



VCE CHEMISTRY 2009

YEAR 12 TRIAL EXAM UNIT 3

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Time allowed: 90 minutes

Total marks: 83

20 Multiple Choice Questions

7 Short Answer Questions

An Answer Sheet is provided for Section A.

Answer all questions in Section B in the space provided.

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 2009 Year 12 Trial Exam Unit 3

Multiple Choice (Section A) Answer Sheet

Use a pencil to circle the letter corresponding to the correct or best alternative answer.

If you make a mistake erase your answer and select the correct one. Marks will **not** be deducted for incorrect answers.

<i>Question 1</i>	A	B	C	D	<i>Question 2</i>	A	B	C	D
<i>Question 3</i>	A	B	C	D	<i>Question 4</i>	A	B	C	D
<i>Question 5</i>	A	B	C	D	<i>Question 6</i>	A	B	C	D
<i>Question 7</i>	A	B	C	D	<i>Question 8</i>	A	B	C	D
<i>Question 9</i>	A	B	C	D	<i>Question 10</i>	A	B	C	D
<i>Question 11</i>	A	B	C	D	<i>Question 12</i>	A	B	C	D
<i>Question 13</i>	A	B	C	D	<i>Question 14</i>	A	B	C	D
<i>Question 15</i>	A	B	C	D	<i>Question 16</i>	A	B	C	D
<i>Question 17</i>	A	B	C	D	<i>Question 18</i>	A	B	C	D
<i>Question 19</i>	A	B	C	D	<i>Question 20</i>	A	B	C	D

VCE Chemistry 2009 Year 12 Trial Exam Unit 3

Multiple Choice Section

Section A

*Section A consists of 20 multiple-choice questions.
Section A is worth approximately 25 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

A standard 0.103 M sodium carbonate solution was prepared in a volumetric flask. 25.00 mL aliquots were measured into a conical flask and titrated against a dilute solution of approximately 0.2 M hydrochloric acid. Which of the following indicators is most suitable for use in this titration?

- A. Methyl red.
- B. Phenol red.
- C. Phenolphthalein.
- D. Bromthymol blue.

Question 2

An aqueous solution of potassium dichromate has a clear orange colour. The concentration of such a solution is determined using UV-Visible spectroscopy.

An aqueous solution of potassium dichromate would be expected to

- A. absorb orange light and hence allow orange light to pass through the solution.
- B. absorb blue light and hence allow orange light to pass through the solution.
- C. absorb orange light and hence allow blue light to pass through the solution.
- D. absorb blue light and hence allow blue light to pass through the solution.

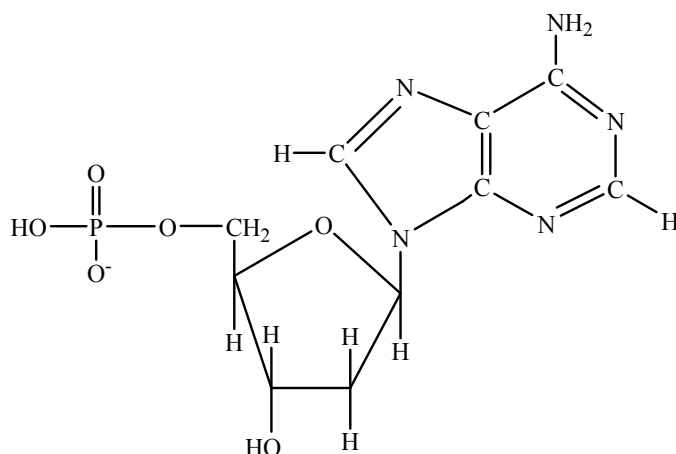
Question 3

The low resolution ^1H NMR spectrum of a compound shows that it has two peaks in the area ratio 9 : 1.

The spectrum could be that of

- A. ethanol.
- B. propan-2-ol.
- C. methylpropan-2-ol.
- D. methyl methanoate.

Questions 4 and 5 refer to the molecular structure shown below.



Question 4

This molecular structure is best described as representing

- A. a nitrogen base.
- B. DNA.
- C. RNA.
- D. a nucleotide.

Question 5

This molecular structure may be found as part of a naturally occurring larger molecular structure. Within that larger molecular structure it would be expected to form

- A. one disulfide link.
- B. two hydrogen bonds.
- C. three hydrogen bonds.
- D. three covalent bonds.

Question 6

Analysis of the IR, ¹H NMR and ¹³C spectra of an organic compound shows

- an absorption band centred close to 3400 cm⁻¹
- a ¹H chemical shift close to 11 ppm
- ¹³C chemical shifts close to 55 ppm and 170 ppm

According to these data the compound could be

- A. ethanamine.
- B. propanoic acid.
- C. ethyl ethanoate.
- D. valine.

Question 7

Two gas containers of equal volume are both at the same temperature and each contain only one substance.

Container X contains 16 g of oxygen gas.

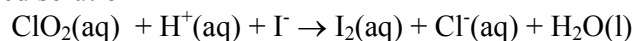
Container Y contains 24 g of ozone gas.

Compared with container X, the pressure and number of atoms in container Y would be

- A. pressure – **the same** number of atoms – **lower.**
- B. pressure – **greater** number of atoms – **the same.**
- C. pressure – **the same** number of atoms – **greater.**
- D. pressure – **greater** number of atoms – **greater.**

Question 8

Consider the unbalanced overall redox equation for the reaction between chlorine dioxide and iodide ions in acidified solution



When this equation is balanced

- A. the coefficient of I^- is 2 and it is the oxidant.
- B. the coefficient of I^- is 10 and it is the reductant.
- C. the coefficient of I^- is 2 and it is the reductant.
- D. the coefficient of I^- is 10 and it is the oxidant.

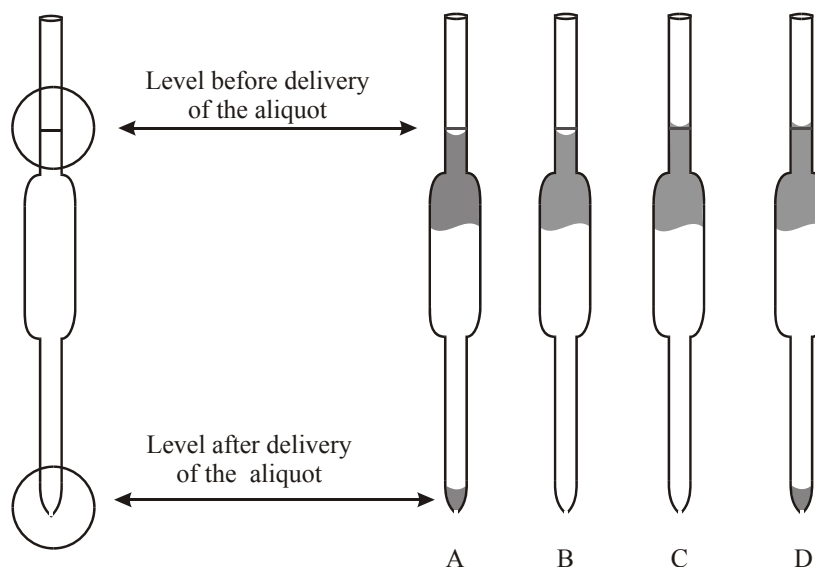
Question 9

Which of the analytical techniques listed below is least likely to be used in deducing the molecular structure of an organic compound?

- A. Mass spectrometry.
- B. Nuclear magnetic resonance spectroscopy.
- C. Infrared spectroscopy.
- D. Atomic absorption spectroscopy.

Question 10

A pipette is an important piece of laboratory equipment in volumetric analysis. In a particular analysis, a 25.0 mL aliquot of the solution being analysed is required. Which of the following diagrams correctly shows the levels of the solution in the pipette before and after delivery of the aliquot?



Question 11

Which of the following pieces of equipment must always be used in an accurate gravimetric analysis?

- A. Electronic balance.
- B. Filter funnel.
- C. Volumetric flask.
- D. Burette.

Question 12

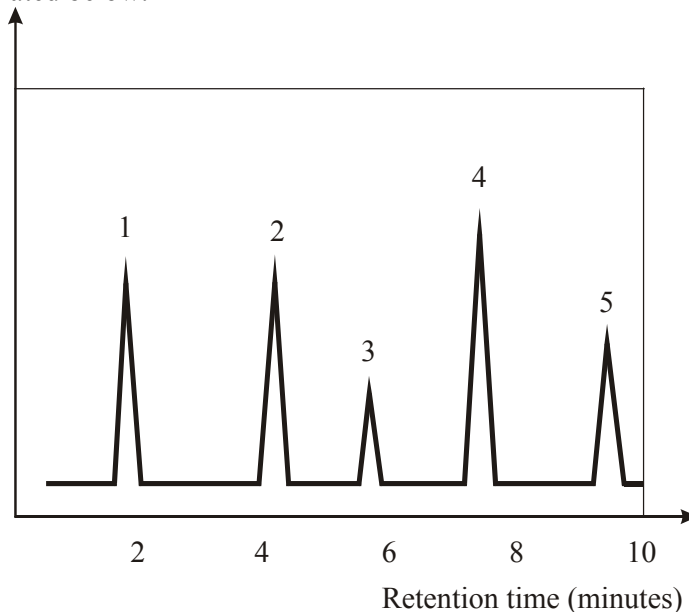
'Rubber' is used in numerous applications, ranging from simple 'elastic' bands to tyres for motor vehicles and aircraft. SBR, a synthetic rubber, is a copolymer of styrene, C_8H_8 , and butadiene, C_4H_6 , combined by an addition reaction in a ratio that produces a product with an empirical formula of $\text{C}_{10}\text{H}_{13}$.

In what mole ratio are styrene and butadiene combined to produce SBR?

- A. 1 mol C_8H_8 : 1 mol C_4H_6
- B. 1 mol C_8H_8 : 3 mol C_4H_6
- C. 3 mol C_8H_8 : 1 mol C_4H_6
- D. 10 mol C_8H_8 : 13 mol C_4H_6

Question 13

A mixture of alkanols, each containing a single hydroxyl functional group on the end carbon and part on an homologous series, was separated using gas chromatography. The smallest alkanol in the mixture had a molar mass of 74 g mol^{-1} . A chromatograph produced during the separation is simulated below.



An accurate interpretation of this chromatogram would be that

- A. alkanol 5. is the most abundant in the mixture.
- B. alkanol 3. could be 1-heptanol.
- C. alkanol 1. is most strongly adsorbed to the stationary phase.
- D. alkanol 4. could be 3,4-dimethylpentan-1-ol.

Question 14

Stages in the creation of a DNA fingerprint include:

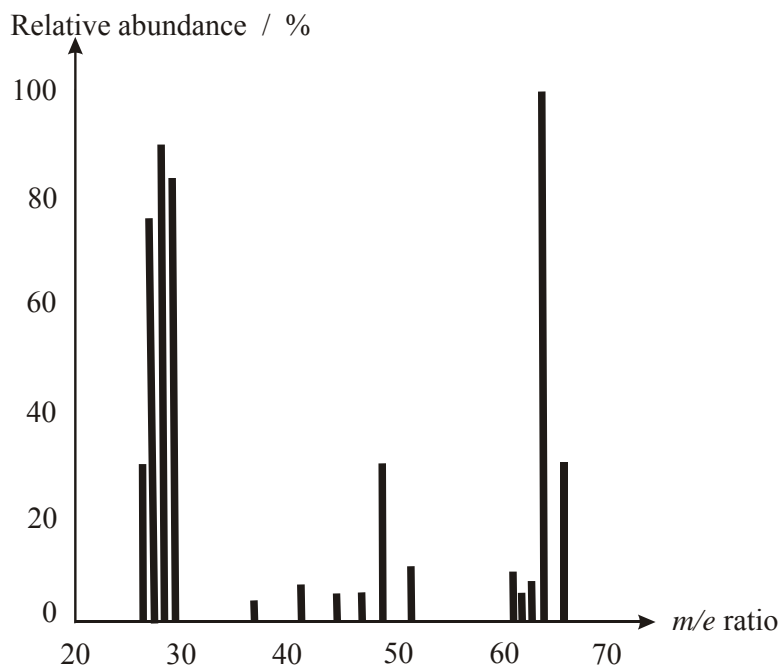
1. Obtain DNA sample.
2. Amplify the DNA sample.
3. Cut up the DNA to produce fragments.
4. Separate the DNA fragments.

Which of the following processes is not involved in these stages?

- A. Polymerase chain reaction.
- B. Gas chromatography.
- C. Gel electrophoresis.
- D. Use of restriction enzymes.

Question 15

The mass spectrum represented below is that of a product of a substitution reaction between ethane and chlorine.



The peaks at m/e ratios 64 and 66 respectively would be due to the species

- A. $\text{CH}_3^{35}\text{Cl}^+$ and $\text{CH}_3^{35}\text{Cl}_2^+$
- B. $\text{CH}_3\text{CH}_2^{35}\text{Cl}$ and $\text{CH}_2^{35}\text{ClCH}_2^{37}\text{Cl}$
- C. $\text{CH}_3\text{CH}_2^{35}\text{Cl}^+$ and $\text{CH}_3\text{CH}_2^{37}\text{Cl}^+$
- D. $\text{C}_2\text{H}_5^{35}\text{Cl}^+$ and $\text{C}_2\text{H}_3^{37}\text{Cl}^+$

Question 16

The following statements, with one key word omitted were part of an article entitled 'Two minds on one track in cancer riddle discovery' which appeared on page 9 of The Sunday Age on December 28, 2008.

'The two young women were not working together though both findings involved an _____ called telomerase, which plays a role in tumour development and is present in most cancers.

'The suppression of telomerase helps reduce the size of tumours and the treatment has no known effect on healthy cells.

Professor Lie said 'telomerase' was not associated with benign tumours. It is a marker for malignant tumours'

The word omitted in the statements was

- A. enzyme
- B. antibiotic
- C. amino acid
- D. disease

Question 17

Pure sulfuric acid, H_2SO_4 , contains unionised H_2SO_4 molecules and is a strong oxidising agent. Which of the following substances is least likely to be produced when concentrated sulfuric acid is the oxidant in a chemical reaction?

- A. H_2S
- B. S
- C. SO_2
- D. SO_3

Question 18

In an aqueous solution at pH 2, lysine would be expected to form a species with a charge of

- A. -1
- B. 0
- C. +1
- D. +2

Question 19

What IR absorption band present in the spectra of the nucleic acids guanine, cytosine and thymine would not be present in the IR spectrum of adenine?

- A. $3350\text{-}3500\text{ cm}^{-1}$
- B. $1670\text{-}1750\text{ cm}^{-1}$
- C. $1610\text{-}1680\text{ cm}^{-1}$
- D. $2850\text{-}3300\text{ cm}^{-1}$

Question 20

The mass, in grams, of one molecule of 2-aminopropane is closest to

- A. 59.0
- B. 9.97×10^{-23}
- C. 9.80×10^{-23}
- D. 3.55×10^{25}

End of Section A

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Short Answer Questions

Section B

Section B consists of 7 short answer questions.

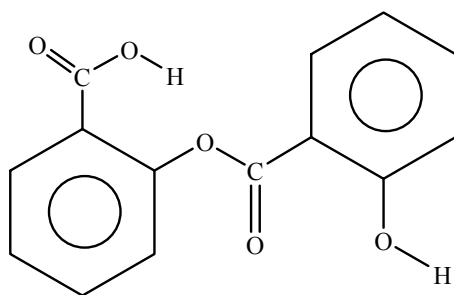
This section is worth approximately 75 per cent of the total marks available.

The marks allotted are shown at the end of each part of each question.

Questions should be answered in the spaces provided.

Question 1

The molecular structure of Salsalate, a drug with analgesic and anti-inflammatory properties, is shown below.



- a. Identify, by circling and naming, all the functional groups present in Salsalate molecules.

(3 marks)

- b. Salsalate molecules are formed by an esterification reaction. Give the molecular structure of the reactant molecules involved in this reaction.

(2 marks)

- c. Give the molecular formula of Salsalate molecules.

(1 mark)

- d. The mass spectrum of Salsalate shows a significant peak at an m/e ratio 257. Give the formula of the fragment causing this peak.

(1 mark)

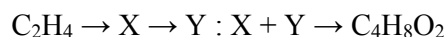
- e. If a mass spectrum of Salsalate showed a very small peak at an m/e ratio of 259, suggest a possible cause of this peak.

(1 mark)

Total 8 marks

Question 2

An organic reaction pathway is represented below.



- a. Draw structures showing all bonds of the molecules represented by X and Y.

(4 marks)

- b. The infrared spectra of all the compounds in the reaction pathway show a number of absorptions. What changes occur in a molecule when it absorbs infrared radiation?

(1 mark)

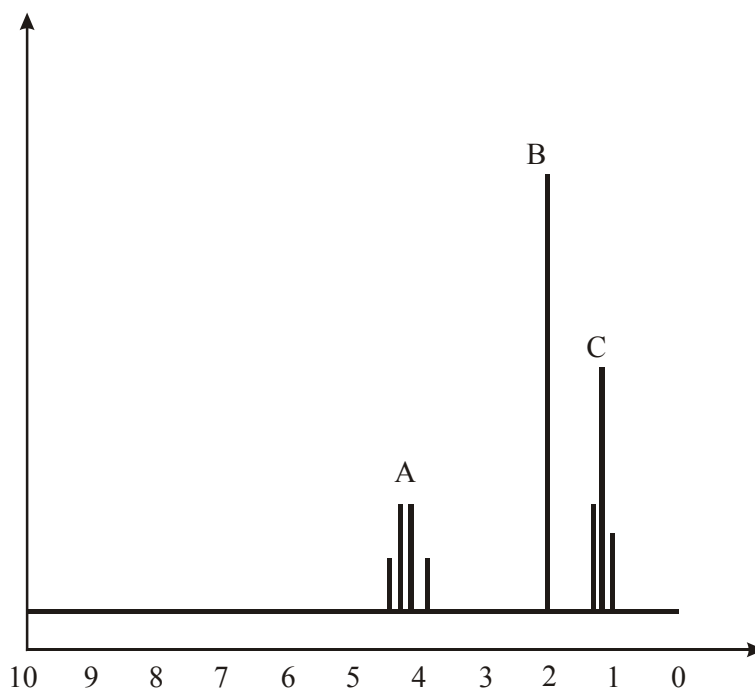
- c. Identify an absorption band which would be expected to be present in the IR spectrum of only one of the compounds in the pathway. Explain your choice.

(2 marks)

- d. Explain why an IR spectrum of X shows a broad absorption band centred around 3400 cm^{-1} whilst an IR spectrum of Y shows a broad absorption band centred around 2900 cm^{-1} .

(2 marks)

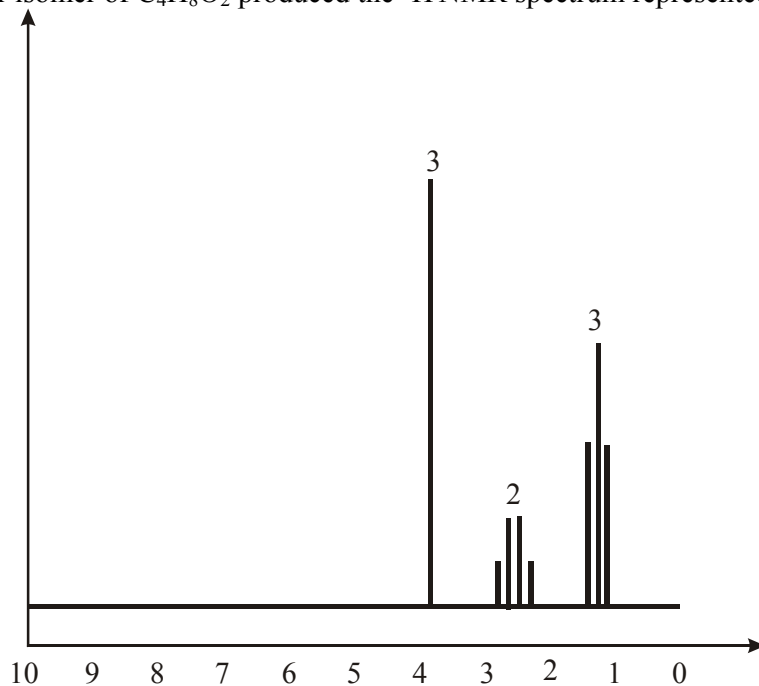
- e. The ^1H NMR spectrum of $\text{C}_4\text{H}_8\text{O}_2$ is represented below.



Draw the structural formula of $\text{C}_4\text{H}_8\text{O}_2$ and identify the H atoms responsible for peaks A, B and C on the spectrum.

(3 marks)

- f. Another isomer of $C_4H_8O_2$ produced the 1H NMR spectrum represented below.



Give the name and semi-structural formula of this compound.

(2 marks)

Total 14 marks

Question 3

A key component of the tertiary structure of many proteins is disulfide links.

- a. Give the name of an amino acid, which, when part of a protein chain, may be involved in disulfide links.

(1 mark)

- b. Draw the structure of a dipeptide formed between the amino acid identified in (a) and a different amino acid containing sulfur. Circle the functional group which is characteristic of a dipeptide.

(2 marks)

- c. Describe the functional group changes that occur during the formation of a dipeptide.

(1 mark)

- d. In terms of bonding what is common to both a peptide link and a disulfide link?

(1 mark)

- e. How is the secondary structure of a protein maintained?

(2 marks)

- f. The amino acid tryptophan is an essential amino acid that is used in the body to produce the B-group vitamin niacin.

- i. What is an 'essential' amino acid?

(1 mark)

- ii. What is the molecular formula of tryptophan?

(1 mark)

- g. Aspects of the structure of a protein may be determined using chromatography. The first step in this process is to gently heat the protein in a dilute solution of hydrochloric acid. What is the purpose of this step?

(1 mark)

Total 10 marks

Question 4

The iodine number of a fatty acid is defined as the number of grams of iodine, I_2 , that reacts with 100 g of the fatty acid in an addition reaction.

- a. i. What is the iodine number of linolenic acid?

(3 marks)

- ii. Why does arachidic acid have an iodine number of zero?

(1 mark)

- b. Biodiesel is manufactured from vegetable oils in a process called 'transesterification'. This involves the reaction of the oil with an alcohol in the presence of a catalyst. It is, in effect, a two step process. Firstly the oil molecules are broken down into their fatty acids and one 'other product'. The fatty acids then react with the alcohol to produce biodiesel.

- i. Give the name and molecular formula of the 'other product' of transesterification.

(1 mark)

- ii. Write a balanced equation for the production of the biodiesel methyl palmitoleate from its fatty acid.

(2 marks)

- c. Give the chemical formula of the main biofuel produced by fermentation.

(1 mark)

- d. What is the main concern with the large scale production of biofuels?

(1 mark)

- e. Suggest a reason why there was less focus on the production of biofuels following the economic downturn that started in second half of 2008.

(1 mark)

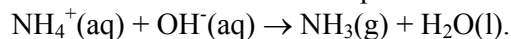
Total 10 marks

Question 5

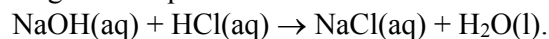
A particular brand of fertiliser contains ammonium sulfate, $(\text{NH}_4)_2\text{SO}_4$, as its only source of nitrogen.

The nitrogen content of the fertiliser was determined using the following method.

A 2.75 g sample of the fertiliser was weighed in a weighing bottle and then added to 100 mL of 0.108 M sodium hydroxide, $\text{NaOH}(\text{aq})$, which was then heated and boiled gently. This converted all the ammonium ions into ammonia. The equation for this reaction is



After all the ammonia had been boiled off, the solution was cooled and then titrated with 0.105 M hydrochloric acid, $\text{HCl}(\text{aq})$. A titre of 14.1 mL was required to neutralise the excess sodium hydroxide, according to the equation



- a. Calculate the amount of NaOH , in mole, remaining unreacted after the conversion of NH_4^+ to NH_3 .

(1 mark)

- b. Calculate the amount of NaOH , in mole, required to convert all the NH_4^+ to NH_3 .

(1 mark)

- c. Determine the percentage, by mass, of nitrogen in the fertiliser.

(3 marks)

- d. Errors that might have occurred during this practical procedure are listed below. For each error, indicate the likely effect of the error on the calculated percentage of nitrogen by placing a tick in the appropriate box.

Error	Calculated % N too high	No effect on calculated % N	Calculated % N too low
A small amount of the cooled solution is split prior to the titration.			
The burette is rinsed with water immediately before adding the acid, prior to the titration.			
Traces of fertiliser remain in the weighing bottle after transfer to the 0.108 M NaOH.			

(3 marks)

Total 8 marks

Question 6

A sample of magnesium oxide is uniformly contaminated with barium oxide. An analysis to determine the composition of this sample uses the fact that whilst both substances react with sulfuric acid to produce metal sulfates, barium sulfate is insoluble but magnesium sulfate is soluble.

A 0.952 g sample was added to 250 mL of 1 M sulfuric acid, which was an excess, and reaction allowed to go to completion. The precipitate formed was collected by filtration, dried and weighed. The mass of precipitate collected was 0.237 g. The filtrate was also collected and made up to 500 mL with deionised water.

- a. Write balanced equations for the reaction of the metal oxides with sulfuric acid.

(2 marks)

- b. Calculate the concentration, in mol L^{-1} , of Mg^{2+} ions in the 500 mL of solution produced from the filtrate.

(4 marks)

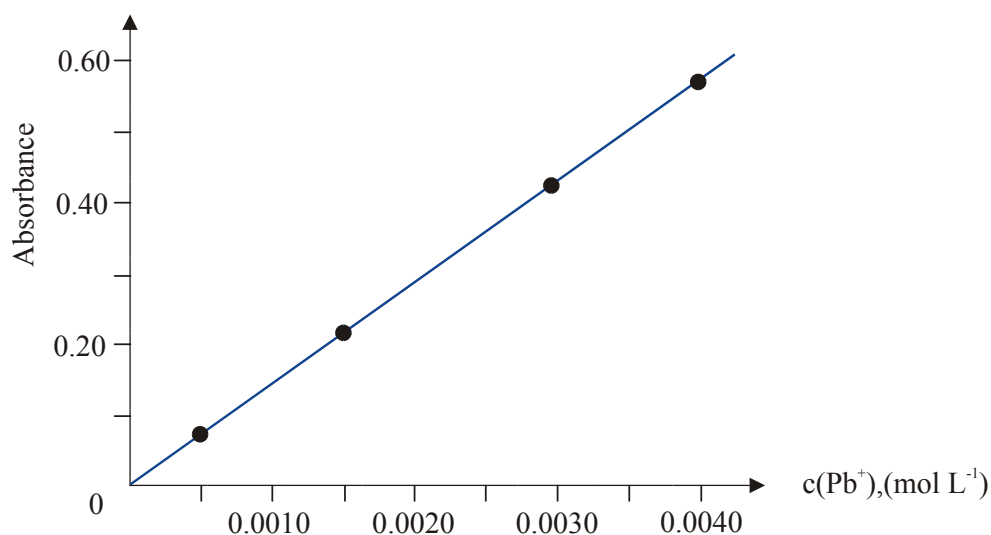
- c. How would **not** washing the precipitate with deionised water in this procedure affect the accuracy of the answer to (b.)?

(2 marks)

Total 8 marks

Question 7

To determine if the level of lead in bore water was safe for drinking, a spectroscopic technique was used to measure the concentration of lead. The absorbances of four standard solutions of $\text{Pb}^{2+}(\text{aq})$ were measured and the calibration curve given below was constructed.



A 50 mL sample of bore water was diluted to 100 mL and when a small sample of the diluted solution was added to the spectrometer an absorbance of 0.50 was recorded.

- a. What analytical instrument was used for the analysis?

(1 mark)

- b. What change occurred to the lead atoms during the energy absorption?

(1 mark)

- c. Determine the concentration of lead, in mol L^{-1} , in the bore water.

(2 marks)

- d. Determine mass of lead, in mg, present in one litre of the bore water.

(1 mark)

Total 5 marks

End of Section B

End of Trial Exam

Suggested Answers

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Multiple Choice Answers – Section A

Question 1

- A. According to the data booklet – Table 11.

Indicator	pH range of colour change
Methyl red	4.2–6.3
Phenol red	6.8–8.5
Phenolphthalein	8.3–10.0
Bromthymol blue	6.0–7.6

$\text{Na}_2\text{CO}_3(\text{aq})$ is a basic solution so the pH in the titration flask will initially be > 7 . As the acid is added to the $\text{Na}_2\text{CO}_3(\text{aq})$ the pH drops. The endpoint of the reaction occurs when all the basic solution has been neutralised by the acid, so the indicator colour should change colour after the pH drops below 7.

Methyl red is the indicator listed that only changes colour once the pH is below 7.

Question 2

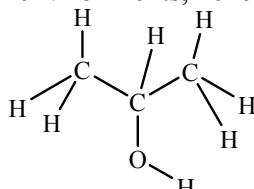
- B. An aqueous solution of potassium dichromate is orange because it transmits orange light, i.e. allows orange light to pass through it. The orange colour of the solution appears in the presence of visible light because that is what remains after complementary colours to orange are absorbed by the solution. The complementary colour to orange, wavelength 580-620 nm, is blue, wavelength 440-470 nm. It is only because wavelengths in the blue region are absorbed that the solution appears orange. The determination of the concentration of the solution would require measuring the absorbance of the solution using a wavelength in the blue region and comparing this absorbance with the absorbances, using the same wavelength, of a series of standards.

Question 3

- C. The fact that the ^1H NMR spectrum shows only two peaks indicates two different H environments. The peak area ratio of 9:1 suggests 9 H atoms in one environment and 1 H atom in the other environment.

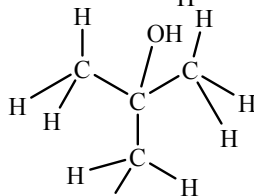
ethanol – $\text{CH}_3\text{CH}_2\text{OH}$ – 3 different H environments, hence 3 peaks in the ratio 3:2:1

propan-2-ol – $(\text{CH}_3)_2\text{CHOH}$ –



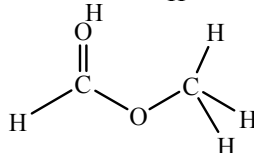
3 different H environments
3 peaks in the ratio 6:1:1

methylpropan-2-ol – $(\text{CH}_3)_3\text{COH}$ –



2 different H environments
2 peaks in the ratio 9:1

methyl methanoate – HCOOCH_3 –



2 different H environments
2 peaks in the ratio 3:1

Hence methylpropan-2-ol is the only possible option. However the ^1H NMR spectrum is not necessarily that of methylpropan-2-ol because methylpropane also produces a ^1H NMR spectrum with 2 peaks in the ratio 9:1. Chemical shift data could be used to distinguish the two spectra.

Question 4

- D. The structure shown is that of a nucleotide in DNA made up of a phosphate group, deoxyribose and a nitrogen base.

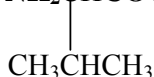
It is clearly not DNA or RNA but is certainly part of DNA.

Question 5

- B. The nucleotide will not form any disulfide links because it contains no sulfur. As part of the primary structure of DNA polynucleotide it will form two covalent bonds at the 5'-phosphate group on one nucleotide and 3'-hydroxyl, -OH, on another nucleotide via condensation polymerisation. Hydrogen bonding between complementary polynucleotides maintains the secondary structure of DNA. The hydrogen bonding occurs between the nitrogen bases on the polynucleotides. **Adenine (A), the nitrogen base on the nucleotide shown, forms two hydrogen bonds with its complementary nitrogen base thymine (T).** The other complementary base pairing is guanine (G) and cytosine (C) between which three hydrogen bonds form.

Question 6

- D. Consider the data:
Absorption band centred close to $3400\text{ cm}^{-1} \rightarrow \text{N-H}$ ($3350\text{--}3500\text{ cm}^{-1}$) as in NH_2 group
 ^1H chemical shift close to 11 ppm $\rightarrow \text{RCOOH}$, i.e. carboxyl group (11.5 ppm)
Both of these pieces of data suggest a compound containing the amino and carboxyl groups – most likely an amino acid.
This is further confirmed by the ^{13}C chemical shifts:
55 ppm $\rightarrow \text{NH}_2$ (35-70 ppm); 170 ppm $\rightarrow \text{COOH}$ (160-185 ppm).
Ethanamine – $\text{CH}_3\text{CH}_2\text{NH}_2$, propanoic acid – $\text{CH}_3\text{CH}_2\text{COOH}$, and ethyl ethanoate ($\text{CH}_3\text{COOCH}_2\text{CH}_3$) are not consistent with this data.
Valine **NH_2CHCOOH** is consistent with the data.



Question 7

- C. Oxygen – O_2 ; ozone – O_3
Container X: $n(\text{O}_2) = 16\text{ g} / 32\text{ g mol}^{-1}$
 $= 0.50\text{ mol}$
 $n(\text{atoms}) = 2 \times 0.50 = 1.0\text{ mol}$
Container Y: $n(\text{O}_3) = 24\text{ g} / 48\text{ g mol}^{-1}$
 $= 0.50\text{ mol}$
 $n(\text{atoms}) = 3 \times 0.50 = 1.5\text{ mol}$

Since both containers are of the same volume and at the same temperature, the pressure in each container is directly dependent on the number of mol of gas molecules present. Since both containers hold the same number of molecules, they will both be at the **same** pressure.

Since each ozone molecule contains 3 atoms, as against 2 atoms in each oxygen molecule, there are more atoms in container Y.

Question 8

- B. The equation $\text{ClO}_2(\text{aq}) + \text{H}^+(\text{aq}) + \text{I}^- \rightarrow \text{I}_2(\text{aq}) + \text{Cl}^-(\text{aq}) + \text{H}_2\text{O}(\text{l})$ can be balanced by developing the two half-equations.
- Oxidation: $2\text{I}^-(\text{aq}) \rightarrow \text{I}_2(\text{s}) + 2\text{e}^-$
- Reduction: $\text{ClO}_2(\text{aq}) + 4\text{H}^+(\text{aq}) + 5\text{e}^- \rightarrow \text{Cl}^-(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$
- To get the overall redox equation, equalise the electrons by multiplying the oxidation half-equation by 5 and the reduction half-equation by 2. This gives the overall equation
- $$2\text{ClO}_2(\text{aq}) + 8\text{H}^+(\text{aq}) + 10\text{I}^- \rightarrow 5\text{I}_2(\text{aq}) + 2\text{Cl}^-(\text{aq}) + 4\text{H}_2\text{O}(\text{l}).$$
- The oxidant is ClO_2 – it oxidises I^- to I_2 (oxidation number of I increases from -1 to 0) and is itself reduced to Cl^- (oxidation number of Cl decreases from +4 to -1).
- The **reductant is I^-** – it reduces ClO_2 to Cl^- (oxidation number of Cl decreases from +4 to -1) and is itself oxidised to I_2 (oxidation number of I increases from -1 to 0).

Question 9

- D. Mass spectroscopy can be used to determine the molecular mass of the compound and to identify molecular fragments.
- Nuclear magnetic resonance spectroscopy can be used to determine hydrogen environments (^1H NMR) and carbon environments (^{13}C NMR).
- Infrared spectroscopy can be used to identify functional groups and bonds present in a molecule.
- Atomic absorption spectroscopy** is not used because it is generally used for the quantitative analysis of metals.

Question 10

- D. When a pipette is used accurately, the initial level of the liquid is such that the **bottom of the meniscus is line with the calibration mark**. Such is the calibration of a pipette that when the aliquot is allowed to run smoothly from the pipette, a small amount of the liquid will remain, due to surface tension effects, in the tip of the pipette. Hence **alternative D** is the correct representation

Question 11

- A. Gravimetric analysis is most often associated with the collection and weighing of a precipitate. Whilst a precipitate can be collected by filtration or decanting, the use of a filter funnel is not essential. However an electronic balance is essential if the weight of the precipitate is to be measured accurately.

Question 12

- B. The empirical formula of styrene, C_8H_8 , is CH , and the empirical formula of 1,3-butadiene, C_4H_6 , is C_2H_3 .
- Comparison of the C:H ratios – styrene 1:1 1,3-butadiene 1:1.5 SBR 1:1.3
- SBR has a higher C:H ratio than styrene but a lower C:H ratio than 1,3-butadiene.
- This suggests that SBR contains more 1,3-butadiene than styrene. Consider the mole ratios suggested in the alternatives.
- A. If the ratio was 1:1 the C:H ratio would be
 $(8+4) : (8+6) \rightarrow 12 : 14 \rightarrow 6:7 \rightarrow 1:1.16$
- B. If the ratio was 1:3 the C:H ratio would be
 $(8 + 3 \times 4) : (8 + 3 \times 6) \rightarrow 20:26 \rightarrow \mathbf{10:13} \rightarrow \mathbf{1:1.3}$
- C. If the ratio was 3:1 the C:H ratio would be
 $(3 \times 8 + 4) : (3 \times 8 + 6) \rightarrow 28:30 \rightarrow 14:15 \rightarrow 1:1.07$
- D. If the ratio was 10:13 the C:H ratio would be
 $(10 \times 8 + 13 \times 4) : (10 \times 8 + 13 \times 6) \rightarrow 132:158 \rightarrow 1:1.2$

Question 13

- D. The smallest alkanol, with a molar mass of 58 g mol^{-1} could be 1-butanol $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$ or the other isomer of $\text{C}_4\text{H}_{10}\text{O}$ with a terminal $-\text{OH}$ group in 2-methylpropan-1-ol, $(\text{CH}_3)_2\text{CHCH}_2\text{OH}$. Since the mixture is part of an homologous series, i.e. successive members differ by CH_2 , and molecules of 1. contain 4 C atoms, then molecules of 2. will contain 5 C atoms, molecules of 3. will contain 6 C atoms, whilst molecules of 4 and 5 will contain 7 and 8 C atoms respectively.
- Considering the alternatives.
- A. The most abundant alkanol in the mixture is the one with the highest peak area on the chromatogram. This is alkanol 4., not alkanol 5.
- B. Alkanol must contain 6 C atoms and could be 1-hexanol, not 1-heptanol.
- C. Alkanol 1. with the shortest retention time is 'least' strongly attracted to the mobile phase.
- D. Alkanol 4. must contain 7 C atoms and could 1-heptanol or one of the alkanol isomers of $\text{C}_7\text{H}_{16}\text{O}$.
3,4-dimethylpentanol $\text{CH}_3\text{CH}(\text{CH}_3)\text{CH}(\text{CH}_3)\text{CH}_2\text{CH}_2\text{OH}$ which has the molecular formula $\text{C}_7\text{H}_{16}\text{O}$ is one such isomer.

Question 14

- B. The main steps in the creation of a DNA profile are
1. Extract / isolate a DNA sample, e.g.. from a blood spot, piece of hair etc
 2. Amplify the DNA using PCR (polymerase chain reaction).
 3. Cut up the DNA using special enzymes called restriction enzymes which recognise specific sequences on the DNA and cut at specific sites on the recognised sequence. This produces fragments of DNA.
 4. Separate the DNA fragments using gel electrophoresis
 5. 'Light up' or probe the DNA fragments using radioactive or fluorescent dyes.
- Gas chromatography is normally not part of this process.

Question 15

- C. $\text{CH}_3\text{CH}_3(\text{g}) + \text{Cl}_2(\text{g}) \rightarrow \text{CH}_3\text{CH}_2\text{Cl}(\text{g}) + \text{HCl}(\text{g})$
Consider the m/e ratio of the species in the alternatives
- A. $\text{CH}_3^{35}\text{Cl}^+ = 50$; $\text{CH}_3^{35}\text{Cl}_2^+ = 85$
- B. $\text{CH}_3\text{CH}_2^{35}\text{Cl} = 64$; $\text{CH}_2^{35}\text{ClCH}_2^{37}\text{Cl} = 100$
- C. $\text{CH}_3\text{CH}_2^{35}\text{Cl}^+ = 64$ and $\text{CH}_3\text{CH}_2^{37}\text{Cl}^+ = 66$
- D. $\text{C}_2\text{H}_5^{35}\text{Cl}^+ = 64$ and $\text{C}_2\text{H}_5^{37}\text{Cl}^+ = 64$
- Since the isotopic composition of chlorine is approximately 75 percent ^{35}Cl and 25 percent ^{37}Cl , there are two possible molecular ions for $\text{CH}_3\text{CH}_2\text{Cl}$, with, as the height of the peaks mass spectrum indicates, the relative proportions of $\text{CH}_3\text{CH}_2^{35}\text{Cl}$ and $\text{CH}_3\text{CH}_2^{37}\text{Cl}^+$ is 3 : 1.

Question 16

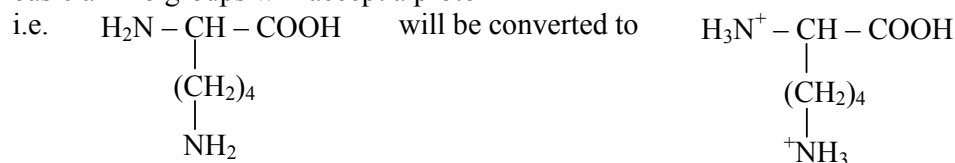
- A. Antibodies, and other organ specific proteins, can act as markers for disease and organ damage.
Since enzymes are proteins, then telomerase is an enzyme.

Question 17

- D.** If H_2SO_4 is the oxidant, it will cause oxidation and be itself reduced. Hence when it acts as an oxidant one of the atoms in the molecule must decrease in oxidation number. Consider the oxidation numbers
 $\text{H}_2\text{SO}_4 - \text{H} = +1, \text{S} = +6, \text{O} = -2$
 $\text{H}_2\text{S} - \text{H} = +1, \text{S} = -2$, hence H_2S is a possible product.
 $\text{S} - \text{S} = 0$, hence S is a possible product.
 $\text{SO}_2 - \text{S} = +4, \text{O} = -2$, hence SO_2 is a possible product.
 $\text{SO}_3 - \text{S} = +6, \text{O} = -2$; no change in oxidation number compared to H_2SO_4 , hence SO_3 is **not** a possible product.

Question 18

- D.** The structural formula of lysine, an amino acid, is in the data book, Table 8.
 In a solution of pH 2 (acidic), the amino acid will act as a base and each of the two basic amino groups will accept a proton



and assume an overall charge of +2.

Question 19

- B.** The bonds associated with the absorption bands can be identified from Table 7 in the Data Booklet.
 $3350\text{-}3500\text{ cm}^{-1} \rightarrow \text{N-H bond}$
 $1670\text{-}1750\text{ cm}^{-1} \rightarrow \text{C=O bond}$
 $1610\text{-}1680\text{ cm}^{-1} \rightarrow \text{C=C bond}$
 $2850\text{-}3300\text{ cm}^{-1} \rightarrow \text{C-H bond}$
 Checking the structural formulae for the four nucleic acids in Table 10 in the Data Booklet, the bond not present in adenine but present in the other three is C=O .

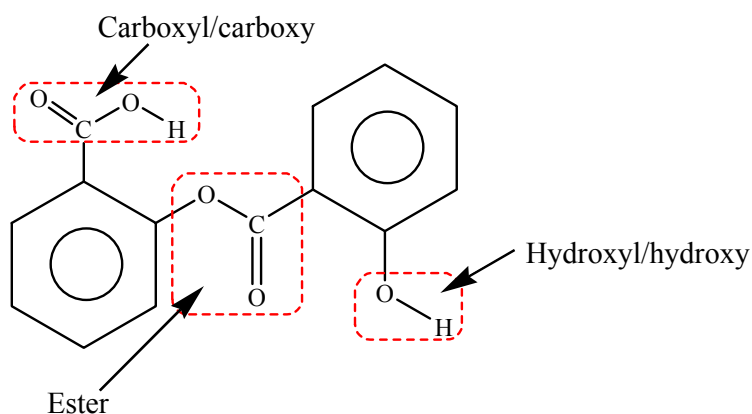
Question 20

- C.** 2-aminopropane – $\text{CH}_3\text{CHNH}_2\text{CH}_3$
 $M(\text{CH}_3\text{CHNH}_2\text{CH}_3) = 59.0\text{ g mol}^{-1}$
 Since one mol (59.0 g) of $\text{CH}_3\text{CHNH}_2\text{CH}_3$ contains 6.02×10^{23} molecules
 Mass of one $\text{CH}_3\text{CHNH}_2\text{CH}_3$ molecule = $59.0 / 6.02 \times 10^{23}$
 $= 9.80 \times 10^{-23}\text{ g}$

Short Answers (Answers) – Section B

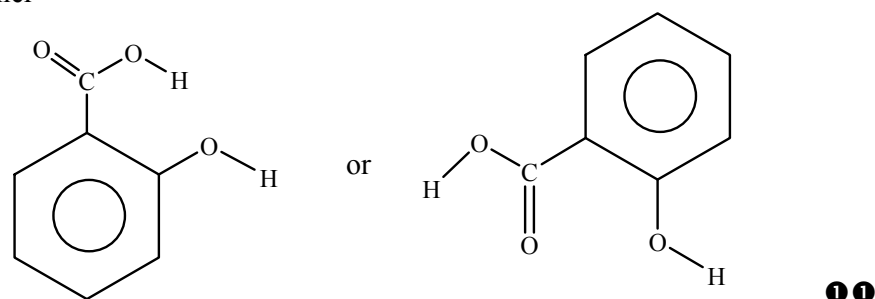
Question 1

a.

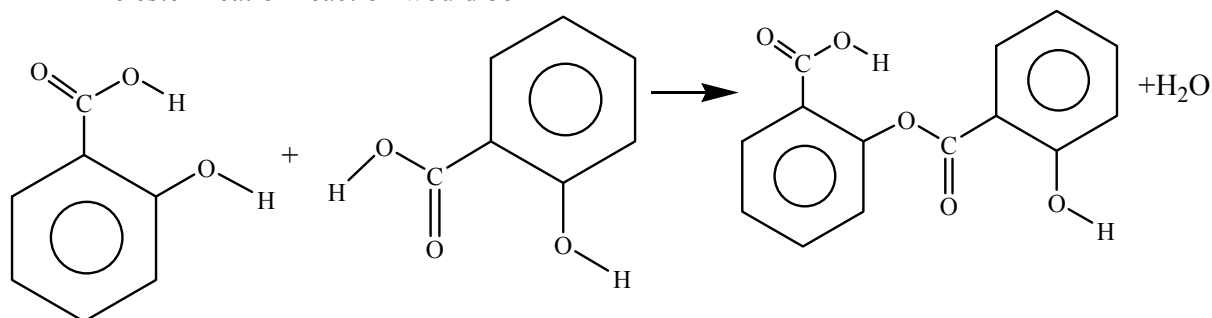


❶ for each correct combination of circled functional group and name.

b. Since the ester functional group is formed by reaction between a carboxyl and an hydroxyl functional group, there is only one reactant – salicylic acid – represented by either



The esterification reaction would be



c. C₁₄H₁₀O₅ ❶

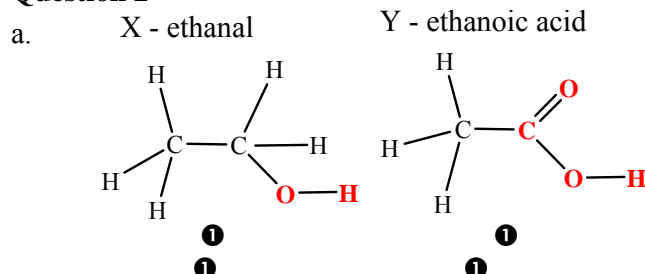
N.B. The benzene ring, by itself C₆H₆, loses one H for each group attached to the ring. Hence in this molecule each of the two benzene rings is C₆H₄.

d. C₁₄H₉O₅⁺ ❶

The relative molecular mass of Salsalate is 258 (14 x 12.0 + 10 x 1.0 + 5x16.0). Hence its molecular ion, C₁₄H₁₀O₅⁺, peak would be expected to show at an *m/e* ratio of 258. So a peak at 257 would be associated with an ion with one less H atom

- e. A peak at an m/e ratio one higher than the molecular ion suggests it is associated with the presence of an isotope of one of the elements making up the compound in a small proportion of the molecules. Most likely carbon-13, ^{13}C . ①

Question 2



Since $\text{C}_4\text{H}_8\text{O}_2$ may be the molecular formula of a carboxylic acid or an ester, the fact that two reactants X and Y are involved suggests it is an ester. Since the starting material is C_2H_4 , X and Y are ethanol and ethanoic acid respectively.

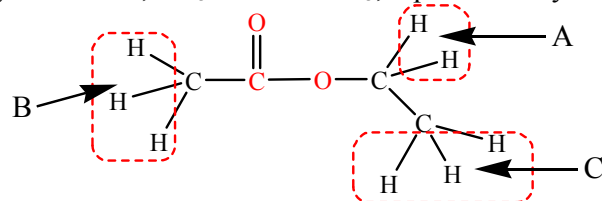
- b. Bonds in molecules stretch *or* bend *or* vibrate *or* bond angle changes ①
 c. $1610\text{--}1680\text{ cm}^{-1}$, ① associated with a $\text{C}=\text{C}$ double bond ① would be present only in ethene $\text{CH}_2=\text{CH}_2$

Alternatively

$2500\text{--}3300\text{ cm}^{-1}$, associated with O-H in acids, would only be present in Y (CH_3COOH).

$3200\text{--}3550\text{ cm}^{-1}$, associated with O-H in alcohols, would only be present in X ($\text{CH}_3\text{CH}_2\text{OH}$)

- d. X – $\text{CH}_3\text{CH}_2\text{OH}$ – is an alcohol and the O-H bond will show an absorption band of $3200\text{--}3550\text{ cm}^{-1}$. ①
 X – CH_3COOH – is a carboxylic acid and the O-H bond will show an absorption band of $2500\text{--}3300\text{ cm}^{-1}$. ①
 e. $\text{C}_4\text{H}_8\text{O}_2$ is ethyl ethanoate, $\text{CH}_3\text{COOCH}_2\text{CH}_3$, represented by the structural formula



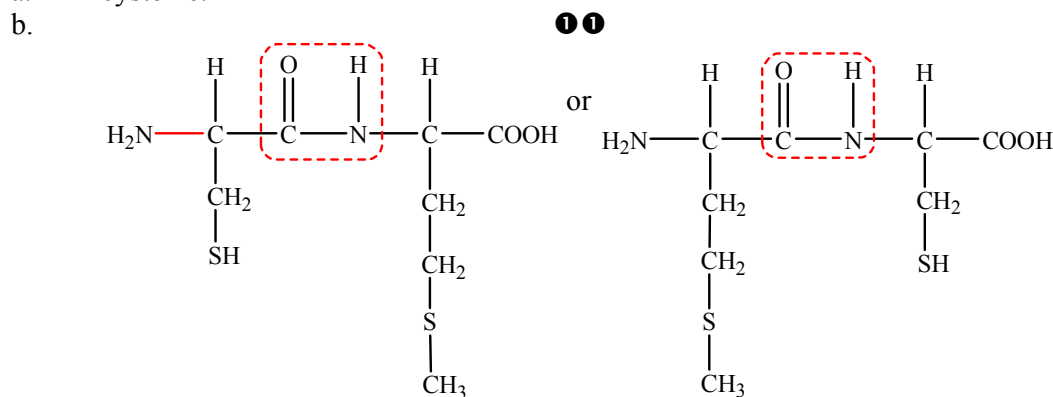
Peak A – split into a quartet, must be due to the H atoms on the CH_2 group ①, the signal for which is split into a quartet by the 3 H atoms on the adjacent CH_3 group.
 Peak B – a singlet, must be due to the H atoms on the CH_3 group to the left of the ester group ①, the signal for which is not split because there are no H atoms on the adjacent C atom.

Peak C – split into a triplet, must be due to the H atoms on the CH_3 group bonded to CH_2 ①, the signal for which is split into a triplet by the 2 H atoms on the adjacent CH_2 group.

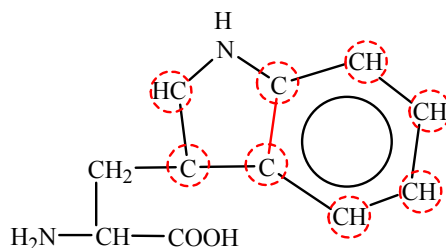
- f. methyl propanoate ❶, $\text{CH}_3\text{CH}_2\text{COOCH}_3$ ❶
 Isomers of $\text{C}_4\text{H}_8\text{O}_2$ – other than ethyl ethanoate, $\text{CH}_3\text{COOCH}_2\text{CH}_3$, include
 $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$, butanoic acid, – 4 peaks on the ^1H NMR
 $(\text{CH}_3)_2\text{CHCOOH}$, 2-methyl propanoic acid, – 3 peaks on the ^1H NMR, a singlet
 (COOH) , a doublet $(\text{CH}_3)_2$ and a multiplet (CH)
 **$\text{CH}_3\text{CH}_2\text{COOCH}_3$, methyl propanoate – 3 peaks on the ^1H NMR, a quartet, a
 triplet and a singlet.**
 $\text{HCOOCH}_2\text{CH}_2\text{CH}_3$, 1-propyl methanoate – 4 peaks on the ^1H NMR, a singlet
 (HCOO) , a triplet (CH_2) , a multiplet (CH_2) and a triplet (CH_3) .
 $\text{HCOOCH}(\text{CH}_3)_2$, 2-propyl methanoate – 3 peaks on the ^1H NMR, a singlet (HCOO) ,
 a multiplet (CH) and a doublet $(\text{CH}_3)_2$.

Question 3

a. cysteine. ❶



- c. An amino group $-\text{NH}_2$, reacts with a carboxyl group $-\text{COOH}$, to produce a peptide group $-\text{CONH}-$. ❶
 d. Covalent bonding. ❶
 e. The secondary structure is maintained by hydrogen bonding ❶ between the H on one peptide group and the O on a different peptide group ❶ in the protein chain.
 f. i Essential amino acids are not synthesised in the body and so must be part of the diet. ❶
 ii $\text{C}_{11}\text{H}_{12}\text{N}_2\text{O}_2$ ❶

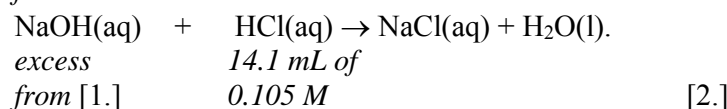
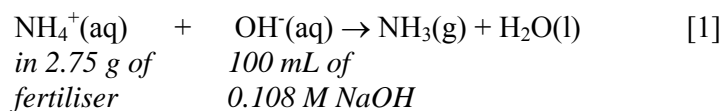


- g. Gently heating the protein in a dilute solution of hydrochloric acid causes hydrolysis reactions at the peptide links and so separates the protein into its constituent amino acids which can then be separated using chromatography. ❶

Question 4

- a. i. Linoleic acid, $C_{17}H_{33}COOH$, has the molecular formula $C_{18}H_{33}O_2$ (from data book). Since a saturated fatty acid with 18 C atoms has the molecular formula $C_{18}H_{36}O_2$, linoleic acid is unsaturated and each molecule contains 3 C=C double bonds. One I_2 molecule reacts across each double bond.
- $$n(C_{18}H_{33}O_2) = 100 \text{ g} / 278 \text{ g mol}^{-1} = 0.360 \text{ mol} \quad \text{①}$$
- $$n(I_2) \text{ reacting} = 3 \times n(C_{18}H_{33}O_2) = 3 \times 0.360 \quad \text{①}$$
- $$= 1.08 \text{ mol}$$
- $$m(I_2) \text{ required} = 1.08 \text{ mol} \times 254 \text{ g mol}^{-1} = 274 \text{ g} \quad \text{①}$$
- Iodine number of linoleic acid is 274
- ii. Arachidic acid, $C_{19}H_{39}COOH$, has the molecular formula $C_{20}H_{40}O_2$ and so is saturated, i.e. has no C=C double bonds and does not undergo an addition reaction with iodine. ①
- b. i. Glycerol, $C_3H_8O_3$ ①
- ii. $C_{15}H_{31}COOH(l) + CH_3OH(l) \rightarrow C_{15}H_{31}COOCH_3(l) + H_2O(l)$ ①①
The formula for palmitoleic acid is obtained from the data booklet (Table 9).
- c. C_2H_6O / CH_3CH_2OH ①, i.e. ethanol
- d. The use of crops such as corn for the production of bio fuels means that if land normally used to produce food is dedicated to the production of biofuels, there will be less food produced and the price of basic foodstuffs will increase. ①
- e. The sharp falls in the price of oil, and hence petrol. ①

Question 5



- a. $n(NaOH) \text{ remaining} = n(HCl) \text{ used}$
 $= c(HCl) \times V(HCl)$
 $= 0.105 \times 14.1 \times 10^{-3}$
 $= 1.48 \times 10^{-3} \text{ mol} \quad \text{①}$
- b. $n(NaOH) \text{ required} = n(NaOH) \text{ supplied} - n(NaOH) \text{ in excess}$
 $= 0.108 \times 100 \times 10^{-3} - 1.48 \times 10^{-3}$
 $= 1.08 \times 10^{-2} - 1.48 \times 10^{-3}$
 $= 9.32 \times 10^{-3} \text{ mol} \quad \text{①}$
- c. $n(N) \text{ in sample} = n(NH_4^+) = n(NaOH) \text{ required}$
 $= 9.32 \times 10^{-3} \text{ mol} \quad \text{①}$
- $m(N) \text{ in sample} = n(N) \times m(N)$
 $= 9.32 \times 10^{-3} \times 14.0$
 $= 0.130 \text{ g} \quad \text{①}$
- % N in sample $= [m(N) / m(\text{sample})] \times 100$
 $= [0.130 / 2.75] \times 100$
 $= 4.74 \% \quad \text{①}$

d.

Error	Calculated % N too high	No effect on calculated % N	Calculated % N too low
i. A small amount of the cooled solution is spilt prior to the titration.	✓ ①		
ii. The burette is rinsed with water immediately before adding the acid prior to the titration.			✓ ①
iii. Traces of fertiliser remain in the weighing bottle after transfer to the 0.108 M NaOH.			✓ ①

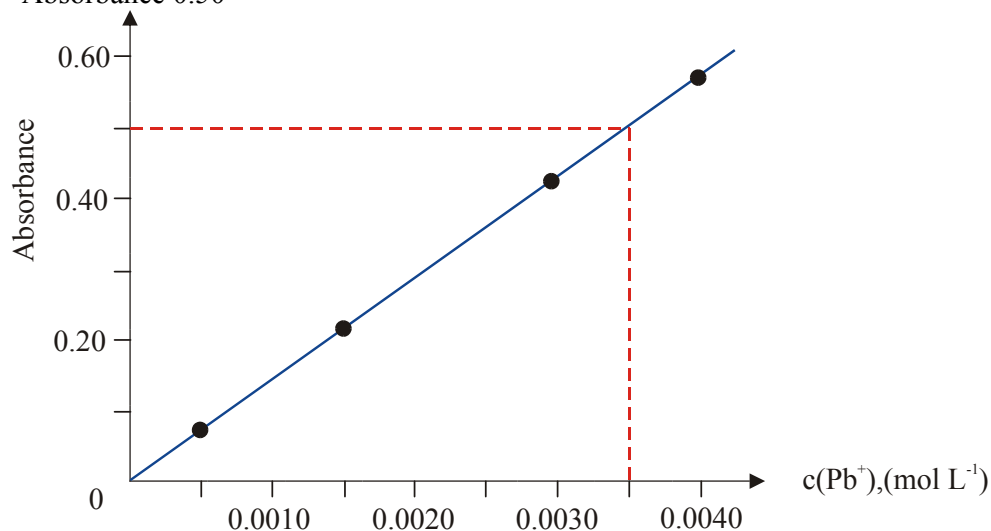
- i. This will lead to an **increase** in the calculated amount of nitrogen.
A smaller $V(\text{HCl})$ will be required (less OH^- to react with) \rightarrow a smaller calculated $n(\text{OH}^-)$ remaining \rightarrow a larger calculated $n(\text{OH}^-)$ reacting with NH_4^+ \rightarrow a larger calculated $n(\text{NH}_4^+)$ \rightarrow a larger $n(\text{N})$ \rightarrow a larger $m(\text{N})$ \rightarrow a larger % N
- ii. This will lead to a **decrease** in the calculated amount of nitrogen.
A larger $V(\text{HCl})$ will be required (concentration decreased by water) \rightarrow larger calculated $n(\text{OH}^-)$ remaining \rightarrow smaller calculated $n(\text{OH}^-)$ reacting with NH_4^+ \rightarrow smaller calculated $n(\text{NH}_4^+)$ \rightarrow smaller $n(\text{N})$ \rightarrow smaller $m(\text{N})$ \rightarrow a smaller % N
- iii. This will lead to a **decrease** in the calculated amount of nitrogen.
Because there is less than 2.75 g (say 2.72 g) of fertiliser actually added to the $\text{NaOH}(\text{aq})$, the calculations resulting from the analysis will give the actual mass of N in the 2.72 g of fertiliser.
However in calculating % N = $m(\text{N}) [\text{in } 2.72 \text{ g}] / 2.75 \text{ g} \times 100$, the division by the assumed 2.75 g will lead to a lower than true % N

Question 6

- a. $\text{BaO}(\text{s}) + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow \text{BaSO}_4(\text{s}) + \text{H}_2\text{O}(\text{l})$ ①
 $\text{MgO}(\text{s}) + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow \text{MgSO}_4(\text{aq}) + \text{H}_2\text{O}(\text{l})$ ①
- b. $n(\text{BaSO}_4)$ produced = $0.237 \text{ g} / [233.4 \text{ g mol}^{-1}]$
 = $1.02 \times 10^{-3} \text{ mol}$
 So $n(\text{BaO})$ reacting = $1.02 \times 10^{-3} \text{ mol}$
 $m(\text{BaO})$ in sample = $1.8 \times 10^{-3} \text{ mol} \times [153.3 \text{ g mol}^{-1}]$
 = 0.156 g ①
 $m(\text{MgO})$ in sample = $0.952 - m(\text{BaO})$
 = $0.952 - 0.156$
 = 0.796 g ①
 $n(\text{MgO})$ present = $0.796 \text{ g} / [40.3 \text{ g mol}^{-1}]$
 = $1.97 \times 10^{-2} \text{ mol}$ ①
 $n(\text{Mg}^{2+})$ in 500 mL of solution = $n(\text{MgO})$
 = $1.97 \times 10^{-2} \text{ mol}$
 $c(\text{Mg}^{2+})$ in sample = $1.97 \times 10^{-2} \text{ mol} / 0.500 \text{ L}$
 = $0.0394 \text{ mol L}^{-1}$ ①
- c. Not washing the precipitate with water will leave any soluble impurities trapped and lead to a higher than true mass $m(\text{BaSO}_4)$. ① This will lead to a lower calculated $m(\text{MgO})$, hence a lower $n(\text{Mg}^{2+})$ and a lower $c(\text{Mg}^{2+})$ in the filtrate solution. ①

Question 7

- a. Since the analysis was for the amount of the metal lead in the bore water an **atomic absorption spectrophotometer** ❶ would be used.
- b. Electrons are promoted to higher energy levels. ❶
- c. Absorbance 0.50



$c(\text{Pb})$ in diluted sample of bore water = **0.0035 mol L⁻¹** ❶

Since the original bore water sample had been diluted by a factor of 2, from 50 mL to 100 mL, then

$$\begin{aligned} c(\text{Pb}) \text{ in bore water} &= 2 \times 0.0035 \\ &= \mathbf{0.0070 \text{ mol L}^{-1}} \quad \text{❶} \end{aligned}$$

- d. $m(\text{Pb})$ in one litre
- $$\begin{aligned} &= 0.0070 \times 207.2 \\ &= 1.45 \text{ g} \\ &= 1.45 \times 10^3 \text{ mg (} 1.5 \times 10^3 \text{ ... 2 sig figures)} \quad \text{❶} \end{aligned}$$

End of Suggested Answers