OCR

RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

CHEMISTRY (SALTERS)   **2854**

Chemistry by Design

Wednesday   **29 JANUARY 2003**   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 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	23	
2	24	
3	30	
4	19	
5	24	
TOTAL	120	

This question paper consists of 15 printed pages and 1 blank page.

     [Turn over

Answer all the questions.

1   Drink and driving don't mix! This message is well understood by most of the British public but a minority still disregards it. The police identify people driving 'over the limit' by the use of breathalysers.

   (a)   The earliest breathalysers contained a reagent mixture which turned from orange to green in the presence of ethanol.

      (i)   The reagent mixture oxidises the ethanol. Give the name and **full structural formula** of the **carboxylic acid** which is formed by the oxidation of ethanol, C_2H_5OH.

        name...

        full structural formula

                                          [2]

      (ii)   Name **two compounds** which are present in the reagent mixture.

        ....

        ....[2]

   (b)   Some modern breathalysers detect ethanol in the breath by measuring the intensity of the absorption at 2950 cm^{-1} in the infrared region. The infrared spectrum of ethanol is shown below.
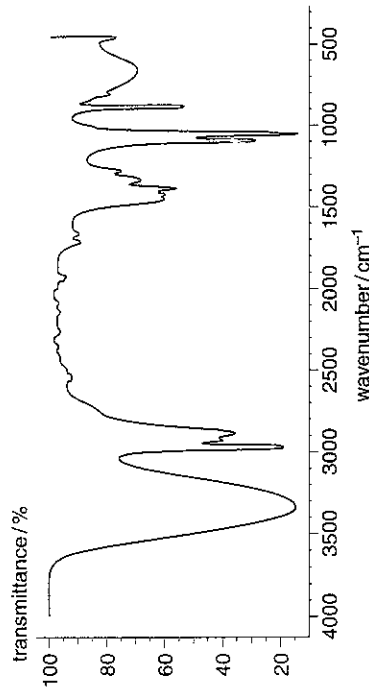
      (i)   Use your *Data Sheet* to identify the bond which causes the absorption at 2950 cm^{-1}.

        ....[1]

(ii) The absorption at 3350 cm⁻¹ is caused by the O–H bond. Suggest why this absorption is **not** used as a measure of the ethanol concentration in a person's breath.

....

....

....

[2]

(iii) Describe the effect on the ethanol molecule of absorbing infrared radiation at 3350 cm⁻¹.

....

....

....

[3]

(c) Wine tasters often notice the taste of ethanal, CH_3CHO. This is because some ethanol has turned into ethanal.

(i) Name the **type** of reaction by which ethanal is formed from ethanol.

....

[1]

(ii) Draw the **full structural formula** for ethanal.

[1]

(iii) Use your Data Sheet to give the formula of a reagent which will convert ethanal **back** to ethanol.

[1]

(iv) Write the structural formula of the product which is obtained when ethanal reacts with hydrogen cyanide.

[1]

(d) Ethanol and ethanal may be distinguished using infrared spectroscopy. Ethanal has a strong absorption peak in its spectrum which is not present in the spectrum of ethanol. Use your Data Sheet to give the range in which you would expect the wavenumber of this peak and the bond that causes it.

wavenumber range .... cm⁻¹

bond ....

[2]

[Turn over

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

The mass spectrum shown below is **either** that of ethanal, CH_3CHO, **or** that of ethanol, C_2H_5OH.

intensity/%
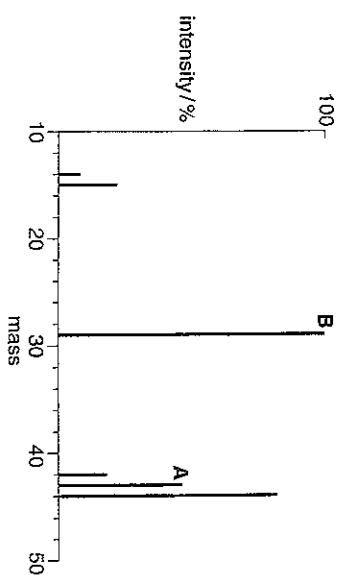
Identify the spectrum, giving a reason.

....

....

....

Suggest the identity of the ion which gives rise to peak A and the ion which gives rise to peak B.

[A_r: C, 12; H, 1; O, 16]

....

....

....

....

....

[5]

Quality of Written Communication [1]

[Total: 23]

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Turn to page 6 for Question 2.

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2 Eye-wash solutions often contain boric acid and its salts. These are used to buffer the solution.

(a) Boric acid is $B(OH)_3$,
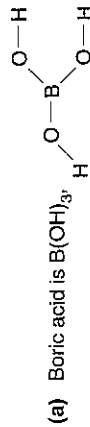
(i) Give the oxidation state of boron in boric acid. ....[1]

(ii) Explain why the presence of O–H bonds in boric acid might lead to acidity. .
[Electronegativity values: O, 3.4; B, 2.0; H, 2.2]

....

....[2]

(b) Boric acid reacts with water to form an acidic solution. Some books give the following equation.

$$H_3BO_3(aq) \rightleftharpoons H_2BO_3^-(aq) + H^+(aq) \qquad \textbf{equation 2.1}$$
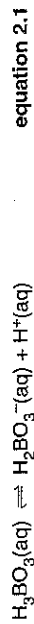
(i) Boric acid is described as a weak acid. Explain, by reference to the above reaction, what is meant by a *weak* acid.

....

....[1]

(ii) Use **equation 2.1** to write an expression for the acidity constant, K_a, for boric acid.

[2]

(iii) The acidity constant for boric acid from **equation 2.1** is $5.8 \times 10^{-10} \, mol \, dm^{-3}$.
Calculate the pH of $0.10 \, mol \, dm^{-3}$ aqueous boric acid.

answer ....[3]

[Turn over

(iv) Write an equation for the reaction of aqueous boric acid with aqueous sodium hydroxide, **showing state symbols.**

....

....

....[3]

(c) (i) The manufacturers of an eye-wash solution wish to produce a buffer solution to use in their product. They mix a solid salt containing $H_2BO_3^-$ ions with 1.0 dm^3 of 0.10 mol dm^{-3} aqueous boric acid. Calculate the amount in moles of $H_2BO_3^-$ ions they would need to use to achieve a pH of 8.5.

For a buffer solution, $K_a = [H^+] \times \dfrac{[salt]}{[acid]}$

answer .... mol [4]

(ii) Suggest why a buffer solution is necessary in an eye-wash solution.

....

....

....[3]

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

Explain how a buffer solution based on boric acid works.

....

....

....

....

....

....

....[4]
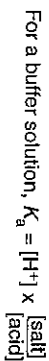
Quality of Written Communication [1]

[Total: 24]

[Turn over

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3 Chemists have discovered a novel way of fixing atmospheric nitrogen (converting nitrogen gas into its compounds). Moist nitrogen is passed over a TiO_2 plate which has been coated with other chemicals. The nitrogen is thought to react with moisture in the air at room temperature and pressure to form ammonia. A *possible* equation for the reaction is given below.

$$5N_2(g) + 6H_2O(g) \rightleftharpoons 4NH_3(g) + 6NO(g) \quad \Delta H = +1808\,kJ\,mol^{-1} \quad \textbf{equation 3.1}$$

(a) (i) Explain why there are only a few reactions that 'fix' nitrogen.

....

....[2]

(ii) Explain why nitrogen compounds are important in agriculture.

....

....[2]

(b) (i) Nitrogen monoxide is a co-product of ammonia in the process in **equation 3.1**. Explain what you understand by the term *co-product*.

....

....[2]

(ii) Give the oxidation states of nitrogen in

N_2 .... NH_3 .... NO .... [3]

(c) Suggest the function of the TiO_2 in the reaction in **equation 3.1**.

....[1]

(d) Calculate the **maximum** mass of ammonia which could be obtained from 1.0 kg of nitrogen if the reaction in **equation 3.1** went to completion.

[A_r: N, 14; H, 1.0]

Answer .... [3]

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

The chemists investigated the effect of raising the temperature on the reaction in **equation 3.1**. Describe and explain the effect of increasing the temperature on the **rate** of the reaction.

....

....

....

....[4]

Quality of Written Communication [1]

(ii) Describe and explain the effect of increasing the temperature on the **equilibrium yield** of products in **equation 3.1**.

....

....

....

....[4]

(f) Explain, with reasons, why increasing the pressure has only a small effect on the equilibrium position of the reaction in **equation 3.1**.

....

....[2]

(g) It has been suggested that this method of making ammonia does not offer any advantages over the Haber process.

(i) State the conditions used in the Haber process for the manufacture of ammonia.

Temperature .... °C Pressure .... atm Catalyst .... [3]

(ii) Suggest and explain **one** advantage and **one** disadvantage of the process in **equation 3.1** as a method of making ammonia compared with the Haber process.

advantage ....

....

disadvantage ....

....[4]

[Total: 30]

[Turn over

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4 The Gulf Stream carries water from the Gulf of Mexico to the western shores of the UK and Ireland. The water is returned to the Gulf of Mexico by deep water currents of low salinity.

(a) The climate of the UK differs from the climate of North American countries of the same latitude. State **one** difference which results from the effect of the Gulf Stream.

....

....[1]

(b) This part of the question compares the abilities of water and hexane to transport energy.

Water is a good liquid for transporting energy as it has a high *specific heating capacity* (the amount of energy needed to raise 1 g by 1K). The specific heating capacity for water is $4.18 \, J \, g^{-1} \, K^{-1}$, whereas the value for hexane is $2.26 \, J \, g^{-1} \, K^{-1}$.

(i) The high specific heating capacity of water is caused by hydrogen bonding between the molecules. Draw a diagram to illustrate how one water molecule can be associated with four hydrogen bonds. Show the lone pairs and the partial charges on the atoms.

[4]

(ii) Draw a structural formula for hexane.

[2]

(iii) State the strongest type of intermolecular force that occurs between hexane molecules.

....[1]

(iv) Describe how these forces arise between hexane molecules.

....

....

...[3]

(v) Use the values of specific heating capacity to calculate how much more effective water is than hexane at transporting energy.

answer .... times more effective [1]

(c) The salinity of water depends on how much salt, principally sodium chloride, dissolves in the water.

The diagram below shows an enthalpy cycle that can be used to calculate the enthalpy change of solution of sodium chloride in water.

enthalpy

$Na^+(g) + Cl^-(g)$

$NaCl(s)$

$Na^+(aq) + Cl^-(aq)$
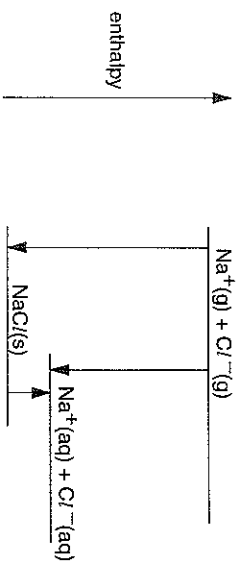
(i) Write the following labels by the appropriate arrows on the diagram.

lattice enthalpy

enthalpy change of solution

[2]

(ii) Use the data in the table to calculate a value for the enthalpy change of solution of sodium chloride.

enthalpy change	$\Delta H/\text{kJ mol}^{-1}$
lattice enthalpy of NaCl	-788
enthalpy change of hydration of Na$^+$	-390
enthalpy change of hydration of Cl$^-$	-384

Answer .... [2]

[Turn over]

(d) Calcium carbonate is almost insoluble in water. Magnesium carbonate is slightly more soluble.

One factor affecting this difference is that the enthalpy change of hydration for the magnesium ion is more negative than that for the calcium ion.

Explain why the enthalpy change of hydration for the magnesium ion is more negative than that for the calcium ion.

....

....

....[3]

[Total: 19]

5 One of the first 'fibre reactive dyes' was *Procion Brilliant Red 2BS*.
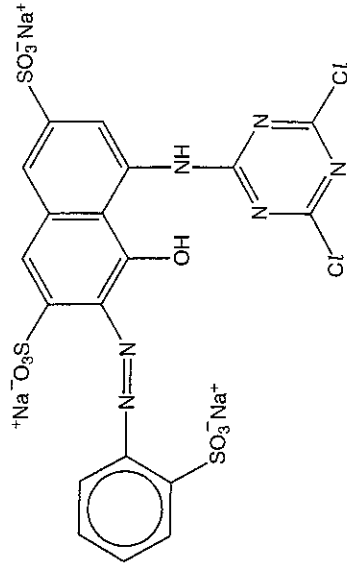
Procion Brilliant Red 2BS

(a) Draw a circle round the phenol group on the dye structure. [1]

(b) Which functional group on the dye molecule makes it soluble in water?

.... [1]

(c) This dye can be made by diazotising **compound X** and coupling it with **compound Y**. The structure of **compound Y** below is incomplete.

(i) Complete the structure of **compound Y**.

compound Y (incomplete)
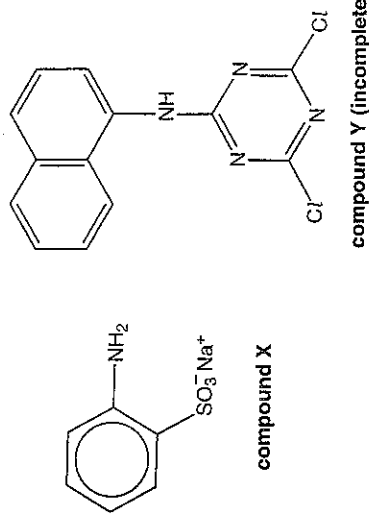
compound X

(ii) State the reagents and conditions needed to diazotise **compound X**.

....

.... [2]

.... [3]

[Turn over

(d) **Compound X** can be made from **compound A** by a series of reactions. The following route was suggested:
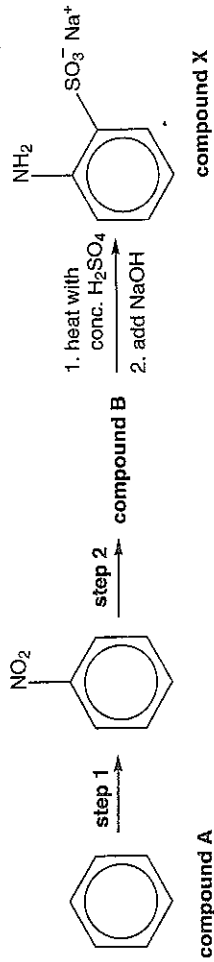
compound A

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

(ii) Give the reagents and conditions needed for the nitration in **step 1**.

.... [3]

(iii) Use the reactions in the *Data Sheet* to answer this part.

Suggest the structure of **compound B** and then give the reagents and conditions for **step 2**.

compound B

reagents and conditions for **step 2** ....

.... [2]

(e) All the compounds in the diagram above contain rings of six carbon atoms with delocalised electrons.

(i) What general name is given to such compounds?

.... [1]

(ii) What do we mean when we say that the electrons are *delocalised*?

.... [1]

(f) *Procion Brilliant Red 2BS* is used to dye cotton. The OH groups on the cotton displace the Cl atoms from the Procion dye structure.

(i) In this reaction, the dye forms covalent bonds with the cotton and HCl is formed. What **type** of reaction is being described here?
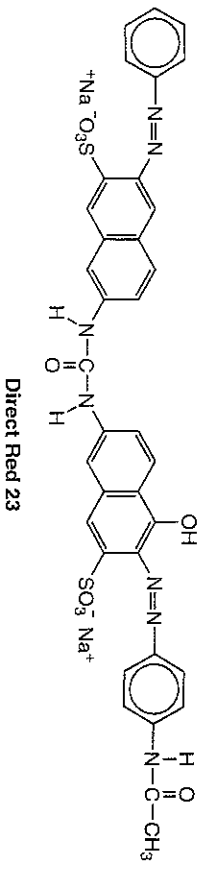
.... [1]

(ii) Illustrate the reaction by completing the 'after' diagram below.

rest of Procion dye

before

→

rest of Procion dye

+ 2HCl

after
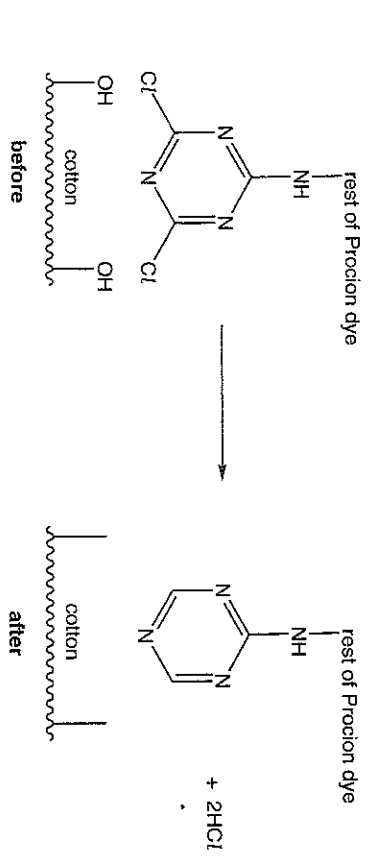
[2]

(g) The dye *Direct Red 23* is also used to dye cotton.

Direct Red 23

This dye binds to cotton with intermolecular forces that are much weaker than covalent bonds.

(i) Suggest which is the strongest type of intermolecular force involved in binding this dye to cotton, giving a reason for your answer.

....

.... [3]

(ii) A student has two pieces of cotton fabric, one dyed with the Procion dye and the other with the Direct Red dye. He places each one in a separate beaker containing the same volume of water and boils them for ten minutes.
What difference would he expect to see in the contents of the two beakers? Explain your answer.

....

.... [3]

[Total: 24]