Advanced Subsidiary GCE Subject Chemistry B (Salters)

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

Introduction

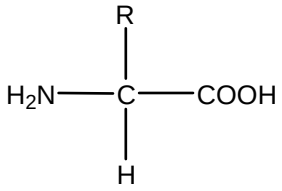
OCR has produced these candidate style answers to support teachers in interpreting the assessment criteria for the new GCE specifications and to bridge the gap between new specification release and availability of exemplar candidate work.

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.

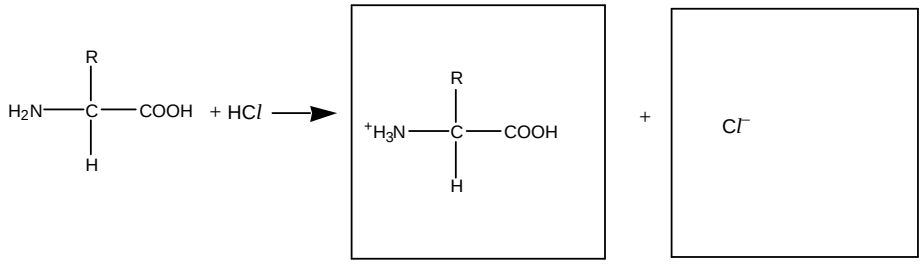


arginine

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

Candidate style answer	*Examiner's commentary*
`amino acid`	Correct, scores the mark.

(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]

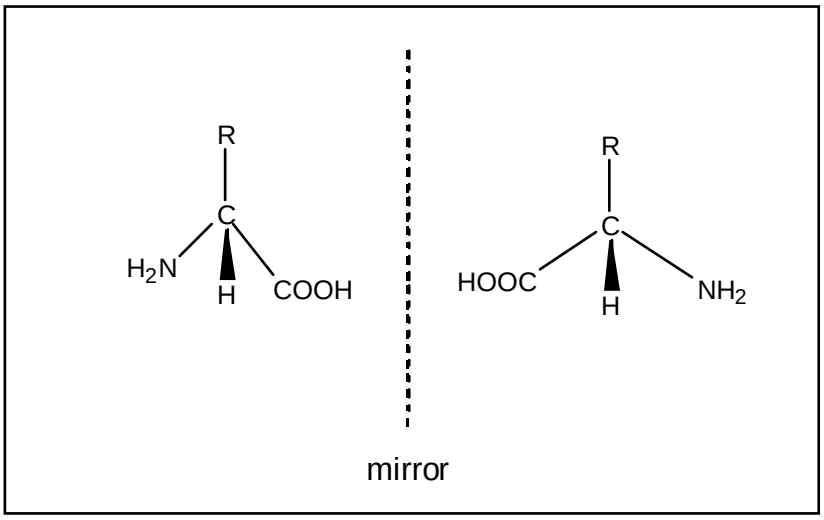
Candidate style answer	*Examiner's commentary*
	This is completely correct.

(c) Arginine forms two enantiomers.

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

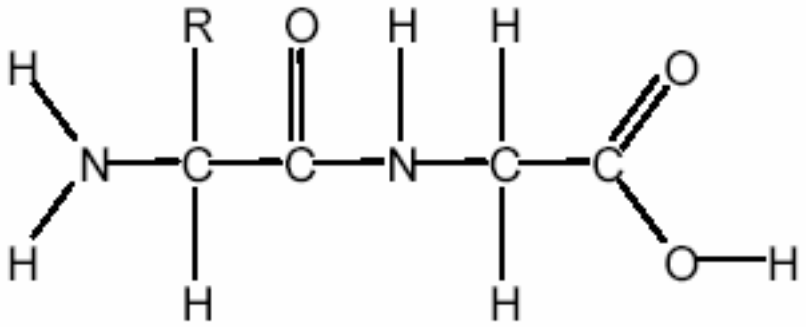
Candidate style answer	*Examiner's commentary*
`they exist as non-superimposable object and mirror image`	Part **(i)** is correct chemistry but it does not answer the question. The question asks for the *structural feature,* which is a chiral centre or asymmetric carbon atom.

(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*
	In part **(ii)** a mark is scored for the mirror images but the structures have not been shown as fully three-dimensional, so the other mark is not scored. Some 'dotted' bonds (going into the paper) should also be shown).

(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 and scores two marks.

(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*
Enzyme reactions take place at an active site. Only one of the enantiomers will fit into the active site, so that the activation enthalpy is lowered. At high temperatures, hydrogen bonds are broken, so that the active site is destroyed.	Part **(i)** is quite a good answer, but it does not score full marks. The vital marking point missing is that the active site has a definite shape. This is possibly implied, but not clearly stated.

(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: Rate = k[arginine] [enzyme] units of rate constant: s^{-1}	Part **(ii)** has a correct rate equation and scores two marks but the units for the rate constant are wrong, so the third mark is not scored. The units are $dm^3\ mol^{-1}\ s^{-1}$.

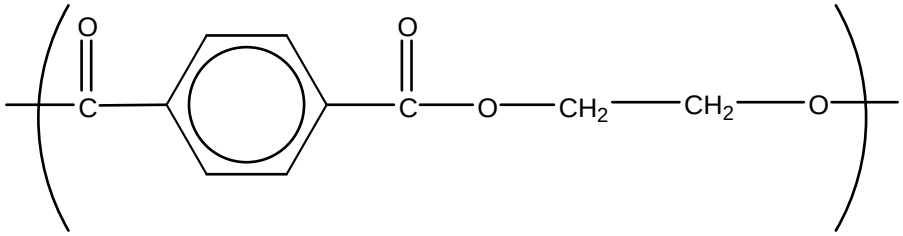
(iii) At high concentrations of arginine, the order of the reaction with respect to arginine becomes zero.

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

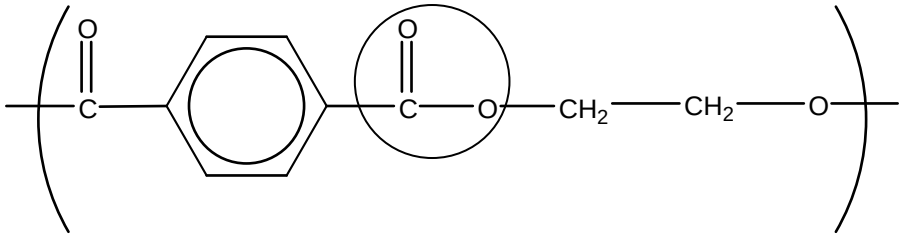
Candidate style answer	*Examiner's commentary*
`first order at low substrate concentration but zero order at high substrate concentration since all enzyme sites are full`	Part **(iii)** is a bit short for a four-mark answer and only scores one mark, for reference to the sites being full. The other three marks are for explanations of the first order behaviour and detail of why the full enzyme sites make the order zero.

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]

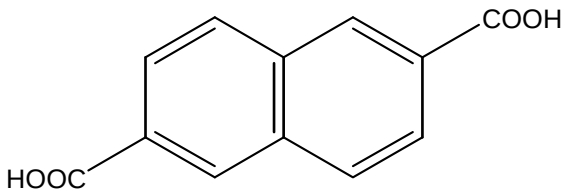
Candidate style answer	*Examiner's commentary*
`burning – this produces useful energy` `recycling – this reuses the plastic and avoids landfill`	These are correct.

(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]**

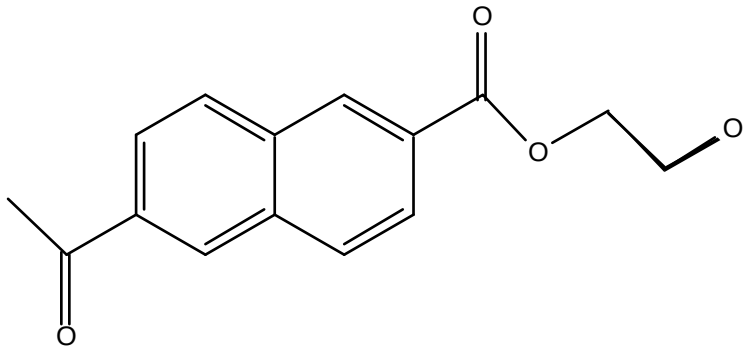
Candidate style answer	*Examiner's commentary*
below the T_g the chains are not able to slide over each other.	This is not enough detail for full marks. The other points that are required are that there is not enough energy for the chains to slide and that the structure will snap when a force is applied.

(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 correct.

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

Assume both polymers have similar average relative molecular masses.

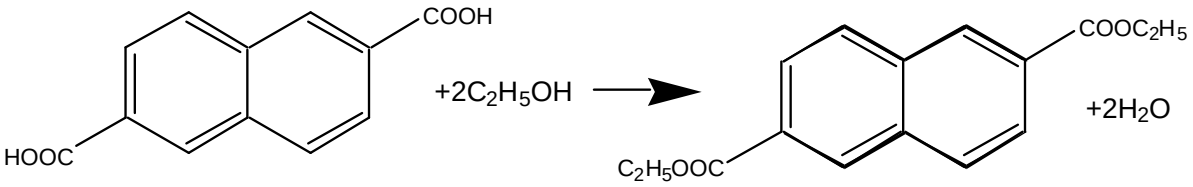
Suggest why PEN has a higher melting temperature than PET. **[2]**

Candidate style answer	*Examiner's commentary*
There are more intermolecular bonds in PEN and the chains can fit better together.	Part **(ii)** contains an error. The intermolecular bonds are *stronger* (not 'more') in PEN so this mark is not scored. The chains can fit better together (because of the flat aromatic structure) so the second mark is scored.

(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 2500-3200 which will be missing in PEN	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 sulphuric acid; heat	Part **(i)** scores both marks. Although the modern spelling of the acid is 'sulfuric', the candidate would not be penalised for writing 'sulphuric'.

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

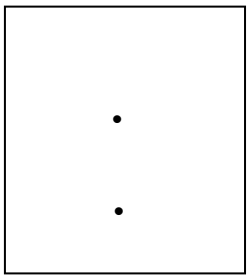
addition elimination rearrangement condensation [1]

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*
PET and PEN are made by condensation reactions where poly(ethene) is made by addition	Part **(iii)** is not sufficiently detailed. One mark is scored for distinguishing the reactions but the other two marks are for the fact that condensation reactions have lower atom economies (because of the water produced) than addition reactions, which have 100% atom economy.

(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 moved by solvent front.	Part **(iv)** scores both marks.

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*
$[Fe(H_2O)_6]^{3+}$	Part **(i)** is correct and scores full marks.

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

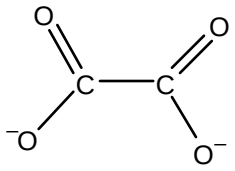
Candidate style answer	*Examiner's commentary*
the Fe^{2+} ions are oxidised to give Fe^{3+}	In part **(ii)**, the fact has been omitted that it is oxygen from the air which carries out the oxidation. The candidate might think that this fact is obvious, but must still be sure to write it down.

(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*
$Fe^{3+}(aq) + 3OH^-(aq) \rightarrow Fe(OH)_3(s)$	Part **(iii)** is correct.

(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*
	Part **(i)** is correct,

(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*
Substitution	Part **(ii)** is not full enough. The reaction, in the context of complex ions, must be described as *ligand substution* (or ligand exchange) to score.

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

Candidate style answer	*Examiner's commentary*
it reflects green light and absorbs the complementary colour	Part **(iii)** scores the two marks but it is rather brief. It would have been safer to give the complementary colour to green (red and/or violet)

(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 it is above it in the table. $2Fe^{3+} + SO_4^{2-} + 2H^+ \rightarrow SO_3^{2-} + H_2O + 2Fe^{2+}$	The choice of the reducing agent and the equation are fine. However, the reason given is weak and does not score. Some statement like 'electrons will flow from the SO42–/ SO32– electrode to the Fe3+/Fe2+ electrode' is needed.

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. Potassium permanganate is placed in a biuret and run into the flask until a faint pink colour just persists. The permanganate is added drop by drop as the end point is approached. The titration is repeated several times until concordant results are obtained.	This is quite a good answer. Marks are lost for the failure to mention adding sulfuric acid to the flask and for the incorrect spelling of *burette*.

(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 = 5/2 x 3.44 x 10^{-4} concentration = 5/2 x 3.44 x 10^{-4} x 1000/10 = 0.0860 mol dm^{-3}	There is just one mistake in part **(i)**. The candidate has failed to keep in mind that the original sample of hydrogen peroxide was diluted by a factor of 10, so the answer is ten times too small.

(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*
0.086 x 34 = 2.924 g per 1000cm^3 = 0.294 g per 100 cm^3 so it is suitable.	Part **(ii)** should thus give the answer 2.94 g per 100 cm^3 but the answer given is consistent, as is the comment that it is suitable.

(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*
$H_2O_2(aq) \rightarrow H_2O(l) + 0.5$	Part **(i)** is correct.

(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+} can be oxidised by one reagent to Fe^{3+} and then reduced back to Fe^{2+} by another.	Part **(ii)** is correct as far as it goes and scores two marks but, for the third mark, it is necessary to mention that the activation enthalpy for the new route is lower than for the catalysed reaction.

(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 of volume of oxygen against time. Measure the slope at the origin, which is the initial rate.	Part **(iii)** is correct.

(iv) **The reaction is found to be first order with respect to hydrogen peroxide with a rate constant of 2.0 x 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 x 10-6 x 2 = 4 x 10-6 mol dm3 s-1`	Part **(iv)** is correct.

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.**

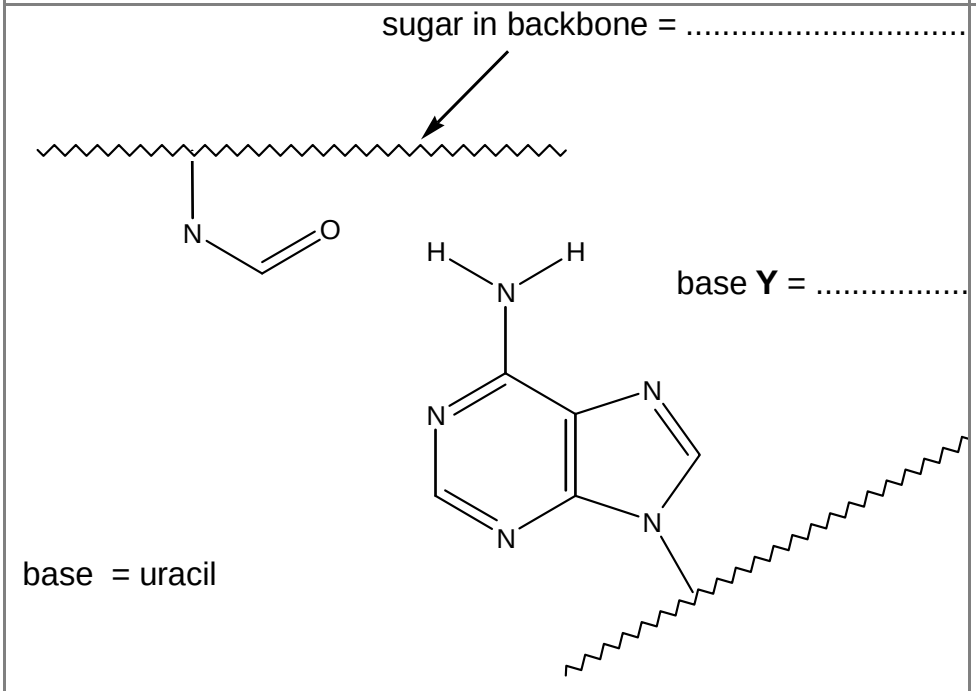
DNA is a polymer made from monomers called nucleotides.

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

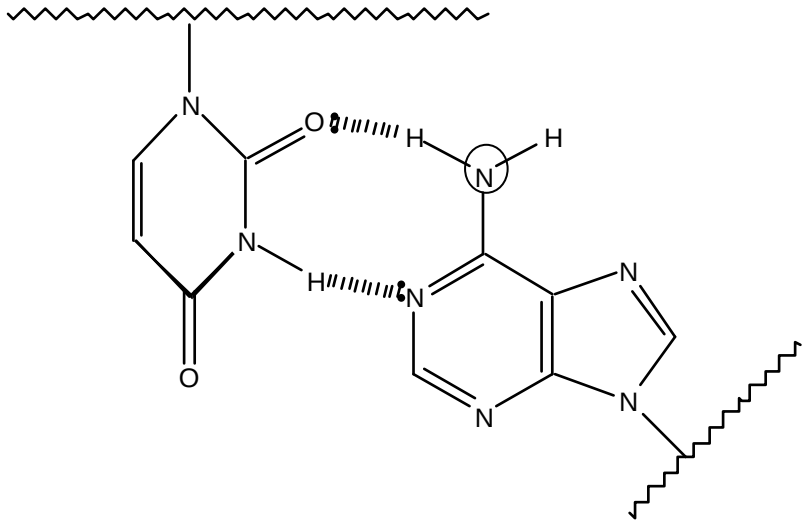
(a)(i) **DNA is formed from two polynucleotide chains. These chains are held together by hydrogen bonds between base units on adjacent chains. On the diagram below:**

- **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*
	Part **(i)** scores some marks. The structure of uracil has been completed correctly and adenine named correctly (from the Data Sheet). The hydrogen bonds have been correctly identified with lone pairs shown. The candidate has just forgotten to include the partial charges. If the question had been read again when the answer was thought to be complete, this would almost certainly have been spotted.

(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 acts as a base by accepting protons	In part **(ii)**, the correct nitrogen has been ringed but the answer omits the statement that it is the lone pair that accepts the proton.

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

Candidate style answer	*Examiner's commentary*
double helix	Part **(iii)** is correct.

(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 explains all the observations about DNA	This is one of many possible answers and scores the mark.

Overall banding: High

The candidate clearly understands most of the chemical ideas. Quite a few marks have been lost by not reading the question carefully and not giving the detail expected.