OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS
Advanced GCE

CHEMISTRY (SALTERS) 2854

Chemistry by Design

Tuesday **25 JUNE 2002** Morning 2 hours

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

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 *Data Sheet for Chemistry (Salters).*
- You are advised to show all the steps in any calculations.

FOR EXAMINER'S USE		
Qu.	Max.	Mark
1	29	
2	27	
3	26	
4	16	
5	22	
TOTAL	120	

This question paper consists of 20 printed pages.

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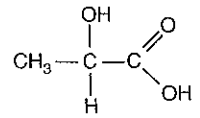
For Examiner's Use

1 Lactic acid is formed in sour milk. It also occurs in the muscle tissues of athletes suffering from cramp. Its structure is shown below.

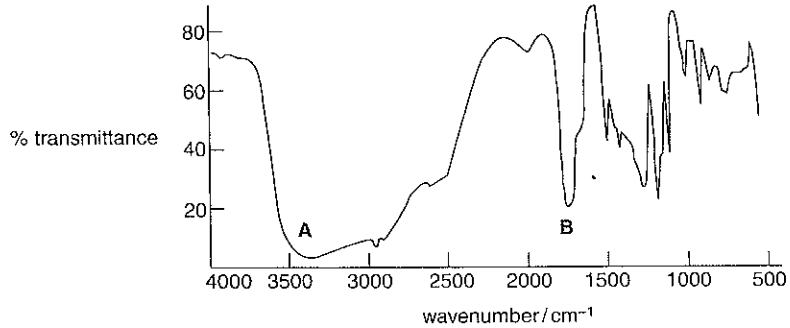


lactic acid

(a) (i) Give the systematic name for lactic acid.

..... [2]

(ii) The infra-red spectrum of lactic acid is shown below. (Data about characteristic infra-red absorptions are given in the *Data Sheet* which accompanies this paper.)



Which bonds are responsible for the absorptions at **A** and **B**?

A .....

B ..... [2]

(b) Lactic acid can be made industrially by the following route, using ethene as a feedstock.

stage 1 $CH_2=CH_2 + {}^1/_2O_2 \xrightarrow{PdCl_2/CuCl_2(aq)} CH_3-C(=O)-H$

ethanal

stage 2 $CH_3-C(=O)-H + HCN \longrightarrow$ **compound A**

stage 3 **compound A** $\xrightarrow{\text{reflux/dilute HCl(aq)}}$ $CH_3-C(OH)(H)-C(=O)-OH$

lactic acid

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

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..... [1]

(ii) Name a raw material from which ethene can be obtained.

..... [1]

(c) **(i)** Draw a dot–cross diagram for an ethan**al** molecule. (Show outer shell electrons only.)

[3]

(ii) Explain why the $-C(=O)-H$ bond angle in ethanal is 120°.

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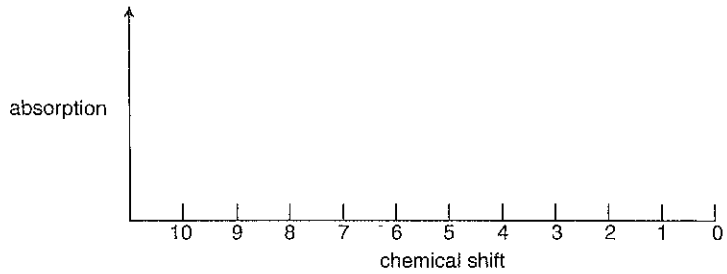
..... [3]

(iii) Sketch the low resolution n.m.r. (^1H) spectrum of ethan**al**, showing the relative intensities. Use the *Data Sheet* provided.

$CH_3-C(=O)-H$

ethanal



[3]

(d) In **stage 2** of the industrial manufacture of lactic acid, ethan**al** reacts with hydrogen cyanide to form a nitrile compound, **compound A**.

$CH_3-C(=O)-H + HCN \longrightarrow$ **compound A**

(i) Draw the structure of **compound A.**

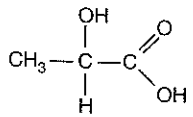
[1]

(ii) Name the **type** of mechanism for the reaction that produces **compound A.**

..... [2]

(iii) Draw a diagram to show the first step of this mechanism, the attack of CN^- ions on ethan**al**.

[3]



lactic acid

(e) (i) Lactic acid exists as two optical isomers. Draw 3-dimensional structures to show these two isomers. Draw a ring round the chiral centre on one of your structures.

mirror

[3]

(ii) Lactic acid isolated from muscle tissue exists as a **single** optical isomer. Suggest why.

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..... [2]

(f) A sample of lactic acid is synthesised in the laboratory from ethan**al**. A student started with 5.00 g of ethan**al** (M_r 44.0) and obtained 7.02 g of lactic acid (M_r 90.0). Calculate the % yield of lactic acid.

1 mole

1 mole

Answer ..... [3]

[Total : 29]

2 The carbon dioxide produced as a result of human activities goes into the atmosphere. Some is absorbed by the surface waters of the oceans.

Carbon dioxide dissolves in water. Some of the dissolved carbon dioxide reacts with water to produce the following ions.

- hydrogencarbonate, HCO_3^-
- hydrogen, H^+
- carbonate, CO_3^{2-}

$$CO_2(g) \rightleftharpoons CO_2(aq) \qquad \textbf{equation 2.1}$$

$$CO_2(aq) + H_2O(l) \rightleftharpoons H^+(aq) + HCO_3^-(aq) \qquad \textbf{equation 2.2}$$

$$HCO_3^-(aq) \rightleftharpoons H^+(aq) + CO_3^{2-}(aq) \qquad \textbf{equation 2.3}$$

(a) Use **equation 2.3** to write an expression, in terms of concentrations, for the acidity constant, K_a, of the hydrogencarbonate ion.

[2]

(b) (i) The surface waters of the oceans are mildly alkaline, with a pH of about 8.1.

Use **equations 2.1** and **2.2** to explain why more carbon dioxide will dissolve in alkaline solution than will dissolve in neutral water.

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..... [4]

(ii) Give the mathematical definition of pH.

..... [2]

For Examiner's Use

(c) Carbon dioxide is much more soluble in water than nitrogen and oxygen. Explain why the carbon dioxide molecule forms stronger inter-molecular forces with water molecules than oxygen or nitrogen do. Use diagrams where appropriate to illustrate your answer.

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

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[Turn over

For Examiner's Use

(d) One source of carbon dioxide is the cement manufacturing industry. A mixture of limestone and clay is heated in kilns. The limestone decomposes to form calcium oxide and carbon dioxide.

$$CaCO_3(s) \longrightarrow CaO(s) + CO_2(g) \qquad \Delta H^{\ominus} = +180 \text{ kJ mol}^{-1}$$

In this reaction the entropy changes are significant.

(i) Use the following data to calculate the change in entropy for this system, ΔS_{sys}, as the limestone decomposes.

$S^{\ominus}$ [$CaCO_3(s)$] = +93 J mol^{-1} K^{-1}

$S^{\ominus}$ [$CaO(s)$] = +38 J mol^{-1} K^{-1}

$S^{\ominus}$ [$CO_2(g)$] = +214 J mol^{-1} K^{-1}

Answer ..... J mol^{-1} K^{-1} [2]

(ii) Use the expression $\Delta S_{surr} = -\Delta H/T$ to calculate ΔS_{surr} for the decomposition of limestone at 1300 K.

Answer ..... J mol^{-1} K^{-1} [3]

(iii) Use your answers to **(d)(i)** and **(d)(ii)** to calculate ΔS_{total}.

Answer ..... J mol^{-1} K^{-1} [2]

(iv) Use your answer to **(d)(iii)** to explain whether you expect limestone to decompose at 1300 K.

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..... [1]

For Examiner's Use

(e) Calcium oxide reacts with a limited amount of water to produce a powder called *slaked lime* (calcium hydroxide) which is used in the preparation of mortar in the building industry.

Write a balanced chemical equation for the reaction between calcium oxide and water. Include state symbols.

..... [3]

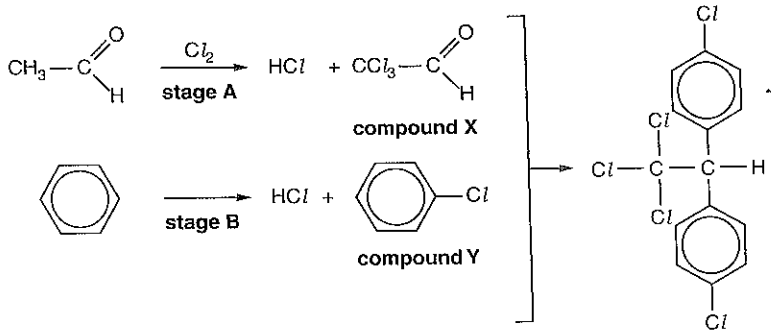
[Total : 27]

[Turn over

For Examiner's Use

3 DDT is an important insecticide which has prevented millions of deaths from diseases such as malaria. It has also led to an improvement in crops since it kills crop insect pests. Unfortunately, it has serious disadvantages and its use is now strictly controlled.

DDT can be manufactured by the following route.



(a) **(i)** Give the molecular formula for **compound X**.

..... [1]

(ii) Give the systematic name for **compound Y**.

..... [1]

(b) **(i)** State the reagents and conditions needed for **stage B**.

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..... [3]

(ii) The reaction mechanism in **stage A** can be classified as a radical substitution.

What is a *radical*?

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..... [2]

(iii) Both **stages A** and **B** produce hydrogen chloride gas. From your knowledge of the **chemical** properties of this gas, suggest a safe method for treating the effluent gas from the process so that hydrogen chloride is not released into the atmosphere.

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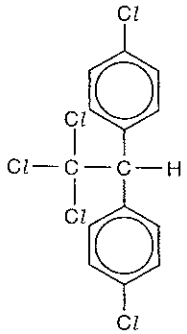
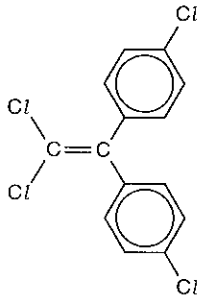
For Examiner's Use

(c) Some crop pest insects have developed a resistance to DDT. They produce enzymes that catalyse the conversion of DDT to DDE which is non-toxic.



DDT



DDE

(i) What simple molecule is eliminated from DDT to form DDE?

..... [1]

(ii) By considering the **shapes** of DDT and DDE, suggest why DDE is **biologically** inactive as an insecticide.

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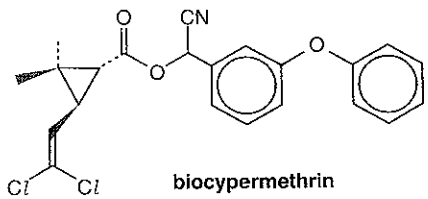
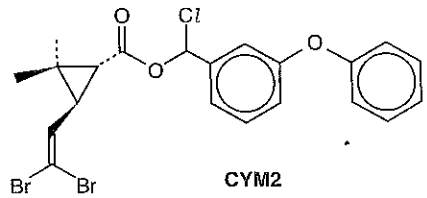
[Turn over

For Examiner's Use

(d) More recently chemists have synthesised insecticides which are more active and which are rapidly hydrolysed on contact with soil. Two such insecticides are biocypermethrin and CYM2:



biocypermethrin



CYM2

(i) Name **two** functional groups common to both biocypermethrin and CYM2.

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..... [2]

(ii) State the reagents and conditions required to carry out the laboratory hydrolysis of the  link in biocypermethrin.

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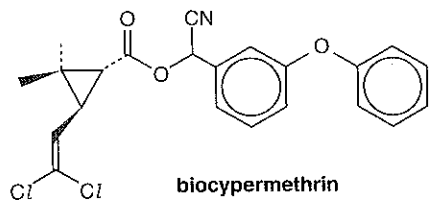
..... [3]

(iii) Draw the structures for the **two** hydrolysis products of biocypermethrin.



biocypermethrin

[2]

For Examiner's Use

(e) Thin layer chromatography can be used to show if this reaction has been successful. Describe in outline (giving experimental details) how you would carry out this procedure and describe the observations you would expect to make if the biocypermethrin has been **completely** hydrolysed.

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

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[Total : 26]

[Turn over

For Examiner's Use

4 Hydrogen is an important chemical feedstock obtained from natural gas by partial oxidation with steam.

$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \quad \Delta H^{\ominus} = +206\,kJ\,mol^{-1}$ **equation 4.1**

(a) (i) Write the expression for the equilibrium constant, K_p, for the reaction in **equation 4.1.**

[2]

(ii) Methane and steam are sealed into a vessel at 1000 K. When equilibrium is reached, the partial pressures of the separate components of the mixture are as given below.

component	partial pressure / atmospheres
methane $CH_4(g)$	0.7
steam $H_2O(g)$	0.7
carbon monoxide $CO(g)$	0.3
hydrogen $H_2(g)$	0.9

Calculate the value for K_p at 1000 K. Include the units in your answer.

Answer ..... [3]

For Examiner's Use

(b) In industry, a high yield of hydrogen is obtained from the reaction between natural gas and steam. This is done by maintaining the reactor at 1100 K and 25 atm in the presence of a finely divided nickel catalyst. Suggest why these conditions are chosen.

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

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(c) In the UK, nitrogen is usually 'fixed' by the Haber Process in which nitrogen and hydrogen react together to make ammonia.

(i) State the reaction conditions (of temperature, pressure and the catalyst used) required in the Haber Process to synthesise ammonia.

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..... [3]

(ii) Give the oxidation states of N in N_2 and NH_3.

N_2 ..... NH_3 ..... [2]

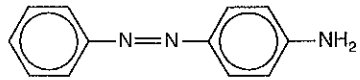
[Total : 16]

[Turn over

For Examiner's Use

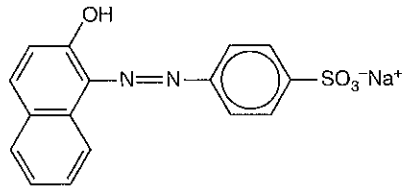
5 The 19th century was a time of great innovation in the production of dyes for cloth. The development of azo compounds provided chemists with the opportunity to create a vast range of azo dyes. A whole rainbow of colours is now available although most azo dyes are yellow, orange or red with relatively few blues and greens.

Around 1858 a young German student, called Peter Griess, unknowingly produced the first of the azo dyes, Aniline Yellow.



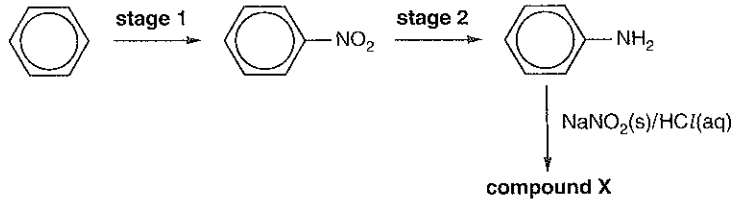
Aniline Yellow

Aniline Yellow had little commercial value since it was sensitive to acids. One of the first successful azo dyes to be marketed was Orange II.



Orange II

Part of the reaction sequence for the preparation of Orange II is shown below.



(a) Use your understanding of bonding to explain the significance of the 'circle' drawn inside the benzene ring in the above formulae.

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..... [4]

For Examiner's Use

(b) **(i)** State the reagents and conditions needed to convert benzene into nitrobenzene in **stage 1**.

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..... [3]

(ii) Choose from the following list **two** terms that, together, describe the reaction mechanism in **stage 1**.

nucleophilic **radical** **substitution** **addition** **electrophilic** **elimination**

..... [2]

(c) **Compound X** is a diazo compound. Draw the structural formula of **compound X**.

[2]

(d) Aniline Yellow is described as being 'sensitive to acids'. Suggest how Aniline Yellow could react with an acid.

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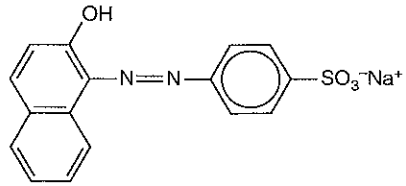
..... [2]

[Turn over

For Examiner's Use

(e) **(i)** Explain, in terms of transitions between electronic energy levels and the structures of the compounds, why Orange II is coloured but benzene is colourless.



Orange II

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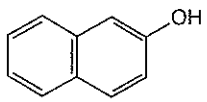
For Examiner's Use

(ii) The coupling agent used to form Orange II is shown below.



Describe a simple chemical test which can be used to indicate the presence of the –OH group in this compound.

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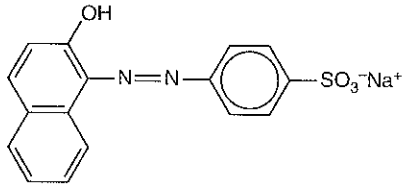
..... [2]

(iii) Name the functional group in Orange II which is responsible for its solubility in water. Explain why this group makes the dye molecule water soluble.



Orange II

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[Total : 22]