OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

CHEMISTRY (SALTERS) 2854

Chemistry by Design

Wednesday **25 JANUARY 2006** Afternoon 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 provided 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	**21**	
2	**20**	
3	**26**	
4	**35**	
5	**18**	
TOTAL	**120**	

This question paper consists of 16 printed pages.

Registered Charity Number: 1066969
[Turn over

Answer **all** the questions.

1 Chemists have recently created a 'super black' surface that absorbs light many times better than black paint. This has uses in road signs and also specialist applications like the Hubble space telescope.

An aluminium surface is covered with an alloy of nickel and phosphorus. This is etched to produce craters which absorb light very efficiently.

The following reactions are involved in creating the alloy.

$$Ni^{2+} + H_2PO_2^- + H_2O \rightarrow Ni + H_2PO_3^- + 2H^+ \qquad \textbf{equation 1.1}$$

$$3H_2PO_2^- \rightarrow 2P + H_2PO_3^- + 2OH^- + H_2O \qquad \textbf{equation 1.2}$$

(a) Suggest why lettering in 'super black' on a white road sign is easy to read.

..... [1]

(b) **(i)** Suggest the **formulae** of two compounds that could be mixed in solution to cause **equation 1.1** to occur.

compound containing Ni^{2+} .....

compound containing $H_2PO_2^-$ ..... [2]

(ii) What change of pH would you expect as **equation 1.1** occurred? Explain your answer.

.....

..... [2]

(iii) Give the **formula** of the acid from which $H_2PO_3^-$ is derived.

..... [1]

(c) **(i)** Give the oxidation states of phosphorus in the following.

P ..... $H_2PO_2^-$ ..... $H_2PO_3^-$ .....
[3]

(ii) Classify **equation 1.2** as redox or acid-base, giving a reason for your choice.

.....

..... [1]

(d) In the etching process, nickel is oxidised to NiO by nitric acid. NO_2 is formed.

(i) Give the systematic name of NO_2.

..... [1]

(ii) The half-equations below show the etching reaction.
Combine them to produce an overall balanced equation.

$$Ni + H_2O \rightarrow NiO + 2H^+ + 2e^-$$

$$HNO_3 + H^+ + e^- \rightarrow NO_2 + H_2O$$

[2]

(e) Nickel oxide normally reacts as a basic oxide.
Explain what is meant by the term *basic oxide.*
Illustrate your answer with a balanced equation that shows nickel oxide acting as a base.

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..... [3]

(f) **(i)** Nitric acid acts as a strong acid in aqueous solution.
Explain the meaning of the term *strong* when applied to acids.
Write an equation to illustrate this.

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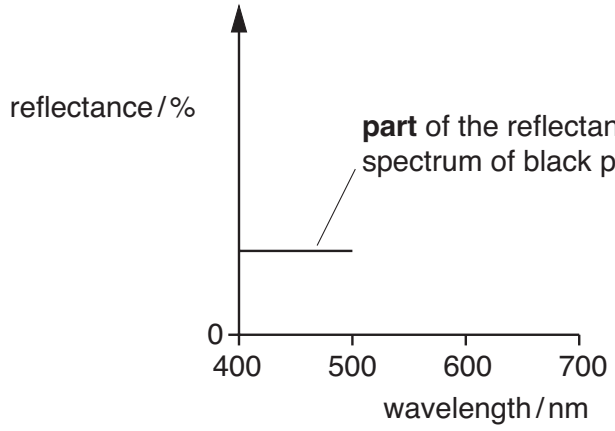
..... [2]

(ii) Calculate the pH of a 0.010 mol dm^{-3} solution of nitric acid.

pH = ... [1]

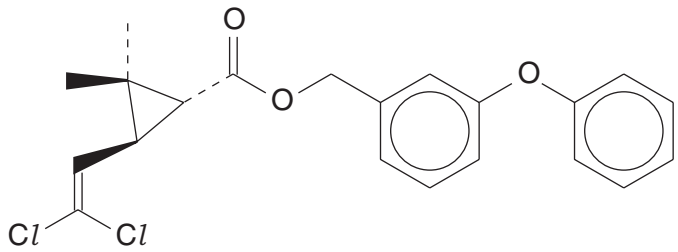
(g) 'Super black' absorbs light three times better than a certain black paint. Part of the **reflectance** spectrum of this black paint is shown on the axes below.
Draw the reflectance spectrum of 'super black' on the axes below.



[2]

[Total: 21]

2 Pyrethroids are insecticides which are powerful against insects but are usually harmless to mammals.
The pyrethroid *permethrin* contains a mixture of stereoisomers, one of which is *biopermethrin*.



biopermethrin

(a) (i) Give the molecular formula of biopermethrin.

..... [2]

(ii) Biopermethrin has an ester group and aromatic rings. Name **two** other functional groups in the structure.

..... [2]

(iii) On the structure above, put a circle round **two** *chiral centres*. [2]

(iv) Explain why the C=C bond in biopermethrin does **not** give rise to geometric isomers.

.....

..... [1]

(b) The *partition coefficient* for a pesticide is defined as shown below.

$$K_{ow} = \frac{\text{concentration of compound in octan-1-ol}}{\text{concentration of compound in water}}$$

For biopermethrin, the value of K_{ow} is 1×10^5.

(i) Write a structural formula for octan-1-ol.

..... [1]

(ii) Explain the significance of a high value of K_{ow} on the efficiency of a pesticide.

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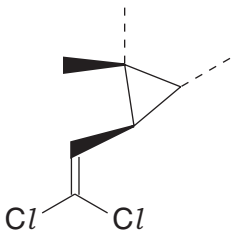
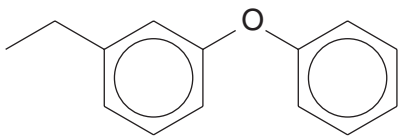
..... [4]

(c) Biopermethrin is broken down in mammals by hydrolysis of the ester link. The K_{ow} values for the hydrolysis products are too low to make them harmful.
Complete the structures below to show the products of hydrolysis of biopermethrin.





[2]

(d) Having synthesised *biopermethrin*, chemists set out to prepare even better pesticides. Suggest **two** properties of these new pesticides that could make them more environmentally acceptable.

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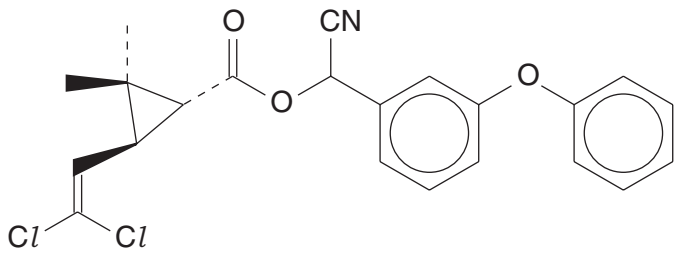
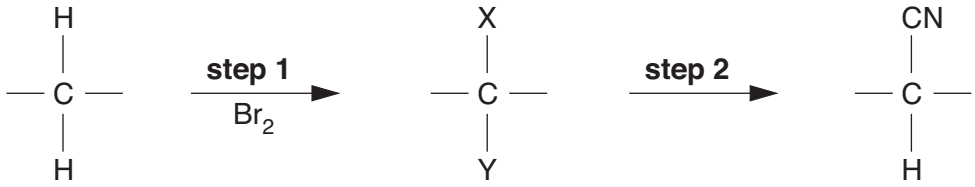
..... [2]

(e) The substance *biocypermethrin* was found to be more efficient than *biopermethrin*.



biocypermethrin

A nitrile (–CN) group can be substituted for a hydrogen atom in a carbon chain by using the following sequence.



(i) Classify the **type** of mechanism for the substitution reaction in **step 1** and give an important condition.

.....

..... [2]

(ii) Identify **X** and **Y** in the middle compound.

..... [1]

(iii) Use your *Data Sheet* to write down the reagent for **step 2**.

..... [1]

[Total: 20]

3 Over millions of years, the pH of the oceans has remained close to 8, even though the concentration of carbon dioxide in the atmosphere was once much higher. This is because of the buffering action of compounds dissolved in the water.

The main reaction involved is given below.

$$CO_2(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + H^+(aq) \qquad \textbf{equation 3.1}$$

(a) (i) Give the hydrogen ion concentration in a solution of pH 8 with the appropriate units.

$[H^+]$ = ... [2]

(ii) Calculate the hydroxide ion concentration in a solution of pH 8.
$K_w = 1 \times 10^{-14}\,mol^2\,dm^{-6}$

$[OH^-]$ = ... [2]

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

Use ideas of inter-molecular forces to explain why carbon dioxide is only slightly soluble in water, whereas sodium hydrogencarbonate (containing HCO_3^-) is very soluble.

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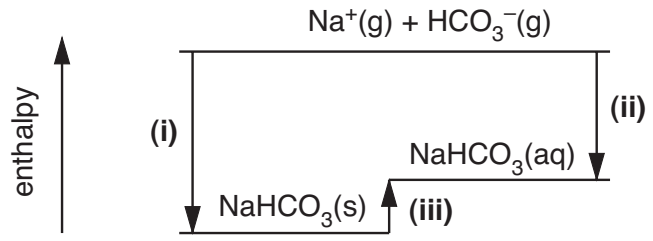
..... [5]

Quality of Written Communication [1]

(c) An enthalpy level diagram for the dissolving of sodium hydrogencarbonate is shown below. Give appropriate labels for the arrows at **(i)**, **(ii)** and **(iii)**.



(i) .....

(ii) .....

(iii) ..... [3]

(d) The dissolving of sodium hydrogencarbonate is an endothermic process. What can you say about the sign and magnitude of $\Delta S^{\ominus}_{system}$ for this process?
Explain your answer.

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..... [3]

(e) The oceans are kept at pH 8 by the buffering effect of **equation 3.1**.

$$CO_2(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + H^+(aq) \qquad \textbf{equation 3.1}$$

(i) The acidity constant, K_a, for **equation 3.1** is 4.5×10^{-7} mol dm^{-3}.
Write down the expression for K_a in terms of $[CO_2]$, $[H^+]$ and $[HCO_3^-]$, leaving out the concentration of water.

[1]

(ii) Calculate the ratio $\dfrac{[HCO_3^-]}{[CO_2]}$ when $[H^+] = 1 \times 10^{-8}$ mol dm^{-3}.

$\dfrac{[HCO_3^-]}{[CO_2]}$ = ... [3]

(iii) The solubility of carbon dioxide is 3.3×10^{-2} mol dm^{-3} at 298 K. Calculate the mass of $NaHCO_3$ which must be dissolved in 1.0 dm^3 of a saturated solution of carbon dioxide, so that

$$\frac{[HCO_3^-]}{[CO_2]} = 1.0$$

A_r: Na, 23; C, 12; O, 16; H, 1.0

mass of $NaHCO_3$ = ...g [3]

(iv) Explain in terms of **equation 3.1** how sea-water acts as a buffer solution when a very small amount of hydrochloric acid is added.

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..... [3]

[Total: 26]

4 Ethanol is manufactured by the hydration of ethene over a phosphoric acid catalyst at 60–70 atmospheres pressure and 570 K.

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g) \quad \Delta H = -46 \text{ kJ mol}^{-1} \qquad \textbf{equation 4.1}$$

(a) Suggest a raw material from which ethene could be obtained.

..... [1]

(b) The industrial ethanol made by **equation 4.1** is not used to produce drinks. Suggest another **industrial** use of ethanol.

..... [1]

(c) Calculate the maximum mass of ethanol that could be made from 1.0 kg of ethene, assuming 100% conversion.
Give your answer in kilograms to a **suitable** number of significant figures.

A_r: C,12; H, 1.0; O,16

mass of ethanol = ... kg [3]

(d) (i) For **equation 4.1**, suggest, with reasons, why a temperature of greater than 570 K is **not** used.

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..... [3]

(ii) For **equation 4.1**, suggest, with a reason, why a pressure of greater than 70 atm is **not** used.

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..... [2]

(e) (i) Write down the expression for K_p for the reaction in **equation 4.1** in terms of the partial pressures of the reactants and products.

[2]

(ii) At one particular temperature, the partial pressures of the gases in the reaction vessel at equilibrium are as shown in the table.

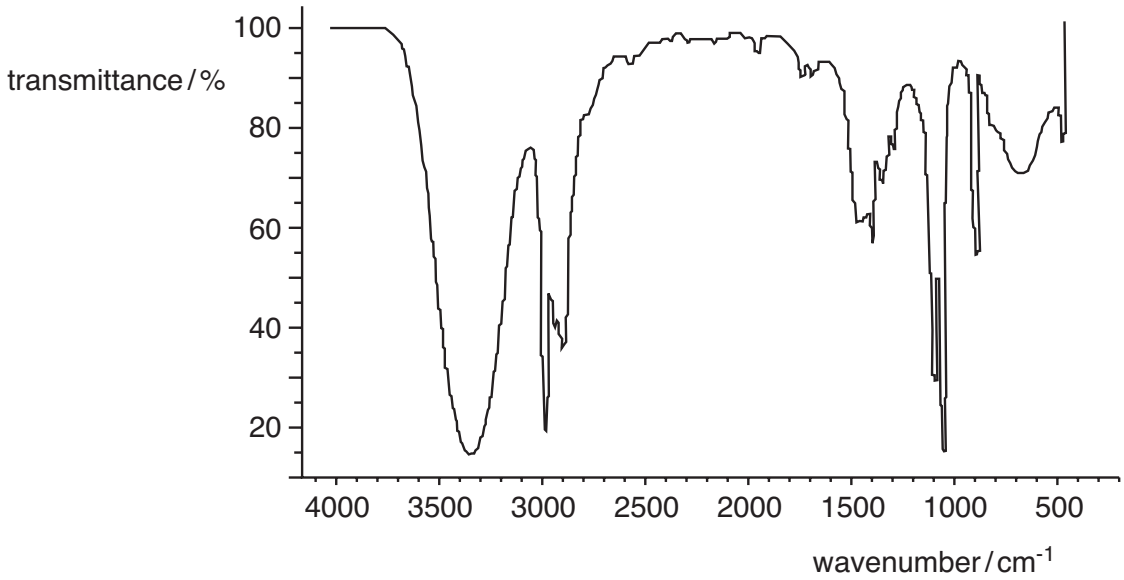
substance	partial pressure / atm
C_2H_4 (g)	35
H_2O (g)	21
C_2H_5OH (g)	4

Calculate the value of K_p at this temperature, giving its units, if any.

K_p = ... [2]

(f) Breathalysers are used to detect ethanol vapour. One such type of breathalyser uses infrared spectroscopy to detect the quantity of ethanol in the breath.

(i) The infrared spectrum of ethanol is shown below. Mark **two** characteristic absorptions on the spectrum. Refer to your *Data Sheet* and indicate, on the spectrum, which bonds are responsible for these absorptions.



[2]

(ii) Suggest which **one** of these absorptions is used for the detection and measurement of ethanol in a person's breath, giving reasons.

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..... [2]

[Turn over

(g) Ethanol was once an industrial source of both ethanal and ethanoic acid. Both were made by oxidation reactions.

(i) Draw the **full structural** formulae for ethanal and ethanoic acid in the boxes below.

ethanal ethanoic acid [2]

(ii) Name the reagents which would be used **in a laboratory** to oxidise ethanol to ethanal.

.....

..... [2]

(h) Ethanal has a lower boiling point than ethanol and ethanoic acid and thus can be distilled out of the reaction mixture before further oxidation occurs.

Draw a labelled diagram to show how a mixture can be distilled in the laboratory to collect a volatile product.

[3]

(i) In this question, two marks are available for the quality of use and organisation of scientific terms.

Ethanal and **ethanoic acid** can be distinguished by their infrared spectra but their proton n.m.r. spectra are rather similar.

Describe and explain

- **two** important **differences** between their i.r. spectra
- **two similarities** of their n.m.r. spectra.

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Quality of Written Communication [2]

[Total: 35]

5 Colour photographs are printed from digital cameras using a special process. This involves heating magenta (red), cyan (blue) and yellow dyes to temperatures up to 400 °C. The dyes are then transferred separately to white paper so that the right mix is made to create the colour required.

(a) (i) Suggest why these three colours are chosen.

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..... [1]

(ii) Special dyes had to be designed for this process. Suggest why most known dyes were found to be useless.

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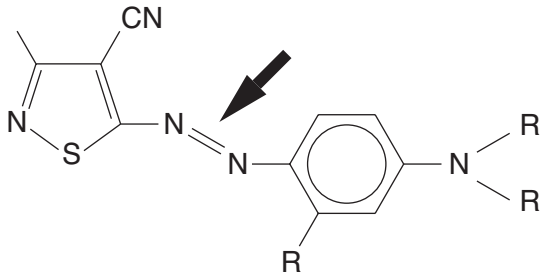
..... [1]

(b) The magenta dye has the structure shown below.



(i) Name the chemical group that is indicated by the arrow in the structure.

..... [1]

(ii) Describe and explain what is meant by the circle in the centre of the benzene ring.

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..... [4]

(c) A chemist decides to substitute a $-SO_3H$ group on to the benzene ring by an electrophilic substitution reaction.

(i) Suggest which property of the dye is changed by doing this. Assume that the colour is not affected.

..... [1]

(ii) Describe the reagents and conditions for the substitution reaction.

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..... [2]

(iii) Explain why this reaction is described as *substitution*.

.....

..... [1]

(iv) Explain what you understand by the term *electrophile*.

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..... [3]

(d) Explain, in terms of electronic energy levels, why a dye appears a particular colour.

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..... [4]

[Total: 18]

END OF QUESTION PAPER