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9701/41

May/June 2011

2 hours

Additional Materials: Data Booklet

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.

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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9	
Total	

This document consists of **18** printed pages and **2** blank pages.

Section A

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

- 1 Taken together, nitrogen and oxygen make up 99% of the air. Oxygen is by far the more reactive of the two gases, and most of the substances that react with air combine with the oxygen rather than with the nitrogen.

(a) State **one** reason why the molecule of nitrogen, N_2 , is so unreactive.

.....[1]

Despite the apparent lack of reactivity of N_2 , nitrogen atoms have been found to form bonds with almost all of the elements in the Periodic Table. Lithium metal reacts with nitrogen gas at room temperature to give lithium nitride, Li_3N . Magnesium produces magnesium nitride, Mg_3N_2 , as well as magnesium oxide, when heated in air.

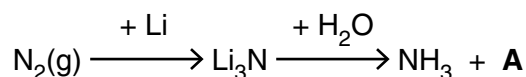
(b) Calculate the lattice energy of magnesium nitride using the following data, in addition to relevant data from the *Data Booklet*.

enthalpy change	value/ kJ mol^{-1}
atomisation of $Mg(s)$	+148
total of electron affinities for the change $N(g) \rightarrow N^{3-}(g)$	+2148
enthalpy of formation of $Mg_3N_2(s)$	-461

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

- (c) Lithium reacts readily with nitrogen, and because of this Li_3N has been considered as a possible intermediate in the 'fixing' of nitrogen to make ammonia-based fertilisers.

For
Examiner's
Use



- (i) Construct an equation for the reaction between Li_3N and H_2O , and hence identify compound **A**.

.....

- (ii) Using your knowledge of the Haber process, consider **one** advantage and **one** disadvantage of using lithium as a means of fixing nitrogen, rather than the Haber process.

advantage of the lithium method

.....

disadvantage of the lithium method

.....

[3]

- (d) Another possible advantage of Li_3N is that it contains a large percentage by mass of nitrogen. Another fertiliser that contains a large percentage by mass of nitrogen is urea, NH_2CONH_2 .

- (i) Calculate and compare the percentages by mass of nitrogen in Li_3N and NH_2CONH_2 .

.....

.....

.....

- (ii) What *class* of organic compound is urea?

.....

- (iii) Write an equation for the production of ammonia by the reaction between urea and water.

.....

- (iv) Urea can be applied directly to the soil either before or during the growing of crops.

What would be a major **disadvantage** of using lithium nitride in this way?

.....

.....

[5]

[Total: 12]

2 (a) State briefly what is meant by the following terms.

(i) reversible reaction

.....

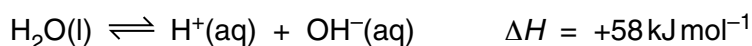
(ii) dynamic equilibrium

.....

.....

[2]

(b) Water ionises to a small extent as follows.



(i) Write an expression for K_c for this reaction.

.....

(ii) Write down the expression for K_w , the ionic product of water, and explain how this can be derived from your K_c expression in (i).

.....

.....

(iii) State and explain how the value of K_w for hot water will differ from its value for cold water.

.....

.....

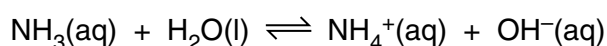
[3]

(c) K_w can be used to calculate the pH of solutions of strong and weak bases.

(i) Use the value of K_w in the *Data Booklet* to calculate the pH of $0.050 \text{ mol dm}^{-3}$ NaOH.

pH = ...

Ammonia ionises slightly in water as follows.



The following expression applies to this equilibrium.

$$[\text{H}_2\text{O}] \times K_c = [\text{NH}_4^+][\text{OH}^-]/[\text{NH}_3] = 1.8 \times 10^{-5} \text{ mol dm}^{-3}$$

- (ii) Calculate $[\text{OH}^-(\text{aq})]$ in a $0.050 \text{ mol dm}^{-3}$ solution of NH_3 . You may assume that only a small fraction of the NH_3 ionises, so that $[\text{NH}_3]$ at equilibrium remains at $0.050 \text{ mol dm}^{-3}$.

For
Examiner's
Use

$[\text{OH}^-(\text{aq})] = \dots\dots\dots$

- (iii) Use the value of K_w in the *Data Booklet*, and your answer in (ii), to calculate $[\text{H}^+(\text{aq})]$ in $0.050 \text{ mol dm}^{-3} \text{ NH}_3(\text{aq})$.

$[\text{H}^+(\text{aq})] = \dots\dots\dots$

- (iv) Calculate the pH of this solution.

pH = $\dots\dots\dots$
[6]

[Total: 11]

- 3 (a) State and explain the variation in the oxidation numbers of the chlorides of the elements Na, Mg, Al and Si.

For
Examiner's
Use

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

- (b) Describe the reaction of phosphorus(V) chloride with water, and write an equation for the reaction.

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

- (c) When microwave radiation is passed through phosphorus(III) chloride, PCl_3 , at low pressure, a new chloride of phosphorus, **B**, is formed.

B contains 69.6% by mass of chlorine and 30.4% by mass of phosphorus, and its M_r is approximately 200.

- (i) Calculate the empirical and molecular formulae of **B**.

.....

- (ii) Assuming phosphorus and chlorine show their typical valencies, draw the displayed formula of **B**, showing all bonds and lone pairs.

.....

- (iii) Calculate the oxidation number of phosphorus in **B**.

.....

- (iv) One mole of **B** reacts with four moles of water.
Suggest the structure of the phosphorus-containing product of this reaction.

.....
[6]

[Total: 10]

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- 4 The combustion of fuels in motor vehicles, trains, aeroplanes and power stations produces the pollutant gas NO_2 .

(a) Write an equation to show how NO_2 is formed in these situations.

.....[1]

(b) (i) How is the NO_2 removed from the exhaust gases of motor vehicles?

.....

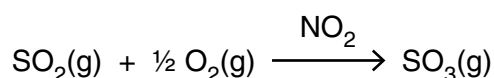
(ii) Write an equation for this process.

.....[2]

(c) Suggest whether the production of the pollutant NO_2 would be reduced if fossil fuels were replaced by hydrogen as a fuel for combustion. Explain your answer.

.....
.....[1]

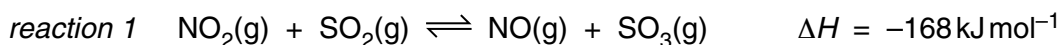
(d) In the atmosphere, NO_2 acts as a catalyst for the oxidation of SO_2 to SO_3 .



(i) What is the environmental significance of this reaction?

.....

The oxidation takes place in two steps. The initial reaction is that between NO_2 and SO_2 .



(ii) Write an equation to show how the NO_2 is regenerated in the second step of the oxidation.

.....

(iii) Write an expression for the equilibrium constant, K_p for reaction 1, stating its units.

$K_p =$
units

(iv) If equal amounts of $\text{NO}_2(\text{g})$ and $\text{SO}_2(\text{g})$ are allowed to react at room temperature, it is found that 99.8% of the gases have been converted into products at equilibrium. Calculate a value for K_p .

$K_p =$

- (v) The temperature of the atmosphere decreases with height. How will this affect the position of the equilibrium in *reaction 1*? Explain your answer.

For
Examiner's
Use

.....

.....

[7]

[Total: 11]

- 5 (a) There are several ways of introducing chlorine atoms into organic molecules. State the reagents and conditions necessary to carry out the following transformations.

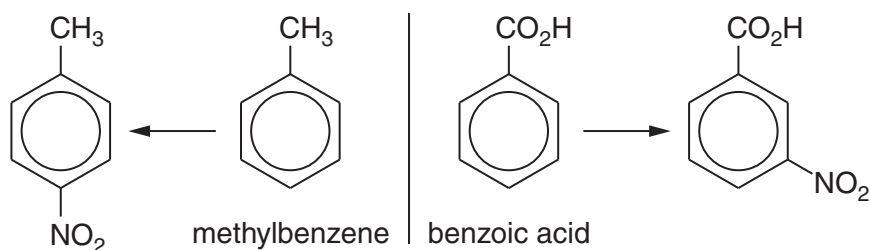
For
Examiner's
Use

transformation	reagents + conditions
$\text{C}_2\text{H}_4 \longrightarrow \text{C}_2\text{H}_5\text{Cl}$	
$\text{C}_2\text{H}_5\text{OH} \longrightarrow \text{C}_2\text{H}_5\text{Cl}$	
$\text{C}_2\text{H}_6 \longrightarrow \text{C}_2\text{H}_5\text{Cl}$	
$\text{C}_2\text{H}_4 \longrightarrow \text{C}_2\text{H}_4\text{Cl}_2$	
$\text{CH}_3\text{CO}_2\text{H} \longrightarrow \text{CH}_3\text{COCl}$	
 $\text{C}_6\text{H}_5\text{CH}_3 \longrightarrow \text{Cl-C}_6\text{H}_4\text{CH}_3$	
 $\text{C}_6\text{H}_5\text{CH}_3 \longrightarrow \text{C}_6\text{H}_5\text{CH}_2\text{Cl}$	

[6]

- (b) (i) When treated with concentrated $\text{HNO}_3 + \text{H}_2\text{SO}_4$ at 55°C , benzene produces nitrobenzene.
Outline the mechanism of this reaction. You should include all charges, and use curly arrows to represent the movement of electron pairs.

In aromatic substitution of monosubstituted benzenes, the orientation of an incoming group depends on the nature of the group already attached to the ring.
For example, using the same reagents and conditions as in (i), methylbenzene and benzoic acid produce the following nitro compounds.



- (ii) Using this information as an aid, suggest a structure for compound **C** in the following synthesis of 3-bromobenzoic acid.



- (iii) Suggest reagents and conditions for steps 1 and 2.

step 1

step 2

[6]

[Total: 12]

- 6 (a) The reaction producing tri-iodomethane (iodoform) can be used as a test for the presence of certain groups within a molecule.

For
Examiner's
Use

- (i) State the reagents and conditions used for this reaction.

.....

- (ii) Write the structural formula of **one** functional group that would give a positive result with this iodoform reaction.

.....

- (iii) What do you observe in a positive test?

.....

.....

- (iv) In the following table place a tick (✓) in the column against each compound that would give a positive result with this test, and a cross (X) against each compound that would give a negative result.

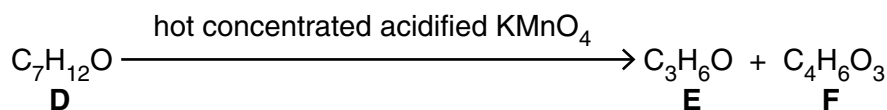
compound	result
CH ₃ OH	
CH ₃ CH ₂ OH	
CH ₃ CHO	
CH ₃ CO ₂ H	
 -CHO	
 -COCH ₃	

[6]

- (b) The iodoform test can be used, along with other reactions, to work out the structures of unknown compounds.

Use the information in the table below to deduce the structures of the compounds in the following scheme, and draw these structures in the boxes provided.

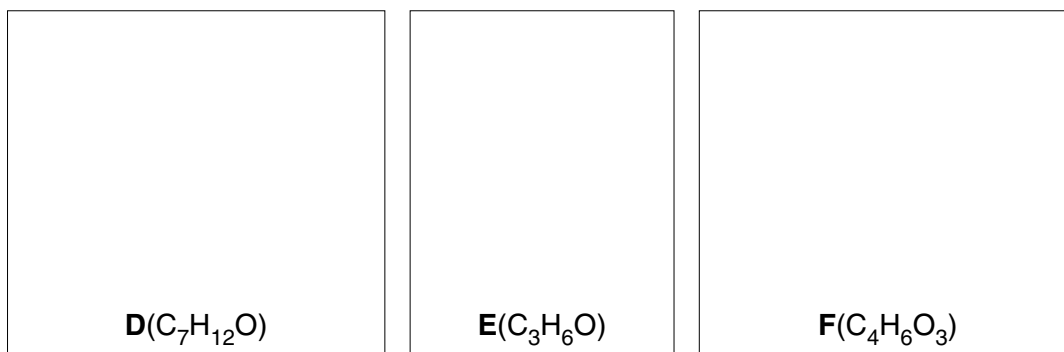
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Use



Results of tests (✓ indicates a positive result; ✗ indicates a negative result)

test	results of tests with each compound		
	D	E	F
iodoform	✗	✓	✓
Fehling's solution	✓	✗	✗
2,4-dinitrophenyl-hydrazine reagent	✓	✓	✓
Na ₂ CO ₃ (aq)	✗	✗	✓

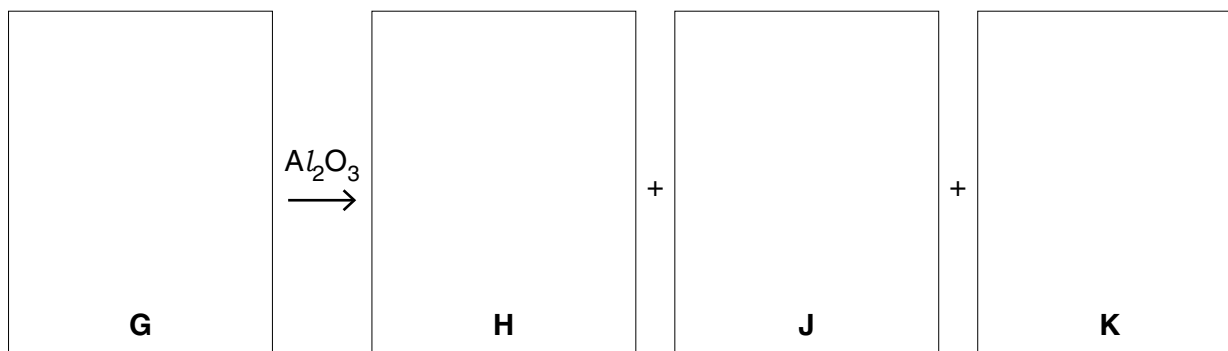
structures



[3]

- (c) Treatment of compound **F** with NaBH₄ gives compound **G**, C₄H₈O₃. Heating **G** with Al₂O₃ gives a mixture of three isomeric unsaturated carboxylic acids **H**, **J** and **K**, C₄H₆O₂, two of which are stereoisomers of each other.

Suggest structures for **G**, **H**, **J**, and **K**, and name the type of stereoisomerism shown.



type of stereoisomerism[5]

[Total: 14]

Section B

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

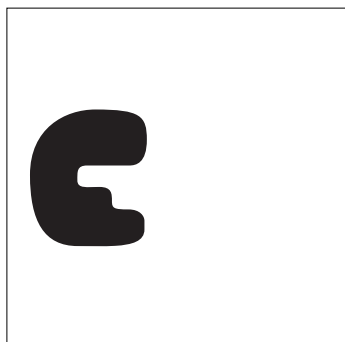
- 7 Enzymes are a special group of protein molecules present in large amounts in living organisms. Enzymes behave as catalysts but, unlike inorganic catalysts, they generally catalyse only one particular reaction.

- (a) Inorganic catalysts often work better on heating, but enzymes rarely work at temperatures much above 45°C. Explain why this is the case.

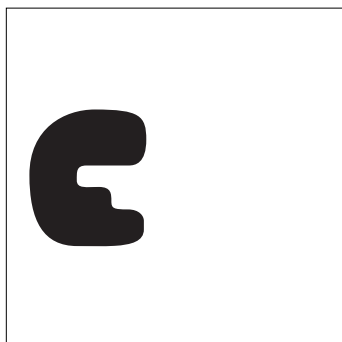
.....

 [2]

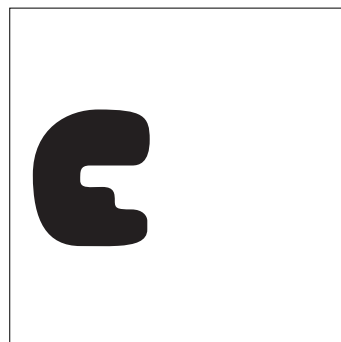
- (b) Using the shape below to represent an enzyme, sketch how an enzyme is specific to the breakdown of a particular substrate molecule



enzyme + substrate



enzyme-substrate complex



enzyme + products

[3]

- (c) Describe the effects of a competitive, and of a non-competitive inhibitor on the interaction between enzyme and substrate.

For
Examiner's
Use

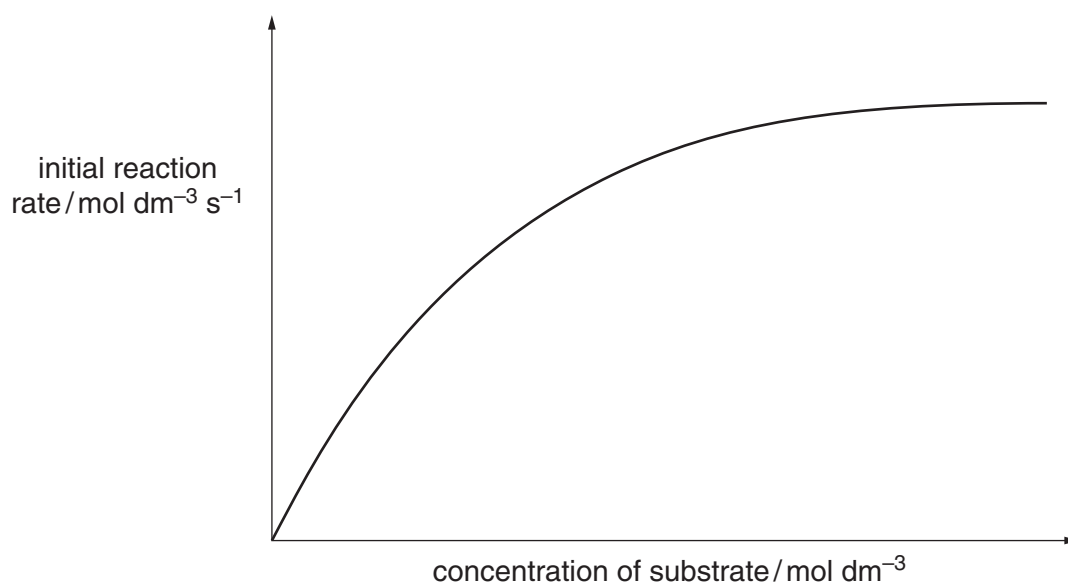
.....

.....

.....

..... [2]

- (d) (i) The diagram shown illustrates an enzyme-catalysed reaction. On the diagram sketch the graph that would be obtained if the same reaction was carried out in the presence of a **non-competitive** inhibitor.



- (ii) Explain why a **non-competitive** inhibitor has this effect on the reaction.

.....

..... [3]

[Total: 10]

- 8 Chromatography is an important analytical technique in chemistry. There is a number of techniques under the general heading of chromatography.

For
Examiner's
Use

- (a) Paper and gas chromatography rely on partition to separate the components in a mixture, whereas thin-layer chromatography uses adsorption.

Explain what is meant by (i) *partition* and (ii) *adsorption*, in the context of chromatography.

(i) partition

.....

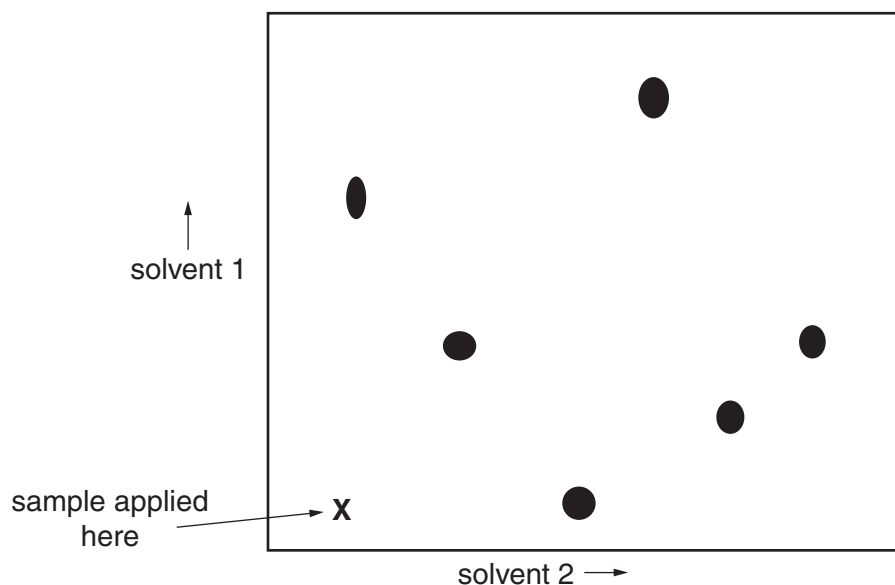
.....

(ii) adsorption

.....

.....[2]

- (b) In paper or thin-layer chromatography, better separation may be achieved by running the chromatogram in one solvent, then turning the paper at right angles and running it in a second solvent. The chromatogram below was produced in this way.

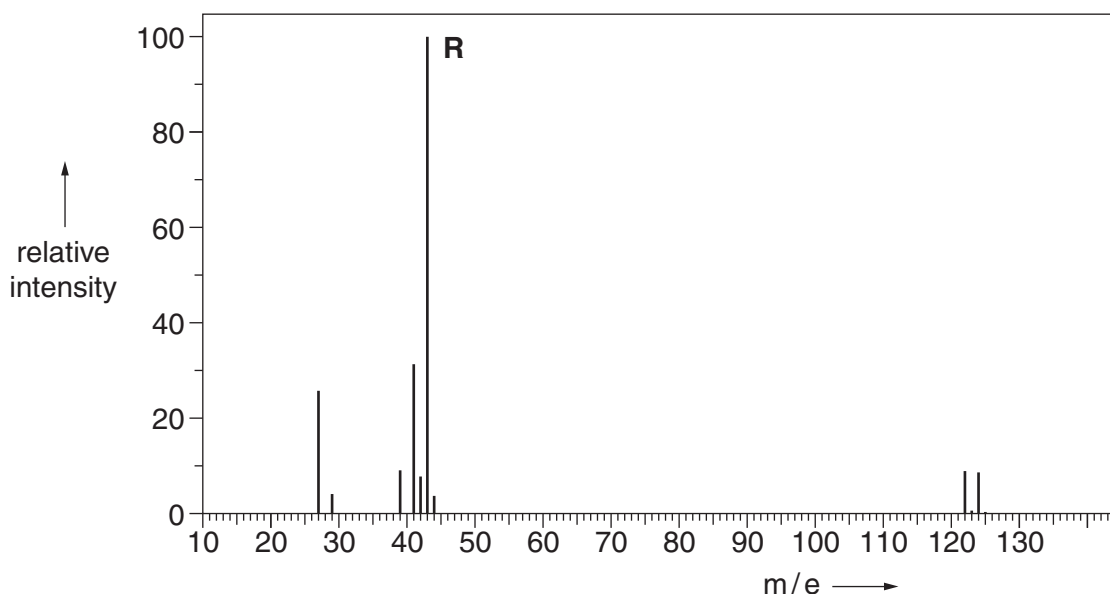


- (i) Ring the spot which was insoluble in solvent 1.
(ii) Label as **A** and **B** the spots which were **not** resolved using solvent 1.

[2]

- (c) The mass spectrum shown was obtained from a compound of formula C_pH_qX , where X represents a halogen atom.

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Use



- (i) Deduce the identity of X , giving a reason.

X is
.....

- (ii) If the relative heights of the M and $M+1$ peaks are 9 and 0.3 respectively, calculate the value of p . Use this value and the m/e value of the molecular ion to calculate the value of q , and hence the molecular formula of the compound. Show your working.

- (iii) Suggest a formula for the ion responsible for the peak labelled **R**.

..... [4]

- (d) In the fragmentation of alcohols which occurs in a mass spectrometer, small stable, neutral molecules are sometimes produced. Suggest the identity of **two** such molecules, each with an M_r less than 30.

(i) (ii) [2]

[Total: 10]

- 9 In today's world, many traditional materials have been replaced by different sorts of polymers. This includes rigid polymers such as those used in car bodies to replace steel and flexible polymers like those used in textiles to replace cotton or wool.

(a) (i) To form a polymer, what is the **minimum** number of functional groups that the monomer must possess?

.....

(ii) Illustrate your answer to (i) with the structure of a possible monomer.

[2]

(b) State **two** differences between addition and condensation polymerisation.

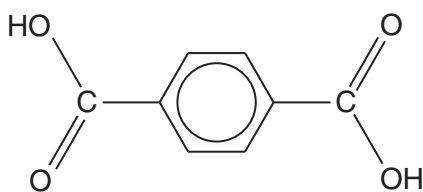
(i)

.....

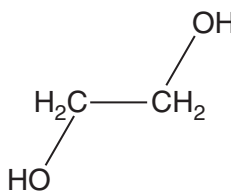
(ii)

..... [2]

(c) The polymer formed from the co-polymerisation of the two monomers shown is known as *Terylene*.



benzene-1, 4-dicarboxylic acid



ethane-1-2-diol

(i) The two monomers react by condensation polymerisation. What other molecule is formed in this reaction?

.....

(ii) Draw the structure of **one** repeat unit of *Terylene*.

(iii) What is the name given to polymers containing the same functional group as *Terylene*?

.....

[4]

(d) The monomers ethene and but-1-ene can also co-polymerise to form a polyalkene, but this does not produce a regular alternating structure like *Terylene*. Explain why this is the case, drawing diagrams if you wish.

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

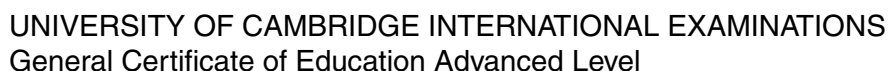
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[Total: 10]

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9701/42

May/June 2011

2 hours

Additional Materials: Data Booklet

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Answer **all** questions.

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This document consists of **16** printed pages and **4** blank pages.

Section A

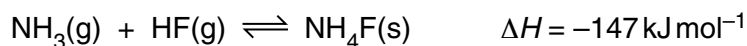
For
Examiner's
UseAnswer **all** questions in the spaces provided.

- 1 (a) Hydrogen fluoride, HF, behaves as a weak acid in water, with $K_a = 5.6 \times 10^{-4} \text{ mol dm}^{-3}$.

Calculate the pH of a $0.050 \text{ mol dm}^{-3}$ solution of HF.

pH = ...[2]

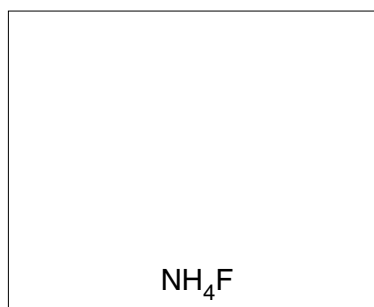
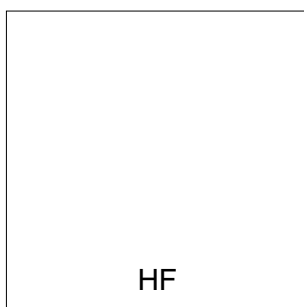
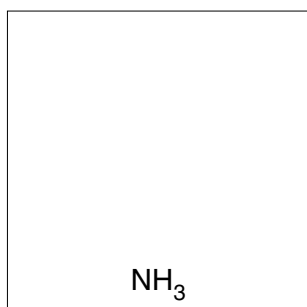
- (b) Gaseous ammonia and hydrogen fluoride react together to give solid ionic ammonium fluoride.



- (i) What *type of reaction* is this?

.....

- (ii) Draw dot-and-cross diagrams (outer shells only) describing the bonding in the three compounds involved in this reaction.



- (iii) There are **three** types of bonding in NH₄F.
Give the names of each of the three types, and state where in the compound each type occurs.

.....

.....

.....

- (iv) The reaction between NH_3 and HF is reversible. What conditions of temperature and pressure would favour the **reverse** reaction, i.e. the dissociation of NH_4F ? Explain your answer.

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

[9]

- (c) Many commercial copper and brass polishes contain ammonia. The tarnish that forms on the surface of copper is often copper sulfide, CuS . In the presence of O_2 from the air, NH_3 can combine with this copper sulfide to produce the soluble cuprammonium sulfate, $[\text{Cu}(\text{NH}_3)_4]\text{SO}_4$.

- (i) Construct an equation for this reaction.

.....

- (ii) State the colour of cuprammonium sulfate solution.

.....

- (iii) Describe what you would see if a solution of cuprammonium sulfate was diluted with water. Explain your answer.

.....
.....

[3]

- (d) When sulfuric acid is added to $\text{Cu}^{2+}(\text{aq})$, no colour change occurs, but when concentrated hydrochloric acid is added to $\text{Cu}^{2+}(\text{aq})$, the solution turns yellow-green. The solution reverts to its original colour when it is diluted with water.

Suggest the type of reaction occurring with $\text{HCl}(\text{aq})$, suggest what is formed during the reaction, and write an equation for the change.

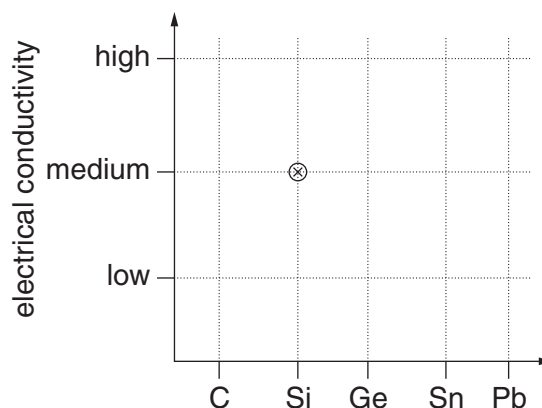
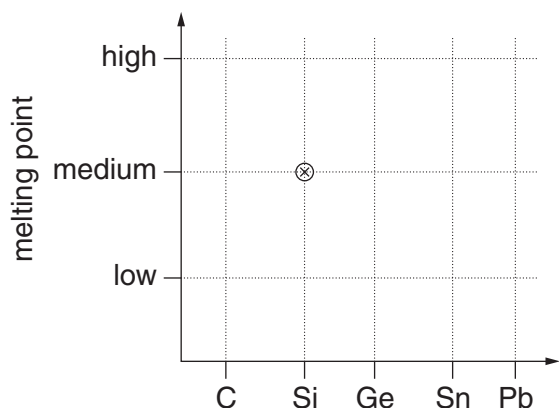
.....
.....
.....
.....

[3]

[Total: 17]

- 2 (a) (i) On the following grids, plot points showing the variation in the named property of the Group IV elements. Your points should show for each element, whether the melting point/electrical conductivity is 'high', 'medium' or 'low'. The point for silicon has already been plotted in each case.

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Examiner's
Use



- (ii) Suggest explanations of these trends in terms of the structure and bonding of the Group IV elements.

melting point

.....

electrical conductivity

.....

[6]

- (b) Choose **one** reaction to illustrate **each** of the following statements. Write an equation for each of your chosen reactions, and describe what you would see as the reaction is carried out.

- (i) PbO is more stable than PbO₂.

.....

- (ii) CO is easily oxidised to CO₂.

.....

- (iii) Aqueous SnCl₂ is a useful reducing agent.

.....

[4]

[Total: 10]

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- 3 (a) State the relationship between the Faraday constant, F , the charge on the electron, e , and the Avogadro number, L .

For
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Use

.....[1]

- (b) If the charge on the electron, the A_r and the valency of copper are known, the value of the Avogadro number can be determined experimentally. This is done by passing a known current for a known time through a copper electrolysis cell, and weighing the mass of copper deposited onto the cathode.

- (i) Draw a diagram of suitable apparatus for carrying out this experiment.
Label the following: power supply (with + and – terminals); anode; cathode; and ammeter.
State the composition of the electrolyte.

The following are the results obtained from one such experiment.

current passed through the cell	= 0.500 A
time current was passed through cell	= 30.0 min
initial mass of copper cathode	= 52.243 g
final mass of copper cathode	= 52.542 g

- (ii) Use these data and relevant information from the *Data Booklet* to calculate a value of L to **3 significant figures**.

$L =$
[9]

- (c) Use relevant information from the *Data Booklet* to identify the substances formed at the anode and at the cathode when aqueous solutions of the following compounds are electrolysed.

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Use

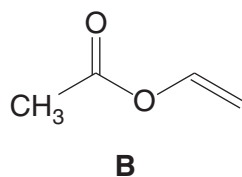
compound	product at anode	product at cathode
AgF		
FeSO ₄		
MgBr ₂		

[5]

[Total: 15]

- 4 (a) Polyvinyl acetate, PVA, is a useful adhesive for gluing together articles made from wood, paper or cardboard. The monomer of PVA is ethenyl ethanoate, **B**.

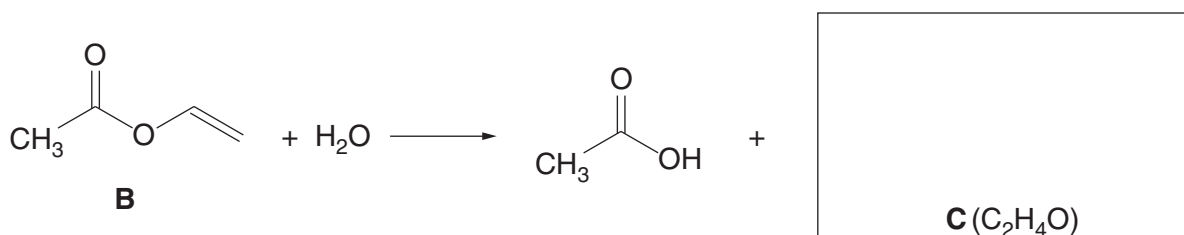
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Use



PVA is formed from **B** by the process of addition polymerisation.

- (i) Draw a section of the PVA molecule containing at least 2 monomer molecules, and identify clearly the repeat unit.

The ester **B** can be hydrolysed in the usual way, according to the following equation.



- (ii) Use this information to suggest a possible structure for **C** and draw it in the box above.

When substance **C** is extracted from the product mixture, it is found that it does **not** decolourise Br₂(aq), but it **does** form a pale yellow precipitate with alkaline aqueous iodine.

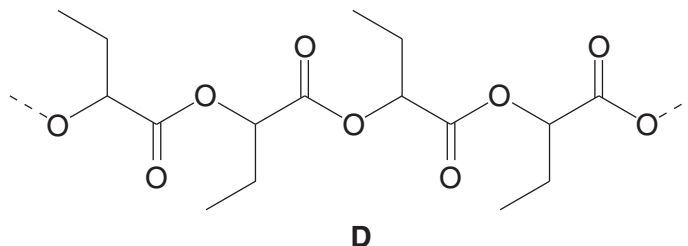
- (iii) Suggest a structure for **C** that fits this new information.

- (iv) Suggest a confirmatory test for the functional group in the structure you have drawn in (iii). Your answer should include the reagent you would use and the observation you would make.

.....

[6]

(b) The following diagram represents a section of another polymer.



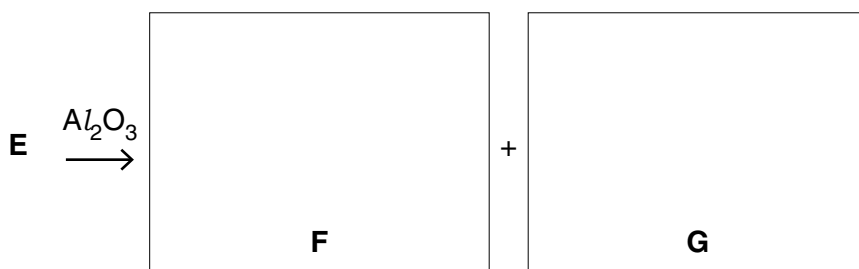
- (i) On the above formula draw brackets, [], around the atoms that make up the repeat unit of this polymer.
- (ii) Name the functional group in polymer **D**.
-
- (iii) Suggest and draw the structure of the monomer, **E**, that could form this polymer.
-
- (iv) What *type of polymerisation* is involved in making polymer **D** from its monomer?
-
- (v) What is the relationship between the repeat unit of polymer **D** and the repeat unit of PVA?
-

[5]

(c) Monomer **E** exists as two stereoisomers. Heating either isomer with Al_2O_3 gives a mixture of two unsaturated carboxylic acids **F** and **G**, which are stereoisomers of each other.

- (i) Name the *type of stereoisomerism* shown by compound **E**.
-

- (ii) Suggest structures for **F** and **G**, and name the type of stereoisomerism they show.



type of isomerism

[4]

[Total: 15]

- 5 (a) Describe and explain how the acidities of ethanol and phenol compare to that of water.

For
Examiner's
Use

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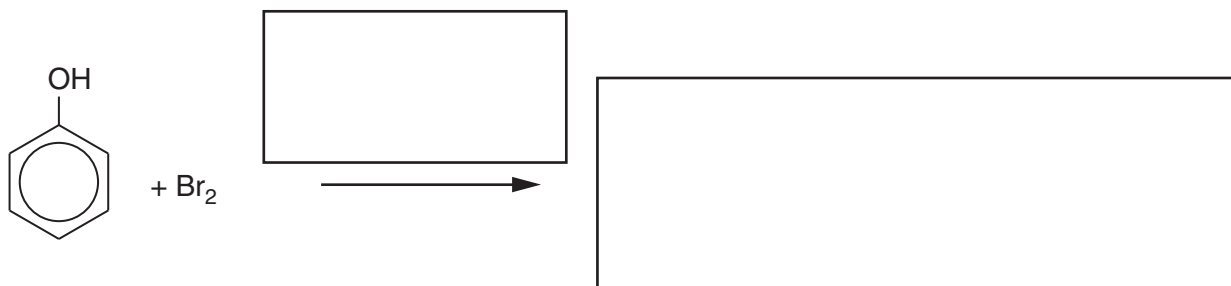
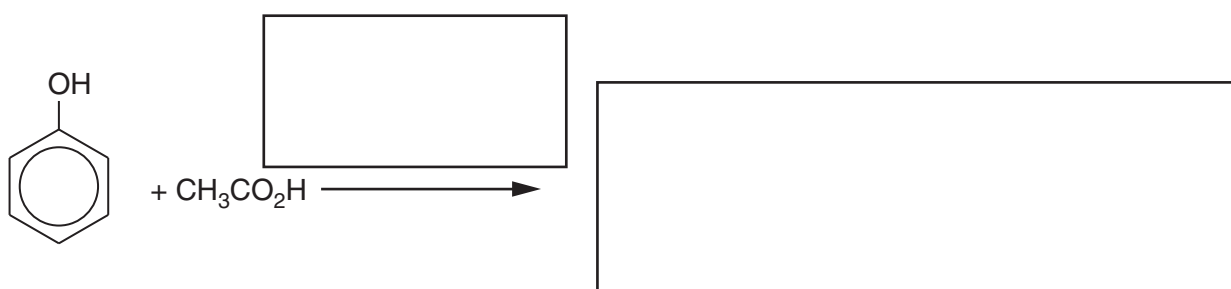
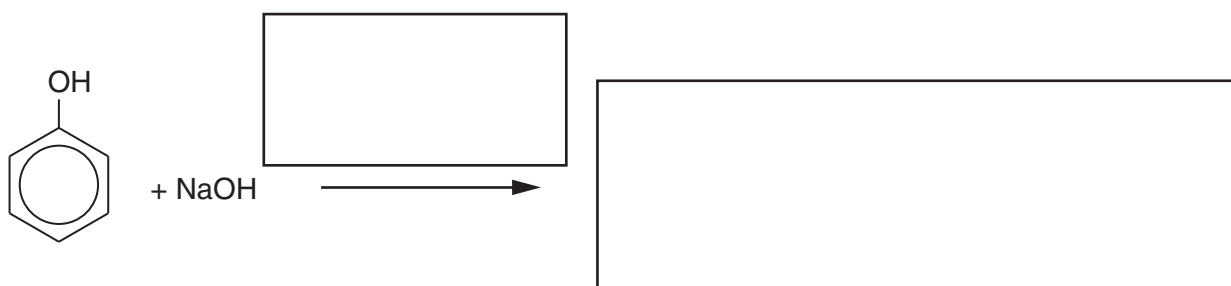
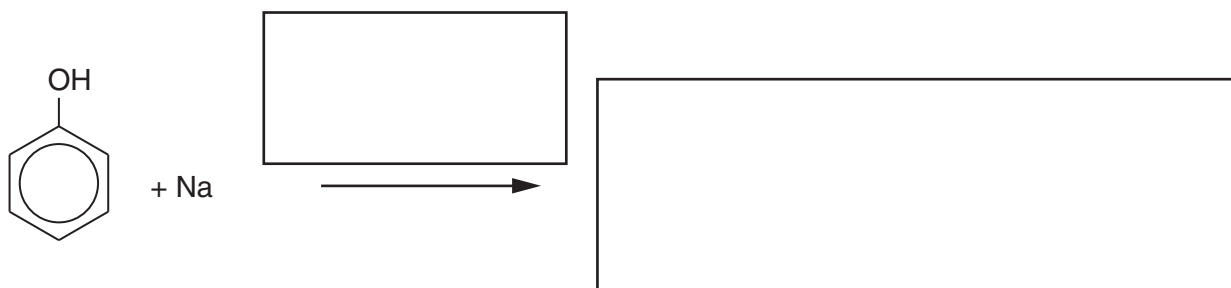
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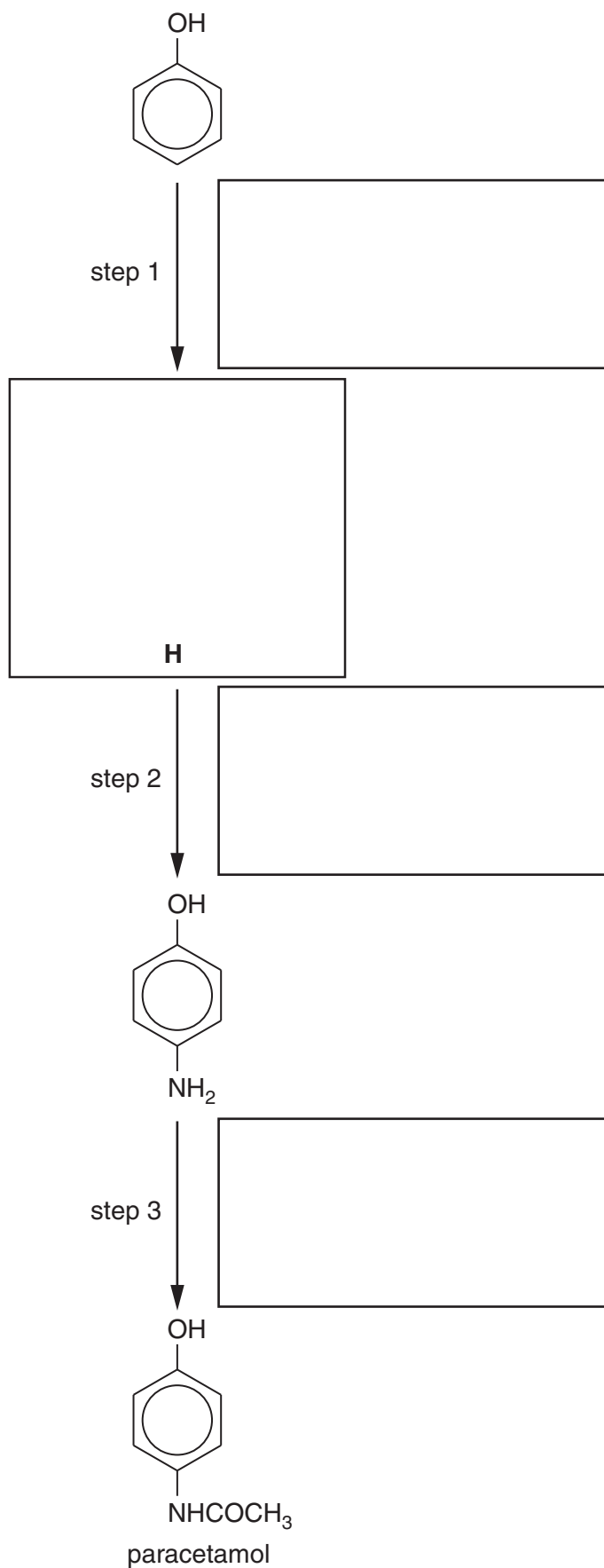
- (b) Complete the following equations showing **all** the products of each of these reactions of phenol. Include reaction conditions where appropriate in the boxes over the arrows. If no reaction occurs write **no reaction** in the products box.



[5]

- (c) The analgesic drug paracetamol can be synthesised from phenol by the following route. Suggest reagents and conditions for the each of three steps, and suggest the structure of the intermediate **H**. Write your answers in the boxes provided.

For
Examiner's
Use



[4]

[Total: 13]

Section B

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

For
Examiner's
Use

- 6 Enzymes are protein molecules that are highly efficient in catalysing specific chemical reactions in living organisms.

- (a) To work in tissues, enzyme molecules generally need to be water-soluble. What does this tell you about the nature of the side-chains on the exterior of the molecules?

.....
[1]

- (b) Enzymes function by a substrate molecule interacting with a particular part of the enzyme known as the 'active site'. The substrate is converted into products that are then released, to be replaced by another substrate molecule.

- (i) Describe briefly the primary, secondary and tertiary structures of an enzyme.

.....

- (ii) The activity of an enzyme depends upon the tertiary structure of the protein molecule. Explain how the tertiary structure produces an effective active site.

.....

- (iii) Give **two** conditions that can **reduce** the activity of an enzyme, explaining the reason in each case.

I

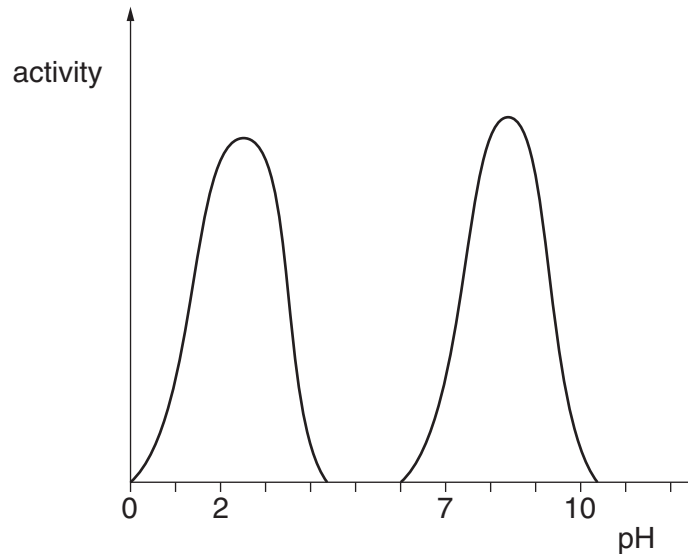
 II

[6]

(c) An individual enzyme operates best at a specific pH. Different enzymes operate best under conditions of different pH. Three enzymes involved in the digestion of food are amylase, pepsin and trypsin.

- Amylase, found in saliva, hydrolyses starch to a mixture of glucose and maltose under approximately neutral conditions.
- Pepsin hydrolyses proteins to peptides in the acid conditions of the stomach.
- Trypsin continues the hydrolysis of peptides to amino acids in the mildly alkaline conditions of the small intestine.

The graph below shows the activity of two of the three enzymes mentioned above.



- (i) Label each peak shown with the name of the enzyme responsible, either amylase, pepsin or trypsin.
- (ii) On the axes above, sketch the graph that the third enzyme would produce, and label it with the name of that enzyme.

[3]

[Total: 10]

- 7 The technique of DNA fingerprinting has been one of the most important developments in biochemical analysis in recent times. It has enabled enormous advances to be made in forensic science, medicine and archaeology.

- (a) The table shows different stages in the production of a genetic fingerprint. Use the numbers 1 to 6 to put the stages in the correct sequence in the blank column.

stages	process	correct sequence (numbers)
A	place samples on agarose gel	
B	use polymerase chain reaction	
C	label with radioactive isotope	
D	extract DNA	
E	use restriction enzyme	
F	carry out electrophoresis	

[3]

- (b) One of the stages above uses a radioactive isotope.

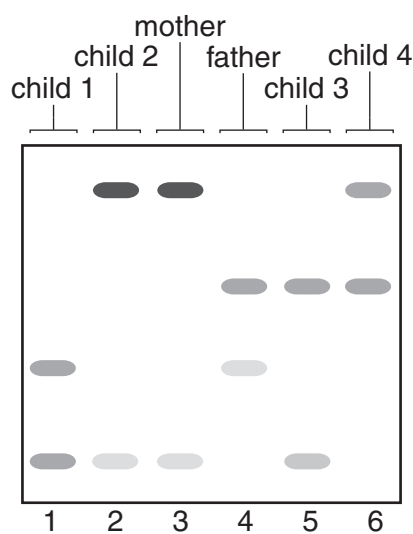
(i) What isotope is used?

(ii) Why is this isotope chosen?

.....
.....

[2]

- (c) The following DNA fingerprints were taken from a family of mother, father and four children.



- (i) Are all of the children related to the mother? State the evidence for your answer.

.....

.....

- (ii) Which child is unlikely to be related to the father? State the evidence for your answer.

.....

.....

[2]

- (d) DNA fingerprinting has been successfully used in archaeological investigations.

- (i) Ancient writings were often made on goatskins. Over the centuries these have often become broken into fragments, making reconstruction of the writings almost impossible.

Suggest how the use of DNA fingerprinting might be able to identify which fragments came from a particular skin.

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- (ii) Apart from the examples of human remains and goatskins, state one other material that could be investigated using this technique.

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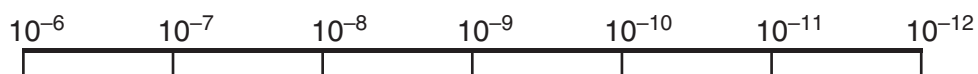
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[Total: 10]

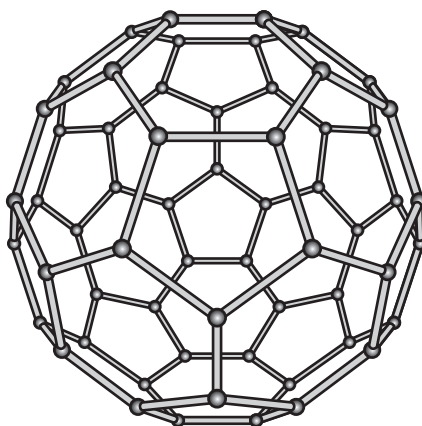
- 8** Nanotechnology is a fast-developing area of science based on the ability to manipulate materials of very small dimensions.

- (a)** On the scale shown in metres, mark the upper and lower limits of the range of sizes for nanoparticles.



[2]

- (b)** One of the most commonly recognised nanoparticles is the 'buckyball', a spherical form of carbon containing 60 carbon atoms. It has been referred to as the third allotrope of carbon.



Diamond and graphite are two other allotropes of carbon. Suggest what is meant by the term *allotrope*.

.....

 [2]

- (c)** Nanoparticles are used to deliver drugs within cells. Suggest what property of nanoparticles enables them to be used in this way. Explain your answer.

.....

 [2]

- (d) Copper is an important metal that has been used for thousands of years. The problem today is that most of the ores rich in copper compounds have been used up. A century ago ores containing >2% of copper by mass would have been worked; today's mines have to operate at much lower percentages, down to 0.5% of copper by mass.

- (i) By what *type of reaction* is the copper present in the ore converted to copper metal?

.....

One of the main ores of copper contains the mineral *chalcopyrite*, CuFeS_2 .

- (ii) Calculate the percentage of copper by mass in *chalcopyrite*.
- (iii) If the ore contains 2% of *chalcopyrite* by mass, calculate the mass of copper which can be produced from each tonne of ore.
- (iv) Certain bacteria are able to extract copper from the 'spoil' heaps of previously mined copper ore. These bacteria are sprayed onto the spoil heaps in an aqueous solution and the resulting solution containing iron(II) sulfate and copper(II) sulfate is collected in tanks.

Suggest how the copper could be recovered as metal.

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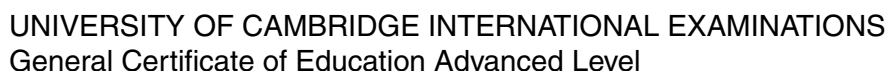
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9701/43

May/June 2011

2 hours

Additional Materials: Data Booklet

DO **NOT** WRITE IN 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	
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Total	

This document consists of **16** printed pages and **4** blank pages.

Section A

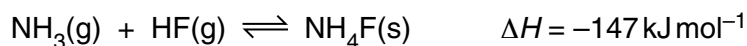
For
Examiner's
UseAnswer **all** questions in the spaces provided.

- 1 (a) Hydrogen fluoride, HF, behaves as a weak acid in water, with $K_a = 5.6 \times 10^{-4} \text{ mol dm}^{-3}$.

Calculate the pH of a $0.050 \text{ mol dm}^{-3}$ solution of HF.

pH = ...[2]

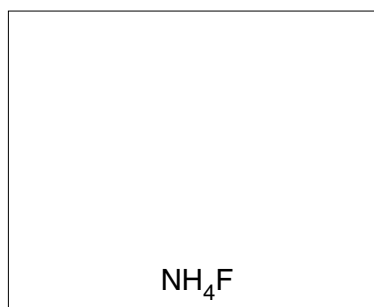
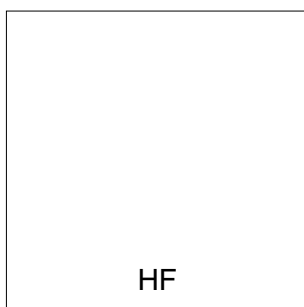
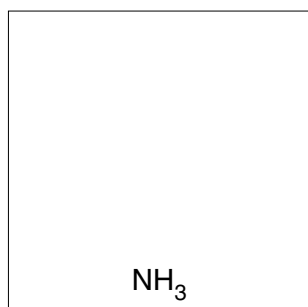
- (b) Gaseous ammonia and hydrogen fluoride react together to give solid ionic ammonium fluoride.



- (i) What *type of reaction* is this?

.....

- (ii) Draw dot-and-cross diagrams (outer shells only) describing the bonding in the three compounds involved in this reaction.



- (iii) There are **three** types of bonding in NH₄F.
Give the names of each of the three types, and state where in the compound each type occurs.

.....

.....

.....

- (iv) The reaction between NH_3 and HF is reversible. What conditions of temperature and pressure would favour the **reverse** reaction, i.e. the dissociation of NH_4F ? Explain your answer.

.....

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[9]

- (c) Many commercial copper and brass polishes contain ammonia. The tarnish that forms on the surface of copper is often copper sulfide, CuS . In the presence of O_2 from the air, NH_3 can combine with this copper sulfide to produce the soluble cuprammonium sulfate, $[\text{Cu}(\text{NH}_3)_4]\text{SO}_4$.

- (i) Construct an equation for this reaction.

.....

- (ii) State the colour of cuprammonium sulfate solution.

.....

- (iii) Describe what you would see if a solution of cuprammonium sulfate was diluted with water. Explain your answer.

.....

.....

[3]

- (d) When sulfuric acid is added to $\text{Cu}^{2+}(\text{aq})$, no colour change occurs, but when concentrated hydrochloric acid is added to $\text{Cu}^{2+}(\text{aq})$, the solution turns yellow-green. The solution reverts to its original colour when it is diluted with water.

Suggest the type of reaction occurring with $\text{HCl}(\text{aq})$, suggest what is formed during the reaction, and write an equation for the change.

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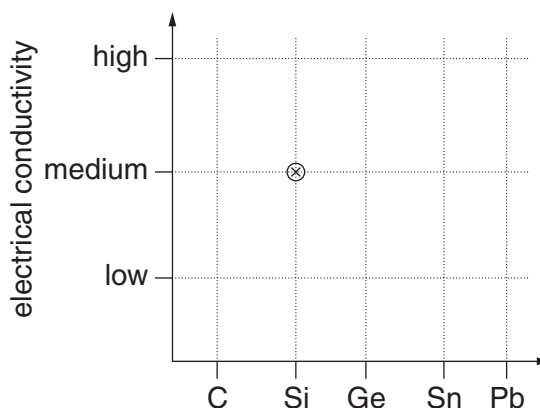
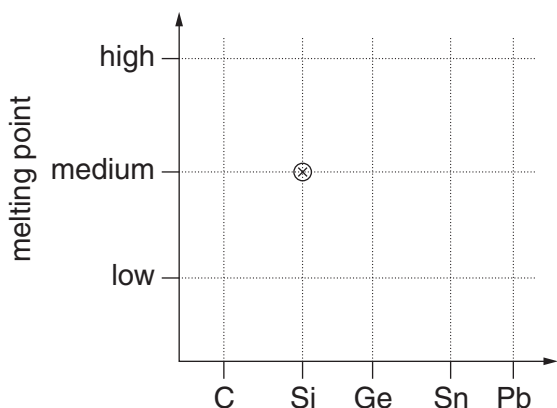
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[3]

[Total: 17]

- 2 (a) (i) On the following grids, plot points showing the variation in the named property of the Group IV elements. Your points should show for each element, whether the melting point/electrical conductivity is 'high', 'medium' or 'low'. The point for silicon has already been plotted in each case.

For
Examiner's
Use



- (ii) Suggest explanations of these trends in terms of the structure and bonding of the Group IV elements.

melting point

.....

electrical conductivity

.....

[6]

- (b) Choose **one** reaction to illustrate **each** of the following statements. Write an equation for each of your chosen reactions, and describe what you would see as the reaction is carried out.

- (i) PbO is more stable than PbO₂.

.....

- (ii) CO is easily oxidised to CO₂.

.....

- (iii) Aqueous SnCl₂ is a useful reducing agent.

.....

[4]

[Total: 10]

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- 3 (a) State the relationship between the Faraday constant, F , the charge on the electron, e , and the Avogadro number, L .

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.....[1]

- (b) If the charge on the electron, the A_r and the valency of copper are known, the value of the Avogadro number can be determined experimentally. This is done by passing a known current for a known time through a copper electrolysis cell, and weighing the mass of copper deposited onto the cathode.

- (i) Draw a diagram of suitable apparatus for carrying out this experiment.
Label the following: power supply (with + and – terminals); anode; cathode; and ammeter.
State the composition of the electrolyte.

The following are the results obtained from one such experiment.

current passed through the cell	= 0.500 A
time current was passed through cell	= 30.0 min
initial mass of copper cathode	= 52.243 g
final mass of copper cathode	= 52.542 g

- (ii) Use these data and relevant information from the *Data Booklet* to calculate a value of L to **3 significant figures**.

$L =$
[9]

- (c) Use relevant information from the *Data Booklet* to identify the substances formed at the anode and at the cathode when aqueous solutions of the following compounds are electrolysed.

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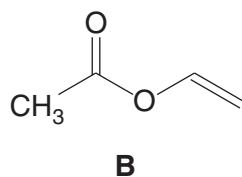
compound	product at anode	product at cathode
AgF		
FeSO ₄		
MgBr ₂		

[5]

[Total: 15]

- 4 (a) Polyvinyl acetate, PVA, is a useful adhesive for gluing together articles made from wood, paper or cardboard. The monomer of PVA is ethenyl ethanoate, **B**.

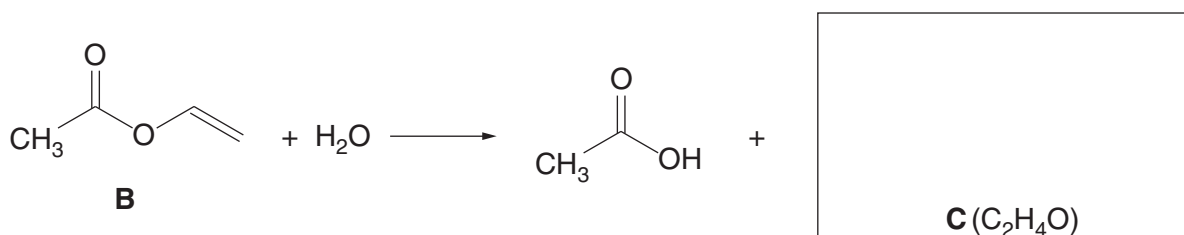
For
Examiner's
Use



PVA is formed from **B** by the process of addition polymerisation.

- (i) Draw a section of the PVA molecule containing at least 2 monomer molecules, and identify clearly the repeat unit.

The ester **B** can be hydrolysed in the usual way, according to the following equation.



- (ii) Use this information to suggest a possible structure for **C** and draw it in the box above.

When substance **C** is extracted from the product mixture, it is found that it does **not** decolourise Br₂(aq), but it **does** form a pale yellow precipitate with alkaline aqueous iodine.

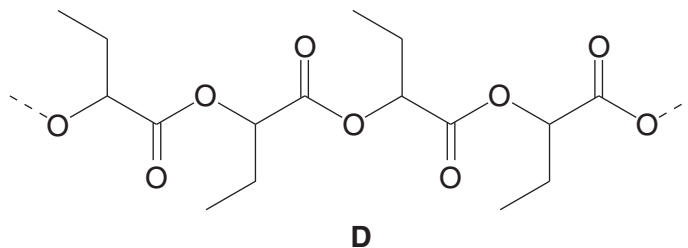
- (iii) Suggest a structure for **C** that fits this new information.

- (iv) Suggest a confirmatory test for the functional group in the structure you have drawn in (iii). Your answer should include the reagent you would use and the observation you would make.

.....
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[6]

(b) The following diagram represents a section of another polymer.



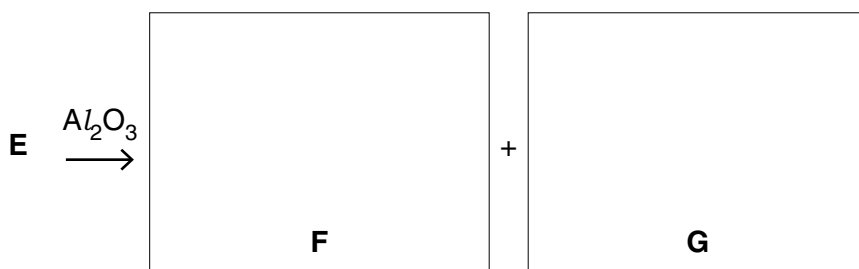
- (i) On the above formula draw brackets, [], around the atoms that make up the repeat unit of this polymer.
- (ii) Name the functional group in polymer **D**.
-
- (iii) Suggest and draw the structure of the monomer, **E**, that could form this polymer.
-
- (iv) What *type of polymerisation* is involved in making polymer **D** from its monomer?
-
- (v) What is the relationship between the repeat unit of polymer **D** and the repeat unit of PVA?
-

[5]

(c) Monomer **E** exists as two stereoisomers. Heating either isomer with Al_2O_3 gives a mixture of two unsaturated carboxylic acids **F** and **G**, which are stereoisomers of each other.

- (i) Name the *type of stereoisomerism* shown by compound **E**.
-

- (ii) Suggest structures for **F** and **G**, and name the type of stereoisomerism they show.



type of isomerism

[4]

[Total: 15]

- 5 (a) Describe and explain how the acidities of ethanol and phenol compare to that of water.

For
Examiner's
Use

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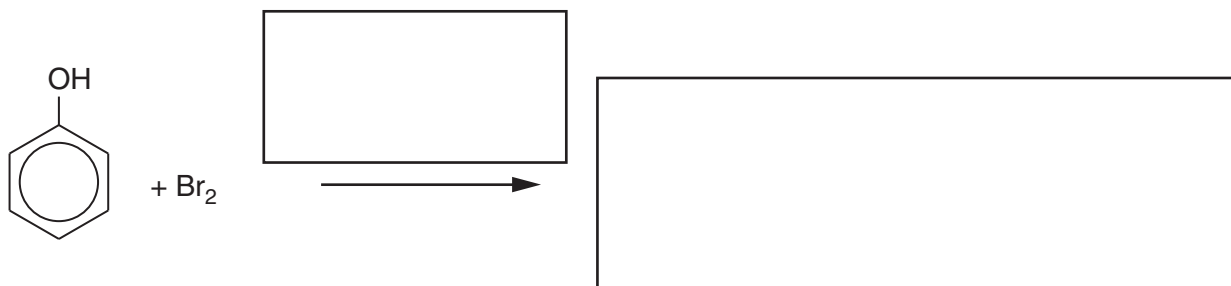
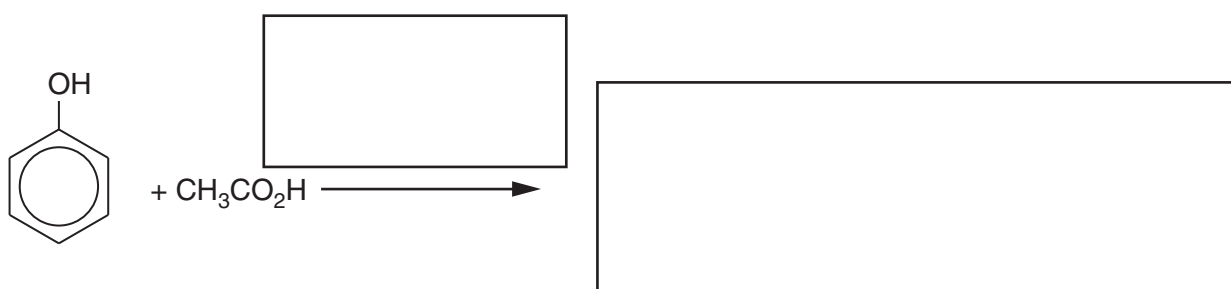
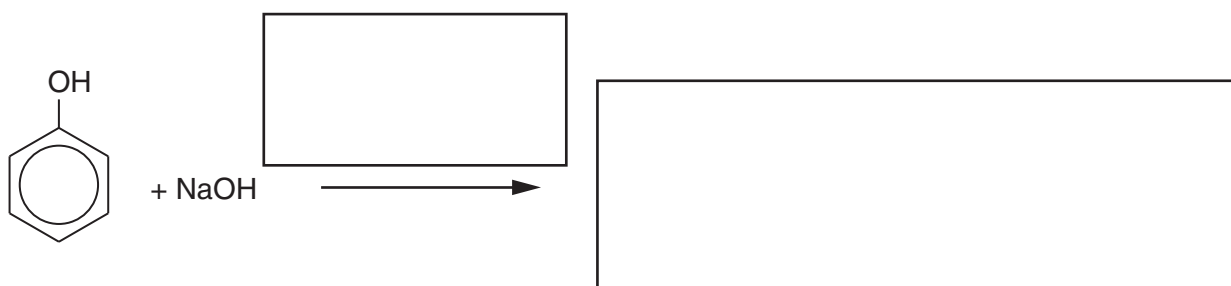
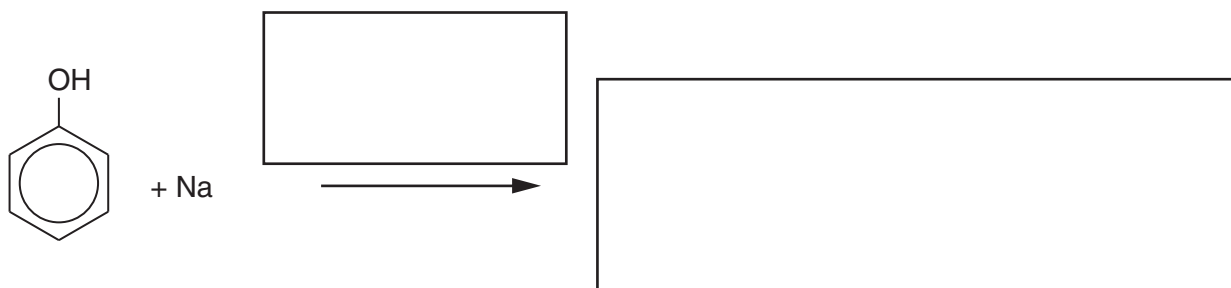
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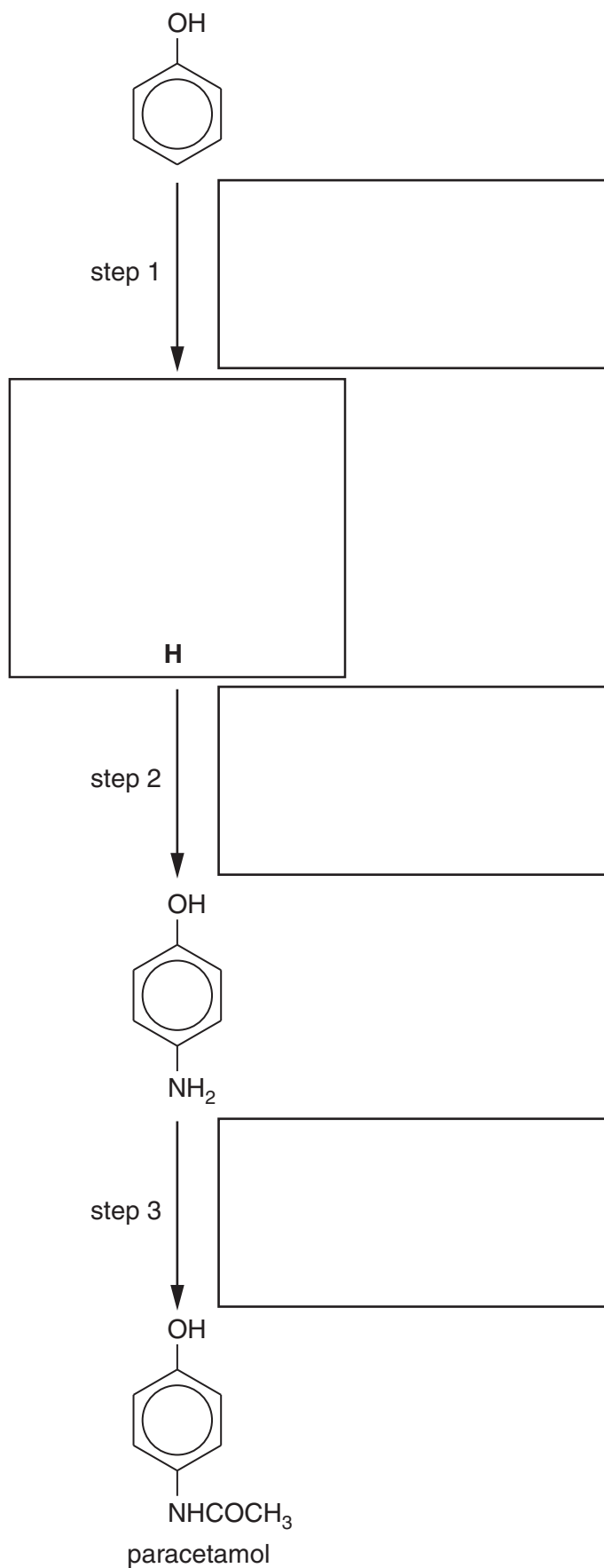
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[5]

- (c) The analgesic drug paracetamol can be synthesised from phenol by the following route. Suggest reagents and conditions for the each of three steps, and suggest the structure of the intermediate **H**. Write your answers in the boxes provided.

For
Examiner's
Use



[4]

[Total: 13]

Section B

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

For
Examiner's
Use

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- (ii) The activity of an enzyme depends upon the tertiary structure of the protein molecule. Explain how the tertiary structure produces an effective active site.

.....
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- (iii) Give **two** conditions that can **reduce** the activity of an enzyme, explaining the reason in each case.

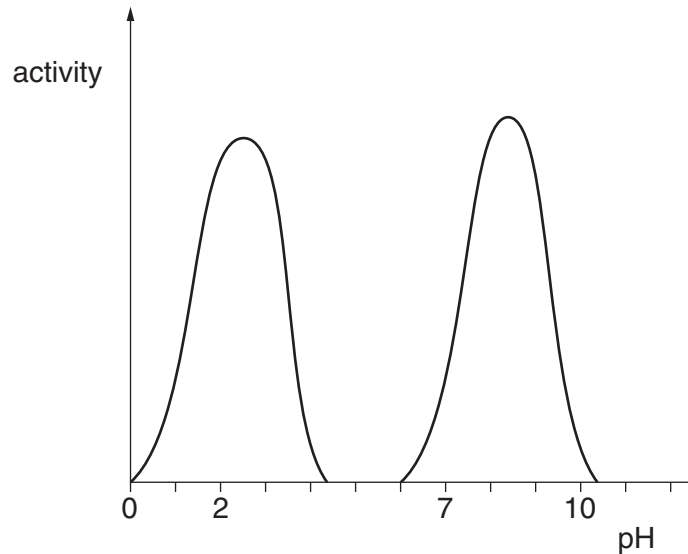
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[6]

(c) An individual enzyme operates best at a specific pH. Different enzymes operate best under conditions of different pH. Three enzymes involved in the digestion of food are amylase, pepsin and trypsin.

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The graph below shows the activity of two of the three enzymes mentioned above.



- (i) Label each peak shown with the name of the enzyme responsible, either amylase, pepsin or trypsin.
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[3]

[Total: 10]

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- (a) The table shows different stages in the production of a genetic fingerprint. Use the numbers 1 to 6 to put the stages in the correct sequence in the blank column.

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[3]

- (b) One of the stages above uses a radioactive isotope.

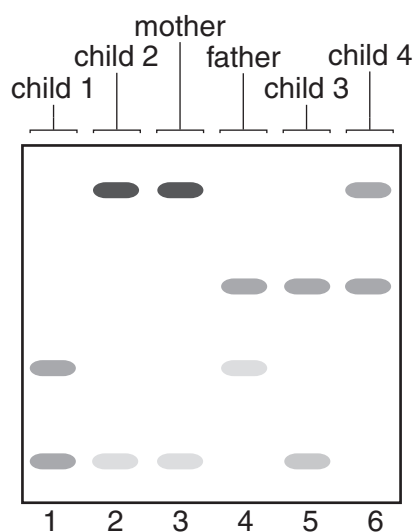
(i) What isotope is used?

(ii) Why is this isotope chosen?

.....

[2]

- (c) The following DNA fingerprints were taken from a family of mother, father and four children.



- (i) Are all of the children related to the mother? State the evidence for your answer.

.....

.....

- (ii) Which child is unlikely to be related to the father? State the evidence for your answer.

.....

.....

[2]

- (d) DNA fingerprinting has been successfully used in archaeological investigations.

- (i) Ancient writings were often made on goatskins. Over the centuries these have often become broken into fragments, making reconstruction of the writings almost impossible.

Suggest how the use of DNA fingerprinting might be able to identify which fragments came from a particular skin.

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- (ii) Apart from the examples of human remains and goatskins, state one other material that could be investigated using this technique.

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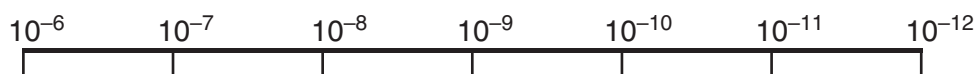
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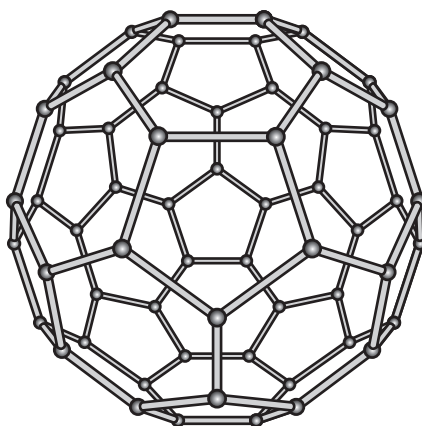
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[2]

- (b) One of the most commonly recognised nanoparticles is the 'buckyball', a spherical form of carbon containing 60 carbon atoms. It has been referred to as the third allotrope of carbon.



Diamond and graphite are two other allotropes of carbon. Suggest what is meant by the term *allotrope*.

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 [2]

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Suggest how the copper could be recovered as metal.

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[4]

[Total: 10]

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