OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS
Advanced GCE

CHEMISTRY (SALTERS)

Chemistry of Materials

Unit 2849

Thursday **24 JANUARY 2002** Morning 1 hour 30 minutes

Candidates answer on the question paper.
Additional materials:
Data Sheet for Chemistry (Salters)
Scientific calculator

Candidate Name	Centre Number	Candidate Number

TIME 1 hour 30 minutes

INSTRUCTIONS TO CANDIDATES

- Write your name in the space above.
- Write your Centre number and Candidate number in the boxes above.
- Answer **all** the questions.
- Write your answers in the spaces on the question paper.
- Read each question carefully and make sure you know what you have to do before starting your answer.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [ ] at the end of each question or part question.
- You will be awarded marks for the quality of written communication where this is indicated in the question.
- You may use a scientific calculator.
- You may use the *Data Sheet for Chemistry (Salters).*
- You are advised to show all the steps in any calculations.

FOR EXAMINER'S USE		
Qu.	Max.	Mark
1	16	
2	19	
3	9	
4	15	
5	12	
6	19	
7	27	
TOTAL	117	

This question paper consists of 15 printed pages and 1 blank page.

Registered Charity Number: 1066969
[Turn over

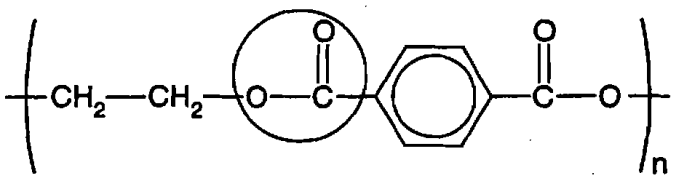
1 PET, polyethylene terephthalate, is a polymer that has been used as a fibre for many years. More recently, plastics made from PET have replaced glass as the preferred container for fizzy drinks. Like glass, plastics made from PET are transparent and gases do not diffuse through them to any appreciable extent. This is especially important in food packaging.

(a) Suggest a reason why it is important for plastics made from PET to be airtight.

.....

.....[1]

The repeating unit of PET is shown below.



(b) Name the functional group circled on the structure above.

.....[1]

(c) PET belongs to a group of polymers known as condensation polymers.

Explain the term *condensation polymer*.

.....

.....

.....[3]

(d) PET is made from two monomers, ethane-1,2-diol and benzene-1,4-dicarboxylic acid. Complete the table below by drawing the **full structural** formula of each of the monomers.

Full structural formula of ethane-1,2-diol	Full structural formula of benzene-1,4-dicarboxylic acid

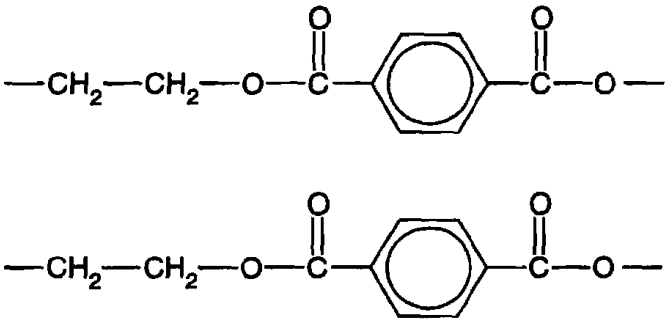
[3]

Plastics made from PET are very strong. They are used to manufacture thin-walled tubing for use in medical products.

(e) **(i)** What is the **strongest** type of intermolecular force which exists between the polymer chains of PET?

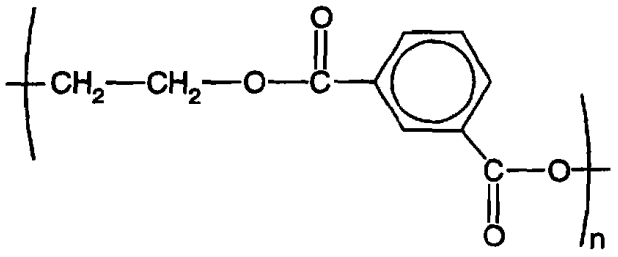
.....[1]

(ii) Complete the diagram below to show clearly how this type of intermolecular force results between the polymer chains:
- draw dotted lines to show where these intermolecular forces occur;
- label the structures to show how these intermolecular forces arise.



[3]

A polymer related to PET, **polymer X**, has been produced. A repeating unit of this is shown below.



Polymer X

(f) Explain why the melting temperature of PET(around 600 °C) is higher than the melting temperature of **polymer X** (around 209 °C).

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.....[4]

[Total : 16]

2 Aspartame is sold under the trade name *Nutrasweet*. Its sweetness was discovered accidentally by a chemist trying to make an anti ulcer drug. He forgot to wash his hands and noticed a sweet taste on his fingers.

(a) The chemist had a sample of impure solid aspartame. Describe how he could produce a pure sample of aspartame by recrystallisation using methanol as a solvent. *In this question one mark is available for quality of written communication.*

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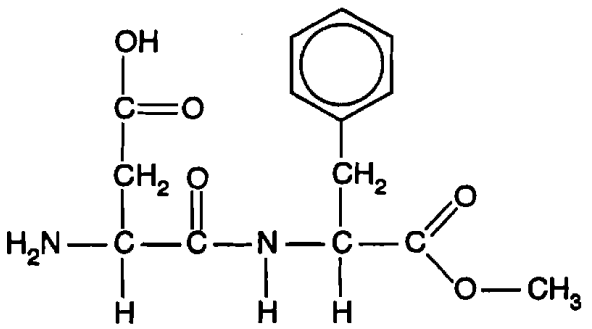
.....[5]

The structure of aspartame is shown below.



aspartame

(b) Clearly circle the following functional groups on the structure of aspartame.

The **amide** group. Label this X.
The **carboxylic acid** group. Label this Y [2]

Aspartame is a chiral molecule. It contains two chiral carbon atoms.

(c) (i) On the structure of aspartame above identify each of the two chiral carbon atoms with an asterisk *. [2]

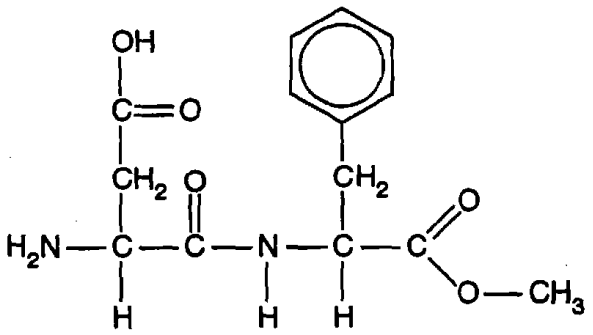
(ii) What feature makes a carbon atom chiral?

.....

.....[1]

Chemists believe that the sensation of sweetness occurs when the aspartame molecule forms a hydrogen bond with protein molecules in the surface of the tongue.

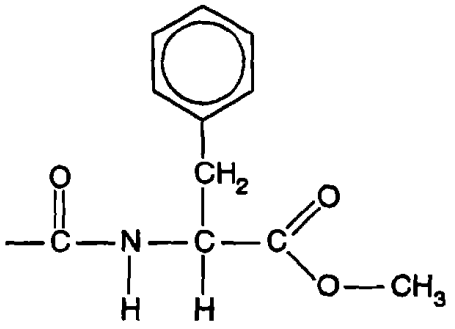
(d) On the diagram below circle all the hydrogen atoms on the aspartame molecule which could form hydrogen bonds.



[3]

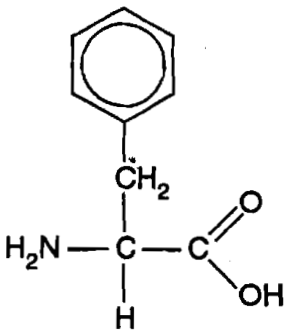
Aspartame exists completely as zwitterions.

(e) Complete the structure below to show the zwitterion formed by aspartame.

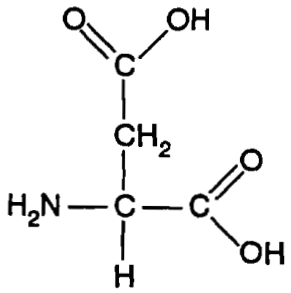


[2]

A sample of aspartame can be hydrolysed to give the amino acids shown below.



phenylalanine



aspartic acid

(f) Describe how you could hydrolyse a sample of aspartame.

.....

.....

.....[2]

A different dipeptide linkage is formed when the NH_2 group on the aspartic acid reacts with the –COOH group on phenylalanine.

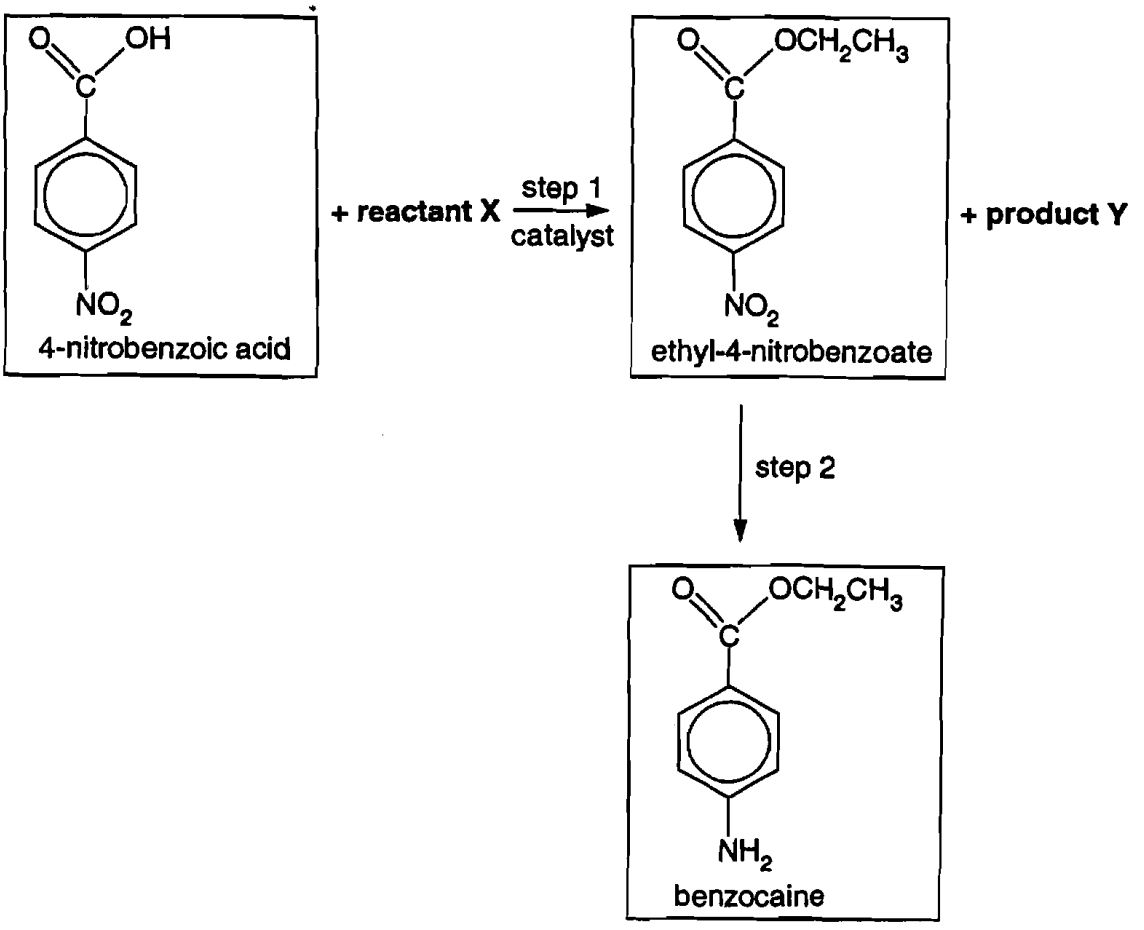
(g) Draw the structure of the resulting molecule.

[2]

[Total : 19]

3 Local anaesthetics such as benzocaine are used to provide a temporary loss of pain to areas of the body. They work by interrupting signals sent along the nerves to the brain.

Benzocaine can be prepared in the laboratory from 4-nitrobenzoic acid in two steps. These are shown below.



(a) (i) Draw the structures of **reactant X** and **product Y** in step 1 in the boxes below.

reactant X	**product Y**

[2]

(ii) Name a suitable catalyst for the reaction in step 1.

.....[1]

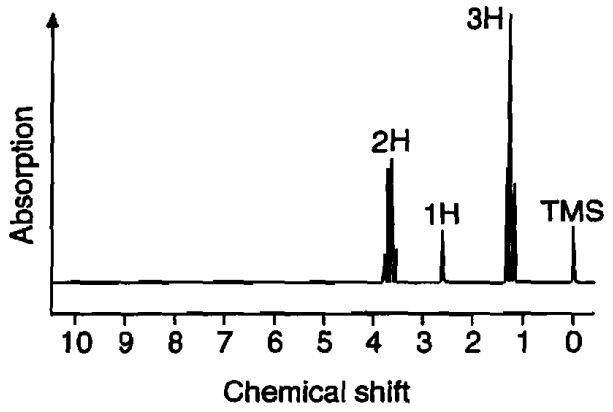
Compound Z can be used in place of 4-nitrobenzoic acid in step 1. **Compound Z** contains an acyl chloride group and reacts much faster than 4-nitrobenzoic acid to give ethyl-4-nitrobenzoate.

(b) Draw the structure of **compound Z** showing the full structural formula of the acyl chloride group.

[2]

When benzocaine is hydrolysed an alcohol with M_r 46 is isolated. The identity of this alcohol is confirmed using proton n.m.r..

The n.m.r. spectrum is shown below.



(c) **(i)** Use the spectrum above and the data sheet which accompanies this paper to determine the type of proton responsible for each of the chemical shifts.

chemical shift from spectrum	relative number of protons	type of proton
1.2	3	
2.7	1	
3.8	2	

[3]

(ii) Use the information to suggest the **full structural** formula of this alcohol.

[1]

[Total : 9]

For Examiner's Use

4 Food chemists divide sweeteners into two categories: bulk sweeteners and intense sweeteners. Aspartame is an intense sweetener and sucrose is a bulk sweetener.

Sucrose can be hydrolysed in the presence of hydrogen ions to form glucose and fructose.

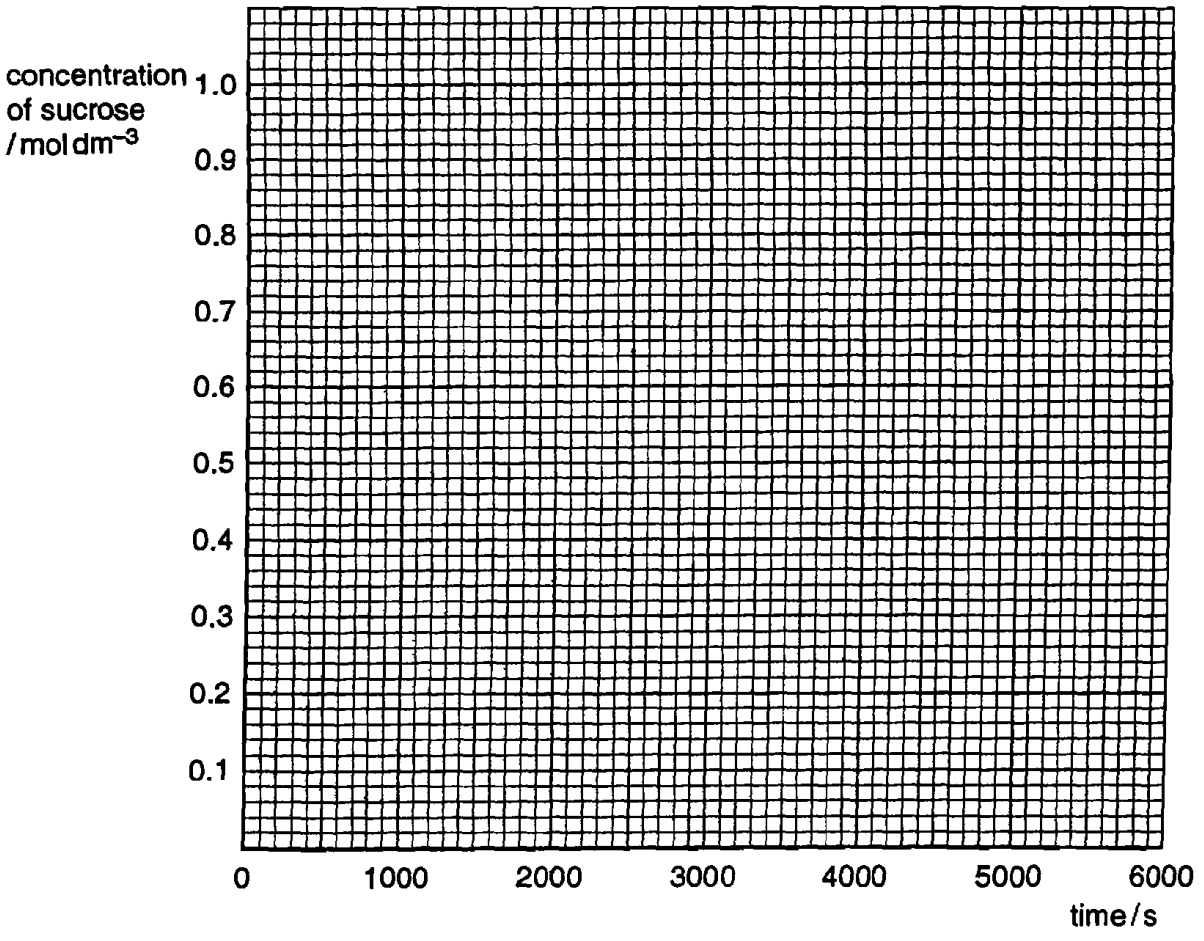
$$\underset{\text{sucrose}}{C_{12}H_{22}O_{11}} + H_2O \longrightarrow \underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{fructose}}{C_6H_{12}O_6}$$

A student carried out this reaction at 25 °C in the presence of 1.0 mol dm^{-3} aqueous hydrochloric acid.

The following data were obtained.

time /seconds	concentration of sucrose / mol dm^{-3}
0	1.04
900	0.74
1800	0.52
2700	0.40
3600	0.30
4500	0.22
5400	0.16

(a) (i) Plot the data on the axes below.



[3]

(ii) Label two half lives on your graph. [2]

(iii) Give the value of each half life.

first half life .....

second half life ..... [2]

(iv) What is the order of reaction with respect to sucrose? Explain clearly how you arrived at your answer.

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.....[2]

(v) Explain how you would use your graph to find the initial rate (rate at t = 0 s) of the reaction.

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.....[2]

In a separate set of experiments, the student found that the reaction is first order with respect to the concentration of hydrogen ions.

(b) Use the above information and your answer to **(a)(iv)** to construct the rate equation for the hydrolysis of sucrose in the presence of hydrogen ions.

.....[3]

(c) What would happen to the rate of reaction if the concentration of the hydrochloric acid was halved? Assume that the concentration of sucrose remains constant.

.....[1]

[Total :15]

5 A hoard of bronze axes was found in Yearsley Common in Yorkshire. They are believed to date back to the Bronze Age (around 2000 B.C.) when bronze was used to make tools.

Bronze is an alloy of copper and tin and is much stronger than copper alone.

(a) Explain in terms of the arrangement of atoms how alloying increases the strength of copper.

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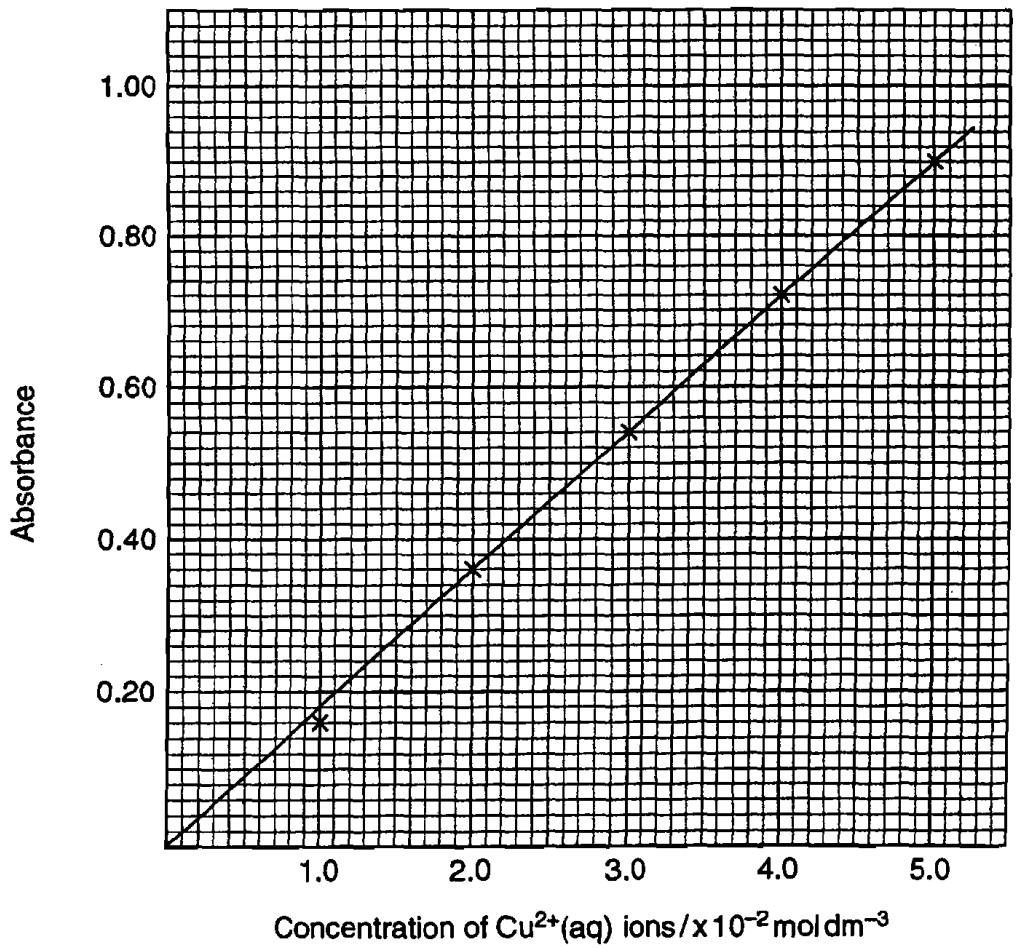
.....[3]

A chemist determined the amount of copper in a sample of bronze by the following method.

- 0.200 g of bronze were treated with concentrated nitric acid.
- A precipitate of tin(IV) oxide formed and this was filtered off.
- The remaining blue solution contained $Cu^{2+}(aq)$ ions and was made up to 100 cm^3 with water in a volumetric flask **(solution P)**.
- The concentration of $Cu^{2+}(aq)$ ions in **solution P** was determined using a colorimeter.

The chemist produced the calibration graph shown below.



(b) Outline the steps the chemist would take to produce a calibration graph to use in the determination.

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.....[4]

Solution P was found to give an absorbance reading of 0.48.

(c) (i) What is the concentration of the $Cu^{2+}(aq)$ ions in mol dm^{-3} in **Solution P**?

.....[1]

(ii) Calculate the mass of copper present in the sample of bronze. (A_r: Cu, 63.5)

Answer = ...g [3]

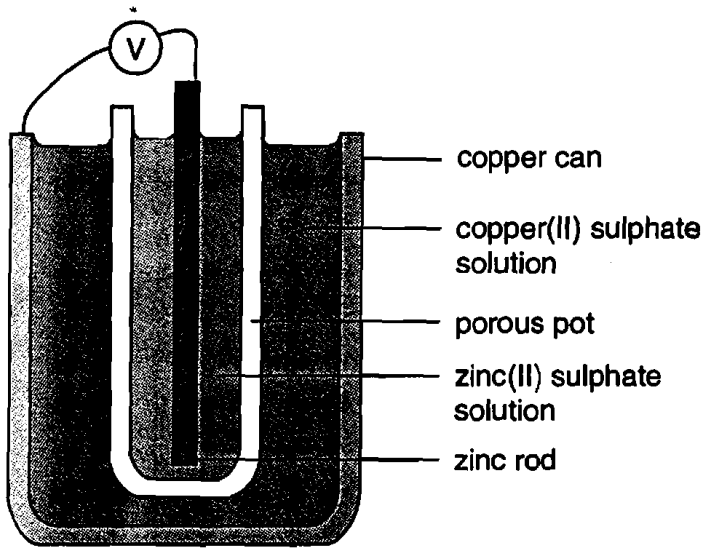
(iii) Use your answer from **(ii)** to calculate the percentage of copper present in the sample of bronze.

Answer = ...[1]

[Total : 12]

6 In 1826 John Fredrick Daniell constructed a simple cell.
He used a zinc rod immersed in zinc(II) sulphate solution and a copper can containing copper(II) sulphate solution. The two electrodes were separated by a porous partition.

A diagram of the cell is shown below.



(a) Use the information below to **(i)** write a balanced equation for the overall cell reaction and **(ii)** calculate $E^{\ominus}_{cell}$.

$Zn^{2+} + 2e^- \rightarrow Zn \quad E^{\ominus} = -0.76\,V$
$Cu^{2+} + 2e^- \rightarrow Cu \quad E^{\ominus} = +0.34\,V$

(i) Equation .....[1]

(ii) $E^{\ominus}_{cell}$ = ...V [1]

The atomic number of an atom of copper is 29. In the solution of copper(II) sulphate the oxidation state of the copper is +2.

(b) **(i)** Complete the space below to show the electronic configuration of an **atom** of copper.

$1s^2 2s^2 2p^6 3s^2 3p^6$ ..... [2]

(ii) State the number of electrons present in the 3d subshell of a Cu^{2+} ion.

.....[1]

Copper(II) sulphate is one of the electrolytes in the Daniell cell. The solution contains the blue complex ion $[Cu(H_2O)_6]^{2+}$.

(c) Explain what is meant by the term *complex ion*.

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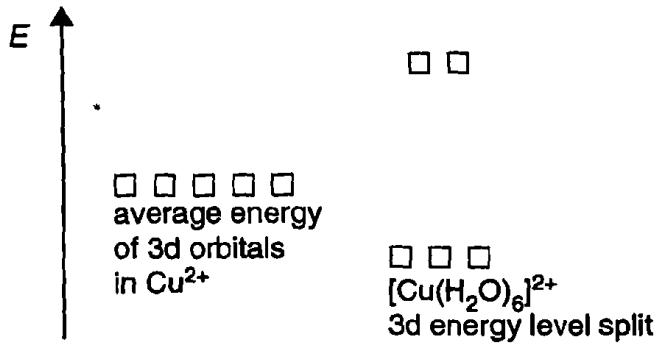
.....[2]

The five d orbitals in an isolated Cu^{2+} ion have the same energy. The diagram shows what happens to the energies of these orbitals in the complex ion $[Cu(H_2O)_6]^{2+}$.



(d) Use the diagram above and your understanding of electron energy levels to explain why transition metal compounds such as aqueous copper(II) sulphate are coloured.

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.....[4]

(e) When concentrated hydrochloric acid is added to the copper(II) sulphate solution, the following reaction takes place.

$$[Cu(H_2O)_6]^{2+}(aq) + 4Cl^-(aq) \rightleftharpoons [CuCl_4(H_2O)_2]^{2-}(aq) + 4H_2O(l)$$

blue yellow

The final solution appears green. What does this tell you about the position of equilibrium?

.....

.....[1]

(f) Write an expression for the equilibrium constant, K_c, for this reaction.

[3]

The equilibrium constant in **(e)** is called the stability constant K_{stab} $[CuCl_4(H_2O)_2]^{2-}$. The table below gives information about the stability constants K_{stab} of three complex ions of copper.

complex ion	colour	lg K_{stab}
$[CuCl_4(H_2O)_2]^{2-}$	yellow	5.6
$[Cu(NH_3)_4(H_2O)_2]^{2+}$	violet	13.1
$[Cu(edta)]^{2+}$	pale blue	18.1

(g) Use the information in the table to predict what you would expect to **see** when

(i) a solution containing $edta^{4-}$ ions is added to the green solution in **(e)**. until just in excess. Explain your answer

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.....

.....[2]

(ii) concentrated ammonia solution is added to the solution formed in **(g)(i)**. Explain your answer.

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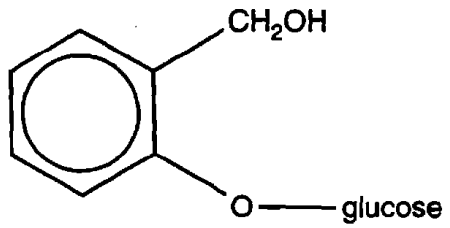
.....[2]

[Total : 19]

For Examiner's Use

7. In the early years of the nineteenth century, chemists isolated *salicin* from willow bark.



salicin

(a) **(i)** Circle in the list below the **type** of alcohol group present in salicin.

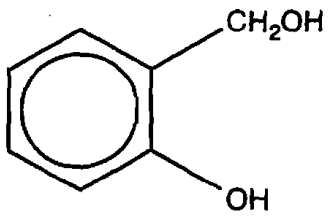
primary **secondary** **tertiary** [1]

(ii) Explain your choice.

.....

.....[1]

(b) Hydrolysis of salicin leads to the formation of two products. One is glucose. The other is shown below and is called salicyl alcohol.



salicyl alcohol

(i) Thin layer chromatography can be used to show that the hydrolysis mixture contains **two** products, one of which is salicyl alcohol. With the aid of labelled diagrams, describe how you would carry this out.

[5]

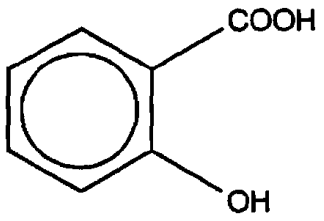
(ii) Give the reagent used in a chemical test to show that salicyl alcohol contains a phenol group. What would you expect to see?

reagent added .....

observation .....

[2]

(c) Salicyl alcohol is easily oxidised to salicylic acid.



salicylic acid

Salicylic acid contains a carboxylic acid group. Draw the **full structural formula** of a carboxylic acid group.

[1]

(d) (i) The relative molecular mass of salicylic acid is 138. What would you look for in a mass spectrum of salicylic acid to confirm this is true?

.....[1]

(ii) The mass spectrum of salicylic acid, $C_7H_6O_3$, contains a peak at a mass of 120. What fragment is lost from the molecular ion to produce this peak?

.....[1]

(iii) What is the molecular formula of the ion responsible for the peak at a mass of 120?

.....[1]

(e) Salicylic acid is soluble in warm water. The concentration of a solution can be determined by titration with aqueous sodium hydroxide.

(i) What name is given to the **type** of reaction which occurs in this titration?

.....[1]

(ii) What piece of apparatus should a student use to measure out 25.0 cm^3 of aqueous salicylic acid?

.....[1]

(iii) 33.3 cm^3 of 0.015 mol dm^{-3} sodium hydroxide solution reacted with the 25.0 cm^3 of salicylic acid solution.

Calculate the number of moles of sodium hydroxide added to the salicylic acid.

answer ..... mol [2]

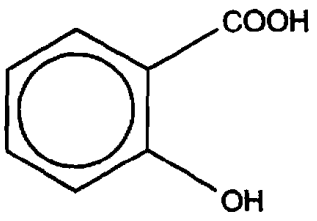
(iv) **Two** moles of sodium hydroxide react with **one** mole salicylic acid. Use your answer from (iii) to calculate the number of moles of salicylic acid in 25.0 cm^3 of salicylic acid solution.

answer ..... mol [1]

(v) Calculate the concentration of the salicylic acid solution.

answer ..... mol dm^{-3} [2]

(f) List **all of the types** of intermolecular force present between salicylic acid molecules.



salicylic acid

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.....[3]

For Examiner's Use

(g) The carboxylic acid group, — COOH, in salicylic acid reacts with water reversibly to produce an acidic solution according to the equation below.

$$— COOH(aq) + H_2O(l) \rightleftharpoons — COO^-(aq) + H_3O^+(aq)$$

(I) Explain why water is acting as a base in this reaction.

.....

.....[1]

(II) A solution containing $— COO^-$ ions is added to the acidic solution. Use the equation above and Le Chatelier's principle to explain what would happen to the concentration of the H_3O^+ ions.

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.....[3]

[Total: 27]