THE SCHOOL FOR EXCELLENCE (TSFX)

UNIT 3 CHEMISTRY 2008

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	7	7	68	68
				Total 88	Total 88

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SECTION A - MULTIPLE CHOICE QUESTIONS

QUESTION 1

The number of molecules present in $224\,L$ of methane at $0^{o}C$ and $101.3\,kPa$ is:

A 3.0×10^{24}
B 6.0×10^{24}
C 3.0×10^{23}
D 6.0×10^{23}

QUESTION 2

The simplest formula for a compound which contains 51.8% carbon, 9.8% hydrogen and 38.4% chlorine is:

A $CHCl$
B C_4H_9Cl
C C_4H_8Cl
D CH_2Cl

QUESTION 3

300 ml of a 0.35 M $Ca(OH)_2$ solution was reacted with 300 ml of 0.40 M HCl .
The pH of the resultant solution is closest to:

A   0.82
B   1.12
C   12.88
D   13.18

QUESTION 4

A student wishes to determine the percentage by mass of barium in a sample. Which solution could be used to produce a precipitate containing barium?

A NaI
B $NaCl$
C $NaNO_3$
D Na_2SO_4

QUESTION 5

Which of the following reactions is **NOT** a redox process?

A $2K_{(s)} + Br_{2(l)} \rightarrow 2KBr_{(s)}$

B $Ca(OH)_{2(s)} + CO_{2(g)} \rightarrow CaCO_{3(s)} + H_2O_{(l)}$

C $NH_4NO_{3(s)} \rightarrow N_2O_{(g)} + 2H_2O_{(g)}$

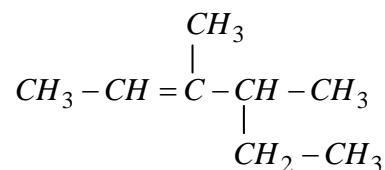D $CH_{4(g)} + Cl_{2(g)} \rightarrow CH_3Cl_{(g)} + HCl_{(g)}$

QUESTION 6

Which of the following statements is incorrect?

A The oxidation number of sulfur in $S_4O_6^{2-}$ is 2.5

B The oxidation number of oxygen in HOF is -2

C The oxidation number of nitrogen in NH_4NO_2 is ± 3

D The oxidation number of carbon in $C_6H_{12}O_6$ is 0

QUESTION 7

The systematic name for the molecule below is:

$$CH_3 - CH = \overset{\overset{\textstyle CH_3}{\textstyle |}}{C} - \overset{\overset{}{\underset{\underset{\textstyle CH_2 - CH_3}{\textstyle |}}{}}}{CH} - CH_3$$

A 2-ethyl-3-methyl-3-pentene

B octene

C 3,4-dimethyl-2-hexene

D 3-methyl-4-ethyl-2-pentene

QUESTION 8

An organic species is water soluble and displays a boiling point of 78.3^o. This compound may be used as a fuel and may be prepared in aqueous solutions from the fermentation of sugars. The organic species is most likely

A Methanol

B Ethanol

C Methanoic acid

D Ethanoic acid

QUESTION 9
The species with the lowest solubility in water is

A   Decanoic acid
B   Ethanoic acid
C   Pentanoic acid
D   Propanoic acid

QUESTION 10
At pH 6, the amino acids glycine, glutamic acid, asparagine and histidine exist in their fully charged (zwitterion) form. Which amino acid would migrate the furthest towards the positive terminal in gel electrophoresis?

A   Asparagine
B   Glutamic acid
C   Glycine
D   Histidine

QUESTION 11
The α-amino acid alanine has the molecular formula $C_3H_7O_2N$. If three alanine molecules react together to form a tripeptide, the relative molecular mass of this tripeptide would be:

A   89
B   231
C   267
D   283

QUESTION 12
A food chemist is developing a new chocolate paste that will be used as a spread on cakes and bread. A large percentage of the composition of the spread is in the form of a lipid. Which of the following fatty acids would you choose to produce a paste that spreads very easily?

A   Lauric acid
B   Linoleic acid
C   Oleic acid
D   Palmitic acid

QUESTION 13
Which of the following statements regarding monosaccharides is incorrect?

A   The functional group in monosaccharides is the hydroxy group
B   Monosaccharides behave as weak reductants
C   Monosaccharides cannot be hydrolysed to produce smaller units
D   Monosaccharides can be oxidised to produce smaller units

The following information relates to Questions 14 and 15:

The structure of salicylic acid and acetyl salicylic acid are given below.

Salicylic acid   Acetylsalicylic acid
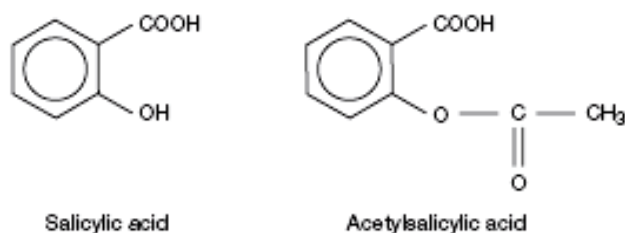
QUESTION 14
Which of the following reactants is required to convert salicylic acid into acetylsalicylic acid?

A Water
B Methanol
C Ethanol
D Ethanoic acid

QUESTION 15
Which technique could **not** be used to distinguish salicylic acid and acetylsalicylic acid?

A Infra-red spectroscopy
B Mass spectrometry
C Atomic absorption spectroscopy
D Carbon NMR spectroscopy

QUESTION 16
Which of the following statements relating to paper chromatography is incorrect?

A R_f values increase as temperature increases.

B Better resolution of sample components may be obtained by increasing the length of the chromatogram.

C Components of a sample separate due to differences in their rates of absorption and desorption.

D Paper chromatography may be used to separate components of mixtures.

QUESTION 17

The ultraviolet spectrum of two different sugars is given below.

Absorbance (Units)
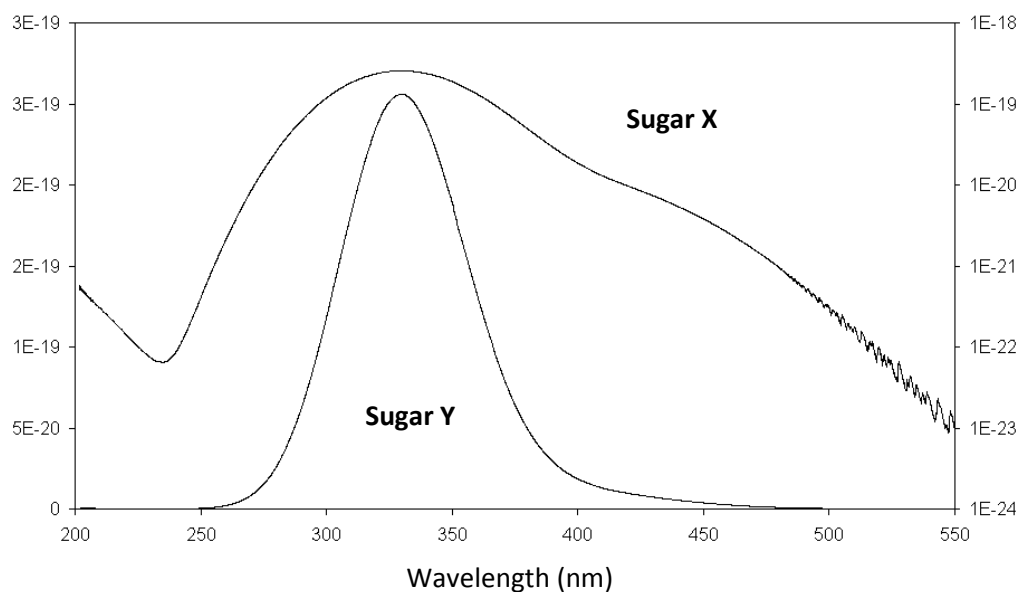
Wavelength (nm)

Which wavelength would you select to measure the concentration of Sugar X without interference from Sugar Y?

A   200 nm
B   240 nm
C   335 nm
D   550 nm

QUESTION 18

The purpose of the electron beam in the mass spectrometer is to

A   separate particles based on charge.
B   separate particles based on mass.
C   accelerate ions in the electric field.
D   convert atoms into ions.

QUESTION 19

A compound introduced into a mass spectrometer gave a spectrum corresponding to fragments including CCl_3^+, CCl_2F^+, CCl_2^+, CCl^+ and CF^+. Which of the following is the most likely formula for the compound?

A CCl_3F

B CCl_2F_2

C $CClF_3$

D $CHClF_2$

QUESTION 20

Which of the following statements is incorrect?

A The ^{12}C nucleus will undergo a measurable change in spin energy levels when exposed to radiation from the radio wave region of the electromagnetic spectrum.

B There is insufficient energy in the radio wave radiation to cause bending and stretching in covalent bonds.

C Energies corresponding to the visible spectrum are able to cause excitation of valence electrons in atoms and molecules.

D Different functional groups in organic molecules absorb radiation of different frequencies from the infra-red region of the electromagnetic spectrum.

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

a. $1.336\,g$ of pure anhydrous Na_2CO_3 was dissolved in water and made up to $250.00\,ml$ of solution in a volumetric flask. Calculate the concentration of this standard solution.

_____

_____

_____

_____

_____

_____

<div align="right">2 marks</div>

b. This standard Na_2CO_3 solution was used to standardise an approximately $0.1\,M$ HCl solution. A $20.00\,ml$ sample of the Na_2CO_3 solution required $19.02\,ml$ of HCl for complete neutralisation. Calculate the concentration of HCl.

_____

_____

_____

_____

_____

_____

_____

_____

_____

<div align="right">3 marks</div>

c. The neutralisation curve for the titration used in **part b.** is given below.
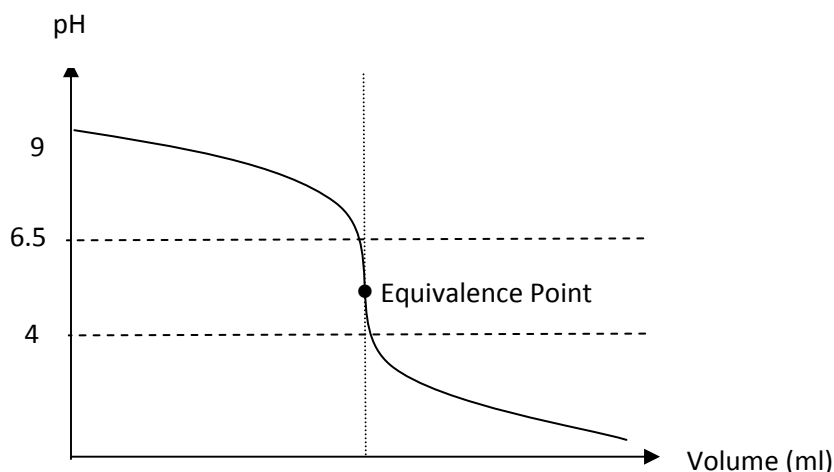
(i) Name one indicator that could be used to accurately detect the equivalence point for the reaction in **part b.**

_____

(ii) How would the calculated HCl concentration differ from that determined in part b. if phenolphthalein was used as the indicator for this reaction? Circle one option from the answers below.

Concentration will be   Concentration will be   Concentration will be the
lower than in part b.   higher than in part b.   same as in part b.

(iii) Hydrated Na_2CO_3 is not a good primary standard because it is efflorescent

i.e. it gives off water to the atmosphere. How would the calculated HCl concentration differ from that determined in part b. if hydrated Na_2CO_3 was used as the primary standard for this reaction? Circle one option from the answers below.

Concentration will be   Concentration will be   Concentration will be the
lower than in part b.   higher than in part b.   same as in part b.

1+1+1 = 3 marks

d. The standard HCl solution was then used in a titration to determine the concentration of ammonium ions in lawn fertiliser. A $1.50\,g$ sample of fertiliser was dissolved in water to make a $250.00\,ml$ solution. A $20.00\,ml$ aliquot of this solution was added to a flask containing $20.00\,ml$ of $0.150\,M$ sodium hydroxide solution. The flask was heated until the reaction below was complete.

$$NH_{4(aq)}^{+} + OH^{-}{}_{(aq)} \rightarrow NH_{3(aq)} + H_2O_{(l)}$$

The excess sodium hydroxide in the resulting solution was titrated with the standard hydrochloric acid, using phenolphthalein as indicator. The end point was reached when $22.25\,ml$ had been added.

(i) Calculate the amount, in mole, of sodium hydroxide that reacted with the ammonium ions.

_____

_____

_____

_____

_____

_____

_____

_____

_____

(ii) Hence calculate the percentage by mass of nitrogen in the fertiliser.

_____

_____

_____

_____

_____

_____

_____

3+3 = 6 marks

Total 14 marks

Compound A is a hydrocarbon with molar mass $56\ g/mol$. It reacts with hydrogen bromide gas to produce 1 product only, Compound B.

Compound B reacts with a dilute solution of sodium hydroxide to form Compound D, which oxidises with potassium permanganate to form Compound C.

Compound C reacts with sodium carbonate to produce a salt (Compound F) and carbon dioxide. Compound C may also react with ethanol and sulfuric acid to produce a fruity smelling substance - Compound E.
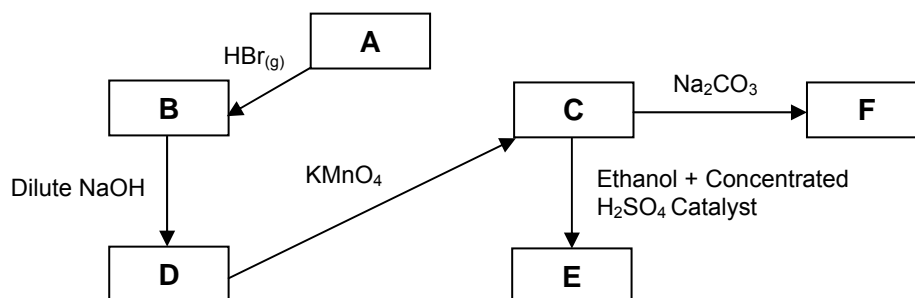
a. Identify compounds:

A: _____

C: _____

E: _____

1+1+1 = 3 marks

b. Write semi-structural equations for the formation of:

(i) Compound B

(ii) Compound D

(iii) Compound F

1+1+1 = 3 marks

Total 6 marks

QUESTION 3

Compound X is an organic molecule with empirical formula $C_3H_6O_2$. The infrared spectrum, mass spectrum and proton NMR spectrum for this compound are given below.

Mass Spectrum For Compound X
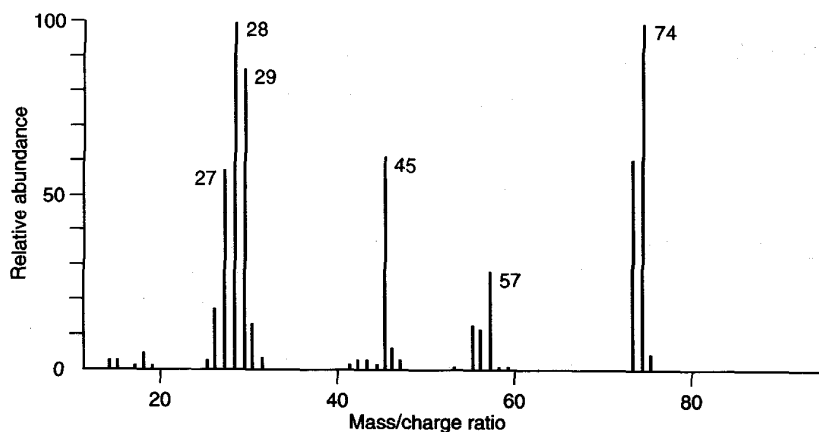
a. (i) Give the formula of the component that produced the peak at mass/charge ratio 74.

_____

(ii) Account for the differences in structure for the components that produced the peaks at mass/charge ratio 74 and 75.

_____

_____

_____

_____

(ii) Would an isomer of Compound X produce the same or different spectrum to that given above? Give a reason for your answer.

_____

_____

_____

_____

1+1+1 = 3 marks

Infra-Red Spectrum For Compound X

Transmission/% vs **Wavenumber/cm⁻¹**
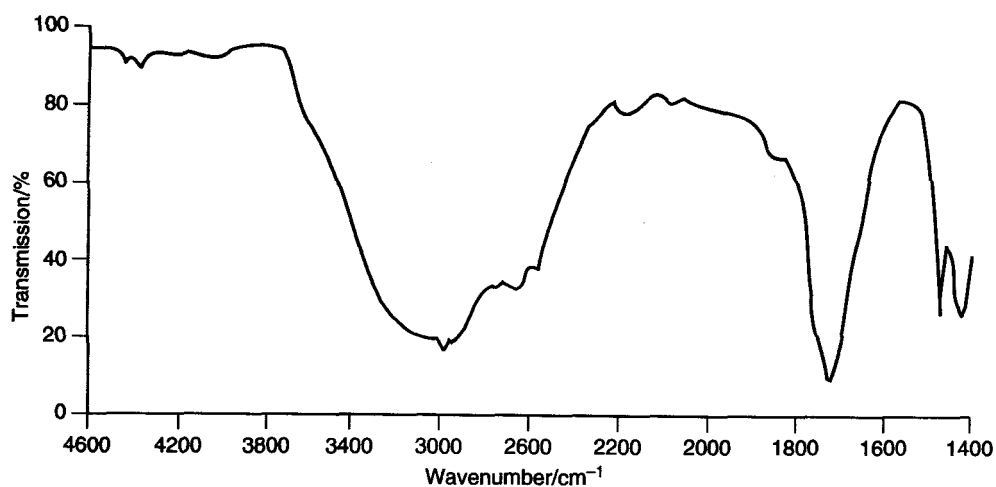
b. (i) Use the spectrum above to indicate the family of organic compounds to which $C_3H_6O_2$ belongs. Give a reason to support your answer.

_____

_____

_____

_____

(ii) Would an isomer of Compound X produce the same or different spectrum to that given above? Give a reason for your answer.

_____

_____

_____

_____

<div align="right">2+1 = 3 marks</div>

Proton NMR Spectrum For Compound X
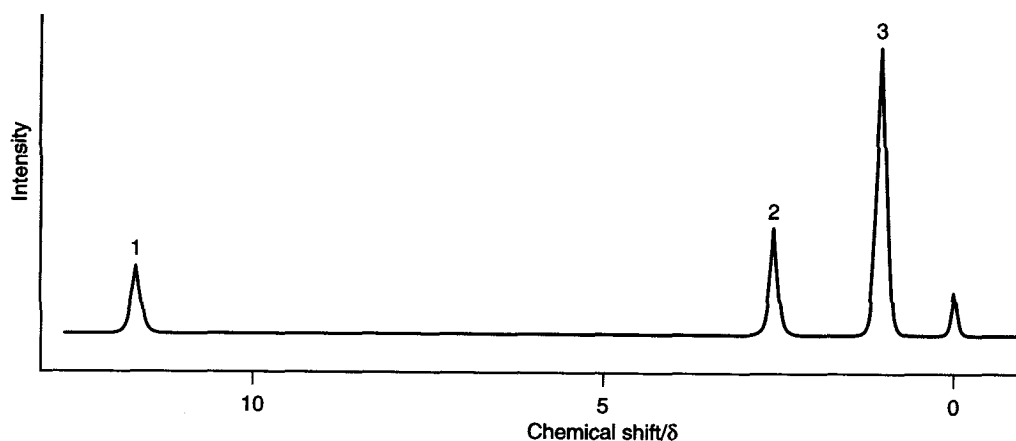
c. (i) What is responsible for the peak at zero chemical shift?

_____

_____

(ii) Use the spectrum above as well as the spectra from **a.** and **b.** to draw the structural formula of Compound X.

(iii) Would an isomer of Compound X produce the same or different spectrum to that given above? Give a reason for your answer.

_____

_____

_____

_____

1+2+1= 4 marks

Total 10 marks

QUESTION 4

Various methods have been used over the years to determine the blood alcohol concentration in drivers of motor vehicles.

The earliest method for detecting ethanol in breath was based on a reaction between dichromate (VI) ions and ethanol to produce chromium (III) ions, which resulted in a colour change from orange to green if ethanol was present in breath.

a. (i)   Write a balanced half equation for the conversion of dichromate (VI) ions, $Cr_2O_7^{2-}$ into chromium (III) ions, Cr^{3+} in acid solution.

_____

_____

(ii) Write a balanced half equation for the conversion of ethanol into its conjugate organic product.

_____

_____

(iii) Hence write an overall ionic equation for the reaction between dichromate (VI) ions and ethanol.

_____

_____

_____

1+1+1 = 3 marks

If large quantities of alcohol are detected in the breath of motorists, accurate determinations of alcohol levels are often employed. This can be achieved by analysing blood or urine specimens by gas-liquid chromatography (GLC).

A series of standards of known ethanol concentration were injected into the GLC and their peak areas were determined from the chromatogram. Shortly after the standards were analysed, a sample of blood from a driver at an accident scene was analysed under identical conditions.

The chromatogram obtained is illustrated below.

Peak Area (Units)

0.05% v/v   0.1% v/v   0.15% v/v

Ethanol Concentration
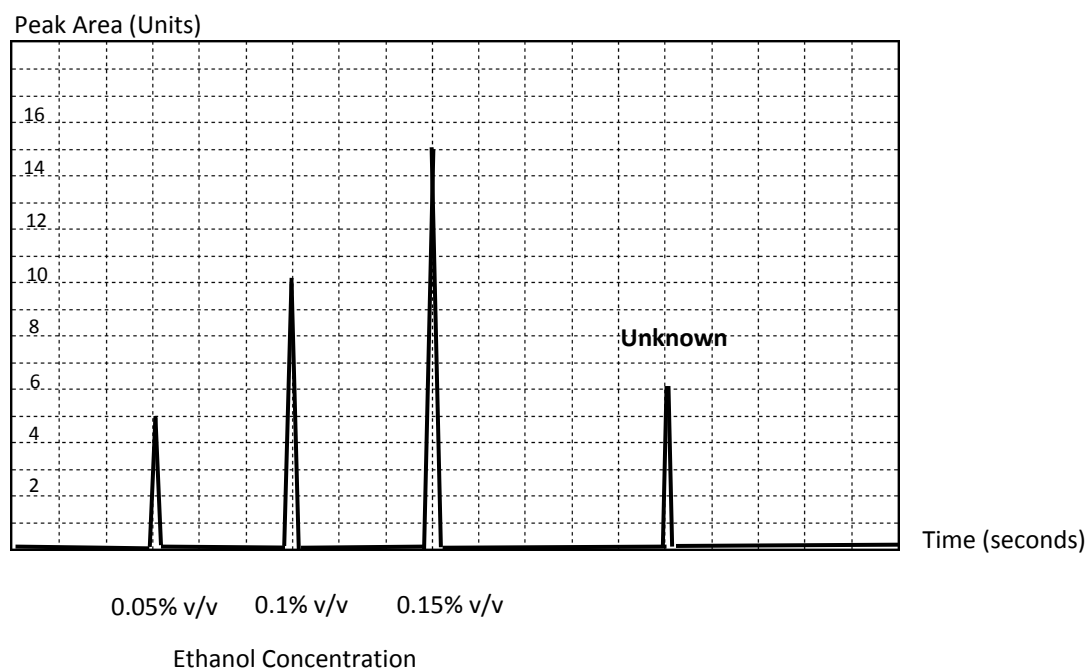
b. (i) Plot a calibration curve of the concentration of ethanol as a function of peak area on the axes below.
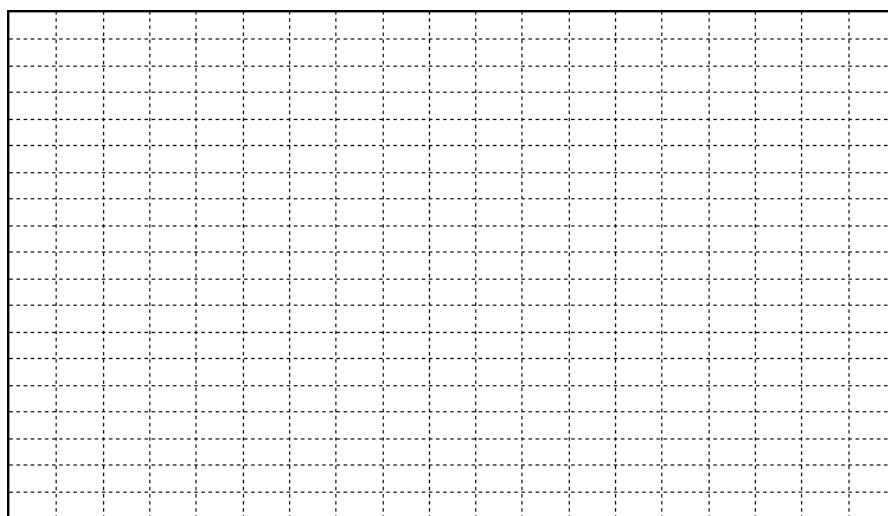
(ii) Determine the %v/v of alcohol in the blood of the motorist.

_____

_____

(iii) The Blood Alcohol Concentration (BAC) is reported in terms of mg ethanol per $100\,ml$ of blood. Therefore, a blood alcohol concentration of 0.05% indicates that there are $50\,mg$ ethanol per $100\,ml$ blood.

If the density of ethanol is $0.789\,g/ml$, determine whether the BAC of the motorist was greater than the legal limit of 0.05.

_____

_____

_____

_____

_____

_____

(iv) What volume of $250\,ppm$ potassium dichromate solution would be required to produce a colour change in reaction **a. (iii)** when $1.000\,ml$ of the motorist's blood is analysed?

_____

_____

_____

_____

_____

_____

_____

_____

_____

1+1+1+3 = 6 marks

c. Draw the spectrum you would expect to observe when ethanol is analysed using Carbon (13) NMR spectroscopy.

200   100   0

Chemical shift (ppm)
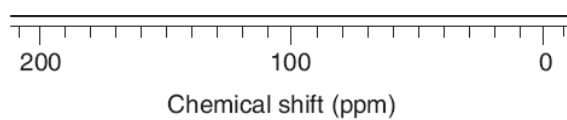
2 marks

Total 11 marks

QUESTION 5

Esters are commonly used as flavours in the food industry. A student decided to prepare an ester in a school laboratory.

a. (i) Which chemicals from the list below would you use to prepare an ester? Circle the appropriate choices.

Ethene	Butanoic acid	H_3PO_4
Methanol	Concentrated H_2SO_4	Glucose
$NaOH$	Ethane	Ethyl ethanoate

(ii) Give the systematic name of the compound formed.

_____

(iii) Which of the following terms does NOT describe the reaction in (ii)?

A   esterification
B   condensation
C   polymerisation
D   dehydration

1+1+1 = 3 marks

b. The ester formed must be distilled in order to isolate it as a pure substance. Explain the meaning of the term "distillation" indicating how this process can be used to isolate your ester in pure form.

_____

_____

_____

_____

_____

2 marks

c. Palmitic acid forms a component of an important biological ester referred to as a triglyceride.

(i) Draw the structural formula for the triglyceride that consists of palmitic acid chains.

(ii) Give an equation to represent the production of a biodiesel fuel from palmitic acid.

_____

_____

_____

2+ 2 = 2 marks

Total 9 marks

QUESTION 6

a. The graphs below illustrate the activity of an enzyme as a function of pH and temperature.

(i) In which regions on the graphs has protein denaturation occurred? Circle the appropriate answer(s) below.

A   **B**   **C**   **D**
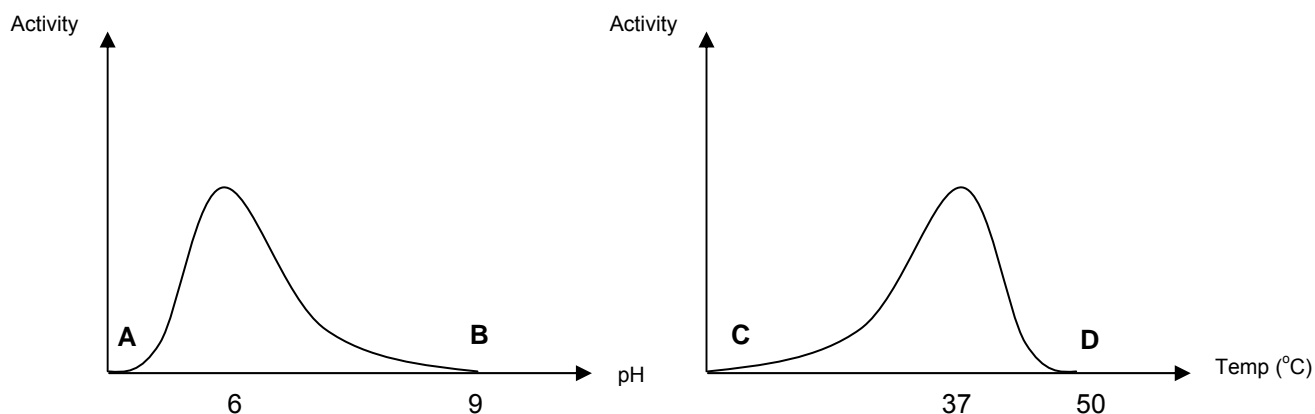
(ii) Explain why the catalytic function of an enzyme molecule is dependent on the way the molecule is folded.

_____

_____

_____

_____

_____

1+2 = 3 marks

Enzymes are made from long chains of amino acids which join together via condensation reactions.

b. (i) Write an equation to represent the condensation of alanine and proline to form the dipeptide Ala-Pro.

(ii) Circle the functional group(s) in this dipeptide.

2 + 1 = 3 marks

c. A polypeptide chain is illustrated below.
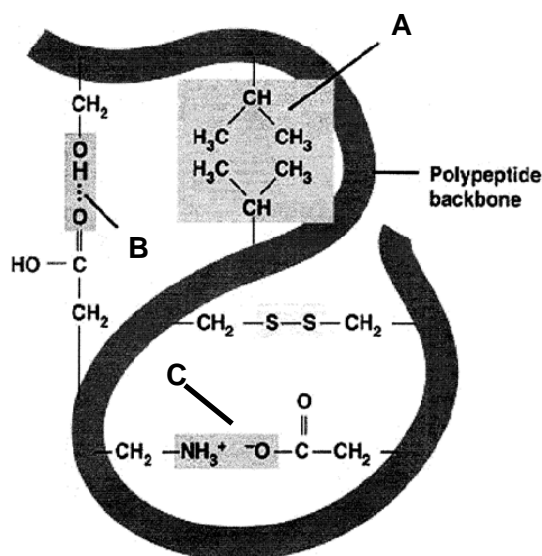
Name the bond and the level of protein structure (primary, secondary or tertiary) at:

(i) A: _____

(ii) B: _____

(iii) C: _____

1+ 1+1 = 3 marks

Total 9 marks

QUESTION 7

The following structures represent some biologically important molecules.

A H_2NCHCH_3COOH

B $CH_3(CH_2)_{14}COOH$

C

D

E

F

G $NH_2CH_2CH_2COOH$

H $C_{12}H_{22}O_{11}$

I H_2O
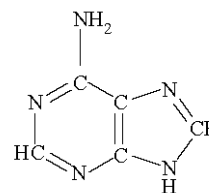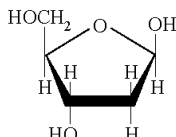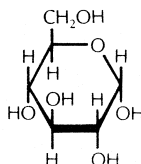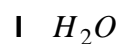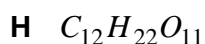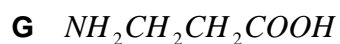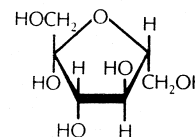
a. Circle the response(s) that best answer the questions below.

(i) Which molecule(s) could be used to form proteins in the human body?

A   B   C   D   E   F   G   H   I

(ii) Which structure(s) represent the product(s) of the hydrolysis of carbohydrates?

A   B   C   D   E   F   G   H   I

(iii) Which structure(s) represent the product(s) of the complete oxidation of fats?

A   B   C   D   E   F   G   H   I

(iv) Which structure would be covalently bonded to a phosphate unit in the DNA molecule?

A   B   C   D   E   F   G   H   I

1+1+1+1 = 4 marks

b. Molecule C forms a component of human DNA. This molecule forms specific bonds with another nitrogen containing compound on a complementary strand of DNA.
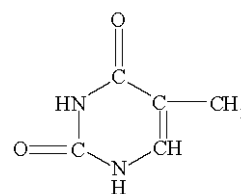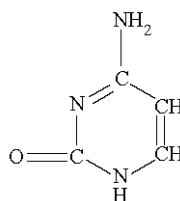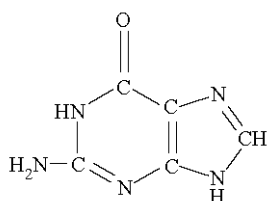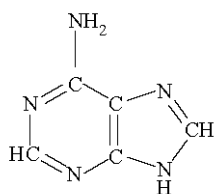
Molecule C

Circle the components directly involved in maintaining the secondary structure of DNA.
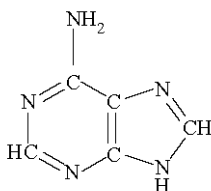
Complementary Base:

Identify the base which is complementary to Molecule C and circle the components of this molecule that are directly involved in maintaining the secondary structure of DNA with molecule C.


1+2 = 3 marks

c. When double stranded DNA samples are heated, the strands separate in a process known as "melting".

DNA melting is often used to detect sequence differences between different strands of DNA, as well as to obtain an indication of the relative amounts of each base in a DNA strand.

The % Melt for 3 different DNA strands at varying temperatures is given below. Assuming that the strands contain the same number of nucleotides, identify the curve (A, B or C below) that most likely represents the melt properties of a strand of DNA containing large amounts of Molecule C. Give a reason for your answer.

% Melt

_____

_____

_____

_____

_____
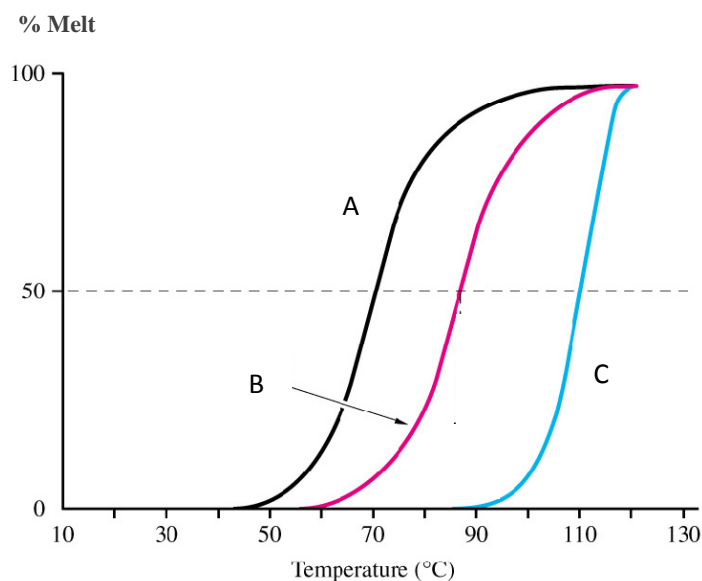
2 marks

Total 9 marks

End of Paper