

Oxford Cambridge and RSA Examinations



Advanced GCE

CHEMISTRY (SALTERS)
Chemistry of Materials

Unit 2849

Specimen Paper

Candidates answer on the question paper.

Additional materials:

Data Booklet for Chemistry (Salters)

To be brought by candidate: electronic calculator

TIME 1 hour 30 minutes

INSTRUCTIONS TO CANDIDATES

Write your name, Centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided on the question paper.

There should be ample space for your answers. If you need more space for answers or rough work you may use the blank spaces at the end of questions or any blank pages. Rough work that is not to be marked should be crossed out.

You will be awarded marks for the quality of your written communication where an answer requires a piece of extended writing.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets [] at the end of each question or part question.

A copy of the Periodic Table and other tables of information are provided on a data sheet for use with this examination; other necessary data are given as required in the questions.

You may use an electronic calculator.

Total Marks = 122.

1. Stainless steel contains chromium which reduces corrosion, mainly by forming a very thin layer of chromium(III) oxide on the surface. Stainless steel is made by adding chromium in the last stage of steelmaking.

(a) Steel is usually made from blast furnace iron by the BOS process. Oxygen is blown through the molten iron and basic oxides (for example, calcium oxide) are added. Carbon escapes as carbon monoxide. Other elements (for example, silicon) form oxides which react with the basic oxides present. Thus they can be removed as slag.

(i) Write equations that show how silicon is removed by the BOS process.

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

(ii) Suggest why the chromium is added after the oxygen blow rather than before it.

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

(b) One way in which the steel may be analysed to find its chromium content is to dissolve out the chromium as the complex $[\text{Cr}(\text{NH}_3)_6]^{3+}$ ion which is green.

(i) What is the oxidation state of chromium in the complex ion?

..... [1]

- (ii) Draw a diagram to show the shape of the $[\text{Cr}(\text{NH}_3)_6]^{3+}$ ion, labelling the metal ion and a ligand molecule. Show clearly which part of the ligand molecule forms a bond with the metal ion.

[2]

- (c) Describe in outline how you would use a colorimeter to find the concentration of the green complex ion in solution, given a sample of the pure green solid.

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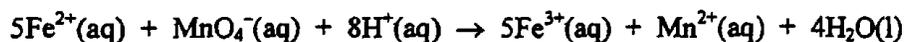
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[5]

- (d) In a separate experiment to find the iron content of a sample of steel, 1.40 g of the metal were dissolved by boiling with acid. The iron in the solution was then all converted into the +2 oxidation state and the solution was made up to 100.0 cm³ using dilute sulphuric acid. 10.0 cm³ of this solution were titrated against a 0.0200 mol dm⁻³ solution of potassium manganate(VII). 24.2 cm³ of the potassium manganate(VII) solution were required to reach the end-point of the titration. The reaction occurring in the titration is:



(i) Calculate the mass of iron in the sample of steel. (A_r : Fe, 56.0)

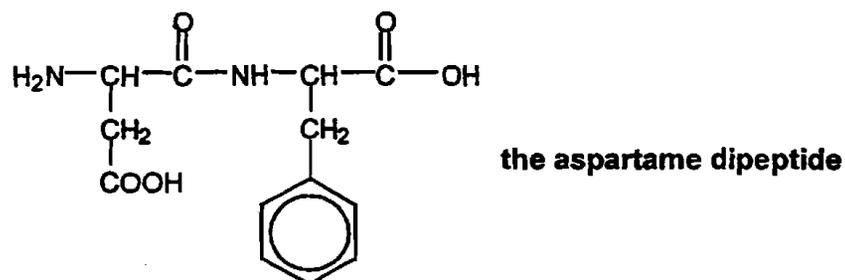
[3]

(ii) Calculate the percentage by mass of iron in the steel.

[1]

Total 15 marks

- 2 Aspartame is an artificial sweetener which is about 200-times sweeter than sucrose. It is a methyl ester of a dipeptide formed from two α -amino acids: aspartic acid and phenylalanine.



- (a) Explain the meaning of the term dipeptide.

.....

..... [2]

- (b) Draw a skeletal formula for the aspartame dipeptide.

[2]

(c) One way to show the composition of aspartame is to hydrolyse it and then separate and identify the substances formed.

(i) Briefly describe the procedure which is used to hydrolyse a protein or a dipeptide.

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

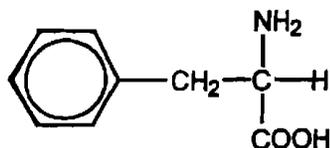
(ii) Three compounds are formed when aspartame is hydrolysed. Name these three compounds and explain what further information you would need to establish the structure of aspartame.

Products of hydrolysis:.....
..... [2]

Further information needed:.....
.....
..... [2]

(d) Both aspartic acid and phenylalanine exist in two optical isomer forms, labelled the L form and the D form. Only the L amino acids occur naturally in proteins. Many of the chemical reactions of L and D amino acids are identical, but in the body they can behave differently. For example, D-phenylalanine tastes sweet, but L-phenylalanine is bitter.

(i) On the diagram of the structure of phenylalanine which follows, place an asterisk (*) next to the atom which indicates to you that there are two optical isomers.



[1]

- (ii) In the space below, draw diagrams to illustrate the two optical isomers of phenylalanine.



mirror

[2]

- (e) A solution of phenylalanine in water will contain few molecules like the one shown in (d)(i). Draw a structure for the form of phenylalanine most likely to be present in an aqueous solution.

[2]

- (f) A disadvantage of using aspartame as a sweetener is that it breaks down much faster than sucrose. In soft drinks stored in cans or bottles, about 10% of the aspartame is destroyed each month. Suggest a reason why aspartame breaks down in this way.

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

Total 16 marks

- 3 Sea squirts (*Ascidia*) have an extensive biochemistry based on vanadium, and some of them have blood containing vanadium compounds. Vanadium can be present in three oxidation states in sea squirts. The effectiveness of a biochemistry based on vanadium compounds is thought to arise, in part, from the ease with which these three oxidation states can be interconverted.

Electrode potential values are given below for the reduction of oxygen to water and for half-reactions which involve V^{3+} , VO^{2+} and VO_2^+ .

These three ions are commonly found in aqueous solutions of vanadium compounds.

These electrode potential values were obtained under standard conditions, except that $pH = 7$.

Electrode potentials:	E^\ominus/V
$VO^{2+}(aq) + 2H^+(aq) + e^- \rightarrow V^{3+}(aq) + H_2O(l)$	-0.50
$VO_2^+(aq) + 2H^+(aq) + e^- \rightarrow VO^{2+}(aq) + H_2O(l)$	+0.16
$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$	+0.98

- (a) In the space below, draw a labelled diagram of the apparatus which could be used to measure the standard electrode potential of a half-reaction involving ions in solution.

[5]

- (b) (i) Predict, using the electrode potentials given above, the oxidation state of vanadium that would be stable in aqueous solution at pH = 7 in the presence of air.

..... [1]

- (ii) Explain how the electrode potential data allow this prediction to be made.

.....

 [2]

- (c) In reactions in living cells, transition metal ions are often present in the form of biochemical complexes. State why the electrode potential data given above do not allow a reliable prediction to be made of the oxidation state of vanadium that would be stable in the presence of oxygen in such reactions.

.....
 [1]

- (d) Vanadium has an atomic (proton) number of 23. Complete the space below to show the electron configuration of a vanadium atom.

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

Ionisation enthalpy changes for vanadium and calcium are given in the table below.

	Ionisation enthalpy changes/kJ mol ⁻¹					
	1st	2nd	3rd	4th	5th	6th
calcium	590	1145	4912	6474	8144	10 496
vanadium	650	1414	2828	4507	6294	12 362

- (e) Write the chemical equation for the third ionisation of vanadium.

..... [2]

(f) Explain, using the ionisation enthalpy data in the table, why vanadium can form high oxidation states in its compounds whereas calcium does not form oxidation states greater than +2 in its compounds.

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..... [2]

Total 15 marks

- 4 A large proportion of the nylon manufactured in the UK is nylon-6,6 made from 1,6-diaminohexane and hexanedioic acid. In the industrial process currently in use, both 1,6-diaminohexane and hexanedioic acid are made from benzene.

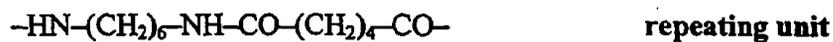
(a) Draw the full structural formula of 1,6-diaminohexane.

[2]

(b) 1,6-diaminohexane is not very soluble in water but dissolves readily in dilute hydrochloric acid. Write a balanced equation for this reaction. (You do not need to draw again the full structural formula for 1,6-diaminohexane, but your formula should show the functional groups clearly.)

[2]

- (c) The repeating unit in nylon-6,6 is shown below:



- (i) Suggest why nylon made in this way is called nylon-6,6.

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

- (ii) Explain, in terms of interactions between polymer chains, why nylon-6,6 is a strong polymer material at room temperature, but becomes less strong as the temperature is raised.

Note: In this question 1 mark is available for the quality of written communication.

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..... [7]

- (d) Chemists have recently developed a new process for making hexanedioic acid from glucose. Enzymes in some organisms can convert glucose into muconic acid. The chemists modified the bacterium *E. coli* by genetic engineering to produce these enzymes. The modified bacteria are then fed glucose and produce muconic acid. This is collected and converted into hexanedioic acid.



muconic acid

- (i) Briefly explain, in outline, how a bacterium such as *E. coli* can be modified by genetic engineering. (It is not necessary to give practical details.)

.....

.....

.....

.....

..... [3]

- (ii) The nuclear magnetic spectrum of muconic acid contains two signals. Suggest, giving a reason, a chemical shift for each signal.

.....

.....

..... [2]

Total 17 marks

- 5 The water which runs from waste heaps associated with copper mines contains low concentrations of dissolved copper ions. Companies have begun removing Cu^{2+} ions from the water by the process of **ligand exchange solvent extraction**.

A compound which is a good ligand for copper ions is dissolved in an organic solvent that is immiscible with water. When this solution is shaken with the water containing the copper ions, the following reaction takes place:



(where L represents the ligand).

- (a) Explain why the process represented in **Equation 5.1** is classed as a **ligand exchange reaction**.

.....

 [2]

- (b) The effect of the process is to remove a low concentration of copper ions from water and to transfer them, at much higher concentration, to the organic solvent. The process can be reversed by then shaking the organic solution with moderately concentrated acid. This pushes Cu^{2+} ions back into aqueous solution and, again, an increase in concentration can be achieved.

- (i) Use **Equation 5.1** to explain why extraction of Cu^{2+} ions into the organic solvent and then their reversal back into the aqueous phase is pH dependent (i.e. depends on the concentration of H^+ ions in solution).

.....

 [2]

- (ii) Suggest how an increase in concentration of copper ions is achieved at each stage of the extraction.

.....
 [1]

- (c) Research chemists have carried out experiments to find equilibrium constant, K_c , values for reactions like the one in Equation 5.1. Aqueous solutions of Cu^{2+} ions were shaken with solutions of a ligand in an organic solvent and allowed to reach equilibrium. In one experiment, which was maintained at $\text{pH} = 2$ (i.e. $[\text{H}^+] = 1.0 \times 10^{-2} \text{ mol dm}^{-3}$) and 298 K throughout, the equilibrium mixture was analysed and found to correspond to the following concentrations:

$[\text{Cu}^{2+}(\text{aq})]$	=	$0.0020 \text{ mol dm}^{-3}$
$[\text{CuL}_2(\text{organic})]$	=	$0.045 \text{ mol dm}^{-3}$
$[\text{LH}(\text{organic})]$	=	0.10 mol dm^{-3}

- (i) Write an expression, in terms of concentrations, for K_c for the reaction in Equation 5.1.

[2]

- (ii) Calculate the ratio of the concentration of Cu^{2+} in the organic phase to the concentration of Cu^{2+} in the aqueous phase, and hence the percentage of copper extracted in the experiment.

[3]

(iii) Calculate a value for K_c at 298 K from the results of this experiment.

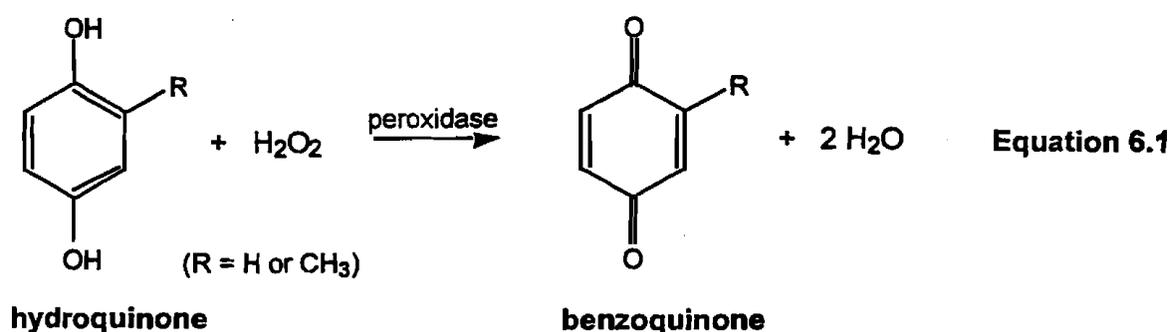
[2]

Total 12 marks

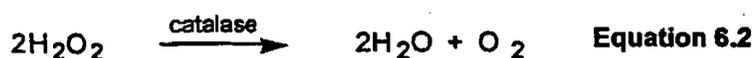
- 6 The South American bombardier beetle has an unusual way of dealing with predators. When threatened, it releases an explosive spray of boiling hot corrosive liquid, aimed with precision from a gland on the tip of its abdomen.

The gland has two separate chambers; one containing a solution of hydroquinones and excess hydrogen peroxide, the other containing a mixture of two enzymes, catalase and peroxidase. When the beetle is attacked, the mixture of hydroquinones and hydrogen peroxide is released into the reaction chamber containing the enzymes. As the chemicals mix, a hot spray is released explosively from the gland.

The enzyme peroxidase catalyses the reaction of hydroquinones with hydrogen peroxide. The reaction is exothermic:



At the same time the decomposition of hydrogen peroxide is catalysed by the enzyme catalase in a second exothermic reaction:



- (a) Explain (in terms of the reactions shown in Equations 6.1 and 6.2) why the spray released from the gland of the bombardier beetle is:

(i) hot

.....
 [1]

(ii) released explosively

.....
 [2]

(b) Name the functional group which is present in:

(i) hydroquinone [1]

(ii) benzoquinone [1]

(c) The effect of the concentration of hydrogen peroxide on the rate of the decomposition reaction in Equation 6.2 was investigated in the laboratory. This was done by adding solid catalase to hydrogen peroxide solution and measuring the rate at which oxygen was given off.

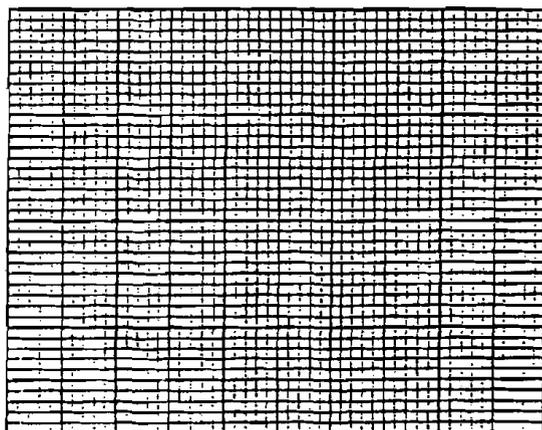
(i) Draw a labelled diagram of the apparatus you would use for this, showing how you would start the reaction and how you would collect the gas.

[4]

- (ii) The table below shows the results of a series of experiments in which the initial rate of the reaction was found for different starting concentrations of hydrogen peroxide. The concentration of catalase and the temperature were the same in each experiment.

Hydrogen peroxide concentration / mol dm ⁻³	Initial rate / (cm ³ of O ₂) s ⁻¹
0.05	0.13
0.10	0.27
0.20	0.53
0.35	0.94

Plot this data on the grid below.



[2]

- (iii) What is the order of the reaction with respect to hydrogen peroxide? Explain your reasoning.

.....

.....

..... [2]

(iv) Using the decomposition of hydrogen peroxide as an example, explain the meaning of the term **rate constant**.

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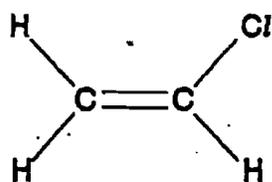
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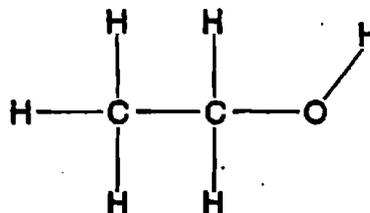
Total 15 marks

Answer all the questions.

- 7 Ethene is used in manufacturing a wide range of chemicals. The structural formulae of two such compounds are given below.



compound A



ethanol

- (a) (i) Give the systematic name of compound A.

.....[1]

- (ii) Compound A is used to manufacture a thermoplastic polymer by addition polymerisation.

Explain the term *thermoplastic*.

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

- (iii) Draw the repeating unit of the polymer formed by addition polymerisation of compound A.



[1]

- (b) Ethanol is used as a polar solvent. Polar molecules contain at least one polar bond.

Use the data given below to identify the most polar bond in ethanol.

Draw this bond and label its partial charges.

[Electronegativity values: H, 2.2; C, 2.6; O, 3.4]

[2]

7 (c) Ethanol can be readily converted into ethanoic acid.

(i) What reagents are used in the laboratory to convert ethanol into ethanoic acid?

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

(ii) The reagents and ethanol are heated together under reflux.

Explain what is meant by the term *heating under reflux*.

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

(iii) Ethanol and ethanoic acid can be distinguished by using infrared spectroscopy. Ethanoic acid has a **strong** absorption peak in its spectrum which is not present in the spectrum of ethanol.

Using the *Data Sheet* provided, give the wavenumber range for this peak and the bond that causes it.

wavenumber cm^{-1}

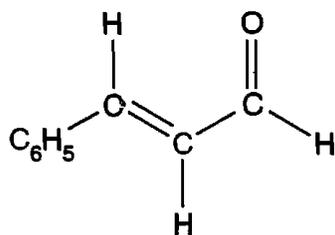
bond

[2]

Total [12]

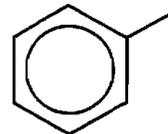
8

Cinnamon oil is obtained from the spicy bark of a tree found in Sri Lanka. The pleasant aroma of this oil is mainly caused by the compound shown below. This compound is commonly called cinnamaldehyde.



cinnamaldehyde

where C_6H_5
represents the
benzene ring



- (a) Draw a ring around the aldehyde group in the structure of cinnamaldehyde. [1]
- (b) Cinnamaldehyde exhibits geometric (*cis-trans*) isomerism.
- (i) Draw the structural formula of the geometric isomer of cinnamaldehyde.

[2]

- (ii) Explain why molecules such as cinnamaldehyde exhibit geometric isomerism.

.....

.....

..... [2]

8 (c) One technique that can be used to show the presence of the different structural features in cinnamaldehyde is mass spectrometry.

- (i) The mass spectrum of a pure compound usually consists of a number of peaks at different masses. Explain why there are many peaks in the mass spectrum of a single pure compound.

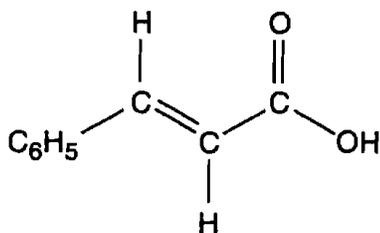
.....
 [1]

- (ii) The table below gives the masses of some of the peaks in the mass spectrum of cinnamaldehyde. The relative molecular mass of cinnamaldehyde is 132. Complete the table by giving the formulae of the ions responsible for the peaks.

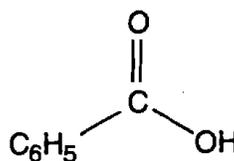
Mass of peak	Formula of the ion
132	
131	
77	

[4]

- (d) Oxidation of cinnamaldehyde by mild oxidising agents forms cinnamic acid. Strong oxidising agents lead to the formation of benzoic acid. The structures of these two acids are shown below.



cinnamic acid



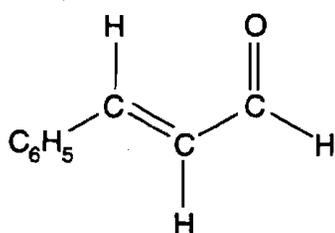
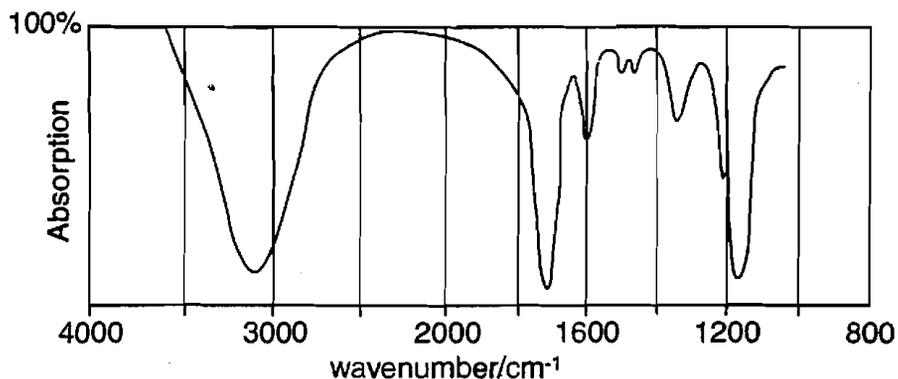
benzoic acid

- (i) One way of distinguishing between the two acids is to shake a sample with bromine water. State what you would see.

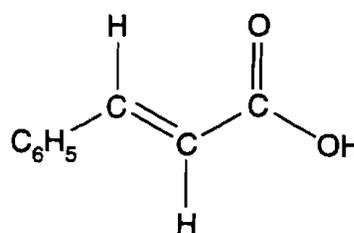
.....
 [2]

8 (e)

A student tried to oxidise cinnamaldehyde to cinnamic acid by leaving a sample in a beaker open to the atmosphere for 24 hours. The infrared spectrum of the product is shown below.



cinnamaldehyde



cinnamic acid

(i) Name the oxidising agent in this case.

..... [1]

(ii) Suggest, giving your reasons, whether you think the student was successful in producing some cinnamic acid. Label on the spectrum any characteristic absorptions that you use in making your evaluation.

A table of characteristic infrared absorptions is given in the Data Sheet accompanying this paper.

.....

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..... [2]

- 8 (f) At room temperature cinnamic acid is a solid, whereas cinnamaldehyde is an oil. Explain in terms of intermolecular forces why the boiling point of cinnamic acid is higher than that of cinnamaldehyde. (*In this question 1 mark is available for the quality of written communication.*)

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..... [5]

[Total: 20]