OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE

CHEMISTRY B (SALTERS)

Chemistry by Design

F335

Candidates answer on the question paper.
A calculator may be used for this paper.

OCR supplied materials:
- *Data Sheet for Chemistry B (Salters)* (inserted)

Other materials required:
- Scientific calculator

Wednesday 15 June 2011
Afternoon

Duration: 2 hours

Candidate forename		Candidate surname	

Centre number						Candidate number				

INSTRUCTIONS TO CANDIDATES

- The insert will be found in the centre of this document.
- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Write your answer to each question in the space provided. Additional paper may be used if necessary but you must clearly show your candidate number, centre number and question number(s).
- Answer **all** the questions.
- Do **not** write in the bar codes.

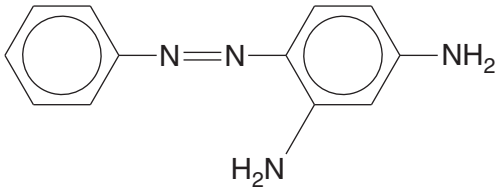
INFORMATION FOR CANDIDATES

- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- Where you see this icon you will be awarded marks for the quality of written communication in your answer.

  This means for example you should:
  - ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear;
  - organise information clearly and coherently, using specialist vocabulary when appropriate.
- You may use a scientific calculator.
- A copy of the *Data Sheet for Chemistry B (Salters)* is provided as an insert with this question paper.
- You are advised to show all the steps in any calculations.
- The total number of marks for this paper is **120**.
- This document consists of **20** pages. Any blank pages are indicated.

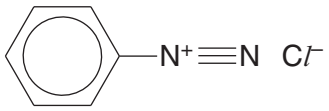
Answer **all** the questions.

1 The first commercially useful azo dye was *chrysoidine*, designed by Otto Witt in 1875.



chrysoidine

(a) Witt made this dye by first forming the diazonium salt **A** shown below.



salt A

(i) Give the **name** of the organic compound from which salt **A** can be made in one step.

..... **[1]**

(ii) Witt reacted another organic compound with salt **A** to make chrysoidine.

Draw the structure of this organic compound.

[1]

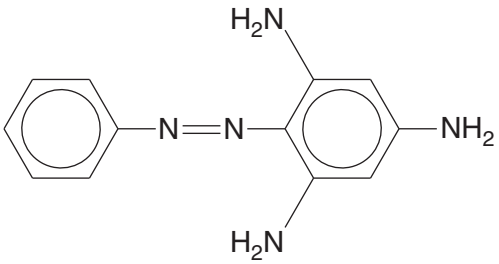
(iii) Give the condition needed for the reaction in **(ii)**.

..... **[1]**

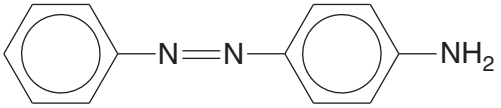
(iv) Classify the reaction mechanism for the coupling reaction in **(ii)**.

..... **[2]**

(b) From the structure, Witt predicted that chrysoidine would be an orange dye, knowing that two other dyes had the colours shown below.



brown



yellow

(i) Explain the reasoning behind Witt's prediction.

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..... **[2]**

(ii) Explain why these three dyes are coloured and why the colour varies between them.

In your answer you should make it clear how the points you make link together.

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..... **[6]**

(c) Explain, in terms of structure and bonding, why benzene undergoes mainly **substitution** reactions, rather than addition reactions.

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..... **[3]**

[Total: 16]

2 Sulfur hexafluoride is a colourless, non-toxic gas. It reacts with lithium to give off a large amount of heat energy that is used to power torpedoes.
Sulfur hexafluoride can be made by oxidising sulfur tetrafluoride with oxygen.
Sulfur tetrafluoride can be made by heating sulfur with copper(II) fluoride as shown in **equation 2.1** below.

$$3S + 2CuF_2 \longrightarrow SF_4 + 2CuS \qquad \textbf{equation 2.1}$$

(a) (i) In **equation 2.1**, what is oxidised and what is reduced?

..... is oxidised from oxidation state ..... to .....

..... is reduced from oxidation state ..... to ..... **[4]**

(ii) Suggest an equation for the reaction of sulfur tetrafluoride with oxygen to form sulfur hexafluoride.

[1]

(b) (i) Write the electron configuration for a sulfur atom, in terms of s and p electrons.

[1]

(ii) Draw a '*dot-and-cross*' diagram for sulfur **hexa**fluoride, SF_6.

[2]

(iii) Draw a three-dimensional diagram to show the shape of **SF_6**. Show **one** bond angle on the diagram and indicate its value.

[3]

The reaction of sulfur **hexa**fluoride with lithium is:

$$8Li + SF_6 \longrightarrow Li_2S + 6LiF \qquad \Delta H = -3000\,kJ\,mol^{-1} \qquad \textbf{equation 2.2}$$

(c) (i) Calculate the mass of lithium needed to react with 297 kg of sulfur hexafluoride. Give your answer to an **appropriate** number of significant figures.

mass = ... kg **[3]**

Some data for the substances in **equation 2.2** are given in **Table 2.1**.

	Li	**SF_6**	**Li_2S**	**LiF**
melting point / K	454	223	1211	1118
S_{298} / $J\,K^{-1}\,mol^{-1}$	+29	+292	+40	+36

Table 2.1

(ii) Give the systematic name for Li_2S.

..... **[1]**

(iii) Name the **type** of bonding, at 298 K, in:

lithium .....

sulfur hexafluoride .....

lithium fluoride ..... **[3]**

(d) SF_6 and hexanedioic acid, $HOOC(CH_2)_4COOH$, have approximately the same M_r.

Explain, in terms of intermolecular bonds, why SF_6 is a gas at room temperature whereas hexanedioic acid is a solid.

In your answer you should use appropriate technical terms, spelled correctly.

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..... **[4]**

(e) **(i)** Use data in **Table 2.1** to calculate ΔS_{sys} for the reaction in **equation 2.2** at 298 K.

$$8Li + SF_6 \longrightarrow Li_2S + 6LiF \qquad \Delta H = -3000\,kJ\,mol^{-1} \qquad \textbf{equation 2.2}$$

ΔS_{sys} = ... $J\,K^{-1}\,mol^{-1}$ **[2]**

(ii) Calculate the value of ΔS_{tot} for the reaction in **equation 2.2** at 298 K.

ΔS_{tot} = ... $J\,K^{-1}\,mol^{-1}$ **[2]**

(f) The reaction in **equation 2.2** is started using a fuse made from aluminium powder and potassium chlorate(VII).

(i) Give the formula of potassium chlorate(VII).

..... **[1]**

(ii) Comment on the need for a fuse, in view of your answer to **(e)(ii)**.

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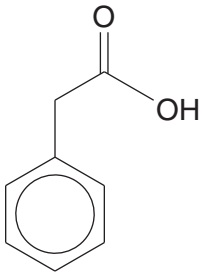
..... **[2]**

[Total: 29]

3 Auxins are hormones that promote plant growth. Phenylethanoic acid acts as an auxin.



phenylethanoic acid

(a) Give the molecular formula of phenylethanoic acid.

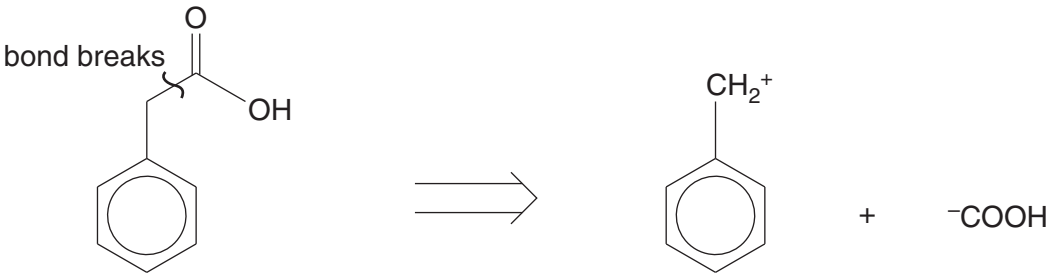
..... **[1]**

(b) Phenylethanoic acid is soluble in hot water. Write the equation for the reaction of phenylethanoic acid solution with calcium carbonate, using molecular formulae.

[2]

(c) Retrosynthetic analysis uses a process called disconnection to describe the imagined breaking of bond(s) to produce fragments, called synthons.

Retrosynthetic analysis can be used to plan the synthesis of phenylethanoic acid. One possible disconnection to produce two synthons is shown below.



phenylethanoic acid **synthons**

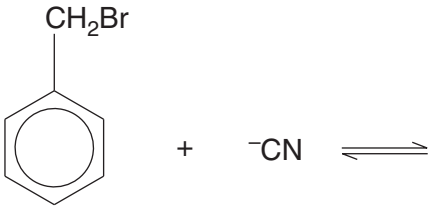
(i) Draw a 'curly arrow' on the molecule of phenylethanoic acid above to show the movement of the electrons if the bond indicated were to break to produce these synthons. **[1]**

(ii) Explain why synthons are not often used to make the required compound.

.....

..... **[1]**

(iii) Reagents that are actually used in the first step of the synthesis of phenylethanoic acid are shown below.



These reagents react by nucleophilic substitution.

Complete the equation above for this reaction. **[1]**

(iv) Use your *Data Sheet* to suggest reagents and conditions to make phenylethanoic acid from the organic product of the reaction in **(iii)**.

..... **[1]**

(v) The forward reaction in **(iii)** is exothermic.

Predict and explain the effect of increasing the temperature on the position of the equilibrium in **(iii)**. How will this affect the equilibrium constant?

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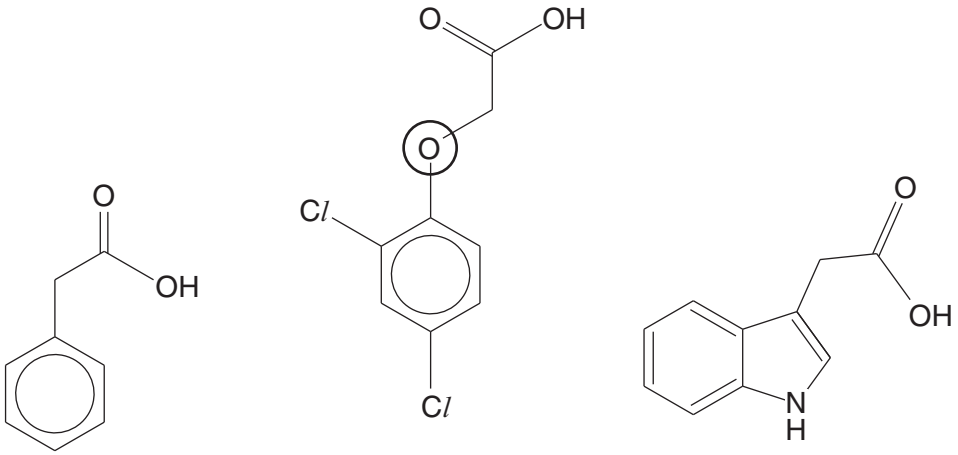
..... **[3]**

(d) Phenylethanoic acid acts as an auxin, promoting plant growth. The formulae of two other auxins, '2,4-D' and 'IAA' are shown below.



phenylethanoic acid **2,4-D** **IAA**

(i) Name the functional group circled in **2,4-D**.

..... **[1]**

(ii) Name a functional group that is in **IAA** but not in **2,4-D** or **phenylethanoic acid**.

..... **[1]**

(iii) Suggest **one** peak (above 1700 cm^{-1}) that would be present in the infrared spectra of **all three** auxins shown above.

Give the wavenumbers of the absorption range and the corresponding bond.

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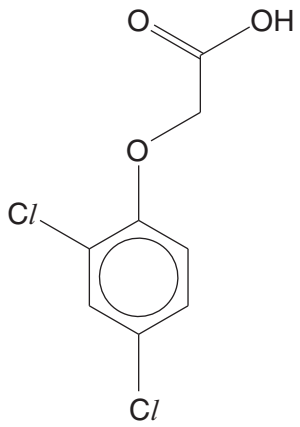
..... **[2]**

(iv) Auxins work by fitting into receptors in the plant cells.
Suggest the part of the molecule that fits into these receptors.
Circle this on the structure of **2,4-D** below.



2,4-D

[1]

(e) **2,4-D** can be used as a herbicide. It has such strong growth-promoting properties that plants grow out of control and die.

2,4-D is often reacted with dimethylamine, $(CH_3)_2NH$, to produce a salt.

(i) Draw the formula of this salt, showing the charges on the ions.

[2]

(ii) The salt of **2,4-D** is preferred for use as a herbicide.

Suggest why **2,4-D** is converted into a salt to be used as the herbicide.

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..... **[1]**

(f) **2,4-D** is an effective herbicide but it is toxic to humans and other animals.

Suggest **two** arguments that farmers might give to be allowed to continue to use **2,4-D**.

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..... **[2]**

[Total: 20]

4 In 1925, A.W. Francis reported that he had reacted ethene with bromine in sodium chloride solution.
An oil was formed in which he identified CH_2BrCH_2Br and CH_2BrCH_2Cl.

(a) Give the systematic names of CH_2BrCH_2Br and CH_2BrCH_2Cl.

.....

..... **[2]**

(b) Carbon–halogen bonds are polar. CH_2BrCH_2Cl has an overall dipole, but another halogenoalkane, CBr_3CBr_3, has no overall dipole.

- Describe and explain the polarity of a carbon–halogen bond.
- Explain why CBr_3CBr_3 has no overall dipole.
- Explain why CH_2BrCH_2Cl has an overall dipole.

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..... **[5]**

(c) Francis fractionally distilled the oil and identified its components using their densities and boiling points. Today, the oil might be vaporised and analysed using a chromatographic technique.

Name this technique.

..... **[1]**

(d) Explain, in terms of intermolecular bonds, why CH_2BrCH_2Br and CH_2BrCH_2Cl dissolve in each other, but do not dissolve in water.

In your answer you should make it clear how the points you make link together.

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..... **[4]**

(e) Francis's experiment led to an understanding of the mechanism of the addition of halogens to alkenes.

(i) Draw the mechanism for the attack of bromine on ethene to form an **intermediate**, showing bond polarisations and curly arrows.

[4]

(ii) The reaction in **(i)** is described as electrophilic addition. Explain the meaning of the term *electrophile*.

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..... **[2]**

(iii) Francis reacted ethene with bromine in sodium chloride solution.

Explain why CH_2ClCH_2Br was formed, but CH_2ClCH_2Cl was **not** formed in this reaction.

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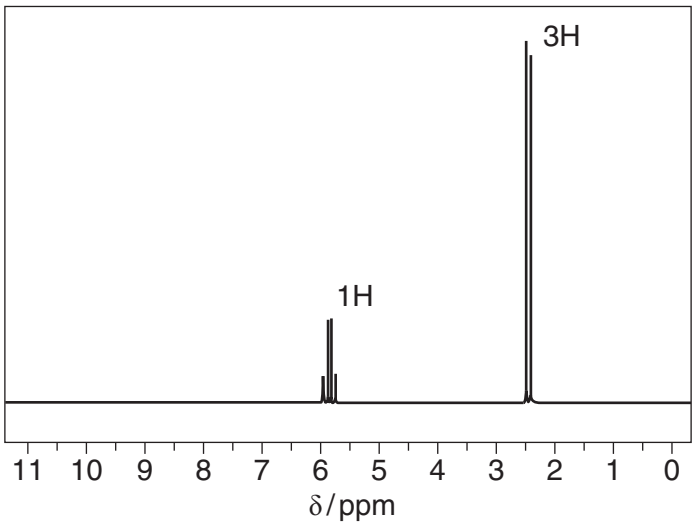
..... **[2]**

(f) From CH_2BrCH_2Br it is possible to make ethanedioic acid, $(COOH)_2$, by a two-step synthesis.

Suggest the intermediate compound and give reagents and essential conditions for the two steps involved.

[4]

(g) There are two isomers of $C_2H_4Br_2$. One isomer has the proton NMR spectrum shown below.



- Give the structural formula of the isomer.
- Explain how the number of the peaks and their areas confirm this.
- Explain the splitting of the peaks.

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..... **[4]**

[Total: 28]

5 The phosphate buffer system operates in the internal fluids of all human cells.
A reaction involved is shown below.

$$H_2PO_4^- \rightleftharpoons H^+ + HPO_4^{2-} \qquad \textbf{equation 5.1}$$

(a) (i) Suggest the systematic name for the ion HPO_4^{2-}, including the oxidation state of the phosphorus.

..... **[2]**

(ii) Write the formula for the *conjugate acid* of $H_2PO_4^-$.

..... **[1]**

(b) (i) Write the expression for the K_a for the reaction shown in **equation 5.1**

K_a =

[1]

(ii) Calculate the pH of a 0.10 mol dm^{-3} solution of $H_2PO_4^-$.
$K_a = 6.2 \times 10^{-8}$ mol dm^{-3}

pH = ... **[2]**

(c) (i) Explain the meaning of the term *buffer solution* and explain why buffer solutions are important in human cells.

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..... **[4]**

$$H_2PO_4^- \rightleftharpoons H^+ + HPO_4^{2-}$$ **equation 5.1**

(ii) Explain how a buffer solution based on **equation 5.1** works when acid is added.

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..... **[3]**

(iii) Calculate the pH of a buffer solution where the concentrations of HPO_4^{2-} and $H_2PO_4^-$ are equal.

pH = ... **[2]**

$$H_2PO_4^- \rightleftharpoons H^+ + HPO_4^{2-}$$ **equation 5.1**

$K_a = 6.2 \times 10^{-8}\,\text{mol dm}^{-3}$

(d) A student prepared 1.0 dm^3 of a pH 7.0 buffer solution based on the system shown in **equation 5.1**.

The solution was prepared by dissolving Na_2HPO_4 and NaH_2PO_4 in deionised water.

The concentration of Na_2HPO_4 in the prepared buffer solution was 0.10 mol dm^{-3}.

Calculate the mass of solid NaH_2PO_4 (M_r 120) that the student used in preparing this buffer solution.

mass of NaH_2PO_4 = ... g **[4]**

(e) 15.0 cm^3 of a 0.10 mol dm^{-3} solution of NaH_2PO_4 is titrated with a 0.40 mol dm^{-3} solution of sodium hydroxide. 7.5 cm^3 of the sodium hydroxide solution is needed to reach the end-point.

$$NaH_2PO_4 + 2NaOH \rightarrow Na_3PO_4 + 2H_2O$$

(i) Use the reaction shown in the equation to explain why 7.5 cm^3 of the sodium hydroxide solution is needed.

[2]

(ii) A student suggests that less than 7.5 cm^3 of sodium hydroxide solution would be needed since $H_2PO_4^-$ is a weak acid.

Explain the error in the student's argument.

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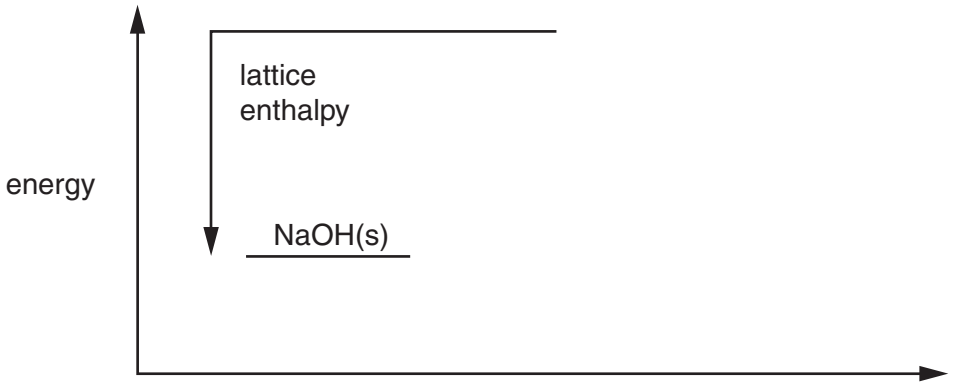
..... **[1]**

(f) When sodium hydroxide is dissolved in water, the solution gets warm.

Complete the diagram below to illustrate this, labelling the energy levels and the enthalpy terms where this has not been done.



[5]

[Total: 27]

END OF QUESTION PAPER

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