

OXFORD CAMBRIDGE AND RSA EXAMINATIONS
Advanced GCE

CHEMISTRY (SALTERS)
Chemistry by Design

2854

Wednesday 30 JANUARY 2002

Afternoon

2 hours

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

Candidate Name

Centre Number

Candidate Number

TIME 2 hours

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.

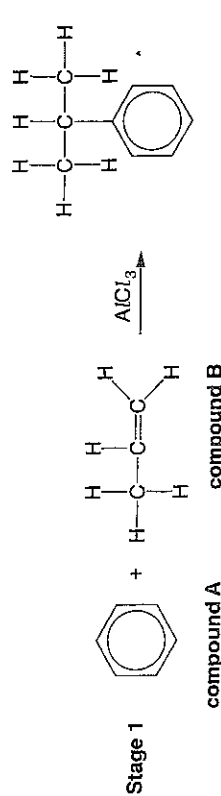
FOR EXAMINER'S USE		
Qu.	Max.	Mark
1	27	
2	24	
3	30	
4	11	
5	28	
TOTAL	120	

This question paper consists of 20 printed pages.

2

For
Examiners
Use

1 The cumene process, shown below, produces two important industrial chemicals, phenol and propanone. Both compounds are used in the manufacture of plastics. Propanone is also an important solvent.



(a) Give the names of compound A and compound B in Stage 1 of the cumene process.

A [2]
B

(b) Suggest one advantage and one disadvantage of having two useful co-products in an industrial process.

Advantage:
Disadvantage: [2]

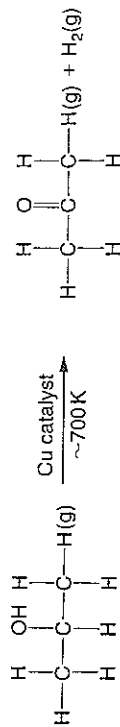
(c) Stage 1 is a type of Friedel-Crafts alkylation reaction.

(i) Choose and underline two words from the list below to describe the reaction mechanism involved in a Friedel-Crafts alkylation reaction. [2]

nucleophilic radical addition substitution oxidation electrophilic

- (ii) From your knowledge of the role of aluminium chloride, $AlCl_3$, in a Friedel-Crafts alkylation reaction, suggest a description of the mechanism involved in **Stage 1** of the **cumene process**.
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- (d) Propanone can also be produced from propan-2-ol. The alcohol vapour is passed over a heated copper catalyst. The propanone vapour is cooled and condensed to separate it from the hydrogen gas. [3]

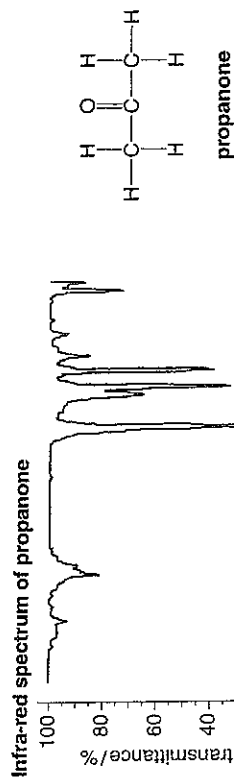


- (i) Draw a labelled diagram of the laboratory apparatus which could be used to safely carry out a small scale preparation of propanone from propan-2-ol using this method. [4]

- (ii) The oxidation of propan-2-ol to propanone in the laboratory is usually carried out by a different method. State the reagents and conditions used.
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- (iii) What colour change would you expect to see if you carried out the oxidation of propan-2-ol by the method you have given in (b)(ii)? [3]
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-

- The infra-red spectrum, low resolution n.m.r. (^1H) spectrum and the mass spectrum of propanone are shown below. [2]



- (c) Nitric(V) acid can be neutralised by alkalis such as calcium hydroxide, Ca(OH)_2 .
 (i) Write the balanced equation for the neutralisation of dilute nitric(V) acid with aqueous calcium hydroxide. Include state symbols.
 [3]
- (ii) Calculate the pH of a $0.00250 \text{ mol dm}^{-3}$ calcium hydroxide solution at 298 K, assuming that the alkali is completely ionised at this concentration.

$[K_w = [\text{H}^+(\text{aq})][\text{OH}^-(\text{aq})] = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6} \text{ at } 298 \text{ K}]$

Answer [4]

- (d) Ammonium nitrate, NH_4NO_3 , is a commonly used fertiliser. In a laboratory experiment to determine the effectiveness of various fertiliser solutions, a solution of ammonium nitrate was allowed to pass slowly through a sample of clay soil.
 (i) Use your knowledge of the structure of clays to explain why ammonium ions are retained by the clay whereas nitrate(V) ions are not.
 (In this question, 1 mark is available for the quality of written communication.)

 [6]

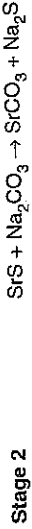
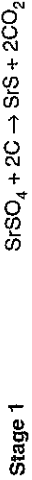
- (ii) If a concentrated solution of sodium chloride is then poured through the clay soil, the ammonium ions are released. With the aid of a simple labelled diagram, explain what is happening.

[3]

- (iii) What is the name of the type of process you have described in (d) (ii)?
 [1]

[Total : 24]

Strontium carbonate is used in the manufacture of the special glass needed for colour television tubes. It is obtained from the mineral celestite, SrSO₄, by the following two-stage process:

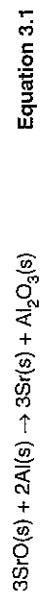


(b) Describe the structure and bonding in aluminium, Al, strontium sulphide, SrS, and carbon dioxide, CO₂.

(In this question, 1 mark is available for the quality of written communication.)

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3 Strontium is the 15th most abundant element on Earth. Strontium metal can be obtained by the electrolysis of molten strontium chloride, SrCl₂, or by the thermal reduction of strontium oxide using aluminium metal (Equation 3.1):



(a) (i) Complete the electronic configuration of a strontium atom.

1s²2s²2p⁶

[1]

(ii) State and explain which element is oxidised in Equation 3.1.

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[2]

(iii) Suggest why strontium metal is usually extracted by the chemical reduction method shown in Equation 3.1 rather than by electrolysis of strontium chloride.

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[1]

(c) Some data for the elements magnesium and strontium are given in Table 3.1.

element	ionisation enthalpies / kJ mol ⁻¹		
	$\Delta H_1(1)$	$\Delta H_1(2)$	$\Delta H_1(3)$
magnesium	+738	+1451	+7733
strontium	+550	+1064	+4210
			$\Delta H_1(4)$
			+10 541
			+5500

Table 3.1

- (i) Write the equation for the second ionisation enthalpy of strontium. [2]
- (ii) Use the data in Table 3.1 to explain why magnesium and strontium form stable ions with a 2+ charge. [2]
- (iii) Use the data in Table 3.1 to suggest why strontium is more reactive than magnesium. [2]
- (iv) In aqueous solution the Sr²⁺ and Mg²⁺ ions are hydrated. Draw a diagram of a hydrated Sr²⁺ ion. [2]

[3]

The Born-Haber cycle, Fig. 3.1, represents the energy changes involved when strontium chloride, SrCl₂, is formed from its elements.

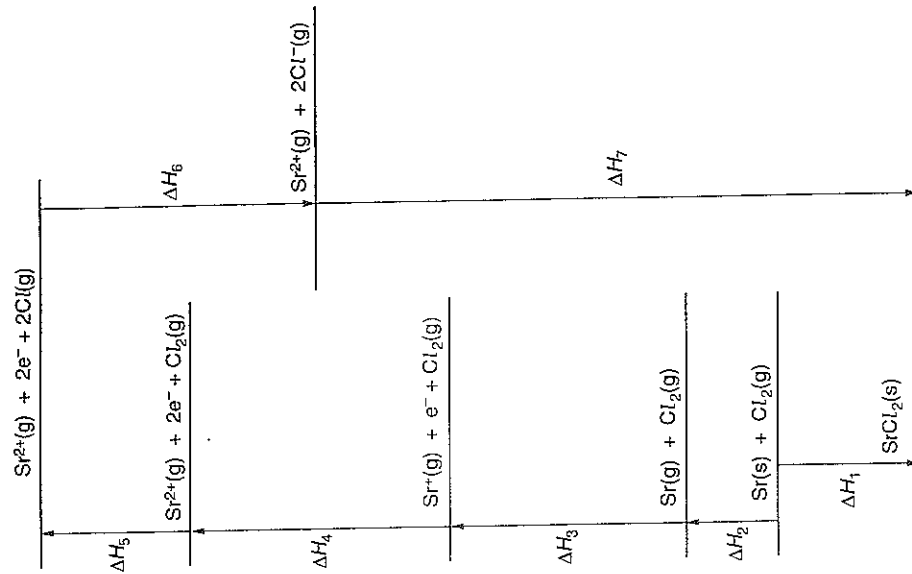


Fig. 3.1

- (d) (i) Using the symbols ΔH₁ to ΔH₇, identify
 - the enthalpy change of atomisation of strontium
 - the bond enthalpy of chlorine
 - the first electron affinity of chlorine
 - the enthalpy change of formation of strontium chloride

[4]

Values of the relevant enthalpy changes in Fig 3.1 are shown below.

For strontium:	$\Delta H_{\text{at}}(\text{Sr})$	+ 164 kJ mol ⁻¹
	$\Delta H_1(1)(\text{Sr})$	+ 550 kJ mol ⁻¹
	$\Delta H_1(2)(\text{Sr}^{+})$	+ 1064 kJ mol ⁻¹
For chlorine	$\Delta H_{\text{at}}(\frac{1}{2}\text{Cl}_2)$	+ 122 kJ mol ⁻¹
	$\Delta H_{\text{EA}}(\text{Cl})$	- 349 kJ mol ⁻¹
	ΔH_1 for SrCl_2	- 829 kJ mol ⁻¹

(ii) Write the expression for the lattice enthalpy, ΔH_{LE} , for strontium chloride, in terms of ΔH_1 to ΔH_7 .

..... [1]

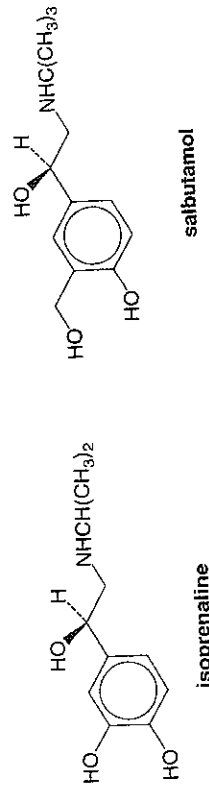
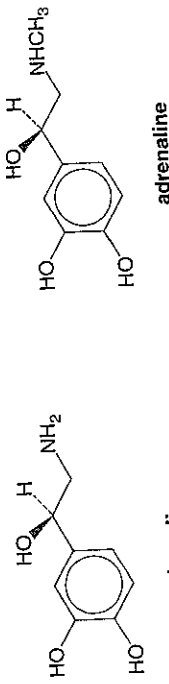
(iii) Use the values given above and your answer to (d)(ii) to calculate the lattice enthalpy, ΔH_{LE} , for strontium chloride.

$$\Delta H_{\text{LE}} \text{ for } \text{SrCl}_2 = \dots\dots\dots \text{ kJ mol}^{-1} \quad [2]$$

[Total : 30]

4 Asthma is a very distressing condition that affects about 5% of the population of the UK. The airways in the lungs become narrowed which makes breathing difficult. One way to relieve an asthma attack is to widen the airways with drugs called bronchodilators.

Adrenaline and noradrenaline are natural compounds produced in the body which act as bronchodilators and other drugs have now been synthesised based on these 'lead' compounds. These synthetic drugs mimic the effects of adrenaline and noradrenaline since they contain similar pharmacophores.



(a) (i) Identify and draw the largest structural fragment common to all four molecules shown above.

[2]

(ii) What is meant by the term *pharmacophore*?

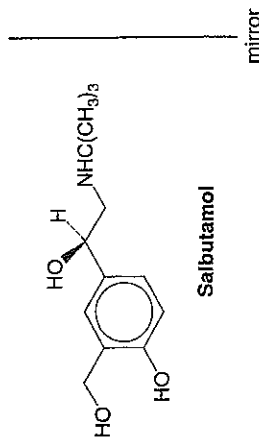
[1]

(b) Salbutamol and its enantiomer differ in their pharmacological activity. One isomer is a much more effective bronchodilator than the other.

(i) What is meant by the term *enantiomer*?

[1]

(ii) Draw out the 3-dimensional structure of the enantiomer of salbutamol. Circle the chiral centre on one of the structures.



[2]

(iii) Suggest how salbutamol is a more effective drug than its enantiomer.

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 [3]

(iv) Suggest why adrenaline and noradrenaline have been used as 'lead' compounds for the synthesis of new asthma drugs.

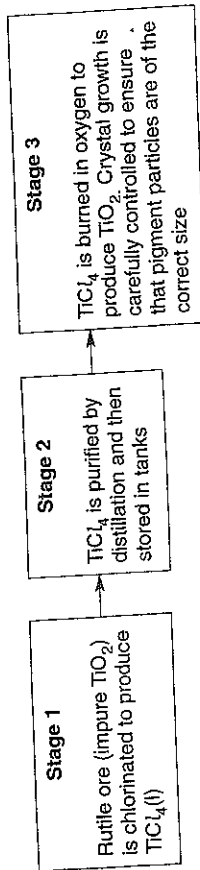
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 [1]

(v) Suggest one way in which the use of computers has enabled chemists to refine their search for more effective drugs.

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 [1]

[Total : 11]

5 More than 50% of the titanium dioxide, TiO_2 , produced worldwide is used as pigments for paints and other surface coatings. One method of producing TiO_2 is by the chloride process.



(a) Suggest two reasons why this method of TiO_2 production is quite expensive.

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 [2]

The table below shows various properties of some of the chlorides of the elements in Period 3.

Formula	NaCl	MgCl ₂	Al ₂ Cl ₆	SiCl ₄	PCl ₅
State at 20 °C	Solid	Solid	Solid	Liquid	Liquid
Conduction of electricity by molten/liquid chloride	Good	Good	Very poor	Nil	Nil
pH of aqueous solution	7	6.5	3	2	2

(b) (i) TiCl_4 is similar in its properties to SiCl_4 . Explain, in terms of structure and the chemical bonding involved, why TiCl_4 is a volatile liquid at room temperature which does not conduct electricity.

(In this question, 1 mark is available for the quality of written communication.)

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[6]

(ii) Suggest a balanced equation for the reaction of TiCl_4 with water. Include state symbols.

[3]

(c) The restoration of an oil painting involves the removal of very small samples of the painting. These samples are then analysed using various techniques. One technique used is a form of atomic emission spectroscopy called *laser microspectral analysis* (LMA). LMA allows chemists to identify the elements present in a sample of paint.

In modern paintings the white pigment is likely to be titanium dioxide, TiO_2 , whereas older paintings will contain 'zinc white' (zinc oxide).

Explain in terms of electron energy levels how an atomic emission spectrum arises. Use your explanation to show how you could determine whether a pigment sample contains titanium dioxide, TiO_2 , or zinc oxide, ZnO .

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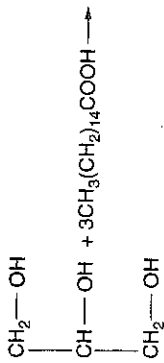
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[5]

(d) Some paints contain natural oils, such as linseed, which dry and harden by a process of oxidative cross linking. The oils are triesters of propane-1,2,3-triol with unsaturated carboxylic acids.

(i) Complete the equation below to show the structural formulae of the two products of the reaction between propane-1,2,3-triol and palmitic acid, $\text{CH}_3(\text{CH}_2)_{14}\text{COOH}$.



[4]

(ii) What type of reaction is shown by the equation you have given in (d)(i)?

..... [1]

(iii) Describe briefly what is meant by the process of oxidative cross-linking.

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..... [3]

(iv) Different oils contain different ratios of the esters of palmitic and stearic acid. The ratio can be used to identify the type of oil in paintings undergoing restoration. The ratio can be measured using the technique of gas-liquid chromatography. Describe briefly how gas-liquid chromatography is used to measure this ratio and hence identify the oil in a painting.

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..... [4]

[Total : 28]