OCR

RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

CHEMISTRY (SALTERS) 2854

Chemistry by Design

Tuesday **25 JANUARY 2005** 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	28	
2	23	
3	26	
4	21	
5	22	
TOTAL	120	

This question paper consists of 16 printed pages.

Registered Charity Number: 1066969
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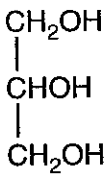
For Examiner's Use

Answer **all** the questions.

1 Glycerol, propane-1,2,3-triol, is also sometimes called glycerine. The oils in oil-based paints are compounds of glycerol.



glycerol

(a) Glycerol forms oils when it combines with long-chain carboxylic acids, R-COOH.

(i) Which atoms make up these *long chains* represented by R-?

.....

.....[2]

(ii) Draw the structure of the *triglyceride* (triester) formed between glycerol and the acid R–COOH.

[2]

(iii) Name the strongest type of intermolecular force that exists between molecules of the trigyceride.

.....[2]

(iv) How would you carry out the reaction of glycerol with a carboxylic acid in the laboratory?

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.....[2]

For Examiner's Use

(b) Oil-based paints contain certain triglyceride oils in which the pigments are suspended.

(i) What important structural feature of these oils makes them useful as the basis for paints?

.....[1]

(ii) Describe the process by which such oils harden.

.....

.....[2]

(c) Glycerol itself is used as a water-soluble lubricant with a relatively high boiling point. These properties can be explained by hydrogen bonding between O–H groups.

(i) Explain, with a diagram, how this hydrogen bonding occurs.

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[4]

(ii) Explain how hydrogen bonding accounts for the water-solubility and the relatively high boiling point of glycerol.

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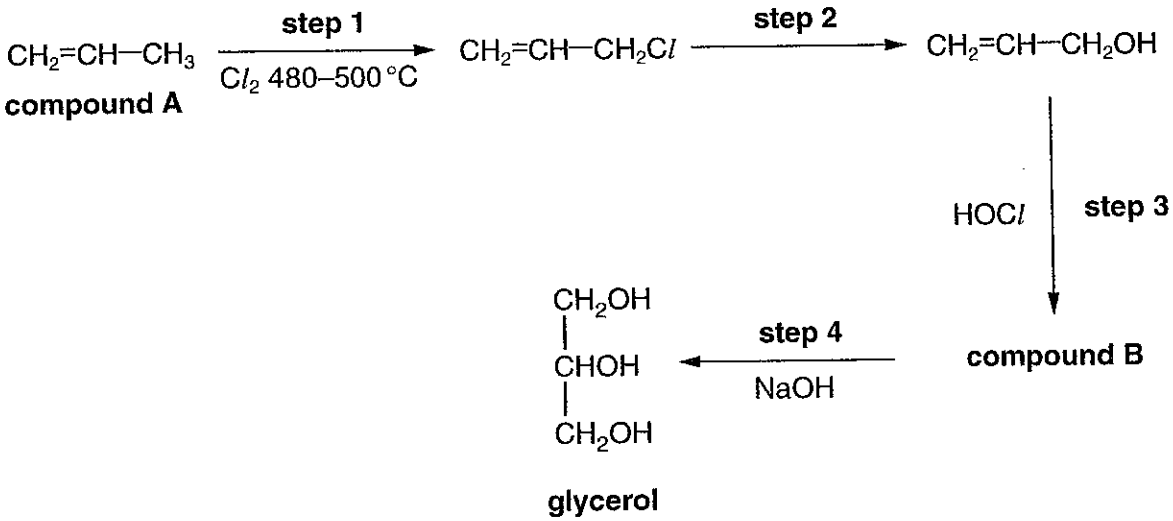
.....[4]

(d) Most glycerol is obtained from fats. The following synthetic route can also be used to make it.



(i) Name **compound A**.

.....[1]

(ii) Suggest a raw material from which this compound is produced in industry.

.....[1]

(iii) Classify the reaction in **step 1** by circling one word.

addition **substitution** **elimination** **condensation**

[1]

(iv) Suggest a reagent for **step 2**.

.....[1]

(v) In **step 3**, the compound HOC*l* adds across the double bond.

Suggest a structure for **compound B**.

[2]

For Examiner's Use

(vi) In a small-scale trial, 2 g of glycerol were made from 30 g of **compound A**. Calculate the percentage yield of the process.

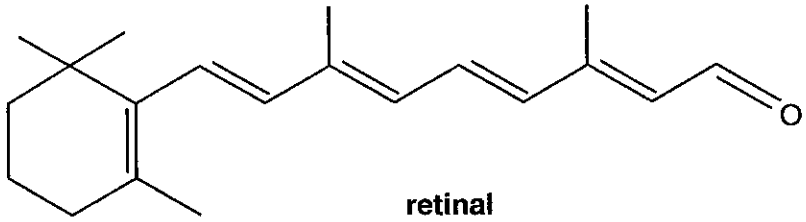
A_r: C, 12; O, 16; H, 1.0

yield = ...% [3]

[Total: 28]

[Turn over

2 The rod cells in the retina at the back of the eye contain an alcohol called retinol which is responsible for their sensitivity to light. Retin**ol** is oxidised in an enzyme-catalysed reaction to the aldehyde retin**al**.

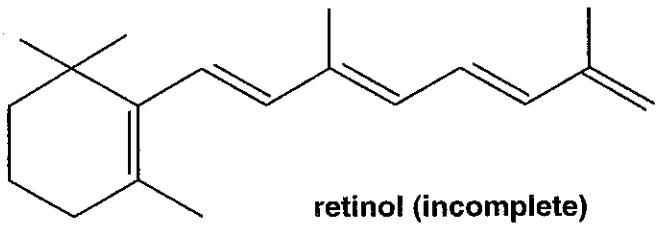


retinal

(a) (i) Deduce the molecular formula of **retinal** from its skeletal formula above.

.....[2]

(ii) Suggest the structure of the alcohol **retinol** by completing the skeletal formula below.



retinol (incomplete)

[2]

(iii) Name a functional group that is present in **both** retinol and retinal.

.....[1]

For Examiner's Use

(b) (i) What reagents and conditions could be used to convert an alcohol to an aldehyde **in a laboratory**?

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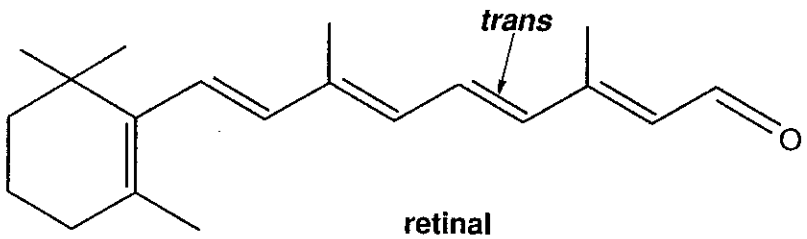
.....[3]

(ii) How many moles of hydrogen molecules would you expect to react with one mole of **retinol**?

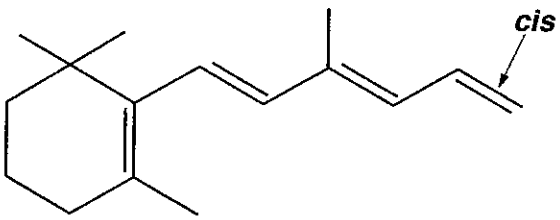
.....[1]

(c) When light shines on the rod cells, an enzyme-catalysed reaction occurs. This changes the arrangement around one of the double bonds from *trans* to *cis*, as indicated in the structure below.

Suggest the structure of *cis*–retinal by completing the skeletal formula below.



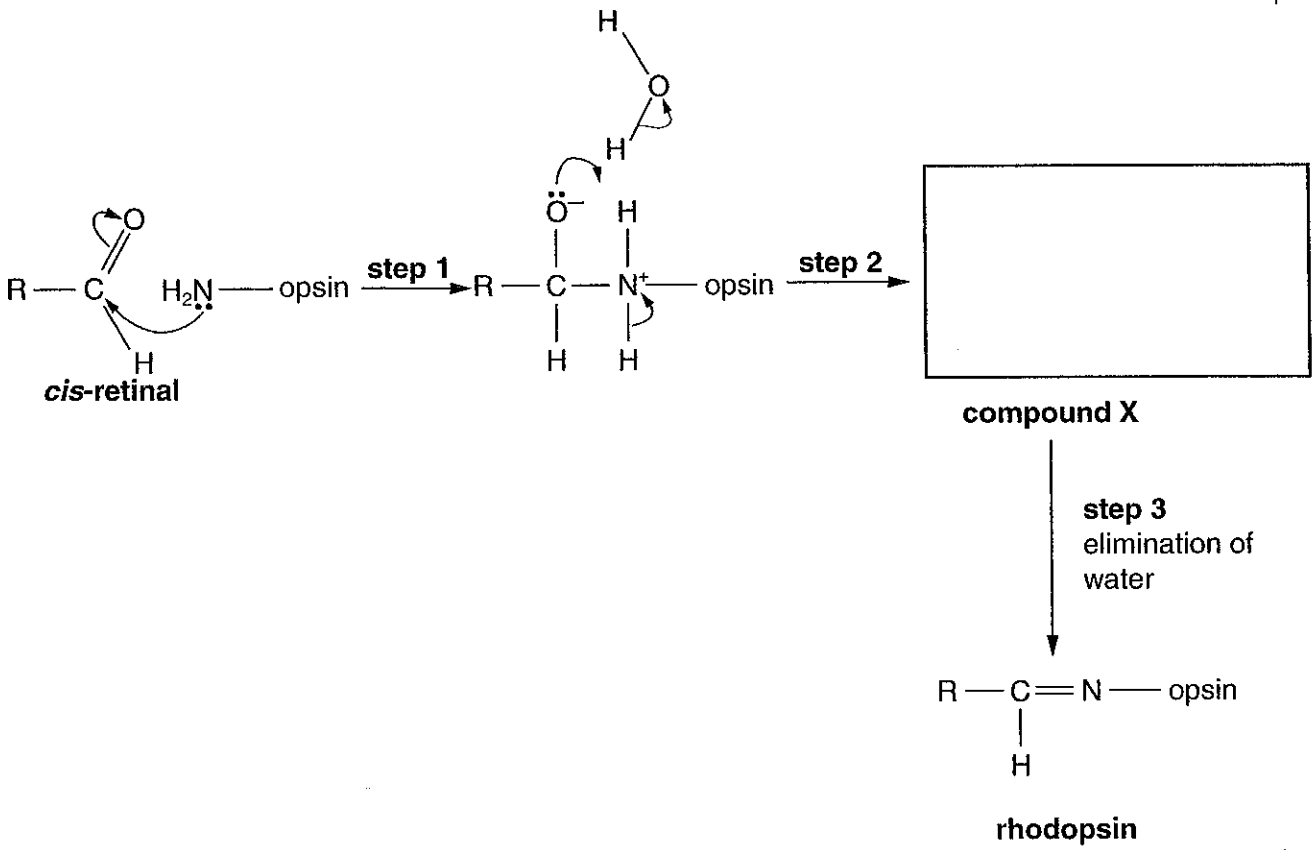
retinal



***cis*-retinal (incomplete)**

[2]

(d) The *cis*–retinal binds to the protein *opsin* to form *rhodopsin*. Part of the mechanism of this reaction is shown below.



(i) Name the functional group on the opsin molecule that is reacting with the aldehyde group on *cis*-retinal.

.....[1]

(ii) Name the **type of reaction mechanism** which starts in **step 1** and is completed in **step 2**.

.....[2]

(iii) Deduce a structure for **compound X** and draw it in the box above. [1]

(e) Only *cis*–retinal, not *trans*–retinal, is able to bind with the protein opsin and react as above. Suggest a reason for this.

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.....[2]

For Examiner's Use

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

The resulting rhodopsin is able to absorb visible light. What feature of the molecule allows it to absorb visible light? Describe what happens when a molecule of rhodopsin **absorbs** light.

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.....[5]

Quality of Written Communication [1]

[Total: 23]

For Examiner's Use

3 Natural rain is slightly acidic because of the carbon dioxide dissolved in it. Rain which is more acidic than natural rain is called *acid rain* and this causes damage to the ecosystem in a number of ways. One effect of acid rain is the leaching of aluminium ions from clay soils into water-courses.

(a) Carbon is in the second period of the Periodic Table. Give the **formula** of a basic oxide of an element in the **same period.**

.....[2]

(b) The main equilibrium that is set up when carbon dioxide dissolves in water is shown below.

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

(i) Write the equation for the acidity constant, K_a, for this reaction and give its units. (Do not include $[H_2O]$).

K_a =

units ..... [3]

(ii) The numerical value of K_a in the above units is 4.5×10^{-7} at room temperature. Calculate the pH of unpolluted rain where $[CO_2(aq)] = 1.2 \times 10^{-5}$ mol dm^{-3}.

pH = ... [3]

(c) A clay material, such as kaolinite, reacts with a solution containing hydrogen ions as shown.

$$Al_2Si_2O_5(OH)_4(s) + 6H^+(aq) \rightleftharpoons 2Al^{3+}(aq) + 2SiO_2(s) + \ldots\ldots \qquad \textbf{equation 3.2}$$

(i) Complete **equation 3.2** by writing on the dotted line above. Include the appropriate state symbol. [2]

(ii) An equilibrium constant for this equation is given by the following expression.

$$K_c = \frac{[Al^{3+}(aq)]^2}{[H^+(aq)]^6}$$

Show that the value of K_c is approximately 1×10^{16} mol^{-4} dm^{12} given that $[Al^{3+}(aq)] = 9 \times 10^{-11}$ mol dm^{-3} when the pH = 6.

[3]

(iii) This equilibrium is very sensitive to pH.
Calculate the concentration of aluminium ions in solution when $[H^+] = 1 \times 10^{-4}$ mol dm^{-3} (i.e. at pH = 4). Assume $K_c = 1 \times 10^{16}$ mol^{-4} dm^{12}.

$[Al^{3+}(aq)]$ = ...mol dm^{-3} [3]

(d) The ionic radius of an isolated (unhydrated) Al^{3+} ion is shown below, together with values for ions of two other metals in Period 3.

ion	radius / nm
Na^+	0.098
Mg^{2+}	0.078
Al^{3+}	0.057

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

Explain why the metals form ions with these charges. Say, in terms of their atomic structure, what the ions have in common and explain the trend in ionic radius across the period from Na^+ to Al^{3+}.

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.....[6]

Quality of Written Communication [2]

(ii) Explain why aluminium ions are the **most hydrated** of the three ions.

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.....[2]

[Total: 26]

4 One of the causes of acid rain is high concentrations of NO_x (NO and NO_2) in the atmosphere.
One mechanism for the oxidation of NO to NO_2 in polluted air is shown below.

$$2NO(g) \rightleftharpoons N_2O_2(g) \qquad \textbf{equation 4.1}$$

$$N_2O_2(g) + O_2(g) \longrightarrow 2NO_2(g) \qquad \textbf{equation 4.2}$$

(a) Write the overall equation for the oxidation of NO to NO_2 by this route.

[1]

(b) Suggest a source of atmospheric NO.

.....[1]

(c) Give the oxidation states of nitrogen in

NO..... N_2O_2..... NO_2..... [3]

(d) NO_2 reacts with water and oxygen to form nitric acid, HNO_3.

$$4NO_2 + O_2 + 2H_2O \longrightarrow 4HNO_3$$

(i) Calculate the mass of nitric acid that could be made from 1.0 kg of nitrogen dioxide.

Give your answer to **an appropriate number of significant figures**.
A_r: H, 1.0; N, 14; O, 16

mass = ... kg [3]

(ii) Suggest **one** advantage and **one** disadvantage of nitric acid being present in the soil.

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.....[2]

(e) Nitric acid in the soil can be neutralised with calcium hydroxide, forming calcium nitrate.

Use your understanding of structure and bonding to predict **three** properties of calcium nitrate.

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.....[3]

Question 4 continues on page 14

(f) **(i)** Suggest, with a reason, the sign of ΔS_{sys} for the forward reaction in **equation 4.1**.

$$2NO(g) \rightleftharpoons N_2O_2(g) \qquad \textbf{equation 4.1}$$

.....

.....[1]

(ii) The forward reaction in **equation 4.1** is **exothermic**. Use your understanding of entropy to explain why you would expect this forward reaction to be **less** likely to occur at higher temperatures.

$\Delta S_{total} = \Delta S_{sys} + \Delta S_{surr}$ $\quad \Delta S_{surr} = -\frac{\Delta H}{T}$

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.....[3]

(g) The equilibrium in **equation 4.1** is established rapidly, so the overall rate of the reactions in **equations 4.1** and **4.2** depends only on the rate of the reaction in **equation 4.2**.

This is summarised below.

$2NO(g) \rightleftharpoons N_2O_2(g)$ **equation 4.1** very rapid rate

$N_2O_2(g) + O_2(g) \longrightarrow 2NO_2(g)$ **equation 4.2** rate = $k[N_2O_2][O_2]$

(i) What is the effect of raising the temperature on the rate constant k?

.....[1]

(ii) The rate of the overall reaction in the two equations is found to **decrease** when the temperature is raised.

Suggest an explanation for this, bearing in mind that the concentration of N_2O_2 is governed by the equilibrium in **equation 4.1**.

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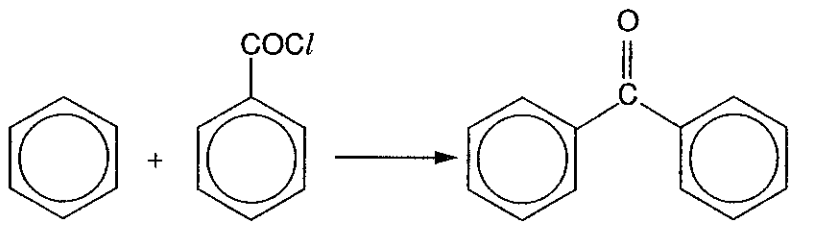
.....[3]

[Total : 21]

5 The compound benzophenone is used in cosmetics and as a sunscreen. It can be prepared in the laboratory by the following reaction in the presence of an aluminium chloride catalyst.



equation 5.1

compound A **compound B** **benzophenone**

(a) (i) Name **compound A**. .....[1]

(ii) Draw the **full structural formula** for the acyl chloride group in **compound B**.

[1]

(b) What is the important property of a sunscreen?

.....

.....[2]

(c) Give the names of the two chemists associated with the type of reaction in **equation 5.1**.

.....[2]

(d) Describe the mechanism by which aluminium chloride catalyses the reaction in **equation 5.1**.

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.....[3]

(e) The most effective way of removing the aluminium chloride at the end of the reaction is to hydrolyse it with water and to run it to waste.

(i) Write the equation for the reaction of aluminium chloride with water.

[3]

(ii) In the 1980s, benzophenone was made industrially by the method using **equation 5.1**. Explain **two** reasons why the process could lead to environmental hazards.

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.....[4]

(f) A chemist wished to confirm the identity of a sample of benzophenone by recording its infrared and proton n.m.r. spectra.

(i) Use the *Data Sheet* to write down the wavenumber range of **two** absorptions in the infra red spectrum of benzophenone and say which bond causes each absorption.

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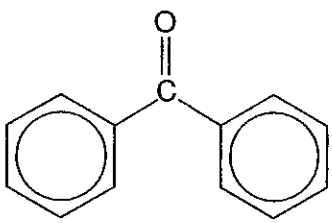
.....[4]

(ii) The proton n.m.r. spectrum of benzophenone contains three signals in the ratio 2: 2: 1.

Mark on the structure below all the protons in each environment, labelling the environments **A**, **B** and **C**.



benzophenone

[2]

[Total: 22]

END OF QUESTION PAPER