UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education Advanced Subsidiary Level and Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

5640244407

CHEMISTRY **9701/41**

Paper 4 Structured Questions **October/November 2009**

1 hour 45 minutes

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen.
You may use a pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Section A
Answer **all** questions.

Section B
Answer **all** questions.

You may lose marks if you do not show your working or if you do not use appropriate units.
A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
4	
5	
6	
7	
8	
9	
Total	

This document consists of **19** printed pages and **1** blank page.

Section A

Answer **all** questions in the spaces provided.

For Examiner's Use

1 **(a)** The Group IV oxides CO_2 and SiO_2 differ widely in their physical properties. Describe these differences and explain them in terms of their structure and bonding.

.....

.....

.....

..... [3]

(b) What are the properties of a *ceramic* material? Why is silicon(IV) oxide very suitable as a component of ceramics?

.....

.....

.....

..... [2]

(c) Lead(II) oxide reacts with both acids and bases.

(i) What is the name given to oxides that have this property?

.....

(ii) Write a balanced equation for the reaction between PbO and NaOH.

.....
[2]

(d) Tin forms an oxide, **A**, that contains the metal in both oxidation states II and IV. The formula of **A** can be found by the following method.

For Examiner's Use

- A sample of **A** was dissolved in $H_2SO_4(aq)$, producing solution **B**, which was a mixture of tin(II) sulfate and tin(IV) sulfate.
- A 25.0 cm^3 sample of solution **B** was titrated with 0.0200 mol dm^{-3} $KMnO_4$. 13.5 cm^3 of $KMnO_4$ was required to reach the end-point.
- Another 25.0 cm^3 sample of solution **B** was stirred with an excess of powdered zinc. This converted all the tin into tin(II). The excess of zinc powder was filtered off and the filtrate was titrated with 0.0200 mol dm^{-3} $KMnO_4$, as before. This time 20.3 cm^3 of $KMnO_4$ was required to reach the end-point.

The equation for the reaction occurring during the titration is as follows.

$$2MnO_4^- + 16H^+ + 5Sn^{2+} \longrightarrow 2Mn^{2+} + 8H_2O + 5Sn^{4+}$$

(i) Write a balanced equation for the reaction between Zn and Sn^{4+}.

.....

(ii) Use the *Data Booklet* to calculate the $E^{\ominus}$ values for the reactions between

- Zn and Sn^{4+}, ...
- MnO_4^- and Sn^{2+}. .....

(iii) Use the results of the two titrations to calculate

- the number of moles of Sn^{2+} in the first titration sample,

.....

.....

- the number of moles of Sn^{2+} in the second titration sample.

.....

.....

(iv) Use the results of your calculation in **(iii)** to deduce the Sn^{2+}/Sn^{4+} ratio in the oxide **A**, and hence suggest the formula of **A**.

.....

.....

.....

[8]

For Examiner's Use

(e) A major use of tin is to make 'tin plate', which is composed of thin sheets of mild steel electroplated with tin, for use in the manufacture of food and drinks cans. A tin coating of 1.0×10^{-5} m thickness is often used.

(i) Calculate the volume of tin needed to coat a sheet of steel 1.0 m × 1.0 m to this thickness, on one side only.

.....

.....

(ii) Calculate the number of moles of tin that this volume represents.
[The density of tin is 7.3 g cm^{-3}.]

.....

.....

.....

(iii) The solution used for electroplating contains Sn^{2+} ions. Calculate the quantity of electricity in coulombs needed to deposit the amount of tin you calculated in **(ii)**.

.....

.....

.....

[4]

[Total: 19]

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For Examiner's Use

2 Calcium chloride, $CaCl_2$, is an important industrial chemical used in refrigeration plants, for de-icing roads and for giving greater strength to concrete.

(a) Show by means of an equation what is meant by the lattice energy of calcium chloride.

..... [1]

(b) Suggest, with an explanation, how the lattice energies of the following salts might compare in magnitude with that of calcium chloride.

(i) calcium fluoride, CaF_2

.....

.....

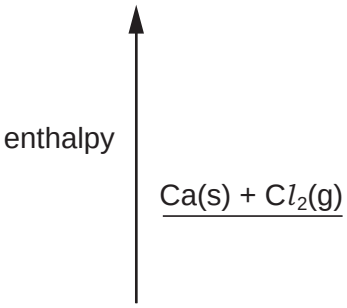
(ii) calcium sulfide, CaS

.....

..... [3]

(c) Use the following data, together with additional data from the *Data Booklet*, to calculate the lattice energy of $CaCl_2$.

standard enthalpy change of formation of $CaCl_2$	–796 kJ mol^{-1}
standard enthalpy change of atomisation of Ca(s)	+178 kJ mol^{-1}
electron affinity per mole of chlorine atoms	–349 kJ mol^{-1}



lattice energy = ... kJ mol^{-1} [3]

(d) When a solution of $CaCl_2$ is added to a solution of the dicarboxylic acid, malonic acid, the salt calcium malonate is precipitated as a white solid. The solid has the following composition by mass: Ca, 28.2%; C, 25.2%; H, 1.4%; O, 45.2%.

For Examiner's Use

(i) Calculate the empirical formula of calcium malonate from these data.

(ii) Suggest the structural formula of malonic acid.

[3]

[Total: 10]

For Examiner's Use

3 One major difference between the properties of compounds of the transition elements and those of other compounds is that the compounds of the transition elements are often coloured.

(a) Explain in detail why many transition element compounds are coloured.

.....

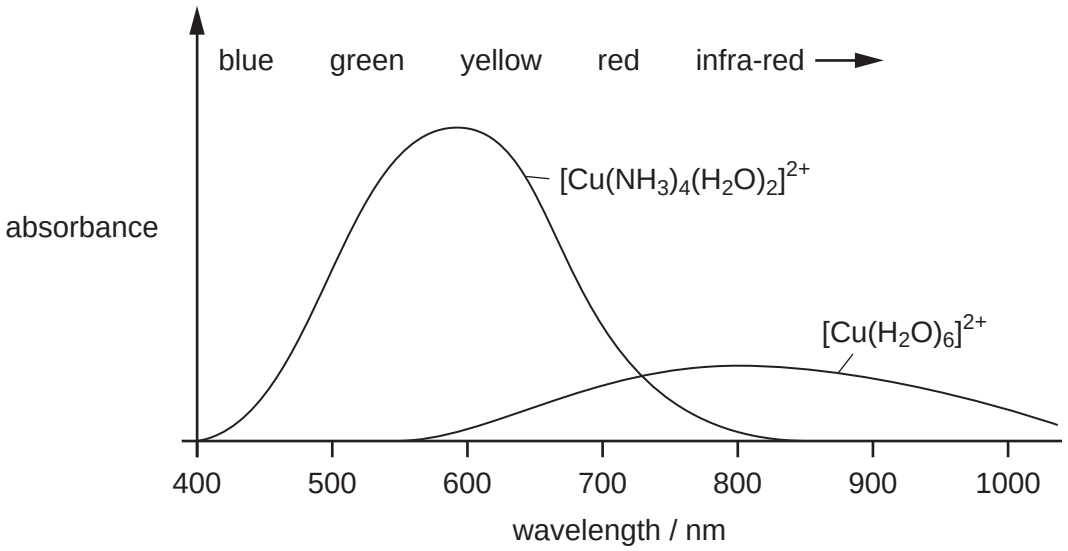
.....

.....

.....

..... [3]

(b) The following graph shows the absorption spectrum of two complexes containing copper.



(i) State the colours of the following complex ions.

$[Cu(H_2O)_6]^{2+}$ .....

$[Cu(NH_3)_4(H_2O)_2]^{2+}$ .....

(ii) Using the spectra above give **two** reasons why the colour of the $[Cu(NH_3)_4(H_2O)_2]^{2+}$ ion is deeper (more intense) than that of the $[Cu(H_2O)_6]^{2+}$ ion.

.....

.....

.....

(iii) Predict the absorption spectrum of the complex $[Cu(NH_3)_2(H_2O)_4]^{2+}$, and sketch this spectrum on the above graph. [6]

(c) Copper forms a complex with chlorine according to the following equilibrium.

For Examiner's Use

$$Cu^{2+}(aq) + 4Cl^{-}(aq) \rightleftharpoons [CuCl_4]^{2-}(aq)$$

(i) Write an expression for the equilibrium constant, K_c, for this reaction, stating its units.

K_c = ... units .....

(ii) The numerical value of K_c is 4.2×10^5.
Calculate the $[[CuCl_4]^{2-}]/[Cu^{2+}]$ ratio when $[Cl^-] = 0.20\,mol\,dm^{-3}$.

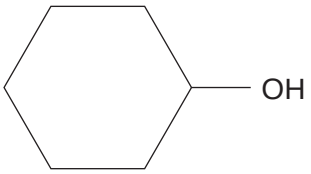
.....

.....
[3]

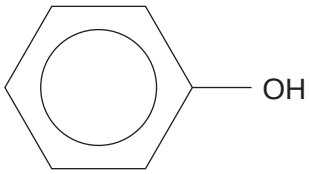
[Total: 12]

4 Cyclohexanol and phenol are both solids with low melting points that are fairly soluble in water.

For Examiner's Use



cyclohexanol



phenol

(a) Explain why these compounds are more soluble in water than their parent hydrocarbons cyclohexane and benzene.

.....

.....

..... [2]

(b) Explain why phenol is more acidic than cyclohexanol.

.....

.....

..... [2]

(c) For **each** of the following reagents, draw the structural formula of the product obtained for **each** of the two compounds. If no reaction occurs write ***no reaction*** in the box.

For Examiner's Use

reagent	product with cyclohexanol	product with phenol
Na(s)		
NaOH(aq)		
Br_2(aq)		
I_2(aq) + OH^-(aq)		
an excess of acidified $Cr_2O_7^{2-}$(aq)		

[7]

(d) Choose **one** of the above five reagents that could be used to distinguish between cyclohexanol and phenol. Describe the observations you would make with each compound.

reagent .....

observation with cyclohexanol .....

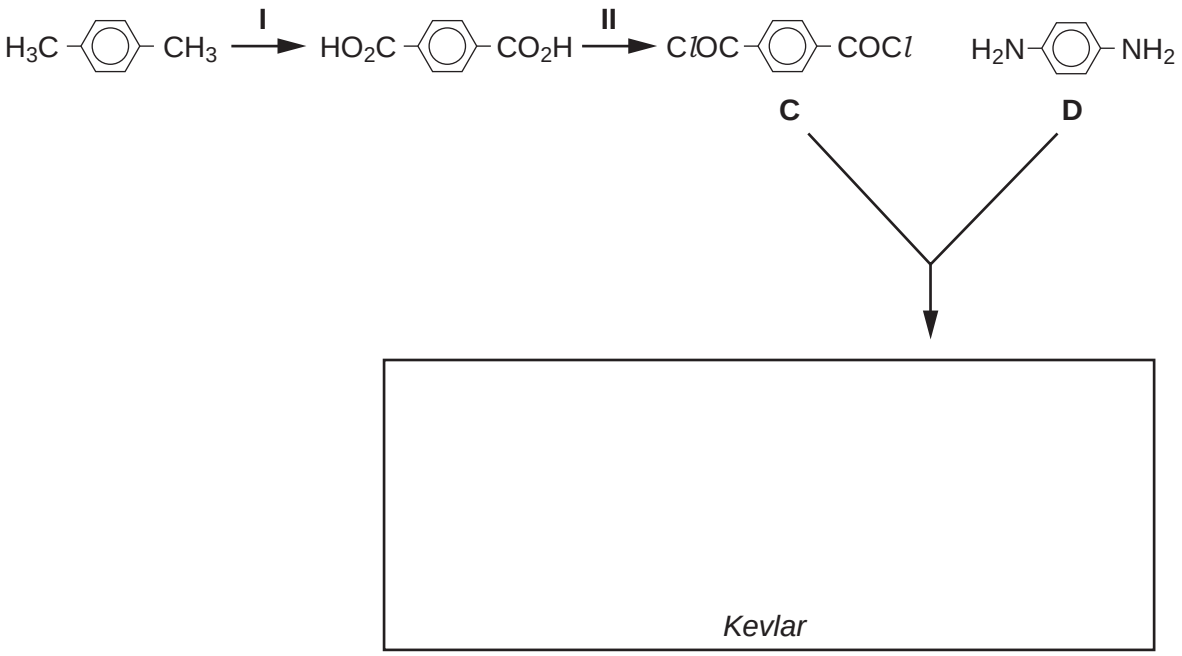
observation with phenol .....

[2]

[Total: 13]

5 *Kevlar* is a tough polyamide used in bullet-proof vests and high-specification bicycle tyres. It can be manufactured by the following process.

For Examiner's Use



(a) **(i)** Suggest reagents and conditions for

reaction **I**, ...

reaction **II**. .....

(ii) Draw the structural formula of **one** repeat unit of *Kevlar* in the box above.

[4]

(b) The di-acid chloride **C** reacts with a variety of reagents. Suggest the structural formulae of the products of the reaction of **C** with

(i) CH_3NH_2,

(ii) $HOCH_2CH_2OH$.

[3]

(c) The diamine **D** also reacts with a variety of reagents. Suggest the structural formulae of the products of the reaction of **D** with

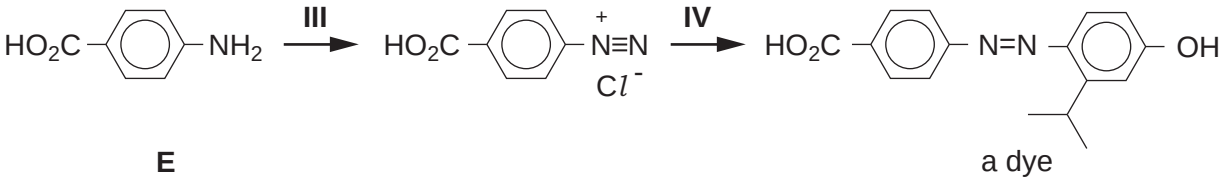
For Examiner's Use

(i) HCl(aq),

(ii) Br_2(aq).

[3]

(d) 4-aminobenzoic acid, **E**, is a useful intermediate for making dyes.



E a dye

Suggest reagents and conditions for

reaction **III**, ...

reaction **IV**. .....

[4]

(e) 4-aminobenzoic acid, **E**, forms a zwitterion.

(i) What is meant by the term *zwitterion*?

.....

.....

(ii) Draw the structural formula of the zwitterion formed from 4-aminobenzoic acid.

[2]

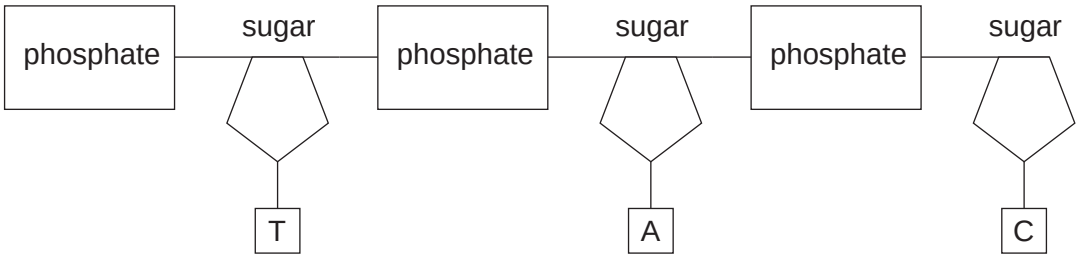
[Total: 16]

Section B

For Examiner's Use

Answer **all** questions in the spaces provided.

6 **(a)** The diagram shows part of one strand of DNA. Draw the complementary strand, labelling the bonds formed to the original strand, and labelling the components of the strand you draw.



[3]

(b) Briefly describe the roles of each of the following in protein synthesis.

(i) tRNA .....

.....

.....

(ii) the ribosome .....

.....

.....

[4]

(c) Some diseases, such as sickle cell anaemia, are caused by a single mutation in the DNA for a particular gene. This causes the haemoglobin produced to change the shape of red blood cells, reducing their efficiency in carrying oxygen.

For Examiner's Use

(i) What is meant by a *mutation*?

.....

(ii) Explain why such a mutation could alter the bonding in haemoglobin.

.....

.....

.....

.....

[4]

[Total: 11]

7 This question is about the modern techniques of analysis which may be used to determine molecular structures.

(a) In X-ray crystallography X-rays are diffracted by the electron clouds surrounding individual atoms in the structure.

(i) What useful information is provided by X-ray crystallography?

.....

.....

(ii) Why cannot hydrogen atoms in a structure be detected by this technique?

.....
[2]

(b) Suggest how structures of complex molecules such as enzymes, derived from X-ray crystallography, can help explain their biochemical behaviour.

.....

.....

..... [2]

(c) NMR spectroscopy, in contrast to X-ray crystallography, is frequently used to examine protons in organic molecules.

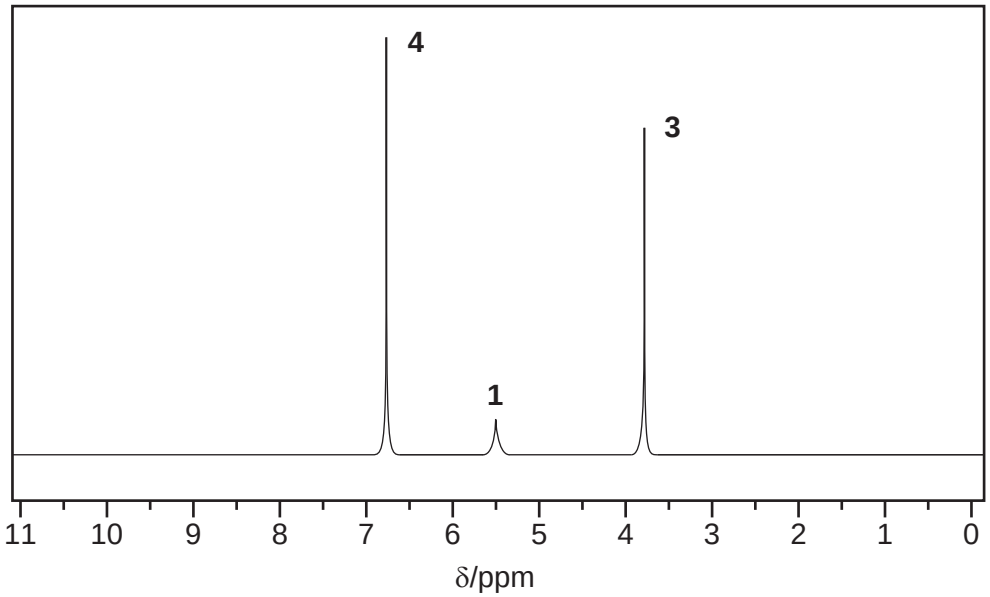
(i) What feature of protons enables their detection by NMR spectroscopy?

.....

(ii) The NMR spectrum below was obtained from a compound **X**, $C_xH_yO_z$. In the mass spectrum of the compound, the M : M+1 ratio was found to be 25:2.

For Examiner's Use

Determine the values of x, y and z in the formula of **X** and deduce a possible structure for the compound, explaining how you arrive at your conclusion.



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Possible structure of **X**

[6]

[Total:10]

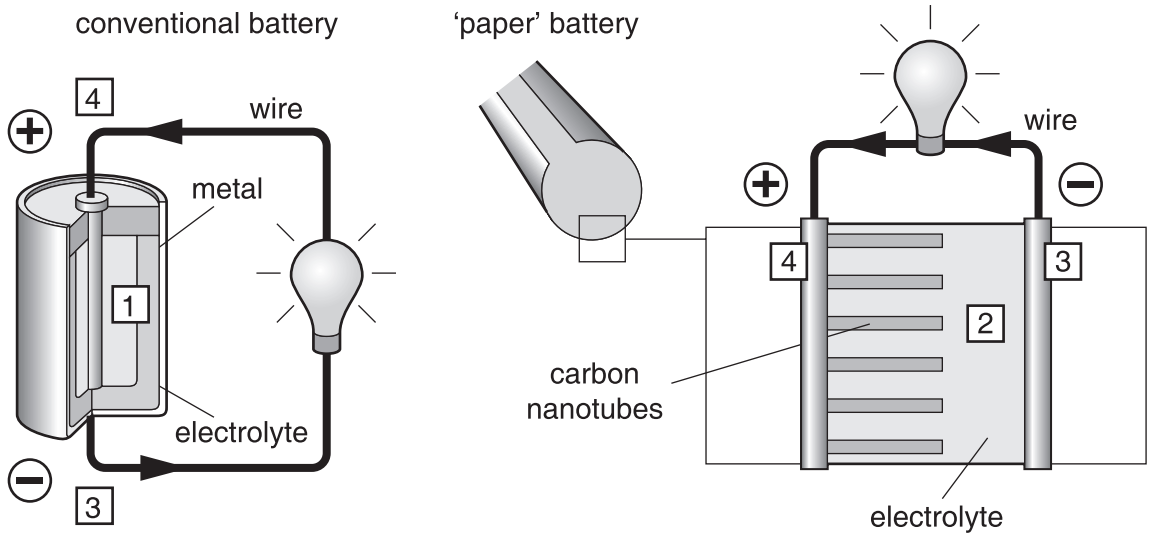
8 A new method of making very light, flexible batteries using nanotechnology was announced in August 2007. Read the passage and answer the questions related to it.

For Examiner's Use

Researchers have developed a new energy-storage device that could easily be mistaken for a simple sheet of black paper. The nano-engineered battery is lightweight, ultra-thin and completely flexible. It is geared towards meeting the difficult design and energy requirements of tomorrow's gadgets, such as implantable medical devices and even vehicles.

Researchers soaked 'paper' in an ionic liquid electrolyte which carries the charge. They then treated it with aligned carbon nanotubes, which give the device its black colour.

The nanotubes act as electrodes and allow the storage devices to conduct electricity. The device, engineered to function as both a battery and a supercapacitor, can provide the long, steady power output comparable to a conventional battery, as well as a supercapacitor's quick burst of high energy. The device can be rolled, twisted, folded, or cut into shapes with no loss of strength or efficiency. The 'paper' batteries can also be stacked, like a pile of printer paper, to boost the total power output.

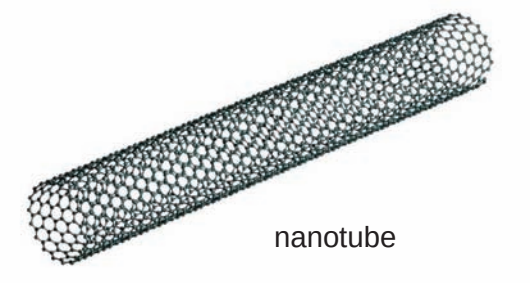


1. *Conventional batteries produce electrons through a chemical reaction between electrolyte and metal.*

2. *Chemical reaction in the 'paper' battery is between electrolyte and carbon nanotubes.*

3. *Electrons collect on the negative terminal of a battery.*

4. *Electrons must flow from the negative terminal, through the external circuit to the positive terminal for the chemical reaction to continue.*



For Examiner's Use

(a) From your knowledge of the different structures of carbon, suggest which of these is used to make nanotubes.

..... [1]

(b) Suggest a property of this structure that makes it suitable for making nanotubes.

.....

..... [1]

(c) Carbon in its bulk form is brittle like most non-metallic solids. Suggest why the energy storage device described can be rolled into a cylinder.

.....

..... [1]

(d) Name an example of an 'ionic *liquid* electrolyte' (not a solution).

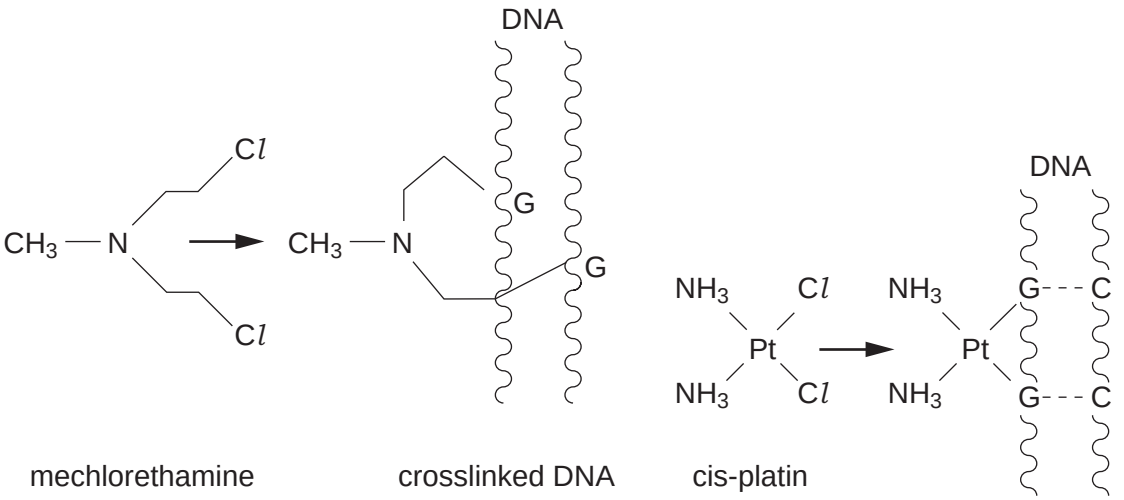
..... [1]

[Total: 4]

9 In recent years a great deal of research has been carried out into finding different anti-cancer drugs. Tumours, which are often symptoms of cancer, are produced when cells replicate uncontrollably. This in turn is brought about by the replication of DNA in these cells.

For Examiner's Use

Two anti-cancer agents are mechlorethamine and *cis*-platin. They work by binding to the DNA and preventing replication.



mechlorethamine crosslinked DNA cis-platin

(a) (i) What type of bonding attaches both anti-cancer agents to the DNA?

.....

(ii) Suggest how **each** of the anti-cancer agents prevents replication of the DNA.

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[5]

[Total: 5]