THE SCHOOL FOR EXCELLENCE (TSFX)

UNIT 3 CHEMISTRY 2010

WRITTEN EXAMINATION 1

Reading Time: 15 minutes
Writing Time: 1 hour 30 minutes

QUESTION AND ANSWER BOOK

Structure of Booklet

Section		*Number of Questions*	*Number of Questions to be Answered*	*Number of Marks*	*Suggested Times (min)*
A	Multiple choice questions	20	20	20	20
B	Short answer questions	9	9	60	70
				Total 80	Total 90

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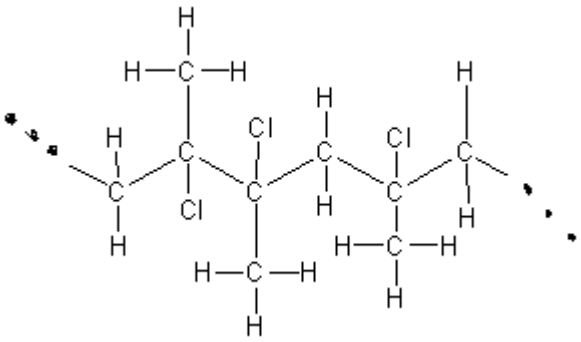
SECTION A - MULTIPLE CHOICE QUESTIONS

Instructions For Section A

Section A consists of 20 multiple-choice questions. Answer all 20 questions.
Choose the response that is **correct** or **best answers the question.**
A correct answer scores 1, an incorrect answer scores 0.
No marks will be given if more than one answer is shown for any question.

QUESTION 1
Below is a segment of a polymer chain.



Possible monomers for this segment are:

A $C(CH_3)ClC(CH_3)Cl$ and $C(CH_3)ClCH_2$
B $C(CH_3)ClCH_2$ only
C CH_2CH_2 and $C(CH_3)ClCH_2$
D $C(CH_3)ClC(CH_3)Cl$ and CH_2CH_2

QUESTION 2
A redox reaction is shown below.

$N_2H_5^+{}_{(aq)} + 2MnO_{2(s)} + 3H^+{}_{(aq)} \rightarrow N_{2(g)} + Mn^{2+}{}_{(aq)} + 4H_2O_{(l)}$

In this equation:

A There is a transfer of four electrons from MnO_2 to $N_2H_5^+$.
B The oxidation number of the reductant changes from -2 to 0.
C All of the atoms have undergone a change in oxidation number.
D The pH of the resulting solution would be lower than the initial solution.

QUESTION 3
Lead is a very toxic metal and there is no concentration of lead in the blood that is considered to be safe. Lead poisoning, however, is defined as a concentration of 10 μgL^{-1}. Which of the following is not equivalent to this concentration?

A 4.8×10^{-8} M
B 1×10^{-6} % w/v
C 0.010 mgL^{-1}
D 0.10 ppm

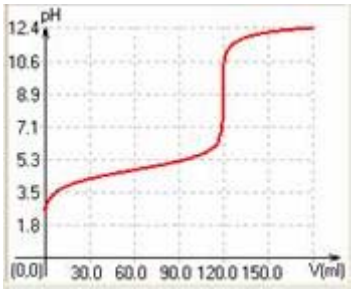
QUESTION 4
Lavoisier contributed much to the understanding of chemistry. In one of his experiments he heated mercury(II) oxide to isolate elemental mercury and oxygen gas. If 40.0g of the compound was heated in a 500mL vessel and 20% (by mass) decomposed, how many atmospheres of oxygen were formed at 25˚C?

A 0.903 atm
B 4.51 atm
C 1.81 atm
D 91.46 atm

QUESTION 5
Which of the following errors would lead to a higher than expected concentration of the unknown species regardless of whether the unknown was placed in the burette or conical flask?

A The burette is rinsed with distilled water.
B The end point occurs before equivalence point.
C The pipette is rinsed with distilled water.
D The standard solution is prepared from a deliquescent primary standard.

QUESTION 6
The following graph shows the pH curve for an acid base titration. What information can be gained from this graph?



A A suitable indicator for this titration would be methyl red.
B Sodium hydroxide was added to the acid.
C Phenolphthalein can be used to accurately predict the equivalence point.
D The acid used was hydrochloric acid.

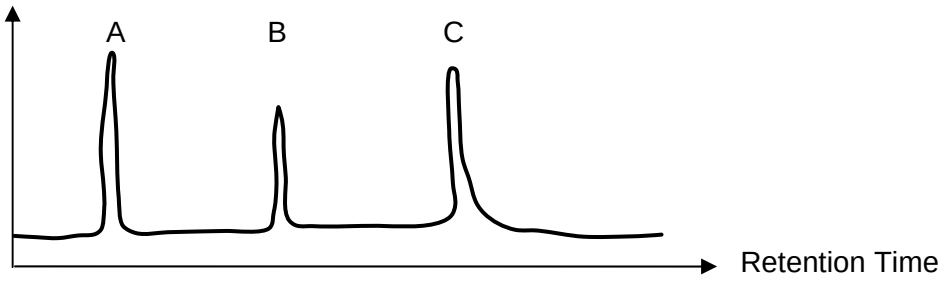
QUESTION 7
Which analytical technique does not utilise the absorption or emission of UV or visible light?

A Flame Tests.
B NMR Spectroscopy.
C Colorimetry.
D Atomic Absorption Spectroscopy.

QUESTION 8
Gas chromatography could not be used to

A Determine the purity of a sample of perfume.
B Separate low molecular weight alcohols.
C Compare the components of two petrol samples.
D Determine the concentration of aspirin in an analgesic tablet.

QUESTION 9
Hexene, hexanol and hexanoic acid were analysed using normal phase column chromatography. Below is the resulting chromatogram.



Which of the following statements is incorrect?

A The order that the molecules would be eluted from the column is the same in both High Performance Liquid chromatography and Gas Liquid chromatography.

B The order that the molecules would be eluted is: hexene, hexanol followed by hexanoic acid.

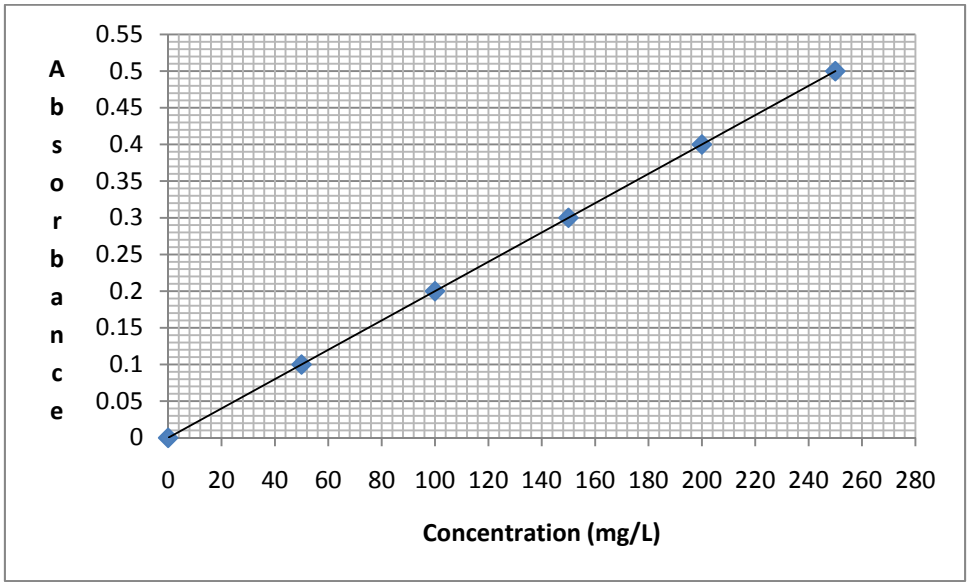
C The order that the molecules would be eluted is: hexanoic acid, hexanol followed by hexene.

D If hexane was added to the mixture its corresponding peak in the chromatogram would appear between peaks A and B.

QUESTION 10
The amount of salt in a packet of potato chips was determined using gravimetric analysis. 5.75g of the chips were ground up and then 50.0ml of water was added. The mixture was filtered and then excess silver nitrate was added. The precipitate was collected, dried and weighed to constant mass. The percentage of sodium chloride in the chips was then determined. Which experimental error/mistake could cause the percentage of sodium chloride to be higher than the actual value?

A Incomplete transfer of the precipitate to the filter paper.
B The amount of silver nitrate added to the mixture was not in excess.
C The mass of the sample was recorded as 5.57g rather than the actual mass of 5.75g.
D Some of the sodium ions remained in solution.

QUESTION 11
The concentration of calcium in mineral water was reported to be 0.021% w/v. An analysis of the mineral water was undertaken to verify this value using Atomic Absorption Spectroscopy. 10.0ml of the mineral water was diluted to 20ml.



Using the calibration curve above, the expected absorbance reading for the diluted sample would be

A 0.10
B 0.22
C 0.02
D 0.42

QUESTION 12
The semi-structural formula of 2 methyl pentan-1-ol is

A $CH_3CH_2CH_2CH(CH_3)CH_2OH$
B $CH_3CH(CH_3)CH_2CH_2CH_2OH$
C $CH_3CH_2CH(CH_3)CH_2CH_2OH$
D $CH_3CH_2CH_2CH_2CH_2CH_2OH$

QUESTION 13
Which statement regarding the reaction of ethanol and ethanoic acid is incorrect?

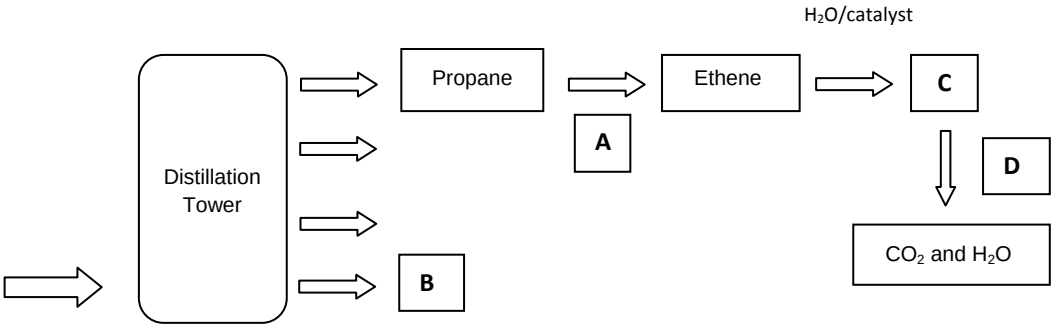
A The reaction can be described as a condensation and an esterification reaction.

B The reaction requires the presence of concentrated sulphuric acid in order to proceed.

C The %C in the product will be less than the total %C in the ethanol and ethanoic acid.

D The product created has the formula $CH_3CH_2OCOCH_3$.

QUESTION 14
Below is a flowchart of some processes that occur after crude oil is distilled.
Which of the following correctly identifies A, B, C and D?



	A	B	C	D
A	Hydration	Low Boiling Point Hydrocarbon	Polyethene	Oxidation
B	Cracking	High Boiling Point Hydrocarbon	Ethanol	Combustion
C	Hydrogenation	Low Boiling Point Hydrocarbon	Ethane	Oxidation
D	Cracking	High Boiling Point Hydrocarbon	Ethanol	Reduction

QUESTION 15
A polypeptide has amino acids connected in the following ratio:

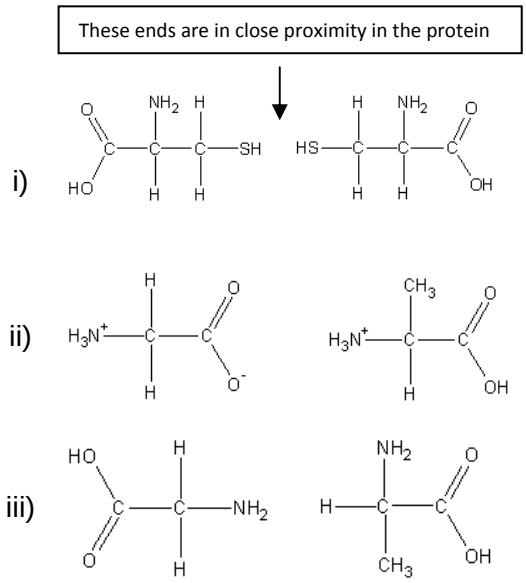
4 Glycine : 2 Alanine : 6 Valine

(M = 76.06 $g.mol^{-1}$) (M = 89.09 $g.mol^{-1}$) (M = 117.15 $g.mol^{-1}$)

The molar mass of the peptide would be closest to

A 987.3 $gmol^{-1}$
B 951.3 $gmol^{-1}$
C 1185.3 $gmol^{-1}$
D 969.3 $gmol^{-1}$

QUESTION 16
If the following amino acids were part of a protein chain and in close proximity to one another, which combination would lead to interactions that would maintain the tertiary structure of the protein?



A i only
B i & ii
C i, ii & iii
D i & iii

QUESTION 17
Which of the following statements regarding biofuels is incorrect?

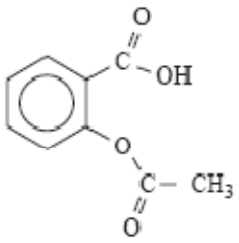
A The use of biofuels increases the overall amount of CO_2 in the atmosphere when combusted.

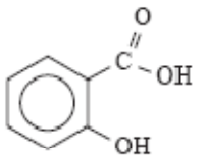
B The reaction that produces some biofuels is similar to the formation of triglycerides in the body in that ester linkages are created during the reaction.

C Heat, acids and bases can be used to accelerate the rate of formation of biofuels.

D The type of alkyl ester that is formed during the production of biofuel is determined by the type of alcohol used as a reactant.

QUESTION 18
The structure of salicylic acid and aspirin are given below.


aspirin


salicylic acid

The synthesis of aspirin from salicylic acid

A is classified as an addition reaction.
B involves the reaction between a carboxylic acid group and acetic anhydride.
C results in the formation of an ether link and a molecule of ethanoic acid.
D involves the transformation of a hydroxyl group into an ester link via a condensation reaction.

QUESTION 19
Stearic acid ($C_{18}H_{36}O_2$), oleic acid ($C_{18}H_{34}O_2$) and linoleic acid ($C_{18}H_{32}O_2$) are all fatty acids that can form triglycerides. When comparing the three acids it can be said that

A stearic acid is the most saturated fatty acid and has the lowest melting point.

B the order of melting points and degree of unsaturation increases in the following order: linoleic acid, oleic acid, stearic acid.

C oleic acid and linoleic acid are both polyunsaturated fatty acids.

D stearic acid is the only fatty acid that will not react with Br_2, and has the highest melting point.

QUESTION 20
Which of the following statements regarding starch is correct?

A During the digestion process, starch is first hydrolysed to form maltose and then further hydrolysed in a separate reaction to form glucose.

B Starch is produced via addition polymerisation reactions involving glucose molecules.

C Starch is produced via addition polymerisation reactions involving maltose molecules.

D The functional group on a starch molecule is called the ester link.

SECTION B – SHORT ANSWER QUESTIONS

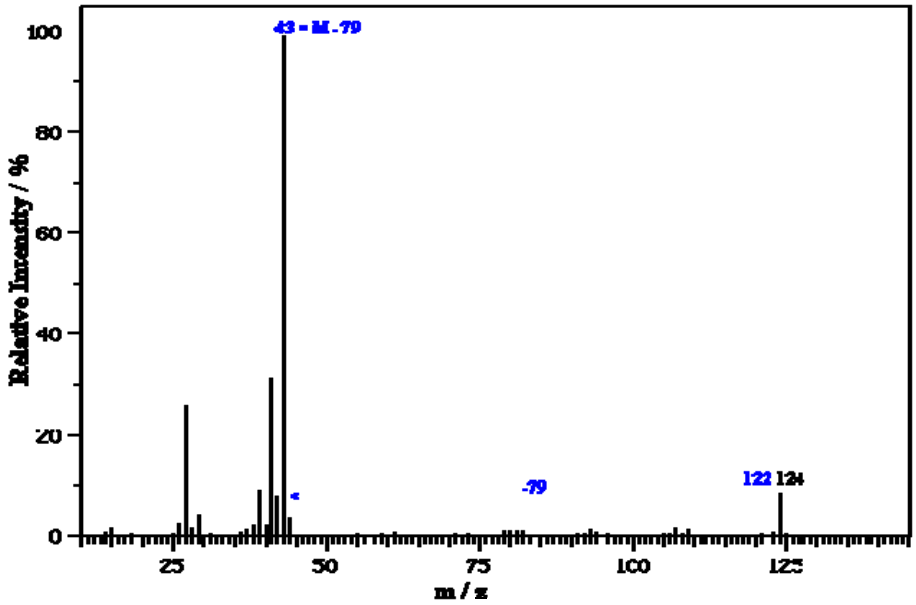
Instructions For Section B

Answer all questions in the spaces provided.

To obtain full marks for your responses you should:

- Give simplified answers with an appropriate number of significant figures for all numerical questions; unsimplified answers will not be given full marks.
- Show all working in your answers to numerical questions. No credit will be given for an incorrect answer unless it is accompanied by details of the working.
- Make sure that all chemical equations are balanced and that the formulas for individual substances include an indication of state (for example, $H_{2(g)}$; $NaCl_{(s)}$).

QUESTION 1
The mass spectrum of 1-bromopropane is given below.



a. This spectrum shows the presence of two molecular ions.

(i) State the m/z at which these ions occur.

_____

1 mark

(ii) Account for the presence of two molecular ions.

_____

_____

_____

_____

1 mark

b. (i) State the formula of the fragment responsible for the peak at m/z 43.

_____

1 mark

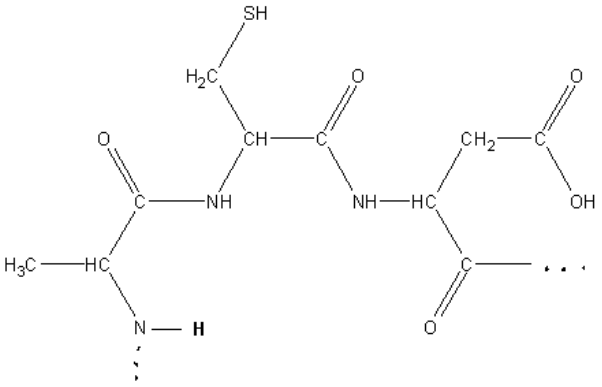
(ii) Identify a fragment that could be responsible for the peak at m/z 44.

_____

1 mark

Total 4 Marks

QUESTION 2
A section of a polypeptide chain is shown below.



a. (i) Circle one of the linkages which connects the monomers together in the structure above. What is the name of this linkage?

_____

1 mark

(ii) On the diagram above, identify a hydrogen atom that could be responsible for maintaining the secondary structure of the protein.

1 mark

b. (i) Draw the structure of the largest molecular weight amino acid that comprises the illustrated chain.

1 mark

(ii) Write an equation that shows the amino acid with the lowest molecular weight reacting with a base.

_____

1 mark

c. (i) All of the amino acids in this protein can be manufactured in the body. What is the name given to these types of amino acids?

_____

1 mark

(ii) Give the chemical formulae for any two of the three waste products that are formed when proteins are completely digested or eliminated from the body.

_____

1 mark

Non-genetic markers of disease can include protein molecules like the one shown on the previous page.

d. Suggest how these protein markers can help doctors diagnose and monitor diseases such as prostate and breast cancer.

_____

_____

_____

_____

2 marks

Total 8 Marks

QUESTION 3

Over time, aspirin decomposes and its percentage purity decreases. To determine the percentage purity of a sample of aspirin, a student followed the procedure outlined below.

A 0.2000g sample of aspirin was crushed and dissolved in 20.00mL of 0.2520M sodium hydroxide. The equation for the reaction is:

$$C_9H_8O_{4(s)} + 2NaOH_{(aq)} \rightarrow CH_3COONa_{(aq)} + HOC_6H_4COONa_{(aq)} + H_2O_{(l)}$$

The solution was made up to 50.00mL and heated for 15 minutes. After heating, the volume was adjusted back to 50.00mL to compensate for any loss of solution during the heating process. 25.00mL of the solution was then titrated with 0.1056M HCl solution to find out how much NaOH was in excess. An average titre of 13.75mL was required to reach the end point.

a. Give a reason why a direct titration was not used for this analysis.

_____

_____

1 mark

b. (i) Determine the amount, in mole, of HCl used in the titration.

_____

_____

1 mark

(ii) Determine the amount, in mole, of NaOH left over in the 50.00mL solution.

_____

_____

1 mark

(iii) Determine the amount, in mole, of NaOH that reacted with the aspirin.

_____

_____

_____

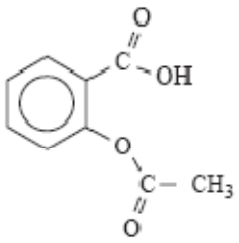
_____

2 marks

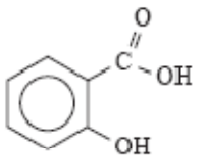
c. Determine the percentage purity of the aspirin sample.

3 marks

The structure of salicylic acid and aspirin are given below.



aspirin



salicylic acid

The active ingredient in aspirin is salicylic acid which is released after hydrolysis in the small intestine before moving into the blood stream.

d. (i) Write an equation showing the hydrolysis of aspirin to produce salicylic acid. Clearly show all structures.

1 mark

(ii) How could you distinguish between aspirin and salicylic acid molecules using infra-red spectroscopy?

1 mark

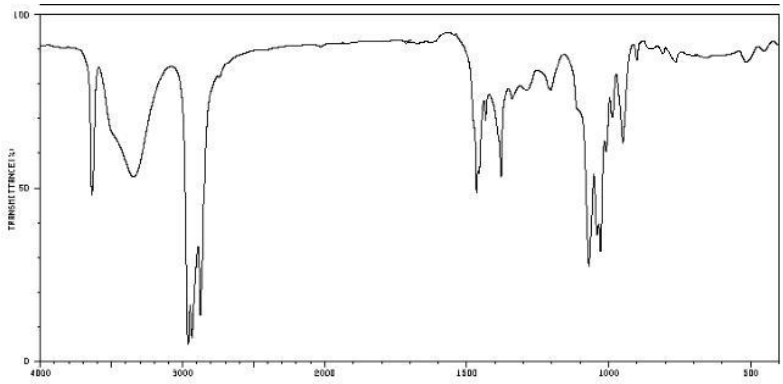
Total 10 Marks

QUESTION 4
A student was given four chemical samples labelled W, X, Y and Z and was told that they were all straight chain molecules with the following chemical formulae:

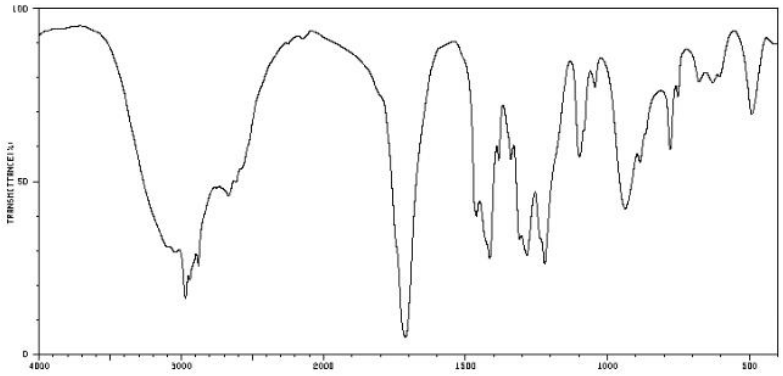
C_4H_{10}
C_4H_8
$C_4H_{10}O$
$C_4H_8O_2$

To determine which sample was which, the student undertook a number of experiments which are described below.

Experiment 1: Compounds W and X were analysed using Infra Red Spectroscopy.



Sample W



Sample X

a. Use these spectra to draw a possible structural formula for molecules W and X.

2 marks

Experiment 2: 0.2500g of sample Y was burnt and 0.7857g of CO_2 was produced.

b. Using this information, determine the molecular formula of compound Y.

3 marks

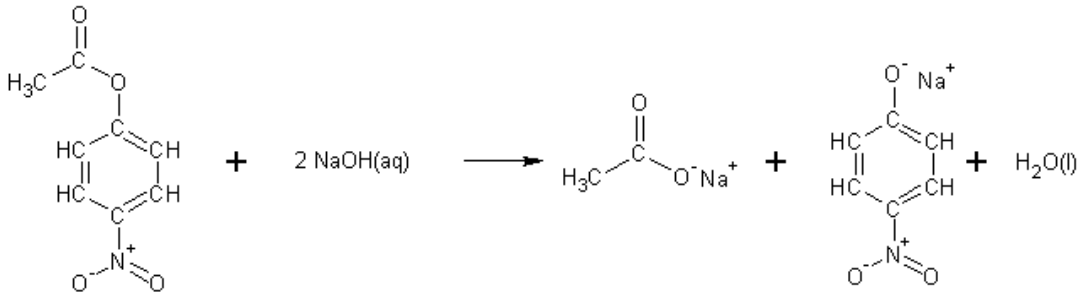
c. Using structural formulae, show a possible reaction sequence that could be used to synthesise molecule X from an unsaturated compound.

2 marks

Total 7 marks

QUESTION 5

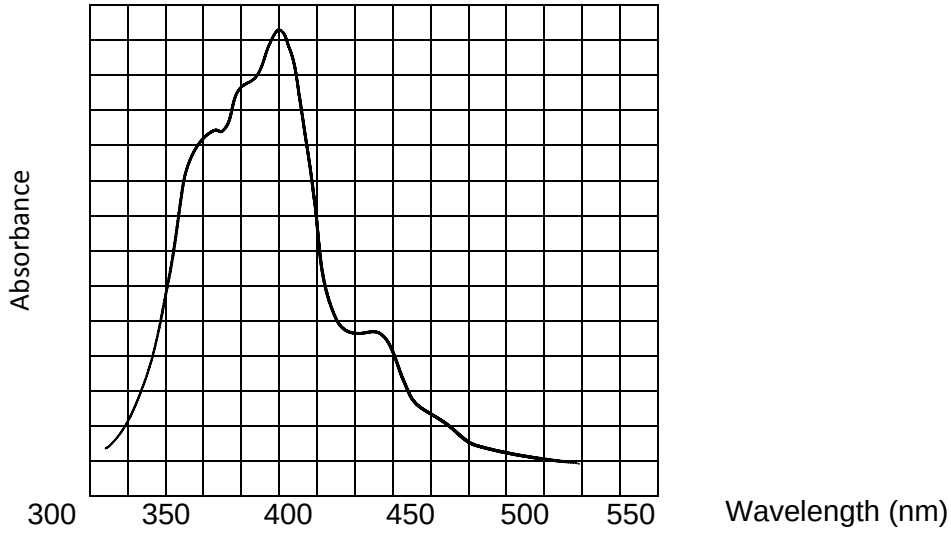
The ion 4-nitrophenoxide is used in the production of pesticides, pharmaceuticals, reagent and dyes. It forms a yellow solution and is produced from the hydrolysis of 4-nitrophenylethanoate as described below.



4 nitrophenylethanoate

yellow 4 nitrophenoxide

The UV-Visible spectrum of 4-nitrophenoxide is illustrated below.

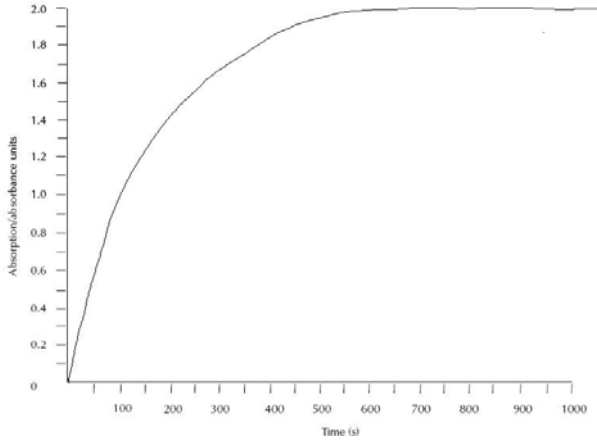


a. Choose the most suitable wavelength to quantitatively analyse a solution of 4-nitrophenoxide.

_____

1 mark

0.250mL of a solution of the starting material (4-nitrophenylethanoate) was injected into a cuvette. An excess of NaOH solution was then added and the volume in the cuvette increased to 2.50mL. The progress of the above reaction was monitored using UV-Visible spectroscopy and the results are illustrated below.

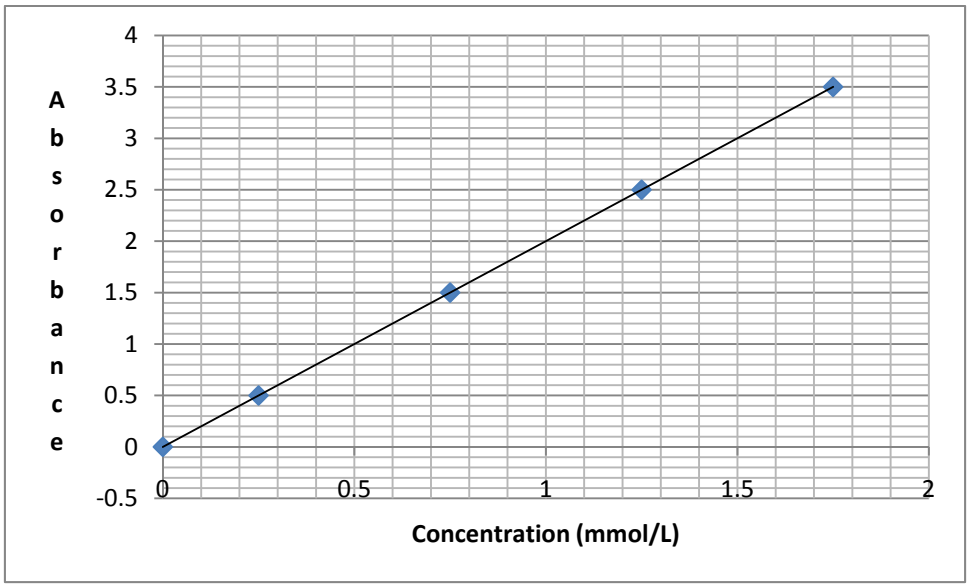


b. At what time was the reaction complete?

_____

1 mark

Standard solutions of 4-nitrophenoxide were then analysed in the same spectrometer. The results are shown below.



c. (i) Determine the concentration of 4-nitrophenoxide present when the reaction is complete.

1 mark

(ii) How many mole of 4-nitrophenoxide were produced?

1 mark

(iii) What would be the minimum concentration (mol/L) of sodium hydroxide required in order for this reaction to proceed to completion?

2 marks

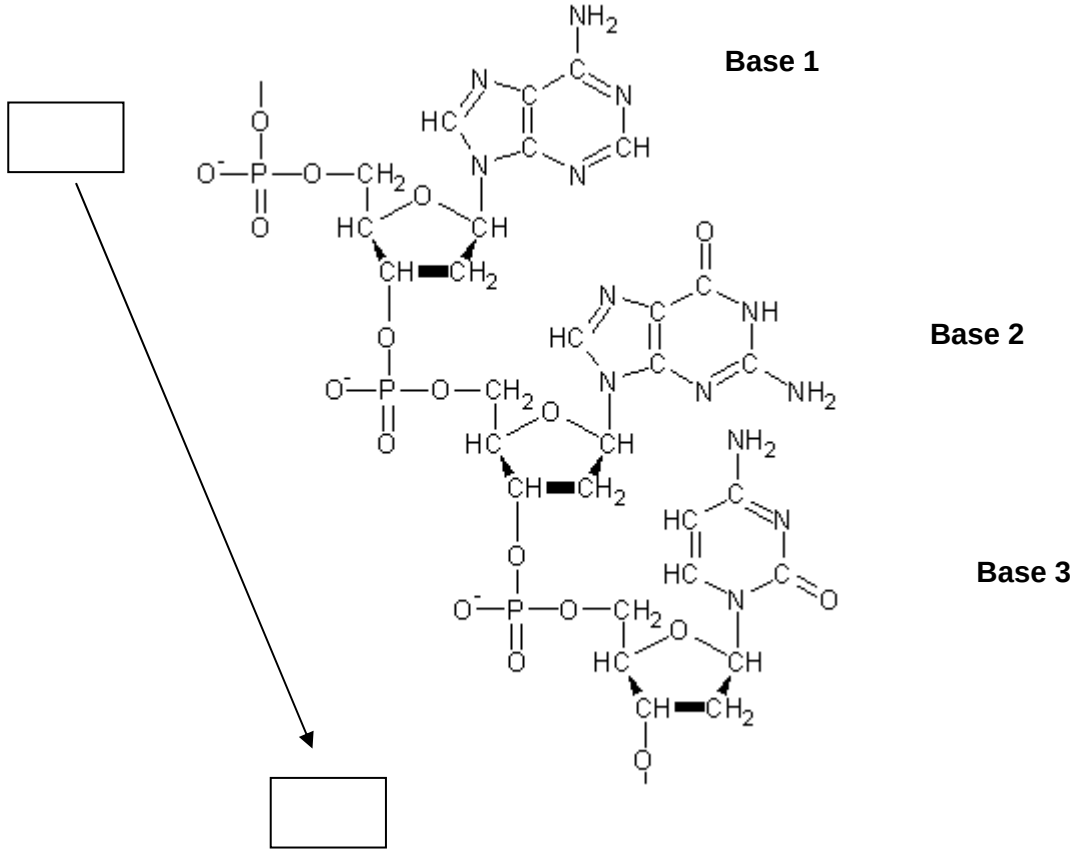
(iv) Double beam UV-Visible spectrometers send light of the chosen wavelength through the sample as well as through a reference cell. Explain the significance of this reference cell indicating the effects that would be observed on the calculated concentration of unknown if this double beam system was not employed.

2 marks

Total 8 Marks

QUESTION 6

A section of a single DNA strand is shown below.



a. (i) Circle and name the linkage holding the DNA backbone together.

_____

1 mark

(ii) How many water molecules would be required to hydrolyse a single strand of DNA consisting of 20 nucleotides into its simplest components?

_____

_____

1 mark

(iii) Give the name of the base that would be found on the complementary strand of the DNA fragment illustrated above.

Complementary Base 1: _____

Complementary Base 2: _____

1 mark

Strands of DNA are said to run in either a 5' to 3' direction or 3' to 5' direction.

b. Clearly label the arrow provided on the diagram to show the 5' and 3' ends of the DNA strand.

1 mark

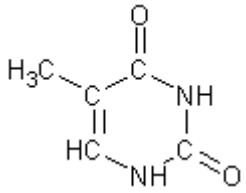
The ratios of some of the base pairs in DNA is shown below.

Base Pair Ratios in DNA			
Source of DNA	G/T	G/C	A/T
Human	0.66	1.00	1.01
Yeast	0.56	1.02	0.99
Ox	0.74	1.00	1.01

c. Explain why the ratio G/C and A/T is always approximately 1 regardless of the organism it comes from but the ratio G/T differs.

2 marks

The structure of thymine is shown below.



d. (i) Clearly indicate where thymine would attach to the DNA backbone.

1 mark

(ii) Identify all the sites where hydrogen bonding would occur between thymine and its complementary base.

1 mark

Total 8 Marks

QUESTION 7
Two esters with distinctly different properties have the molecular formula $C_4H_8O_2$.

a. Give a reason why compounds with the same molecular formulae often display very different chemical and/or physical properties.

1 mark

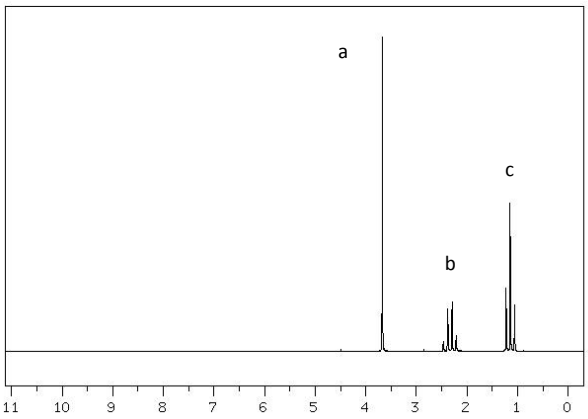
b. (i) Draw the structural formulae for the two esters with formula $C_4H_8O_2$, stating their systematic names.

2 marks

(ii) For one of the esters in (i) above, write an equation showing how it is synthesised, clearly stating the names of the reactants and catalysts involved, as well as the reaction conditions.

2 marks

The ^{1}HNMR spectrum for one of the esters with formula $C_4H_8O_2$ is shown below.



Peak “a” is a singlet, peak “b” is a quartet and peak “c” consists of a triplet.

c. Using the letters “a” to “c” marked on the NMR spectrum, label each hydrogen environment in the appropriate structural diagram provided in part b (i) with the appropriate letter.

3 marks

d. (i) Name an analytical technique that could be used to determine the presence of butanol in a sample.

1 mark

(ii) Write a balanced redox equation showing the oxidation of butanol to butanoic acid using dichromate ions.

2 marks

Total 11 Marks

QUESTION 8

a. In paper chromatography an $\mathbf{R_f}$ value can be used to identify components in a sample. In HPLC, however, it is the $\mathbf{R_t}$ values that serves this function. Explain the difference between the two terms.

2 marks

b. The chemical shift of the R-CH_3 group in ^{1}H-NMR is 0.9 ppm whereas the chemical shift for R-O-CH_3 is 3.3 ppm. Explain the difference in these chemical shift values.

2 marks

c. Both Atomic Absorption Spectroscopy (AAS) and Colorimetry utilise the absorbance of radiation in order to quantitatively analyse a sample. AAS is regarded as the more accurate technique for quantitative analysis. Why is this the case?

2 marks

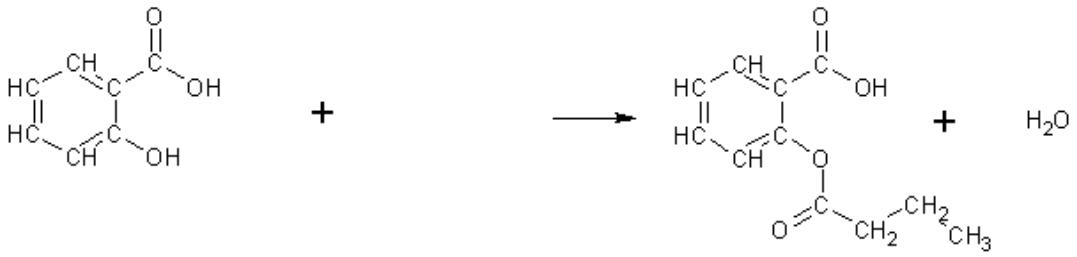
d. Gas liquid chromatography utilises differences in the volatility of gases to separate mixtures. Explain why alkenes are more volatile than alkanes and how this affects the order that the molecules emerge from the column.

2 marks

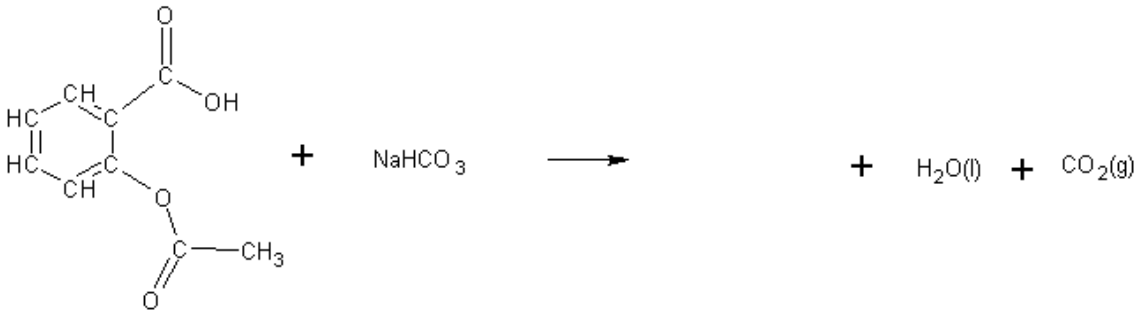
Total 8 Marks

QUESTION 9
Complete the following reaction pathways:

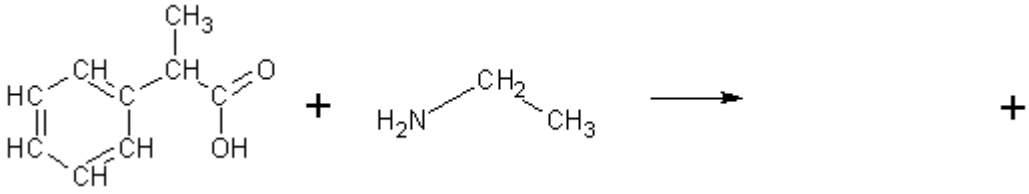
a.



b.



c.

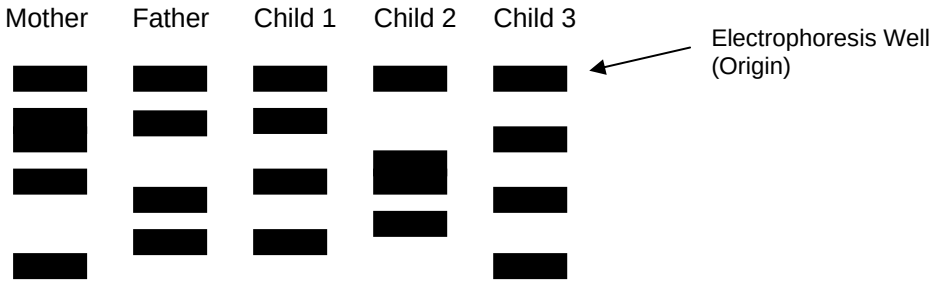


1 + 1 + 1 = 3 marks

Total 3 Marks

BONUS QUESTIONS

QUESTION 1
Shown below is the DNA fingerprint of five members of a family. One of the children was adopted.



a. Which DNA fingerprint is that of the adopted child?

_____

_____

1 mark

DNA fingerprinting involves using fragments of a person's DNA and then separating these fragments using electrophoresis.

b. Describe the basis on which the fragments are separated from each other.

_____

_____

_____

_____

_____

_____

_____

2 marks

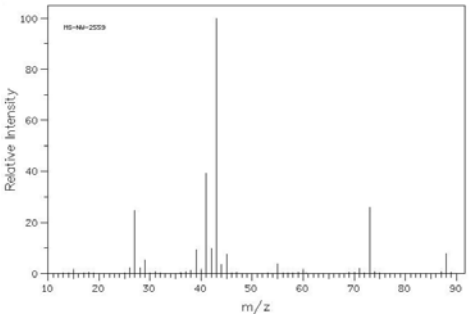
c. On the diagram above, indicate where the heaviest DNA fragments would be located.

1 mark

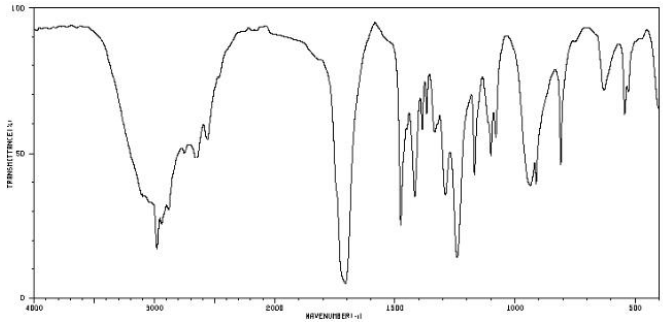
Total 4 Marks

QUESTION 2

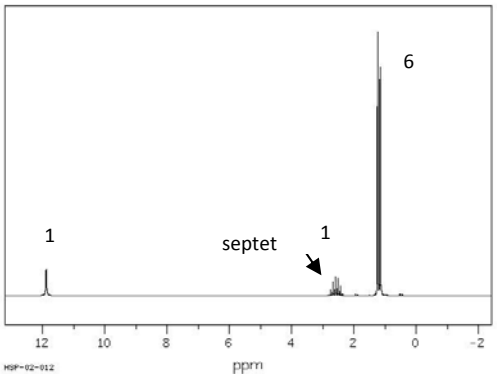
An organic molecule with the empirical formula C_2H_4O is used as a flavouring agent. Shown below is the mass spectrum, the ^1H and ^{13}C NMR spectra and the infra red spectrum for this molecule.



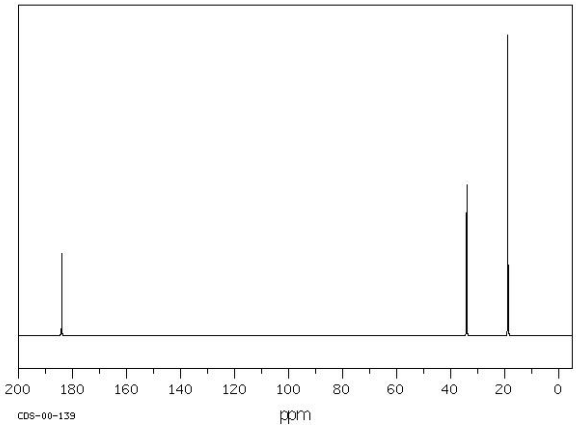
Mass Spectrum



IR Spectrum



^1H-NMR Spectrum



C-NMR Spectrum

a. Use these spectra to determine the molecular mass and molecular formula of the compound.

_____

2 marks

b. Which functional groups are responsible for the following peaks on the infrared spectrum?

(i) 1707 cm^{-1}

_____

1 mark

(ii) 2800 - 3000 cm^{-1}

_____

1 mark

c. (i) How many different carbon environments are present in this molecule?

_____

1 mark

(ii) How many different hydrogen environments are present in this molecule?

_____

1 mark

d. Use the above information to determine the structural formula of the compound.

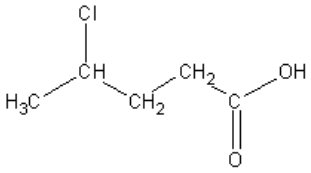
2 marks

Total 8 Marks

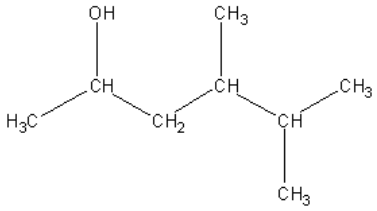
QUESTION 3

a. Give systematic name for the following molecules:

(i)



(ii)



_____

_____

1 + 1 = 2 marks

b. Show the structural formulae for all isomers with the molecular formula C_4H_9Cl.

2 marks

Total 4 Marks