OCR

RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

CHEMISTRY (SALTERS)

Chemistry of Materials

2849

Monday **23 JANUARY 2006** 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, Centre Number and Candidate number in the boxes above.
- Answer **all** the questions.
- Read each question carefully and make sure you know what you have to do before starting your answer.
- Write your answers, in blue or black ink, in the spaces provided on the question paper. Pencils may be used for diagrams and graphs **only**.
- Do not write in the bar code. Do not write in the grey area between the pages.
- **DO NOT** WRITE IN THE AREA **OUTSIDE** THE BOX BORDERING EACH PAGE. ANY WRITING IN THIS AREA WILL NOT BE MARKED.

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	17	
2	19	
3	19	
4	24	
5	11	
TOTAL	90	

This question paper consists of 18 printed pages and 2 blank pages.

SPA (MML 10405 2/05) S97267/5

Registered Charity Number: 1066969

[Turn over

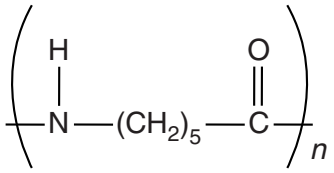
Answer **all** the questions.

1 In the 1930s, chemists began to design polymers that had similar structures to those found in natural fibres. The first of these polymers, nylon-6,6, was quickly followed by the invention of nylon-6.

(a) Suggest a reason why chemists wanted to find synthetic replacements for some natural fibres.

..... [1]

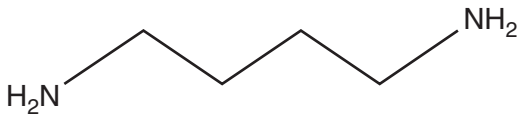
(b) The repeating unit of nylon-6 is shown below.



Draw the structure of a monomer which can be used to make nylon-6.

[2]

(c) At the same time that nylon-6,6 was invented, chemists also made a sample of a nylon by reacting hexanedioic acid with compound **A**. The nylon was found to have a low molecular mass and was therefore not developed any further.



compound A

(i) Name compound **A**.

..... [2]

(ii) Because of its low molecular mass, certain properties of the new nylon are different from those of nylon-6. Describe how **two** of these properties are different from those of nylon-6.

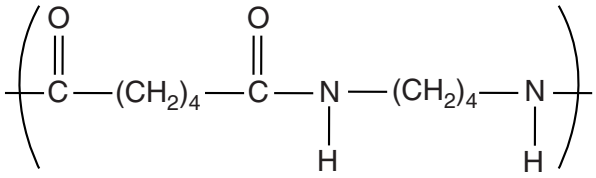
.....

.....

.....

..... [2]

(d) Recently, chemists have been able to make samples of a polymer using compound **A**, but having a much higher M_r of 3×10^4. The polymer was named *Stanyl* and is stronger and has a higher melting point than either nylon-6,6 or nylon-6. It is now used in manufacturing parts for car engines.



repeating unit of *Stanyl*

(i) Approximately how many repeating units are there in a molecule of *Stanyl*?

number of repeating units = ... [2]

(ii) Name the functional group connecting the repeating units in *Stanyl*.

..... [1]

(iii) Explain why the melting point of *Stanyl* is higher than that of nylon-6,6 which has a similar molecular mass.

.....

.....

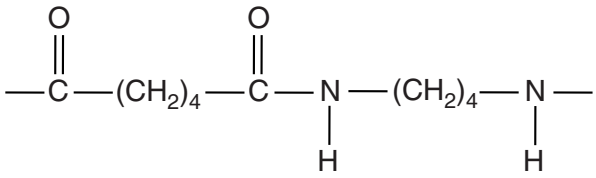
..... [3]

(e) The manufacturers of *Stanyl* state that 'as with all other polyamides, *Stanyl* is attacked by strong mineral acids and absorbs polar solvents'.

(i) Draw the structures of the two organic products formed when *Stanyl* is hydrolysed with a strong acid. (The structure of *Stanyl* is repeated below.)

[2]

(ii) Show using the diagram below how part of a *Stanyl* chain can form an intermolecular bond with a water molecule. Show any partial charges.



[2]

[Total: 17]

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2 Chemists in Australia have recently developed large batteries for the bulk storage of electricity. The batteries, known as vanadium redox batteries, are made from two half-cells, **A** and **B**, both of which contain solutions of compounds of the transition metal vanadium.

(a) In half-cell **A**, the following reaction occurs.

$$VO_2^+ + 2H^+ + e^- \rightleftharpoons VO^{2+} + H_2O$$

(i) Give the oxidation state of the vanadium in VO_2^+.

..... [1]

(ii) The standard electrode potential, $E^{\ominus}$, of this half-cell is +1.00 V.

Draw a labelled diagram of the apparatus used to measure this $E^{\ominus}$ value.

[5]

(b) The solution in half-cell **B** is a mixture of V^{2+} ions and V^{3+} ions. The standard electrode potential for this half-cell is +0.26 V.

(i) Calculate the E_{cell} value for the cell (consisting of half-cells **A** and **B**) used in the vanadium redox battery.

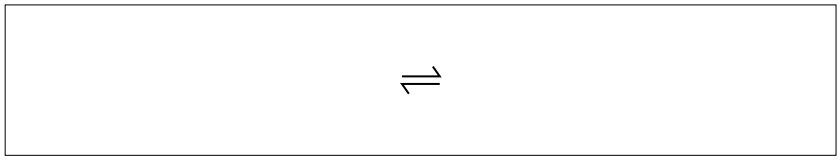
E_{cell} = ... V [1]

(ii) Which half-cell forms the negative electrode? Explain your answer.

.....

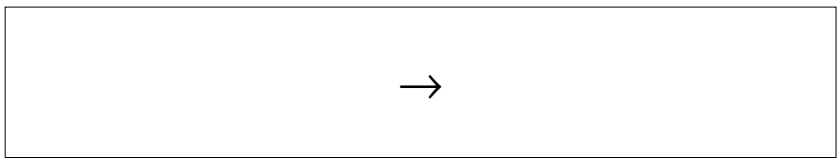
..... [1]

(c) **(i)** Give the half-equation (ion-electron equation) for the reaction involving V^{2+} and V^{3+} ions.



[1]

(ii) Construct an equation for the overall reaction occurring in the vanadium redox battery.



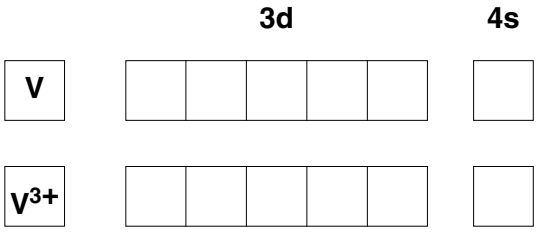
[2]

(d) In aqueous solutions, V^{3+} ions form octahedral complex ions which have a green colour.

(i) Draw a three dimensional structure for these hydrated V^{3+} ions, showing clearly how the ligands bond to the cation.

[2]

(ii) By drawing arrows in the appropriate boxes, complete the outer electron structures for V and V^{3+}.



[2]

(iii) Using ideas of light absorption, ligands and electronic energy levels, explain why V^{3+} ions in water are coloured.

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.....

.....

..... [4]

[Total: 19]

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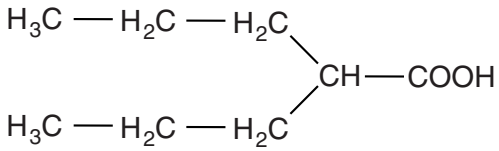
3 Epilim is a medicine widely used today to control epilepsy. It is derived from valproic acid. Valproic acid had first been synthesised in the late 19th century, but it was not until the 1960s that its anti-epileptic properties were discovered by chance. It is an oily, acidic liquid, only slightly soluble in water, with a smell characteristic of carboxylic acids. It was being used as a solvent for possible new medicines, but was found to be medically active itself.

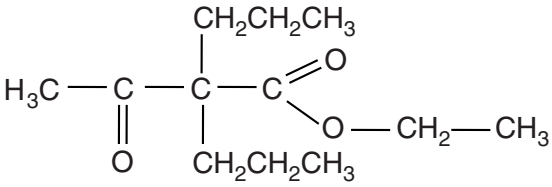
The formula of valproic acid is given below.



(a) Give the systematic chemical name of **valproic acid**.

..... [2]

(b) The first synthesis of valproic acid was from compound **B**.



compound B

Circle the ester linkage in compound **B**. [1]

(c) Compound **B** was heated under reflux with aqueous potassium hydroxide.

Three products were formed:

- potassium valproate
- another salt, compound **C**
- compound **D**, a volatile liquid.

(i) Suggest why the reactants were heated under reflux rather than just heated in a suitable container.

.....

..... [1]

(ii) Suggest a method of obtaining a pure sample of compound **D** from the mixture.

..... [1]

(iii) After removing compound **D** from the mixture, what would you do to the remaining solution to convert the two salts into their respective acids?

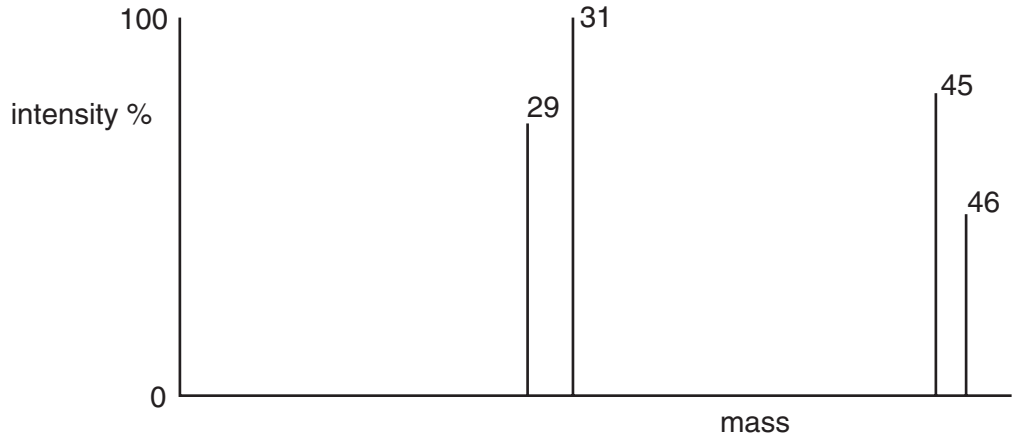
..... [1]

(iv) Compound **C** contains two carbon atoms. Suggest the identity of compound **C**.

..... [1]

(d) Use the mass spectrum of compound **D**, given below, to suggest a **structural formula** for **D**. Explain your reasoning.

Remember **D** was formed from compound **B**.



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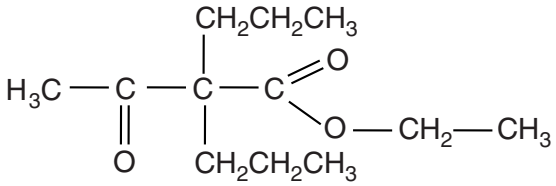
..... [3]

(e) The n.m.r. spectrum of compound **B** consists of **four** peaks.

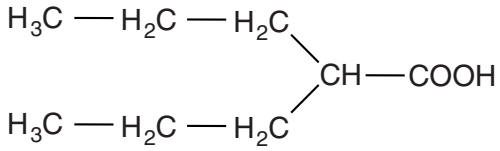


compound B

Identify these four peaks and give their relative intensities by completing the table below.

chemical shift from spectrum	type of proton	relative intensity
1.0		
1.4		
2.2		
3.7		

[3]



valproic acid

(f) Describe how you would use the **infrared** spectrum of **valproic acid** to show that it contains a carboxylic acid group. Give details of any peaks you use in your interpretation.

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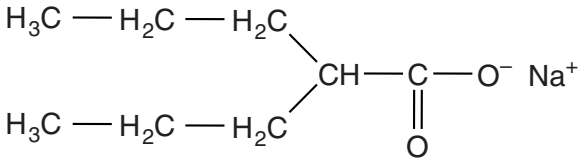
..... [4]

(g) The structure of Epilim is shown below. It is commonly called sodium valproate.



Epilim

Chemists found that sodium valproate and valproic acid had similar anti-epileptic properties. Manufacturing costs were also similar.

Suggest **two** reasons why sodium valproate is used rather than valproic acid.

1 .....

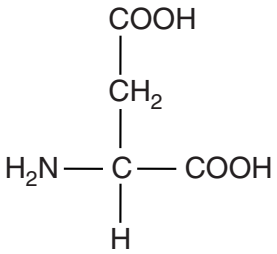
.....

2 .....

..... [2]

[Total: 19]

4 Dentine is the part of a tooth between the enamel crown and the soft pulp-like interior. It is hard and contains about 20% organic materials, such as proteins and amino acids. One of the amino acids present is aspartic acid.



aspartic acid

(a) Aspartic acid has two isomers, D-aspartic acid and L-aspartic acid.

(i) What type of isomerism is shown by aspartic acid?

..... [1]

(ii) Explain why aspartic acid can exist as two isomers and draw structures to show how the two isomers are related.

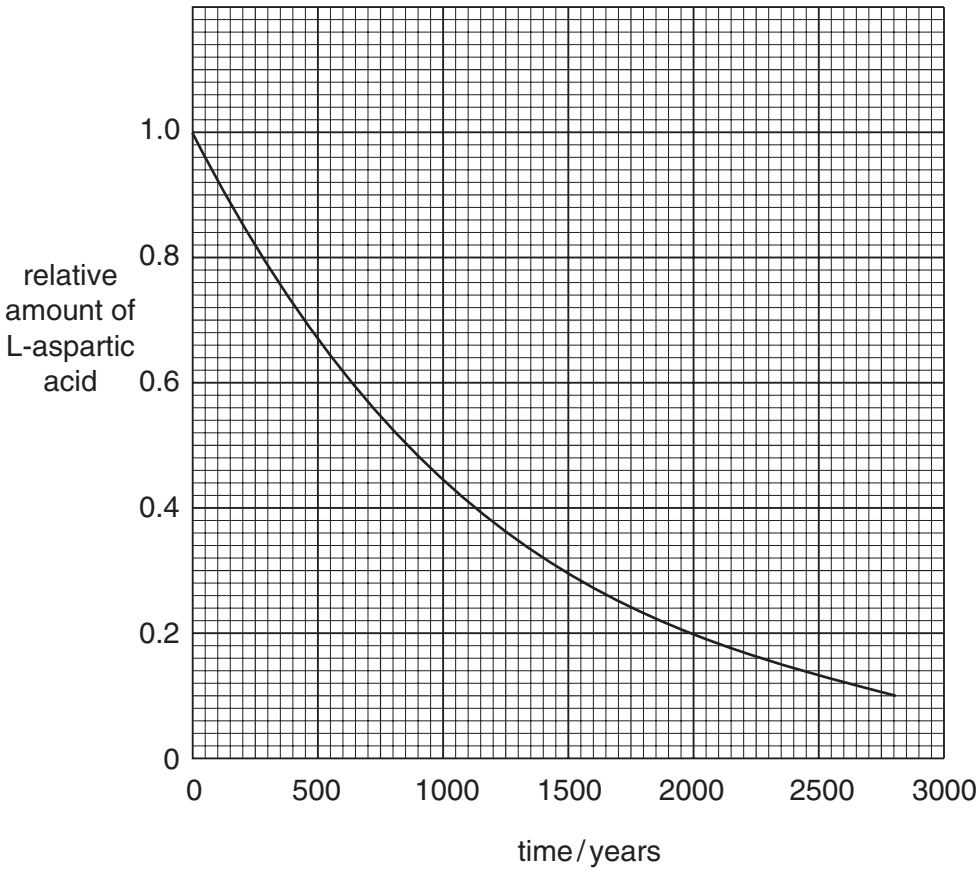
explanation .....

.....

..... [3]

(b) As we grow older, the L-aspartic acid contained in the dentine in our teeth slowly changes to the D-form and continues to do so after we die. Chemists have used this process to date the age of human skulls that have been buried in the ground for up to 1000 years.

The graph below shows the way the concentration of L-aspartic acid changes with time.



(i) Use the graph to determine **three** half-lives for the process. Show your working on the graph.

1 .....

2 .....

3 ..... [3]

(ii) Explain how you can conclude that the conversion of L-aspartic acid is a first order process.

.....

..... [1]

(iii) Write down the rate equation for the conversion of L-aspartic acid into its D isomer.

..... [2]

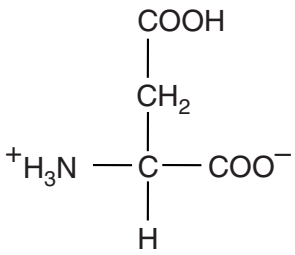
(iv) Give the units of the rate constant in your rate equation in **(iii)**.

units ..... [1]

(v) What is the significance of the value for the rate constant when the concentration of L-aspartic acid is 1.0 mol dm^{-3}?

..... [1]

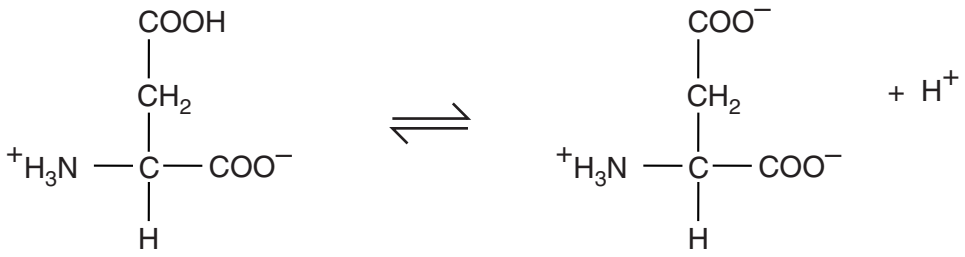
(c) The particles of aspartic acid in the solid state are ionised. Many have the structure given below.



What is the name given to this type of ion?

..... [1]

(d) In solution, these ions are in equilibrium with other ions. The equation for one of these equilibria is given below.



ion **E** ion **F**

(i) Write the expression for the equilibrium constant, K_c, for this reaction. You may use the letters **E** and **F** to represent the ions in your answer.

[1]

(ii) The value of K_c at 298 K is 1.38×10^{-4} mol dm^{-3}.

At equilibrium, the concentration of ion **E** is 0.50 mol dm^{-3}. Assume that ions **F** and H^+ both have the same concentration as each other.

Calculate the concentration of H^+ ions. Give your answer to **an appropriate number** of significant figures.

$[H^+]$ = ... mol dm^{-3} [3]

(e) Aspartic acid is an essential component of the primary structure of a large number of proteins. Some of these proteins act as enzymes by enabling substrates to bind ionically to the active site. The aspartic acid also modifies the secondary structure of these proteins, increasing their solubility.

In this question, one mark is available for the quality of spelling, punctuation and grammar.

Explain

- the terms primary and secondary structure as applied to proteins
- how aspartic acid makes proteins more soluble
- how enzymes can form ionic bonds with substrates.

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..... [6]

Quality of Written Communication [1]

[Total: 24]

5 Over 100 years ago, Robert Hadfield discovered how to make a steel which is ductile yet very hard and gets even harder if it is hit. It was used to make safes to store valuables! Hadfield steel is still used today in many areas, particularly in railway applications.

(a) Hadfield steel is quite expensive because of its high manganese content. Suggest **one** use for it by the railway companies.

..... [1]

(b) The table below shows how the composition of Hadfield steel differs from the composition of pig iron from which it is made.

element	pig iron %	Hadfield steel %
carbon	4.42	1.35
silicon	0.66	1.00
manganese	0.41	13.00
phosphorus	0.09	0.07
sulphur	0.03	0

(i) Magnesium is added to the molten pig iron. Why is this done?

.....

..... [1]

(ii) Describe and explain how the carbon content of the molten pig iron is adjusted.

.....

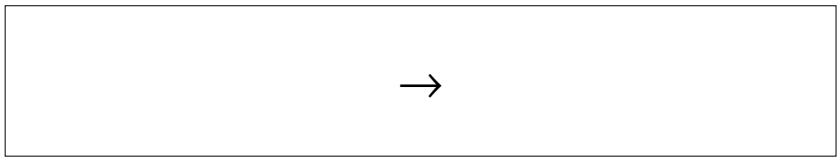
..... [2]

(c) All of the phosphorus is oxidised in the process of removing the carbon. Phosphorus(V) oxide is removed using calcium oxide.

(i) What property of phosphorus(V) oxide causes it to react with calcium oxide?

..... [1]

(ii) Write an equation for the reaction of phosphorus(V) oxide with calcium oxide.



[3]

(iii) How is the 0.07% phosphorus in the Hadfield steel achieved?

..... [1]

(d) At one stage in the manufacture of the steel, aluminium is added. Why is this done?

..... [1]

(e) Steel is recycled by adding it to the pig iron in the converter. This is, of course, important in conserving resources.

Give **one** problem which chemists face in recycling steel.

.....

..... [1]

[Total: 11]

END OF QUESTION PAPER

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