VCE CHEMISTRY 2010

YEAR 12 TRIAL EXAM UNIT 3

Time allowed: 90 minutes
Total marks: 76

20 Multiple Choice Questions
6 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*

• **Biology** • **Physics** • **Chemistry** • **Psychology** • **Mathematics** •

Student Name.....…………………..

VCE Chemistry 2010 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 2*	A	B	C	D
Question 3	A	B	C	D	*Question 4*	A	B	C	D
Question 5	A	B	C	D	*Question 6*	A	B	C	D
Question 7	A	B	C	D	*Question 8*	A	B	C	D
Question 9	A	B	C	D	*Question 10*	A	B	C	D
Question 11	A	B	C	D	*Question 12*	A	B	C	D
Question 13	A	B	C	D	*Question 14*	A	B	C	D
Question 15	A	B	C	D	*Question 16*	A	B	C	D
Question 17	A	B	C	D	*Question 18*	A	B	C	D
Question 19	A	B	C	D	*Question 20*	A	B	C	D

VCE Chemistry 2010 Year 12 Trial Exam Unit 3

Multiple Choice Questions – Section A

Section A consists of 20 multiple-choice questions.
Section A is worth approximately 26 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
Consider the simulated ^{13}C NMR spectrum shown below.
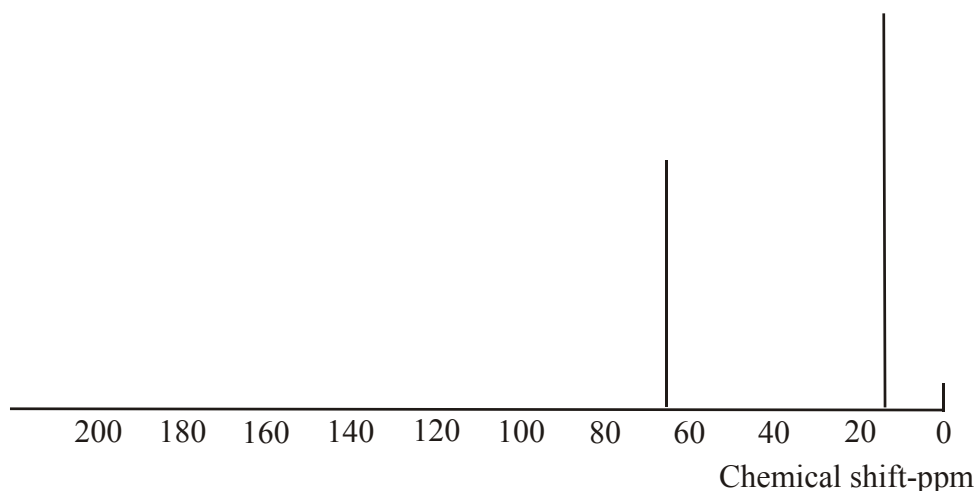
The compound most likely to produce this spectrum would have the semi-structural formula
A. CH_3NH_2
B. $CH_3CH_2OCH_2CH_3$
C. CH_3COOH
D. $CH_3CH_2CH_2OH$

Question 2
When studying low-resolution ^{1}H NMR spectra of
   (i) ethanol,
   (ii) methylpropane, and
   (iii) 2,3-dichlorobutane
the number of different chemical shifts (> 0) at which peaks should be evident would be
A.   (i) two, (ii) two, (iii) four.
B.   (i) two, (ii) three, (iii) one.
C.   (i) three, (ii) one, (iii) two.
D.   (i) three, (ii) two, (iii) two.

Question 3

An appropriate technique to use in the quantitative analysis of the active ingredients present in sunscreens is
A.   UV-visible spectroscopy.
B.   atomic absorption spectroscopy.
C.   gas chromatography.
D.   IR spectroscopy.

Question 4

The possibility of using plastic engines to reduce the weight of motor vehicles has been investigated for the last 30 years. In the mid 1980's, Polimotor Research Inc in New Jersey, USA, developed an engine using the polymer Torlon®. The structure of a section of a Torlon polymer chain is shown below.
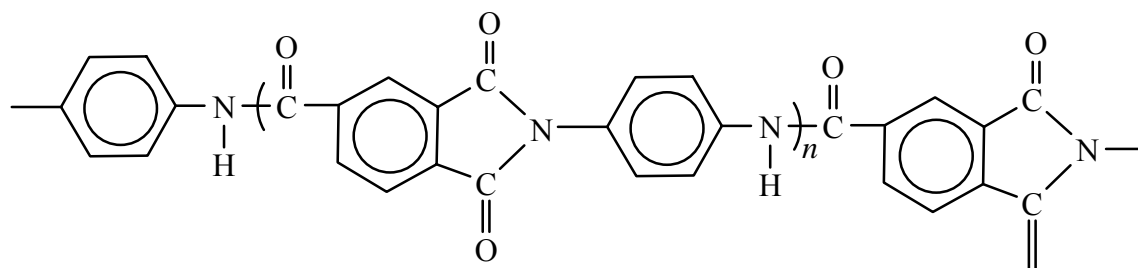
Which of the following statements about Torlon is **not** correct?
A.   Its IR spectrum would show a strong absorption band at 1700 cm^{-1}.
B.   It is a condensation polymer.
C.   It contains more nitrogen atoms than hydrogen atoms.
D.   It contains amide groups.

Question 5

Consider the following simulated high resolution proton NMR signals.
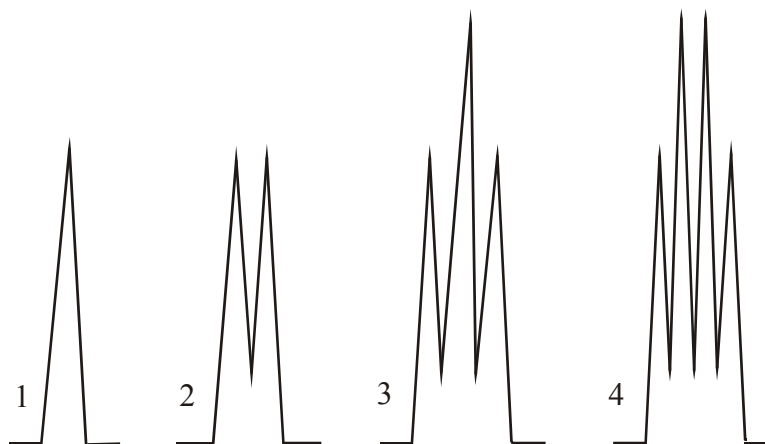
Which of the following statements relating to these signals is correct?
A.   Signal 2 should be present on the spectrum of methylpropane.
B.   Signals 3 and 4 should appear on the spectrum of 1-propanol.
C.   Signal 1 would not be present on the spectrum of ethane.
D.   Signal 4 is always produced when there are CH_3 groups in a molecule.

Question 6

Bromine, Br_2, dissolves in unsaturated hydrocarbons and reacts immediately. Which of the following is the best description of this process?

A.   Bromine is polar and reacts by adding bromine atoms across the double bond.

B.   Bromine is polar and reacts by substituting hydrogen atoms with bromine atoms.

C.   Bromine is non-polar and reacts by substituting hydrogen atoms with bromine atoms.

D.   Bromine is non-polar and reacts by adding bromine atoms across the double bond.

Question 7

The complete combustion of 24.0 g of an organic compound produces 1.20 mol CO_2 and 1.60 mol H_2O. The compound was

A.   propane.

B.   1-propanol.

C.   propanoic acid.

D.   methyl ethanoate.

Question 8

In the titration of a strong base with a strong acid, the following procedure was used.

1.   A burette was rinsed with water and then filled with the standardised acid.

2.   A pipette was rinsed with some of the base solution.

3.   A conical flask was rinsed with some of the base solution.

4.   A pipette was used to transfer a measured volume of the base solution into the conical flask.

5.   Indicator was added to the solution in the conical flask which was then titrated to the endpoint with the acid.

On the basis of this experimental procedure,

A.   phenolphthalein should have been the indicator used.

B.   the calculated base concentration will be too low.

C.   the calculated base concentration will be too high.

D.   thymol blue should have been the indicator used.

Question 9

Phosphoric acid may be produced by reacting phosphorus(V) oxide with water.

$$P_2O_5(s) + 3H_2O(l) \rightarrow 2H_3PO_4(aq)$$
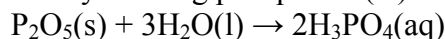
Phosphoric acid is a triprotic acid which reacts with sodium hydroxide according to the equation:

$$H_3PO_4(aq) + 3NaOH(aq) \rightarrow Na_3PO_4(aq) + 3H_2O(l)$$
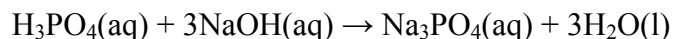
If 2.13 g of phosphorus(V) oxide is fully converted to phosphoric acid, what volume of 0.25 M NaOH(aq) would be required to fully neutralise the phosphoric acid produced?

A.   0.12 L

B.   0.18 L

C.   0.36 L

D.   0.50 L

Question 10

A sample of propene is reacted with hydrogen chloride. Any organic compounds produced are separated from other products. The organic products are then reacted with aqueous NaOH. Any organic compounds produced are again separated out and then reacted with an acidified aqueous solution of potassium dichromate. Analysis of the organic products shows that no carboxylic acid was present.

Which of the following statements is consistent with the lack of carboxylic acid in the final products?

A.   2-chloropropane was not produced in the reaction between propene and hydrogen chloride.

B.   1-chloropropane was not produced in the reaction between propene and hydrogen chloride.

C.   Propan-2-ol can be oxidised to propanoic acid but propan-1-ol cannot.

D.   Acidified dichromate converts alcohols to esters.

Question 11

Coeliac disease (CD) arises when the lining of the small bowel becomes damaged as the result of exposure to **gluten**, which is present in wheat, barley and rye. Recent research has found that over 90 per cent of all cases of CD are found in people with raised levels of HLA - human leukocyte antigen - particularly HLA-DQ2 and HLA-DQ8.

HLA-DQ2 and HLA-DQ8 are most likely to be

A.   carbohydrates.

B.   proteins.

C.   nucleic acids.

D.   nucleotides.

Question 12

A chloride compound of platinum contains 26.68 % chlorine by mass. The oxidation number of platinum in this compound is

A.   +1

B.   +2

C.   +3

D.   +5

Question 13

The tertiary structure of DNA is referred to as supercoiling.

In plants and animals, the 'supercoiling' of DNA results from the interaction between the 'negatively charged' DNA molecules and a group of positively charged proteins called histones, which have sites of positive charge along each protein chain.

The positive charge on histones at low pH is most likely due to the presence of

A.   lysine.

B.   deoxyribose.

C.   aspartic acid.

D.   cysteine.

In 1829, Johan Büchner isolated pure salicin from willow bark. Salicin was recognised as the 'active ingredient' in willow bark, i.e. the pain reliever. In the body salicin was converted into salicylic acid. Since this conversion process takes time, the effect was not felt immediately. The laboratory conversion of salicin to salicylic acid involves the intermediate compound salicyl alcohol. The structures of salicin, salicyl alcohol and salicylic acid are represented below.

Salicin   Salicyl alcohol   Salicylic acid
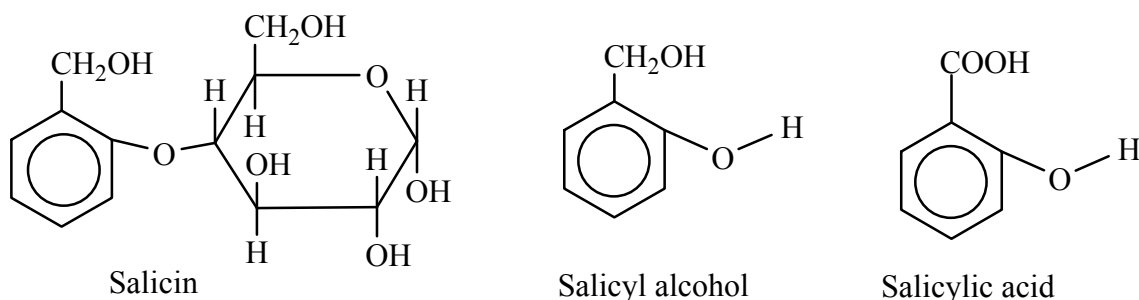
Question 14
The type of reaction involved in the conversion of salicin to salicyl alcohol, and the other product of this reaction are
A.   condensation, fructose.
B.   hydrolysis, glucose.
C.   oxidation, glucose.
D.   reduction, fructose.

Question 15
The laboratory conversion of salicyl alcohol to salicylic acid requires reaction of the alcohol with
A. H_2O, H^+(aq).
B. OH^-(aq).
C. $Cr_2O_7^{2-}$(aq), H^+(aq).
D. H_2SO_4(aq).

Question 16
Because of its simplicity and speed, thin layer chromatography (TLC) has found many applications in pharmaceutical sciences.
Chemicals commonly present in analgesic products include aspirin, codeine and paracetamol. In an analysis, the compounds present in a particular analgesic were to be separated using TLC. When the analysis was performed, the solvent front clearly moved but there seemed to be no separation of the components of the analgesic.
The method most likely to 'improve' the outcome of this analysis would be to
A.   use a different mobile phase.
B.   use a less polar stationary phase.
C.   place a bigger 'spot' of analgesic at the origin.
D.   let the chromatogram develop under UV light.

Question 17
Given below are the mass spectrum and infrared spectrum of an organic compound.
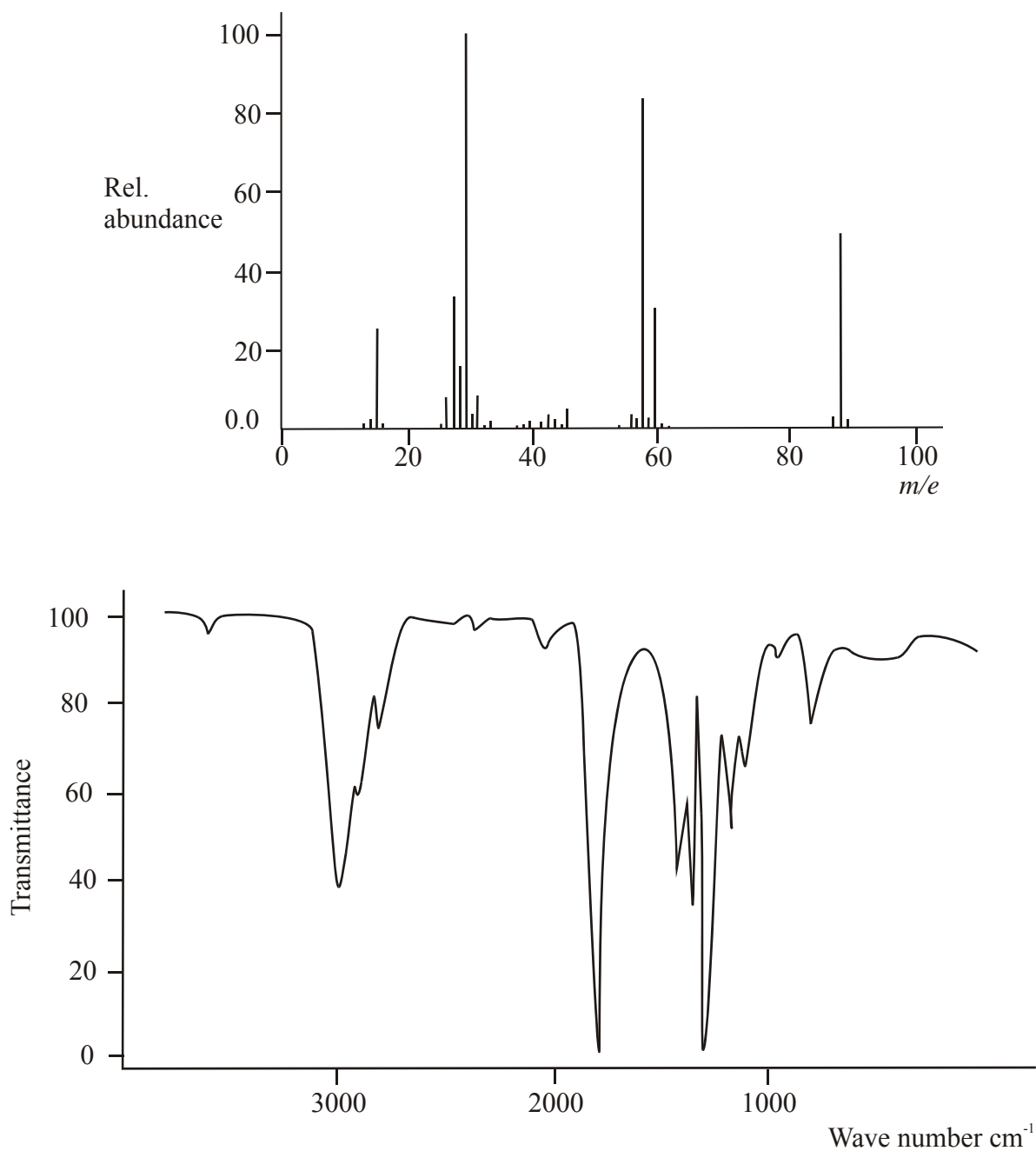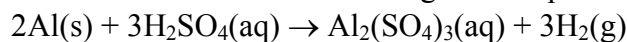

The semi-structural formula of the compound is most likely to be
A.   CH₃CH₂COOCH₃
B.   CH₃CH₂CH₂COOH
C.   HCOOCH₂CH₃
D.   CH₃CH₂COOH

Question 18

Aluminium will react with dilute sulfuric acid according to the equation

$$2Al(s) + 3H_2SO_4(aq) \rightarrow Al_2(SO_4)_3(aq) + 3H_2(g)$$

In a practical investigation, 0.675 g of Al is added to excess dilute sulfuric acid and allowed to react to completion. 735 mL of H_2, measured at SLC, is collected.

What percentage of the H_2 produced in the reaction was actually collected?

A.   12.0 %
B.   40.0 %
C.   80.0 %
D.   100 %

Question 19

The potassium level of a common 'sports drink' was determined by atomic absorption spectrometry.

A series of $K^+(aq)$ standards were prepared, their absorbances determined by aspirating each standard into the spectrometer and the calibration curve below was produced.
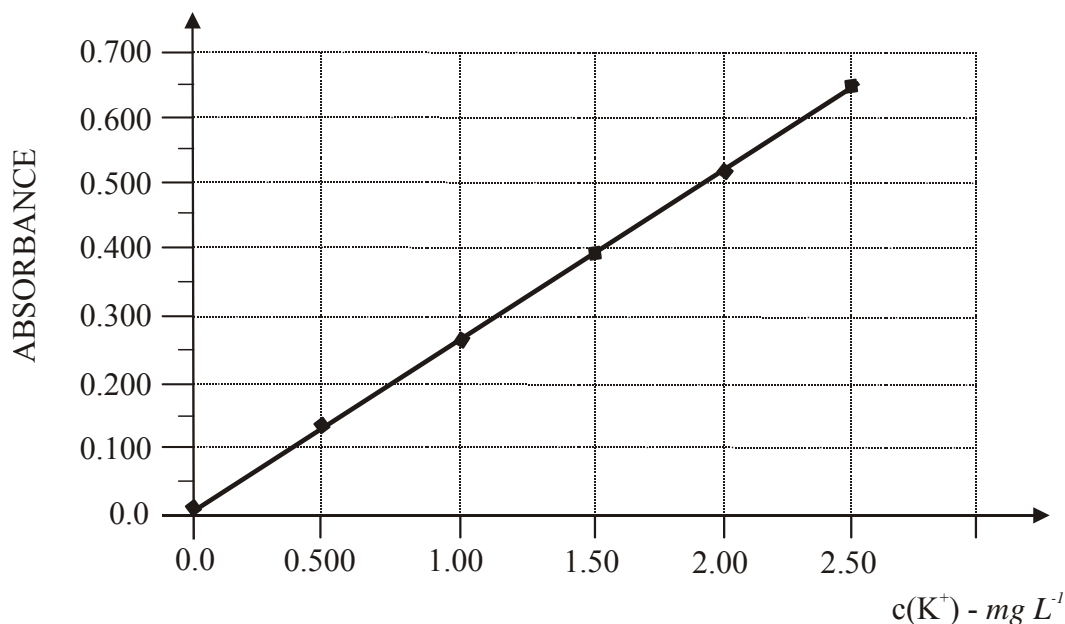
A 10.0 mL sample of the sports drink was diluted to 100 mL with deionised water. Then 10.0 mL of this diluted solution was further diluted to 100 mL with deionised water.

When a sample of the final dilute solution was aspirated into the atomic absorption spectrometer, an absorbance of 0.510 was recorded.

The mass of $K^+(aq)$, in g, present in a standard 175 mL serve of the sports drink, was closest to

A.   0.034
B.   0.20
C.   0.35
D.   2.0

Question 20

A mixture of hexane and oxygen was placed in an evacuated vessel at 300°C. The pressure inside the vessel was 80 kPa. After ignition by a spark, the mixture reacted completely to form CO_2, CO and water vapour. The contents of the container were returned to 300°C and the pressure was found to be 130 kPa.

Which of the following equations best describes the reaction that took place?

A. $C_6H_{14}(g) + 8O_2(g) \rightarrow 3CO(g) + 3CO_2(g) + 7H_2O(g)$.

B. $C_6H_{14}(g) + 7O_2(g) \rightarrow 5CO(g) + CO_2(g) + 7H_2O(g)$.

C. $2C_6H_{14}(g) + 15O_2(g) \rightarrow 8CO(g) + 4CO_2(g) + 14H_2O(g)$.

D. $2C_6H_{14}(g) + 17O_2(g) \rightarrow 4CO(g) + 8CO_2(g) + 14H_2O(g)$.

End of Section A

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Short Answer Questions - Section B

> *Section B consists of 6 short answer questions.*
> *You should answer all of these questions in the spaces provided.*
> *This section is worth approximately 74 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

a.   A student carries out a titration experiment to determine the concentration of ammonia in a bottle of household cleaner. She takes a 20.0 mL sample of the cleaner and dilutes it with water to a volume of 250 mL. She then titrates a 20.0 mL sample of the dilute solution with 0.0830 M hydrochloric acid.
The average titre required was 14.74 mL.
Calculate the concentration, in mol L^{-1}, of ammonia in the bottle of household cleaner.

(3 marks)

b.   When 50.0 mL of 0.168 M $AgNO_3$(aq) is added to an aqueous solution of XO_4^{3-} ions, and reacts completely, a white precipitate is produced.
The precipitate is collected, dried and weighed and found to have a mass of 1.172 g.

   i.   Calculate the amount, in mol, of precipitate produced.

(2 marks)

   ii.   Calculate the molar mass of the precipitate.

(1 mark)

   iii. Identify element X.

(1 mark)

c.   In the production of an ester, 50.0 mL of ethanol was mixed with 50.0 mL of ethanoic acid. The reaction was catalysed with concentrated sulphuric acid. The ester produced was collected by distillation.
The following data were recorded.
d(ethanol) = 0.785 g mL^{-1}
d(ethanoic acid) = 1.05 g mL^{-1}
m(ester) collected = 59.5 g

   i.   Write a balanced equation for the esterification reaction.

(1 mark)

ii. Calculate the initial amounts, in moles, of ethanol and ethanoic acid, available for reaction.

(2 marks)

iii. Calculate the percentage yield of the ester.

(2 marks)

iv. Why is the ester collected by distillation?

(1 mark)

Total 13 marks

Question 2
CSIRO research has established that it's possible to produce biodiesel made from algae at a lower cost and with less greenhouse gas emissions than would otherwise be produced in the manufacture of diesel from fossil fuels.
A one hectare pond filled with algae can produce between 15,000 and 80,000 litres of vegetable oil each year.
Analysis of the composition of a biodiesel produced from algae indicated that it contained methyl myristate and methyl arachidonate.

a.   Give the molecular formula of the fatty acid from which methyl myristate could be produced.

(1 mark)

b.   Explain how the molecular formula of the fatty acid can be used to determine if it is saturated or unsaturated.

(1 mark)

c.   Give the structure, showing all bonds, of the main by-product of the production of biodiesel.

(1 mark)

d.   Calculate the volume of hydrogen gas, at 77°C and 1.10×10^5 Pa, required to convert 150 g of arachidonic acid into a saturated fatty acid.

(3 marks)

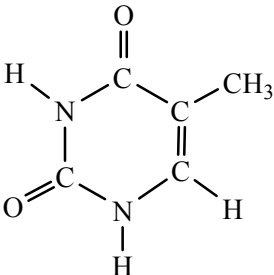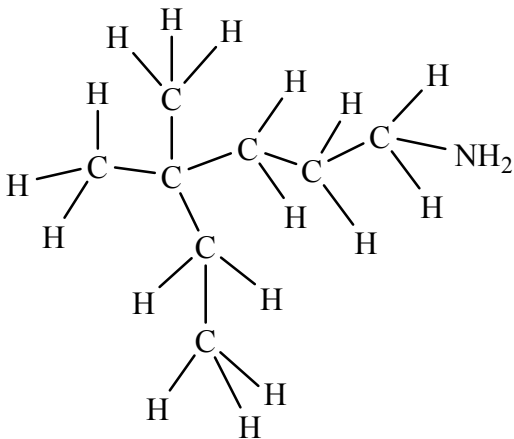e.   Write a balanced equation for the combustion of methyl arachidonate.

(2 marks)

f.   One advantage of producing biodiesel from algae is the greater photosynthetic efficiency of aquatic biomass compared to land plants. What would be a significant environmental advantage of locating an algae pond near a coal fired power station?

(1 mark)

Total marks 9

Question 3
Complete the following table by inserting the missing information for each substance.

a. Systematic Name?	b. Semi-structural formula?	Only functional group present is the **carboxyl** group **Molecule ion peak on mass spectrum at** *m/e* = **74**
1,3-dichlorobutan-2-ol	c. Semi-structural formula?	d. Which absorption bands on the IR spectrum would not be present on the spectrum of butane?
e. Name of compound?		f. What is the empirical formula?
g. Systematic name?		h. Describe how this compound may be prepared from the relevant alkane.

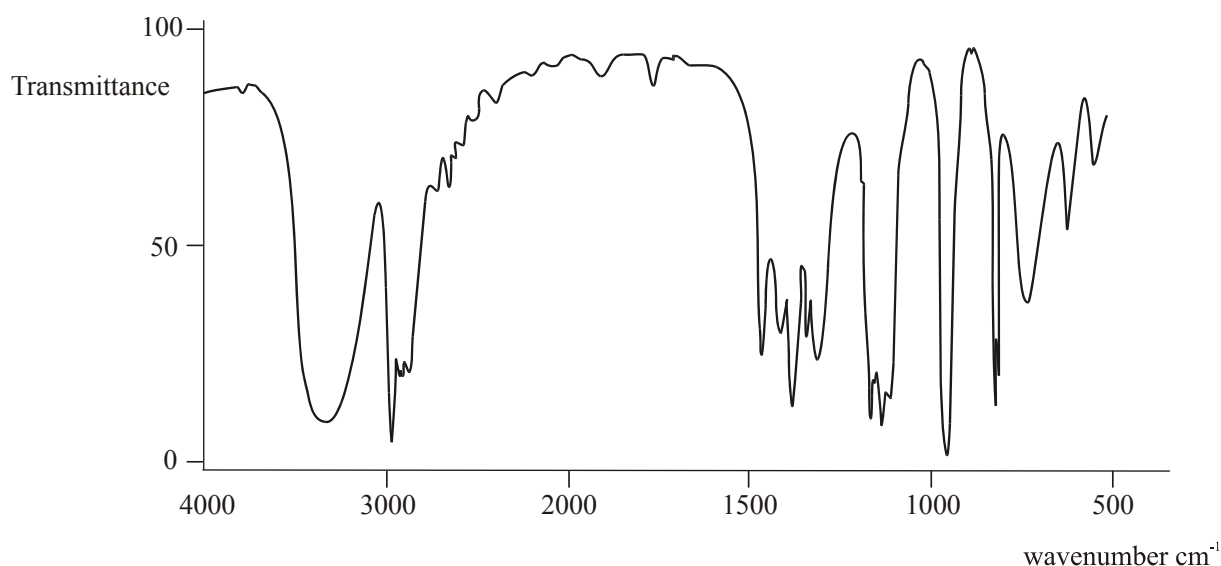$(7 \times 1 + 2 = 9$ **marks)**

Total marks 9

Question 4

The identity and molecular structure of an organic compound is to be determined using a combination of mass, ^{1}H NMR, and IR spectra.

The spectra are shown below.
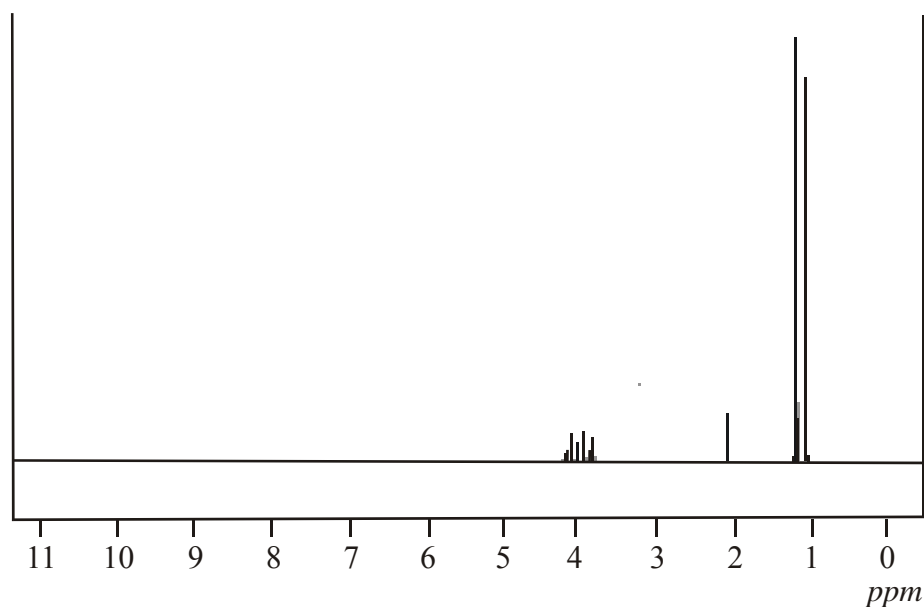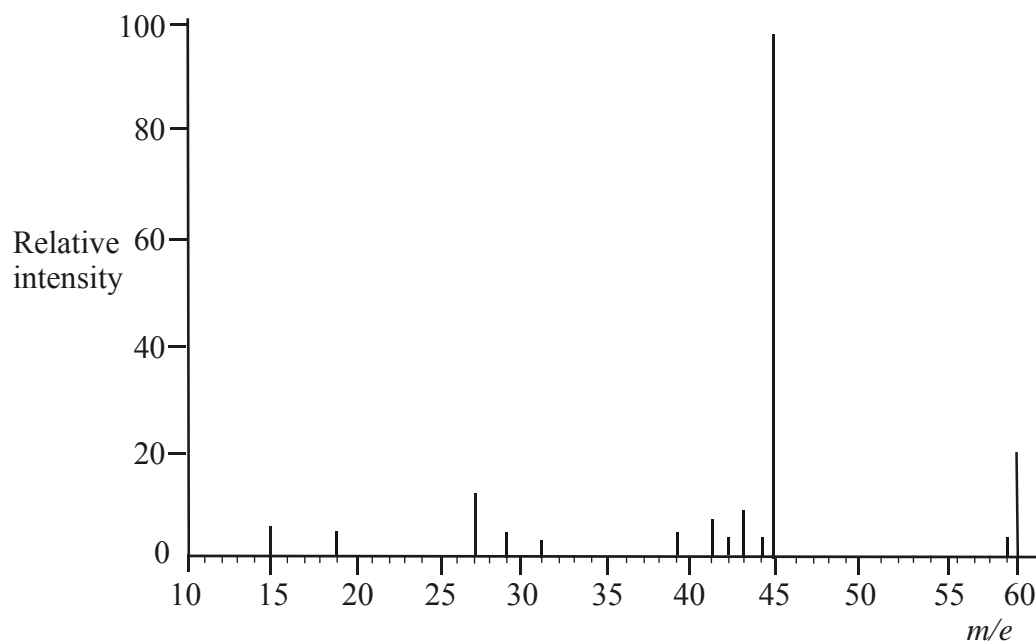
a. Using these spectra, deduce

    i. the relative molecular mass of the compound.

    ii. the identity of any functional groups present in the compound.

    iii. the number of different hydrogen environments in the compound.

(3 × 1 = 3 marks)

b. Deduce the molecular formula of the compound.

(1 mark)

c. Draw the structures, showing all bonds, for two compounds that have the molecular formula deduced in (b) and contain the functional group deduced in (a).

(2 marks)

d. Explain how the NMR spectrum is consistent with one of the structures drawn in (c) but not the other structure.

(2 marks)

e. Give the name of the compound to which all three spectra apply.

(1 mark)

f. Explain

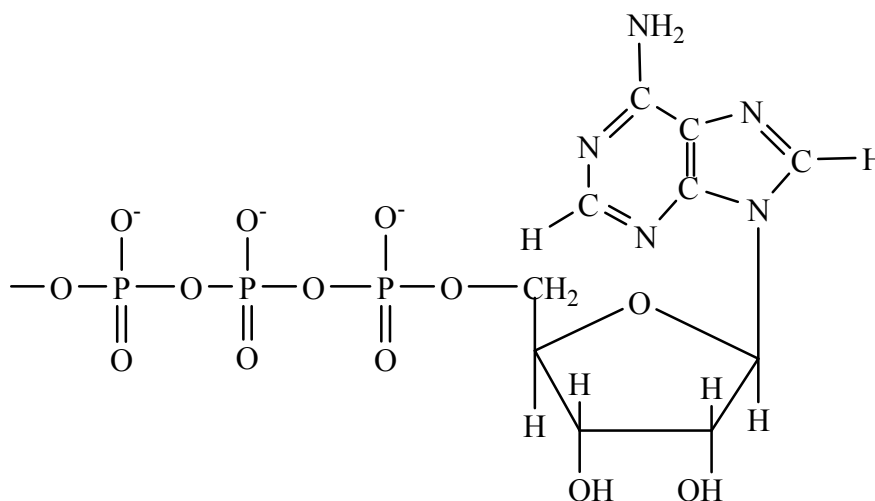i. the presence of a peak at $m/e = 45$ on the mass spectrum.

ii. the presence of the septet at $\delta = 4.0$ on the ^{1}H NMR spectrum.

(2 × 1 = 2 marks)

Total 11 marks

Question 5

Adenosine triphosphate (ATP), a biomolecule often said to be second in importance only to DNA, is the energy-carrying molecule in all living cells. It is a nucleotide and its structure is represented below.

a.   i.   Describe one way in which the structure of ATP is the same as many nucleotides used to produce DNA.

ii.   Describe two ways in which the structure of ATP is different from the nucleotides used to produce DNA.

(1 + 2 = 3 marks)

b.   How is the 'primary' structure of DNA defined?

(1 mark)

c.   What type of bonding maintains the secondary structure of DNA?

(1 mark)

d.   What characteristic of DNA structure explains why A-G and C-T base pairings do not occur?

(1 mark)

Total 6 marks

Question 6

Explain why:

a.   The amino acid cysteine helps stabilise the tertiary structure of many proteins.

(1 mark)

b.   The relative molecular mass of the tripeptide Ala-His-Met is 36 smaller than the sum of the molar mass of the amino acids from which it is formed.

(1 mark)

c.   Ethanol is soluble in both water and octane.

(2 marks)

d. The polymerase chain reaction is important in forensic analysis.

(1 mark)

e. Lipases, enzymes that control the digestion of fats, cannot control the digestion of proteins.

(1 mark)

f. In chromatography, high R_f values are consistent with low retention times.

(2 marks)

Total 8 marks

**End of Section B**

End of Trial Exam

Suggested Answers

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Multiple Choice Answers - Section A

Q1   **B**   Since the ^{13}C NMR spectrum has only two peaks (other than the very small peak at $\delta = 0$ for TMS), the molecules of the compound must have two different C environments.
CH_3NH_2 has one C environment
$CH_3CH_2OCH_2CH_3$ has two different carbon environments – the two CH_3 groups are equivalent and the two CH_2 groups are equivalent, consistent with the symmetry of the molecule.
CH_3COOH has two different C environments.
$CH_3CH_2CH_2OH$ has three different C environments.
In order to determine whether the spectrum is that of $CH_3CH_2OCH_2CH_3$ or CH_3COOH, refer to chemical shift data in Table 6 in the Data Book. Since the carbon atom in the carboxyl group in RCOOH has a chemical shift between 160-185 ppm, the spectrum is that of $CH_3CH_2OCH_2CH_3$ (diethyl ether).

Q2   **D**   In a low resolution ^1H NMR spectrum the number of different peaks depends on the number of different H environments in the molecule.

(i)   (ii)   (iii)

3 different H environments   2 different H environments   2 different H environments
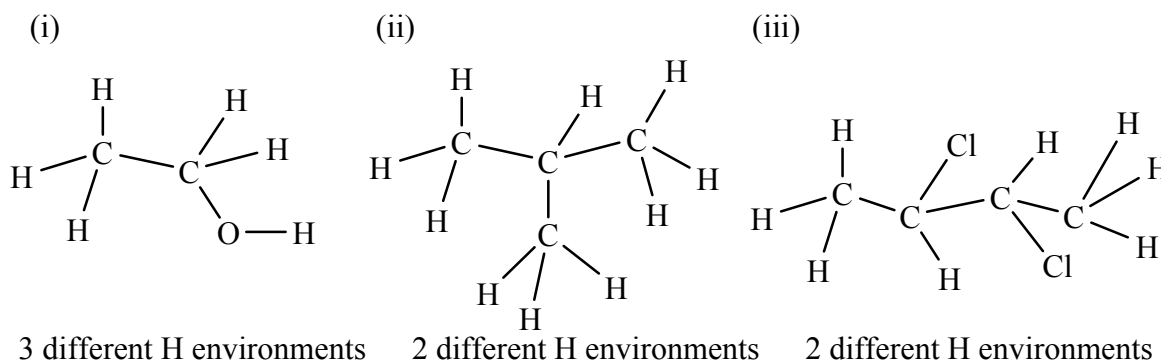
In methyl propane $(CH_3)_3CH$ the three CH_3 groups are in identical bonding environments, hence these 9 H atoms are in the same bonding environment.
In 2,3-dichlorobutane the two CH_3 groups are in identical bonding environments – hence there are 6 H atoms in the same bonding environment, and the two hydrogen atoms in the CHCl groups are in identical bonding environments.
In ethanol there are three distinct hydrogen environments, namely the CH_3, CH_2 and OH groups.

Q3   **A**   Since the purpose of active ingredients in sunscreen is to absorb ultraviolet radiation, the extent of the UV absorption would be analysed using UV-visible spectroscopy.
Important factors in ensuring that a sunscreen provides the best possible protection against UV light include; high concentration of active ingredients, wide dispersion of active ingredients, applying an appropriate amount of sunscreen.
The concentration of the UV absorbing active ingredients can be determined using UV-visible spectroscopy.

Q4 **C** Consider the alternatives.

A – there would be a strong IR absorption band at 1700 cm^{-1} due to the C=O groups.

B – the presence of the amide NH-CO groups suggests that the monomers from which the polymer forms may have amino, -NH$_2$, and –carboxyl, -COOH groups which react together in condensation reactions.

C – since there is an H atom at each vertex of the benzene rings not bonded to another atom, the repeating unit of the polymer contains 8 H atoms and 2 N atoms.

D – the NH-CO group is the 'amide' group.

Q5 **A** Signal 1 – a singlet - is produced by an H atom with no neighbouring H atoms on an adjacent C atom.

Signal 2 – a doublet – is produced by an H atom with one neighbouring H atom on an adjacent C atom.

Signal 3 – a triplet - is produced by an H atom with two neighbouring H atoms on an adjacent C atom.

Signal 4 – a quartet - is produced by an H atom with three neighbouring H atoms on an adjacent C atom.

A.
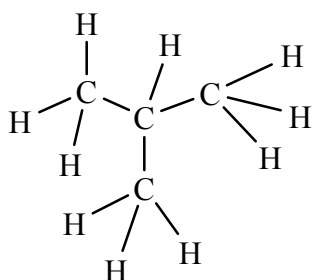
The signal for the 9 equivalent H atoms on the three CH$_3$ groups is split into a **doublet** by the H on CH.

B.
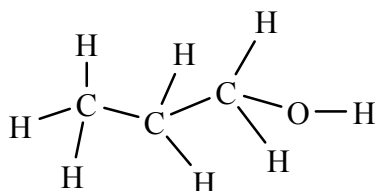
The signal for the 3 equivalent H on CH$_3$ is split into a **triplet,** as is the signal for the two equivalent H on the CH$_2$ bonded to OH, by the 2 neighbouring H on CH$_2$.

However there is **no quartet** on the spectrum, because the signal for the H atoms on the first CH$_2$ is split by the 3 H atoms on the adjacent CH$_3$ **and** by the 2 H atoms on the second CH$_2$.

C.
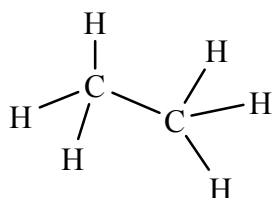
No signal splitting because all 6 H are equivalent. Hence **only a singlet will appear** on the spectrum.

D. In the high resolution ^{1}H NMR spectrum of CH$_3$CH$_2$OH or CH$_3$CH$_2$COOH, the signal for the H on CH$_2$ would be split into a quartet because of the neighbouring CH$_3$. However there would no quartet on the spectra of CH$_3$OH or (CH$_3$)$_3$CH.

Q6 D Br_2 dissolves readily in hydrocarbons, which are non-polar, because it is non-polar. It reacts with unsaturated hydrocarbons in addition reactions across the C=C double bond.
e.g. $CH_2=CH_2 + Br_2 \rightarrow CH_2BrCH_2Br$

Q7 B $n(C)$ in 24.0 g of the compound $= n(CO_2)$ produced
$= 1.2$ mol
$n(H)$ in 24.0 g of the compound $= 2 \times n(H_2O)$ produced
$= 2 \times 1.6$
$= 3.2$ mol

Ratio $n(C) : n(H) = 1.2 : 3.2$ or $n(C) : n(H) = 1.2 : 3.2$
$= 12 : 32$ $= 1 : 2.67$
$= 3 : 8$ $= 3 : 8$

Consider the molecular formulae of the alternatives
Propane, **C_3H_8**
1-propanol, $CH_3CH_2CH_LOH \rightarrow$ **C_3H_8O**
Propanoic acid, $CH_3CH_2COOH \rightarrow C_3H_6O_2$
Methyl ethanoate, $CH_3COOCH_3 \rightarrow C_3H_6O_2$.
The compound has to be propane or 1-propanol.
$n(C_3H_8)$ in 24.0 g $= m(C_3H_8) / M(C_3H_8)$
$= 24.0$ g $ / 44.0$ g mol^{-1}
$= 0.545$ mol
$n(C_3H_8O)$ in 24.0 g $= m(C_3H_8O) / M(C_3H_8O)$
$= 24.0$ g $ / 60.0$ g mol^{-1}
$= 0.400$ mol
The data are consistent with the combustion of **C_3H_8O.**
$C_3H_8O(g) + 3.5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$
0.400 mol   1.20 mol   1.60 mol

Q8 C For a titration of a strong base with a strong acid, at 25°C, the equivalence point occurs at a pH very close to 7. Hence an indicator should be chosen which has 7 in its pH range, e.g. bromothymol blue or phenol red. Phenolphthalein would not be appropriate because it would change colour well before the equivalence point and thymol red would not be appropriate because it would change colour well after the equivalence point. Acid base indicator pH ranges are given in Table 11 in the Data Book.
The burette should have been rinsed with the standardised acid before being filled. As a consequence of the rinsing procedure followed, a larger titre will be required. Also, the conical flask should have been rinsed with water. Rinsing it with the base solution will also result in the need for a larger titre.
Since the amount of acid used will be increased as a result of incorrect rinsing procedures, the calculated n(acid), n(base) and hence c(base) will be too high.

Q9 **C** $n(P_2O_5)$ reacting $= m(P_2O_5) / M(P_2O_5)$
$= 2.13$ g $/ 142$ g mol^{-1}
$= 0.0150$ mol
$n(H_3PO_4)$ produced $= 2$ x $n(P_2O_5)$ $= 2$ x 0.0150 mol
$= 0.0300$ mol
$n(NaOH)$ required $= 3$ x $n(H_3PO_4) = 3$ x 0.0300
$= 0.0900$ mol
$V(NaOH)$ required $= n(NaOH) / c(NaOH)$
$= 0.0900$ mol $/ 0.25$ mol L^{-1}
= **0.36 L**

Q10 **B** In theory, reaction between propene and HCl can produce 1-chloropropane and 2-chloropropane
$CH_3CH=CH_2$ + HCl → **$CH_3CH_2CH_2Cl$ / $CH_3CHClCH_3$**
1-chloropropane reacts with OH⁻ to produce 1-propanol
$CH_3CH_2CH_2Cl$ + OH⁻ → **$CH_3CH_2CH_2OH$** + Cl⁻
2-chloropropane reacts with OH⁻ to produce 2-propanol
$CH_3CHClCH_3$ + OH⁻ → **$CH_3CHOHCH_3$** + Cl⁻
Only 1-propanol, a primary alkanol, will produce a compound containing a carboxyl group, i.e. propanoic acid, when oxidised by $Cr_2O_7^{2-}$ / H^+.
$CH_3CH_2CH_2OH$ → **CH_3CH_2COOH**
The lack of production of propanoic acid suggests that there was no 1-propanol present after the reaction with aqueous NaOH. This in turn suggests that there was no 1-chloropropane present after the initial reaction between propene and hydrogen chloride, i.e. **1-chloropropane was not produced** during this reaction. Esters are produced from reaction between carboxylic acids and alcohols, using an acid catalyst.

Q11 **B** Damaged cells in organs may release into body fluids proteins (and / or amino acids) which are specific to the damaged organ. Hence raised levels of these proteins, called marker proteins – in this case HLA-DQ2 and HLA-DQ8 - can often be linked to specific diseases.
Whilst gluten is a protein, it is not the marker for coeliac disease, nor are the carbohydrates in cereal grains implicated.

Q12 **B** Assume a 100 g sample of the compound
$m(Cl)$ $= 26.68$ g
$m(Pt)$ $= (100 – 28.86)$
$= 73.32$ g
$n(Cl) = 26.68$ g $/ 35.5$ g mol^{-1}
$= 0.752$ mol
$n(Pt) = 73.32 / 195.1$
$= 0.376$ mol
Mole ratio Pt : Cl $= 0.376 : 0.752$
$= 1 : 2$
Empirical Formula $PtCl_2$
Since the oxidation number of Cl is -1, and the sum of the oxidation numbers is 0, the **oxidation number of Pt** must be **+2**

Q13 A   Whilst all amino acids assume a positive charge at low pH due to the basic NH_2 group attached to C-2 (the α-carbon) accepting a proton, this is not the cause of the positive charge along histone protein chains under these conditions. The positive charge along the chain is due to each NH_2 group on amino acid side chains accepting H^+ and becoming NH_3^+.
According to Table 8 of the Data Book, possible amino acids are arginine, asparagine, glutamine, histidine, **lysine**, proline and tryptophan.

Q14 B H_2O reacts across the ether –O– link to produce two hydroxy groups, one on salicyl alcohol and one on glucose.

Salicyl alcohol   Glucose
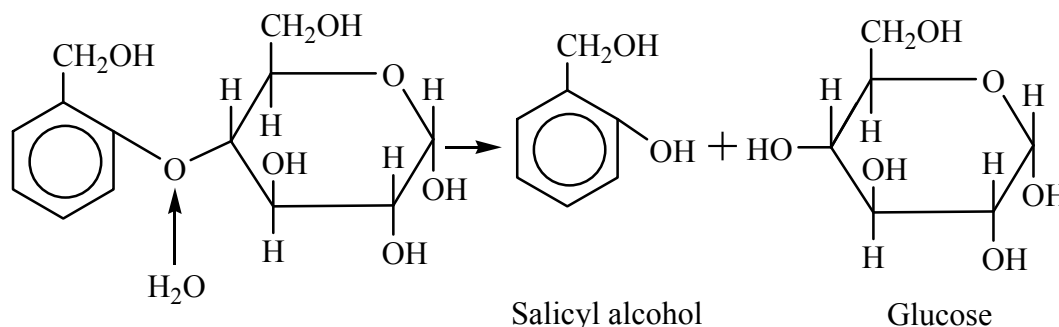
Q15 C   In the laboratory, alcohols can be oxidised to carboxylic acids using acidified dichromate solution,
i.e. $Cr_2O_7^{2-}(aq)/H^+(aq)$.
The $-CH_2OH$ group on salicylic alcohol is oxidised to $-COOH$.

Q16 D   Since most of the components of analgesics such as aspirin, codeine and paracetamol are white solids, and colourless in solution, they will not be visible under white light as they move up the chromatogram. Hence it would be more effective to observe the development of the chromatogram under UV-light.

Q17 A   The mass spectrum shows the molecule ion at $m/e = 88$. Hence the relative molecular mass of the compound is 88.
On the IR spectrum, the strong absorption band at approximately 1700 cm^{-1} indicates the presence of a C=O group. So the compound could be either a carboxylic acid or an ester. However since there is no broad absorption band characteristic of O-H, groups in carboxylic acids, at 2500-3300 cm^{-1}, the compound is not an acid and must be an ester which can now be identified by calculating the relative molecular masses of the two esters in the alternatives.
A. $CH_3CH_2COOCH_3 – M(C_4H_8O_2) = 88$
C. $HCOOCH_2CH_3 – M(C_3H_6O_2) = 74$

Q18 C n(Al) reacting $= m$(Al) / M(Al) $= 0.675$ g / 27.0 g mol^{-1}
$= 0.0250$ mol

According to the equation $2Al(s) + 3H_2SO_4(aq) \rightarrow Al_2(SO_4)_3(aq) + 3H_2(g)$
n(H$_2$) produced $= 3/2$ x n(Al) reacting
$= 1.5$ x 0.0250
$= 0.0375$ mol
n(H$_2$) collected $= V$(H$_2$) collected / V_m(SLC)
$= 0.735 / 24.5$
$= 0.0300$ mol
% H$_2$ collected $= [n$(H$_2$) collected / n(H$_2$) produced] x 100
$= [0.0300 / 0.0375]$ x 100
$= \mathbf{80.0\ \%}$

Alternatively
V(H$_2$) produced $= n$(H$_2$) x V_m(SLC)
$= 0.0375$ x 24.5
$= 0.919$ L
% H$_2$ collected $= [V$(H$_2$) collected / V(H$_2$) produced] x 100
$= [0.735 / 0.919]$ x 100
$= \mathbf{80.0\ \%}$

Q19 A   Using the calibration curve
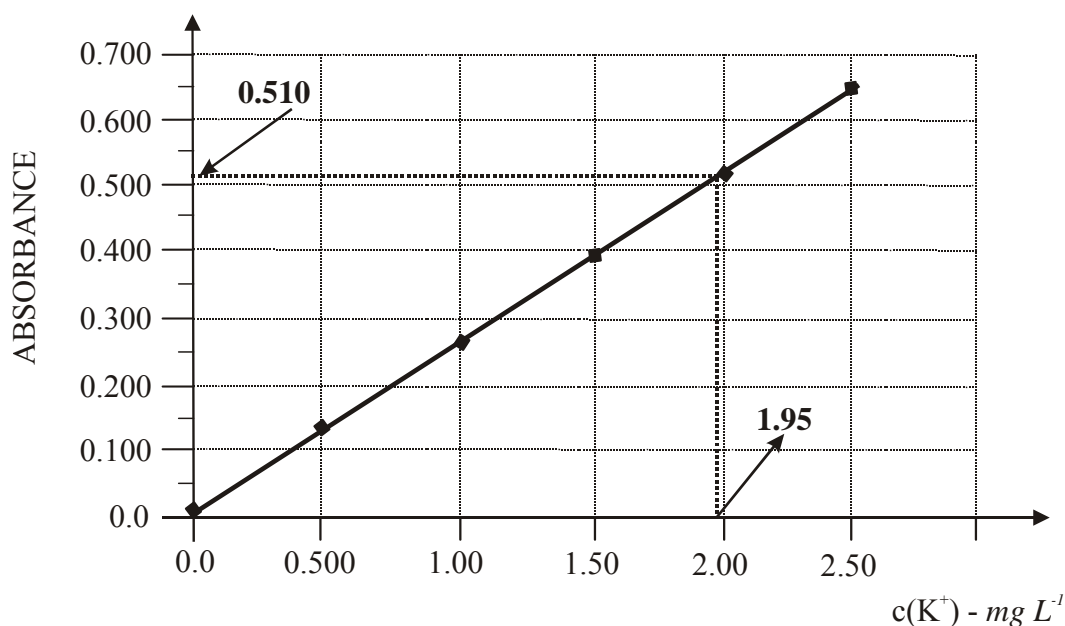
An absorbance of **0.510** corresponds to c(K$^+$) = **1.95 mg L^{-1}**
However this is the c(K$^+$) in the doubly diluted sample of the sports drink.
Since the drink was diluted by a factor of 10 twice, the concentration of the
undiluted sports drink would be 1.95 x 10 x 10 = 195 mg L^{-1}
m(K$^+$) in 1 mL = 195 / 1000 = 0.195 mg
m(K$^+$) in 175 mL serving $= 175$ x 0.195
$= 34.1$ mg
$= \mathbf{0.0341\ g}$

Q20 B According to $pV = nRT$, if the volume of the vessel is constant and the temperature after reaction is allowed to return to the initial temperature, the pressures before and after the reaction are proportional to the numbers of mole of reactants and products respectively.

Since p(after reaction) / p(before reaction) = 130 / 80
= 1.625

Hence n(products) / n(products) = 1.625.
Check each alternative
A. n(products) / n(products) = 13 / 9 = 1.444
B. n(products) / n(products) = 13 / 8 = 1.625
C. n(products) / n(products) = 26 / 17 = 1.529
D. n(products) / n(products) = 26 / 19 = 1.368

Short Answer (Answers) - Section B

Question 1
a. Equation $NH_3(aq) + HCl(aq) \rightarrow NH_4Cl(aq)$
n(HCl) used = c(HCl) x V(HCl)
= 0.0830 mol L^{-1} x 14.74x10^{-3} L
= 1.22x10^{-3} mol ❶
n(NH$_3$) in 20.0 mL diluted cleaner = n(HCl) used
= 1.223x10^{-3} mol
n(NH$_3$) in 20.0 mL cleaner = n(NH$_3$) in 250 mL diluted cleaner
= (250 / 20) x n(NH$_3$) in 20.0 mL diluted cleaner
= (250 / 20) x 1.223x10^{-3}
= 0.0153 mol ❶
c(NH$_3$) in cleaner = n(NH$_3$) / V(cleaner)
= 0.0153 / 20.0x10^{-3}
= 0.765 mol L^{-1} ❶

b. i. Ionic equation: $3Ag^+(aq) + XO_4^{3-}(aq) \rightarrow Ag_3XO_4(s)$
n(AgNO$_3$) = c(AgNO$_3$) x V(AgNO$_3$)
= 0.168 mol L^{-1} x 50.0x10^{-3} L
= 8.40x10^{-3} mol
n(Ag$^+$) = n(AgNO$_3$) = 8.40x10^{-3} mol ❶
n(Ag$_3$XO$_4$) = n(Ag$^+$) / 3
= 8.40x10^{-3} / 3
= **2.80x10^{-3} mol** ❶
ii. M(Ag$_3$XO$_4$) = m(Ag$_2$XO$_4$) / n(Ag$_3$XO$_4$)
= 1.172 g / 2.80x10^{-3} mol
= **418.6 g mol^{-1}** ❶
iii. 418.6 = 3xM(Ag) + M(X) + 4 x M(O)
= 3 x 107.9 + M(X) + 4x16.0
= 387.7 + M(X)
M(X) = 418.6 - 387.7
= 30.9
A_r(X) = 30.9
According to A_r values in Data Book, A_r(P) = 31.0
Hence element X is **phosphorus** ❶

c. i. $CH_3CH_2OH(l) + CH_3COOH(l) \rightarrow CH_3COOCH_2CH_3(l) + H_2O(l)$ ❶
        or $C_2H_6O(l) + C_2H_4O_2(l) \rightarrow C_4H_8O_2(l) + H_2O(l)$

    ii. $m(CH_3CH_2OH)$ = d x V
        = 0.785 g mL^{-1} x 50.0 mL
        = 39.25 g
        $n(\mathbf{CH_3CH_2OH})$ = 39.25 g / 46.0 g mol^{-1}
        = **0.853 mol** ❶
        $m(CH_3COOH)$ = d x V
        = 1.05 g mL^{-1} x 50.0 mL
        = 52.5 g
        $n(\mathbf{CH_3COOH})$ = 52.5 g / 60.0 g mol^{-1}
        = **0.875 mol** ❶

    iii. Since CH_3CH_2OH and CH_3COOH react in a 1:1 mole ratio, CH_3CH_2OH is the
        limiting reagent.
        Maximum n(ester) produced = $n(CH_3CH_2OH)$
        = 0.853 mol
        Maximum m(ester) produced = 0.853 mol x 88.0 g mol^{-1}
        = 75.1 g ❶
        % Yield of ester = [actual m(ester) produced / maximum m(ester)] x 100
        = (59.5 / 75.1) x 100
        = **79.2 %** ❶

    iv. Different organic compounds have different boiling temperatures and so
        distillation is an effective method of separation. ❶
        The ester, ethyl ethanoate, has a lower boiling temperature than the unreacted
        ethanol and ethanoic acid, and the other product water and will be distilled off
        first. This is due to the fact that ethanol, ethanoic acid and water all have
        intermolecular hydrogen bonding which is stronger than the dispersion force
   attraction between ethyl ethanoate molecules.

Question 2

a. Table 9 in the Data Book provides the formulae of some fatty acids.
    Methyl myristate is an ester produced from methanol and **myristic acid**.
    $C_{13}H_{27}COOH \rightarrow$ molecular formula $\mathbf{C_{14}H_{28}O_2.}$ ❶

b. Saturated fatty acids contain a carboxyl group, -COOH, and have the general
    molecular formula $C_nH_{2n}O_2$, i.e. the H : C ratio is exactly 2 : 1
    Myristic acid is **saturated because the H : C ratio in its molecular formula is
    exactly 2 : 1**. ❶

For unsaturated fatty acids, which have less hydrogen, because of the presence of C=C double bonds, the H : C ratio is less than 2 : 1.

c.
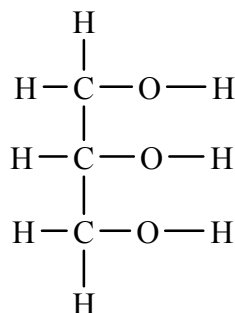
Glycerol from data book
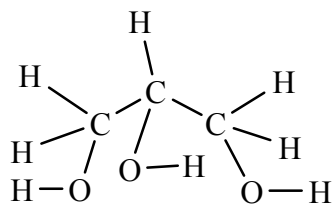
d. Arachidonic acid – $C_{19}H_{31}COOH$ from Data Book, i.e. $C_{20}H_{32}O_2$.
To become saturated each molecule of $C_{20}H_{32}O_2$ needs to gain 8 H atoms, i.e. 4 mol H_2
$n(C_{20}H_{32}O_2) = 152$ g $/ 304$ g mol^{-1}
   $= 0.500$ mol
$n(H_2)$ required $= 4$ x 0.500
   $= 2.00$ mol ❶
$V(H_2)$ required $= n(H_2)$ x RT / p
   $= 2.00$ x 8.31 x $(77+273) / 1.10$x10^2 ❶
   $= \textbf{52.9 L}$ ❶

e. $C_{19}H_{31}COOCH_3(l) + 28.5O_2(g) \rightarrow 21CO_2(g) + 17H_2O(g)$ ❶❶
$2C_{19}H_{31}COOCH_3(l) + 57O_2(g) \rightarrow 42CO_2(g) + 34H_2O(g)$
$2C_{21}H_{34}O_2(l) + 57O_2(g) \rightarrow 42CO_2(g) + 34H_2O(g)$
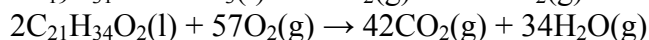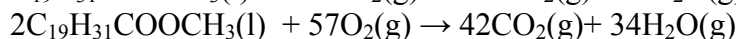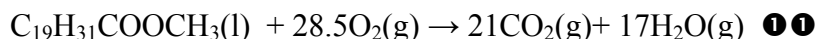
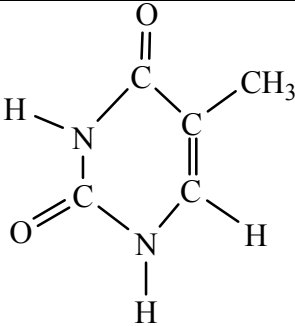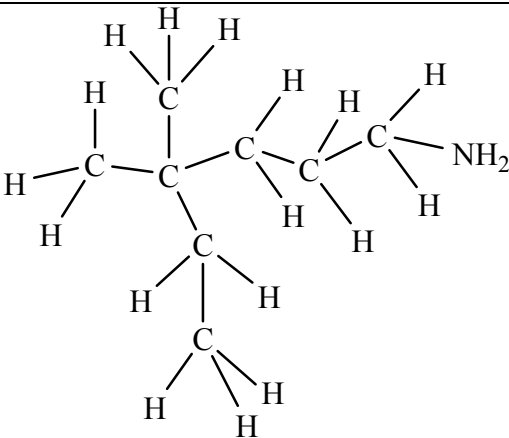f. Algae photosynthesis according to $6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(aq) + 6O_2(g)$.
Hence $CO_2(g)$ produced by the combustion of coal at the power station can be sequestered and bubbled into the algae pond to enhance algal growth. ❶
This reduces CO_2 emissions into the atmosphere from the power station.
Also 'waste' heat from the power station can be used to warm the pond for faster algal growth.

Question 3

Complete the following table by inserting the inserting the missing information for each substance.

| a. Systematic Name?	b. Semi-structural formula?	Functional Group present is **Carboxyl** **Molecule ion peak on mass spectrum at *m/e* = 74**
Propanoic acid ❶	**CH₃CH₂COOH ❶**	
1,3-dichlorobutan-2-ol	c. Semi-structural formula? **CH₃CHClCH(OH)CH₂Cl ❶**	d. Give the IR absorption bands present on the IR spectrum which would not be present on the spectrum of butane? **700-800 (C-Cl)** **1000-1300 (C-O)** **3200-3550 (O-H alcohol) ❶**
e. Name of compound? **Thymine ❶**		f. What is the empirical formula? **C₅H₆N₂O₂ ❶**
g. Systematic name? **4,4-dimethyl-1-hexanamine ❶**		h. Describe how this compound be prepared from the relevant alkane! **Alkane $\xrightarrow{Cl_2}$ Chloroalkane** **Substitution reaction. ❶** **Chloroalkane $\xrightarrow{NH_3}$ Amine** **Substitution reaction. ❶**

a. & b. The molecular ion at 74 indicates the relative molecular mass of the carboxylic acid, which therefore must have 4 C atoms.

c. & d. If you are unsure about the semi-structural formula draw out the full structure first. When asked for absorption bands, state the actual bands not just the bond.

e. & f. When in doubt refer to the Data Book, Table 10.

g. & h. There are 6 C atoms in the longest chain – hence hexane. Carbon-1 is the one with the –NH₂ group. There are two –CH₃ groups attached to Carbon-4.
Amines can be prepared from chloroalkanes by reaction with ammonia.

Question 4
a. i.   60 ❶.
         Deduced the highest m/e value on the spectrum.
     ii. -OH, hydroxy group ❶ in an alcohol.
         Deduced from the broad absorption band on the IR spectrum at around 3300 cm^{-1}.
     iii. Three ❶ different hydrogen environments.
         Deduced from sets of peaks at three distinct chemical shifts on the NMR spectrum.

b. C_3H_8O ❶ NB Molecular formula was required.
    A simple check of common alcohols will identify the one with $M_r = 60$
    Methanol, CH_3OH, $M_r = 32$
    Ethanol, C_2H_5OH, $M_r = 46$
    Propanol, C_3H_7OH, $M_r = 60$

c.
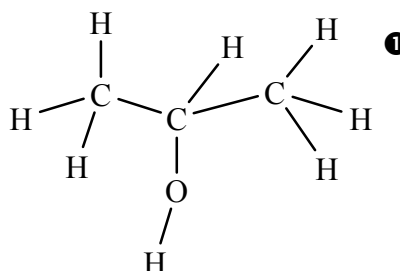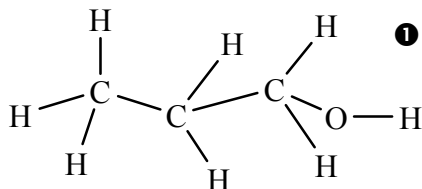
d. The first structure – $CH_3CH_2CH_2OH$ – has four different hydrogen environments and
    would be expected to show four distinct sets of peaks on its ^1H NMR spectrum. ❶
    The second structure – $CH_3CHOHCH_3$ – has three different hydrogen environments (all
    6 H on the two CH_3 are equivalent) and would be expected to show three distinct sets of
    peaks on its ^1H NMR spectrum. ❶

e. 2-propanol ❶

f. i.   The peak at $m/e = 45$ on the mass spectrum is due to the species CH_3CHOH^+,
         formed by the loss of a CH_3 during fragmentation. ❶
         Since CH_3 has a relative mass of 15, a species with an m/e ratio 15 less than the
         molecule ion is identified by taking CH_3 off the molecule ion.
     ii. On the $CH_3CHOHCH_3$ molecule, the H on the carbon atom on CHOH has a total of
         6 equivalent neighbouring H atoms – 3 on each of the two CH_3. Hence its signal on
         the ^1H NMR spectrum is split into 6+1 = 7 smaller signals, i.e. a septet. ❶

Question 5
a. i.   Both ATP and DNA nucleotides contain 'nitrogen' bases. ATP contains adenine
         (identified from Data Book) and many DNA nucleotides also contain adenine. ❶
     ii. ATP has three 'phosphate' groups but each DNA nucleotide has only one
         'phosphate' group. ❶
         DNA nucleotides contain deoxyribose which has one less oxygen than the sugar in
         ATP nucleotides. ❶ The sugar in ATP is ribose.

b.   The primary structure of DNA is the sequence of nitrogen bases in a single strand, the order of nitrogen bases along the sugar-phosphate backbone. ❶

c.   Hydrogen bonding. ❶ Hydrogen bonding between guanine and cytosine, and between adenine and thymine maintains the double helix structure of DNA.

d.   The distance between the strands in the DNA double helix is constant throughout the molecule. Since adenine and guanine are bulkier than cytosine and thymine, this constant distance can only be maintained though A-T and G-C complementary pairs. ❶

Question 6
a.   Cysteine has –CH$_2$SH as its side chain. SH (thiol) groups at different sites in the protein can react together to from disulfide links ❶, each of which is a covalent bond between two S atoms.
-SH + HS- → -S–S-

b.   When the three amino acids react to form the tripeptide, two peptide links, –CONH–, are formed in the reaction between the –COOH group one amino acid and the –NH$_2$ group on an adjacent amino acid. Water is condensed out at each peptide link. ❶
Hence the relative molecular mass of the peptide is 2 x M_r(H$_2$O) less than the sum of the relative molecular masses of the three amino acids .

c.   Ethanol, CH$_3$CH$_2$OH, is soluble in water, because the polar –OH groups hydrogen bond with water molecules. ❶
Ethanol is soluble in petrol because the CH$_3$CH$_2$- end of the molecule is non-polar and dissolves in octane via dispersion force attraction. ❶

d.   The polymerase chain reaction is used to replicate DNA fragments. This means that forensic scientists can work with very small samples of DNA ❶ such as might be extracted from a blood spot at a crime scene.

e.   Different enzymes have different active sites. The active site on each enzyme is structured to permit access to specific molecules, which have a shape and functional groups complementary to structure of the active site. ❶ Whilst fats (lipids) can access the active sites of lipases, proteins cannot.

f. R_f values and retention times both depend on attraction to the stationary phase. The less strongly a component of a mixture being separated by chromatography is attracted to the stationary phase the faster it moves up a thin layer or through a column. ❶
R_F values are determined from the distance moved up the thin layer by the component compared to the distance moved by the solvent front, so weak attraction to the stationary phase gives a high R_F value. Retention time is simply the time the component takes to pass through the column, so weak attraction to the stationary phase gives a low retention time. ❶

End of Suggested Answers