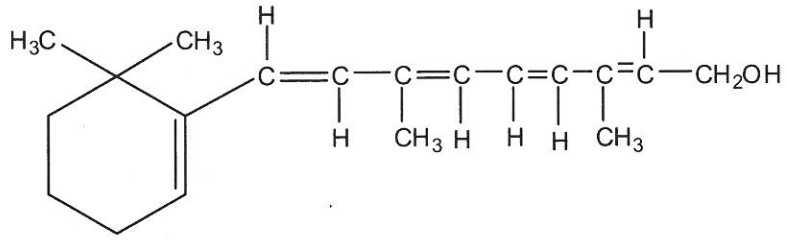
Chapter

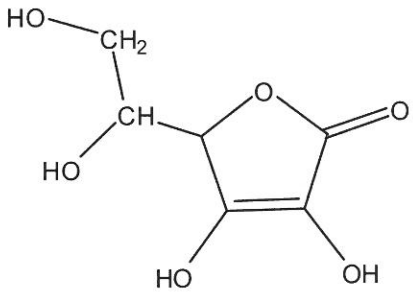
10 Organic Chemistry

1. [3 marks] *4.8 (2009:04)*

Examine the structures for vitamin A and vitamin C shown below.



Vitamin A



Vitamin C

Vitamin C is very soluble in water whilst vitamin A is sparingly soluble in water. (Vitamin A is fat soluble.)

Explain fully this difference in solubility.

2. [6 marks] *4.4 (2009:10)*

Draw the structure and give the IUPAC name of the organic compounds that match the following descriptions.

Show all atoms in the structure

(a) An amine containing 9 hydrogen atoms.

Structure	Name
	.....

(b) The product of the oxidation of pentan-2-ol

Structure	Name
	.....

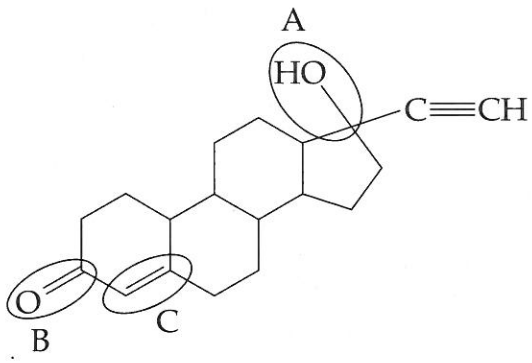
(c) A compound X has the molecular formula C_5H_8. When X is warmed with excess hydrogen in the presence of powdered nickel, it forms a compound with the molecular formula C_5H_{10}.

Give the structure and name of compound X.

Structure	Name
	.....

3. [3 marks] *4.4 (2009:11)*

The steroid norgestrel has the structure shown below. Name the class of compounds associated with each of the groups of atoms indicated.



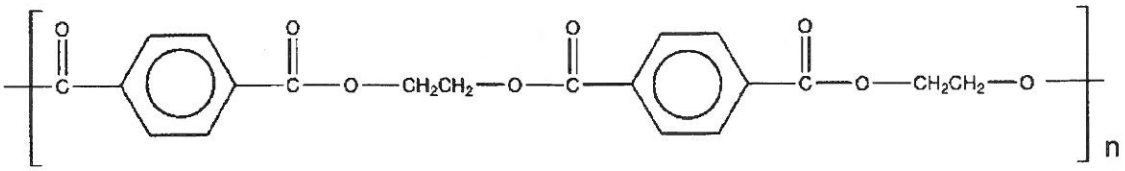
A _____

B _____

C _____

4. [3 marks] *4.10 (2010:31)*

Condensation polymers form from two monomers, each with functional groups at their terminal carbon atoms (that is, the monomers are difunctional). Examine the polyester structure below.



(a) Circle **all** the ester linkages (functional groups that link the monomers) represented in the above structure. [1]

(b) Identify the two monomer compounds (A and B) used in the production of this polymer and draw their molecular structures. [2]

Monomer A

Monomer B

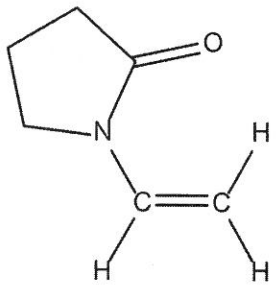
5. [6 marks] *4.6 (2011:30)*

Complete the table below by giving a brief description of a chemical test that could be used to distinguish between the substances listed. List the observations relating to the test for each of Substance 1 and Substance 2.

Substances to be distinguished		Description of chemical test	Observation with Substance 1	Observation with Substance 2
Substance 1	Substance 2			
butan-2-ol	2-methylpropan-2-ol			
methanol	methanal			

6. [2 marks] *4.10 (2011:31)*

Polyvinylpyrrolidone is a polymer with a wide range of applications including as a binder in tablets and hair styling agents. It is made from the monomer shown below.

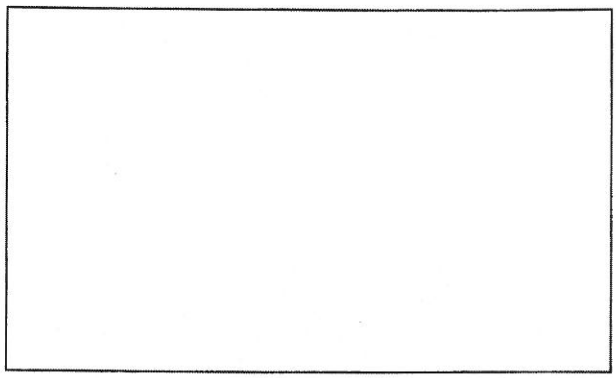


(a) Draw three units in the polymer formed from this monomer. [1]

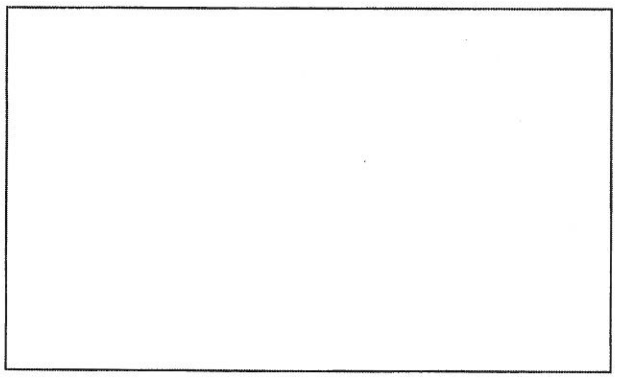
(b) What type of polymerisation reaction occurs to form the polymer from the above monomer? [1]

7. [13 marks] *(2011:32)*

(a) Draw the structure for, and write the name of, any five straight chain isomers for the compounds with the molecular formula C_5H_{10}. Show all atoms in the structures. 4.5 [10]



Name: _____



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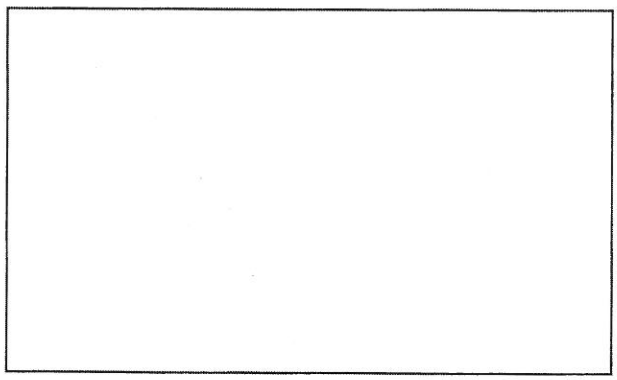

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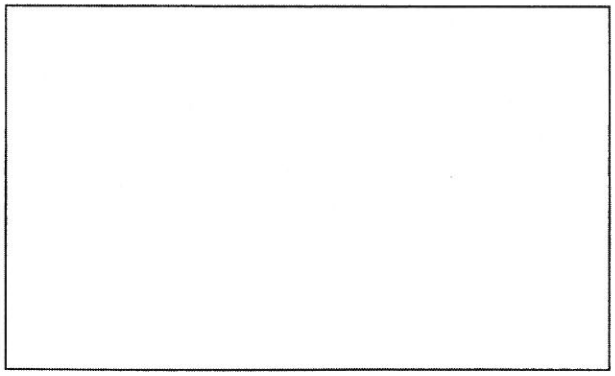

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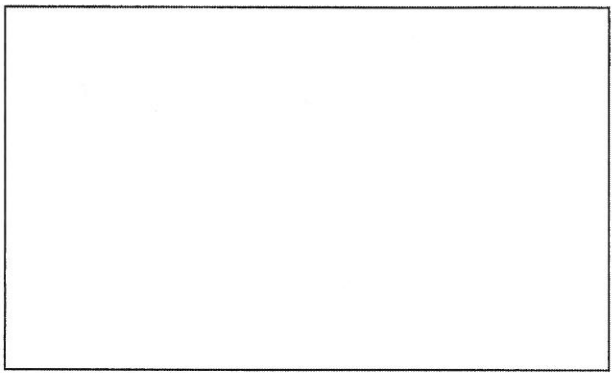

Name: _____

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(b) An organic compound is known to be an ester. Its molar mass is 74 g mol^{-1}.

(i) Draw the structural formula for the compound. Show all atoms in the structure. *4.7* [1]

(ii) Write the name for the compound you have drawn. *4.8* [1]

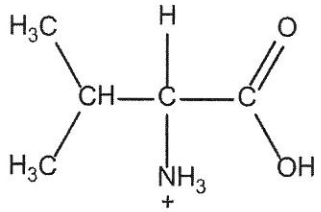
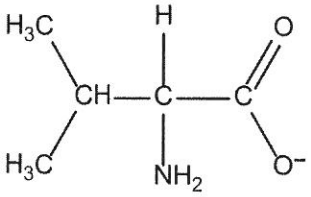
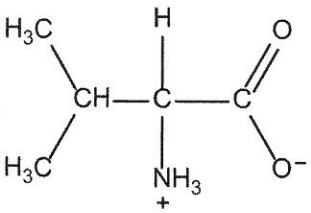
.....

(iii) What is the IUPAC name for a carboxylic acid that has the same molecular formula as the ester above? *4.8* [1]

.....

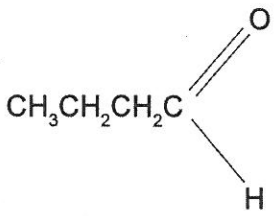
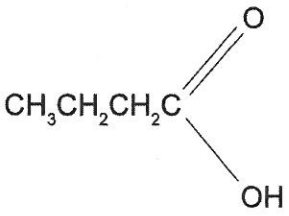
8. [3 marks] *4.15 (2011:33)*

Below are the structures for the amino acid valine under different pH conditions. In the spaces provided, give the approximate pH range (acidic, basic or neutral) under which each valine structure would exist.

Valine structure	pH range
	
	
	

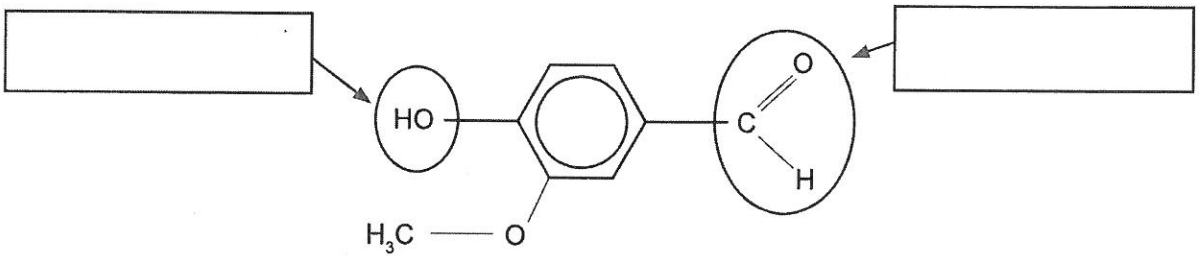
9. [4 marks] *4.8 (2012:27)*

Examine the data in the table below. Use your knowledge of intermolecular forces to explain the differences in boiling points of the three compounds listed in the table.

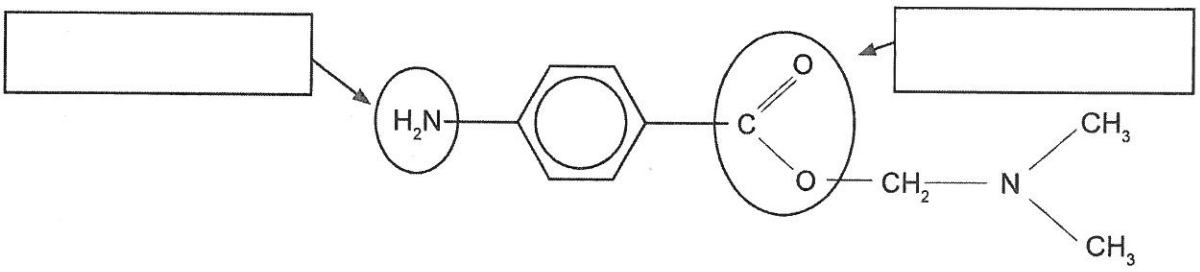
Compound	Structure	Molar mass ($g\ mol^{-1}$)	Boiling point (°C)
Butan-1-ol	$CH_3CH_2CH_2CH_2OH$	74.24	118
Butanal		72.22	75
Butanoic acid		88.22	163

10. [4 marks] *4.1 (2012:31)*

Examine the two compounds below. Compound 1 is the naturally occurring flavouring agent vanillin. Compound 2 is the local anaesthetic procaine. Name the functional groups circled in these two compounds.



Compound 1: Vanillin

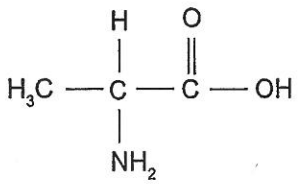


Compound 2: Procaine

11. [8 marks] *(2013:34)*

(a) The chemical formula of the α-amino acid glycine is $C_2H_5NO_2$. Draw the structure of glycine, showing all atoms. *4.14* [1]

(b) The structure for the α-amino acid alanine is given below.



Give the structure for alanine under acidic, neutral and basic conditions by completing the table below. *4.15* [3]

pH	Structure of alanine
acidic	
neutral	
basic	

(c) When crystallised from a neutral solution, alanine exists as a white crystalline solid. The solid has a melting point of 258°C. This contrasts with a melting point of –47°C for 2-methylpropanoic acid (molar mass 87 g mol^{-1}), a molecule of similar size to alanine. With reference to the appropriate structure in (b), explain why alanine has such a high melting point. *4.15* [4]

12. [9 marks] *(2014:33)*

(a) Methanoic acid, HCOOH, may be produced by oxidation of an alcohol with acidified potassium permanganate, MnO_4^-, solution.

Write the oxidation and reduction half-equations and the final redox equation for this reaction. *3.2* [5]

Oxidation half-equation	
Reduction half-equation	
Final redox equation	

(b) Methanoic acid reacts with ethanol in the presence of sulfuric acid to produce a fruity smelling compound.

Write the balanced equation for the reaction of methanoic acid with ethanol. *4.7* [2]

(c) Draw the structural formula for the fruity smelling compound and give its IUPAC name. Show **all** H atoms in the structure. *4.4* [2]

Name: _____

13. [5 marks] *4.6 (2014:34)*

Alcohols can be classified as primary, secondary or tertiary.

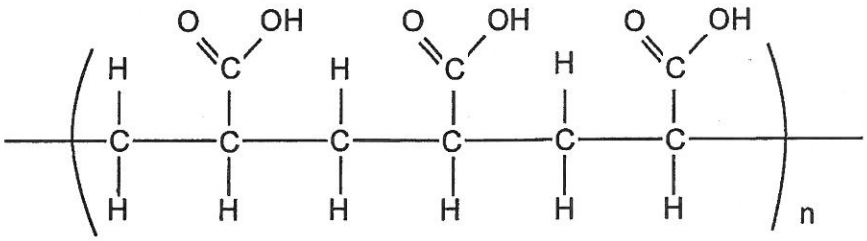
Complete the table below by drawing the structure for a primary alcohol, a secondary alcohol and a tertiary alcohol, each with the molecular formula $C_5H_{12}O$. Show **all** H atoms in your structures.

Give the IUPAC names for the primary and secondary alcohols you have drawn.

	Structure	**Name**
Primary alcohol		
Secondary alcohol		
Tertiary alcohol		**Name not required.**

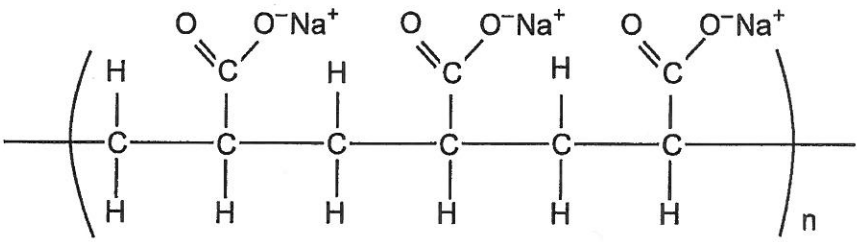
14. [4 marks] *(2014:35)*

(a) The structure below represents a segment of polyacrylic acid.



Draw the structure for the monomer of this addition polymer. *4.10* [1]

(b) The structure below represents sodium polyacrylate made by reacting polyacrylic acid with sodium hydroxide.



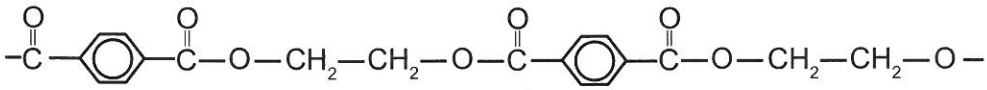
Sodium polyacrylate is a superabsorbent polymer that can absorb approximately 800 times its own weight in water. It is a white powder that swells when water is added. The sodium ions are removed from the polymer structure by interactions with water molecules and then other water molecules move into the swollen structure, where they are held.

(i) What is the name of the interactions occurring between water molecules and sodium ions to enable the removal of the latter from the polymer? *4.8* [1]

(ii) Explain how the polymer sodium polyacrylate can absorb large quantities of water. *4.8* [2]

15. [7 marks] *4.13 (2015:32)*

Dacron is the trade name for a common polyester used in making clothes and water bottles. Part of its structural formula is given below:



(a) Draw the structural formula for the **two** monomers that react to form this polymer. [2]

Monomer one:

Monomer two:

(b) Name the other product of this polymerisation reaction. [1]

(c) Predict and explain the effect on the polyester's rigidity and melting point as the polymer chains increase in length. [4]

16. [10 marks] *4.1, 4.7 (2015:34)*

Three different organic compounds were each tested with two reagents:
- acidified sodium permanganate solution and
- acidified propanoic acid.

Each organic compound has a molecular formula containing four carbon atoms, one oxygen atom and a number of hydrogen atoms.

The observations made are summarised in the following table.

Unknown organic compound	Reagent added	
	Acidified sodium permanganate solution	**Acidified propanoic acid**
1	no observable change	fruity smell
2	purple solution decolourises	no observable change
3	no observable change	no observable change

(a) Complete the table below, identifying the:
- functional group responsible for the observations made
- organic compound, by drawing its structural formula **or** giving its name. [6]

Unknown organic compound	Functional group	Structural formula or name of the organic compound
1		
2		
3		

(b) Draw the structural formula, showing all atoms of the organic product of the reactions of Compound 1 and Compound 2.

(i) Organic Compound 1 with the acidified propanoic acid. [2]

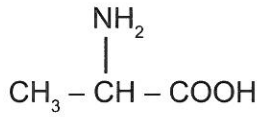
(i) Organic Compound 2 with the acidified sodium permanganate solution. [2]

17. [10 marks] *(2015:39)*

Amino acids are biologically-important organic compounds containing both amine ($-NH_2$) and carboxylic acid (-COOH) functional groups.

An important amino acid is 2-aminopropanoic acid; usually known as alanine. It is a component in more than a thousand different proteins, found in an array of foods and can be produced within the body.

Structural formula for alanine



(a) Alanine is an alpha (α) amino acid. State the structural feature of alanine that allows it to be classified as an **alpha** (α) amino acid. [1]

(b) Use the following information to demonstrate that the molecular formula of alanine is the same as its empirical formula.

When 1.86 g of alanine was vaporised at 550.0°C and 50.0 kPa pressure, it occupied a volume of 2.86 L. [4]

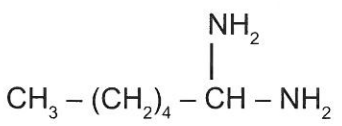
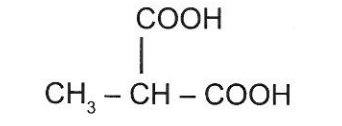
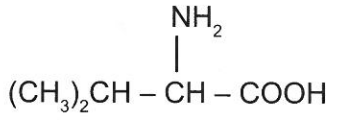
To consider the effect of having both an amine and a carboxylic acid functional group on the same molecule, amino acids can be compared with other organic compounds that have either:

- two amine functional groups on the same molecule (these compounds are called diamines)

or

- two carboxylic acid functional groups on the same molecule (these compounds are called dicarboxylic acids).

Amino acids have significantly higher melting points than diamines and dicarboxylic acids of similar mass and structure. This is illustrated in the table below.

Compound type	Example	Molar mass g mol^{-1}	Melting point °C
diamine	 hexane-1,1-diamine	116.2	39
dicarboxylic acid	 methylpropanedioic acid	118.09	184
amino acid	 2-amino-3-methylbutanoic acid (valine)	117.15	298

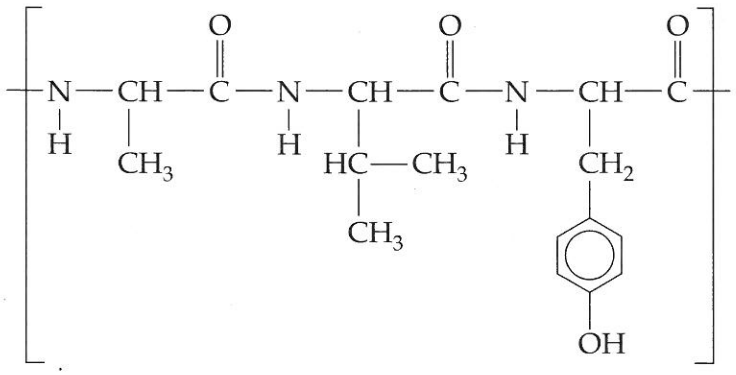
(c) Explain why amino acids form crystalline solids and have significantly higher melting points than other organic molecules of similar mass and structure. Refer to the information provided in the table above and include a labelled diagram using the amino acid valine to illustrate your answer. [5]

18. [3 marks] *4.8 (2016 SP:28b)*

Acetylsalicylic acid is a weak acid, and only partly ionises in water. It is poorly soluble in water, and far less soluble than a related compound, acetic acid (CH_3COOH). Explain why the water solubility of molecular acetylsalicylic acid is less than that of CH_3COOH.

19. [6 marks] *(2016 SP:31)*

Examine the structure below that represents a segment of the primary structure of insulin to answer the questions that follow.



(a) Circle **all** the peptide linkages (functional groups that link the monomers) represented in the above structure. *4.15* [1]

(b) Draw the molecular structures of the **three** α-amino acids that form this segment of insulin. *4.16* [3]

(c) The active form of insulin is made up of two polypeptide chains that contain five alpha helices. State the type of interactions that stabilises these secondary structures and the functional groups involved. *4.19* [2]

Type of interaction	Functional groups

20. [6 marks] *(2016 SP:33)*

Consider the following reactions and complete the tables that follow.

(a) An excess of butan-2-ol is oxidised by acidified $Na_2Cr_2O_7$ solution. *4.6* [3]

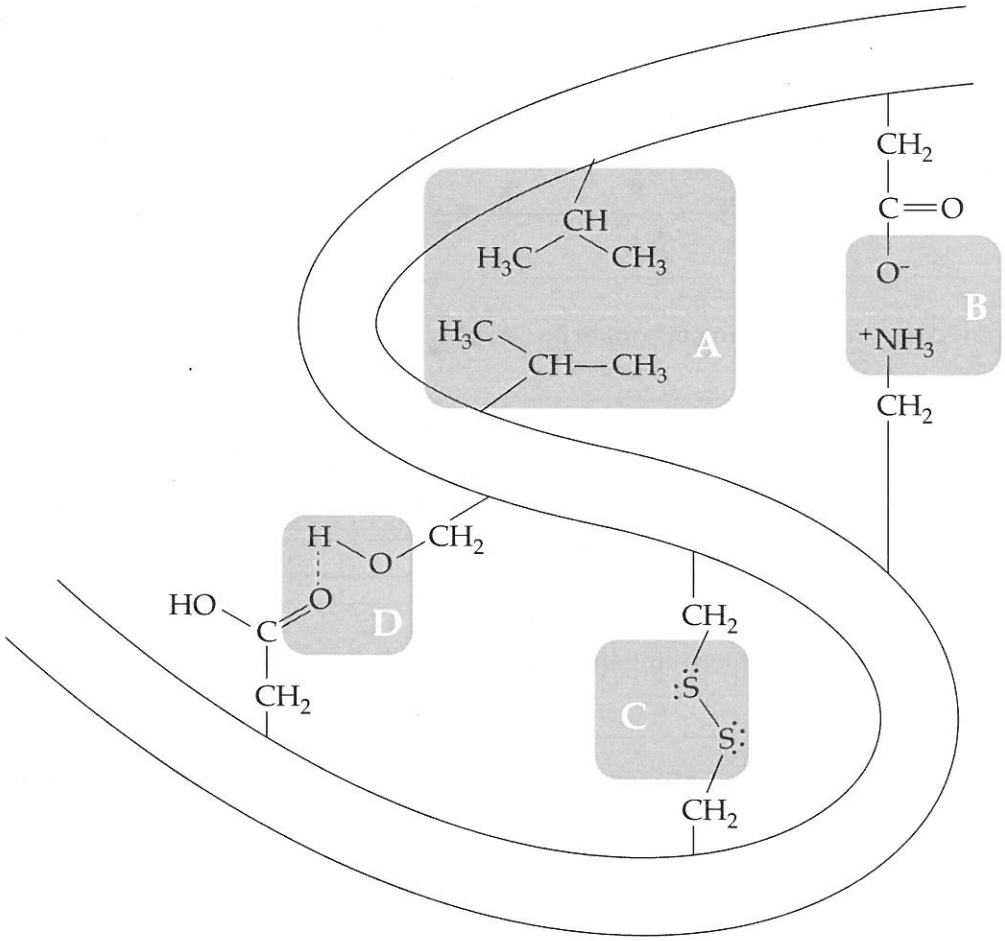
Observations	
Structural formula of organic product **(show all atoms)**	
Name of organic product	

(b) Butanoic acid reacts with methanol in the presence of concentrated H_2SO_4. *4.7* [3]

Observations	
Structural formula of organic product **(show all atoms)**	
Name of organic product	

21. [5 marks] *4.19 (2016 SP:36)*

The diagram below represents a segment of protein, showing the types of interactions that can occur between amino acid side chains to form the tertiary structure.



(a) Identify these types of interactions, labelled **A, B, C and D**, by completing the table below. [4]

Label	Type of interaction
A	
B	
C	
D	

(b) State what is meant by the 'tertiary structure' of a protein. [1]

22. [9 marks] *4.7 (2016:27)*

Write observations for the changes occurring when the substances below are mixed. In your answers include the appearance of the reactants and any product(s) that form.

(a) (i) methanol, pentanoic acid and sulfuric acid [2]

(ii) powdered magnesium carbonate and excess methanoic acid [2]

(iii) acidified potassium permanganate solution and excess propan-2-ol [2]

(b) Name the organic product and write the equation for the reaction when pentanal is added to a solution containing acidified sodium dichromate. [3]

Organic product: _____

23. [9 marks] *4.11 (2016:29)*

Addition and condensation polymers are used in industry to produce a vast range of plastics.

Select **one** addition polymer you have studied and use it to complete parts (a) to (c).

(a) Draw and name the structure of the monomer used to produce this polymer. [2]

Name: _____

(b) Draw and name the polymer, including at least **three** repeating units. [2]

Name: _____

(c) State **one** use for this polymer, making reference to its relevant property/ies. [2]

_____

_____

_____

_____

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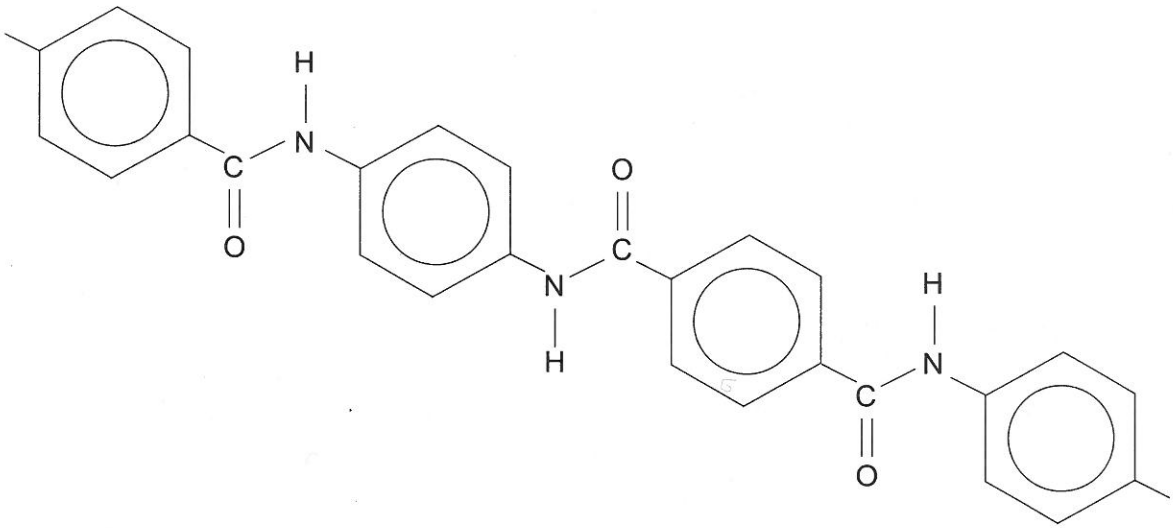
Kevlar is a condensation polymer utilised for its high strength. A section of the Kevlar polymer is drawn below.



(d) Draw the **two** monomers from which Kevlar is derived. [2]

Kevlar's high strength can be attributed in part to the hydrogen bonding that occurs between neighbouring chains. This is similar to a secondary structure of proteins.

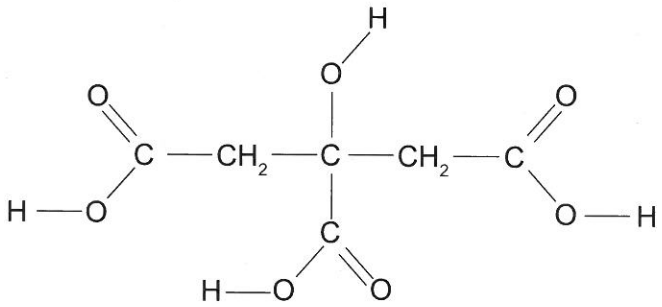
(e) To what secondary structure of proteins does this refer? [1]

24. [5 marks] *4.3 (2016:33)*

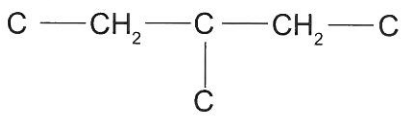
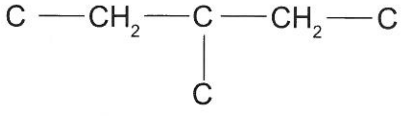
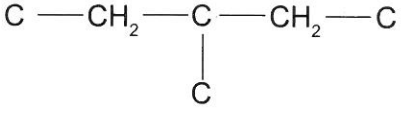
Citric acid, $C_6H_8O_7(aq)$, is a triprotic acid which reacts readily with solid sodium hydroxide, $NaOH(s)$.

(a) Write a balanced chemical equation for this reaction, showing all state symbols. [2]

The structure of $C_6H_8O_7$ is shown below.



(b) In the spaces below, complete the structures, showing **each** successive ionisation of the acidic hydrogen atoms. [3]

H^+ removed	**Structure**
First	
Second	
Third	

25. [9 marks] *4.8 (2016:35)*

For each of the three organic compounds identified in the table below:

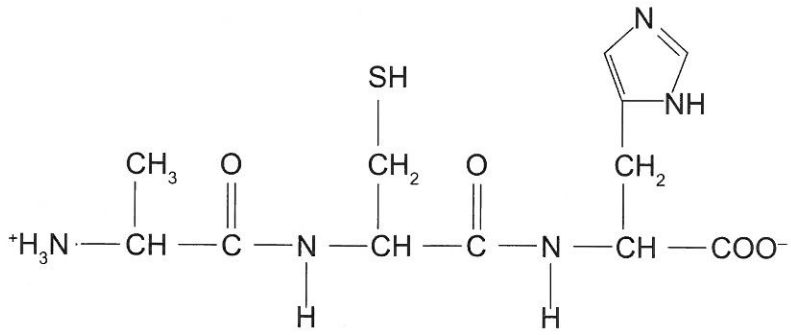
- use a structural formula to show the arrangement of **all** the atoms and **all** the bonds
- state **all** the intermolecular forces that exist between its molecules.

Organic compound	Full structural formula	All intermolecular forces
hexan-3-one		
1,1-difluoroethane		
butanamide		

26. [11 marks] *4.18 (2016:36)*

Condensation reactions will take place between different α-amino acids and results in them being joined by peptide bonds. Structures produced by two α-amino acids are called dipeptides, while those produced by three are called tripeptides.

(a) Below is the structure of a particular tripeptide.



(i) Circle the peptide bonds on the structure. [2]

(ii) Name the **three** α-amino acids that reacted to form this tripeptide. [3]

One: _____

Two: _____

Three: _____

(b) Using the symbols (abbreviations) for these three α-amino acids, give **one** other polypeptide that can be formed from them. [1]

_____

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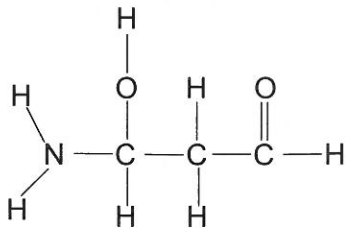
Alanine is one of the simplest examples of the twenty α-amino acids found in the human body. The structure below is an isomer of alanine.

(c) Circle and name each of the **three** functional groups on the isomer of alanine drawn below. [3]



(d) Draw a different isomer of alanine, showing clearly **all** atoms and **all** bonds. [2]

Isomer of alanine structure

27. [5 marks] *4.8 (2016:37)*

Pentane, pentanal and pentanoic acid all contain the same number of carbon atoms but display different physical properties. Their boiling points are given in the table below.

Organic compound	Boiling point (°C)
pentane	36.1
pentanal	102
pentanoic acid	186

Account for the difference in boiling points of the three compounds.