Learning Materials
by Lisachem

VCE CHEMISTRY 2011

YEAR 12 TRIAL EXAM UNIT 3

Time allowed: 90 minutes
Total marks: 86

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*

Learning Materials *by Lisachem*
PO Box 2018, Hampton East, Victoria, 3188
Ph: (03) 9598 4564 Fax: (03) 8677 1725
Email: orders@learningmaterials.com.au or orders@lisachem.com.au
Website: www.learningmaterials.com.au

Student Name....……………………………..

VCE Chemistry 2011 Year 12 Trial Exam Unit 3

Student Answer Sheet
There are 20 Multiple Choice questions to be answered by circling the correct letter in the table below. Use only a 2B pencil. If you make a mistake, erase and enter the correct answer. Marks will not be deducted for incorrect answers.

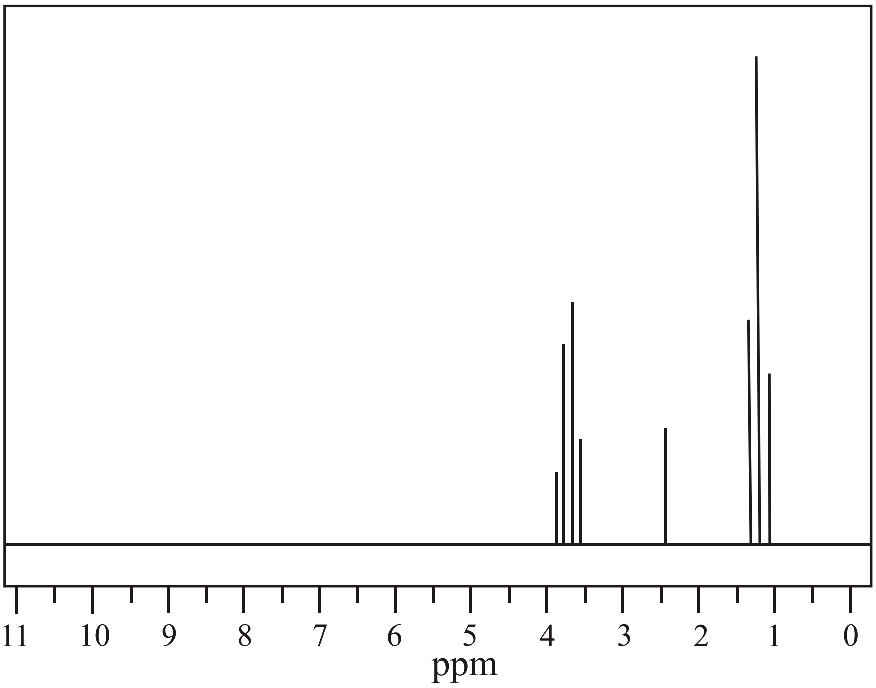
Question 1	A	B	C	D	*Question 2*	A	B	C	D
Question 3	A	B	C	D	*Question 4*	A	B	C	D
Question 5	A	B	C	D	*Question 6*	A	B	C	D
Question 7	A	B	C	D	*Question 8*	A	B	C	D
Question 9	A	B	C	D	*Question 10*	A	B	C	D
Question 11	A	B	C	D	*Question 12*	A	B	C	D
Question 13	A	B	C	D	*Question 14*	A	B	C	D
Question 15	A	B	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 2011 Year 12 Trial Exam Unit 3

SECTION A – Multiple Choice Questions

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

Question 1
The diagram shown below is a representation of a spectrum obtained during the analysis of a chemical compound.



The spectrum is a
A. ^{13}C NMR spectrum of propane.
B. ^{1}H NMR spectrum of ethanol
C. ^{1}H NMR spectrum of ethyl ethanoate
D. ^{13}C NMR spectrum of propanoic acid

Question 2
Three key processes occurring in a mass spectrometer are acceleration in an electric field, deflection in a magnetic field, and ionisation in a beam of electrons. Which one of the alternatives below gives the correct order of these processes in a mass spectrometer?

A.	ionisation	deflection	acceleration
B.	ionisation	acceleration	deflection
C.	acceleration	ionisation	deflection
D.	deflection	acceleration	ionisation

Question 3

How many **structural** isomers exist with the molecular formula $C_3H_5Br_3$?

A. 3

B. 4

C. 5

D. 6

Question 4

Propene is converted to 2-propanol in a two stage process.

Propene → X → 2-propanol.

What is the formula of compound X?

A. $CH_3CHClCH_3$

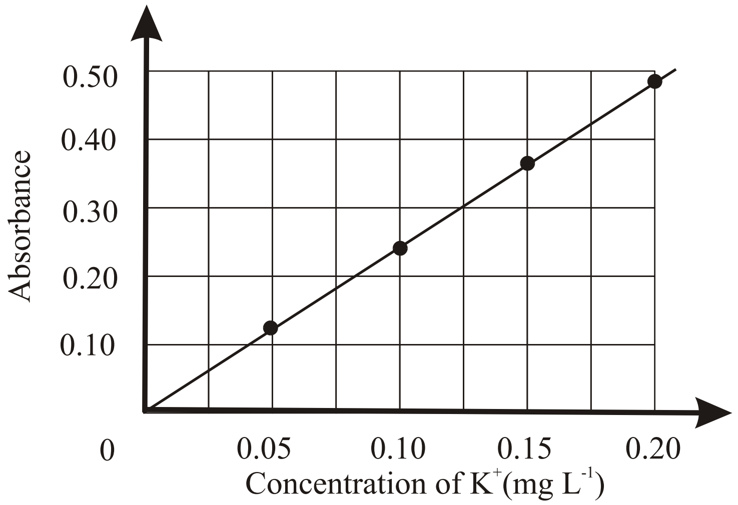
B. $CH_3CH_2CH_3$

C. $CH_3CHOHCH_3$

D. $CH_3CH_2CH_2Cl$

Question 5

The potassium content of a banana was determined using Atomic Absorption Spectroscopy. Firstly a set of standard solutions of potassium were prepared and used to establish a calibration curve.



0.20 g of banana was treated with nitric acid and the resulting solution made up to 200 mL. Then 5.00 mL of this solution was diluted to 250 mL. The absorbance of the final solution was then determined to be 0.18

The concentration of potassium in the banana, in mg per 100 g was closest to

A. 0.08

B. 38

C. 75

D. 380

Question 6

Which of the alternatives below shows the semi-structural formula of the product of the reaction between but-2-ene and iodine?

A. $CH_3CH_2CH_2CH_2I$
B. $CH_3CHICHICH_3$
C. $CH_3CH_2CHICH_3$
D. $CH_2ICH_2CH_2CH_2I$

Question 7

Spectroscopic analysis of an organic compound which has the empirical formula, C_2H_4O, has a major peak centred at 1715 cm^{-1} and a short narrow peak centred at 3100cm^{-1} in its infrared spectrum. Its mass spectrum shows a fragment peak at $m/e^{-} = 29$. On its ^1H NMR spectrum there is a peak at $\delta = 4.1$ ppm.

The semi-structural formula of the compound is most likely to be

A. CH_3CHO
B. CH_3COOH
C. $CH_3COOCH_2CH_3$
D. $CH_3CH_2CH_2COOH$

Question 8

The boiling temperatures of methanol and propanoic acid are 65°C and 141°C respectively. When reacted together two products are formed, one of which has a boiling temperature of 80°C.

Simple distillation of a mixture containing both reactants and both products produces four pure liquids which are collected in separate beakers, labelled 1, 2, 3 and 4 in order of collection.

The products of the reaction would be in

A. Beakers 1 and 2.
B. Beakers 2 and 3.
C. Beakers 2 and 4.
D. Beakers 3 and 4.

Question 9

A sample of impure limestone contains 30 per cent, by mass, calcium. All the calcium in the sample is present as calcium carbonate.

The percentage, by mass, of calcium carbonate in the sample would be closest to

A. 30
B. 40
C. 70
D. 75

Question 10

Citric acid, $C_6H_8O_7$, the main acid in lemon juice, is a triprotic acid.
When 20.0 mL aliquots of lemon juice were fully titrated with 0.350 M NaOH, the volume of the average titre was 37.09 mL.
What was the concentration, in g L^{-1}, of citric acid in the lemon juice?

A. 0.831
B. 2.50
C. 41.5
D. 374

Question 11

When the iron ore, haematite, $Fe_2O_3(s)$, is heated with coke, a form of carbon, it is reduced to iron according to the equation

$$Fe_2O_3(s) + 3C(s) \rightarrow 3CO(g) + 2Fe(s)$$

The maximum mass of Fe(s) that can be obtained when 640 g of haematite (s) is heated with 130 g of coke is closest to

A. 224 g
B. 404 g
C. 448 g
D. 679 g

Question 12

What is the concentration, in mol L^{-1}, of $I^-(aq)$ in a solution that is 5.00% KI, by mass, if the solution has a density of 1.038 g mL^{-1}?

A. 0.0301
B. 0.0313
C. 0.313
D. 0.625

Question 13

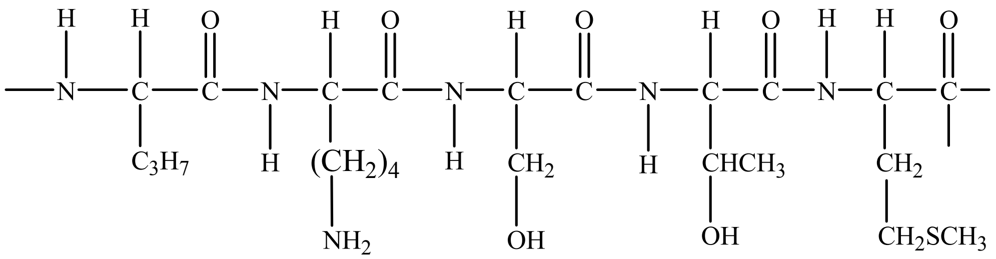
An unbalanced equation for a redox reaction is shown below

$$\_\_Cr_2O_7^{2-}(aq) + \_\_HNO_2(aq) + \_\_H^+(aq) \rightarrow \_\_Cr^{3+}(aq) + \_\_NO_3^-(aq) + \_\_H_2O(l)$$

When this equation is balanced, with all species coefficients in the lowest whole number ratio, the coefficient for H_2O is

A. 1
B. 4
C. 5
D. 7

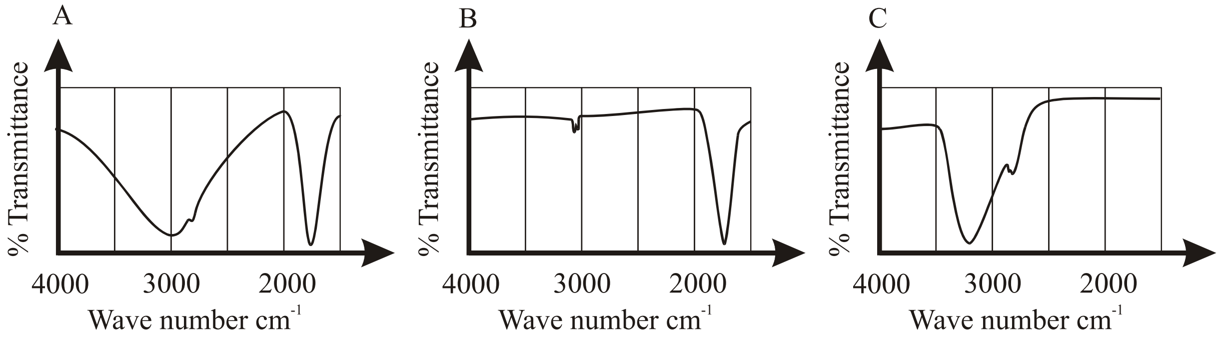
Question 14
Part of the primary structure of a section of a protein chain is represented below.



Which of the amino acids listed below would not be produced when this section of protein undergoes hydrolysis?

A. Leucine.
B. Threonine.
C. Methionine.
D. Serine.

Question 15
For a practical investigation of an organic reaction pathway starting from ethene, A, B and C show sections of three IR spectra associated with compounds produced during the investigation

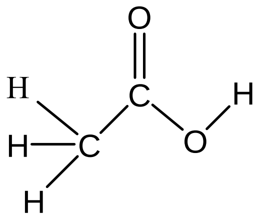


Which of the alternatives below best represents the order in which these compounds would be produced in the pathway?

A. A then B then C
B. C then A then B
C. B then C then A
D. A then C then B

Question 16
Aspirin is produced by reaction between salicylic acid and ethanoic (acetic) anhydride. The structures of these of these reactants are

A.



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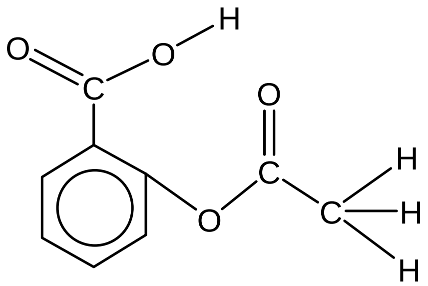
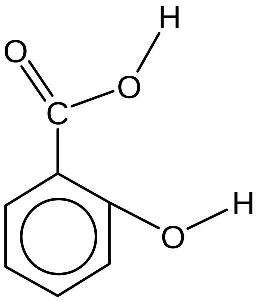


B.



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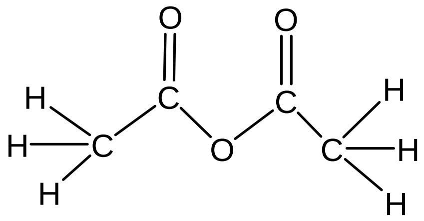
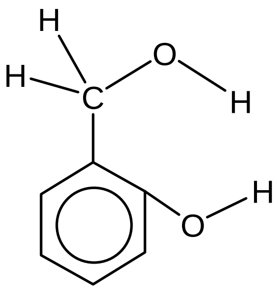


C.



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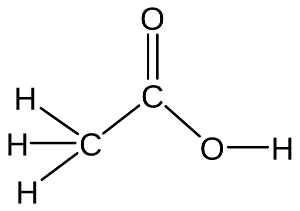
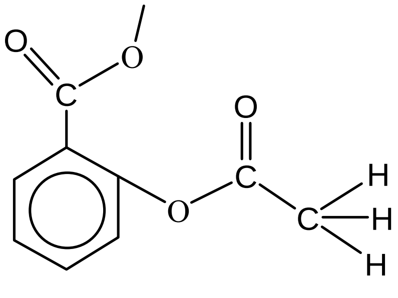


D.



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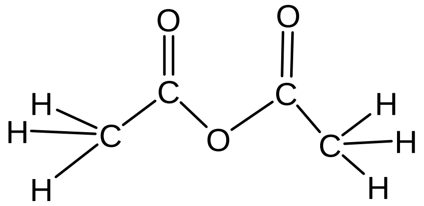
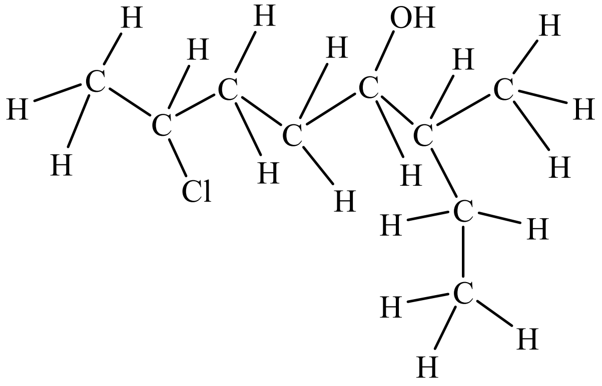
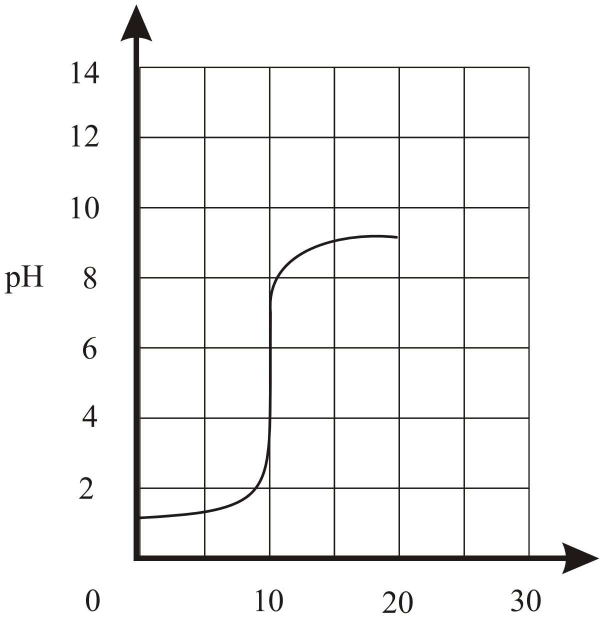


Question 17
What is the correct systematic name of the compound which has the molecular structure represented below?



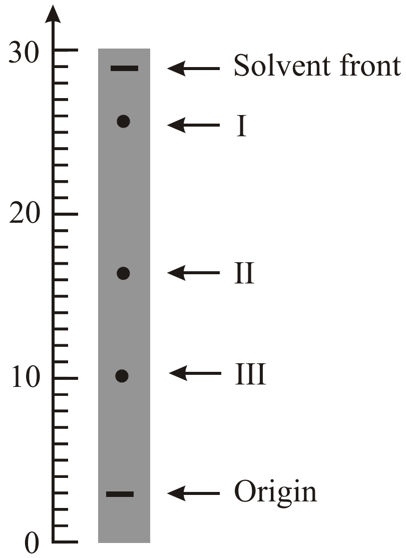
A. 2-chloro-6-methyl-5-octanol.
B. 6-chloro-2-ethyl-3-heptanol.
C. 2-chloro-6-ethyl-5-heptanol.
D. 7-chloro-3-methyl-4-octanol.

Question 18
The following titration curve was obtained by measuring the pH during an acid-base titration.



This titration curve best represents the titration of
A. 10 mL of 0.1 M CH_3COOH(aq) with 0.1 M KOH(aq) using phenol red indicator.
B. 10 mL of 0.1 M HCl(aq) with 0.1 M NaOH(aq) using bromophenol blue indicator.
C. 10 mL of 0.1 M HNO_3(aq) with 0.1 M NH_3(aq) using methyl red indicator.
D. 10 mL of 0.1 M H_2SO_4(aq) with 0.1 M NH_3(aq) using phenolphthalein indicator.

Question 19
During a Thin Layer Chromatography investigation of a substance, using a non-polar stationary phase, it separated into three different components, I, II and III, and the following chromatogram was produced.



Which of the following alternatives is consistent with this information?

A. The R_F value of component **II** is 0.54
B. The molecules of component **I** are larger than the molecules of component **II**.
C. The R_F value of component **I** is 0.87
D. The molecules of component **III** are more strongly attracted to the mobile phase than those of component **I**.

Question 20
A confectionary producer uses 100 tonnes of sucrose, $C_{12}H_{22}O_{11}$, each year in the production of one of its chocolates. If 50 million of these chocolates are produced each year how many sucrose molecules, on average, are present in each chocolate?

A. $2.9\text{x}10^6$
B. $3.5\text{x}10^{15}$
C. $3.5\text{x}10^{18}$
D. $3.5\text{x}10^{21}$

End of Section A

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SECTION B – Short Answer Section

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

Question 1

Potassium permanganate, $KMnO_4$, is a versatile chemical which, because of its mild antibacterial disinfectant properties, is used, often under the name Condy's crystals, in the treatment of some skin diseases and fungal infections such as athlete's foot. Dilute solutions of Condy's crystals are also used to wash fruit and vegetables to help remove pesticide residues and harmful bacteria.

The concentration of a dilute aqueous solution of potassium permanganate was determined by using it to titrate an aqueous solution of the primary standard sodium oxalate, $Na_2C_2O_4$.

0.2734 g $Na_2C_2O_4$ was dissolved in water in a 500.0 mL volumetric flask, the solution was acidified with sulfuric acid and made up to the calibration mark.

20.00 mL aliquots were then titrated with the potassium permanganate solution. The equation for the reaction occurring during the titration was

$$5C_2O_4^{2-}(aq) + 2MnO_4^{-}(aq) + 16H^{+}(aq) \rightarrow 2Mn^{2+}(aq) + 10CO_2(g) + 8H_2O(l)$$

Four titrations were carried out and the volumes of potassium permanganate used were recorded in the table below.

Titration Number	Volume of $KMnO_4$(aq) - mL
1	17.98
2	18.32
3	18.07
4	18.16

a. Explain why the reaction occurring during the titration is a redox reaction, and identify the oxidant and the reductant.

(3 marks)

b. Write the oxidation half-equation for the reaction.

(1 mark)

c. Calculate the average volume, in mL, of the concordant titres of potassium permanganate solution.

(1 mark)

d. Calculate the amount, in mol, of $MnO_4^-(aq)$ ions in the average titre of potassium permanganate solution.

(3 marks)

e. Calculate the concentration of the potassium permanganate solution as a % (m/V).

(2 marks)

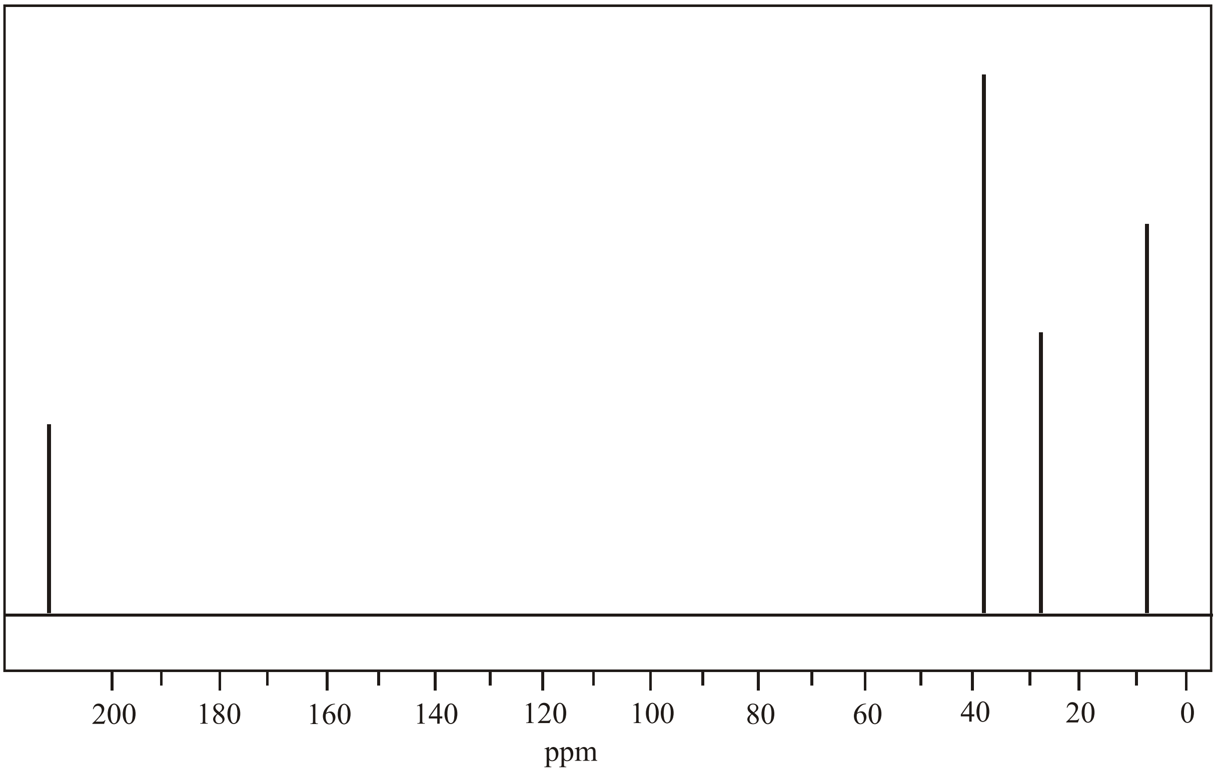
f. A key property of a primary standard is that it must have a 'known chemical formula'. Some compounds are not used as primary standards because their chemical composition becomes uncertain when they are exposed to the atmosphere.
Give the name of one such substance and two reasons why its chemical composition changes on exposure to the atmosphere.

(2 marks)

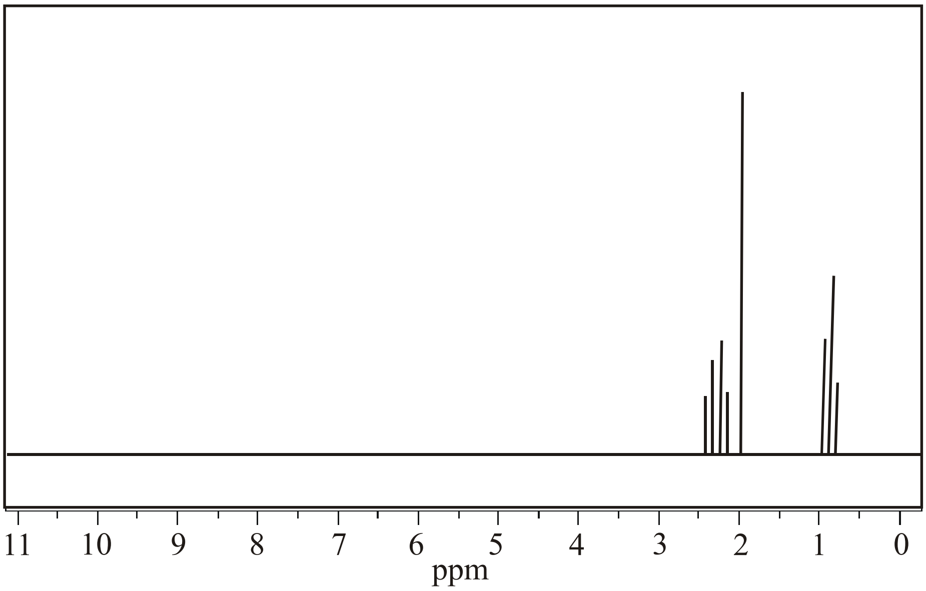
Total 12 marks

Question 2
The structure of a compound containing carbon, hydrogen and oxygen was identified using information gleaned from a number of spectra. These spectra, numbered 1, 2, 3 and 4, are represented below

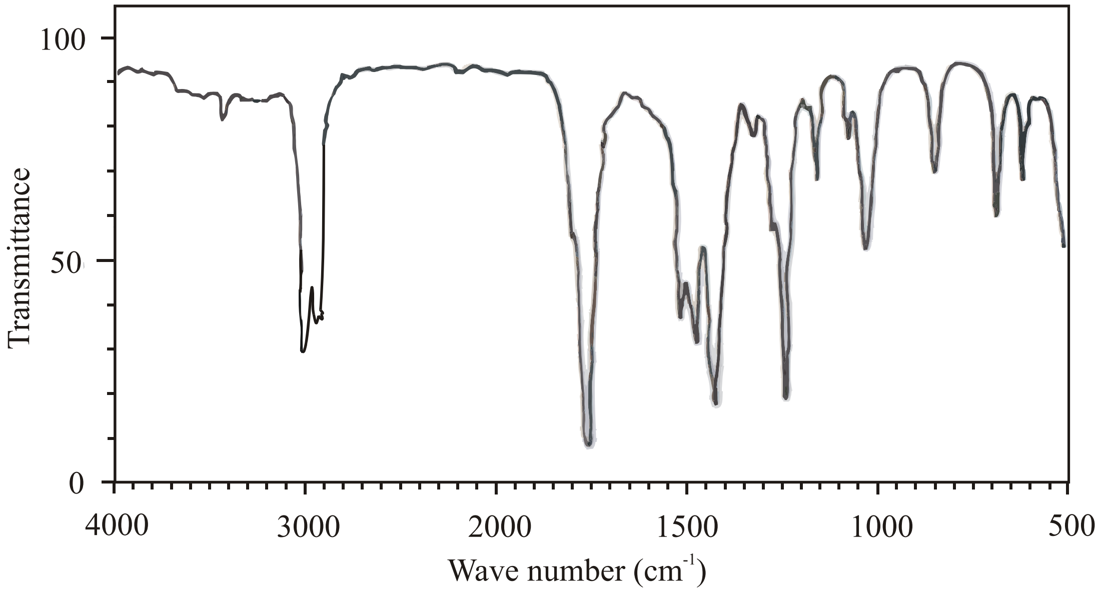
Spectrum **1**



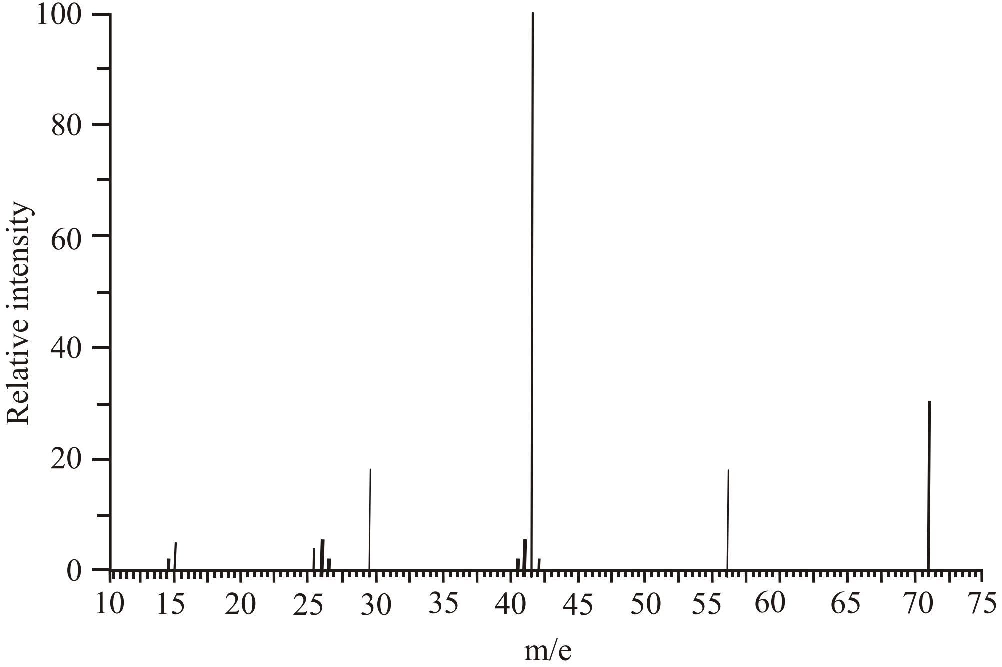
Spectrum **2**



Spectrum **3**



Spectrum **4**



a. Give the name of the 'type' of each spectrum.

Spectrum **1**

Spectrum **2**

Spectrum **3**

Spectrum **4**

(4 x ½ = 2 marks)

b. What can be deduced about the structure of the compound from Spectrum **1?**

(1 mark)

c. From Spectrum **2** it can be deduced that a specific alkyl group is present in molecules of the compound.
Give the name of this alkyl group and explain how the information on the spectrum allows for it to be identified.

(2 marks)

d. Spectrum **3** provides information about the bonding of oxygen in molecules of the compound. What does it indicate about how oxygen is bonded and what is it about the spectrum that enables you to deduce that?

(2 marks)

e. What is the relative molecular mass of the compound?

(1 mark)

f. i. Give the full structural formula of the compound showing all bonds.

(2 marks)

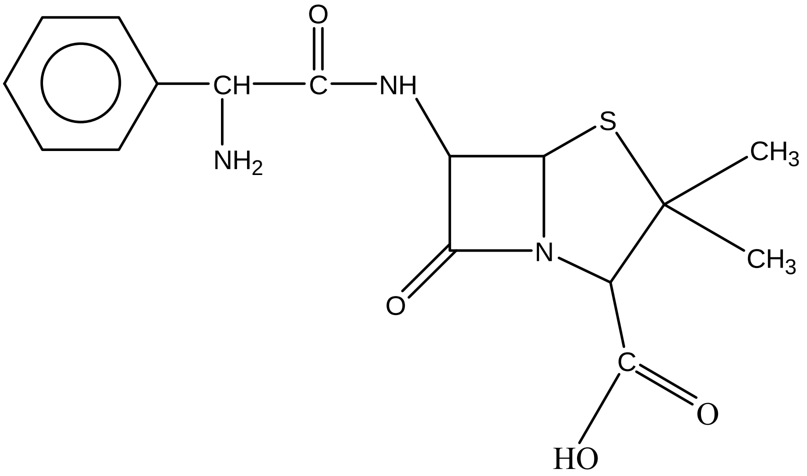
ii. Give the chemical formula of the species causing the peak at *m*/*e* = 43 on Spectrum **4**.

(1 mark)

Total 11 marks

Question 3

Penicillins are antibiotics that kill bacteria by destroying the cell wall of the microorganism. It does this by inactivating an enzyme, transpeptidase, necessary for the cross linking of bacterial cell walls. The chemical structure of ampicillin, a type of penicillin antibiotic, is shown below



a. Identify three functional groups present in molecules of ampicillin by (i) highlighting each one on the structure, and (ii) writing the name of each highlighted group.

(3 x 1 = 3 marks)

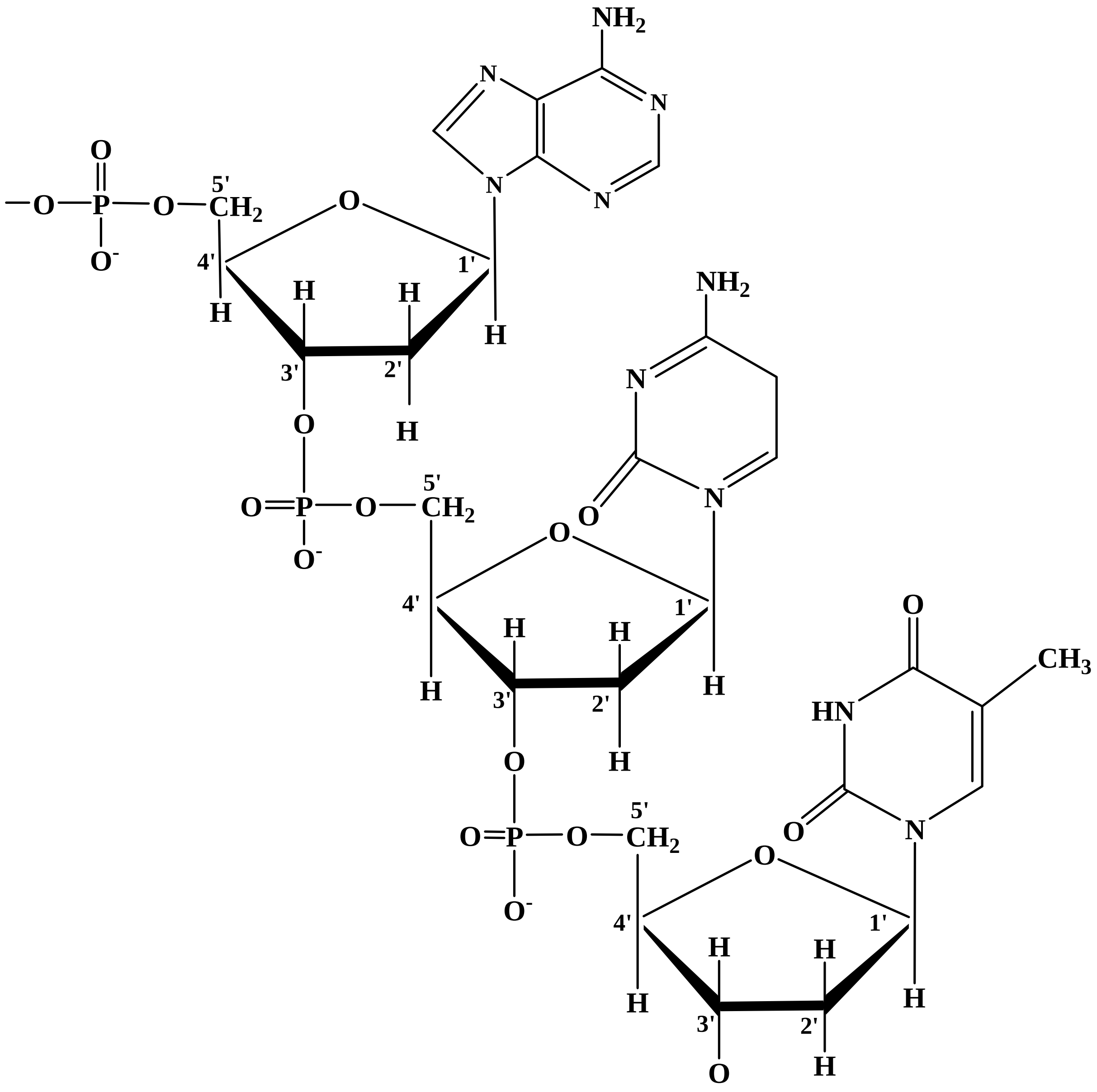
b. i. Draw the structure of the dipeptide **gly**cyl**cys**teine at pH 3.

(2 marks)

ii. What does this structure have in common with the structures of enzymes?

(1 mark)

c. A significant increase in antibiotic resistant bacteria has lead to research into new compounds that can attack bacteria by targeting their DNA. Consider the section of a strand of a nucleic acid molecule below



i. Identify a part of the nucleic acid that represents one nucleotide by circling that nucleotide.

(1 mark)

ii. Name the nitrogen bases in the sequence that identifies the primary structure of the nucleic acid.

(1 mark)

iii. Name the type of bonding that holds the secondary structure of DNA together and explain why the strength of this bonding depends on the relative numbers of the different nitrogen base pairs in the molecule.

(2 marks)

d. C-reactive protein (*CRP*) is a protein released into the bloodstream any time there is active inflammation in the body. As such it can be used to decide when antibiotic treatment can safely be discontinued in some medical treatments. What is the general name used to describe proteins such as CRP?

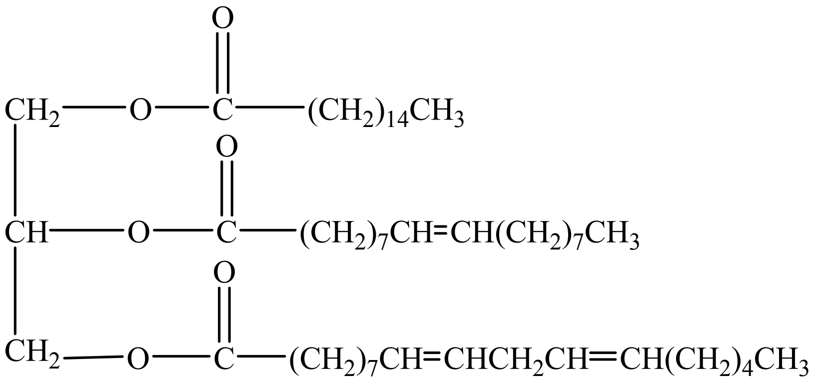
(1 mark)

Total 11 marks

Question 4

On November 22, 2010, Brazil's TAM Airlines conducted a Jatropha based biofuel test flight using one of the airline's CFM56 powered Airbus A320s. The 45 minute flight used a 50:50 Jatropha based biofuel and regular jet fuel blend. The biofuel was produced from oil extracted from the seeds of Jatropha plants.

a. Analysis of an oil sample extracted from Jatropha seeds identified the presence of molecules with the semi-structural formula given below.



i. Name the three fatty acids that would be released during the hydrolysis of these molecules.

(3 marks)

ii. Biodiesel produced from this Jatropha oil contains the methyl ester of the saturated fatty acid. Write a balanced equation for the production of this ester.

(2 marks)

b. 'Regular jet fuel' contains a mixture of hydrocarbons containing between 6 and 16 carbon atoms per molecule. One of those is the 12 C saturated hydrocarbon dodecane. Jet fuel can be collected during fractional distillation of crude oil.

i. Write a balanced equation for the combustion of dodecane.

(2 marks)

ii. During fractional distillation of crude oil, the fraction associated with jet fuel is collection at around 180°C whereas the fraction associated with petrol is collected at around 80°C.
What does that suggest about the composition of petrol compared to jet fuel and why can these different fractions be collected at different temperatures in the fractionating column?

(3 marks)

c. E20 motor vehicle fuel is a blend of bioethanol and petrol containing 20 % ethanol. Alcoholic beverages are aqueous solutions containing various percentages of ethanol.

i. Bioethanol and ethanol in alcoholic beverages are both produced in the chemical reaction represented by the equation below

$$C_6H_{12}O_6(aq) \rightarrow 2\ C_2H_6O(aq) + 2CO_2(g)$$

What is the name of this reaction?

(1 mark)

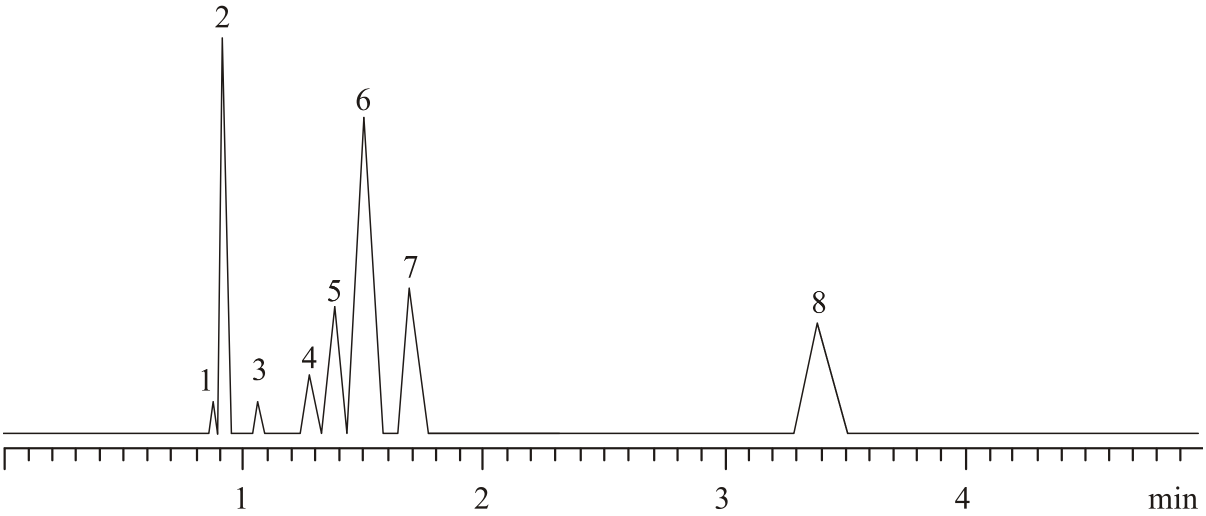
ii. Explain why ethanol dissolves in both petrol and water.

(3 marks)

Total 14 marks

Question 5

The chromatogram represented below was produced during a Gas Chromatography blood alcohol analysis.



The most commonly measured blood alcohol compound is **ethanol – peak 3**.
However, there are other compounds that could be present in the bloodstream that may interfere with the identification or quantification of ethanol.
A small amount of **methanol – peak 1** may be present in alcohol beverages.
Ethanol in the body is oxidised to **ethanal**, **CH_3CHO – peak 2.**
2-propanol – peak 4 is present in soft drinks
Propanone (CH_3COCH_3) – peak 5 is present in cosmetics and foodstuffs and is produced when the body uses fat rather than glucose (glycogen) as an energy source
2-methyl-2-propanol – peak 6, **1-propanol – peak 7**, and **2-butanol – peak 8** are also ingredients in some consumer products.

a. How can you tell from the chromatogram which alcohol was most strongly attracted to the stationary phase as the sample was run through the chromatograph?

(1 mark)

b. On the basis of the information given in the chromatogram, what is the advantage in using gas chromatography to determine the amount of ethanol in a blood sample?

(1 mark)

c. Other than the information obtained from the chromatograph shown, what other information is needed to calculate the actual amount of ethanol in the blood sample?

(1 mark)

d. Propanone is the product of the oxidation of 2-propanol. Write a half-equation for this reaction.

(1 mark)

e. Two of the molecules causing peaks in the chromatogram are structural isomers and they also have two other additional isomers with the same functional group. Draw the structures, showing all bonds, of the other two isomers and name each one.

(3 marks)

f. Two of the compounds causing peaks on the chromatogram can be used to produce, via at least one intermediate reaction, an ester with four carbon atoms in each molecule and which produces 3 peaks on its ^{13}C NMR spectrum.

i. Identify the two compounds.

(2 marks)

ii. Give the name and semi-structural formula of the ester produced.

(1 mark)

Total 10 marks

Question 6

Glyceryl trinitrate, more commonly known as nitroglycerin, is a compound of carbon, hydrogen, nitrogen and oxygen.

Its molar mass is 227 g mol^{-1}.

In an analysis of nitroglycerin, it was recorded that a 1.7321 g sample contains 0.2747 g of carbon, 0.3205 g of nitrogen and 1.0988 g of oxygen.

a. Use the data recorded in the analysis to determine

  i. the mass of hydrogen in the analysed sample

(1 mark)

  ii. the empirical formula of glyceryl trinitrate

(3 marks)

  iii. the molecular formula of glyceryl trinitrate

(1 mark)

b. Glyceryl trinitrate is an unstable compound which, when exposed to a shock, undergoes explosive decomposition to produce carbon dioxide, nitrogen, water vapour and oxygen according to the equation

$$\mathbf{4}\text{Glyceryl trinitrate} \rightarrow \mathbf{12}CO_2(g) + \mathbf{10}H_2O(g) + \mathbf{6}N_2(g) + O_2(g)$$

A 50.1 g sample of glyceryl trinitrate decomposes explosively in a confined space of 800 mL.
If a temperature of 227 °C is generated, calculate the pressure in MPa, that results from the explosion.

(3 marks)

Total 8 marks

End of Section B

End of Trial Exam

Suggested Answers

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SECTION A – Multiple Choice Answers

Q1 B Because the spectrum shows peak splitting it is a **high resolution ^{1}H NMR spectrum**. Three different peaks indicate that there are three different hydrogen environments.

Ethanol, CH_3CH_2OH, and ethyl ethanoate, $CH_3COOCH_2CH_3$, both have three different hydrogen environments and both produce a quartet (q), a triplet (t) and a singlet (s) on the respective ^{1}H NMR spectra.

CH_3CH_2OH $CH_3COOCH_2CH_3$
↓ ↓ ↓ ↓ ↓ ↓
t q s **s q t**

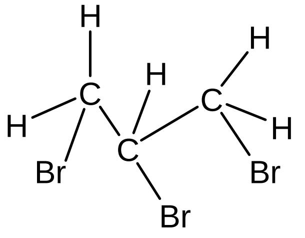
The **peak area ratio q : t : s** should be **2 : 3 : 1** for **CH_3CH_2OH** but **2 : 3 : 3** for **$CH_3COOCH_2CH_3$**. Hence the **small peak area for the singlet** suggests that the spectrum is that of **ethanol**.

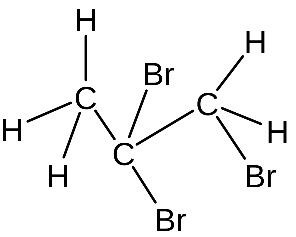
That the spectrum is **not** that of $CH_3COOCH_2CH_3$ is also supported by chemical shift data, δ(s) = 2.6, δ(q) = 3.7, δ(t) = 1.3.

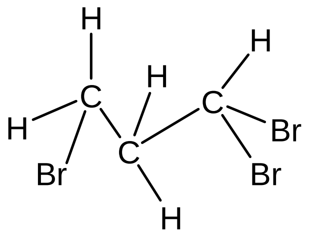
Q2 B The process of mass spectroscopy involves the following sequence:

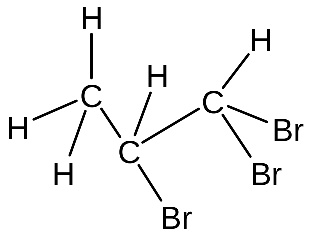
1. A gaseous sample is injected into a mass spectrometer.
2. Individual molecules / atoms assume a positive charge as they pass through the **ionising source** - an electron is knocked off each particle by a high speed electron beam.
3. The positive ions are **accelerated** through an electric field.
4. The ions are separated in a magnetic field where they follow curved paths as they are **deflected,** the extent of which depends on their mass to charge (m/e) ratios.

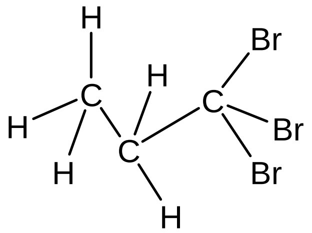
Q3 C


1,2,3-tribromopropane


1,2,2-tribromopropane


1,1,3-tribromopropane


1,1,2-tribromopropane


1,1,1- tribromopropane

Q4 A Since alcohols can be produced from chloroalkanes, the first step is the conversion of propene into **2-chloropropane** by an addition reaction with HCl and second step is the conversion of 2-chloropropane to 2-propanol by a substitution reaction with OH^-

$CH_3CH{=}CH_2 + HCl \rightarrow \mathbf{CH_3CHClCH_3}$

$CH_3CHClCH_2 + OH^- \rightarrow CH_3CHOHCH_3 + Cl^-$

Pathway is $CH_3CH{=}CH_2 \rightarrow \mathbf{CH_3CHClCH_3} \rightarrow CH_3CHOHCH_3$

Q5 D According to the calibration curve, the absorbance of 0.18 indicates that the concentration of K (as K^+) in the 250 mL of diluted solution was 0.075 mg L^{-1}. To get this diluted solution 5.00 mL of the original solution (200.0 mL) containing the K from 0.20 g banana had been diluted by a factor of 50 (5 mL to 250 mL).

c(K) in original solution = 50 x 0.075
= 3.75 mg L^{-1}

m(K) in original 200 mL solution = 0.200 L x 3.75 mg L^{-1}
= 0.75 mg

All 0.75 mg K in the original 200 mL of solution came from 0.20 g of banana.

∴ *m*(K) in 100 g banana = (0.75 / 0.20) x 100
= 375 mg

c(K) in banana = **375 mg K per 100** g banana.

Hence the closest value is 380 mg K per 100 g.

Q6 B Iodine, I_2, reacts with but-2-ene, $CH_3CH{=}CHCH_3$, in an addition reaction according to

$CH_3CH{=}CHCH_3 + I_2 \rightarrow \mathbf{CH_3CHICHICH_3}$ (2,3-diiodibutane)

Q7 C According to Infrared absorption data supplied in the Data Book:

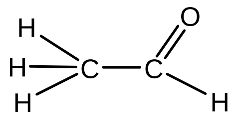
With respect to the IR spectrum data, the major peak centred at 1715 cm^{-1} is characteristic of **C=O** whilst the short narrow peak centred at 3100 cm^{-1} is characteristic of **C-H**.

The mass spectrum fragment at m/e^- = 29 could be due to $\mathbf{CH_3CH_2^+}$ or $\mathbf{COH^+}$

The ^1H NMR peak at δ = 4.1 ppm is characteristic of **H atoms bonded to a C which is bonded to the singly bonded O of an ester group**, $RCOOC\mathbf{H_2}R$

Consider the alternatives

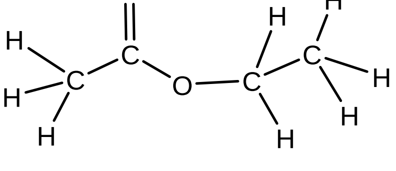
A. The only possible structure for CH_3CHO is shown



It has the empirical formula C_2H_4O.
It will produce C=O and C-H peaks on its IR spectrum.
It can produce a fragment at m/e^- = 29 (CHO^+).
It will **not** produce a ^1H NMR peak at δ = 4.1 ppm.

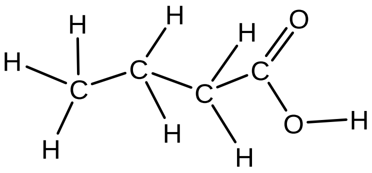
B. $CH_3COOH \rightarrow$ **empirical formula CH_2O**

C. The structure for $CH_3COOCH_2CH_3$ is shown



It has the **empirical formula C_2H_4O**.
It will produce **C=O and C-H peaks** on its IR spectrum.
It can produce a **fragment at m/e^- = 29** ($CH_3CH_2^+$).
It will produce a **^1H NMR peak at δ = 4.1 ppm** ($CH_3COOC\mathbf{H_2}CH_3$).

D. The structure for $CH_3CH_2CH_2COOH$ is shown
It has the empirical formula C_2H_4O.
It will produce C=O and C-H peaks on its IR spectrum.
It can produce a fragment at $m/e^- = 29$ ($CH_3CH_2^+$).
It will **not** produce a ^1H NMR peak at $\delta = 4.1$ ppm



Q8 B When a mixture is distilled, the components of the mixture boil off and are collected in order of increasing boiling temperature.
The reaction occurring (showing boiling temperatures) is
CH_3OH (65°C) + CH_3CH_2COOH (141°C) → **$CH_3COOCH_2CH_3$ (80°C) + H_2O (100°C)**
↓ ↓ ↓ ↓
Beaker 1 Beaker 4 **Beaker 2** **Beaker 3**

Q9 D Assume a 100 g sample of limestone
m(Ca) present = 30 g
n(Ca) present = 30 g / 40.1 g mol^{-1}
= 0.75 mol
Since the chemical formula for calcium carbonate is $CaCO_3$
$n(CaCO_3)$ in sample = 0.75 mol
$m(CaCO_3)$ in sample = 0.75 mol x 100.1 g mol^{-1}
= 75 g
75 g $CaCO_3$ in 100 g limestone →**%, by mass, $CaCO_3$ = 75 %**

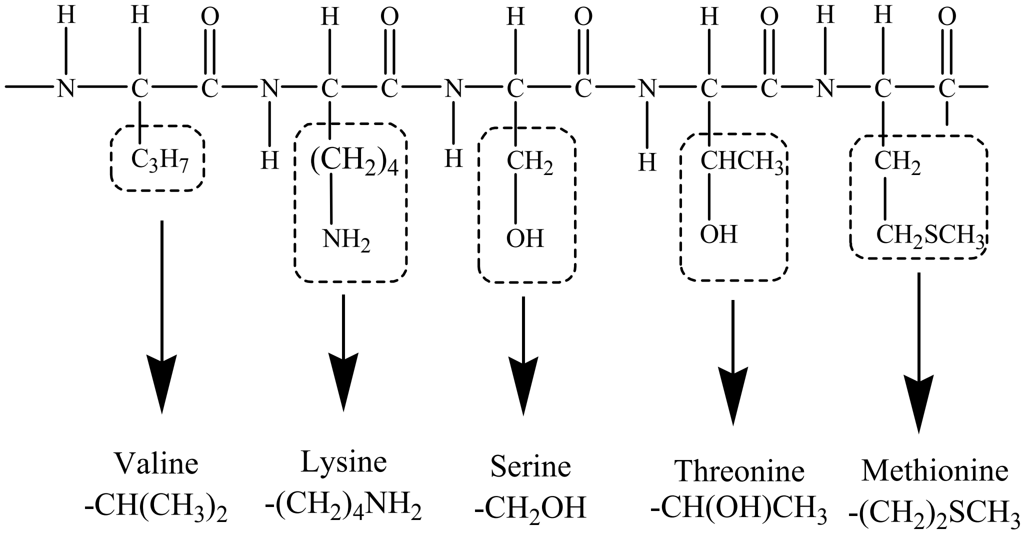
Q10 C Since citric acid is triprotic then **1 mol $C_6H_8O_7$ reacts with 3 mol NaOH**
n(NaOH) reacting = 0.350 mol L^{-1} x 37.09x10^{-3} L
= 1.30x10^{-2} mol
$n(C_6H_8O_7)$ reacting = n(NaOH) / 3
= 1.30x10^{-2} / 3
= 4.33x10^{-3} mol
$m(C_6H_8O_7)$ in 20.0 ml = 4.33x10^{-3} mol x 192.0 g mol^{-1}
= 0.831 g
$c(C_6H_8O_7)$ in g L^{-1} = (0.831 / 20.0) x 1000
= **41.5 g L^{-1}**

Q11 B $Fe_2O_3(s) + 3C(s) \rightarrow 3CO(g) + 2Fe(s)$
640 g ***130 g***
$n(Fe_2O_3)$ = 640 g / 159.8 g mol^{-1}
= 4.01 mol
n(C) = 130 g / 12.0 g mol^{-1}
= 10.8 mol
Since, according to the equation 4.01 mol Fe_2O_3 requires 3x4.01 = 12.03 mol C for complete reaction, and there is only 10.8 mol C available, then C is the limiting reactant.
n(Fe) produced = 2 x n(C) / 3
= 2 x 10.8 / 3
= 7.22 mol
m(Fe) produced = 7.22 mol x 55.9 g mol^{-1}
= **404 g**

Q12 C Since the concentration is to be in mol L^{-1}, assume a one litre solution.
V(solution) = one litre
m(solution = *d* x V
= 1.038 g mL^{-1} x 1000 mL
= 1038 g
m(KI) in solution = 5 % of 1038 g
= (5/100) x 1038
= 51.9 g
n(KI) in solution = 51.9 g / 166.0 g mol^{-1}
= 0.313 mol
Since $KI(aq) \rightarrow K^+(aq) + I^-(aq)$
$c(I^-)$ = $c(KI)$ = **0.313 mol L^{-1}**

Q13 B $\_\_Cr_2O_7^{2-}(aq) + \_\_HNO_2(aq) + \_\_H^+(aq) \rightarrow \_\_Cr^{3+}(aq) + \_\_NO_3^-(aq) + \_\_H_2O(l)$
Oxidation number changes - Cr decreased from +6 to +3 and N increased from +3 to +5 – indicate that $Cr_2O_7^{2-}(aq)$ is reduced to $Cr^{3+}(aq)$ and $HNO_2(aq)$ is oxidised to $NO_3^-(aq)$.
Write the half-equations, using the standard balancing technique of 'atoms other than O and H' followed by 'O', then 'H' and then 'electrons'.
Oxidation: $HNO_2(aq) + H_2O(l) \rightarrow NO_3^-(aq) + 3H^+(aq) + 2e^-$
Reduction: $Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$
To get the overall redox equation, the oxidation half-equation must be multiplied by 3 to equalise the electrons.
This leads to $3H_2O$ on the reactants side in oxidation which, when added to the $7H_2O$ on the products side in reduction leads to **$4H_2O$** on the products side in the overall redox equation.
The overall equation is
$Cr_2O_7^{2-}(aq) + 3HNO_2(aq) + 5H^+(aq) \rightarrow 2Cr^{3+}(aq) + 3NO_3^-(aq) + \mathbf{4H_2O}(l)$

Q14 A During hydrolysis, water reacts across the peptide groups to form amino and carboxyl groups and releases the amino acids.
So it is a matter of using the Data Book to identify the amino acids from the side-groups.



Q15 B The sections of spectra shown are from IR spectra, so it is a matter of using the absorption bands corresponding to the peaks to deduce structural information.

Spectrum A

The broad band centred near 3000 cm^{-1} is indicative of **O-H (acids).**

The peak centred near 1700 cm^{-1} is indicative of **C=O**

So A is most likely a **carboxylic acid.**

Spectrum B

The narrow shallow band centred near 3000 cm^{-1} is indicative of **C-H**, there is no evidence of O-H on this spectrum.

The peak centred near 1700 cm^{-1} is indicative of **C=O**

So B is most likely an **ester.**

Spectrum C

The broad band centred near 3300 cm^{-1} is indicative of **O-H (alcohols).**

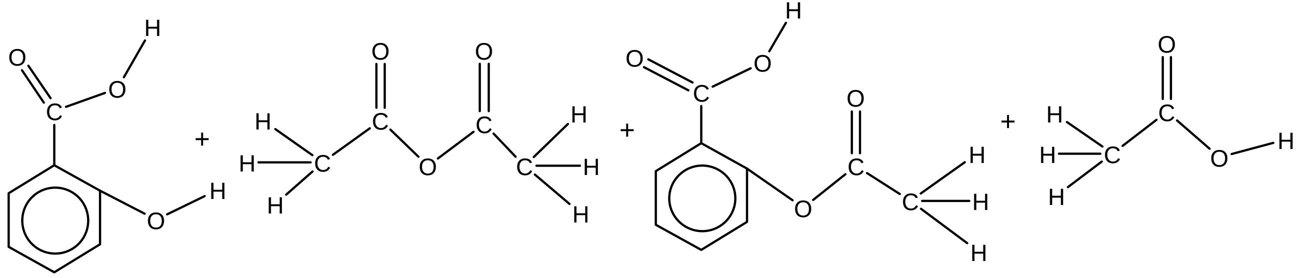
So C is most likely an **alcohol.**

Since the pathway starts with $CH_2{=}CH_2$, the logical order is **C then A then B** consistent with

$CH_2{=}CH_2 \rightarrow CH_3CH_2OH \rightarrow CH_3COOH \rightarrow CH_3COOCH_2CH_3$

The reaction types are, in order, addition, oxidation, esterification (condensation).

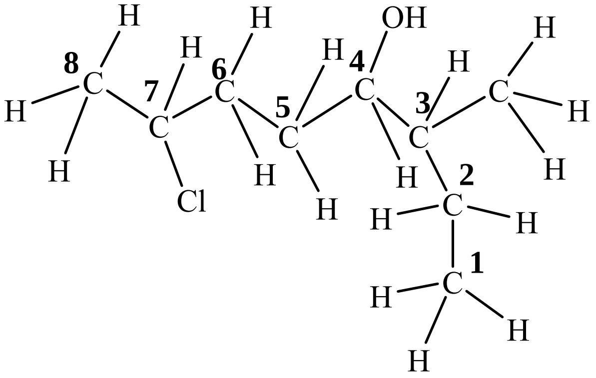
Q16 B The equation, using structural formulae for aspirin production, is



Salicylic acid **ethanoic anhydride** **aspirin** **ethanoic acid**

The other structure which appeared in alternative C was that of salicyl alcohol which is an intermediate in the production of salicylic acid from salicin.

Q17 D Since the compound is an **alcohol**, number the longest unbranched chain of C atoms from the end that will assign the lowest number to the hydroxyl (-OH) group.



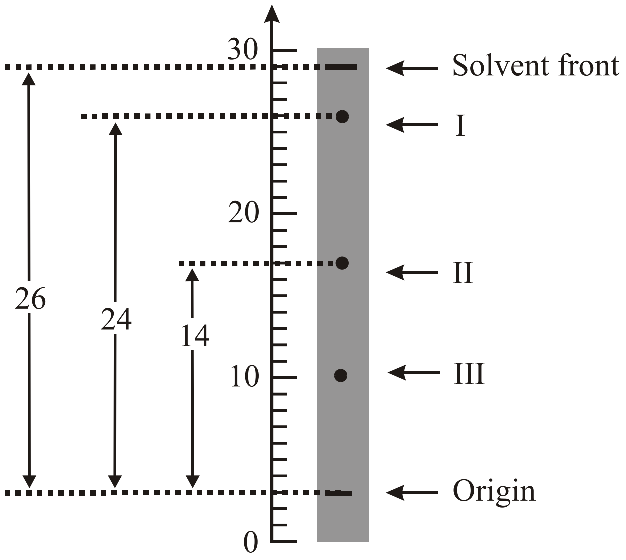
The longest unbranched chain contains 8 C atoms and the hydroxyl (-OH) group is on C-4 hence 4-octanol.

There is a methyl ($-CH_3$) substituent on C-3 and a chloro (-Cl) functional group on C-7. Since substituents are arranged alphabetically in systematic nomenclature, the systematic name of the compound is **7-chloro-3-methyl-4-octanol.**

Q18 C On the titration curve the pH at the start of the titration is 1. This is consistent with a 0.1 M solution of a strong monoprotic acid, i.e. HCl(aq) or HNO_3(aq).
The pH levels of around 9 are consistent with a solution of a weak base, suggesting that the titration was of a strong acid with a weak base. NH_3(aq) is a weak base.
The titration curve shows that the endpoint of the titration occurs between pH 4.5 and 7 and so would be most accurately picked up using methyl red (pH range 4.2-6.3).
Consider the alternatives

A. Initial pH is too low for 0.1 M CH_3COOH(aq) – a weak acid, and the pH at which the curve levels off is too low for KOH(aq) – a strong base.
B. The pH at which the curve levels off is too low for NaOH(aq) - a strong base, and the indicator would change colour before the endpoint.
C. Correct Answer
D. Because H_2SO_4(aq) is a diprotic acid, the 20 mL of 0.1 M NH_3(aq) would be required to reach the endpoint. Also phenolphthalein would change colour after the endpoint.

Q19 A Since component **I** moves the greatest distance along the chromatogram, it is less strongly attracted to the stationary phase than component **III** and would therefore be expected to have smaller molecules. Since component **III** moves the least distance along the chromatogram, its molecules are **less strongly attracted to the mobile phase** than the molecules of component **I**.



R_F = distance moved by component from origin / distance moved by solvent front from origin
$R_F(\mathbf{I})$ = 24 / 26
= 0.92
$R_F(\mathbf{II})$ = 14 / 26
= **0.54**

Q20 D $n(C_{12}H_{22}O_{11})$ = 100x10^6 g / 342.0 g mol^{-1}

= 2.92x10^5 mol
$n(C_{12}H_{22}O_{11})$ in each chocolate = 2.92x10^5 / 50x10^6
= 5.85x10^{-3} mol
$\mathbf{N(C_{12}H_{22}O_{11})}$ **in each chocolate** = 5.85x10^{-3} x 6.02x10^{23}
= **3.5x10^{21}**

SECTION B – Short Answer (Answers)

Question 1

a. The reaction is a redox reaction because there are changes in oxidation numbers during the reaction

$$5\overset{+3}{C}_2\overset{-2}{O}_4{}^{2-}(aq) + 2\overset{+7}{Mn}\overset{-2}{O}_4{}^{-}(aq) + 16H^+(aq) \rightarrow 2\overset{+2}{Mn}{}^{2+}(aq) + 10\overset{+4}{C}\overset{-2}{O}_2(g) + 8H_2O(l)$$

The **oxidation number of C increases from +3 to +4** as **$C_2O_4^{2-}$(aq) is oxidised** to CO_2(g) ❶

The **oxidation number of Mn decreases from +7 to +2** as **MnO_4^-(aq is reduced** to Mn^{2+}(aq) ❶

The **oxidant MnO_4^-(aq)** causes oxidation and is itself reduced; the **reductant $C_2O_4^{2-}$(aq)** causes reduction and is itself oxidised. ❶

b. $C_2O_4^{2-}$(aq) is oxidised to CO_2(g)

$C_2O_4^{2-}(aq) \rightarrow 2CO_2(g) + 2e^-$ ❶

c. Concordant titres are with 0.1 mL of each other, so there are three concordant titres – 17.98, 18.07 and 18.16 mL

Average titre = (17.98 + 18.07 + 18.16) / 3
= **18.07** mL ❶

d. $n(Na_2C_2O_4)$ in 500.0 mL flask = 0.2734 g / 134.0 g mol^{-1}
= 2.040 x 10^{-3} mol ❶
$n(C_2O_4^{2-})$ in 20.00 mL aliquot = (2.040x10^{-3} / 500) x 20
= 8.161x10^{-5} mol ❶
$n(MnO_4^-)$ in average titre = 2 x $n(C_2O_4^{2-})$ / 5
= 2 x 8.161x10^{-5} / 5
= **3.264x10^{-5}** mol ❶

e. Calculate the concentration of the potassium permanganate solution as a % (m/V).
$n(KMnO_4)$ in average titre = 3.264x10^{-5} mol
$m(KMnO_4)$ in average titre = 3.264x10^{-5} mol x 197.1 g mol^{-1}
= 0.06434 g ❶
% (m/V) $KMnO_4$ = $m(KMnO_4)$ / V(average titre) x 100
= (0.06434 / 18.07) x 100
= **0.03561** % ❶

f. **Sodium hydroxide** ❶

Sodium hydroxide is deliquescent, i.e. it **absorbs water from the atmosphere**.
As a base it also **reacts with atmospheric carbon dioxide** which is an acidic oxide. ❶
As a consequence of these properties A sample of NaOH left exposed to the atmosphere will contain H_2O and $NaHCO_3$.

Question 2

a. Spectrum **1.** ^{13}**C NMR** spectrum
Spectrum **2.** **High resolution ^{1}H NMR** spectrum
Spectrum **3.** **Infrared (IR)** spectrum
Spectrum **4.** **Mass** spectrum

❶❶ for all four correct, ❶ for two or three correct

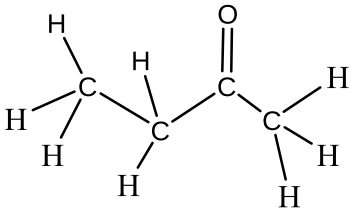
b. The molecules have **four different carbon environments**. ❶
Can also deduce the presence of CH_3 – peak at 9 ppm, and CH_2 – peak at 30 ppm

c. **Ethyl group** (CH_3CH_2) ❶
The high resolution ^{1}H NMR spectrum shows a **quartet and a triplet**. The quartet indicates that the H atoms causing that peak have **3 neighbouring equivalent H atoms** (n+1 rule). The triplet indicates that the H atoms causing that peak have **2 neighbouring equivalent H atoms.** This is characteristic of the CH_3CH_2 group. ❶

d. **O** is involved in a **double covalent bond with C**, i.e. in the **C=O** group. ❶
The **strong peak just above 1700 cm^{-1}** ❶ Table 7 in the Data Book indicates that C=O produces an absorption peak in the range 1670-1750 cm^{-1}.

e. **72** ❶
The highest *m*/*e* ratio on the mass spectrum usually corresponds to the relative molecular mass of the molecular ion.

f. i. $CH_3CH_2COCH_3$



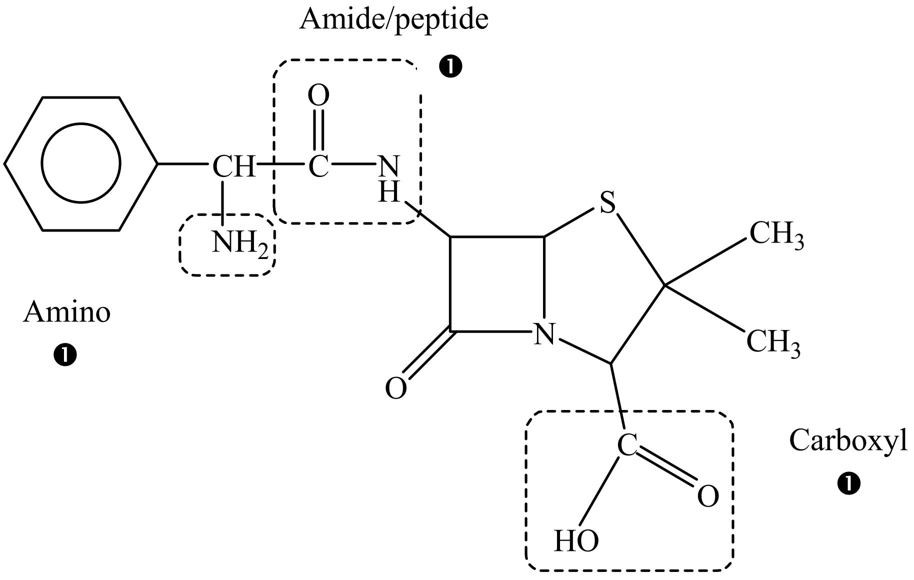
❶❶

Relative mass of **CH_3CH_2** is 29
Relative mass of **C=O** is 28
Relative molecular mass = 72
So the remainder of the molecule has a relative mass of 72 – (29+28) = 15.
Since the molecule has 4 C atoms, the rest must be a **CH_3** group.

ii. **$[CH_3CO]^+$** ❶
m/*e* of 43 is 29 less than the relative molecular mass of 72. This suggests a CH_3CH_2 has been chopped off the molecule, leaving behind the charged fragment, according to
$[CH_3CH_2COCH_3]^+ \rightarrow CH_3CH_2\bullet + [CH_3CO]^+$
In mass spectrometer only the charged species are detected and produce a peak.

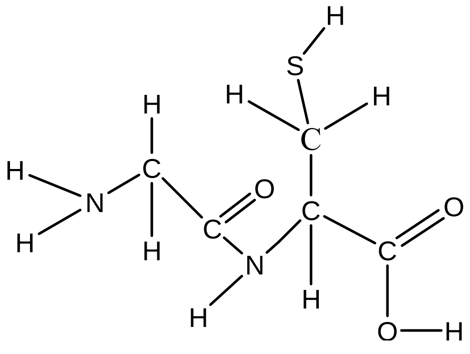
Question 3

a.

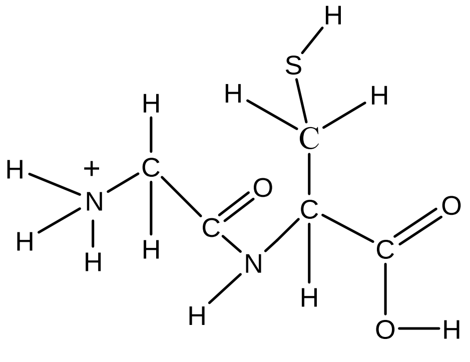


1 mark for each correct combination of highlighted functional group and name.

b. A dipeptide is formed when two amino acids react together, hence **gly**cyl**cys**teine is a dipeptide formed when the –COOH group on glycine reacts with the $–NH_2$ group on cysteine to produce a linking peptide –CONH- group.
Since the structures of glycine and cysteine are given in the Data Book, the structure of glycysteine may be determined to be

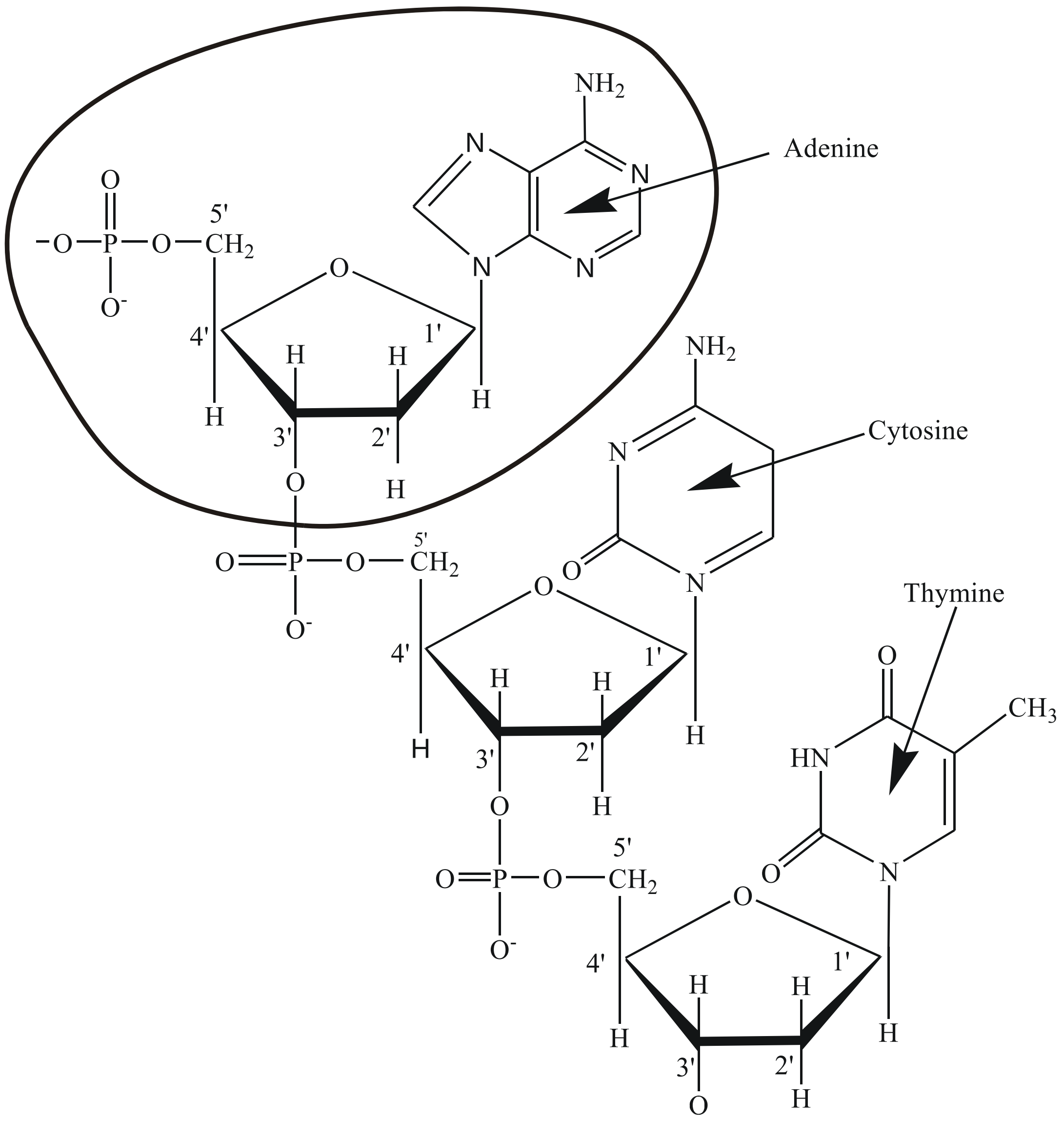


i. However at pH 3, i.e. in an acidic environment, the amino, $-NH_2$, group will be protonated so the structure at pH 3 will be



❶❶ - one mark for the correct amino acids, one mark for the correct overall structure.

ii. Since enzymes are proteins also produced from amino acids, then the **structures of enzymes and the dipeptide both contain the peptide group –CONH. ❶**



c. i. See diagram ➊

ii. Read the nitrogen base sequence from the top, using the Data Book to identify the nitrogen bases ➊

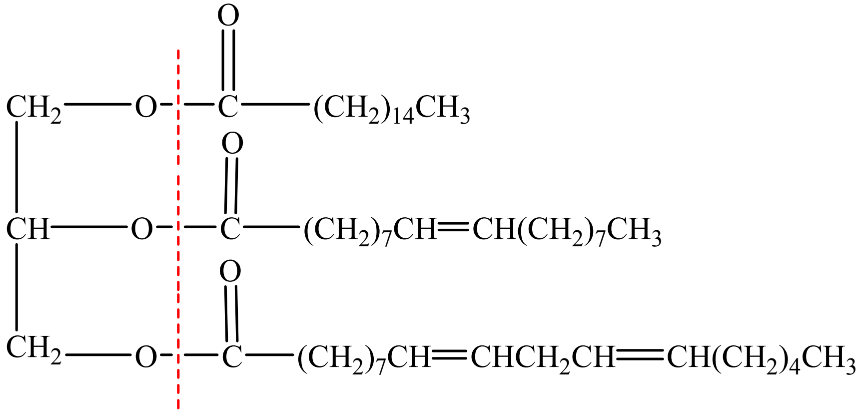
iii. **Hydrogen bonding** ➊ between complementary bases, i.e. between Guanine (G) and Cytosine(C) and between Adenine (A) and Thymine (T) on adjacent strands.

The hydrogen in the G-C base pair is stronger than the hydrogen bonding in the A-T base pair because there are **three sites on each guanine and each cytosine molecule where hydrogen bonds can occur, but only two sites on adenine and thymine molecules**. So the **higher the proportion of G-C base pairs in DNA, the stronger the hydrogen bonding in the secondary structure.** ➊

d. **Marker** proteins. ➊

Question 4

a. i. The three fatty acids can be identified be recalling that the fat was formed by reaction between one of the hydroxyl, -OH, groups on glycerol and the carboxyl, -COOH group on each of the fatty acids. With an ester group formed in each case. During hydrolysis H_2O reacts across the ester groups releasing the fatty acids and glycerol.



Hence the three fatty acids are

$CH_3(CH_2)_{14}COOH \rightarrow C_{15}H_{31}COOH$ – **palmitic acid** ❶

$CH_3(CH_2)_7CH{=}CH(CH_2)_7C\ OOH \rightarrow C_{17}H_{33}COOH$ – **oleic acid** ❶

$CH_3(CH_2)_7CH{=}CHCH_2CH{=}CH\ (CH_2)_4C\ OOH \rightarrow C_{17}H_{31}COOH$–**linoleic acid** ❶

ii. **$C_{15}H_{31}COOH(l) + CH_3OH(l) \rightarrow C_{15}H_{31}COOCH_3(l) + H_2O(l)$** ❶❶

b. i. Molecular formula of dodecane is **$C_{12}H_{26}$**

$C_{12}H_{26}(l) + 18.5O_2(g) \rightarrow 12CO_2(g) + 13H_2O(\text{g or l})$ *or*

$2C_{12}H_{26}(l) + 37O_2(g) \rightarrow 24CO_2(g) + 26H_2O(\text{g or l})$

One mark for all reactants and products correct. ❶

One mark for correct balancing and correct states. ❶

ii. In fractional distillation, the fractions with smaller molecules are collected at lower temperatures so, on average, **petrol contains smaller lower molecular mass molecules** than jet fuel. ❶

The **temperature in a fractionating tower decreases moving up the column**. ❶ As the mixture rises up the tower the **jet fuel fraction** which has larger molecule compounds with **higher boiling temperatures**, **liquefies out before the petrol fraction because the temperature drops below their boiling temperatures first**. ❶ The petrol fraction of smaller molecule compounds continues to rise until the temperature drops below their boiling temperatures.

c. i. **Fermentation** ❶

ii. Ethanol, **CH_3CH_2OH, molecules have a polar region, -OH, and a non-polar region, CH_3CH_2.** ❶

This enables **CH_3CH_2OH** to

- **dissolve in petrol via dispersion force attraction with the non-polar molecules** ❶ in petrol
- **dissolve in water via hydrogen bonding with the polar H_2O molecules** ❶

Question 5

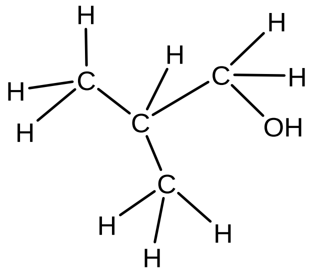
a. **2-butanol** was most strongly attracted to the stationary because it has the **largest the retention time.** ❶

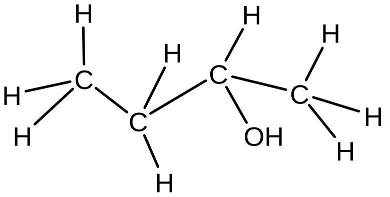
b. **Ethanol has a unique retention time.** ❶ and so the amount present can be determined without it being affected by the amounts of the other substances present.

c. To work out the amount of ethanol in an analysed sample, we need to calculate the **relationship between the area under the ethanol peak and ethanol concentration.** ❶ This can be obtained by measuring the peak area for standards of known ethanol concentration.

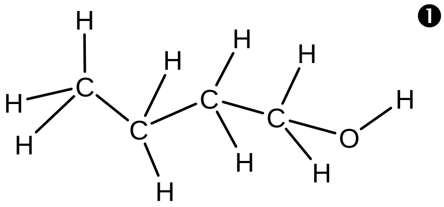
d. **$CH_3CHOHCH_3 \rightarrow CH_3COCH_3 + 2H^+ + 2e^-$** ❶

e. 2-methyl-2-propanol, $(CH_3)_3COH$ - peak 6, and 2-butanol, $CH_3CH_2CH_2CH_2OH$ – peak 8, are structural isomers with molecular formula $C_4H_{10}O$. The structures of these two isomers are represented below.

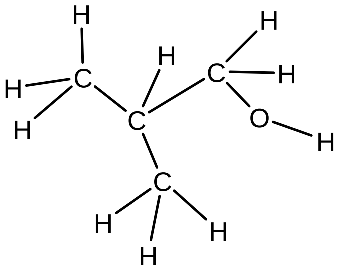




The structures of the **other two isomers showing all bonds** are



❶ and



❶

The names of these two isomers are **1-butanol** and **2-methyl-1-propanol** ❶

f. i. Since the ester has 4 C atoms but only 3 peaks on its ^{13}C NMR spectrum, two of the C atoms must be in the same bonding environment.

The ester is produced from an acid (produced from one of the alcohols) and an alcohol so the possible C atom combinations in the ester are

- 2 from the acid and 2 from the alcohol – ethanoic acid CH_3COOH and ethanol CH_3CH_2OH
- 3 from the acid and 1 from the alcohol – propanoic acid CH_3CH_2COOH and methanol CH_3COOH
- 1 from the acid and 3 from the alcohol – methanoic acid HCOOH and either 1-propanol $CH_3CH_2CH_2OH$ or 2-propanol $CH_3CHOHCH_3$.

Since only 2-propanol molecules have 2 carbon atoms in the same bonding environment, the compounds used to produce the ester are **methanol** (CH_3OH) ❶ from which methanoic acid is produced in the intermediate reaction, and **2-propanol** $(CH_3)_2CHOH$ ❶

ii. **2-propyl methanoate, $HCOOCH(CH_3)_2$** ❶

Question 6

a. i. m(H) = m(sample) - [m(C) + m(N) + m(O)]
= 1.7321 - [0.2747 + 0.3205 + 1.0988]
= 1.7321 - 1.694
= **0.0381 g** ❶

ii.

	C	:	H	:	N	:	O	
mass ratio	0.2747	:	0.0381	:	0.3205	:	1.0988	g
mole ratio	0.2747/12.0	:	0.0381/1.0	:	0.3205/14.0	:	1.0988/16.0	
	0.0229	:	0.0381	:	0.0229	:	0.0687	mol❶
simplest ratio	0.0229/0/0229	:	0.0381/0/0229	:	0.0229/0.0229	:	0.0687/0.0229	
	1	:	1.67	:	1	:	3 ❶	
	1	:	$1^{2}/_{3}$	:	1	:	3	
	1	:	5/3	:	1	:	3	
	3	:	5	:	3	:	9	

Empirical formula: $\mathbf{C_3H_5N_3O_9}$ ❶

iii. Empirical Formula mass - EFM = 3x12 + 5x1 + 3x14 + 9x16
= 277

Molecular Formula = [M_r / *EFM*] x Empirical Formula
= [227 / 227] x $C_3H_8N_3O_9$
= $\mathbf{C_3H_5N_3O_9}$ ❶

b. $n(C_3H_5N_3O_9)$ = 50.1 g / 227 g mol^{-1}
= 0.221 mol

According to the equation
4 mol $C_3H_5N_3O_9$ → 29 mol gas
So 1 mol $C_3H_5N_3O_9$ → 29/4 mol gas
n(gas) = 29/4 x $n(C_3H_5N_3O_9)$
= 29/4 x 0.221
= 1.60 mol ❶
p(gas) = n(gas) x RT / V
= 1.60 x 8.31 x (227+273) / 800×10^{-3} ❶
= 8.31×10^{3} kPa
= 8.31 MPa ❶

End of Suggested Answers