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9701/41

May/June 2010

1 hour 45 minutes

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	
1	
2	
3	
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5	
6	
7	
8	
9	
10	
Total	

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

Section A

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

For
Examiner's
Use

- 1 (a) Phosphorus and sulfur are two non-metallic elements on the right hand side of the Periodic Table.

For each of these elements describe the observations you would make when it burns in air, and write a balanced equation for the reaction.

phosphorus

observation

equation

sulfur

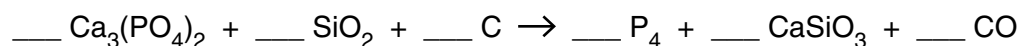
observation

equation

[4]

- (b) White phosphorus, P_4 , is produced commercially by heating calcium phosphate(V) rock with a mixture of silica, SiO_2 , and coke in an electric furnace at $1400^\circ C$. Calcium silicate, $CaSiO_3$, and carbon monoxide are the other products.

- (i) Balance the following equation which represents the overall process.



When heated to $400^\circ C$ in the absence of air, white phosphorus is changed into the red form of the element. The following table lists some of the properties of the two forms, which are known as allotropes.

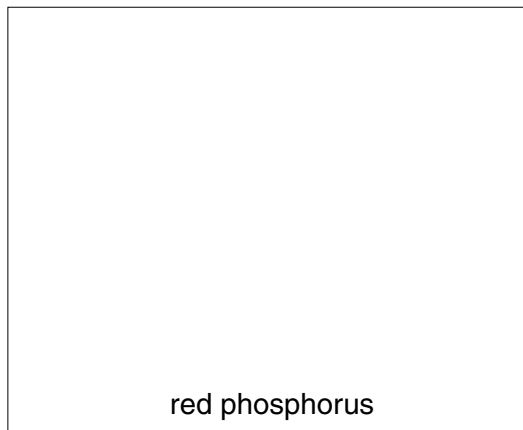
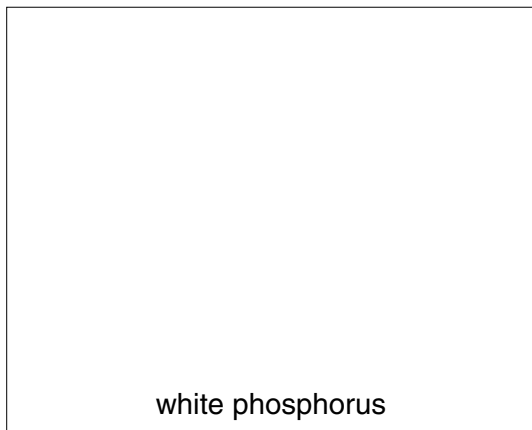
allotrope	electrical conductivity	melting point / $^\circ C$	solubility in water	solubility in benzene
white	none	44	insoluble	soluble
red	none	500	insoluble	insoluble

- (ii) Suggest the type of structure and bonding in each allotrope.

allotrope	type of structure	type of bonding
white		
red		

- (iii) In both allotropes, phosphorus has a valency of 3. Suggest by means of diagrams how the phosphorus atoms might be joined together in each allotrope.

*For
Examiner's
Use*



[7]

[Total: 11]

- 2 (a) Describe **three** characteristic chemical properties of transition elements that are not shown by Group II elements.

.....

[3]

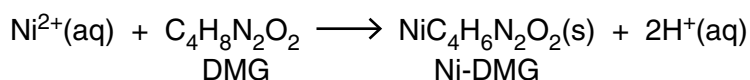
- (b) When $\text{NH}_3(\text{aq})$ is added to a green solution containing $\text{Ni}^{2+}(\text{aq})$ ions, a grey-green precipitate is formed. This precipitate dissolves in an excess of $\text{NH}_3(\text{aq})$ to give a blue-violet solution.

Suggest an explanation for these observations, showing your reasoning and including equations for the reactions you describe.

.....

[4]

- (c) Dimethylglyoxime, DMG, is a useful reagent for the quantitative estimation of nickel. It forms an insoluble salt with nickel ions according to the following equation.



A small coin of mass 3.40 g was dissolved in nitric acid and an excess of DMG was added. The precipitated Ni-DMG was filtered off, washed and dried. Its mass was 4.00 g.

Calculate the % of nickel in the coin.

percentage of nickel = ...% [3]

[Total: 10]

- 3 (a) Describe how the behaviour of the oxides of tin and lead in their +4 oxidation states differ on heating.

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

- (b) Explain the following by using data from the *Data Booklet* where appropriate, and writing equations for all reactions.

- (i) A sample of liquid PbCl_4 is placed in a flask and the flask is gently warmed. A gas is evolved and a white solid is produced. When the gas is bubbled through KI(aq) , purple fumes are produced.

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

- (ii) Repeating the same experiment using liquid SnCl_4 instead of PbCl_4 results in no evolution of gas, and no reaction with KI(aq) .

.....
.....

[4]

- (c) The molecule dichlorocarbene, CCl_2 , can be produced under certain conditions. It is highly unstable, reacting with water to produce carbon monoxide and a strongly acidic solution.

- (i) Suggest the electron arrangement in CCl_2 and draw a dot-and-cross diagram showing this. Predict the shape of the molecule.

- (ii) Construct an equation for the reaction of CCl_2 with water.

.....
[3]

[Total: 8]

- 4 Ethanolamine and phenylamine are two organic bases that are industrially important. Ethanolamine is a useful solvent with basic properties, whilst phenylamine is an important starting material in the manufacture of dyes and pharmaceuticals. The following table lists some of their properties, together with those of propylamine.

For
Examiner's
Use

compound	formula	M_r	boiling point/ $^{\circ}\text{C}$	solubility in water
propylamine	$\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2$	59	48	fairly soluble
ethanolamine	$\text{HOCH}_2\text{CH}_2\text{NH}_2$	61	170	very soluble
phenylamine		93	184	sparingly soluble

- (a) Suggest why the boiling point of ethanolamine is much higher than that of propylamine. Draw a diagram to illustrate your answer.

.....

[2]

- (b) Describe and explain the relative basicities of propylamine and phenylamine.

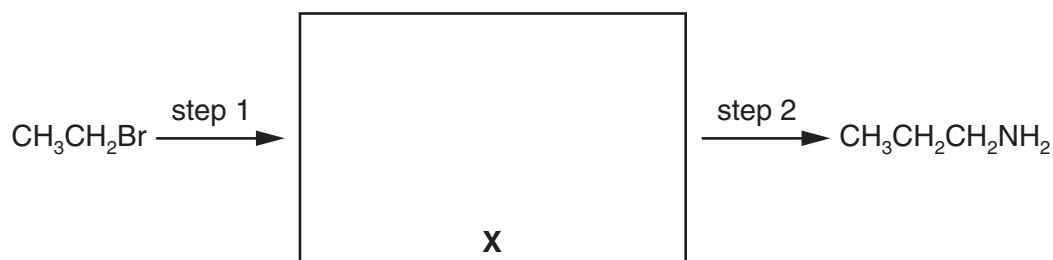
.....

 [2]

- (c) Write an equation showing ethanolamine acting as a Brønsted-Lowry base.

..... [1]

(d) Propylamine can be synthesised from bromoethane by the following route.



(i) Draw the structure of the intermediate compound **X** in the box above.

(ii) Suggest reagents and conditions for

step 1

step 2

[3]

(e) Apart from their relative basicities, ethanolamine and phenylamine differ in many of their reactions.

For **each** of these two compounds, describe **one** test that would give a positive result with the stated compound, but a negative result with the other.

ethanolamine

test

observation

phenylamine

test

observation

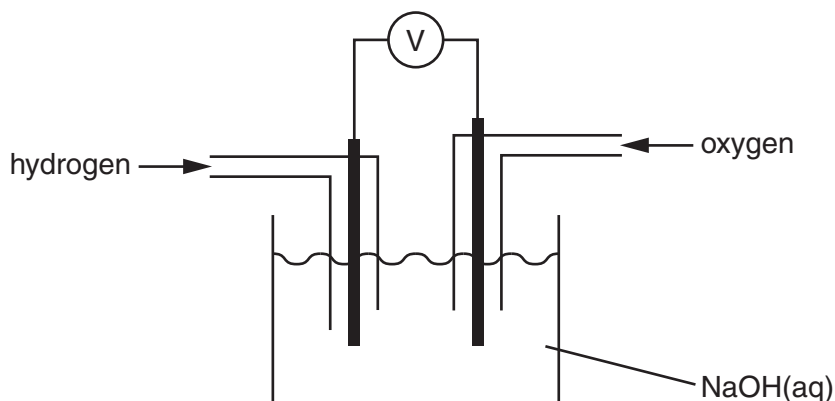
[4]

[Total: 12]

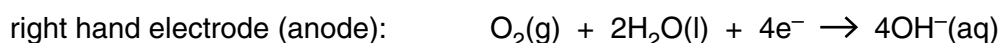
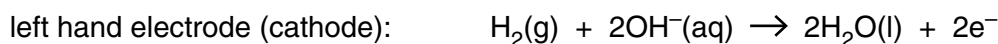
- 5 Although standard electrode potentials are measured for solutions where the concentrations of ions are 1.0 mol dm^{-3} , cells used as sources of battery power tend to operate with more concentrated solutions. This question concerns the electrode reactions involved in the hydrogen-oxygen fuel cell and the lead-acid car battery.

For
Examiner's
Use

- (a) In the hydrogen-oxygen fuel cell, $\text{H}_2(\text{g})$ and $\text{O}_2(\text{g})$ are fed onto two inert electrodes dipping into $\text{NaOH}(\text{aq})$.



The following reactions take place.



- (i) Use the *Data Booklet* to calculate $E_{\text{cell}}^\ominus$ for this reaction.

.....

- (ii) Construct an equation for the overall reaction.

.....

- (iii) By using **one** of the phrases *more positive*, *more negative* or *no change*, deduce the effect of increasing $[\text{OH}^-(\text{aq})]$ on the electrode potential of

• the left hand electrode

• the right hand electrode

- (iv) Hence deduce whether the overall E_{cell} is likely to *increase*, *decrease* or *remain the same*, when $[\text{OH}^-(\text{aq})]$ increases. Explain your answer.

.....

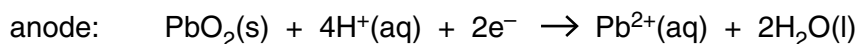
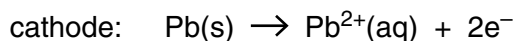
.....

- (v) Suggest **one** other reason why a high $[\text{NaOH}(\text{aq})]$ is used in the fuel cell.

.....

[6]

(b) In the cells of a lead-acid car battery the following reactions take place.



- (i) Use the *Data Booklet* to calculate $E_{\text{cell}}^{\ominus}$ for this reaction.

.....

- (ii) Construct an equation for the overall reaction.

.....

The electrolyte in a lead-acid cell is $\text{H}_2\text{SO}_4(\text{aq})$. Most of the $\text{Pb}^{2+}(\text{aq})$ ions that are produced at the electrodes are precipitated as the highly insoluble $\text{PbSO}_4(\text{s})$.

- (iii) Construct an equation for the overall cell reaction in the presence of H_2SO_4 .

.....

- (iv) By considering the effect of decreasing $[\text{Pb}^{2+}(\text{aq})]$ on the electrode potentials of the cathode and the anode, deduce the effect of the presence of $\text{H}_2\text{SO}_4(\text{aq})$ in the electrolyte on the overall E_{cell} .

State whether the E_{cell} will *increase*, *decrease* or *remain the same*.

Overall E_{cell} will

Explain your answer.

.....

.....

[5]

[Total: 11]

6 Acyl chlorides are useful intermediates in organic syntheses.

For
Examiner's
Use

(a) (i) State a suitable reagent for converting carboxylic acids into acyl chlorides.

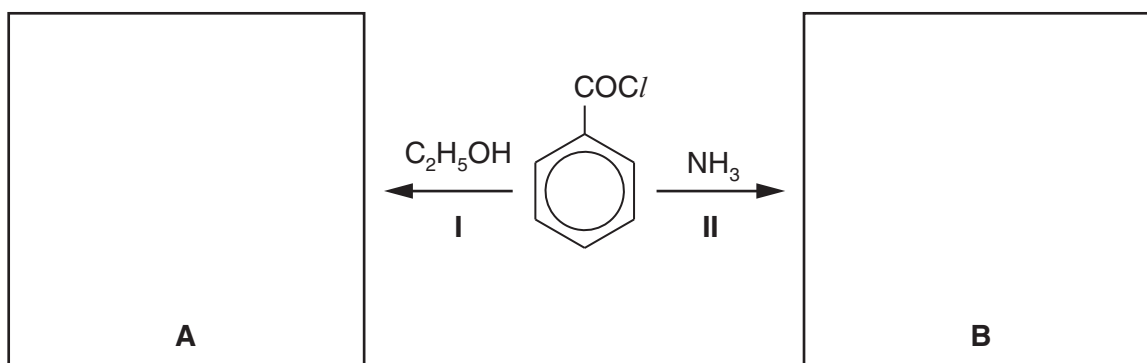
.....

(ii) Construct an equation for the reaction between ethanoic acid, $\text{CH}_3\text{CO}_2\text{H}$, and the reagent you have stated in (i).

.....

[2]

(b) (i) In the boxes provided draw the structures of the compounds formed when benzoyl chloride undergoes the following reactions.



(ii) Name the functional group in

• compound **A**

• compound **B**

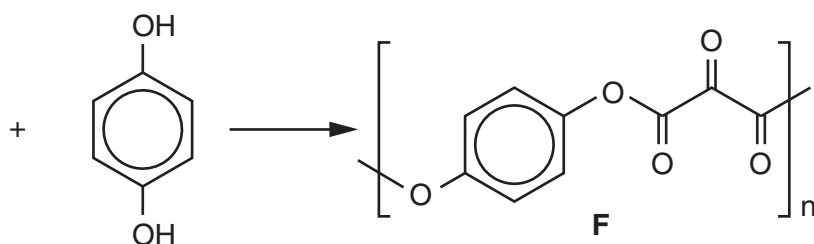
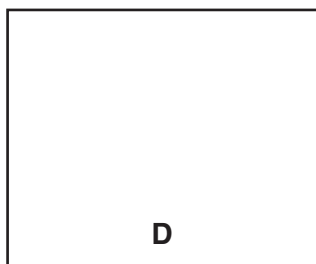
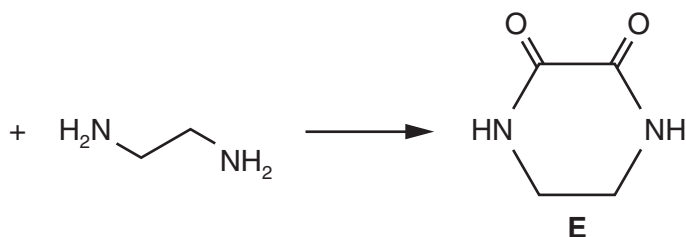
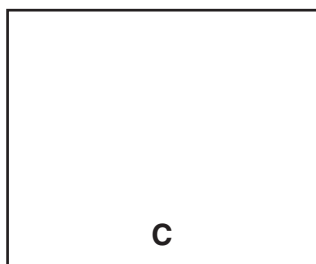
(iii) What *type of reaction* is reaction **II**?

.....

[5]

- (c) (i) Suggest suitable acyl chlorides to use in the following reaction. Draw their structures in the boxes provided.

For
Examiner's
Use



Compound **E** dissolves in, but does not react with, cold water.

- (ii) Suggest the major type of intermolecular interaction that occurs between **E** and water.

.....

- (iii) A solution of the diamine $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$ in water has $\text{pH} = 11$ but a solution of **E** in water has $\text{pH} = 7$. Suggest why this is the case.

.....

.....

- (iv) What type of polymer is compound **F**?

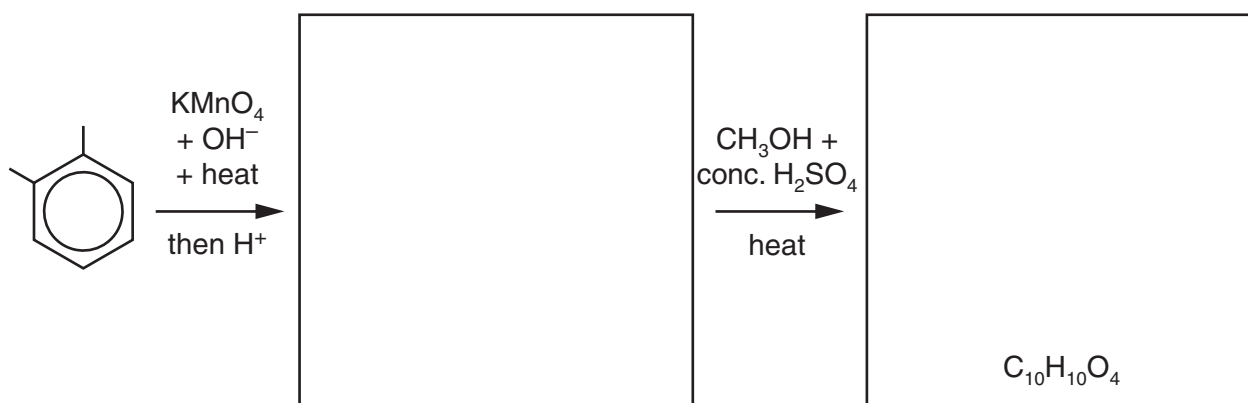
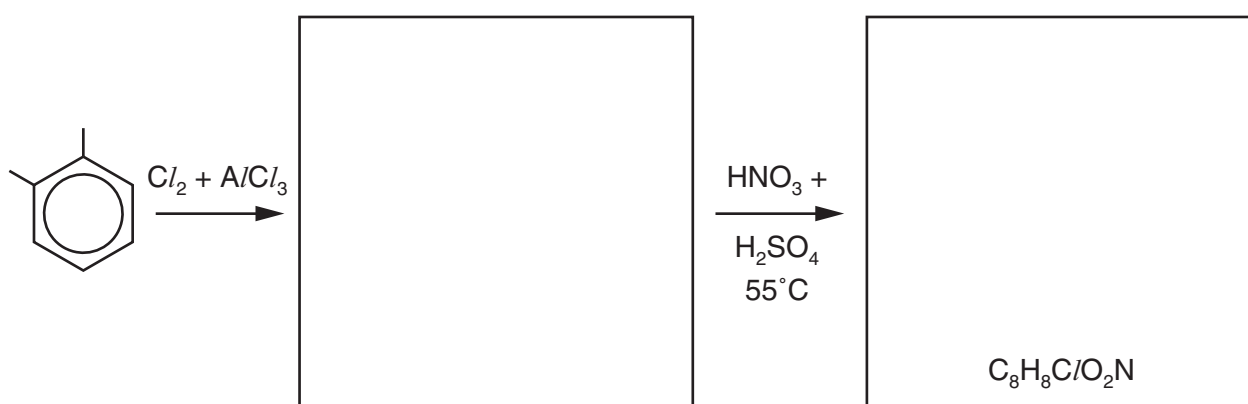
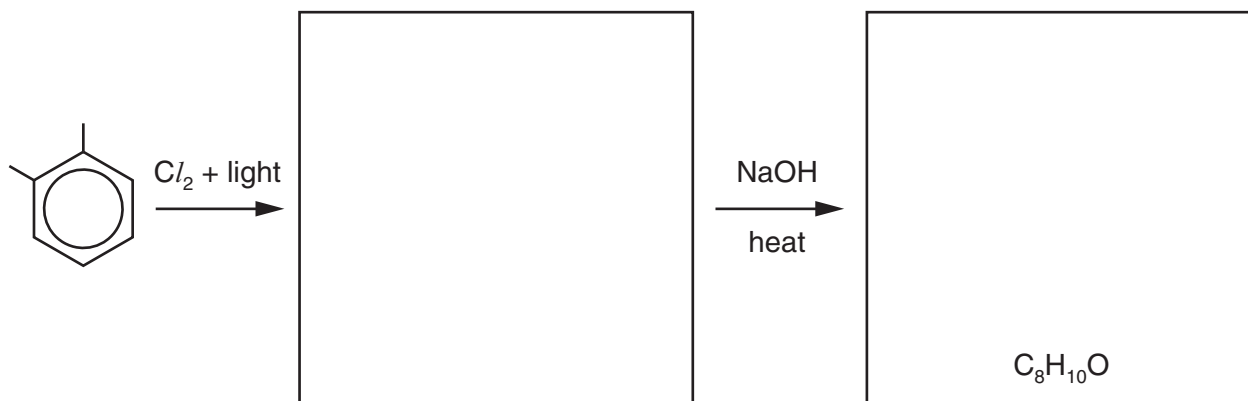
.....

[5]

[Total: 12]

- 7 Predict the products of the following reactions and draw their structures in the boxes provided. Note that the molecular formula of the final product is given in each case.

For
Examiner's
Use



[6]

[Total: 6]

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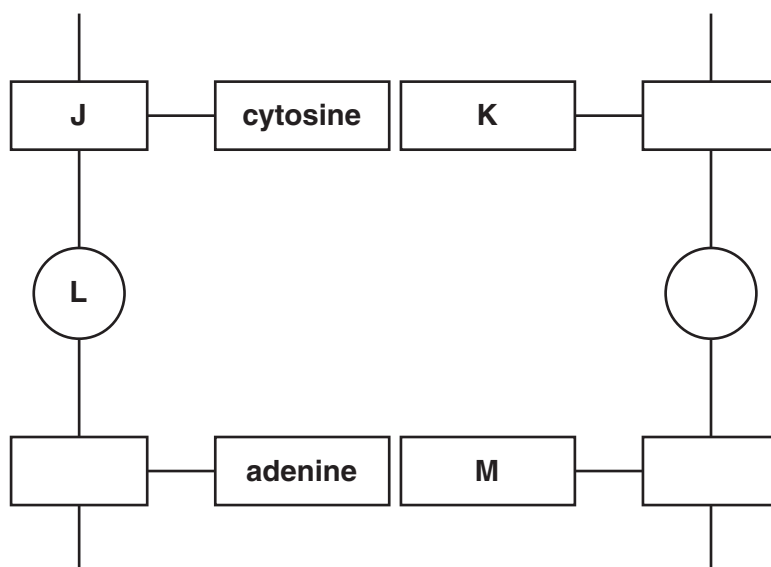
Section B

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

For
Examiner's
Use

- 8 The molecule that contains the genetic information for an individual organism is called deoxyribonucleic acid, DNA.

- (a) The diagram shows part of a DNA molecule. Study the diagram and identify the blocks labelled **J**, **K**, **L** and **M** as accurately as you can.



block letter	identity
J	
K	
L	
M	

[3]

- (b) The DNA molecule is formed from two polymer strands.
What stops these strands from separating from each other?

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

(c) List **three** differences between the structures of DNA and RNA.

For
Examiner's
Use

1.
.....
.....
2.
.....
.....
3.
.....
.....

[3]

(d) Outline the different **roles** of mRNA and tRNA in the processes of transcription and translation.

mRNA
.....
.....

tRNA
.....
.....

[2]

[Total: 10]

- 9 A range of modern analytical techniques has made the identification of molecules, and atoms in compounds, much more rapid than traditional laboratory analysis.

For
Examiner's
Use

- (a) One instrumental technique is NMR spectroscopy, which uses the fact that under certain conditions protons can exist in two different energy states.
Explain how these different energy states arise.

.....

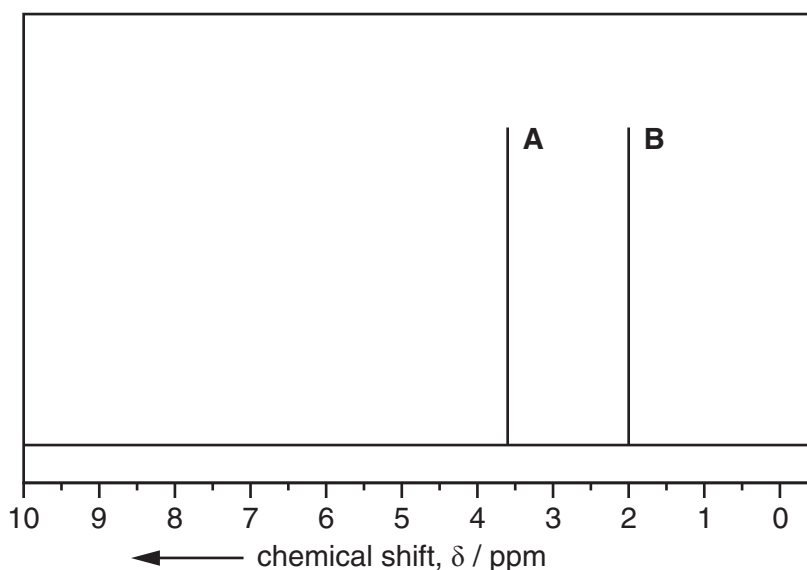
 [2]

- (b) When methanol, CH_3OH , is examined using NMR spectroscopy, it absorbs at two different frequencies. Explain why, and predict the relative areas of the two peaks.

.....

 [2]

- (c) The NMR spectrum below is that of one of three possible isomers of molecular formula $\text{C}_3\text{H}_6\text{O}_2$.



The compound could be propanoic acid, methyl ethanoate or ethyl methanoate.

For
Examiner's
Use

- (i) In the boxes provided, draw the structures of the three compounds.



propanoic acid



methyl ethanoate



ethyl methanoate

- (ii) Explain which compound produced the spectrum shown, indicating which protons are responsible for each of the peaks **A** and **B**.

.....

- (iii) The NMR spectrum of another of the compounds has a peak at $\delta 11.0$. State which compound this would be, and identify the proton(s) responsible for this peak.

compound

proton(s)

[4]

- (d) X-ray crystallography is a technique used to identify the relative positions of atoms in a crystal of a compound.

- (i) What further information about organic macromolecules can be deduced by the use of X-ray crystallography?

.....

- (ii) Which atoms cannot be located by X-ray crystallography?

.....

[2]

[Total: 10]

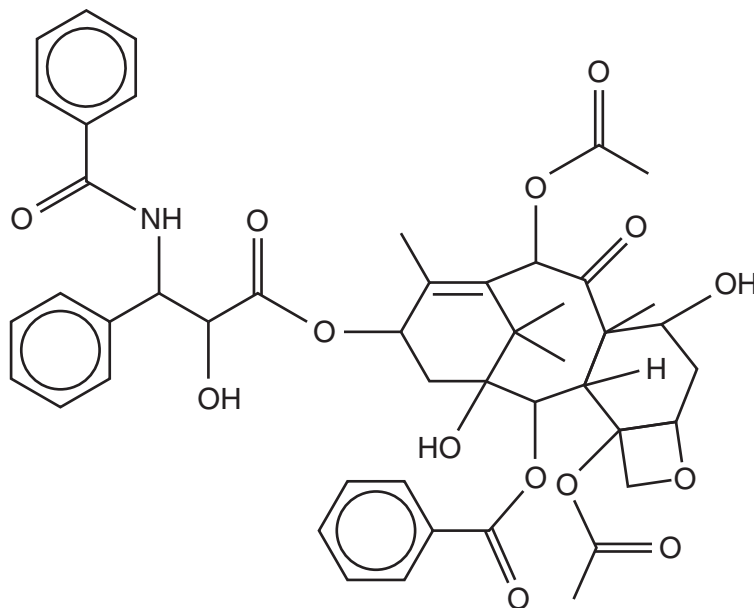
- 10 The nature and variety of drugs that are available to treat diseases or life-threatening conditions has never been greater. At the same time, we are much better able to deliver drugs to their targets in the body.

(a) Some drugs have to be given by injection, rather than by mouth.

Name a functional group in a drug molecule that might be broken down by the acid in the stomach.

.....[1]

(b) The anti-cancer drug *Taxol* could be broken down if taken by mouth.

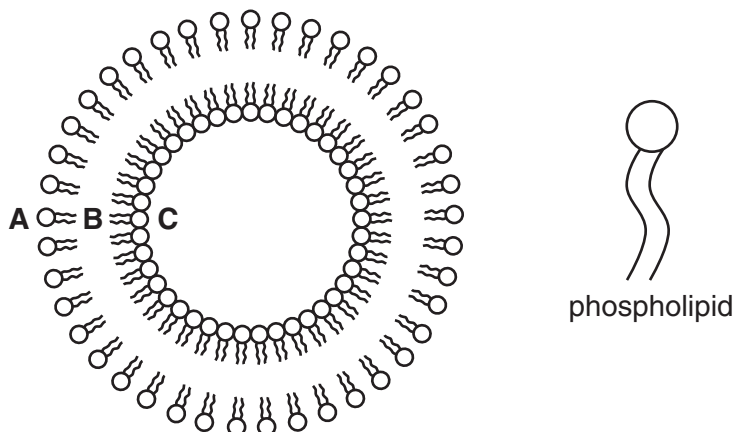


Taxol

Circle **two** bonds, each in a **different** functional group, that could be hydrolysed in the digestive system. [2]

- (c) One way of protecting drug molecules that are taken by mouth is to enclose them in liposomes. These are artificially created spheres made from phospholipids which have an ionic phosphate 'head' and two hydrocarbon 'tails'.

For
Examiner's
Use



- (i) State in which area of the liposome, **A**, **B** or **C**, each of the following types of drug would be carried.

a hydrophilic drug

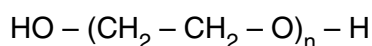
a hydrophobic drug

- (ii) For the remaining position, **A**, **B** or **C**, explain why this would **not** be a suitable area for carrying a drug.

.....
.....

[3]

- (d) One way of carrying drugs in the bloodstream is to attach them by a chemical bond to a polymer. One such polymer is polyethylene glycol or PEG.



- (i) Where would a drug be attached to a molecule of PEG?

.....

- (ii) Suggest why a liposome can carry more drug molecules than a molecule of PEG.

.....

.....

[2]

- (e) Better-targeted delivery of drugs allows smaller amounts to be used, which brings significant advantages.

Suggest **two** advantages of using smaller drug doses.

*For
Examiner's
Use*

.....

.....

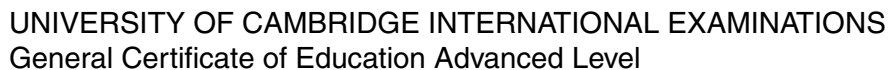
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..... [2]

[Total: 10]

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9701/42

May/June 2010

1 hour 45 minutes

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

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Answer **all** questions.

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For Examiner's Use	
1	
2	
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This document consists of **17** printed pages and **3** blank pages.

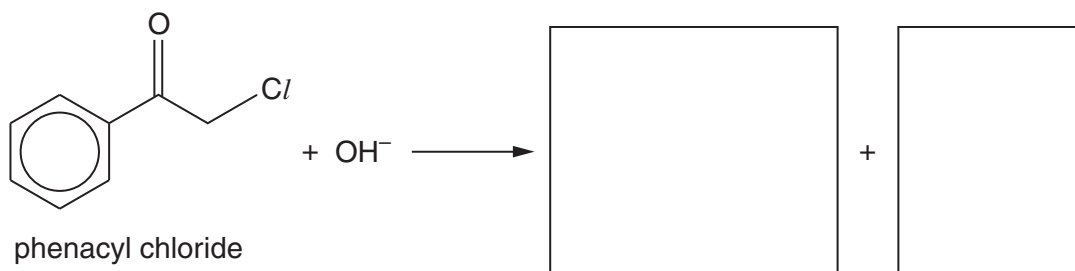
Section A

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

For
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Use

- 1 Phenacyl chloride has been used as a component of some tear gases. Its lachrymatory and irritant properties are due to it reacting with water inside body tissues to produce hydrochloric acid.

It undergoes a nucleophilic substitution reaction with NaOH(aq).



- (a) Write the formulae of the products of this reaction in the two boxes above. [2]

When the rate of this reaction was measured at various concentrations of the two reagents, the following results were obtained.

experiment number	[phenacyl chloride]	[NaOH]	relative rate
1	0.020	0.10	1.0
2	0.030	0.10	1.5
3	0.025	0.20	2.5

- (b) (i) What is meant by the term *order of reaction*?

.....

- (ii) Use the above data to deduce the order with respect to each reactant. Explain your reasoning.

.....

.....

.....

.....

.....

- (iii) Write the overall rate equation for the reaction.

.....

- (iv) Describe the mechanism for this reaction that is consistent with your overall rate equation.
You should show all intermediates and/or transition states and partial charges, and you should represent the movements of electron pairs by curly arrows.

For
Examiner's
Use

[7]

- (c) (i) Describe an experiment that would show that $\text{CH}_3\text{COC}l$ reacts with water at a much faster rate than phenacyl chloride. Include the reagents you would use, and the observations you would make with each chloride.

.....

.....

.....

.....

.....

.....

.....

- (ii) Suggest an explanation for this difference in reactivity.

.....

.....

[4]

[Total: 13]

- 2 (a) Describe and explain how the solubilities of the sulfates of the Group II elements vary down the group.

For
Examiner's
Use

.....

.....

.....

.....

.....

.....[3]

- (b) The following table lists some enthalpy changes for magnesium and strontium compounds.

enthalpy change	value for magnesium /kJ mol ⁻¹	value for strontium /kJ mol ⁻¹
lattice enthalpy of $M(OH)_2$	-2993	-2467
enthalpy change of hydration of $M^{2+}(g)$	-1890	-1414
enthalpy change of hydration of $OH^-(g)$	-550	-550

- (i) Use the above data to calculate values of $\Delta H_{\text{solution}}^\ominus$ for $Mg(OH)_2$ and for $Sr(OH)_2$.

$Mg(OH)_2$

.....

$$\Delta H_{\text{solution}}^\ominus = \text{..... kJ mol}^{-1}$$

$Sr(OH)_2$

.....

$$\Delta H_{\text{solution}}^\ominus = \text{..... kJ mol}^{-1}$$

- (ii) Use your results in (i) to suggest whether $Sr(OH)_2$ is more or less soluble in water than is $Mg(OH)_2$. State any assumptions you make.

.....

.....

- (iii) Suggest whether $Sr(OH)_2$ would be more or less soluble in hot water than in cold. Explain your reasoning.

.....

.....

[5]

(c) Calcium hydroxide, $\text{Ca}(\text{OH})_2$, is slightly soluble in water.

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Use

- (i) Write an expression for K_{sp} for calcium hydroxide, and state its units.

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

- (ii) 25.0 cm^3 of a saturated solution of $\text{Ca}(\text{OH})_2$ required 21.0 cm^3 of $0.0500\text{ mol dm}^{-3}$ HCl for complete neutralisation.

Calculate the $[\text{OH}^-(\text{aq})]$ and the $[\text{Ca}^{2+}(\text{aq})]$ in the saturated solution, and hence calculate a value for K_{sp} .

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

$[\text{Ca}^{2+}(\text{aq})] =$

$K_{\text{sp}} =$

- (iii) How would the solubility of $\text{Ca}(\text{OH})_2$ in 0.1 mol dm^{-3} NaOH compare with that in water?

Explain your answer.

.....

.....

[6]

[Total: 14]

- 3 (a) Fluorine is much more electronegative than both silicon and sulfur, but whereas the molecule of SF_4 has an overall dipole, that of SiF_4 has none.

Suggest a reason for this difference.

.....
[1]

- (b) Predict whether or not the following molecules will have an overall dipole. Place a tick in the appropriate column.

compound	molecule has an overall dipole	molecule does not have an overall dipole
BCl_3		
PCl_3		
CCl_4		
SF_6		

[2]

- (c) Boron and silicon are two elements adjacent to carbon in the periodic table. CCl_4 does not react with water, whereas BCl_3 and SiCl_4 do react.

- (i) Suggest a reason for this difference in reactivity.

.....

- (ii) Construct equations showing the reaction of these two chlorides with an excess of water.

BCl_3

SiCl_4

[3]

- (d) When reacted with a small quantity of water, SiCl_4 produces an oxychloride **X**, $\text{Si}_x\text{Cl}_y\text{O}_z$. The mass spectrum of **X** shows peaks at mass numbers of 133, 149, 247, 263 and 396. (You should assume that the species responsible for all these peaks contain the ^{16}O , the ^{35}Cl and the ^{28}Si isotopes only.)

For
Examiner's
Use

- (i) Use these data to deduce the molecular formula of **X**.

molecular formula

- (ii) Suggest the structures of the fragments responsible for the peaks at the following mass numbers.

mass number	structure
133	
247	
263	

- (iii) Hence suggest the displayed formula of **X**.

[5]

[Total: 11]

- 4 (a) Complete the electronic structures of the Cr^{3+} and Mn^{2+} ions.

Cr^{3+} $1s^2 2s^2 2p^6$

Mn^{2+} $1s^2 2s^2 2p^6$

[2]

- (b) (i) Describe what observations you would make when dilute $\text{KMnO}_4(\text{aq})$ is added slowly and with shaking to an acidified solution of $\text{FeSO}_4(\text{aq})$ until the KMnO_4 is in a large excess.

.....

.....

.....

.....

.....

.....

- (ii) Construct an ionic equation for the reaction that occurs.

.....

[4]

- (c) By selecting relevant $E^\ominus$ data from the *Data Booklet* explain why acidified solutions of $\text{Fe}^{2+}(\text{aq})$ are relatively stable to oxidation by air, whereas a freshly prepared precipitate of $\text{Fe}(\text{OH})_2$ is readily oxidised to $\text{Fe}(\text{OH})_3$ under alkaline conditions.

relevant $E^\ominus$ values and half equations

.....

.....

.....

.....

explanation

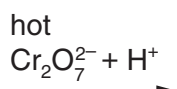
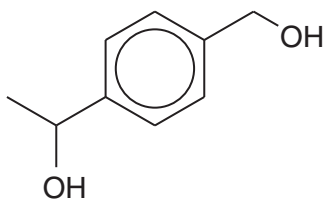
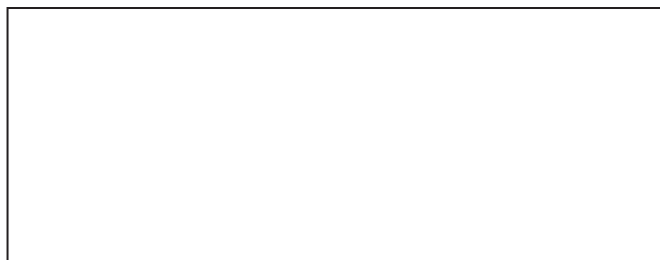
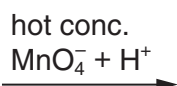
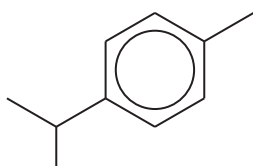
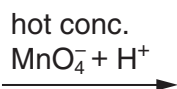
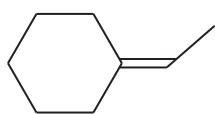
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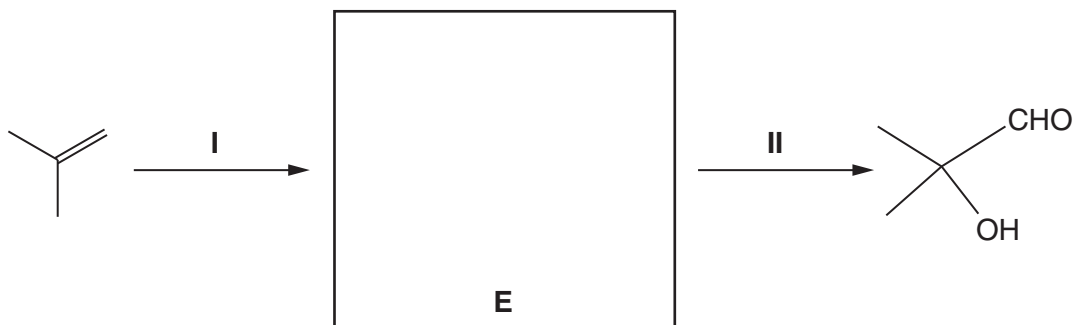
- (d) Predict the organic products of the following reactions and draw their structures in the boxes below. You may use structural or skeletal formulae as you wish.

For
Examiner's
Use



[4]

- (e) KMnO_4 and $\text{K}_2\text{Cr}_2\text{O}_7$ are the reagents that can be used to carry out the following transformation.



- (i) Draw the structure of intermediate **E** in the box above.
 (ii) Suggest reagents and conditions for the following.

reaction I

reaction II

[3]

[Total: 17]

- 5 (a) (i) Briefly explain why the benzene molecule is planar.

.....

.....

.....

- (ii) Briefly explain why all the carbon-carbon bonds in benzene are the same length.

.....

.....

.....

[2]

- (b) Benzene can be nitrated by warming it with a mixture of concentrated sulfuric and nitric acids.

- (i) By means of an equation, illustrate the initial role of the sulfuric acid in this reaction.

.....

- (ii) Name the type of reaction and describe the mechanism for the nitration reaction, including curly arrows showing the movement of electrons and all charges.

type of reaction

mechanism

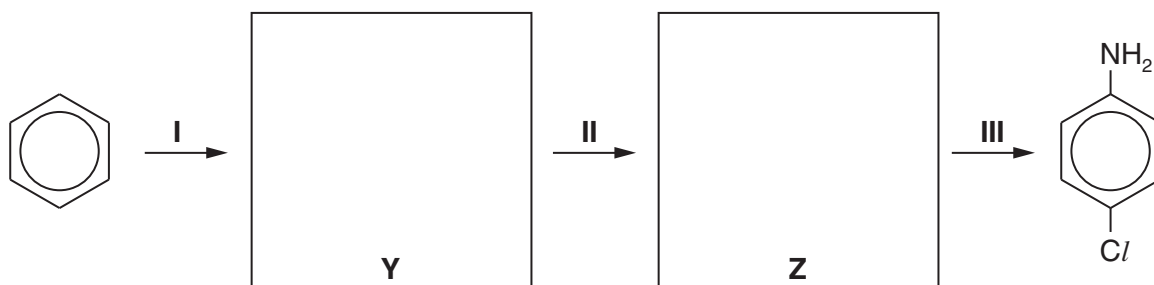
[4]

- (c) State the reagents and conditions needed to convert benzene into chlorobenzene.

.....[1]

- (d) Nitrobenzene undergoes further substitution considerably more slowly than chlorobenzene. In nitrobenzene the incoming group joins to the benzene ring in the 3-position, whereas in chlorobenzene the incoming group joins to the benzene ring in the 4-position.

- (i) Use these ideas to suggest the structures of the intermediate compounds **Y** and **Z** in the following synthesis of 4-chlorophenylamine.

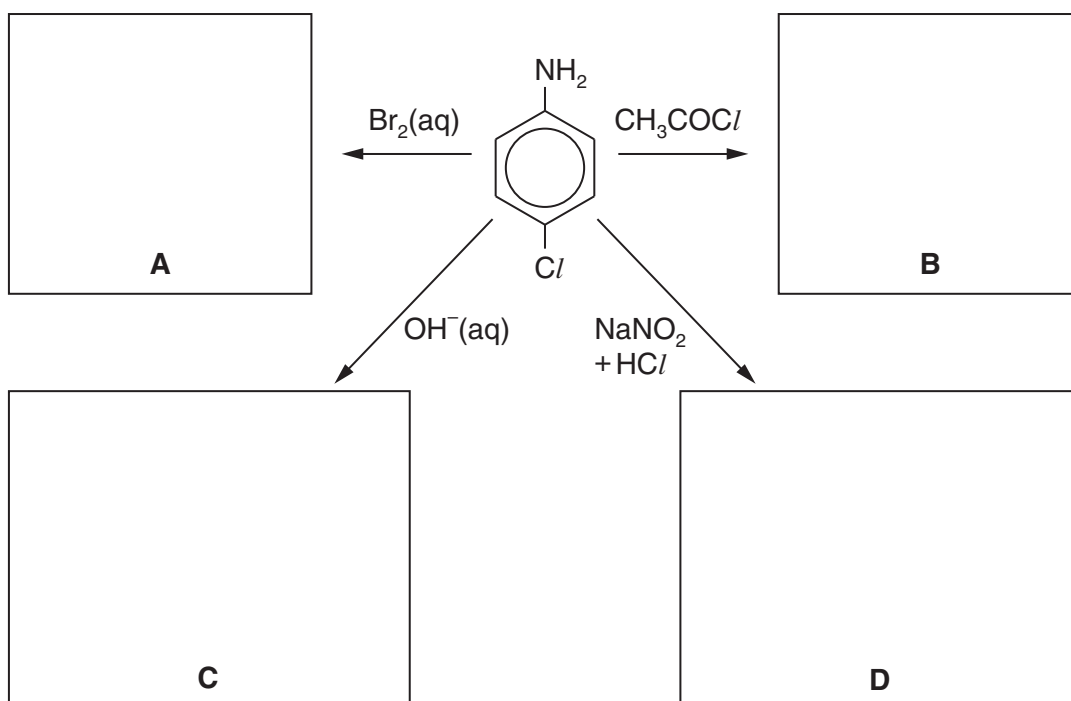


- (ii) Suggest the reagents and conditions needed for reaction **III** in the above synthesis.

.....

.....

- (iii) Suggest the structural formulae of the products **A**, **B**, **C** and **D** of the following reactions. If no reaction occurs write "no reaction" in the relevant box.



[8]

[Total: 15]

Section B

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

For
Examiner's
Use

- 6 Human hair and silk both consist of proteins. Proteins are described as having three major levels of structure: primary, secondary and tertiary.

(a) Outline what is meant by the terms *primary structure* and *tertiary structure* of a protein.

primary structure

.....

.....

tertiary structure

.....

.....

[2]

- (b) In hair, the secondary structure consists of α -helices which are cross-linked by disulfide bonds. The amino acid responsible for this cross-linking is cysteine, $\text{H}_2\text{NCH}(\text{CH}_2\text{SH})\text{CO}_2\text{H}$.

(i) Show by means of a diagram how the disulfide cross-links are formed.

(ii) What type of reaction is this?

.....

- (iii) State **three** other interactions that stabilise the tertiary structure of proteins.

.....

.....

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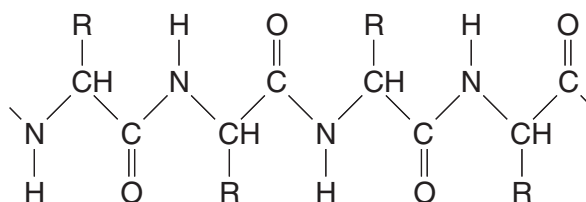
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- (c) The β -pleated sheet is a different form of secondary structure found in proteins, such as those in silk.

- (i) What type of bonding is responsible for stabilising the β -pleated sheet in silk?

.....

- (ii) On the diagram below, draw a second polypeptide strand and show how bonds would be formed that stabilise this β -pleated sheet.



[3]

- (d) The cysteine-containing protein in hair is called α -keratin. A similar sequence of amino acids can produce β -keratin proteins found in the scales, claws and shells of reptiles such as tortoises. In β -keratin the secondary structure of the protein is in the form of a β -pleated sheet.

Suggest what makes the β -pleated sheet in β -keratin so much less flexible than the β -pleated sheet in silk.

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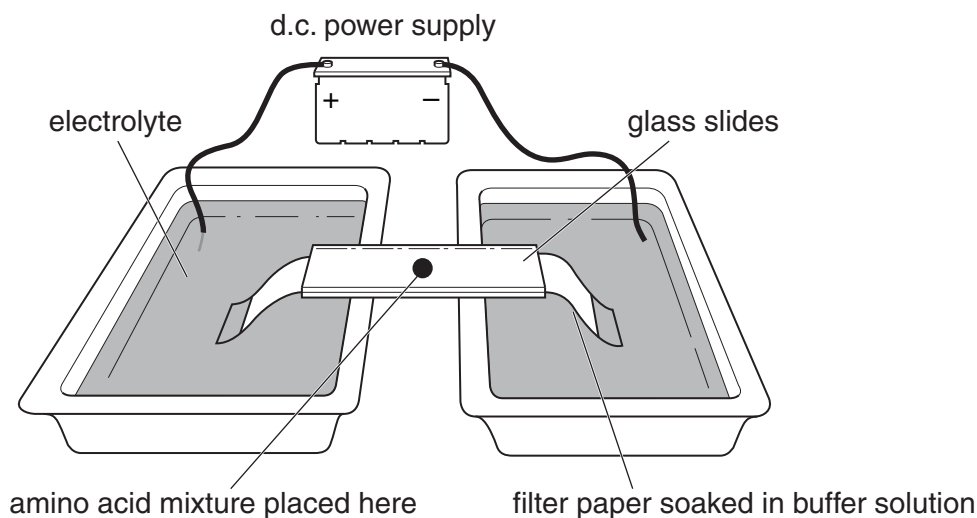
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[1]

[Total: 10]

- 7 A mixture of amino acids may be separated using electrophoresis. A typical practical set-up is shown in the diagram.

For
Examiner's
Use



- (a) When the power supply is switched on, some amino acids may **not** move, but remain stationary. Suggest an explanation for this observation.

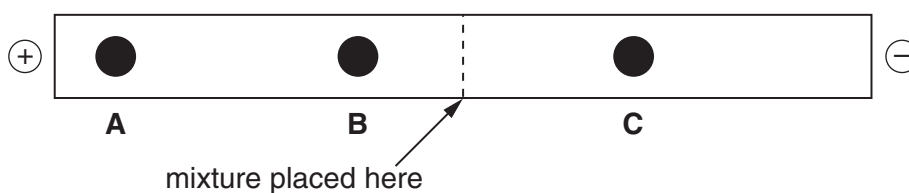
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 [2]

- (b) The amino acid glycine has the formula $\text{H}_2\text{NCH}_2\text{CO}_2\text{H}$. Identify the species formed on the filter paper if glycine moves to the left (positive) end of the filter paper.

..... [1]

- (c) The following result was obtained from another electrophoresis. What can be deduced about the relative sizes of, and charges on, the amino acid species **A**, **B** and **C**?



amino acid	relative size	charge
A		
B		
C		

[3]

(d) The sequence of amino acids in a polypeptide may be determined by partial hydrolysis of the chain into smaller pieces, often tripeptides.

(i) Following such a partial hydrolysis, the following tripeptides were obtained from a given polypeptide.

ala-gly-asp gly-ala-gly lys-val-ser ser-ala-gly val-ser-ala

Given that the N-terminal amino acid is lysine (lys) suggest the amino acid sequence of the **shortest** polypeptide that would give the above tripeptides.

.....

The structural formulae of the amino acids in the polypeptide are given below.

abbreviation	amino acid	structural formula
ala	alanine	$\text{H}_2\text{NCH}(\text{CH}_3)\text{CO}_2\text{H}$
asp	aspartic acid	$\text{H}_2\text{NCH}(\text{CH}_2\text{CO}_2\text{H})\text{CO}_2\text{H}$
gly	glycine	$\text{H}_2\text{NCH}_2\text{CO}_2\text{H}$
lys	lysine	$\text{H}_2\text{NCH}(\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2)\text{CO}_2\text{H}$
ser	serine	$\text{H}_2\text{NCH}(\text{CH}_2\text{OH})\text{CO}_2\text{H}$
val	valine	$\text{H}_2\text{NCH}(\text{CH}(\text{CH}_3)_2)\text{CO}_2\text{H}$

(ii) Which of the tripeptides in (i) has the lowest M_r ?

.....

(iii) Select **one** amino acid **from those listed in the table** which contains an ionic side-chain at pH 8.

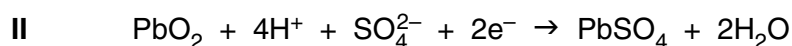
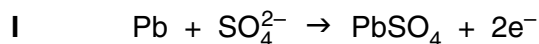
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[4]

[Total: 10]

8 The design and development of batteries has been a major research area in recent years.

- (a) Lead-acid batteries, used in cars, are made up of a number of rechargeable cells in series, and were first developed in 1860. They have the disadvantage of a relatively high mass compared to the energy stored. During discharge, the electrode reactions in the cells of these batteries are as follows.



State which of these reactions occurs at the positive electrode in a lead-acid cell during discharge, explaining your answer.

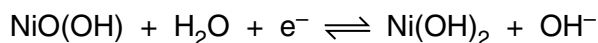
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[1]

- (b) Use the *Data Booklet* and the equations I and II above to calculate the voltage produced by a lead-acid cell under standard conditions.

[2]

- (c) Nickel-metal hydride batteries were developed in the 1980s and have become increasingly common particularly for small devices such as mobile phones and digital cameras that need near-constant sources of electrical energy. These cells use nickel oxohydroxide ($\text{NiO}(\text{OH})$) as one electrode and a hydrogen-absorbing alloy such as LiNi_5 as the other electrode.

One reaction that takes place in these batteries is



- (i) State the oxidation state of nickel in $\text{NiO}(\text{OH})$

- (ii) Suggest a likely advantage of these batteries compared with lead-acid batteries.

.....
[2]

- (d) Hydrogen fuel cells have been suggested as the next major advance in electrically powered vehicles. In these fuel cells hydrogen is oxidized to produce water, using a catalyst and inert electrodes.

(i) Suggest a material for the electrodes.

.....

(ii) Use your knowledge of hydrogen to suggest a disadvantage of these fuel cells in powering vehicles.

.....

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[2]

- (e) Many of the world's countries are developing ways of recycling materials which are valuable or which require large amounts of energy to produce.

For each of the following recyclable materials, state whether recycling of this material is important in saving energy or in saving resources. Use your knowledge of chemistry to explain each choice.

glass

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steel

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plastics

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.....

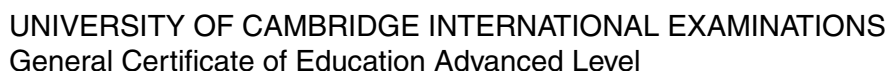
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[Total: 10]

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9701/43

May/June 2010

1 hour 45 minutes

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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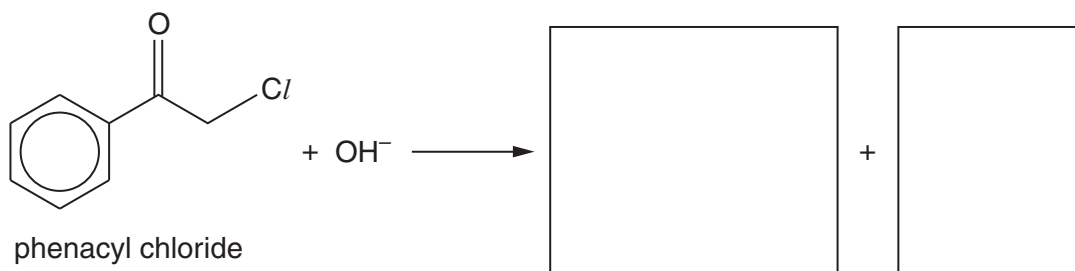
Section A

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

For
Examiner's
Use

- 1 Phenacyl chloride has been used as a component of some tear gases. Its lachrymatory and irritant properties are due to it reacting with water inside body tissues to produce hydrochloric acid.

It undergoes a nucleophilic substitution reaction with NaOH(aq).



- (a) Write the formulae of the products of this reaction in the two boxes above. [2]

When the rate of this reaction was measured at various concentrations of the two reagents, the following results were obtained.

experiment number	[phenacyl chloride]	[NaOH]	relative rate
1	0.020	0.10	1.0
2	0.030	0.10	1.5
3	0.025	0.20	2.5

- (b) (i) What is meant by the term *order of reaction*?

.....

- (ii) Use the above data to deduce the order with respect to each reactant. Explain your reasoning.

.....

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- (iii) Write the overall rate equation for the reaction.

.....

- (iv) Describe the mechanism for this reaction that is consistent with your overall rate equation.
You should show all intermediates and/or transition states and partial charges, and you should represent the movements of electron pairs by curly arrows.

For
Examiner's
Use

[7]

- (c) (i) Describe an experiment that would show that CH_3COCl reacts with water at a much faster rate than phenacyl chloride. Include the reagents you would use, and the observations you would make with each chloride.

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- (ii) Suggest an explanation for this difference in reactivity.

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[4]

[Total: 13]

- 2 (a) Describe and explain how the solubilities of the sulfates of the Group II elements vary down the group.

For
Examiner's
Use

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.....[3]

- (b) The following table lists some enthalpy changes for magnesium and strontium compounds.

enthalpy change	value for magnesium /kJ mol ⁻¹	value for strontium /kJ mol ⁻¹
lattice enthalpy of $M(OH)_2$	-2993	-2467
enthalpy change of hydration of $M^{2+}(g)$	-1890	-1414
enthalpy change of hydration of $OH^-(g)$	-550	-550

- (i) Use the above data to calculate values of $\Delta H_{\text{solution}}^\ominus$ for $Mg(OH)_2$ and for $Sr(OH)_2$.

$Mg(OH)_2$

.....

$$\Delta H_{\text{solution}}^\ominus = \text{..... kJ mol}^{-1}$$

$Sr(OH)_2$

.....

$$\Delta H_{\text{solution}}^\ominus = \text{..... kJ mol}^{-1}$$

- (ii) Use your results in (i) to suggest whether $Sr(OH)_2$ is more or less soluble in water than is $Mg(OH)_2$. State any assumptions you make.

.....

.....

- (iii) Suggest whether $Sr(OH)_2$ would be more or less soluble in hot water than in cold. Explain your reasoning.

.....

.....

[5]

(c) Calcium hydroxide, Ca(OH)_2 , is slightly soluble in water.

For
Examiner's
Use

- (i) Write an expression for K_{sp} for calcium hydroxide, and state its units.

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

- (ii) 25.0 cm^3 of a saturated solution of Ca(OH)_2 required 21.0 cm^3 of $0.0500\text{ mol dm}^{-3}$ HCl for complete neutralisation.

Calculate the $[\text{OH}^-(\text{aq})]$ and the $[\text{Ca}^{2+}(\text{aq})]$ in the saturated solution, and hence calculate a value for K_{sp} .

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

$[\text{Ca}^{2+}(\text{aq})] =$

$K_{\text{sp}} =$

- (iii) How would the solubility of Ca(OH)_2 in 0.1 mol dm^{-3} NaOH compare with that in water?

Explain your answer.

.....

.....

[6]

[Total: 14]

- 3 (a) Fluorine is much more electronegative than both silicon and sulfur, but whereas the molecule of SF_4 has an overall dipole, that of SiF_4 has none.

For
Examiner's
Use

Suggest a reason for this difference.

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

- (b) Predict whether or not the following molecules will have an overall dipole. Place a tick in the appropriate column.

compound	molecule has an overall dipole	molecule does not have an overall dipole
BCl_3		
PCl_3		
CCl_4		
SF_6		

[2]

- (c) Boron and silicon are two elements adjacent to carbon in the periodic table. CCl_4 does not react with water, whereas BCl_3 and SiCl_4 do react.

- (i) Suggest a reason for this difference in reactivity.

.....
.....

- (ii) Construct equations showing the reaction of these two chlorides with an excess of water.

BCl_3

SiCl_4

[3]

- (d) When reacted with a small quantity of water, SiCl_4 produces an oxychloride **X**, $\text{Si}_x\text{Cl}_y\text{O}_z$. The mass spectrum of **X** shows peaks at mass numbers of 133, 149, 247, 263 and 396. (You should assume that the species responsible for all these peaks contain the ^{16}O , the ^{35}Cl and the ^{28}Si isotopes only.)

For
Examiner's
Use

- (i) Use these data to deduce the molecular formula of **X**.

molecular formula

- (ii) Suggest the structures of the fragments responsible for the peaks at the following mass numbers.

mass number	structure
133	
247	
263	

- (iii) Hence suggest the displayed formula of **X**.

[5]

[Total: 11]

- 4 (a) Complete the electronic structures of the Cr^{3+} and Mn^{2+} ions.

Cr^{3+} $1s^2 2s^2 2p^6$

Mn^{2+} $1s^2 2s^2 2p^6$

[2]

- (b) (i) Describe what observations you would make when dilute $\text{KMnO}_4(\text{aq})$ is added slowly and with shaking to an acidified solution of $\text{FeSO}_4(\text{aq})$ until the KMnO_4 is in a large excess.

.....

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.....

.....

- (ii) Construct an ionic equation for the reaction that occurs.

.....

[4]

- (c) By selecting relevant $E^\ominus$ data from the *Data Booklet* explain why acidified solutions of $\text{Fe}^{2+}(\text{aq})$ are relatively stable to oxidation by air, whereas a freshly prepared precipitate of $\text{Fe}(\text{OH})_2$ is readily oxidised to $\text{Fe}(\text{OH})_3$ under alkaline conditions.

relevant $E^\ominus$ values and half equations

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explanation

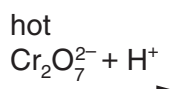
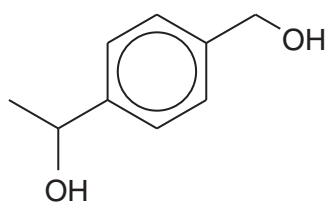
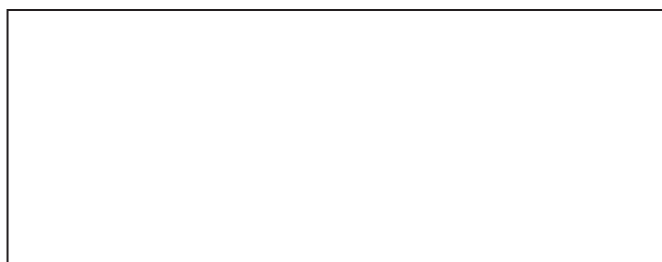
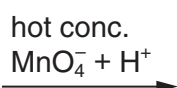
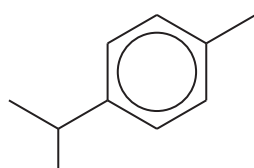
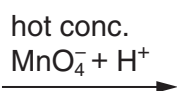
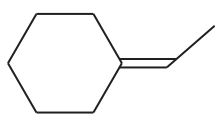
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[4]

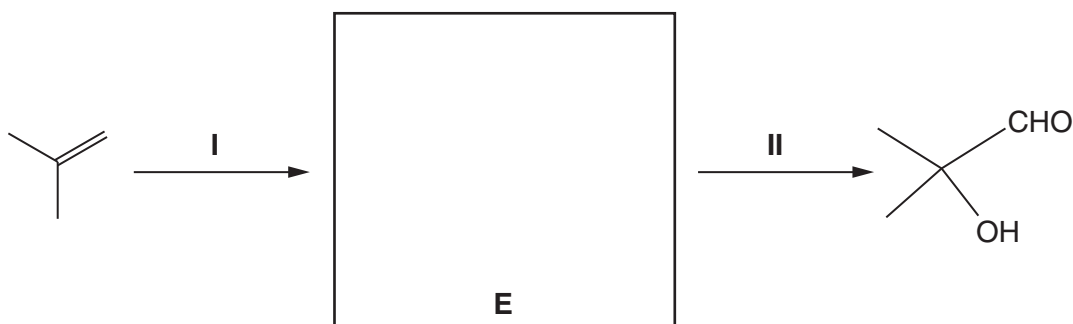
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For
Examiner's
Use



[4]

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- (i) Draw the structure of intermediate **E** in the box above.
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reaction I

reaction II

[3]

[Total: 17]

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.....

.....

.....

- (ii) Briefly explain why all the carbon-carbon bonds in benzene are the same length.

.....

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.....

[2]

- (b) Benzene can be nitrated by warming it with a mixture of concentrated sulfuric and nitric acids.

- (i) By means of an equation, illustrate the initial role of the sulfuric acid in this reaction.

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- (ii) Name the type of reaction and describe the mechanism for the nitration reaction, including curly arrows showing the movement of electrons and all charges.

type of reaction

mechanism

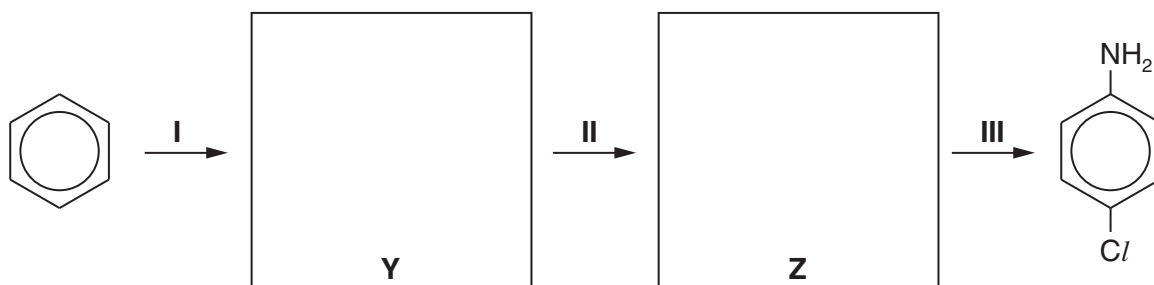
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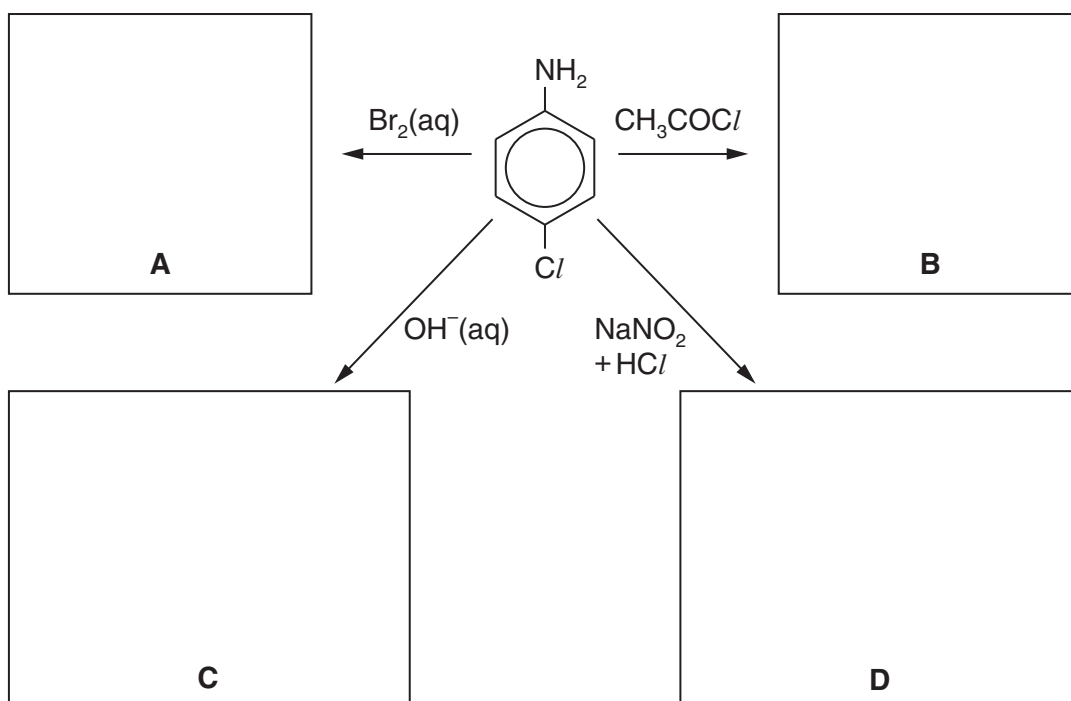


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.....

.....

- (iii) Suggest the structural formulae of the products **A**, **B**, **C** and **D** of the following reactions. If no reaction occurs write "no reaction" in the relevant box.



[8]

[Total: 15]

Section B

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For
Examiner's
Use

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(a) Outline what is meant by the terms *primary structure* and *tertiary structure* of a protein.

primary structure

.....

.....

tertiary structure

.....

.....

[2]

- (b) In hair, the secondary structure consists of α -helices which are cross-linked by disulfide bonds. The amino acid responsible for this cross-linking is cysteine, $\text{H}_2\text{NCH}(\text{CH}_2\text{SH})\text{CO}_2\text{H}$.

(i) Show by means of a diagram how the disulfide cross-links are formed.

(ii) What type of reaction is this?

.....

- (iii) State **three** other interactions that stabilise the tertiary structure of proteins.

.....

.....

.....

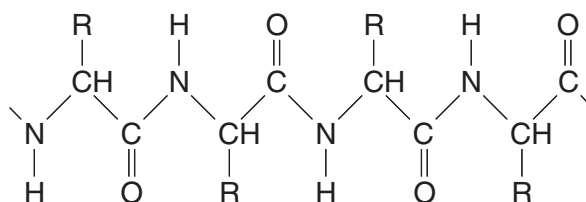
[4]

- (c) The β -pleated sheet is a different form of secondary structure found in proteins, such as those in silk.

- (i) What type of bonding is responsible for stabilising the β -pleated sheet in silk?

.....

- (ii) On the diagram below, draw a second polypeptide strand and show how bonds would be formed that stabilise this β -pleated sheet.



[3]

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Suggest what makes the β -pleated sheet in β -keratin so much less flexible than the β -pleated sheet in silk.

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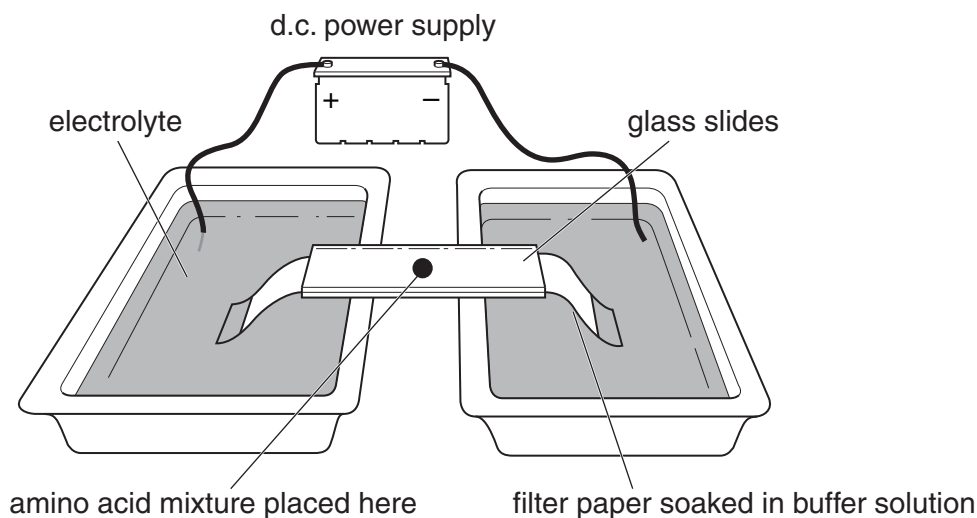
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[1]

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For
Examiner's
Use



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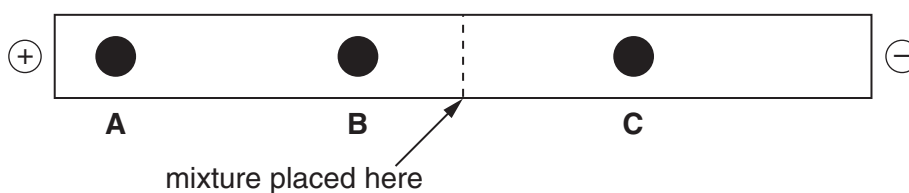
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 [2]

- (b) The amino acid glycine has the formula $\text{H}_2\text{NCH}_2\text{CO}_2\text{H}$. Identify the species formed on the filter paper if glycine moves to the left (positive) end of the filter paper.

..... [1]

- (c) The following result was obtained from another electrophoresis. What can be deduced about the relative sizes of, and charges on, the amino acid species **A**, **B** and **C**?



amino acid	relative size	charge
A		
B		
C		

[3]

(d) The sequence of amino acids in a polypeptide may be determined by partial hydrolysis of the chain into smaller pieces, often tripeptides.

(i) Following such a partial hydrolysis, the following tripeptides were obtained from a given polypeptide.

ala-gly-asp gly-ala-gly lys-val-ser ser-ala-gly val-ser-ala

Given that the N-terminal amino acid is lysine (lys) suggest the amino acid sequence of the **shortest** polypeptide that would give the above tripeptides.

.....

The structural formulae of the amino acids in the polypeptide are given below.

abbreviation	amino acid	structural formula
ala	alanine	$\text{H}_2\text{NCH}(\text{CH}_3)\text{CO}_2\text{H}$
asp	aspartic acid	$\text{H}_2\text{NCH}(\text{CH}_2\text{CO}_2\text{H})\text{CO}_2\text{H}$
gly	glycine	$\text{H}_2\text{NCH}_2\text{CO}_2\text{H}$
lys	lysine	$\text{H}_2\text{NCH}(\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2)\text{CO}_2\text{H}$
ser	serine	$\text{H}_2\text{NCH}(\text{CH}_2\text{OH})\text{CO}_2\text{H}$
val	valine	$\text{H}_2\text{NCH}(\text{CH}(\text{CH}_3)_2)\text{CO}_2\text{H}$

(ii) Which of the tripeptides in (i) has the lowest M_r ?

.....

(iii) Select **one** amino acid **from those listed in the table** which contains an ionic side-chain at pH 8.

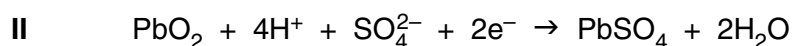
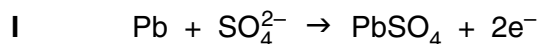
.....

[4]

[Total: 10]

8 The design and development of batteries has been a major research area in recent years.

- (a) Lead-acid batteries, used in cars, are made up of a number of rechargeable cells in series, and were first developed in 1860. They have the disadvantage of a relatively high mass compared to the energy stored. During discharge, the electrode reactions in the cells of these batteries are as follows.



State which of these reactions occurs at the positive electrode in a lead-acid cell during discharge, explaining your answer.

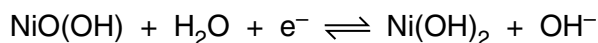
.....
[1]

- (b) Use the *Data Booklet* and the equations I and II above to calculate the voltage produced by a lead-acid cell under standard conditions.

[2]

- (c) Nickel-metal hydride batteries were developed in the 1980s and have become increasingly common particularly for small devices such as mobile phones and digital cameras that need near-constant sources of electrical energy. These cells use nickel oxohydroxide ($\text{NiO}(\text{OH})$) as one electrode and a hydrogen-absorbing alloy such as LiNi_5 as the other electrode.

One reaction that takes place in these batteries is



- (i) State the oxidation state of nickel in $\text{NiO}(\text{OH})$
- (ii) Suggest a likely advantage of these batteries compared with lead-acid batteries.

.....
[2]

- (d) Hydrogen fuel cells have been suggested as the next major advance in electrically powered vehicles. In these fuel cells hydrogen is oxidized to produce water, using a catalyst and inert electrodes.

(i) Suggest a material for the electrodes.

.....

(ii) Use your knowledge of hydrogen to suggest a disadvantage of these fuel cells in powering vehicles.

.....

.....

[2]

- (e) Many of the world's countries are developing ways of recycling materials which are valuable or which require large amounts of energy to produce.

For each of the following recyclable materials, state whether recycling of this material is important in saving energy or in saving resources. Use your knowledge of chemistry to explain each choice.

glass

.....

.....

steel

.....

.....

plastics

.....

.....

[3]

[Total: 10]

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