THIS IS A LEGACY SPECIFICATION

OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE

CHEMISTRY (SALTERS)

Chemistry by Design

2854/01

Candidates answer on the Question Paper
A calculator may be used for this paper

OCR Supplied Materials:
- *Data Sheet for Chemistry (Salters) (inserted)*

Other Materials Required:
- Scientific calculator

Wednesday 27 January 2010
Morning

Duration: 2 hours

OCE/12291

2854401

Candidate Forename		Candidate Surname	

Centre Number						Candidate Number				

INSTRUCTIONS TO CANDIDATES

- Write your name clearly in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- Write your answer to each question in the space provided, however additional paper may be used if necessary.

INFORMATION FOR CANDIDATES

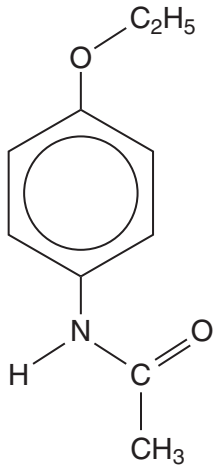
- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- The total number of marks for this paper is **120**.
- You will be awarded marks for the quality of written communication where this is indicated in the question.
- You may use a scientific calculator.
- A copy of the *Data Sheet for Chemistry (Salters)* is provided as an insert with this question paper.
- You are advised to show all the steps in any calculations.
- This document consists of **24** pages. Any blank pages are indicated.

Examiner's Use Only:			
1			
2			
3			
4			
5			
Total			

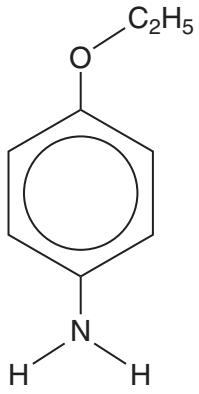
DC (SJF5496/CGW) 12291/7

Answer **all** the questions.

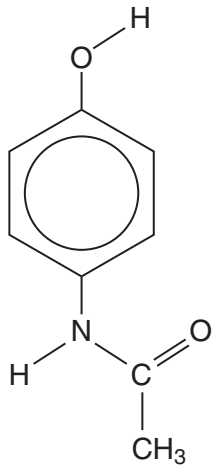
1 Phenacetin was used in pain-killing medicines until 1960. Chemists then found that it was metabolised in the body to paraphenetidine, which is toxic. Phenacetin has now been replaced in many medicines by paracetamol.



phenacetin



paraphenetidine



paracetamol

(a) Name the functional group, apart from the benzene ring:

(i) that phenacetin and paraphenetidine have in common.

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

(ii) that phenacetin and paracetamol have in common.

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

(iii) that paraphenetidine has and neither of the others has.

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

(b) Give the values of the bond angles:

(i) around the nitrogen atom in the $-NH_2$ group of paraphenetidine.

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

(ii) around the carbon atom in the C=O group of paracetamol.

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

(c) Describe a positive chemical test for paracetamol that will distinguish it from both phenacetin and paraphenetidine.

Give the name of the reagent and the expected result of the test.

.....

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

(d) (i) By what **type** of reaction is phenacetin converted to paraphenetidine?

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

(ii) Give laboratory reagents and conditions that you would use to carry out this reaction.

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

(e) The infrared spectra and proton n.m.r. spectra of **phenacetin** and **paraphenetidine** are compared.

Describe and explain **one** similarity and **one** difference between the infrared spectra of these two compounds.

Give the number of peaks and their relative numbers of protons in the n.m.r. spectrum of **phenacetin**. Describe how the spectrum of **paraphenetidine** would differ.

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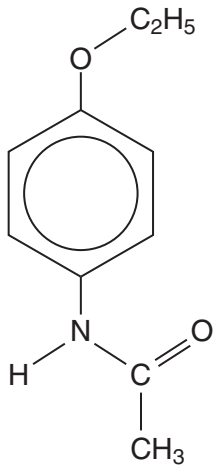
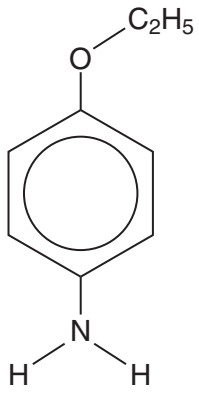
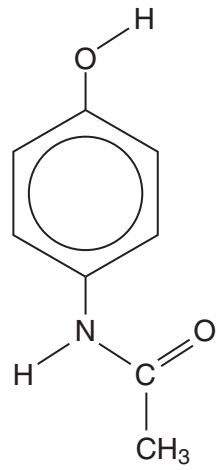


phenacetin



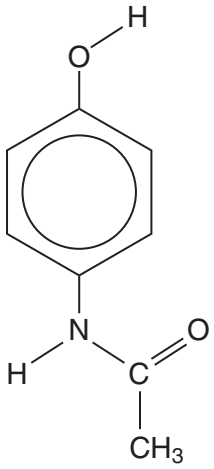
paraphenetidine



paracetamol

(f) Paracetamol and phenacetin are both pain-killers.

(i) On the structure of paracetamol below, circle the structure of the pharmacophore that it shares with phenacetin.



[1]

(ii) Explain the meaning of *pharmacophore* in terms of the action of paracetamol and phenacetin.

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

(g) The enzyme responsible for the metabolism of phenacetin is not able to catalyse a similar reaction for paracetamol.

Suggest and explain a reason, comparing functional groups, why the enzyme cannot catalyse the reaction of paracetamol.

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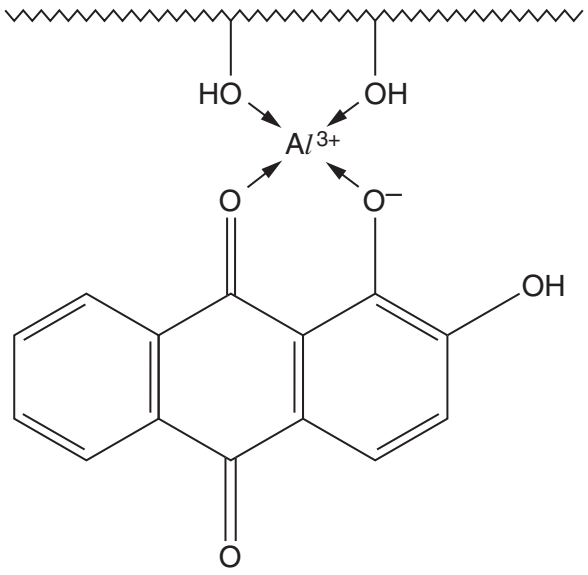
..... **[2]**

[Total: 21]

2 The dye alizarin only sticks fast to cotton when a 'mordant' is used.

If an aluminium compound is used as a mordant under alkaline conditions, aluminium ions become bonded to the hydroxyl groups of cotton. Alizarin can bond with the aluminium ions, giving the structure below which dyes the cotton red.



(a) (i) Give the electron configuration of Al^{3+}.

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

(ii) Aluminium hydroxide is precipitated from a solution of aluminium ions on addition of sodium hydroxide.

Write an ionic equation for this reaction. Show state symbols.

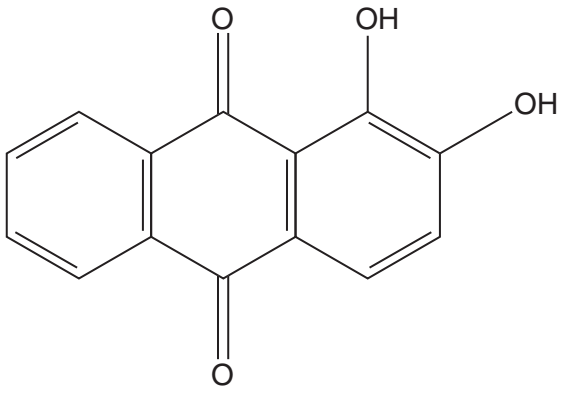
[2]

(iii) In the list below, underline the type of reaction by which alizarin reacts with hydrated aluminium ions.

acid-base **ligand exchange** **polymorphism** **redox**

[1]

(iv) The alizarin structure is shown below.



alizarin

Suggest **one** reason why alkaline conditions are needed for alizarin molecules to bond with the aluminium ions.

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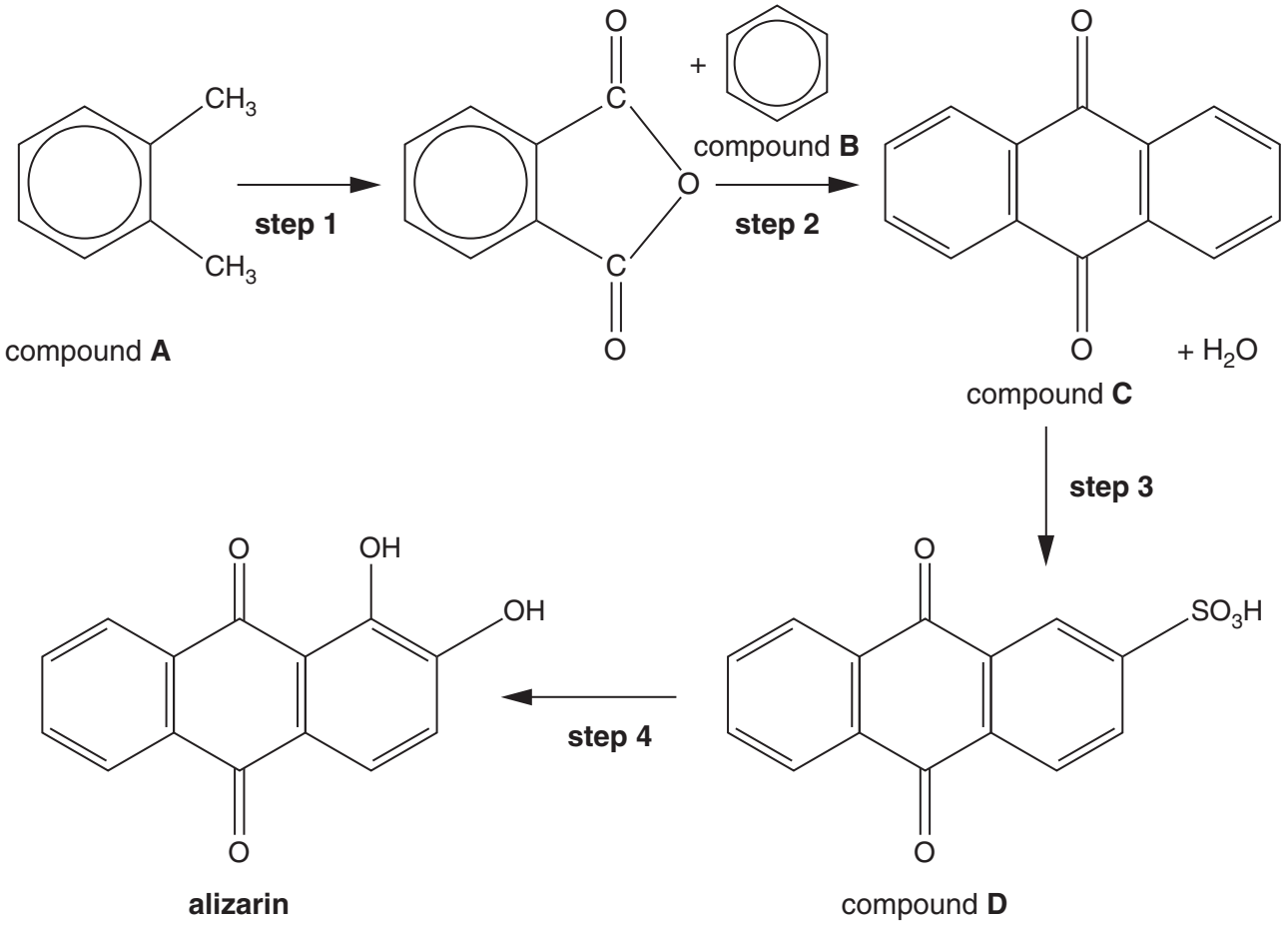
..... **[2]**

(v) A piece of cloth dyed red with alizarin is placed in a bath of boiling water. Very little red dye enters the water.

Suggest a substance that could be added to the water that will make the dye **less** colour-fast.

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

(b) Alizarin is made from readily available starting materials as shown.



(i) Suggest a source of compounds **A** and **B.**

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

(ii) Choose from the list below the **type** of reaction that occurs in **step 2.**

addition **condensation** **oxidation** **substitution**

[1]

(iii) Name the functional group, apart from the arene system, in compound **C.**

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

(iv) Give a reagent for the sulphonation in **step 3**.

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

(v) Calculate the maximum mass of alizarin that could be made from 53 kg of compound **A**.

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

Mass = ... kg **[3]**

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

The alizarin molecule is itself coloured.

Explain, in terms of electron energy levels,

- the origin of colour in dye molecules
- why different dyes can be different in colour.

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

Quality of Written Communication **[2]**

(d) Compounds **A** and **B** have benzene rings with delocalised electrons.

Explain the meaning of the term *delocalised*.

In your answer indicate where the delocalised electrons in benzene come from and how they are arranged.

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

(e) Benzene can be brominated using liquid bromine and iron(III) bromide. This is an example of an electrophilic substitution reaction.

(i) Explain the meanings of *electrophilic* and *substitution*.

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

(ii) Explain how iron(III) bromide acts as a catalyst for the bromination reaction.

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

(iii) Write a balanced equation for the electrophilic substitution of benzene by bromine.

[2]

[Total: 31]

3 The gas dinitrogen oxide, N_2O, is used in rocket engines.
One way in which the gas is made is by the oxidation of ammonia over a metal catalyst.

$$2NH_3(g) + 2O_2(g) \rightleftharpoons N_2O(g) + 3H_2O(g) \quad \Delta H = -552\,kJ\,mol^{-1} \qquad \textbf{equation 3.1}$$

(a) (i) Give the oxidation state of nitrogen in:

NH_3 .....

N_2O ..... **[2]**

(ii) In the forward reaction, which substance is reduced? Give a reason for your answer.

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

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

Suggest, with reasons, suitable conditions of temperature and pressure to obtain a satisfactory yield of N_2O at an economic rate.

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

Quality of Written Communication **[1]**

(c) Give the reaction conditions and catalyst required for the synthesis of ammonia from nitrogen and hydrogen.

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

(d) **(i)** Calculate $\Delta S^{\ominus}_{sys}$ for the forward reaction in **equation 3.1**, using the data in the table.

substance	$S^{\ominus}$ /J mol^{-1} K^{-1}
$H_2O(g)$	+189
N_2O (g)	+220
$NH_3(g)$	+192
$O_2(g)$	+205

$2NH_3(g) + 2O_2(g) \rightleftharpoons N_2O(g) + 3H_2O(g) \quad \Delta H^{\ominus} = -552\,kJ\,mol^{-1}$ **equation 3.1**

$\Delta S^{\ominus}_{sys}$ = ... J mol^{-1} K^{-1} **[2]**

(ii) Comment on the magnitude of your answer, referring to the equation.

.....

.....

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

(iii) Use the given expressions to calculate a value for $\Delta S^{\ominus}_{tot}$ for the forward reaction at 298 K.

$\Delta S^{\ominus}_{tot} = \Delta S^{\ominus}_{sys} + \Delta S^{\ominus}_{surr}$ $\Delta S^{\ominus}_{surr} = -\Delta H^{\ominus}/T$

$\Delta S^{\ominus}_{tot}$ = ... J mol^{-1} K^{-1} **[2]**

(e) N_2O decomposes at low temperatures.

$$N_2O \longrightarrow N_2 + \tfrac{1}{2}\, O_2 \quad \Delta H = -82\,kJ\,mol^{-1}$$

(i) Suggest **two** reasons why N_2O can be used on its own as a rocket propellant.

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

(ii) Oxygen has the ability to relight a glowing wooden splint. N_2O is the only other gas which can do this.

Suggest why N_2O gives this result.

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

[Total: 24]

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TURN OVER FOR QUESTIONS 4 AND 5

4 Crude oil fractions often contain unwanted sulphur compounds. These sulphur compounds can be converted to hydrogen sulphide by mixing the oil fractions with hydrogen under pressure and passing the mixture over a heated catalyst.

(a) (i) Suggest a source of the hydrogen gas that is used in this process.

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

(ii) Explain why the removal of sulphur compounds from crude oil fractions is important for the environment.

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

(b) Hydrogen sulphide is formed and is removed from the gas stream by reacting it with 'monoethanolamine' .

$$H_2S + \underset{\text{'monoethanolamine'}}{2HOCH_2CH_2NH_2} \rightarrow 2HOCH_2CH_2NH_3^+ + S^{2-}$$

(i) Give the systematic name for 'monoethanolamine'.

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

(ii) H_2S is acting as an acid when it reacts with monoethanolamine.

Give evidence from the equation that H_2S has donated a proton.

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

(c) Hydrogen sulphide is a weak acid and ionises in water as shown below.

$$H_2S \rightleftharpoons HS^- + H^+ \quad K_a = 8.9 \times 10^{-8} \text{ mol dm}^{-3} \text{ at 298 K}$$

(i) Explain the meaning of the term *weak* when used to describe acids.

.....

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

(ii) Write the expression for K_a in terms of the concentrations of the molecules and ions involved.

K_a =

[1]

(iii) Calculate the pH of a 0.10 mol dm^{-3} solution of H_2S at 298 K.

pH = ... **[3]**

(d) Hydrogen sulphide reacts with mercury(II) salts to form mercury(II) sulphide, HgS. This is very insoluble with a solubility product $K_{sp} = 4.0 \times 10^{-53}$ mol^2 dm^{-6} at 298 K.

(i) Write the expression for the solubility product of mercury(II) sulphide in terms of the concentrations of the ions involved.

K_{sp} =

[2]

(ii) Calculate the concentration of Hg^{2+} ions in a saturated solution of HgS in **ions per dm^3.**

Avogadro constant, L , 6.0×10^{23}

concentration = ... ions dm^{-3} **[2]**

(iii) Calculate the solubility, in g dm^{-3}, of HgS in water at 298 K.

A_r: Hg, 201; S, 32

solubility = ... g dm^{-3} **[1]**

(e) The hydrogen sulphide is turned into sulphur dioxide.

Draw a dot-cross diagram for SO_2 showing the outer shell electrons only. Represent one of the sulphur to oxygen bonds as a single dative covalent bond.

[2]

(f) Sulphur dioxide is converted to sulphuric acid, H_2SO_4.

Calculate the mass of sulphuric acid that could be obtained from 1.0 kg of crude oil containing 1.0% of sulphur by mass.

Give your answer in kg to an **appropriate** number of significant figures.

A_r: S, 32; O, 16; H, 1.0

mass of sulphuric acid = ... kg **[3]**

(g) Any remaining sulphur dioxide can be absorbed using a base such as magnesium oxide. In the presence of air, sulphur dioxide reacts with magnesium oxide to form magnesium sulphate.

Magnesium sulphate dissolves in water to give a solution that conducts electricity.

- Give the **type** of bonding in magnesium sulphate.
- Explain, in terms of bonds and intermolecular forces broken and made, why magnesium sulphate is soluble in water.
- Explain why the solution conducts electricity.

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

[Total: 27]

5 Water is the commonest liquid on the Earth. It has some exceptional properties that make it very useful.

The table below shows the enthalpy changes of vaporisation of water and of some other liquids.

liquid	enthalpy change of vaporisation	
	kJ kg^{-1}	kJ mol^{-1}
water	+2260	
ethanol	+840	+38.6
propanone	+520	+30.2
hexane	+330	+28.4

(a) Calculate the enthalpy change of vaporisation of water in kJ mol^{-1} and **write the value in the table above.**

A_r: H, 1.0; O, 16

[1]

(b) The high enthalpy change of vaporisation of water is useful when water transfers energy from the oceans to the land.

(i) Explain how energy is transferred by water from the oceans to the land.

.....

.....

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

(ii) Why does the high enthalpy change of vaporisation of water make this very effective?

.....

.....

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

(c) The enthalpy change of vaporisation of water has the highest value in the table because water, on average, forms two hydrogen bonds per molecule.

(i) Draw a diagram to illustrate this, showing **one** water molecule hydrogen-bonded to **two** others. Include relevant lone pairs and partial charges.

[4]

(ii) Ethanol also forms hydrogen bonds. Explain why the enthalpy change of vaporisation of ethanol is lower than that of water.

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

(d) (i) Draw the **full** structural formula of propanone.

[1]

(ii) Name the strongest intermolecular force between two propanone molecules and explain why it is **not** hydrogen bonding.

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

(e) (i) Draw the **skeletal** formula of hexane.

[1]

(ii) The intermolecular forces in hexane are instantaneous dipole–induced dipole.

The enthalpy changes of vaporisation, in $kJ\,mol^{-1}$, of hexane and propanone are similar.

Explain this similarity in terms of intermolecular forces.

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

[Total: 17]

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