Advanced Subsidiary GCE Subject Chemistry B (Salters)

Unit F334: Chemistry of Materials - Medium banded Candidate style answer

Introduction

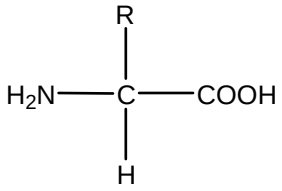
OCR has produced these candidate style answers to support teachers in interpreting the assessment criteria for the new GCE specifications and to bridge the gap between new specification release and availability of exemplar candidate work.

This content has been produced by senior OCR examiners, with the input of Chairs of Examiners, to illustrate how the sample assessment questions might be answered and provide some commentary on what factors contribute to an overall grading. The candidate style answers are not written in a way that is intended to replicate student work but to demonstrate what a "good" or "excellent" response might include, supported by examiner commentary and conclusions.

As these responses have not been through full moderation and do not replicate student work, they have not been graded and are instead, banded "medium" or "high" to give an indication of the level of each response.

Please note that this resource is provided for advice and guidance only and does not in any way constitute an indication of grade boundaries or endorsed answers.

1 A Japanese firm has marketed a range of clothes called 'amino jeans'. The garments are impregnated with arginine. The arginine softens and moisturises the wearer's legs. A simplified structure of arginine is shown below. R represents a carbon chain containing functional groups.

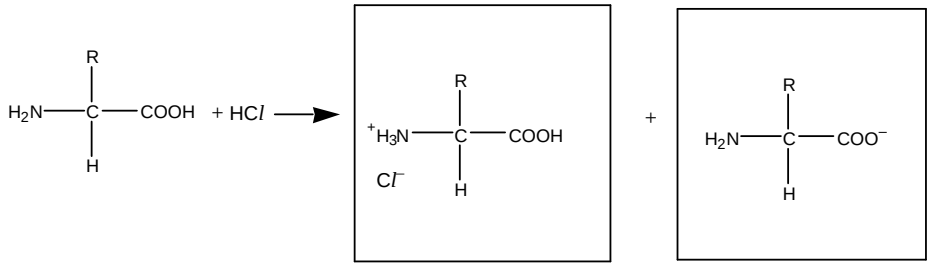


arginine

(a) What is the name for the group of compounds to which arginine belongs? [1]

Candidate style answer	*Examiner's commentary*
amino acid	Correct answer.

(b) Arginine is often used as a salt made by reacting arginine with hydrochloric acid. Complete the equation below to show the ions formed. [3]

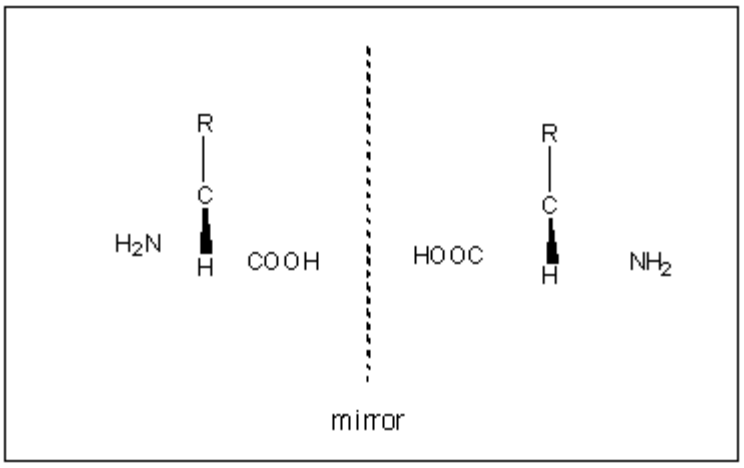
Candidate style answer	*Examiner's commentary*
	The contents of the left-hand box are the complete answer! However, the right hand box contradicts this as it implies that zwitterions are formed.

(c) Arginine forms two enantiomers.

(i) What structural feature causes arginine to have enantiomers? [1]

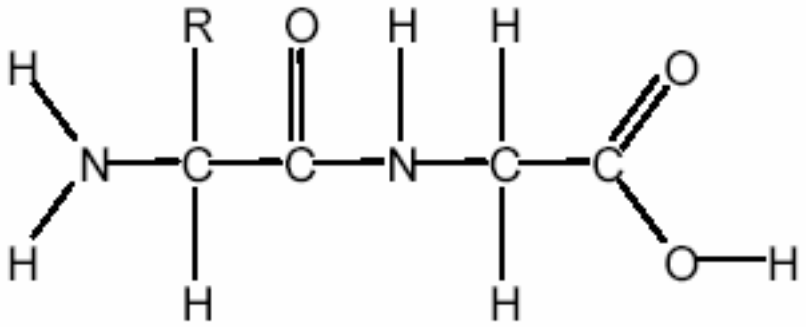
Candidate style answer	*Examiner's commentary*
they have an asymmetric carbon atom	Correct answer.

(ii) On the diagram below draw the three dimensional structures of the two enantiomers to show how they are related. [2]

Candidate style answer	*Examiner's commentary*
	Both parts are correct and score full marks.

(d) Arginine is one of the monomers used to make proteins.

Draw the full structural formula of the organic molecule formed when a molecule of arginine acts as a monomer and joins with a molecule of glycine, NH_2CH_2COOH to make a dimer. [2]

Candidate style answer	*Examiner's commentary*
	This is correct.

(e) Arginine is also a muscle relaxant.

Enzymes in the body cause the breakdown of arginine to form NO, and it is the NO which affects the muscles.

In the first step of this process, only one of the two enantiomers of arginine is affected by an enzyme. The optimum temperature of the enzyme reaction is body temperature.

(i) Describe how an enzyme can catalyse the breakdown of arginine. Using ideas of protein structure and reaction rates, explain why the enzyme has an optimum temperature for its activity and the enzyme will only catalyse the breakdown of one of the two enantiomers. [5]

Candidate style answer	*Examiner's commentary*
`Enzymes have active sights. Only one of the enantiomers will fit into this. At high temperatures the enzyme is killed off.`	Part **(i)** misses a lot of the detail. It scores for the active *site* (note spelling) and for the fact that only one enantiomer will fit. However, enzymes are not alive, so they cannot be killed; they are *denatured* by heat.

(ii) When arginine is at a low concentration, the enzyme catalysed reaction is first order with respect to arginine <u>and</u> first order with respect to the enzyme.

Write down the rate equation for this reaction and give the units of the <u>rate constant</u>. [3]

Candidate style answer	*Examiner's commentary*
rate equation: `= [arginine] [enzyme]` units of rate constant `mol dm3 s-1`	In part **(ii)** the rate equation has quite a bit missing, it should be *Rate = k [arginine] [enzyme].* What is written scores one mark. The units for the rate constant are not correct, they should be $mol^{-1}\ dm^3\ s^{-1}$.

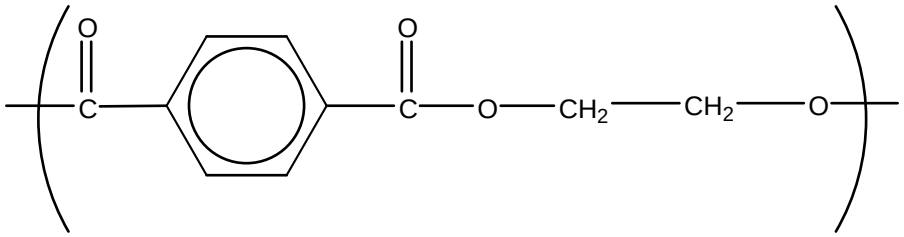
(iii) **At high concentrations of arginine, the order of the reaction with respect to arginine becomes zero.**

Describe a mechanism for this enzyme catalysed reaction which explains why the order of reaction depends on the concentration of arginine. **[4]**

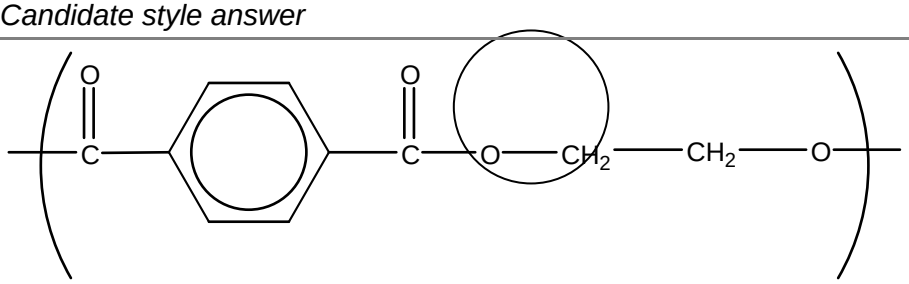
Candidate style answer	*Examiner's commentary*
`the enzyme becomes saturated with substrate, so the order is zero`	In part **(iii)**, there is a lot to say both about the first order part and the zero order. Just one of the latter marks is scored here.

2 **Non-returnable drinks bottles are often made from PET. This produces a huge problem for waste disposal. However, this polymer cannot be used to make returnable bottles.**

PET is a polyester. The repeating unit for PET is given below.



Draw a ring around the ester group in the repeating unit above. **[1]**

Candidate style answer	*Examiner's commentary*
	This is correct and scores the mark.

(b) **Plastic waste is often buried for disposal.**

Give two other methods which are used to deal with plastic waste and explain a different advantage for each method. **[4]**

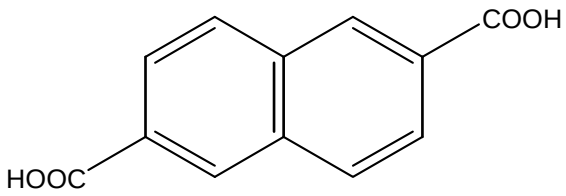
Candidate style answer	*Examiner's commentary*
`burying – this gets rid of the plastic waste` `recycling – this reuses the plastic and avoids landfill`	The first is just a repeat of the question. Be very careful not to do this as it never scores marks. The second is correct.

(c) PET is not used to make returnable bottles because its glass transition temperature, T_g, is too low.

Explain why lowering the temperature of PET below its T_g causes it to become brittle. **[3]**

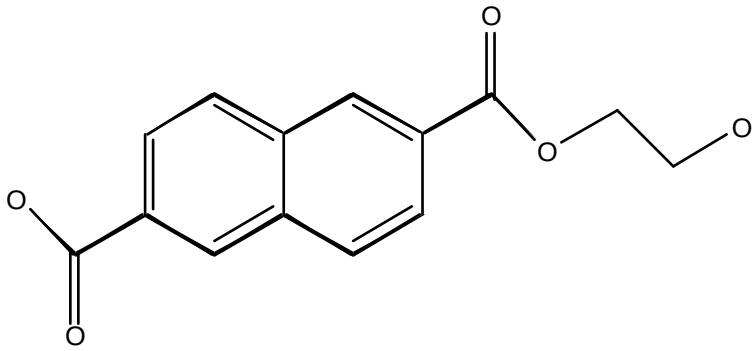
Candidate style answer	*Examiner's commentary*
below the T_g the chains are not able to slide over each other as the energy is too low.	This is not enough detail for full marks; in fact it scores two out of three. The other points that is required is that the structure will snap when a force is applied.

(d) Chemists have developed a new polyester which can be used for producing returnable bottles. It can be made from ethane-1,2-diol, $HOCH_2CH_2OH$, and compound A. The structure of compound A is shown below. The polymer is known as PEN.



compound A

(i) Draw the skeletal formula of the repeating unit of PEN. **[2]**

Candidate style answer	*Examiner's commentary*
	Part **(i)** is very nearly correct but the ester O is repeated on both sides of the structure.

(ii) PEN has a higher melting temperature than PET.

Assume both polymers have similar average relative molecular masses.

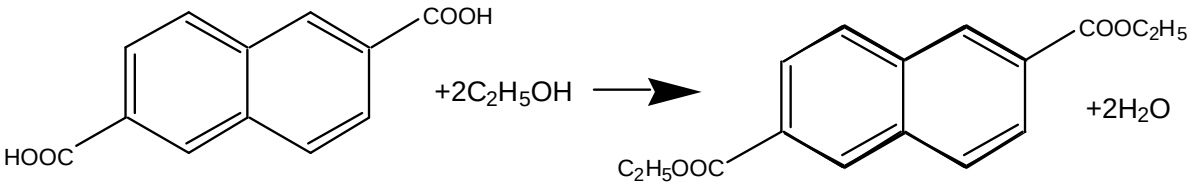
Suggest why PEN has a higher melting temperature than PET. **[2]**

Candidate style answer	*Examiner's commentary*
More energy is needed to soften the structure	Part **(ii)** is does not score any marks. The answer required was in terms of how the chains fitted together and the strength of the intermolecular bonds.

(iii) Explain how the infrared spectra of compound A and PEN would differ in one significant respect. Use the Data Sheet to look up any relevant absorbances you need. [2]

Candidate style answer	*Examiner's commentary*
there will be an O–H absorption in compound A at 2500-PEN has no O-H bond, so this will be missing	Part **(iii)** is correct.

(e) Industrially, PEN is made by reacting a diester of compound A with ethane-1,2-diol. The diester is made by reacting Compound A with with ethanol according to the equation below.



compound **A**

(i) What other chemical is added to an acid and alcohol mixture to make an ester in the laboratory? Give the conditions used. [2]

Candidate style answer	*Examiner's commentary*
concentrated sulfuric acid; reflux	Part **(i)** scores both marks.

(ii) Classify the reaction in which PEN is made by underlining one of the following reaction types.

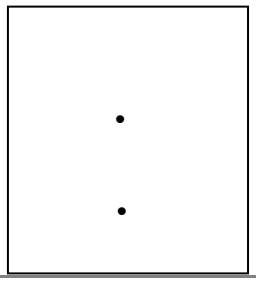
addition elimination rearrangement condensation [1]

Candidate style answer	*Examiner's commentary*
Condensation	Part **(ii)** scores the mark also.

(iii) Explain, using ideas of atom economy, why the polymerisation reactions in which PET and PEN are formed are less environmentally friendly than those in which poly(ethene) is made. [3]

Candidate style answer	*Examiner's commentary*
Addition reactions have 100% atom economy	Part **(iii)** is not sufficiently detailed, although it looks as though the candidate understands what is going on. There is no mention of the lower atom economy of a condensation reaction because of the water formed, nor is it clear that poly(ethene) is made by addition polymerisation.

(iv) Compound A and its diester can be distinguished by thin layer chromatography.
A spot of a mixture of the two is run on a tlc plate.
Draw a diagram of the resulting tlc plate showing the located spots.
Explain how you would measure the R_f values of the spots. [2]



Candidate style answer	*Examiner's commentary*
R_f value is distance moved by spot/distance to top of paper.	Part **(iv)** scores a mark for the two dots, but R_f is defined wrongly; it is distance moved by the spot/ distance moved by the solvent front.

3 Groundwater usually contains iron compounds and therefore water from wells will contain significant amounts of iron compounds. The main problem with household water containing iron compounds is the staining it causes to laundry, porcelain and plumbing fittings.

(a) Water containing iron in an oxidation state of +2 is known as 'clear water' since it appears colourless. However on leaving the tap it may become coloured and is then referred to as 'red water'. 'Red water' contains iron(III) compounds.

(i) Give the formula of the complex ion which causes the 'red' colour. [1]

Candidate style answer	*Examiner's commentary*
$[Fe]^{3+}$	Part **(i)** is not the formula of a complex ion, so it does not score.

(ii) What causes the colour change when clear water leaves the tap? [2]

Candidate style answer	*Examiner's commentary*
Fe^{3+} is formed from Fe^{2+}	Part **(ii)** is not sufficiently detailed to score any marks. The marks were for *oxidation* of Fe(II) to Fe(III) and the fact that oxygen in the air was responsible.

(iii) If the 'red water' is made slightly alkaline, for example by adding sodium hydroxide solution, a red-brown precipitate will form.
Write an ionic equation for the formation of the red-brown precipitate.
Include state symbols. [3]

Candidate style answer	*Examiner's commentary*
$Fe^{3+}(aq) + 3NaOH(aq) \rightarrow Fe(OH)_3(s) + 3Na^+(aq)$	Part **(iii)** is not completely correct since the NaOH should be shown as OH^- and the Na^+ should not be there. However, the mark-scheme allows the equation as written, so three marks are scored.

(b) 'Iron stains' contain iron(III) compounds and can be removed using a variety of products available in the supermarket. One commonly used chemical is ethanedioic acid. It is used in stain removers as the disodium salt.

(i) Draw the full structural formula of the ethanedioate ion, $C_2O_4^{2-}$. [1]

Candidate style answer	*Examiner's commentary*
$^{-}O—O—C—C—O—O^{-}$	Part **(i)** is incorrect and does not score.

(ii) Ethanedioate ions in aqueous solution react with 'red water' to form green $[Fe(C_2O_4)_3]^{3-}$ ions.
Name the type of reaction. [1]

Candidate style answer	*Examiner's commentary*
`ligand exchange`	Part (**ii)** is correct.

(iii) Explain why a green substance looks green. [2]

Candidate style answer	*Examiner's commentary*
`it absorbs light and then emits green`	Part (**iii**) does not score as it does not say what is absorbed (the complementary colour to green). Also, green light is not *emitted*, it is *transmitted* or *reflected.*

(c) Iron stains can be removed by adding a solution of a suitable reducing agent.
Use the data in the table below to identify a reducing agent which can reduce iron(III) ions under standard conditions. Explain your answer and write an equation for the reaction that occurs. [4]

half-reaction	**$E^{\ominus}$ / V**
$SO_4^{2-} + 2H^+ + 2e^- \rightarrow SO_3^{2-} + H_2O$	**-0.93**
$Fe^{3+} + e^- \rightarrow Fe^{2+}$	**+0.44**
$2H^+ + O_2 + 2e^- \rightarrow H_2O_2$	**+0.68**

Candidate style answer	*Examiner's commentary*
SO_3^{2-} `will reduce` Fe^{3+} `ions. This is because of the anticlockwise circle rule.` $Fe^{3+} + SO_4^{2-} + 2H^+ \rightarrow SO_3^{2-} + H_2O + Fe^{2+}$	The choice of the reducing agent is correct and scores the first mark. However, the reason given is just a 'rule of thumb' that some people use and it does not explain anything, so it does not score. Some statement like 'electrons will flow from the SO_4^{2-}/ SO_3^{2-} electrode to the Fe^{3+}/Fe^{2+} electrode' is needed. The equation has the correct reagents and products, so it scores one mark, but it is not balanced, so it does not score the second.

4 Hydrogen peroxide is a mild oxidising agent which is used in the restoration of oil paintings. Paintings darken over time as some of the metal ions in the paints react with atmospheric pollutants. Hydrogen peroxide can be used to convert these unwanted dark coloured compounds to white products.

(a) Write down the half-equation (ion-electron equation) for hydrogen peroxide, H_2O_2, acting as an oxidising agent. This reaction takes place in acid solution and water is the only product. [2]

Candidate style answer	*Examiner's commentary*
$H_2O_2 + 2H^+ + 2e^- \rightarrow 2H_2O$	This is correct.

(b) The concentration of an H_2O_2 solution can be found by titration of samples of this with aqueous potassium manganate(VII) of known concentration using acidic conditions.

(i) Describe how this titration would be carried out. Give clear experimental details and state how the end point is determined.
In your answer, you should use appropriate technical terms, spelt correctly. [7]

Candidate style answer	*Examiner's commentary*
The hydrogen peroxide is measured out using a pipette into a conical flask containing acid. Potassium manganate(VII) is placed in a burette and run into the flask until the solution goes clear. The manganate is added drop by drop as the end point is approached. The titration is repeated several times until concordant results are obtained.	This is a good answer. The end-point details are wrong; the solution goes from colourless to pink when the manganate(VII) is in excess. Another mark is lost for not specifying that sulfuric acid must be used.

(ii) 25.0 cm^3 of a concentrated solution of hydrogen peroxide is diluted to 250 cm^3. 10.0 cm^3 of this diluted H_2O_2 reacted with exactly 17.2 cm^3 of 0.0200 mol dm^{-3} MnO_4^- solution.

The equation for the reaction taking place is given below.

$$2MnO_4^-(aq) + 6H(aq) + 5H_2O_2(aq) \rightarrow 2Mn^{2}(aq) + 8H_2O(l) + 5O_2(g)$$

Calculate the concentration of the <u>concentrated</u> H_2O_2 solution.

Give your answer to an <u>appropriate number</u> of significant figures. [4]

Candidate style answer	*Examiner's commentary*
moles MnO_4^- = 17.2 x 0.02/1000 = 3.44 x 10^{-4} moles H_2O_2 = 3.44 x 10^{-4} concentration 3.44 x 10^{-4} x 1000/10 = 0.034 mol dm^{-3}	Part **(i)** scores one mark for the calculation of the moles of manganate(VII). However, the candidate does not multiply by 5/2 (the mole ratio from the equation). The fact that 10 cm^3 of a solution was used has been taken into account but the candidate has overlooked the fact that a *diluted* solution was used and these two ideas were tied together. The answer is also not given to three significant figures.

(iii) **The concentration of the hydrogen peroxide solution used for treating paintings must not be greater than 3.0 %. Assume this means 3.0 g of H_2O_2 in 100 cm^3 of solution.**

Is the undiluted solution of H_2O_2 suitable to be used for treating paintings?

Show your working. **[2]**

Candidate style answer	*Examiner's commentary*
30/34 moles in 1 dm^3 = 0.88 This is bigger than 0.034 so the solution is suitable.	Part **(ii)**, however, is correct, with error carried forward from part **(i)**, so both marks are scored.

(c) **Restorers of paintings are instructed to make up the solutions of hydrogen peroxide in a polythene bottle with pure water rather than tap water.**
Traces of transition metal ions, such as Fe^{2+}, present in tap water, can catalyse the decomposition of hydrogen peroxide.

(i) **Write the equation for the decomposition of hydrogen peroxide into water and oxygen. Give the state symbols.** **[1]**

Candidate style answer	*Examiner's commentary*
$H_2O_2(aq) \rightarrow H_2O(l) + 1/2\ O_2(g)$	Part **(i)** is correct and scores the mark.

(ii) **The decomposition of hydrogen peroxide is a redox reaction.**
Explain how Fe^{2+}(aq) ions can catalyse a redox reaction in aqueous solution. **[3]**

Candidate style answer	*Examiner's commentary*
Fe^{2+} has another oxidation state and so can act as a catalyst.	Part **(ii)** is too vague and does not score any marks.

(iii) **A solution of hydrogen peroxide stored in a glass bottle at room temperature was found to be completely decomposed after two weeks.**
Describe an experimental procedure you could use to measure the oxygen produced when hydrogen peroxide decomposes.
Show how you would use your results to find the initial rate of the reaction. **[3]**

Candidate style answer	*Examiner's commentary*
measure the volume of oxygen produced in a gas syringe; plot a graph. Measure the slope of the graph, which is the initial rate.	Part **(iii)** scores one mark for the method of collection but then fails to say what is plotted against what and the fact that it is the slope at the origin that gives the initial rate.

(iv) **The reaction is found to be first order with respect to hydrogen peroxide with a rate constant of 2.0×10^{-6} s^{-1} at 298K.**

Calculate the rate of decomposition of a 2.0 mol dm^{-3} hydrogen peroxide solution at 298 K. **[2]**

Candidate style answer	*Examiner's commentary*
Rate = $2.0 \times 10^{-6} \times 2 = 4 \times 10^{-6}$ mol dm^3 s^{-1}	Part **(iv)** scores both marks.

5 **Now that chemists have unlocked the significance of the DNA structure and developed experimental methods, DNA technology is being used by people tracing their family histories.**

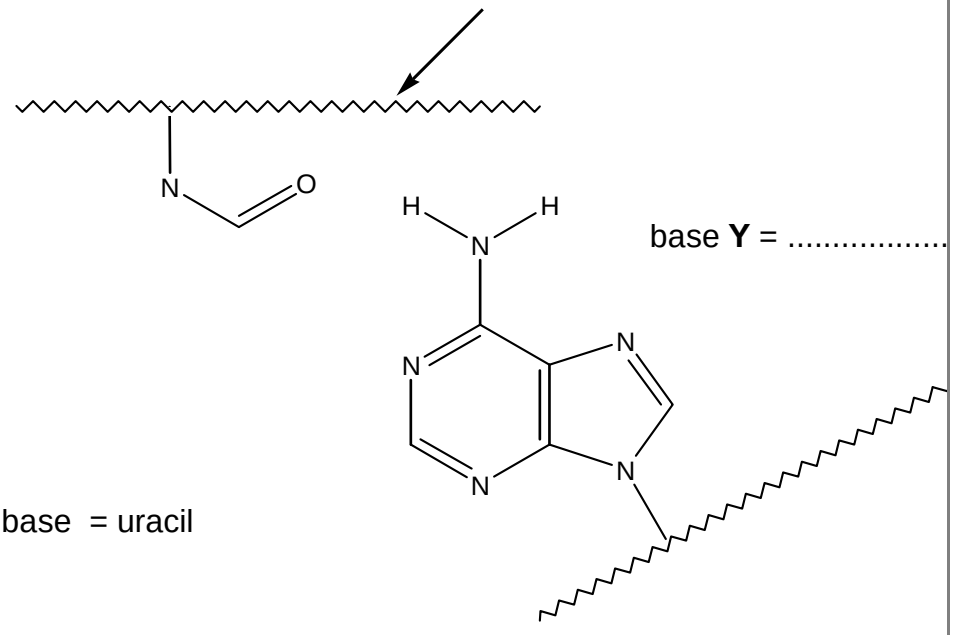
DNA is a polymer made from monomers called nucleotides.

Nucleotides consist of a base joined to a sugar joined to a phosphate group.

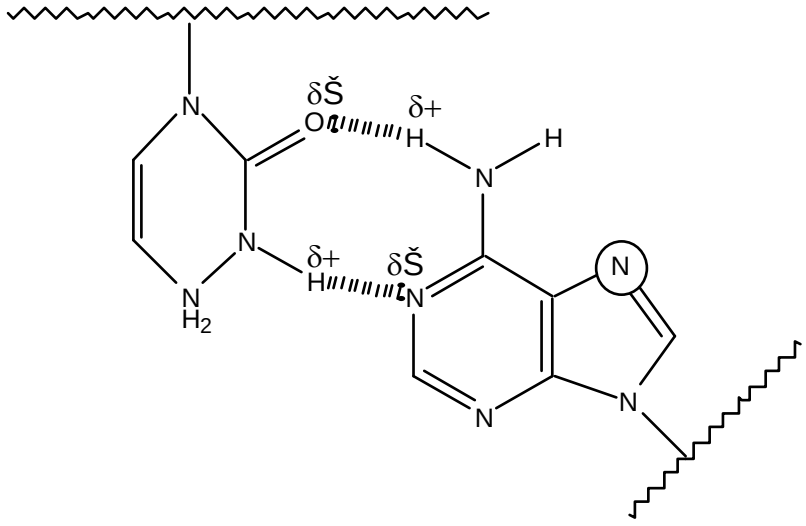
(a)(i) **DNA is formed from two polynucleotide chains. These chains are held together by hydrogen bonds between base units on adjacent chains. On the diagram below:**

- **use the data sheet to name the base Y and complete the structure of uracil,**
- **show clearly the hydrogen bonds between the bases including any relevant lone pairs and partial charges.**

[4]

Candidate style answer	*Examiner's commentary*
sugar in backbone = ...  base = uracil	Part **(i)** scores some marks. The structure of uracil has not been completed correctly but the hydrogen bonds have been correctly identified with lone pairs and partial charges shown.

(ii) One the diagram of the base Y above, circle the atom which enables it to act as a base.
Explain how the atom acts as a base. [3]

Candidate style answer	*Examiner's commentary*
 base Y = adenine it reacts with acids	In part **(ii)**, the wrong nitrogen has been ringed; it should be the NH_2 one. The answer then does not mention the lone pair accepting a proton, so no marks are scored.

(iii) What is the shape of a DNA molecule? [1]

Candidate style answer	*Examiner's commentary*
helical	Part **(iii)** is incomplete; *double helix* is the required answer to score the mark.

(b) The model of DNA discussed in (a) was first described by Watson and Crick in 1953. Before 1953 several other models of DNA had been published by other scientists.
Suggest a reason why after 50 years scientists are still using Watson and Crick's model for DNA. [1]

Candidate style answer	*Examiner's commentary*
it fits what is known about DNA	This is one of many possible answers and scores the mark.

Overall banding: Medium

The candidate has usually made the most of a respectable understanding of the chemical ideas. There are occasions, however, where more marks could have been scored by reading the question carefully and giving more detail.