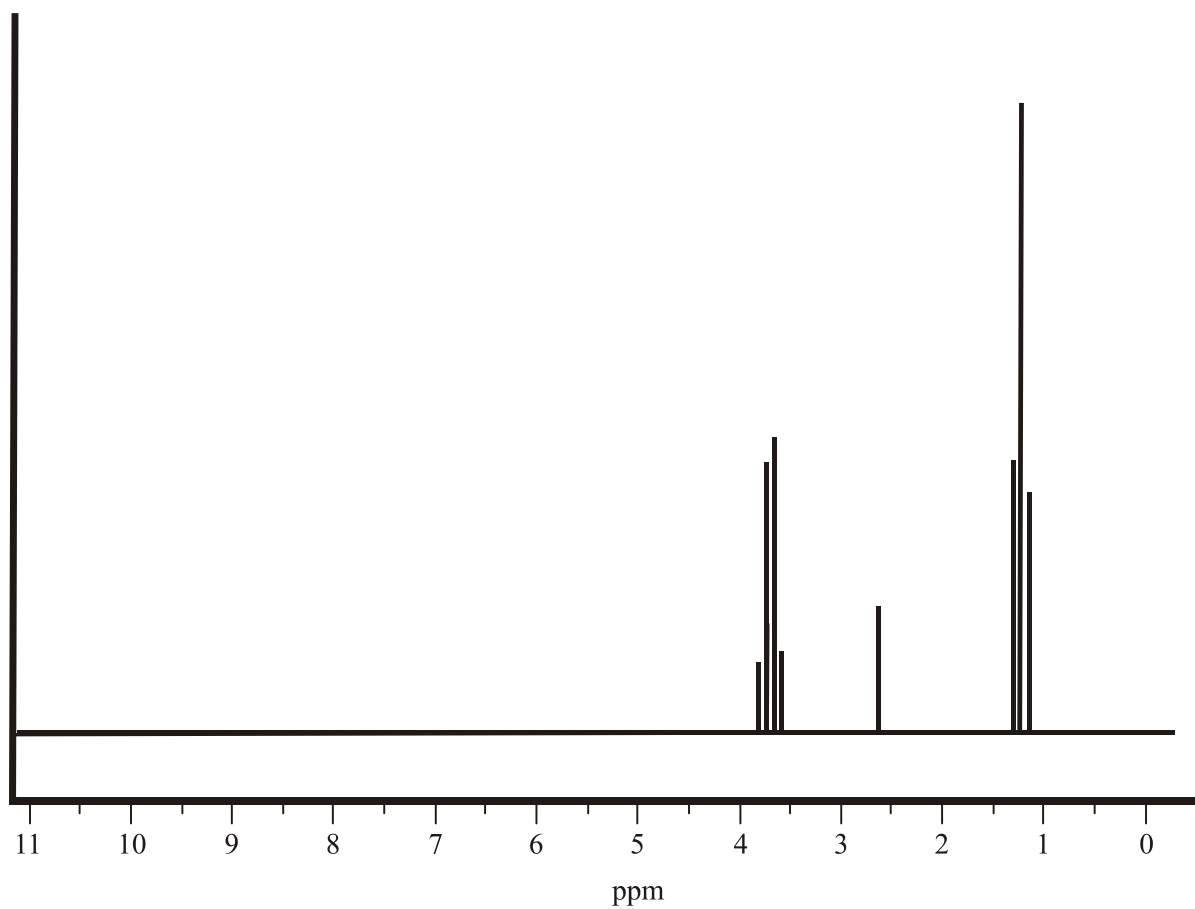
The two layers referred to in this procedure would be

- A. a fatty acid and water.
- B. biodiesel and glycerol.
- C. an alcohol and a carboxylic acid.
- D. oil and water.

Question 20

All of the spectra shown below are of the same compound.





The compound is

- A. ethanol.
- B. ethanoic acid.
- C. ethyl ethanoate.
- D. 1-propanol.

End of Section A

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SECTION B – Short Answer Section

*Section B consists of 6 short answer questions.
You should answer all of these questions in the spaces provided.
This section is worth approximately 76 per cent of the total marks available.
The marks allotted are shown at the end of each part of each question.*

Question 1 (10 marks)

Magnesium oxide has a wide variety of uses, including infrared optics, cement manufacture and as source of magnesium in dietary supplements. It occurs naturally as the mineral periclase, but is mostly produced from magnesium carbonate minerals such as magnesite. The solubility of magnesium oxide in water at 25°C is only 0.0086 g / 100 mL, so the analysis of the percentage purity of a sample of magnesium oxide by volumetric analysis requires the use of a 'back titration' method.

In such an analysis, 4.06 g of impure magnesium oxide was completely dissolved in 250.0 mL of 1.00 M hydrochloric acid. Three 20.0 mL aliquots of the resultant solution were titrated with 0.200 M sodium hydroxide solution using bromothymol blue indicator. An average titre of 19.7 mL was required to reach the endpoint of the reaction.

- a. Write a balanced equation for the reaction between magnesium oxide and hydrochloric acid.

(1 mark)

- b. Calculate the amount, in mol, of hydrochloric acid remaining unreacted after the reaction with magnesium oxide.

(2 marks)

- c. Calculate the amount, in mol, of hydrochloric acid that reacted with magnesium oxide.

(1 mark)

- d. Calculate the mass of magnesium oxide that reacted with the hydrochloric acid, and determine the % purity of the magnesium oxide.

(3 marks)

- e. The accuracy of this analysis in determining the percentage purity of the sample depends on the assumption that the only substance that reacts with hydrochloric acid was magnesium oxide. If this assumption was not valid, how would the calculated percentage purity compare with the actual percentage purity? Explain your answer.

(2 marks)

- f. When phenolphthalein is used as the indicator rather than phenol red, the solution being titrated turns cloudy before the endpoint is reached. What is most likely to cause this cloudiness?

(1 mark)

Question 2 (10 marks)

Aspartame, the low-calorie, intense sweetener used in beverages, desserts, dairy, chewing gums, and energy and weight control products, has at times caused controversy about its safe use during its four decades in the market place. Aspartame, aspartyl-phenylalanine methyl ester, is produced by the reaction between the amino acid aspartic acid and the methyl ester of the amino acid phenylalanine.

- a. Draw the structure of the methyl ester of phenylalanine.

(1 mark)

- b. Draw the structure of aspartame.

(2 marks)

- c. Give the name of the other compound produced during the production of aspartame.

(1 mark)

- d. Describe the changes in functional groups that occur during the production of aspartame.

(2 marks)

- e. Name the three products produced when aspartame undergoes hydrolysis in the body.

(2 marks)

- f. In late 2011, researchers at Massachusetts General Hospital in Boston, Massachusetts, identified five amino acids whose levels in body fluids indicated an increased diabetes risk. Phenylalanine is one of these amino acids.

What term is used to describe phenylalanine in this context?

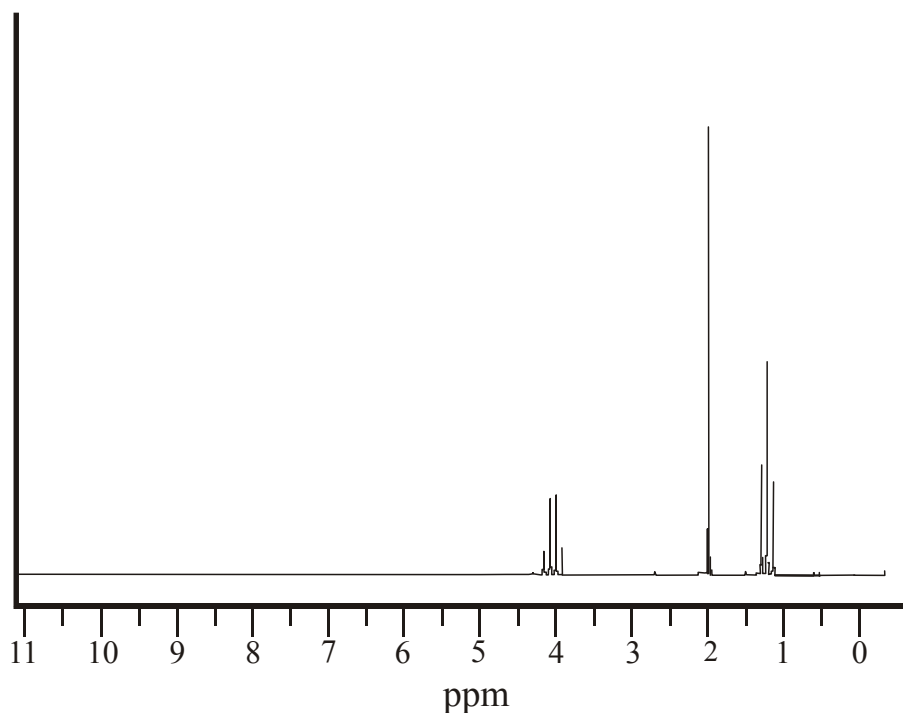
(1 mark)

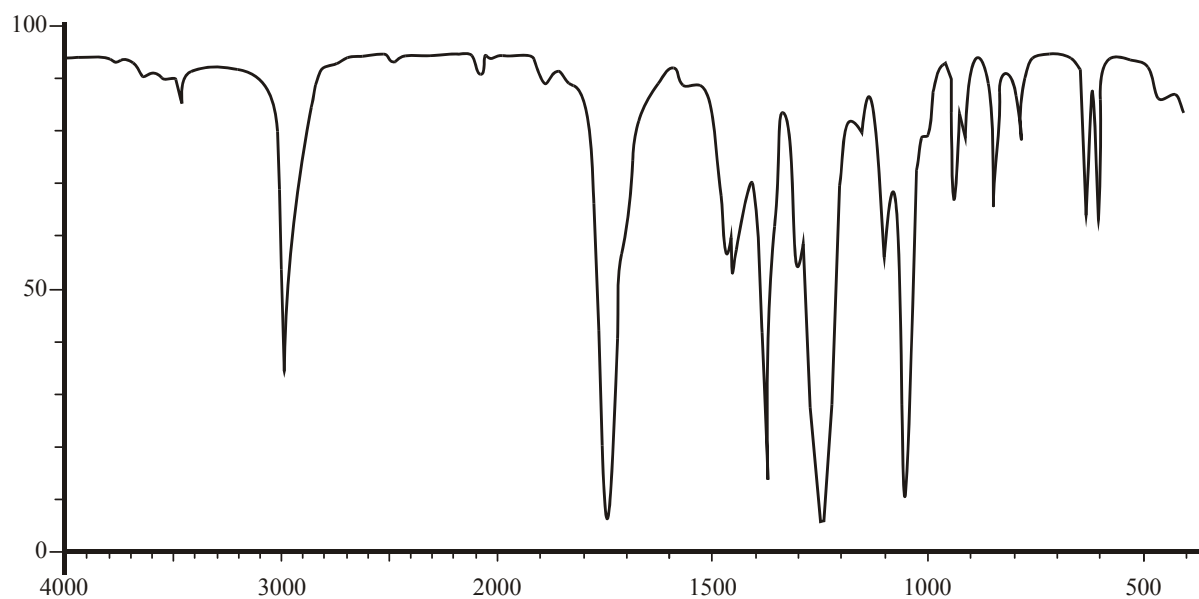
- g. The IR spectra of aspartic acid, phenylalanine and aspartyl-phenylalanine methyl ester, all show a significant absorption band centred around 3400 cm^{-1} . Why?

(1 mark)

Question 3 (13 marks)

Shown below are the high resolution ^1H NMR and IR spectra of a compound produced via a reaction pathway that starts with ethane as the only organic reactant.





- a. What can be deduced about the molecules in the compound from the ^1H NMR spectrum?

(2 marks)

- b. What can be deduced about the molecules in the compound from the IR spectrum?

(2 marks)

- c. Name the compound.

(1 mark)

- d. Draw the structure, showing all bonds, of the compound.

(1 mark)

- e. Show a reaction pathway, including all inorganic reactants, for the production of the compound from ethane.

(4 marks)

- f. Write a balanced equation for the final step in the production of the compound.

(1 mark)

- g. Name all of the different types of reaction occurring in the reaction pathway in (e).

(1 mark)

- h. Why can the compound be separated from the other product and the reactants in the equation in (f) by fractional distillation?

(1 mark)

Question 4 (10 marks)

Cetane (hexadecane), $C_{16}H_{34}$, a fossil fuel derivate, is a major component of the fuel used in cars with diesel engines. Modern diesel engines also run efficiently on biodiesel.

- a. Give a semi-structural formula for biodiesel in which the molecules have one more carbon atom than cetane molecules.

(1 mark)

- b. Draw the structure of a fat from which the biodiesel in (a) could be produced.

(2 marks)

- c. Cetane releases energy in a diesel engine by way of the combustion equation
 $2C_{16}H_{34}(l) + 49O_2(g) \rightarrow 32CO_2(g) + 34H_2O(l)$
What volume of CO_2 , in ML, at $28^\circ C$ and 1.25×10^5 Pa pressure, would be produced from the combustion of fifty litres of diesel fuel which has a density of 0.850 g mL^{-1} ? Assume the diesel fuel is pure cetane.

(4 marks)

- d. Bioethanol is another biofuel, which is produced from cereal crops and sugar cane. A key step in the production of bioethanol is the fermentation of glucose.
Write balanced equations for
i. fermentation

(1 mark)

- ii. the combustion of ethanol

(1 mark)

- e. State a key issue which may impact upon the sustainability of biofuels.

(1 mark)

Question 5 (8 marks)

- a. Two students, A and B, standardise an approximately 0.1 M aqueous solution of hydrochloric acid, by each titrating a 20.0 mL aliquot of 0.050 M $\text{Na}_2\text{CO}_3(\text{aq})$ with the acid to the methyl orange endpoint. The only variation in their techniques was that student A rinsed the pipette used to measure the 20.0 mL aliquot of the $\text{Na}_2\text{CO}_3(\text{aq})$ solution with water and then that solution, whilst student B rinsed the pipette only with water.

One of the students determined the $c(\text{HCl})$ to be 0.098 M whilst the other student determined it to be 0.095 M.

State which calculated $c(\text{HCl})$ is more accurate and explain how the less accurate calculated concentration is a consequence of the incorrect rinsing procedure.

(2 marks)

- b. Proteins and DNA both have secondary structures maintained by hydrogen bonding. However, whilst the strength of bonding that results from the hydrogen bonds formed at each site is relatively consistent throughout the secondary structure of a protein, this is not the case for DNA. Explain.

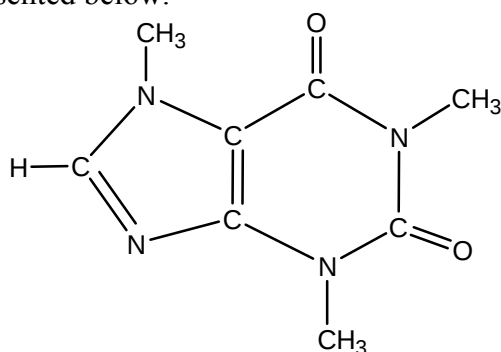
(3 marks)

- c. The mass spectrum of 2-propanol shows peaks at mass / charge ratios of 45 and 60. Give formulae for the species producing these peaks and explain how they were produced in the mass spectrometer.

(3 marks)

Question 6 (6 marks)

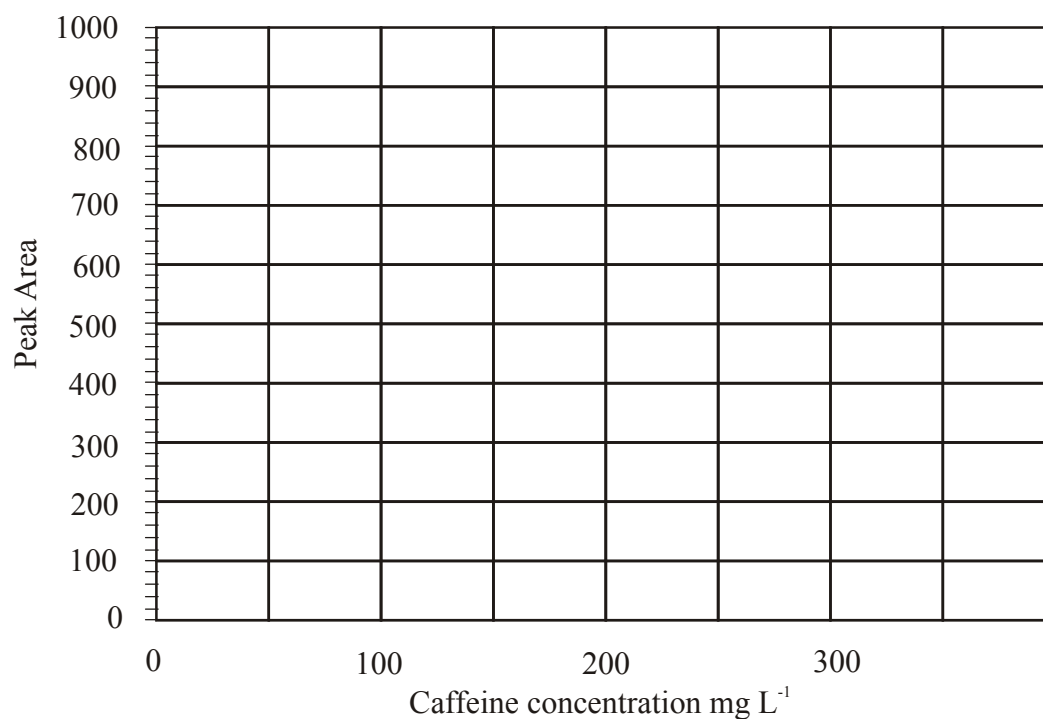
Coffee, tea and various cola drinks contain the stimulant caffeine. The structural formula of caffeine molecules is represented below.



The caffeine content of beverages is often determined using HPLC. In one such analysis, a set of standards of known caffeine concentration were prepared and the HPLC peak areas of these standards were recorded. Then the caffeine HPLC peak area for a cola based beverage was recorded. The data collected are presented below.

Sample Tested	Peak Area
100 mg L ⁻¹ standard	230
200 mg L ⁻¹ standard	540
300 mg L ⁻¹ standard	820
Cola beverage	600

- a. Use the data provided to plot a calibration graph and use it to determine the caffeine concentrate of the cola-based beverage in ppm(m/V).



(2 marks)

- b. The cola based beverage produced many peaks on its HPLC chromatogram. How was the peak caused by the caffeine content identified?

(1 mark)

- c. How many caffeine molecules would be present in a 200mL bottle of cola beverage?

(3 marks)

End of Section B

End of Trial Exam

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Q1 **B** When reading the scale on a burette, it is read from top to bottom and at the bottom of the meniscus (the slight concave curve formed at the top of the liquid).
Initial reading 2.30
Final Reading 17.65
 $V(\text{NaOH})$ used in the titration $= 17.65 - 2.30$
 $= 15.35 \text{ mL}$
 $n(\text{NaOH})$ used $= c \times V$
 $= 0.500 \text{ mol L}^{-1} \times 15.35 \times 10^{-3} \text{ L}$
 $= 7.675 \times 10^{-3} \text{ mol}$
 $n(\text{CH}_3\text{COOH})$ in 20.0 mL aliquot $= 7.675 \times 10^{-3} \text{ mol}$
 $c(\text{CH}_3\text{COOH}) = n / V$
 $= 7.675 \times 10^{-3} \text{ mol} / 20.0 \times 10^{-3} \text{ L}$
 $= \mathbf{0.384 \text{ mol L}^{-1}}$

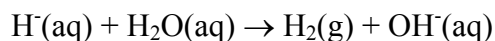
Q2 **B** The reaction for the preparation of 1-propylamine from 1-chloropropane may be represented by the equation

$$\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl} + \text{NH}_3 \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2 + \text{HCl}$$

i.e. the other compound is ammonia, NH_3

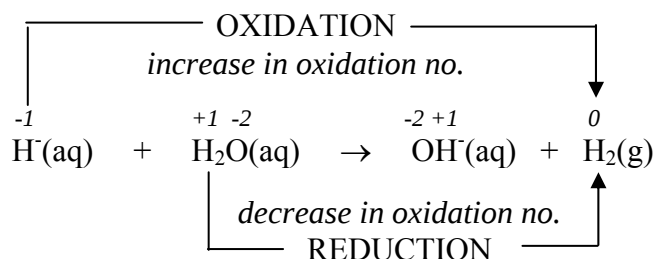
$$\begin{aligned} n(\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl}) \text{ reacting} &= m / M \\ &= 2.17 \text{ g} / 78.5 \text{ g mol}^{-1} \\ &= 0.0276 \text{ mol} \end{aligned}$$
$$\begin{aligned} n(\text{NH}_3) \text{ reacting} &= 0.0276 \text{ mol} \\ m(\text{NH}_3) \text{ reacting} &= n \times M \\ &= 0.0276 \text{ mol} \times 17.0 \text{ g mol}^{-1} \\ &= \mathbf{0.470 \text{ g}} \end{aligned}$$

- Q3 C Phenolphthalein turning red indicates the presence of $\text{OH}^-(\text{aq})$ as a result of the reaction of the metal hydride with water. Since all potassium compounds are soluble and KH is an ionic compound, it may be expected to dissociate into $\text{K}^+(\text{aq})$ and $\text{H}^-(\text{aq})$ ions on addition to water. So the production of the gas and OH^- ions is due to reaction between $\text{H}^-(\text{aq})$ and H_2O . This suggests that the $\text{H}^-(\text{aq})$ ion accepts a proton from H_2O according to the equation:



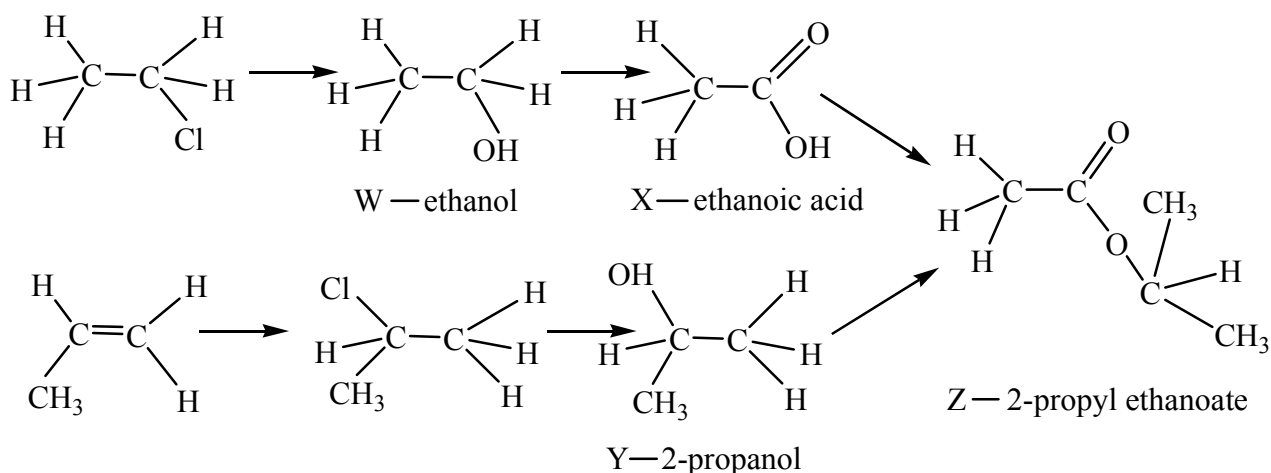
Hence **$\text{H}^-(\text{aq})$ acts as a base.**

Closer inspection of the equation shows that the reaction between $\text{H}^-(\text{aq})$ is also a redox reaction. This can be shown by assigning oxidation numbers.



This shows that hydrogen is both oxidised, from H^- to H_2 , and reduced, from H_2O to H_2 . Since H^- causes the reduction of H_2O (to H_2) and is itself oxidised (to H_2), **$\text{H}^-(\text{aq})$ acts as a reductant.**

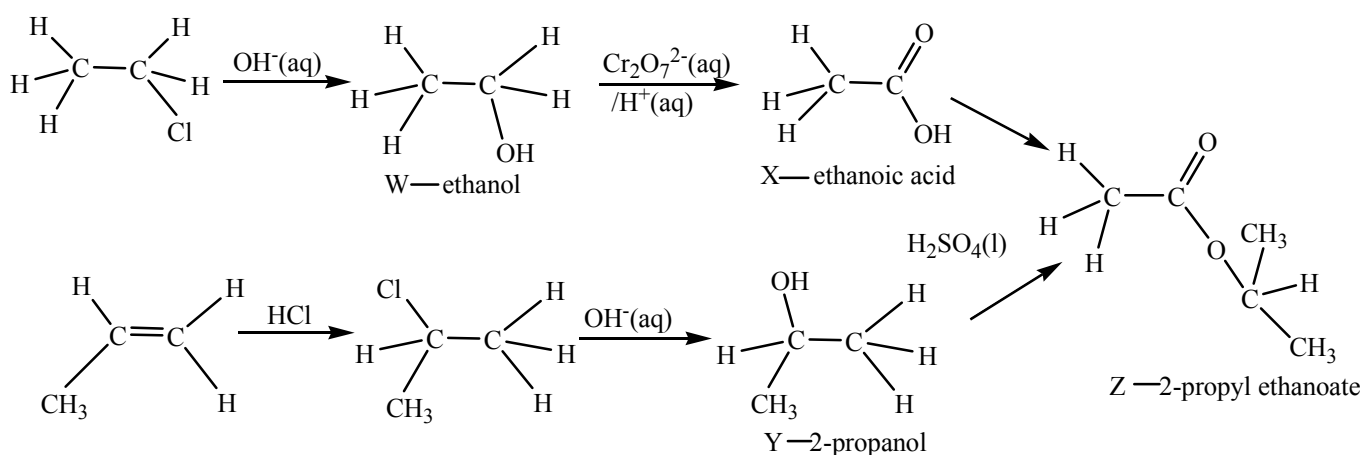
- Q4 D Since Z is a compound with a fruity odour it is an ester, which means each of X and Y have to be either the alcohol or the carboxylic acid. Y cannot be the carboxylic acid because 2-chloropropane cannot be converted directly to a carboxylic acid. Hence **Y must be 2-propanol** and **X must be ethanoic acid**, as shown in the pathway below.



Q5 B According to the structure for Z shown in the pathway above

- A. The structure for 2-propyl ethanoate shows that it has **four different carbon environments**; hence its ^{13}C NMR will have **four peaks**.
- B. The structure for 2-propyl ethanoate shows that it has **three different hydrogen environments**; hence its low resolution ^1H NMR spectrum will have **three peaks**.
- C. Since $M(2\text{-propyl ethanoate}) = 102.0 \text{ g mol}^{-1}$ it **cannot produce a peak at $m/z = 112$** .
- D. The IR absorption band in the $2500 - 3300 \text{ cm}^{-1}$ region is characteristic of O-H present in carboxylic acids, which will **not** be present **on the IR spectrum** of 2-propyl ethanoate.

Q6 C The pathway below shows the inorganic reagents used in the pathway.

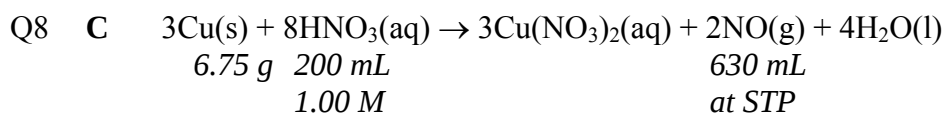


No Cl_2 is used in the pathway.

Q7 C **When ammonia acts as a reductant**, it reduces another species and is itself oxidised. When ammonia is oxidised **the oxidation number of nitrogen increases**.

In NH_3 the **oxidation number of N is -3**

- A. NaNO_3 contains the NO_3^- ion in which the oxidation number of N has increased to +5
- B. In HNO_3 the oxidation number of N has increased to +5
- C. $(\text{NH}_4)_2\text{SO}_4$ contains the NH_4^+ ion in which the **oxidation number of N is -3**, i.e. it has not changed
- D. In N_2 the oxidation number of N has increased to 0
- Hence ammonium sulfate will not be produced when NH_3 acts as a reductant.



$$n(\text{Cu}) \text{ added} = 6.75 / 63.6$$

$$= 0.106 \text{ mol}$$

$$n(\text{HNO}_3) = 1.00 \times 0.200$$

$$= 0.200 \text{ mol}$$

Since 0.106 mol Cu requires $\frac{8}{3} \times 0.106$, i.e. 0.283 mol HNO_3 , to completely react, then Cu is in excess and HNO_3 is the limiting reactant.

$$n(\text{NO}) \text{ produced} = \frac{2}{8} \times n(\text{HNO}_3)$$

$$= 0.25 \times 0.200$$

$$= 0.0500 \text{ mol}$$

$$n(\text{NO}) \text{ collected} = V(\text{NO}) \text{ collected} / V_m(\text{STP})$$

$$= 630 \times 10^{-3} \text{ L} / 22.4 \text{ L mol}^{-1}$$

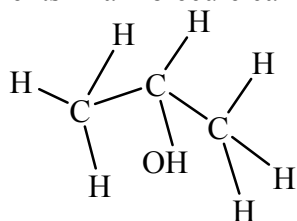
$$= 0.0281 \text{ mol}$$

$$\% \text{ NO collected} = [n(\text{NO}) \text{ collected} / n(\text{NO}) \text{ produced}] \times 100$$

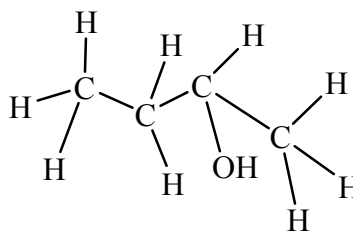
$$= [0.0281 / 0.0500] \times 100$$

$$= \mathbf{56.3 \%}$$

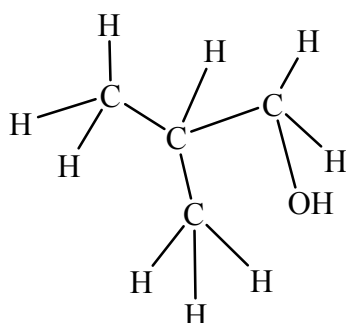
- Q9 C Three peaks on the ^{13}C NMR spectrum indicate the presence of three different carbon environments on the molecules of the compound. The number of different carbon environments in a molecule can be determined from the bonding around each carbon.



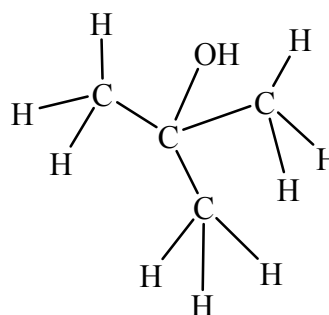
2-propanol
not consistent with the molecular formula
two different carbon environments



2-butanol
four different carbon environments



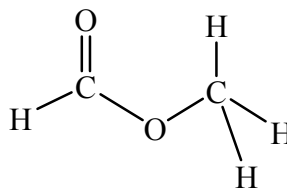
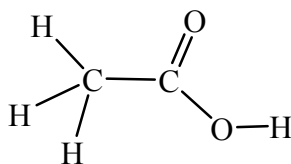
methyl-1-propanol
three different carbon environments



methyl-2-propanol
two different carbon environments.

N.B. methyl-1-propanol is the same as 2-methyl-1-propanol. No other position is possible for the methyl group.

- Q10 A The bonds present in molecules of ethanoic acid, CH_3COOH and methyl methanoate HCOOCH_3 are shown in their structural formulae:



Both compounds contain C-O, C=O and C-H bonds but since **only ethanoic acid** has O-H bonds only it will show a **significant peak** in the $2500\text{--}3300\text{ cm}^{-1}$ absorption band region, **due to O-H (acids) stretching**

- Q11 C $n(\text{KHC}_8\text{H}_8\text{O}_4)$ in 200 mL solution = $0.864\text{ g} / 204.1\text{ g mol}^{-1}$
 $= 4.23 \times 10^{-3}\text{ mol}$
 $n(\text{HC}_8\text{H}_4\text{O}_4^-)$ reacting with OH^- = $(4.23 \times 10^{-3} / 200.0) \times 19.25$
 $= 4.07 \times 10^{-4}\text{ mol}$
 $n(\text{OH}^-)$ in 20.0 mL $\text{Ca}(\text{OH})_2(\text{aq})$ = $4.07 \times 10^{-4}\text{ mol}$
 $n[\text{Ca}(\text{OH})_2]$ in 20.0 mL $\text{Ca}(\text{OH})_2(\text{aq})$ = $\frac{1}{2} \times n(\text{OH}^-)$
 $= \frac{1}{2} \times 4.07 \times 10^{-4}$
 $= 2.04 \times 10^{-4}\text{ mol}$
 $c[\text{Ca}(\text{OH})_2]$ = $2.04 \times 10^{-4}\text{ mol} / 20.0 \times 10^{-3}\text{ L}$
 $= 0.0102\text{ M}$ ($1.02 \times 10^{-2}\text{ mol L}^{-1}$)

- Q12 C In order to balance the equation for the reaction, write the oxidation and reduction half-equations.

Oxidation: $\text{H}_2\text{C}_2\text{O}_4(\text{aq}) \rightarrow 2\text{CO}_2(\text{g}) + 2\text{H}^+(\text{aq}) + 2\text{e}^-$

Reduction: $\text{MnO}_4^-(\text{aq}) + 8\text{H}^+(\text{aq}) + 5\text{e}^- \rightarrow \text{Mn}^{2+}(\text{aq}) + 4\text{H}_2\text{O}(\text{l})$

To get the overall equation, multiply the oxidation half-equation by 5 and the reduction half-equation by 2, then add the two half-equations together.

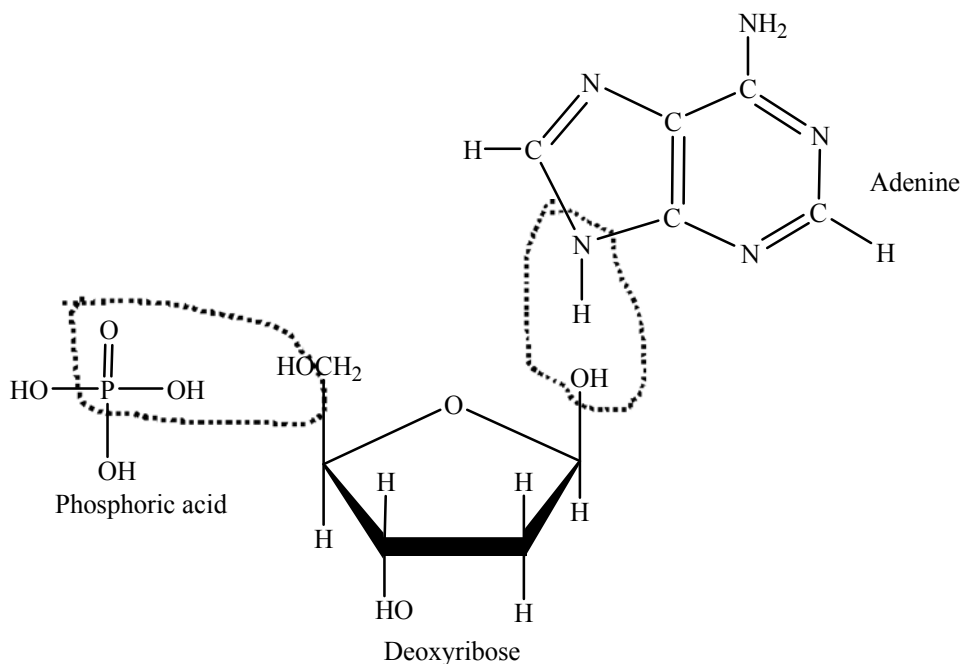
$5\text{H}_2\text{C}_2\text{O}_4(\text{aq}) + 2\text{MnO}_4^-(\text{aq}) + 6\text{H}^+(\text{aq}) \rightarrow 10\text{CO}_2(\text{g}) + 2\text{Mn}^{2+}(\text{aq}) + 8\text{H}_2\text{O}(\text{l})$

The balanced equation shows that for every 2 mol MnO_4^- reacting, there must be 5 mol $\text{H}_2\text{C}_2\text{O}_4$ reacting.

- Q13 D The further a region is from the origin on the chromatography, the less strongly the molecules in that region are attracted to the stationary phase, and the more strongly they are attracted to the mobile phase.
The order of increasing attraction to the stationary phase is $\text{I} < \text{II} < \text{III}$, whilst the order of increasing attraction to the mobile phase is $\text{III} < \text{II} < \text{I}$.
Alternatives A and C are all consistent with these orders of attraction.
 R_f values depend on the distances moved by I, II and III from the origin and the distance moved by the solvent front from the origin. If the solvent front moves a smaller distance, I, II and III also move smaller distances and the R_f values are not affected.
It may be that there is more than one type of molecule, i.e. different compounds, in one or more of regions I, II and III which have very similar attractions to the stationary and mobile phase. Hence we **cannot deduce conclusively** from a single TLC that the substance contains **only three different compounds**. Alternative D is the correct answer.

- Q14 A For quantitative analysis by either AAS or UV-Visible spectroscopy, a set of standards with known concentration of the species for which the analysis is being performed, in this case $\text{Cu}^{2+}(\text{aq})$, are made up. The absorbances of these standards are measured and a plot of absorbance versus concentration used to establish a calibration curve. So alternatives B, C and D apply to both forms of spectroscopy. In AAS the light source used would be a copper lamp. This emits wavelengths of light that only copper will absorb. So it is **not** necessary to 'determine' the wavelength to be used, because none of the other metals that may be present in the solution will absorb at the wavelengths emitted by the copper lamp. Whereas AAS is metal specific, UV-Visible is not and there may be non-metallic species present in the solution which also absorb at some of the wavelengths at which copper absorbs strongly. Hence for the UV-Visible analysis, an absorbance spectrum of the solution is compared with the absorbance spectrum for a pure $\text{Cu}^{2+}(\text{aq})$ solution to identify a wavelength at which $\text{Cu}^{2+}(\text{aq})$ will strongly absorb but other species in the solution do not. If a wavelength is used at which other species also absorb, the concentration of copper will be calculated as higher than the true value.
- Q15 C From the side chains on the amino acids in the protein chain, the data book can be used to identify the amino acids present. These were, from left to right: alanine, cysteine, valine, aspartic acid and serine respectively. **Hydrophobic regions** reduce solubility in water because of the **non-polar side chains** that give rise to them. Only alanine, $-\text{CH}_3$, and valine, $-\text{CH}(\text{CH}_3)_2$ or $-\text{C}_3\text{H}_7$, have non-polar side chains which are needed for hydrophobic patches to form. The **non-polar side chain on valine molecules is larger** than that on alanine molecules. Hence **valine** will provide the more hydrophobic region.
- Q16 A Covalent bonds in the tertiary structure of a protein are associated with disulfide links. For disulfide links to form, interaction between side-chains containing sulfur is necessary. Cysteine, with the side chain $-\text{CH}_2\text{SH}$, is the only amino acid in the section of protein that contains sulfur. SH (thiol) groups at different sites on the protein chain react together to form a covalent bond between two sulfur atoms, i.e. $-\text{SH} + \text{HS}- \rightarrow -\text{S}-\text{S}-$

Q17 D The nucleotide formation involves at the circled groups



Water is released in both the reaction between phosphoric acid and deoxyribose and the reaction between deoxyribose and adenine. Both are **condensation reactions**.

Q18 C When glycolic acid and lactic acid react together to form the polyester, H_2O molecules are released as the carboxyl $-\text{COOH}$ group on one molecule reacts with the hydroxyl, $-\text{OH}$, group on an adjacent molecule to form an ester functional group.

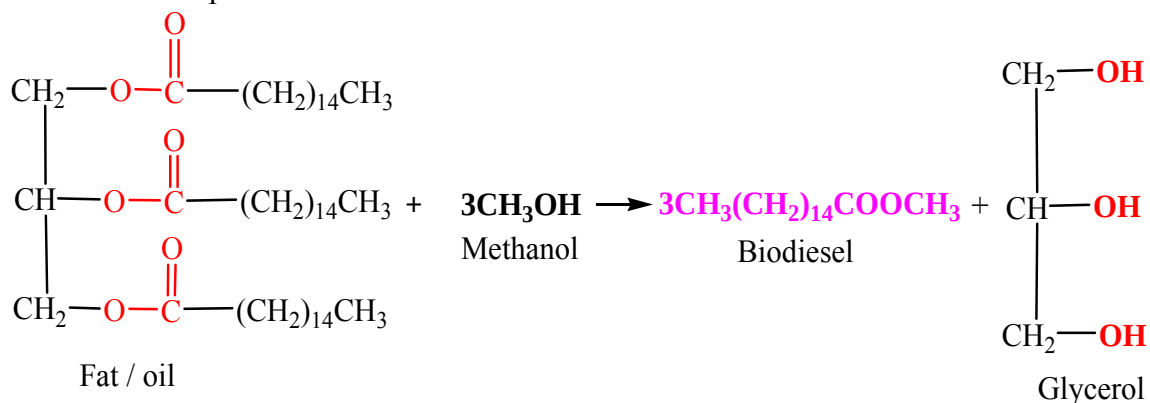
When 1000 molecules – 500 lactic acid and 500 glycolic acid – react together, 999 H_2O molecules are released in the condensation reactions.

So the **relative molecular mass of the polyester** will be $999 \times 18 = 17982$ **lower than the sum of the relative molecular masses of lactic acid and glycolic acid.**

Q19 B The combination of cooking oil, sodium hydroxide and methanol is used in the production of the fuel biodiesel.

In this procedure, biodiesel is produced in a transesterification reaction between a fat – from the cooking oil – and methanol in the presence of sodium hydroxide acting as a catalyst. The products of the reaction are a methyl ester (the **biodiesel**) and **glycerol**.

For example



- Q20 A The first spectrum is a mass spectrum with the m/z ratio for the molecule ion equal to 46.
 The second spectrum is an IR spectrum with a pronounced peak in the region of $3200\text{--}3550\text{ cm}^{-1}$ characteristic of the O-H bond in **alcohols**.
 The only alcohol that will produce a parent ion peak at $m/z = 46$ on its mass spectrum is ethanol **$\text{CH}_3\text{CH}_2\text{OH}$** .
 The third spectrum is the ^1H NMR spectrum which has **three sets of peaks**, including a **triplet** and a **quartet**, which is consistent with the presence of an **ethyl group CH_3CH_2** in the structure of **ethanol $\text{CH}_3\text{CH}_2\text{OH}$**

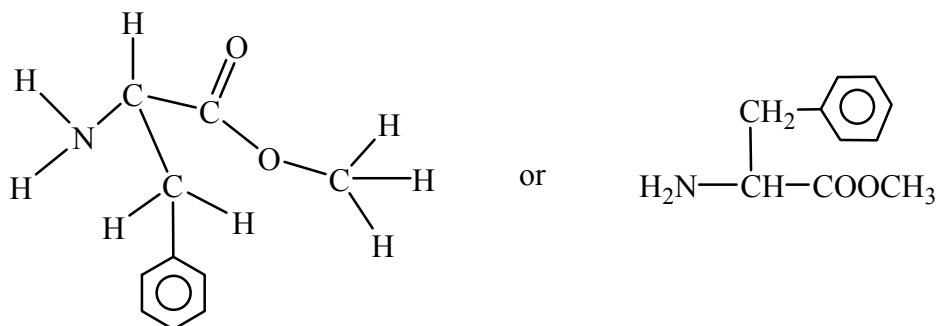
SECTION B – Short Answer (Answers)

Question 1

- a. $\text{MgO(s)} + 2\text{HCl(aq)} \rightarrow \text{MgCl}_2\text{(aq)} + \text{H}_2\text{O(l)}$ ❶ *or*
 $\text{MgO(s)} + 2\text{H}^+\text{(aq)} \rightarrow \text{Mg}^{2+}\text{(aq)} + \text{H}_2\text{O(l)}$
- b. The excess HCl(aq) in 20.0 mL aliquot of the solution remaining after reaction with MgO reacts with NaOH according to $\text{HCl(aq)} + \text{NaOH(aq)} \rightarrow \text{NaCl(aq)} + \text{H}_2\text{O(l)}$
 $n(\text{HCl})$ remaining in 20.0 mL aliquot = $n(\text{NaOH})$ reacting
 $= c(\text{NaOH}) \times V(\text{NaOH})$
 $= 0.200 \times 19.7 \times 10^{-3}$
 $= \mathbf{0.00394 \text{ mol}}$ ❶
- $n(\text{HCl})$ unreacted = $n(\text{HCl})$ in 250 mL
 $= (n(\text{HCl}) \text{ remaining in 20.0 mL aliquot}) / 20.0 \times 250$
 $= (0.00394 / 20.0) \times 250$
 $= \mathbf{0.0493 \text{ mol}}$ ❶
- c. $n(\text{HCl})$ reacted with $\text{MgO} = n(\text{HCl})$ supplied – $n(\text{HCl})$ in excess
 $= 1.00 \times 250 \times 10^{-3} - 0.0493$
 $= 0.250 - 0.0493$
 $= \mathbf{0.201 \text{ mol}}$ ❶
- d. $n(\text{MgO})$ reacted = $\frac{1}{2} \times n(\text{HCl})$ reacted
 $= \frac{1}{2} \times 0.201$
 $= 0.100 \text{ mol}$ ❶
- $m(\text{MgO})$ reacted = $n(\text{MgO}) \times M(\text{MgO})$
 $= 0.100 \times 40.3$
 $= 4.04 \text{ g}$ ❶
- % MgO in sample = $\{m(\text{MgO}) / m(\text{sample})\} \times 100$
 $= \{4.03 / 4.06\} \times 100$
 $= \mathbf{99.6 \%}$ ❶
- e. The calculated percentage purity would be **higher** ❶. If there are impurities present in the sample which **do** react with HCl(aq) , the average titre will be lower because less HCl will be in excess ❶. This will lead to the calculated $n(\text{HCl})$ reacting with MgO being larger and the calculated percentage purity being higher than the actual percentage purity.
- f. Since the phenolphthalein does not start to change colour until the pH is greater than 8.3 (Table 11 Data book), extra $\text{OH}^-\text{(aq)}$ ions will be added. These may cause formation of $\mathbf{\text{Mg(OH)}_2}$ ❶ which would make the solution cloudy.

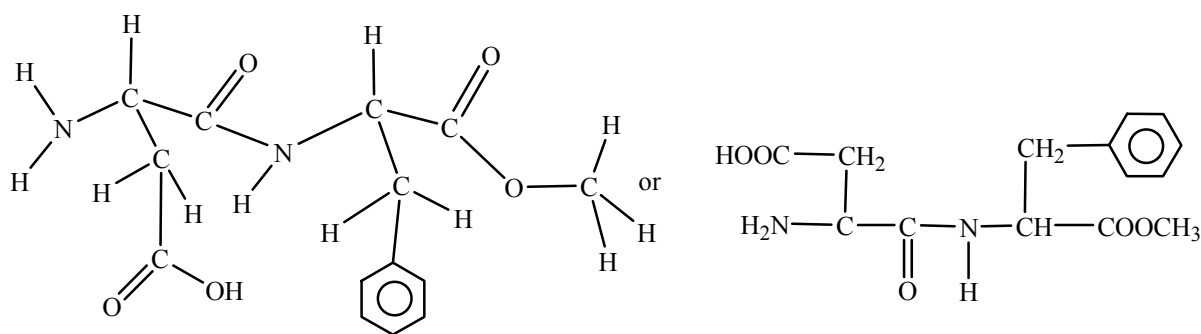
Question 2

a.



❶ must have correct location of CH_3

b.



❶ for the amide/peptide $-\text{CONH}-$ group, ❶ for the complete structure

c. **Water** ❶

d. The α -carbon **carboxyl group**, $-\text{COOH}$, on an aspartic acid molecule **reacts with the amino group**, $-\text{NH}_2$, on phenylalanine methyl ester **to produce a peptide group**, $-\text{CONH}-$ ❶❶

(When the methyl ester of phenylalanine is produced, the carboxyl group, $-\text{COOH}$, on phenylalanine reacts with the hydroxyl group, $-\text{OH}$, on methanol, CH_3OH , to form an ester group, $-\text{COO}-$).

e. During hydrolysis, water is added across the peptide and ester groups on aspartame molecules. So the three products will be **aspartic acid**, **phenylalanine** ❶ and **methanol** ❶

f. **Biomarker**, ❶ or marker for disease.

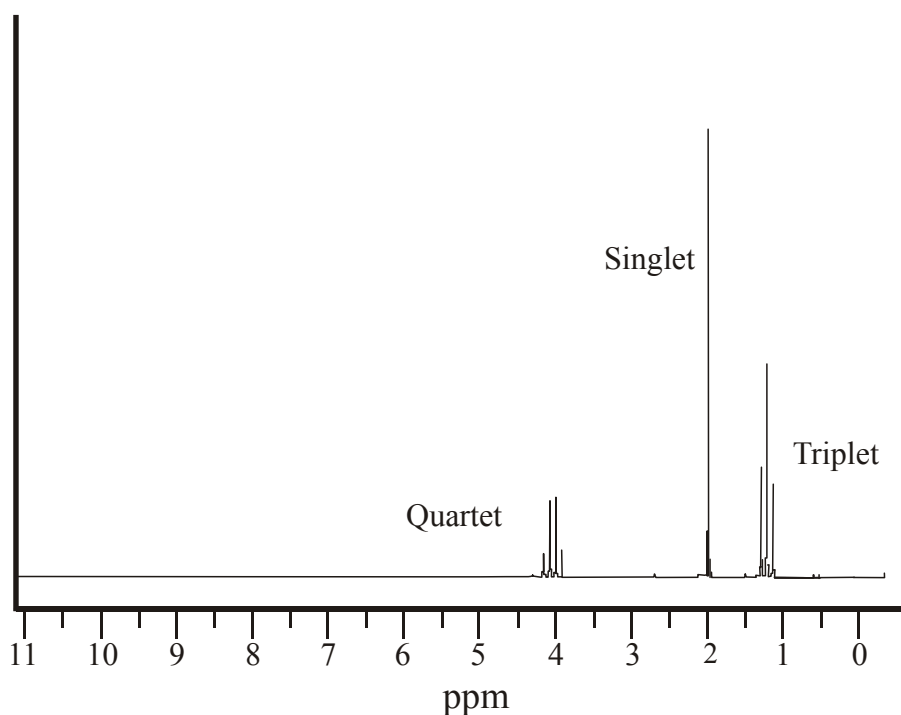
g. All **three contain N-H bonds**, ❶ which absorb IR radiation in the $3350\text{--}3500\text{ cm}^{-1}$ region.

Question 3

a. The compound has **three different hydrogen environments** ❶

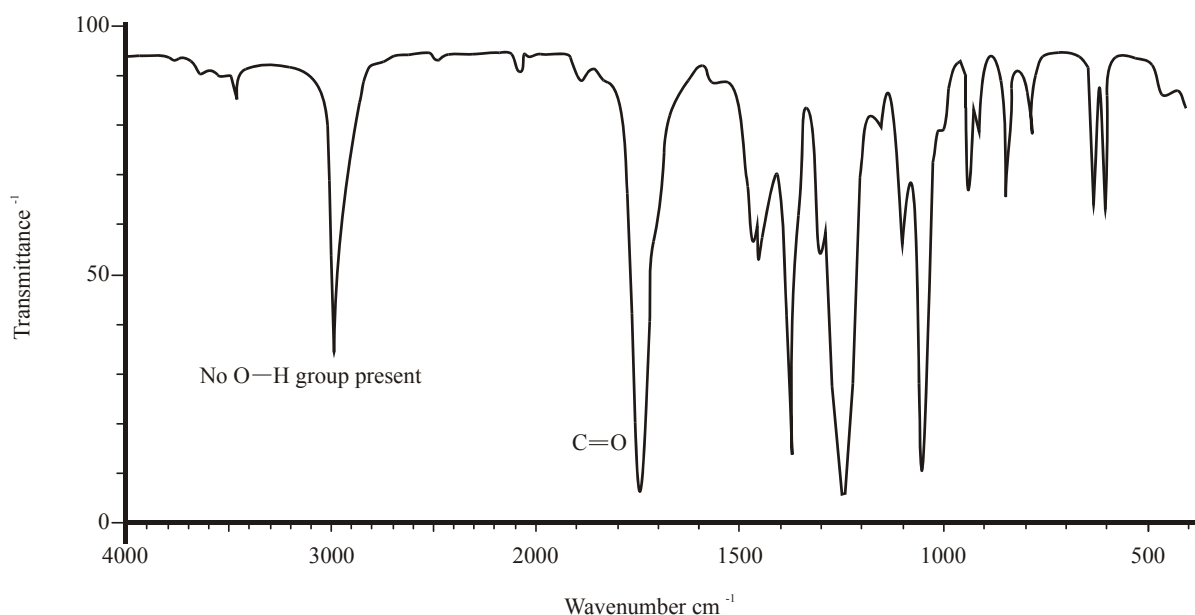
The presence of a **triplet** and a **quartet** suggests the presence of an **ethyl**, CH_3CH_2 group ❶

The quartet at $\delta = 4.1\text{ ppm}$ is consistent with an ester RCOOCH_2R



- b. The presence of a strong absorption peak at 1750 cm^{-1} indicates the **presence of a C=O bond**. ❶

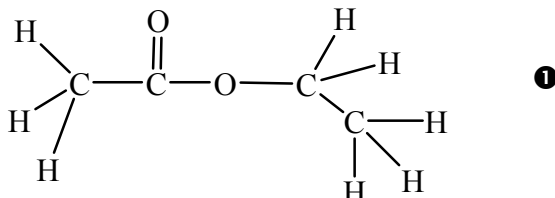
The **lack of a broad absorption band** centred around 3000 cm^{-1} indicates the **lack of any O-H bond** (either O-H acid or O-H alcohol). ❶



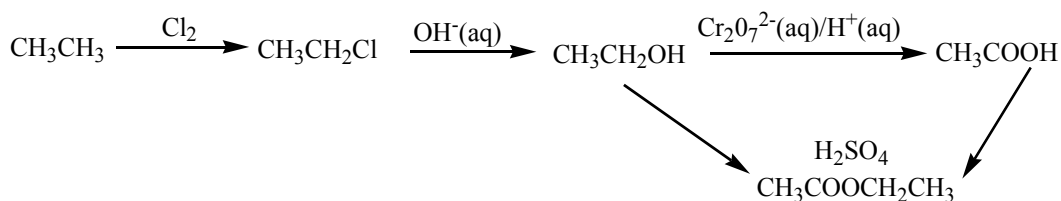
- c. **Ethyl ethanoate** ❶

The presence of C=O, lack of O-H and the fact that ethane was the only reactant suggests that compound has to be an ester.

- d.



- e. ❶❶ for correct formulae for organic reactants in the pathway (4 x ½)
 ❶❶ for correct formulae for inorganic reactants in the pathway (4 x ½)



- f. $\text{CH}_3\text{COOH}(\text{l}) + \text{CH}_3\text{CH}_2\text{OH}(\text{l}) \rightarrow \text{CH}_3\text{COOCH}_2\text{CH}_3(\text{l}) + \text{H}_2\text{O}(\text{l})$
 ❶ all states must be (l)
- g. **substitution** – for CH_3CH_3 reacting with Cl_2 and $\text{CH}_3\text{CH}_2\text{Cl}$ reacting with $\text{OH}^-(\text{aq})$
oxidation – for $\text{CH}_3\text{CH}_2\text{OH}$ reacting with acidified $\text{Cr}_2\text{O}_7^{2-}(\text{aq})$
condensation – for the reaction between $\text{CH}_3\text{CH}_2\text{OH}$ and CH_3COOH
 ❶ for all three reaction types correct

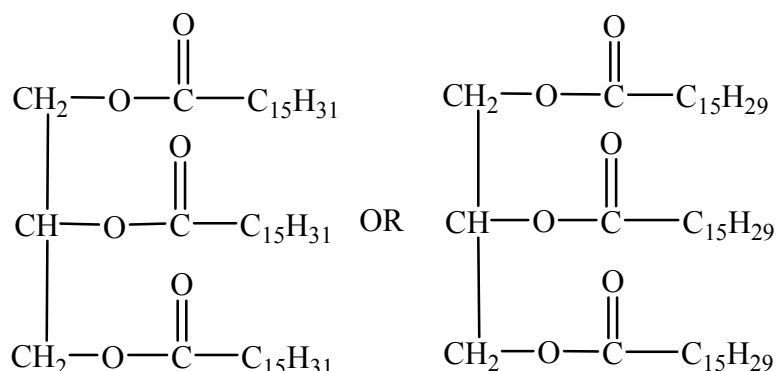
- h. Because ethanoic acid, ethanol, ethyl ethanoate and water all have **different boiling temperatures** ❶ (CH_3COOH : 117.9°C , $\text{CH}_3\text{CH}_2\text{OH}$: 78.3°C , $\text{CH}_3\text{COOCH}_2\text{CH}_3$: 77.1°C , H_2O : 100°C). Ethyl ethanoate actually has the lowest boiling temperature because it is the only one which does not have hydrogen bonding between its molecules.

Question 4

- a. Biodiesel production can be simplified to reaction between a fatty acid and a small alcohol, e.g. methanol, CH_3OH . Table 8 in the Data Book provides formulae of some fatty acids – two of which have 16 C atoms - palmitic $\text{C}_{15}\text{H}_{31}\text{COOH}$, and palmitoleic $\text{C}_{15}\text{H}_{29}\text{COOH}$ – which react with CH_3OH to produce biodiesel with 17 C atoms (one more than cetane) in each molecule



- b.



❶ for the correct representation of CH_2CHCH_2 backbone and $\text{C}_{15}\text{H}_{31}$ or $\text{C}_{15}\text{H}_{29}$

❶ for correct representation of, and attachments to, the ester groups.

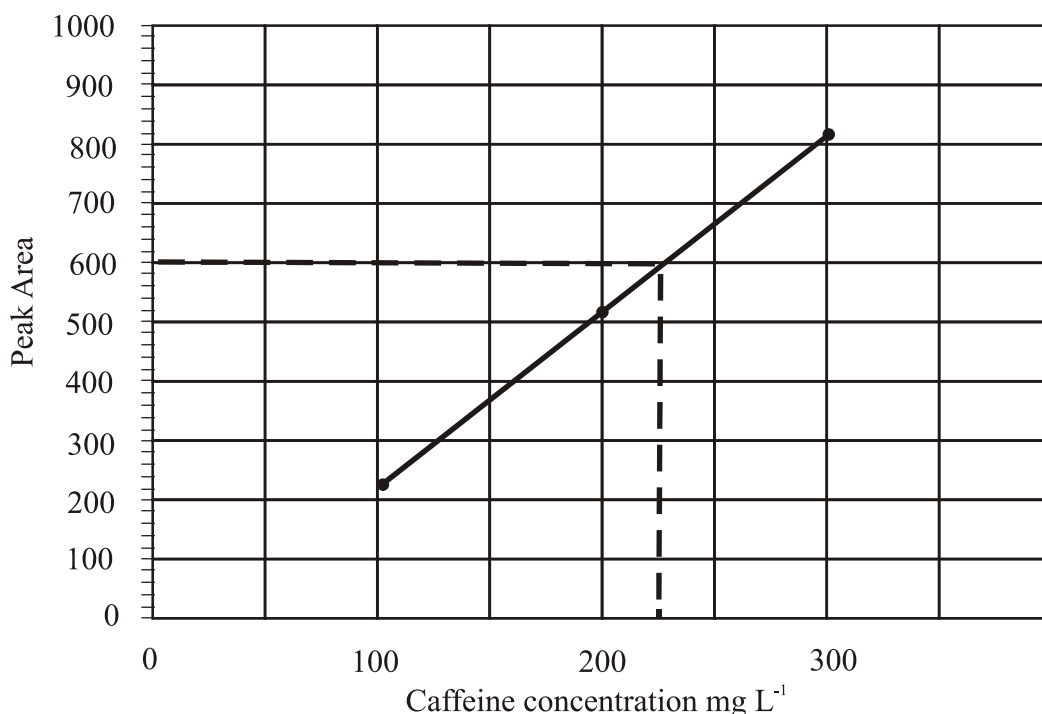
- c. $m(\text{C}_{16}\text{H}_{34}) = d \times V$
 $= 850 \text{ g L}^{-1} \times 50.0 \text{ L}$
 $= 4.25 \times 10^4 \text{ g}$
 $n(\text{C}_{16}\text{H}_{34}) \text{ reacting} = 4.25 \times 10^4 \text{ g} / 226.0 \text{ g mol}^{-1}$
 $= 188 \text{ mol}$ ❶
 $n(\text{CO}_2) \text{ produced} = 16 \times n(\text{C}_{16}\text{H}_{34})$
 $= 16 \times 188$
 $= 3.01 \times 10^3 \text{ mol}$ ❶
 $V(\text{CO}_2) \text{ produced} = n(\text{CO}_2) \times RT / p$
 $= 3.01 \times 10^3 \times 8.31 \times (28+273) / (1.25 \times 10^5 / 10^3)$ ❶
 $= 6.02 \times 10^4 \text{ L}$
 $= 6.02 \times 10^4 / 10^6 \text{ ML}$
 $= 6.02 \times 10^{-2} \text{ ML}$ ❶
- d. (i) $\text{C}_6\text{H}_{12}\text{O}_6(\text{aq}) \rightarrow 2\text{CH}_3\text{CH}_2\text{OH}(\text{aq}) + 2\text{CO}_2(\text{g})$ ❶
(ii) $\text{CH}_3\text{CH}_2\text{OH}(\text{l}) + 3\text{O}_2(\text{g}) \rightarrow 2\text{CO}_2(\text{g}) + 3\text{H}_2\text{O}(\text{g})$ ❶
- e. Availability of land to grow crops from which biofuels can be produced without impacting significantly on the availability or cost of food. ❶

Question 5

- a. The correct rinsing procedure was followed by student A. **When the pipette was rinsed with water alone, a small amount of water would have remained in the pipette and slightly diluted the $\text{Na}_2\text{CO}_3(\text{aq})$ solution. This would have resulted in a smaller titre and, since $c(\text{HCl}) = n(\text{HCl}) / V(\text{titre})$, the calculated concentration will be higher than the true value. ❶ Hence 0.095 M was the more accurate concentration. ❶**
- b. **All the hydrogen bonds in the secondary structure of a protein are between the O atom on one peptide group and the H atom on another peptide group. ❶**
In the secondary structure of DNA, the hydrogen bonds occur between guanine and cytosine or between adenine and thymine. However **whereas guanine and cytosine form hydrogen bonds at three sites, adenine and thymine form hydrogen bonds only at two sites. ❶** This means that the bonding that results from **hydrogen bonding between guanine and cytosine is stronger than the bonding that results from hydrogen bonding between adenine and thymine. ❶**
- c. Since 2-propanol has the semi-structural formulae $\text{CH}_3\text{CHOHCH}_3$, the peak at 60 would be due to the molecule ion with the formula $\text{CH}_3\text{CHOHCH}_3^+$. ❶ This species is **produced as the sample is bombarded with a beam of electrons**; its formation can be represented by the equation $\text{CH}_3\text{CHOHCH}_3 + \text{e}^- \rightarrow \text{CH}_3\text{CHOHCH}_3^+ + 2\text{e}^-$ ❶
The **peak at 45**, caused by a species with formula CH_3CHOH^+ is produced when **fragmentation of molecule ions occurs. ❶** This could be represented as $\text{CH}_3\text{CHOHCH}_3^+ \rightarrow \text{CH}_3\text{CHOH}^+ + \text{CH}_3\bullet$. NB Only the charged species produce peaks on a mass spectrum.

Question 6

- a. The calibration graph ❶



indicates that the caffeine concentration is 225 mg L^{-1} , i.e. **225 ppm (m/V). ❶**

- b. The caffeine peak would appear at the **same retention time as caffeine in the standards.** ❶
- c. According to the structural formula, the molecular formula of caffeine is $\text{C}_8\text{H}_{10}\text{N}_4\text{O}_2$

$$\begin{aligned} m(\text{caffeine}) \text{ in } 200 \text{ mL of the beverage} &= (225 / 1000) \times 200 \text{ mg} \\ &= 45.0 \text{ mg} \\ &= 45.0 \times 10^{-3} \text{ g} \quad \text{❶} \end{aligned}$$

$$\begin{aligned} n(\text{caffeine}) &= 45.0 \times 10^{-3} \text{ g} / 194.0 \text{ g mol}^{-1} \\ &= 2.32 \times 10^{-4} \text{ mol} \quad \text{❶} \end{aligned}$$

$$\begin{aligned} N(\text{caffeine}) &= n(\text{caffeine}) \times N_{\text{A}} \\ &= 2.32 \times 10^{-4} \times 6.02 \times 10^{23} \\ &= \mathbf{1.40 \times 10^{20} \text{ molecules}} \quad \text{❶} \end{aligned}$$

End of Suggested Answers