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9701/41

October/November 2010

1 hour 45 minutes

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, Centre number and candidate number 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 ON ANY BARCODES.

Answer **all** questions.

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	
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Total	

This document consists of **17** printed pages and **3** blank pages.

Section A

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

For
Examiner's
Use

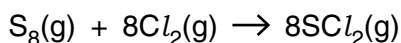
- 1 (a) Write a balanced equation for the reaction of each of the following chlorides with water.

phosphorus(V) chloride

silicon(IV) chloride.....

[2]

- (b) When sulfur is heated under pressure with chlorine, the major product is SCl_2 (Cl-S-Cl).



Use data from the *Data Booklet* to calculate the enthalpy change, ΔH , for this reaction. The eight sulfur atoms in the S_8 molecule are all joined in a single ring by single bonds.

$\Delta H = \dots\dots\dots \text{kJ mol}^{-1}$

[2]

- (c) Under suitable conditions, SCl_2 reacts with water to produce a yellow precipitate of sulfur and a solution **A**. Solution **A** contains a mixture of $\text{SO}_2(\text{aq})$ and compound **B**.

(i) What is the oxidation number of sulfur in SCl_2 ?

(ii) Work out how the oxidation number of sulfur changes during the reaction of SCl_2 with water.

.....

.....

(iii) Suggest the identity of compound **B**.

(iv) Construct an equation for the reaction between SCl_2 and water.

.....

(v) What would you observe when each of the following reagents is added to separate samples of solution **A**?

$\text{AgNO}_3(\text{aq})$

$\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$

[7]

[Total: 11]

- 2 (a) (i) What is meant by the term *ligand* in the context of transition element chemistry?

For
Examiner's
Use

.....
.....

- (ii) Decide which of the following species could be a ligand, and which could not be. Place a tick (✓) in the appropriate column.

species	can be a ligand	cannot be a ligand
OH^-		
NH_4^+		
CH_3OH		
CH_3NH_2		

[3]

- (b) Read the following description of some reactions of copper(II) sulfate, and answer the questions that follow.

When 0.1 mol of white anhydrous CuSO_4 is dissolved in liquid ammonia at -33°C , a deep blue solution **C** results.

When 0.2 mol of solid NaOH is added to solution **C**, and the ammonia solvent allowed to evaporate, a solid residue is obtained.

Heating this residue to 200°C produces a dark coloured mixture of two solids.

When water is added to this mixture, a black solid **D** and a colourless solution **E** are formed. Neither **D** nor **E** contains nitrogen.

Adding $\text{BaCl}_2(\text{aq})$ to solution **E** produces a white precipitate **F**.

Solid **D** dissolves in $\text{HNO}_3(\text{aq})$ on warming, without evolution of gas, to give a pale blue solution containing $\text{Cu}(\text{NO}_3)_2(\text{aq})$.

- (i) Suggest the formula of the compound contained in each of the following.

solution **C**

solid **D**

solution **E**

white precipitate **F**

- (ii) Name the type of reaction that is occurring when **D** reacts with $\text{HNO}_3(\text{aq})$.

.....

[5]

- (c) (i) Describe what you would observe when a solid sample of anhydrous $\text{Cu}(\text{NO}_3)_2$ is strongly heated.

For
Examiner's
Use

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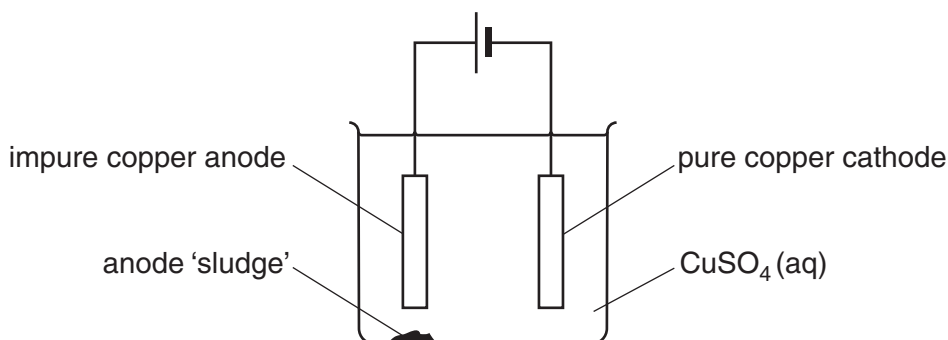
- (ii) Write an equation for this reaction.

.....
[2]

[Total: 10]

- 3 The electrolytic purification of copper can be carried out in an apparatus similar to the one shown below.

For
Examiner's
Use



The impure copper anode contains small quantities of metallic nickel, zinc and silver, together with inert oxides and carbon resulting from the initial reduction of the copper ore with coke. The copper goes into solution at the anode, but the silver remains as the metal and falls to the bottom as part of the anode 'sludge'. The zinc also dissolves.

- (a) (i) Write a half equation including state symbols for the reaction of copper at the anode.

.....

- (ii) Use data from the *Data Booklet* to explain why silver remains as the metal.

.....

- (iii) Use data from the *Data Booklet* to predict what happens to the nickel at the anode.

.....

.....

- (iv) Write a half equation including state symbols for the main reaction at the cathode.

.....

- (v) Use data from the *Data Booklet* to explain why zinc is not deposited on the cathode.

.....

.....

- (vi) Suggest why the blue colour of the electrolyte slowly fades as the electrolysis proceeds.

.....

.....

[7]

- (b) Most of the current passed through the cell is used to dissolve the copper at the anode and precipitate pure copper onto the cathode. However, a small proportion of it is 'wasted' in dissolving the impurities at the anode which then remain in solution. When a current of 20.0 A was passed through the cell for 10.0 hours, it was found that 225 g of pure copper was deposited on the cathode.

(i) Calculate the following, using appropriate data from the *Data Booklet*.

- number of moles of copper produced at the cathode
- number of moles of electrons needed to produce this copper
- number of moles of electrons that passed through the cell

- (ii) Hence calculate the percentage of the current through the cell that has been 'wasted' in dissolving the impurities at the anode.

[4]

- (c) Nickel often occurs in ores along with iron. After the initial reduction of the ore with coke, a nickel-iron alloy is formed.

Use data from the *Data Booklet* to explain why nickel can be purified by a similar electrolysis technique to that used for copper, using an impure nickel anode, a pure nickel cathode, and nickel sulfate as the electrolyte. Explain what would happen to the iron during this process.

.....
.....
.....
.....[2]

[Total: 13]

- 4 The most typical oxides of tin and lead are SnO , SnO_2 , PbO and PbO_2 .

For
Examiner's
Use

The following two generalisations can be made about the oxides of the elements in Group IV.

- As the metallic character of the elements increases down the Group, the oxides become more basic.
- The oxides of the elements in their higher oxidation states are more acidic than the oxides of the elements in their lower oxidation states.

- (a) Use these generalisations to suggest which of the above oxides of tin or lead is **most likely** to react with each of the following reagents. In each case write a balanced equation for the reaction.

- (i) with NaOH(aq)

formula of oxide

equation

- (ii) with HCl(aq)

formula of oxide

equation

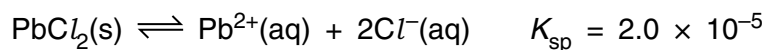
[4]

- (b) 'Red lead' is used as a pigment, and as a metal primer paint to prevent the corrosion of steel. It is an oxide of lead that contains 9.30% oxygen by mass.

Calculate to **3 significant figures** the number of moles of oxygen and lead contained in a 100.0 g sample of red lead. Hence calculate its empirical formula.

empirical formula:[2]

(c) Lead(II) chloride is slightly soluble in water.



For
Examiner's
Use

- (i) Write an expression for the solubility product, K_{sp} for lead(II) chloride and state its units.

$K_{\text{sp}} = \dots\dots\dots$ units $\dots\dots\dots$

- (ii) Calculate $[\text{Pb}^{2+}(\text{aq})]$ in a saturated solution of PbCl_2 .

$\dots\dots\dots$
 $\dots\dots\dots$

An excess of $\text{PbCl}_2(\text{s})$ is stirred with 0.50 mol dm^{-3} NaCl until equilibrium has been established. The excess $\text{PbCl}_2(\text{s})$ is then filtered off.

- (iii) Assuming $[\text{Cl}^{-}]$ remains at 0.50 mol dm^{-3} throughout, calculate the $[\text{Pb}^{2+}(\text{aq})]$ in the remaining solution.

$\dots\dots\dots$
 $\dots\dots\dots$

- (iv) Suggest an explanation for the difference between this value and the value that you calculated in (ii).

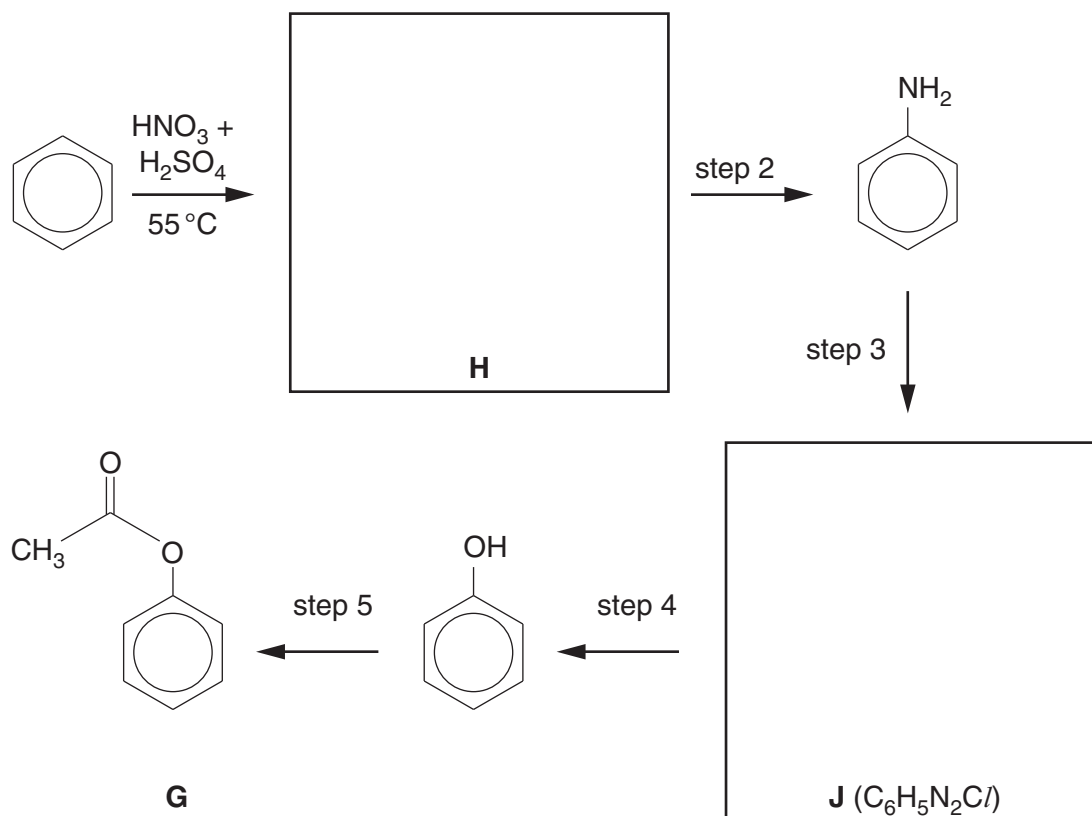
$\dots\dots\dots$

[4]

[Total: 10]

- 5 (a) Compound **G** can be synthesised from benzene by the route shown below.

For
Examiner's
Use



- (i) **Name** the functional group formed in step 5.

.....

- (ii) Draw the structures of the intermediates **H** and **J** in the boxes above.

- (iii) Suggest reagents and conditions for the following.

step 2

step 3

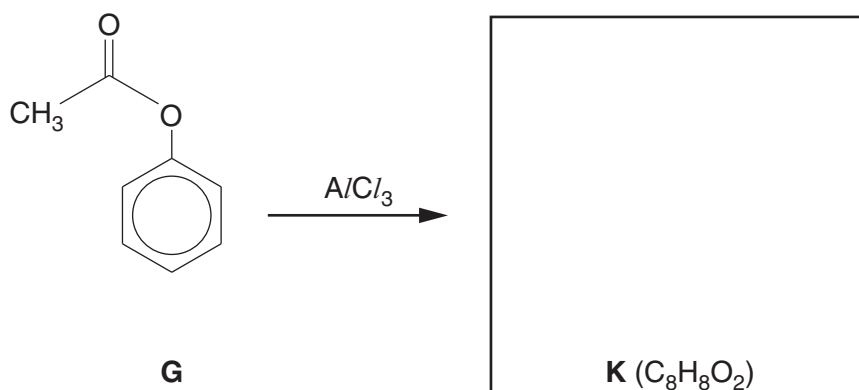
step 4

step 5

[7]

- (b) In a reaction discovered just over 100 years ago by the German chemist Karl Fries, compound **G** is converted into compound **K** when it is heated with AlCl_3 . Compound **K** is a structural isomer of **G**.

For
Examiner's
Use



Compound **K** is a 1,4-disubstituted benzene derivative. It is insoluble in water, but dissolves in NaOH(aq) . It gives a white precipitate with $\text{Br}_2(\text{aq})$, and a yellow precipitate with alkaline aqueous iodine.

- (i) What is meant by the term *structural isomerism*?

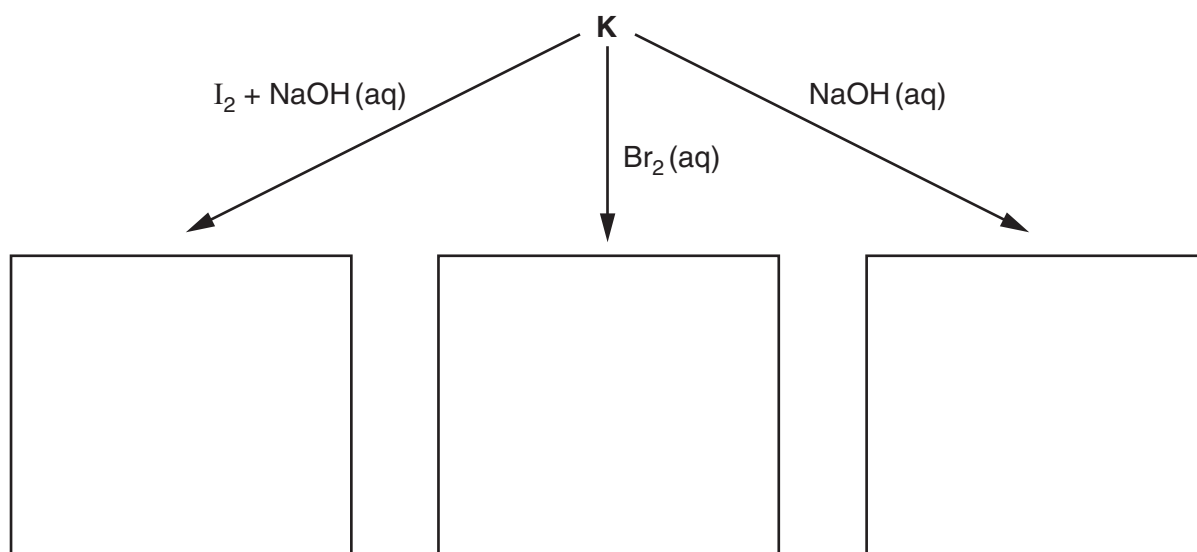
.....

- (ii) Use the information given above to **name** two functional groups in compound **K**.

.....

- (iii) Suggest the structural formula of **K**, and draw it in the box above.

- (iv) Suggest structures for the aromatic products of the following reactions.

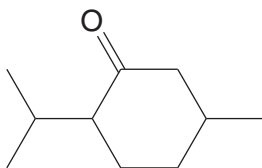


[7]

[Total: 14]

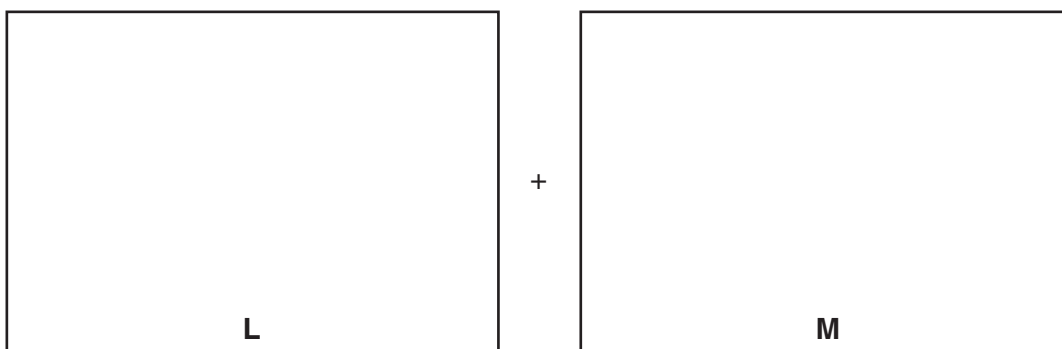
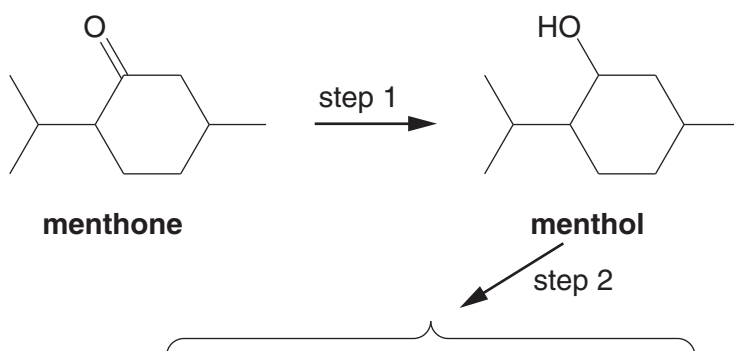
- 6 Menthone, $C_{10}H_{18}O$, is a cyclic ketone that occurs in oil of peppermint.

For
Examiner's
Use



menthone

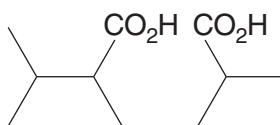
- (a) Use asterisks (*) on the formula above to identify any chiral centres in the molecule of menthone. [2]
- (b) Menthone can be reduced to menthol, which can be dehydrated to a mixture of two alkenes, **L** and **M**.



- (i) Suggest reagents for
 step 1, ...
 step 2.
- (ii) Suggest structures for **L** and **M** and draw them in the boxes above. [4]

- (c) When heated with concentrated, acidified $\text{KMnO}_4(\text{aq})$, one of the two alkenes **L** or **M** produces the dicarboxylic acid **N**.

For
Examiner's
Use



N

- (i) Give the letter of the alkene that produced **N** by this reaction.

.....

- (ii) Suggest the structure of the product, **P**, of the reaction between the other alkene you have drawn and hot concentrated acidified KMnO_4 .



P

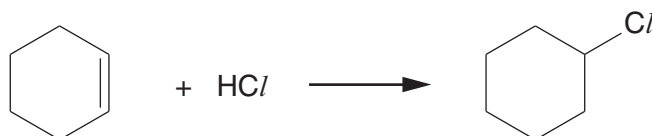
- (iii) Suggest **one** chemical test that would enable you to distinguish between **N** and **P**.

reagent(s)

observation.....

[3]

- (d) Chlorocyclohexane can be prepared by bubbling $\text{HCl}(\text{g})$ through a solution of cyclohexene.



Suggest the mechanism of this 2-stage reaction by means of a diagram. Include all whole or partial charges, and represent the movements of electron pairs by curly arrows.

[3]

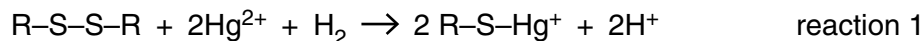
[Total: 12]

Section B

For
Examiner's
UseAnswer **all** the questions in the spaces provided.

- 7 Whilst small amounts of some metal ions are vital in the human body, others can be highly toxic.

- (a) Hg^{2+} ions are toxic for a number of reasons. Hg^{2+} ions can react with the R–S–S–R group, which is found in proteins.



- (i) What is the name of the R–S–S–R group in proteins?

.....

- (ii) Which level of protein structure will be affected by reaction 1?

.....

.....

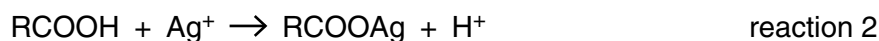
- (iii) Why will this affect the activity of an enzyme?

.....

.....

[3]

- (b) Ag^+ ions can combine with free –COOH groups in the side chains of the amino acid residues in proteins to form partially covalent silver carboxylates.



- (i) What type of behaviour is the –COOH group showing in reaction 2?

.....

.....

- (ii) What types of R group interactions will be affected by reaction 2? Explain your answer.

.....

.....

.....

.....

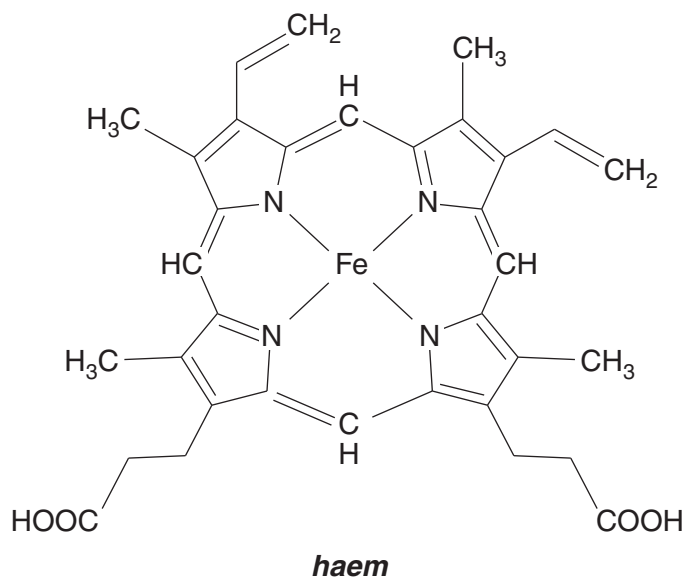
.....

[4]

- (c) By contrast, iron is an extremely important metal used in haemoglobin to transport oxygen molecules from the lungs to muscle cells and to carry carbon dioxide in the reverse direction.

For
Examiner's
Use

One haemoglobin molecule contains four haem groups, each of which contains one iron atom. In the haem group four nitrogen atoms are in the same plane as the iron atom. The oxygen molecule is attached above this plane, and the iron atom is joined to a protein chain below this plane.



- (i) How many oxygen **atoms** could one haemoglobin molecule transport?

.....

- (ii) By what type of bonding is the oxygen molecule likely to be held to the iron atom in haem?

.....

- (iii) What is the geometry of bonding around the iron atom?

.....

[3]

[Total: 10]

- 8 (a) NMR spectroscopy and X-ray crystallography are two techniques that use electromagnetic radiation to look at the structures of large molecules.

For
Examiner's
Use

For each technique state the sub-atomic particle involved, and explain how this particle interacts with the radiation.

NMR.....

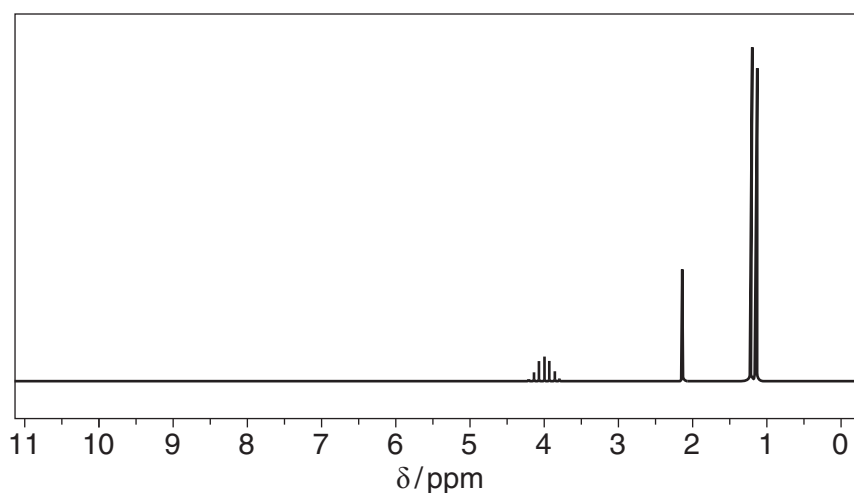
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X-ray

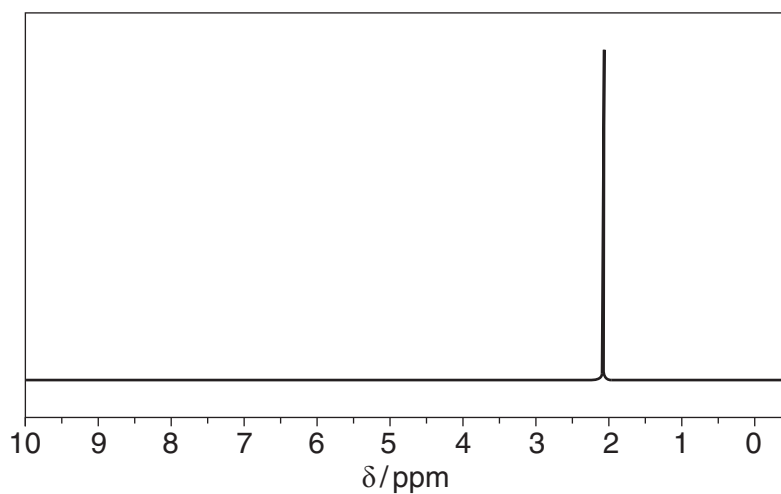
.....

[4]

- (b) The two NMR spectra **1** and **2** were obtained before and after an alcohol, **Y**, was oxidised to give compound **Z**. The numbers of hydrogen atoms responsible for each peak have **not** been shown. All the peaks have been shown.



1



2

- (i) State which spectrum, **1** or **2**, was produced by the alcohol, giving a reason for your answer.

spectrum

reason

.....

- (ii) The mass spectrum of **Y** showed an $M : M + 1$ peak ratio of 17.6:0.6.
Use this and other information in the question to suggest the identities of both **Y** and **Z**.

- (iii) Draw a displayed formula for **Y** in the box provided

Y is



- (iv) Explain why the NMR spectrum of **Z** only shows one peak.

.....

.....

[7]

[Total: 11]

- 9 A possible source of energy for the road vehicles of the future is hydrogen. One of the problems still to be solved is the storage of the hydrogen in the vehicle. A conventional tank holding liquid hydrogen would have to be pressurised and refrigerated. In a crash, this type of tank could break resulting in the rapid release of hydrogen and an explosion.

One alternative is to use a fuel tank packed with carbon nanotubes. The hydrogen in the tank would be adsorbed onto the surface of the nanotubes at a pressure of no more than a few atmospheres.

- (a) (i) What is the approximate width of a carbon nanotube?

.....

- (ii) In what structural form is the carbon in a nanotube?

.....

- (iii) What forces could be responsible for holding the hydrogen on the surface of the nanotubes? Explain your answer.

.....

.....

.....

[4]

- (b) The hydrogen atoms in a fuel tank packed with nanotubes are closer together than in liquid hydrogen. Suggest **one** advantage of this.

.....

.....[1]

- (c) When a nanotube-packed fuel tank is full of hydrogen there is a steady pressure of hydrogen in the tank. While hydrogen gas is being removed from the fuel tank to power the car, the pressure in the fuel tank drops very little for some time. State Le Chatelier's principle, and suggest how it explains this observation.

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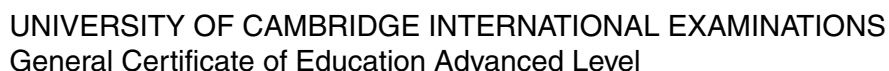
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[Total: 9]

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9701/42

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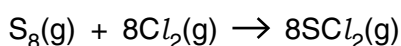
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$\Delta H = \dots\dots\dots \text{kJ mol}^{-1}$

[2]

- (c) Under suitable conditions, SCl_2 reacts with water to produce a yellow precipitate of sulfur and a solution **A**. Solution **A** contains a mixture of $\text{SO}_2(\text{aq})$ and compound **B**.

(i) What is the oxidation number of sulfur in SCl_2 ?

(ii) Work out how the oxidation number of sulfur changes during the reaction of SCl_2 with water.

.....

.....

(iii) Suggest the identity of compound **B**.

(iv) Construct an equation for the reaction between SCl_2 and water.

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(v) What would you observe when each of the following reagents is added to separate samples of solution **A**?

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$\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$

[7]

[Total: 11]

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solution **C**

solid **D**

solution **E**

white precipitate **F**

- (ii) Name the type of reaction that is occurring when **D** reacts with $\text{HNO}_3(\text{aq})$.

.....

[5]

- (c) (i) Describe what you would observe when a solid sample of anhydrous $\text{Cu}(\text{NO}_3)_2$ is strongly heated.

For
Examiner's
Use

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.....

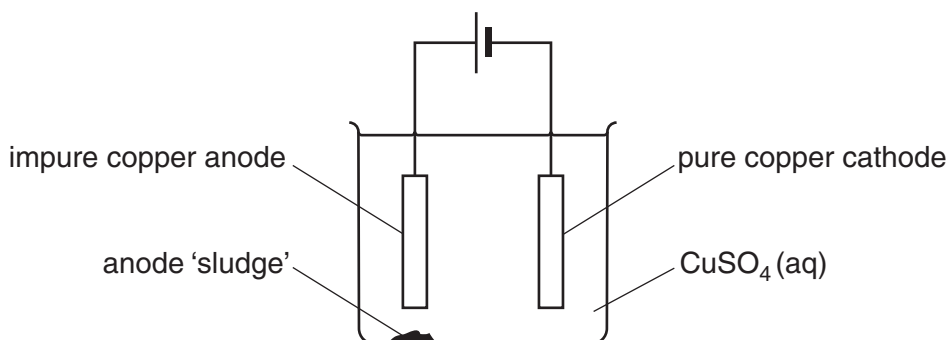
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- (vi) Suggest why the blue colour of the electrolyte slowly fades as the electrolysis proceeds.

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[7]

- (i) Calculate the following, using appropriate data from the *Data Booklet*.

- number of moles of copper produced at the cathode
- number of moles of electrons needed to produce this copper
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- [4]

- Use data from the *Data Booklet* to explain why nickel can be purified by a similar electrolysis technique to that used for copper, using an impure nickel anode, a pure nickel cathode, and nickel sulfate as the electrolyte. Explain what would happen to the iron during this process.

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formula of oxide

equation

- (ii) with HCl(aq)

formula of oxide

equation

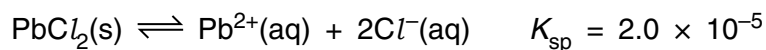
[4]

- (b) 'Red lead' is used as a pigment, and as a metal primer paint to prevent the corrosion of steel. It is an oxide of lead that contains 9.30% oxygen by mass.

Calculate to **3 significant figures** the number of moles of oxygen and lead contained in a 100.0 g sample of red lead. Hence calculate its empirical formula.

empirical formula:[2]

(c) Lead(II) chloride is slightly soluble in water.



For
Examiner's
Use

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$\dots\dots\dots$
 $\dots\dots\dots$

An excess of $\text{PbCl}_2(\text{s})$ is stirred with 0.50 mol dm^{-3} NaCl until equilibrium has been established. The excess $\text{PbCl}_2(\text{s})$ is then filtered off.

- (iii) Assuming $[\text{Cl}^{-}]$ remains at 0.50 mol dm^{-3} throughout, calculate the $[\text{Pb}^{2+}(\text{aq})]$ in the remaining solution.

$\dots\dots\dots$
 $\dots\dots\dots$

- (iv) Suggest an explanation for the difference between this value and the value that you calculated in (ii).

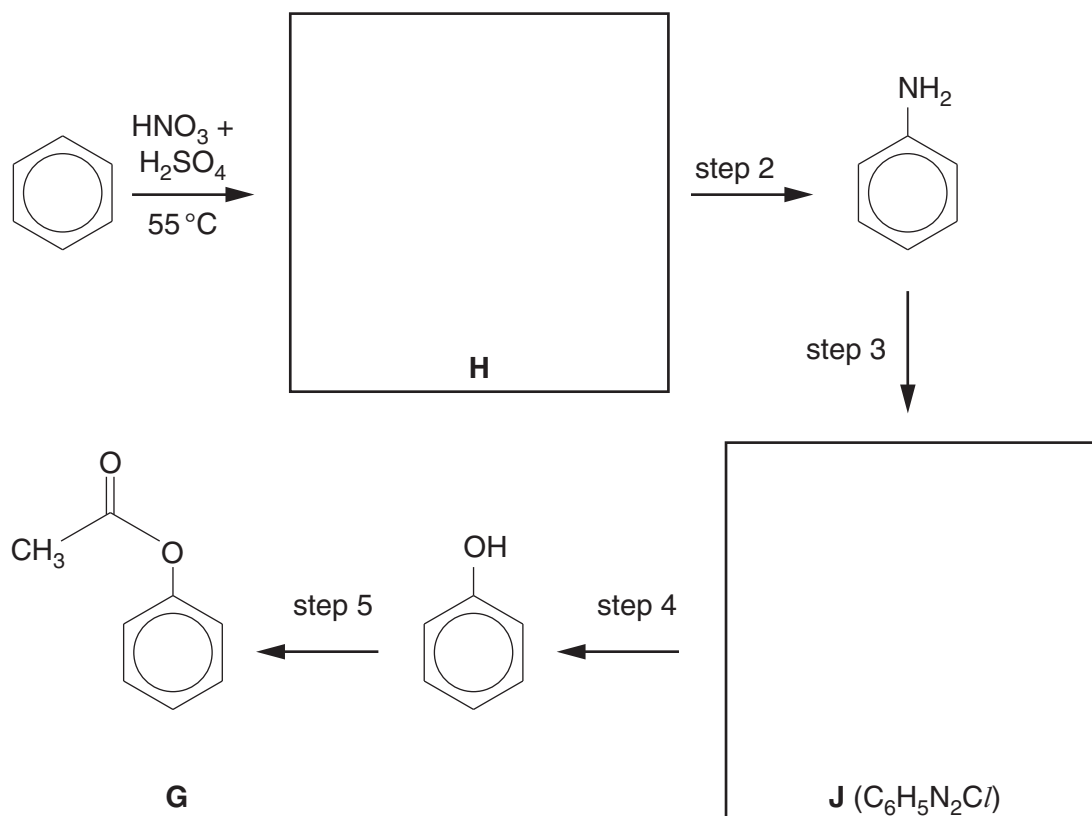
$\dots\dots\dots$

[4]

[Total: 10]

- 5 (a) Compound **G** can be synthesised from benzene by the route shown below.

For
Examiner's
Use



- (i) **Name** the functional group formed in step 5.

.....

- (ii) Draw the structures of the intermediates **H** and **J** in the boxes above.

- (iii) Suggest reagents and conditions for the following.

step 2

step 3

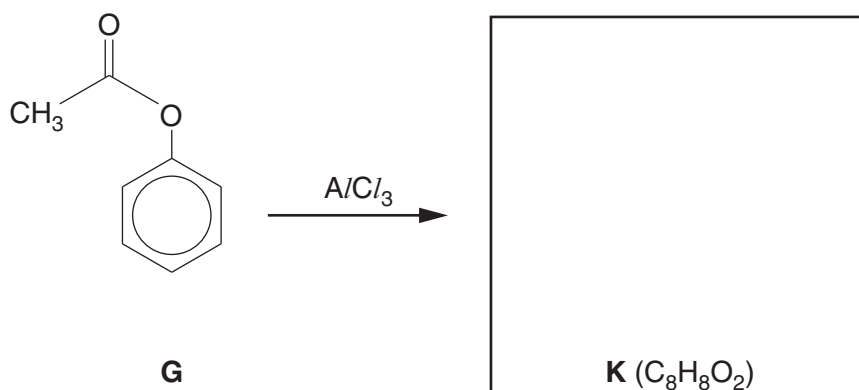
step 4

step 5

[7]

- (b) In a reaction discovered just over 100 years ago by the German chemist Karl Fries, compound **G** is converted into compound **K** when it is heated with AlCl_3 . Compound **K** is a structural isomer of **G**.

For
Examiner's
Use



Compound **K** is a 1,4-disubstituted benzene derivative. It is insoluble in water, but dissolves in NaOH(aq) . It gives a white precipitate with $\text{Br}_2(\text{aq})$, and a yellow precipitate with alkaline aqueous iodine.

- (i) What is meant by the term *structural isomerism*?

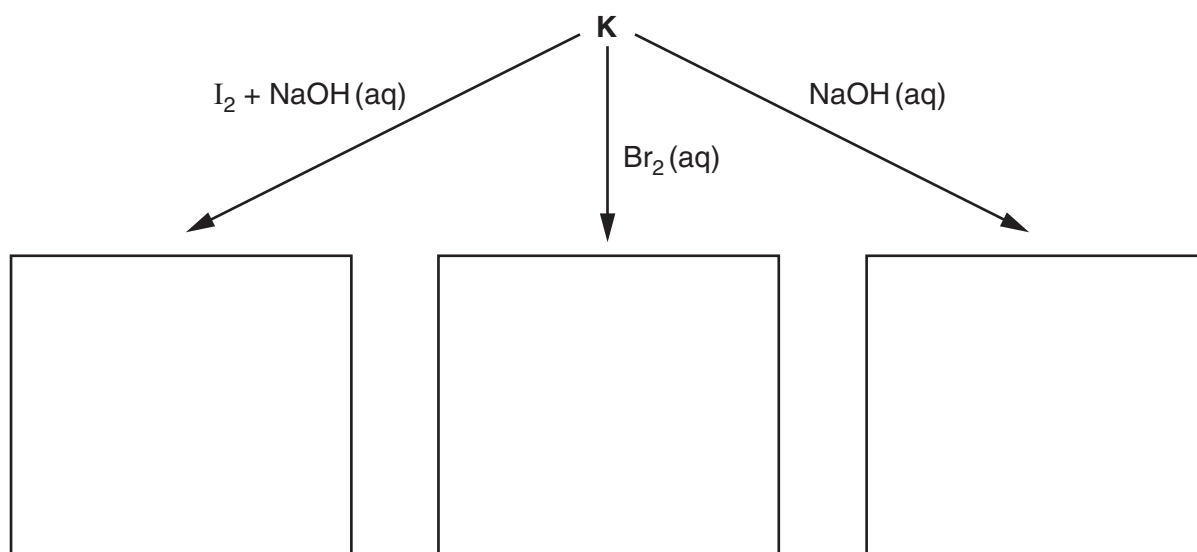
.....

- (ii) Use the information given above to **name** two functional groups in compound **K**.

.....

- (iii) Suggest the structural formula of **K**, and draw it in the box above.

- (iv) Suggest structures for the aromatic products of the following reactions.

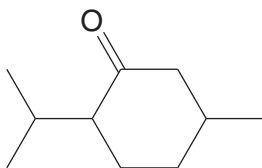


[7]

[Total: 14]

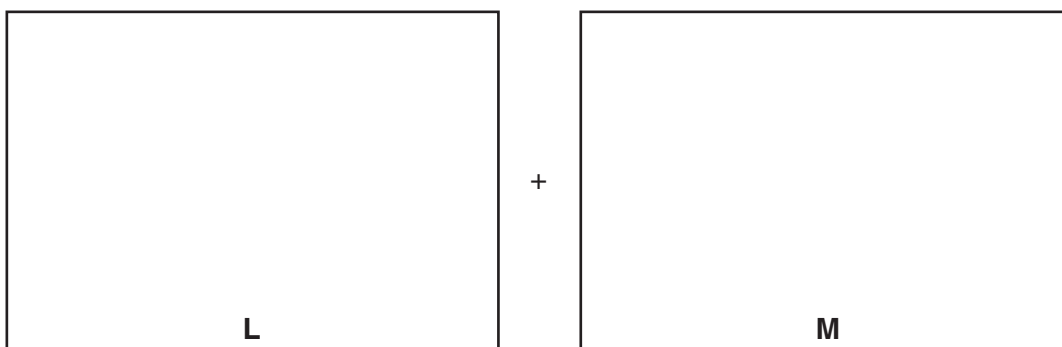
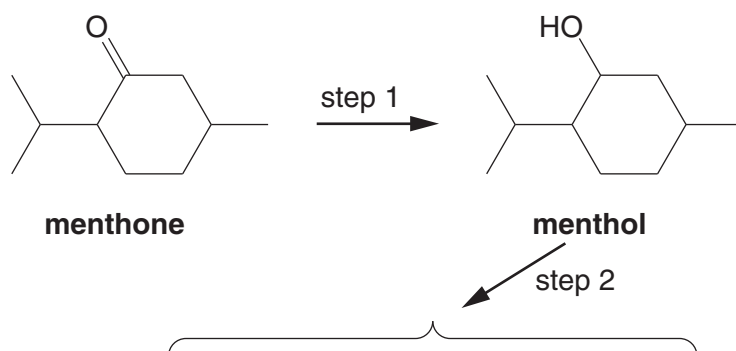
- 6 Menthone, $C_{10}H_{18}O$, is a cyclic ketone that occurs in oil of peppermint.

For
Examiner's
Use



menthone

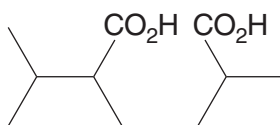
- (a) Use asterisks (*) on the formula above to identify any chiral centres in the molecule of menthone. [2]
- (b) Menthone can be reduced to menthol, which can be dehydrated to a mixture of two alkenes, **L** and **M**.



- (i) Suggest reagents for
- step 1, ...
- step 2.
- (ii) Suggest structures for **L** and **M** and draw them in the boxes above. [4]

- (c) When heated with concentrated, acidified $\text{KMnO}_4(\text{aq})$, one of the two alkenes **L** or **M** produces the dicarboxylic acid **N**.

For
Examiner's
Use



N

- (i) Give the letter of the alkene that produced **N** by this reaction.

.....

- (ii) Suggest the structure of the product, **P**, of the reaction between the other alkene you have drawn and hot concentrated acidified KMnO_4 .



P

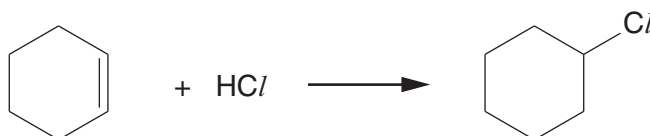
- (iii) Suggest **one** chemical test that would enable you to distinguish between **N** and **P**.

reagent(s)

observation.....

[3]

- (d) Chlorocyclohexane can be prepared by bubbling $\text{HCl}(\text{g})$ through a solution of cyclohexene.



Suggest the mechanism of this 2-stage reaction by means of a diagram. Include all whole or partial charges, and represent the movements of electron pairs by curly arrows.

[3]

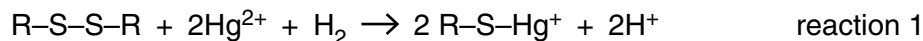
[Total: 12]

Section B

For
Examiner's
UseAnswer **all** the questions in the spaces provided.

- 7 Whilst small amounts of some metal ions are vital in the human body, others can be highly toxic.

- (a) Hg^{2+} ions are toxic for a number of reasons. Hg^{2+} ions can react with the R–S–S–R group, which is found in proteins.



- (i) What is the name of the R–S–S–R group in proteins?

.....

- (ii) Which level of protein structure will be affected by reaction 1?

.....

.....

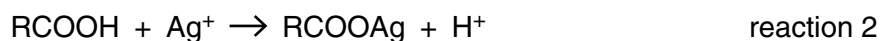
- (iii) Why will this affect the activity of an enzyme?

.....

.....

[3]

- (b) Ag^+ ions can combine with free –COOH groups in the side chains of the amino acid residues in proteins to form partially covalent silver carboxylates.



- (i) What type of behaviour is the –COOH group showing in reaction 2?

.....

.....

- (ii) What types of R group interactions will be affected by reaction 2? Explain your answer.

.....

.....

.....

.....

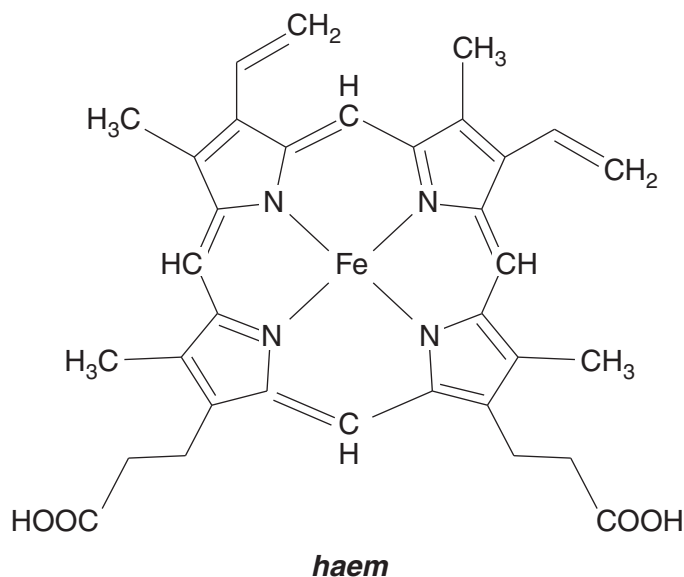
.....

[4]

- (c) By contrast, iron is an extremely important metal used in haemoglobin to transport oxygen molecules from the lungs to muscle cells and to carry carbon dioxide in the reverse direction.

For
Examiner's
Use

One haemoglobin molecule contains four haem groups, each of which contains one iron atom. In the haem group four nitrogen atoms are in the same plane as the iron atom. The oxygen molecule is attached above this plane, and the iron atom is joined to a protein chain below this plane.



- (i) How many oxygen **atoms** could one haemoglobin molecule transport?

.....

- (ii) By what type of bonding is the oxygen molecule likely to be held to the iron atom in haem?

.....

- (iii) What is the geometry of bonding around the iron atom?

.....

[3]

[Total: 10]

- 8 (a) NMR spectroscopy and X-ray crystallography are two techniques that use electromagnetic radiation to look at the structures of large molecules.

For
Examiner's
Use

For each technique state the sub-atomic particle involved, and explain how this particle interacts with the radiation.

NMR.....

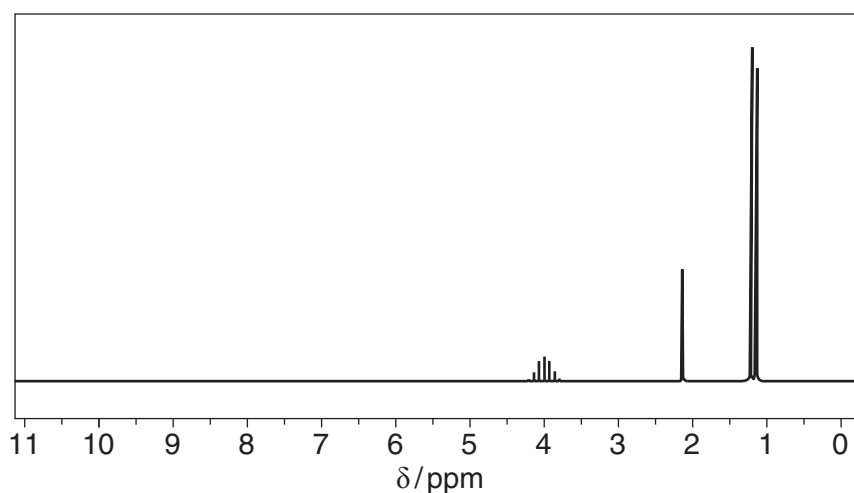
.....

X-ray

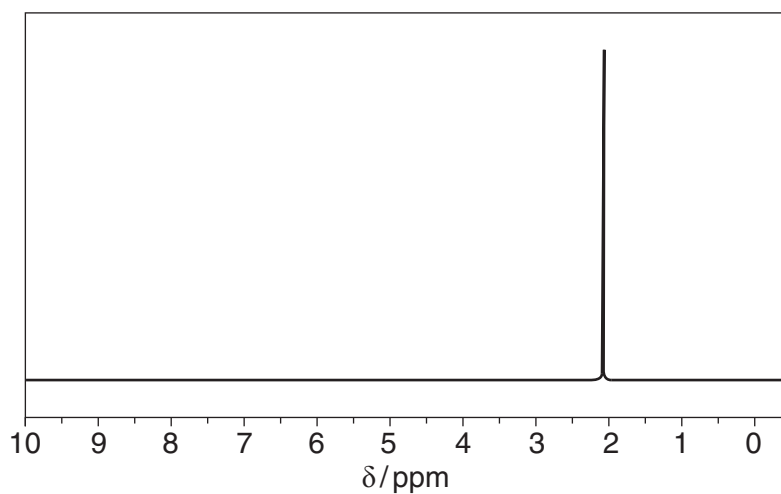
.....

[4]

- (b) The two NMR spectra **1** and **2** were obtained before and after an alcohol, **Y**, was oxidised to give compound **Z**. The numbers of hydrogen atoms responsible for each peak have **not** been shown. All the peaks have been shown.



1



2

- (i) State which spectrum, **1** or **2**, was produced by the alcohol, giving a reason for your answer.

spectrum

reason

.....

- (ii) The mass spectrum of **Y** showed an $M : M + 1$ peak ratio of 17.6:0.6.
Use this and other information in the question to suggest the identities of both **Y** and **Z**.

- (iii) Draw a displayed formula for **Y** in the box provided

Y is



- (iv) Explain why the NMR spectrum of **Z** only shows one peak.

.....

.....

[7]

[Total: 11]

- 9 A possible source of energy for the road vehicles of the future is hydrogen. One of the problems still to be solved is the storage of the hydrogen in the vehicle. A conventional tank holding liquid hydrogen would have to be pressurised and refrigerated. In a crash, this type of tank could break resulting in the rapid release of hydrogen and an explosion.

One alternative is to use a fuel tank packed with carbon nanotubes. The hydrogen in the tank would be adsorbed onto the surface of the nanotubes at a pressure of no more than a few atmospheres.

- (a) (i) What is the approximate width of a carbon nanotube?

.....

- (ii) In what structural form is the carbon in a nanotube?

.....

- (iii) What forces could be responsible for holding the hydrogen on the surface of the nanotubes? Explain your answer.

.....

.....

.....

[4]

- (b) The hydrogen atoms in a fuel tank packed with nanotubes are closer together than in liquid hydrogen. Suggest **one** advantage of this.

.....

.....[1]

- (c) When a nanotube-packed fuel tank is full of hydrogen there is a steady pressure of hydrogen in the tank. While hydrogen gas is being removed from the fuel tank to power the car, the pressure in the fuel tank drops very little for some time. State Le Chatelier's principle, and suggest how it explains this observation.

.....

.....

.....

.....

.....

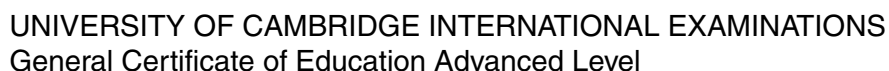
.....[4]

[Total: 9]

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9701/43

October/November 2010

1 hour 45 minutes

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

DO **NOT** WRITE ON ANY BARCODES.

Answer **all** questions.

Answer **all** questions.

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	
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9	
10	
11	
Total	

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

Section A

For
Examiner's
UseAnswer **all** the questions in the space provided.

- 1 (a) (i) Write equations to illustrate the reactions of the following oxides with water.

phosphorus(V) oxide

sulfur(IV) oxide

- (ii) When NO_2 reacts with water, nitrogen undergoes a disproportionation reaction in which one nitrogen atom decreases its oxidation number by 1 and another nitrogen atom increases its oxidation number by 1. A mixture of two acids results. Suggest an equation for the reaction between NO_2 and water.

.....

- (iii) In a similar disproportionation reaction, ClO_2 reacts with aqueous NaOH to produce a solution containing two chlorine-containing sodium salts. Suggest an equation for the reaction between ClO_2 and aqueous NaOH .

.....

[4]

- (b) The major source of sulfur for the manufacture of sulfuric acid by the Contact process is the de-sulfurisation of 'sour' natural gas. Many natural gas wells produce a mixture of volatile hydrocarbons (mainly CH_4 and C_2H_6) together with up to 25% hydrogen sulfide, H_2S .

- (i) Complete and balance the following equation showing the complete combustion of a gaseous mixture consisting of 2 mol of CH_4 , 1 mol of C_2H_6 and 1 mol of H_2S .

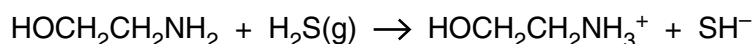


- (ii) Explain why it is important to remove the H_2S before burning the natural gas industrially.

.....

.....

The H_2S is removed by passing the 'sour' natural gas through a solvent containing ethanolamine. The following reaction takes place.



- (iii) If a sample of natural gas contains 5% by volume of H_2S , calculate the mass of ethanolamine required to remove all the H_2S from a 1000dm^3 sample of gas, measured under room conditions.

.....

.....

.....

.....

The H_2S can be recovered by warming the solution to 120°C , when the above reaction is reversed. The ethanolamine can then be recycled.

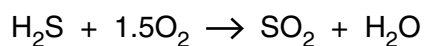
For
Examiner's
Use

- (iv) What *type* of reaction is occurring here?

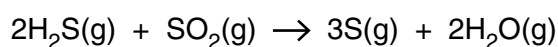
.....

The recovered H_2S is converted to sulfur by the following two reactions.

- I Part of the H_2S is burned in air.



- II The gas stream resulting from reaction I is then blended with the remaining H_2S and fed into an iron oxide catalyst bed, where sulfur and water are produced according to the following equation.



- (v) Use the following data to calculate $\Delta H^\ominus$ for the reaction between H_2S and SO_2 .

compound	$\Delta H_f^\ominus / \text{kJ mol}^{-1}$
$\text{H}_2\text{S}(\text{g})$	-21
$\text{SO}_2(\text{g})$	-297
$\text{H}_2\text{O}(\text{g})$	-242
$\text{S}(\text{g})$	+11

$$\Delta H^\ominus = \dots\dots\dots \text{kJ mol}^{-1}$$

[8]

[Total: 12]

- 2 (a) Explain why complexes of transition elements are often coloured.

For
Examiner's
Use

.....

.....

.....

.....

.....[3]

- (b) When water is added to white anhydrous CuSO_4 , the solid dissolves to give a blue solution. The solution changes to a yellow-green colour when concentrated $\text{NH}_4\text{Cl}(\text{aq})$ is added to it. Concentrating the solution produces green crystals of an ammonium salt with the empirical formula $\text{CuN}_2\text{H}_8\text{Cl}_4$. Explain these observations, showing your reasoning.

.....

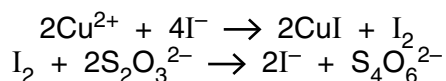
.....

.....

.....

.....[3]

- (c) Copper can be recovered from low-grade ores by 'leaching' the ore with dilute H_2SO_4 , which converts the copper compounds in the ore into $\text{CuSO}_4(\text{aq})$. The concentration of copper in the leach solution can be estimated by adding an excess of aqueous potassium iodide, and titrating the iodine produced with standard $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$.



When an excess of $\text{KI}(\text{aq})$ was added to a 50.0cm^3 sample of leach solution, and the resulting mixture titrated, 19.5cm^3 of 0.0200mol dm^{-3} $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$ were required to discharge the iodine colour.

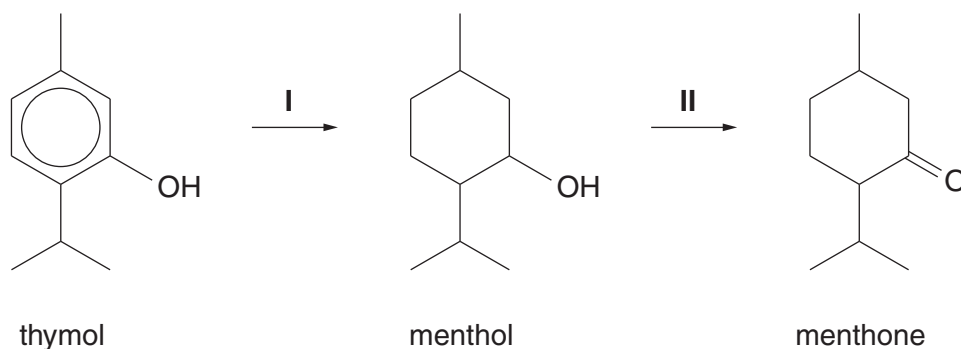
Calculate the $[\text{Cu}^{2+}(\text{aq})]$, and hence the percentage by mass of copper, in the leach solution.

percentage of copper = ...% [3]

[Total: 9]

- 3 Menthol and menthone, the main constituents of oil of peppermint, can be made synthetically from thymol by the following route.

For
Examiner's
Use



- (a) State the *type of reaction* of

- reaction I, ...
- reaction II.

[2]

- (b) Suggest **one** test for **each** of the three compounds that would give a positive result with the stated compound but a negative result with **both** the other two compounds.

thymol

test

observation

menthol

test

observation

menthone

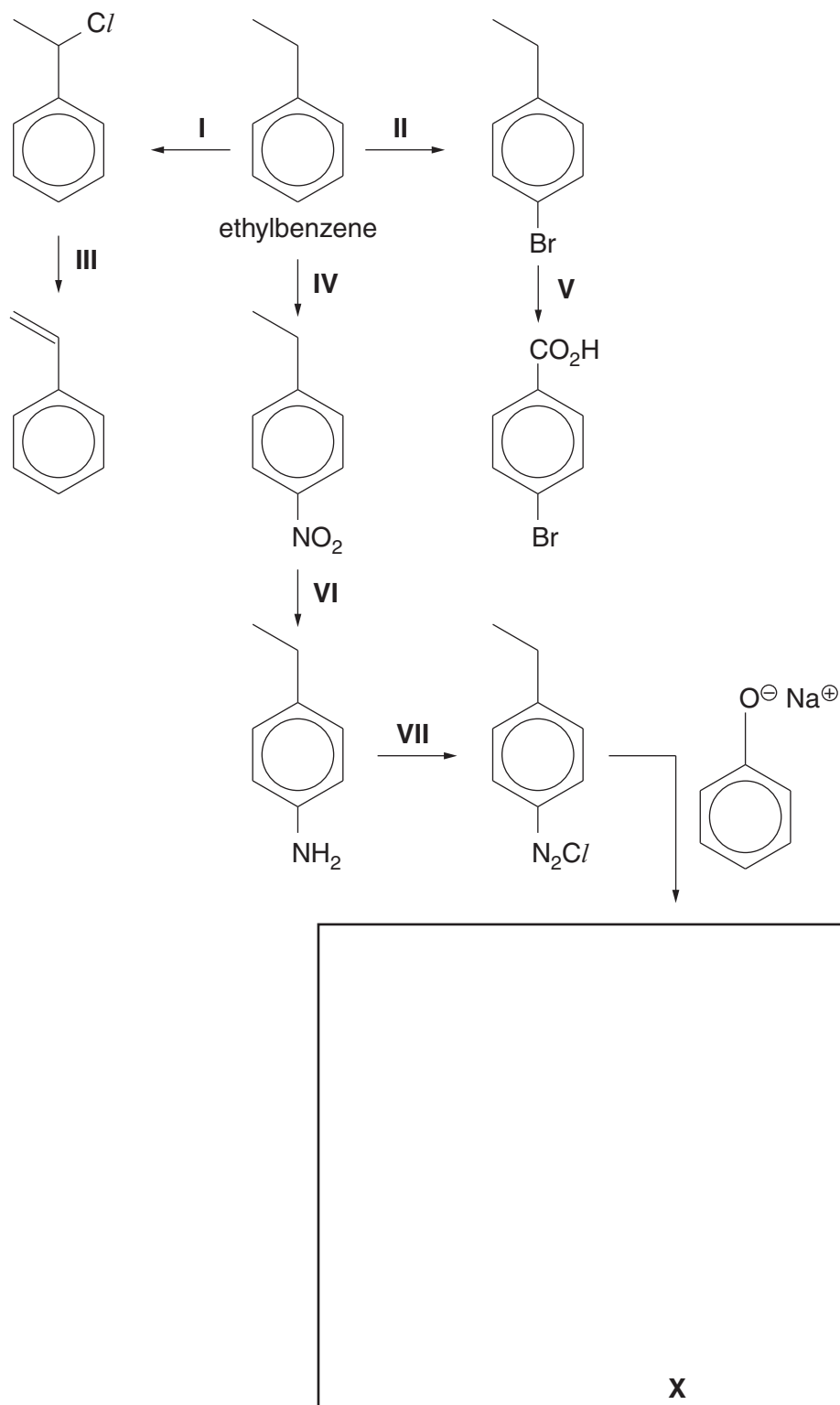
test

observation [6]

[Total: 8]

- 4 The following chart shows some reactions of ethylbenzene and compounds produced from it.

For
Examiner's
Use



- (i) Draw the structure of compound X in the box provided in the chart above.

- (ii) Suggest reagents and conditions for each of the reactions, writing them in the spaces below.

For
Examiner's
Use

reaction I

reaction II

reaction III

reaction IV

reaction V

reaction VI

reaction VII

[Total: 8]

- 5 Chlorine is manufactured by the electrolysis of brine, NaCl(aq) . At the cathode, $\text{H}_2(\text{g})$ and $\text{OH}^-(\text{aq})$ are produced, but the product at the anode depends on the $[\text{NaCl(aq)}]$ in the solution. Either $\text{O}_2(\text{g})$ or $\text{Cl}_2(\text{g})$ is produced.

(a) The equation for the cathode reaction is $2\text{H}_2\text{O(l)} + 2\text{e}^- \rightarrow \text{H}_2(\text{g}) + 2\text{OH}^-(\text{aq})$.

Starting from **neutral** NaCl(aq) , write equations for the production at the anode of

(i) $\text{O}_2(\text{g})$, ...

(ii) $\text{Cl}_2(\text{g})$

[2]

(b) For electrolysis to occur, the voltage applied to the cell must be at least as large as the $E_{\text{cell}}^\ominus$, as calculated from standard electrode potentials.

Use the *Data Booklet* to calculate $E_{\text{cell}}^\ominus$ for the production at the anode of

(i) $\text{O}_2(\text{g})$, ...

(ii) $\text{Cl}_2(\text{g})$

[2]

(c) (i) By using **one** of the phrases *more positive*, *less positive* or *no change*, use the equations you wrote in (a) to deduce the effect of increasing $[\text{Cl}^-(\text{aq})]$ on

• the E_{anode} for the production of $\text{O}_2(\text{g})$, ...

• the E_{anode} for the production of $\text{Cl}_2(\text{g})$

(ii) Hence explain why the $\text{Cl}_2(\text{g}) : \text{O}_2(\text{g})$ ratio increases as $[\text{NaCl(aq)}]$ increases.

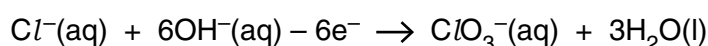
.....

.....[3]

(d) Sodium chlorate(V) is prepared commercially by electrolysis NaCl(aq) in a cell which allows the cathode and anode electrolytes to mix.

The cathode reaction is the same as that described in (a).

The equation for the anode reaction is



(i) Construct an ionic equation for the overall reaction.

.....

- (ii) Calculate the mass of NaClO_3 that is produced when a current of 250 A is passed through the cell for 60 minutes.

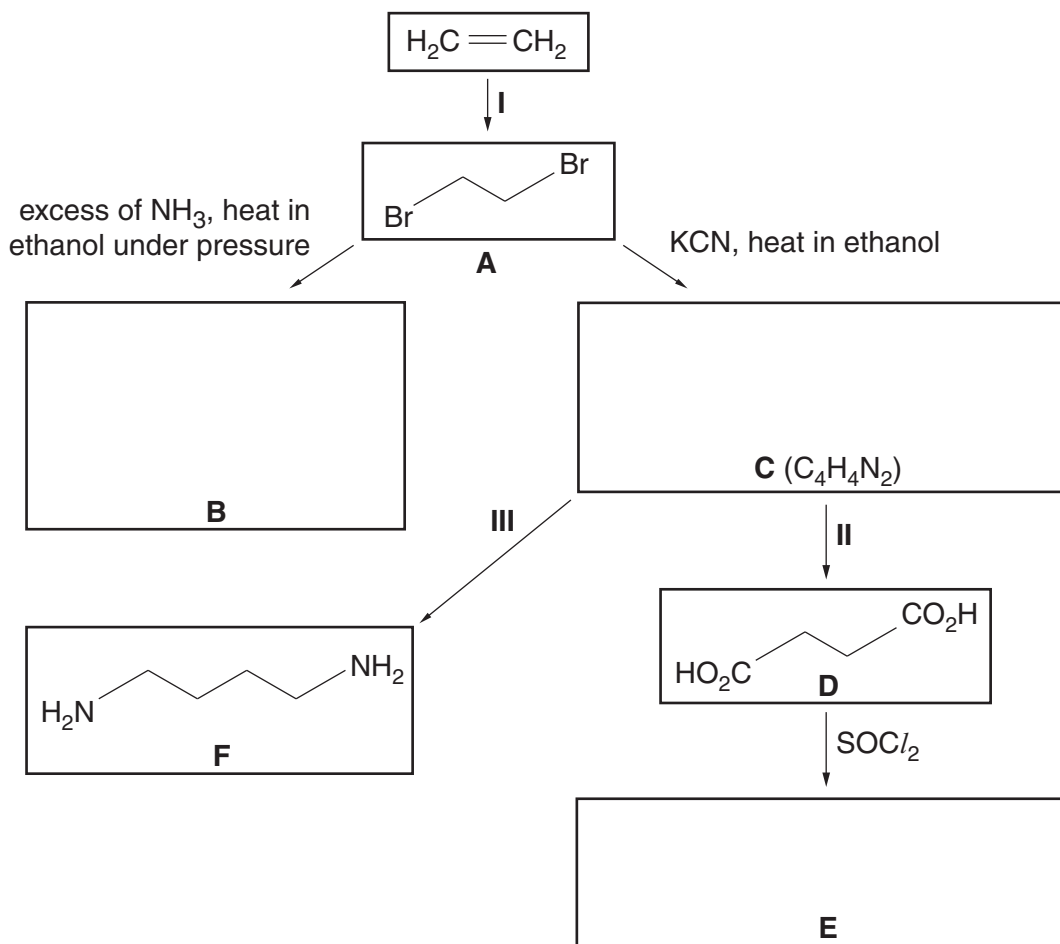
For
Examiner's
Use

mass of NaClO_3 = ... g [4]

[Total: 11]

- 6 The following scheme outlines the production of some compounds from ethene.

For
Examiner's
Use



- (a) (i) Suggest the reagent and conditions for reaction I.

.....

- (ii) Describe the mechanism of reaction I by means of a diagram. Include all whole, partial and induced charges, and represent the movements of electron pairs by curly arrows.

[3]

- (b) Suggest the identities of compounds **B**, **C** and **E**, and draw their structures in the boxes opposite. [3]

- (c) Suggest reagents and conditions for

reaction II,

.....

reaction III.

..... [2]

- (d) During reaction II the nitrogen atoms are lost from the organic molecule. Suggest the identity of the nitrogen-containing ion produced during this reaction.

..... [1]

- (e) Compounds **E** and **F** react together to give a polymer and an inorganic product.

(i) Draw **one** repeat unit of this polymer.

(ii) Identify the inorganic product.

..... [2]

- (f) A $0.100 \text{ mol dm}^{-3}$ solution of compound **D** has a pH of 2.60.

(i) Calculate the $[\text{H}^+]$ in this solution.

.....

.....

(ii) Hence calculate the value of K_a of compound **D**.

.....

.....

[2]

[Total: 13]

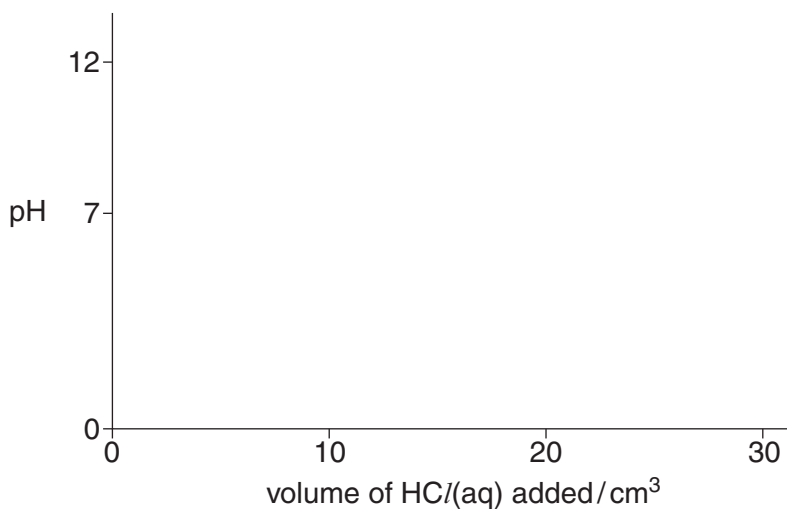
- 7 When an aqueous solution of compound **G**, $\text{NH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2$, is titrated with $\text{HCl}(\text{aq})$, two successive acid-base reactions take place.

For
Examiner's
Use

- (a) Write equations for these two acid-base reactions.

.....
.....[2]

- (b) A 0.10mol dm^{-3} solution of **G** has a pH of 11.3. When 30cm^3 of 0.10mol dm^{-3} HCl is added to 10cm^3 of a 0.10mol dm^{-3} solution of **G**, the final pH is 1.6. Using the following axes, sketch the pH changes that occur during this addition of $\text{HCl}(\text{aq})$.



[2]

[Total: 4]

- 8 (a) (i) By means of a clear, labelled diagram, describe the shape of the tin(IV) chloride molecule.

For
Examiner's
Use

- (ii) Explain the shape of the tin(IV) chloride molecule in terms of its bonding.

.....
.....

[2]

- (b) (i) What would you expect to observe when tin(IV) chloride reacts with water? Suggest an explanation for your answer.

.....
.....
.....

- (ii) Write an equation for the reaction between tin(IV) chloride and water.

.....

[3]

[Total: 5]

Section B

For
Examiner's
UseAnswer **all** questions in the spaces provided.

- 9 DNA is an extremely important chemical in human cells. It has been described as the 'blueprint of life'.

(a) What **three** types of compound are linked together in DNA?

.....[1]

(b) DNA consists of two strands linked together. Draw a **block diagram** to illustrate this and showing **two** repeat units in the backbones, labelling the components and showing and labelling the bonds between the strands.

[4]

(c) DNA is used to encode for the production of a particular protein. Put the following biochemical structures in the correct sequence from the use of DNA as a template to the formation of the protein by writing their names in the relevant box below.

tRNA

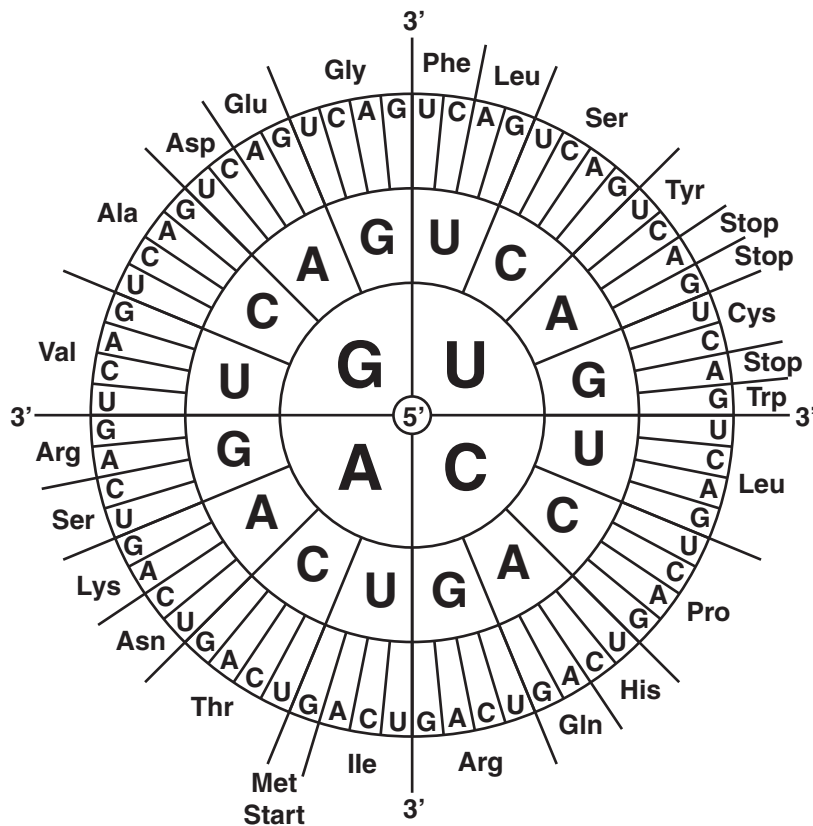
mRNA

ribosomes

DNA → → → → protein [2]

- (d) In order to produce proteins, the information stored in the DNA molecules has to be translated to produce an mRNA strand. A sequence of three bases, called a triplet, on the mRNA describes a particular amino acid. These amino acids are then combined together to form proteins. The amino acid specified by each triplet is shown below.

For
Examiner's
Use



The sequence of three bases in a triplet is read from the middle outwards e.g. UGG specifies Trp.

- (i) There are four different bases present in mRNA. How many different triplets are possible using these four bases.

.....

- (ii) What peptide fragment would the following sequence code for when read from left to right? (Use 3-letter abbreviations for amino acids.)

5' – A U G A G C C G A C U U G A C G U G – 3'

.....

- (iii) What would be the effect of changing the 11th base from U to C?

.....

[4]

[Total: 11]

- 10** Instrumental methods of analysis have become increasingly important in recent years. The use of chromatography to separate substances, and NMR spectroscopy to identify them, has become routine in many laboratories.

For
Examiner's
Use

(a) Chromatography relies on either partition or adsorption to help separate substances.

(i) Briefly explain how each method brings about separation.

partition

.....

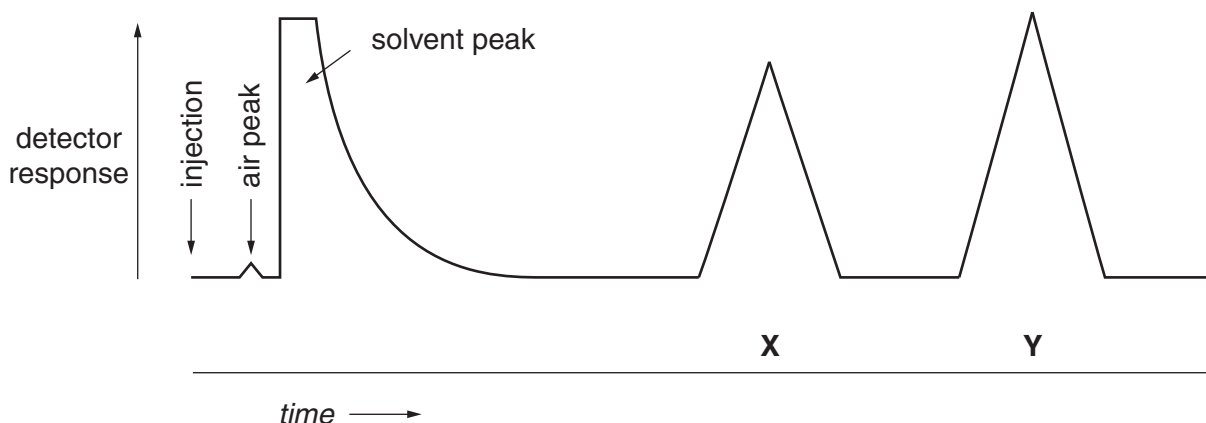
adsorption

.....

(ii) The table shows three different techniques of chromatography. Identify which separation method, *partition or adsorption*, applies to each.

technique	separation method
paper chromatography	
thin-layer chromatography	
gas/liquid chromatography	

(iii) The diagram represents the output from gas/liquid chromatography carried out on a mixture.



Determine the percentage of each of the two components **X** and **Y** in the mixture.

- (b) NMR spectroscopy is a very important analytical technique for use with organic compounds.

For
Examiner's
Use

- (i) Why is NMR spectroscopy particularly useful for organic compounds?

.....

.....

- (ii) Two molecules, propanal and propanone, have the same molecular formula, C_3H_6O . Draw the displayed formula of each compound and explain briefly how NMR spectroscopy can distinguish between the two structures.

.....

.....

.....

.....

[4]

[Total: 9]

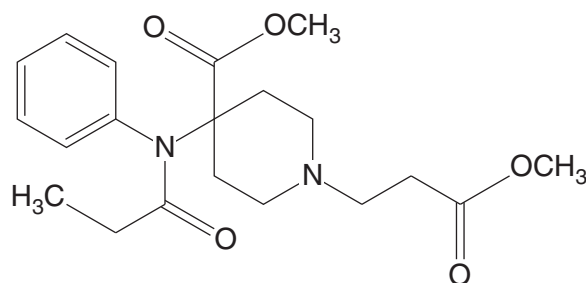
- 11 One of the greatest challenges facing scientists today is the development of effective drugs to treat different forms of cancer.

- (a) Drugs can be introduced into the body by injection or by mouth. Taking drugs by injection avoids the drug being broken down in the digestive system.
State **two** other advantages of giving drugs by injection.

.....

[2]

- (b) The drug *Ultiva* has been developed to treat ovarian cancer, and is usually given by injection.



Ultiva

Study the structure of *Ultiva* and draw a **circle** around **two different** functional groups that could be broken down in the digestive system. [2]

- (c) One way of avoiding the breakdown of drugs in the body is to use a specially designed nanoparticle which encloses the drug. If the nanoparticles are made of a particular sort of polymer, they absorb water at the slightly acidic pH inside some cells, increasing their diameter from around 100 nm to around 1000 nm. This spreads out the polymer chains allowing release of the drug.

- (i) Other than absorbing water, suggest a property this polymer would need to possess for its use in drug delivery.

.....

- (ii) Why would this method of release **not** work if the nanoparticles were taken by mouth?

.....
 [2]

- (d) Polymers may be formed by two different types of chemical reaction.
Name the two types of reaction and write an equation to illustrate each reaction type.

name

equation

name

equation

[3]

- (e) The breakdown of polymers, such as carbohydrates and proteins in the body is important for digestion. What type of reaction is generally involved?

.....[1]

[Total: 10]

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