UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education Advanced Subsidiary Level and Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

CHEMISTRY **9701/04**

Paper 4 Structured Questions **May/June 2009**

1 hour 45 minutes

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen.
You may use a pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Section A
Answer **all** questions.

Section B
Answer **all** questions.

You may lose marks if you do not show your working or if you do not use appropriate units.
A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
4	
5	
6	
7	
8	
9	
Total	

This document consists of **18** printed pages and **2** blank pages.

Section A

For Examiner's Use

Answer **all** questions in the spaces provided.

1 **(a)** Explain what is meant by the *Bronsted-Lowry* theory of acids and bases.

.....

.....

..... [2]

(b) The K_a values for some organic acids are listed below.

acid	K_a/mol dm^{-3}
CH_3CO_2H	1.7×10^{-5}
$Cl CH_2CO_2H$	1.3×10^{-3}
Cl_2CHCO_2H	5.0×10^{-2}

(i) Explain the trend in K_a values in terms of the structures of these acids.

.....

.....

.....

.....

(ii) Calculate the pH of a 0.10 mol dm^{-3} solution of $Cl CH_2CO_2H$.

pH = ...

(iii) Use the following axes to sketch the titration curve you would obtain when 20 cm^3 of 0.10 mol dm^{-3} NaOH is added gradually to 10 cm^3 of 0.10 mol dm^{-3} $ClCH_2CO_2H$.

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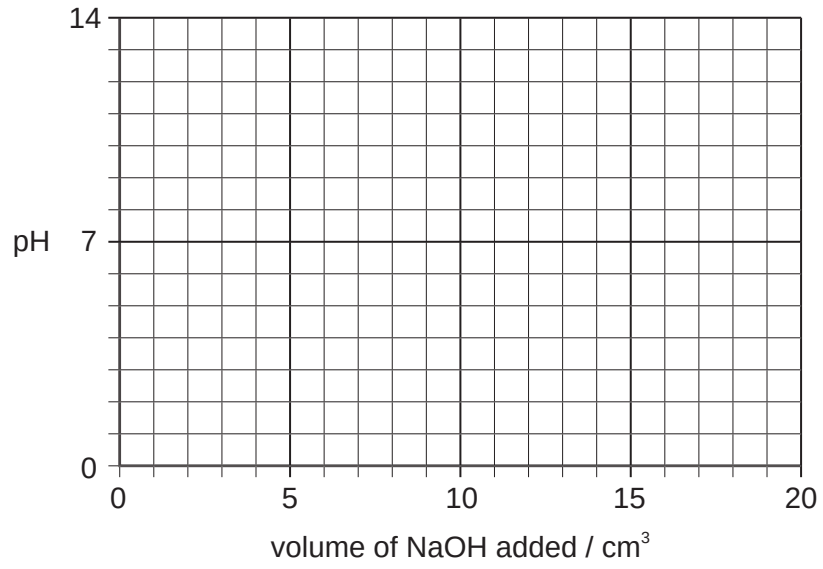


[8]

(c) (i) Write suitable equations to show how a mixture of ethanoic acid, CH_3CO_2H, and sodium ethanoate acts as a buffer solution to control the pH when either an acid or an alkali is added.

.....

.....

(ii) Calculate the pH of a buffer solution containing 0.10 mol dm^{-3} ethanoic acid and 0.20 mol dm^{-3} sodium ethanoate.

pH = ...

[4]

[Total: 14]

[Turn over

For Examiner's Use

2 **(a)** Describe the observations you would make when concentrated sulfuric acid is added to separate portions of NaC*l*(s) and NaBr(s). Write an equation for **each** reaction that occurs.

NaC*l*(s): observation .....

.....

equation

NaBr(s): observation .....

.....

equation

[4]

(b) By quoting relevant $E^{\ominus}$ data from the *Data Booklet*, explain how the observations you have described above relate to the relative oxidising power of the elements.

.....

.....

..... [2]

(c) By referring to relevant $E^{\ominus}$ data choose a suitable reagent to convert Br_2 into Br^-. Write an equation and calculate the $E^{\ominus}$ for the reaction.

.....

.....

..... [3]

[Total: 9]

3 **(a)** Explain what is meant by the term *transition element*.

.....

..... [1]

(b) Complete the electronic configuration of

(i) the vanadium atom, $1s^2 2s^2 2p^6$ .....

(ii) the Cu^{2+} ion. $1s^2 2s^2 2p^6$ .....

[2]

(c) List the **four** most likely oxidation states of vanadium.

..... [1]

(d) Describe what you would see, and explain what happens, when dilute aqueous ammonia is added to a solution containing Cu^{2+} ions, until the ammonia is in an excess.

.....

.....

.....

.....

.....

.....

..... [5]

(e) Copper powder dissolves in an acidified solution of sodium vanadate(V), $NaVO_3$, to produce a blue solution containing VO^{2+} and Cu^{2+} ions.
By using suitable half-equations from the *Data Booklet*, construct a balanced equation for this reaction.

..... [2]

[Total: 11]

[Turn over

4 **(a)** The reaction between iodide ions and persulfate ions, $S_2O_8^{2-}$, is slow.

$$2I^- + S_2O_8^{2-} \longrightarrow I_2 + 2SO_4^{2-} \qquad \textbf{1}$$

The reaction can be speeded up by adding a small amount of Fe^{2+} or Fe^{3+} ions. The following two reactions then take place.

$$2I^- + 2Fe^{3+} \longrightarrow I_2 + 2Fe^{2+} \qquad \textbf{2}$$

$$2Fe^{2+} + S_2O_8^{2-} \longrightarrow 2Fe^{3+} + 2SO_4^{2-} \qquad \textbf{3}$$

(i) What type of catalysis is occurring here?

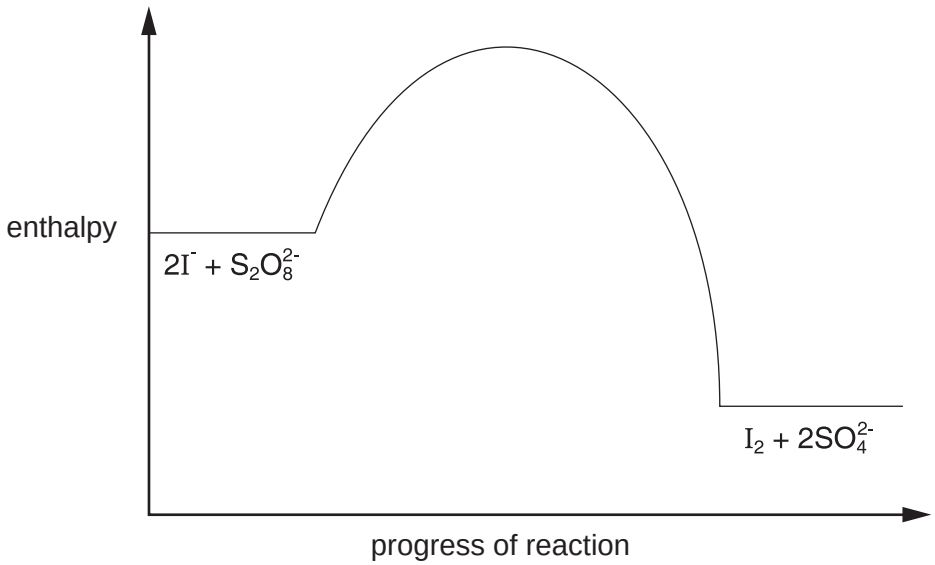
.....

(ii) The rates of reactions **2** and **3** are both faster than that of reaction **1**. By considering the species involved in these reactions, suggest a reason for this.

.....

.....

(iii) The following reaction pathway diagram shows the enthalpy profile of reaction **1**.



Use the same axes to draw the enthalpy profiles of reaction **2** followed by reaction **3**, starting reaction **2** at the same enthalpy level as reaction **1**.

[4]

(b) The oxidation of SO_2 to SO_3 in the atmosphere is speeded up by the presence of nitrogen oxides.

For Examiner's Use

(i) Describe the environmental significance of this reaction.

.....

(ii) Describe a major source of SO_2 in the atmosphere.

.....

(iii) By means of suitable equations, show how nitrogen oxides speed up this reaction.

.....

.....

[4]

[Total: 8]

For Examiner's Use

5 **(a)** In the following boxes draw the structural formulae of **three** alcohols having straight (i.e. unbranched) chains, with the molecular formula $C_5H_{12}O$.

A **B** **C**

[2]

Use the letters **A**, **B** or **C** as appropriate when answering the following questions. Each letter may be used once, more than once or not at all.

(b) Which of the alcohols are chiral? ..... [1]

(c) **(i)** Which of these alcohols react with alkaline aqueous iodine? .....

(ii) Describe the observation you would make during this reaction.

.....

(iii) Draw the structural formulae of the products of this reaction.

[4]

(d) Draw the structural formula of the product obtained when **each** of the alcohols **A**, **B** and **C** is heated with an excess of acidified $K_2Cr_2O_7(aq)$.

A →

B →

C →

[3]

(e) One of the many suggestions for converting biomass into liquid fuel for motor transport is the pyrolysis (i.e. heating in the absence of air) of cellulose waste, followed by the synthesis of alkanes.

For Examiner's Use

(i) In the first reaction, cellulose, $(C_6H_{10}O_5)_n$, is converted into a mixture of carbon monoxide and hydrogen. Some carbon is also produced.

Complete and balance the equation for this reaction.

$(C_6H_{10}O_5)_n \longrightarrow$ _____ + _____ + _____

(ii) The second reaction involves the combination of CO and H_2 to produce alkanes such as heptane.

$$7CO + 15H_2 \longrightarrow \underset{\text{heptane}}{C_7H_{16}} + 7H_2O$$

Using the value of 1080 kJ mol^{-1} as the value for the C≡O bond energy in CO, and other relevant bond energies from the *Data Booklet*, calculate the ΔH for this reaction.

ΔH = ... kJ mol^{-1}
[5]

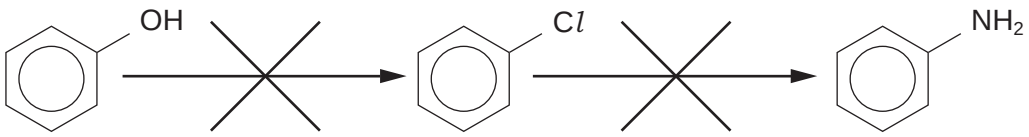
[Total: 15]

6 Phenol and chlorobenzene are less reactive towards certain reagents than similar non-aromatic compounds.
Thus hexan-1-ol can be converted into hexylamine by the following two reactions,

For Examiner's Use

$$\underset{\text{hexan-1-ol}}{CH_3(CH_2)_5OH} \xrightarrow{\text{I}} \underset{\text{1-chlorohexane}}{CH_3(CH_2)_5Cl} \xrightarrow{\text{II}} \underset{\text{hexylamine}}{CH_3(CH_2)_5NH_2}$$

whereas neither of the following two reactions takes place.



(a) (i) Suggest reagents and conditions for

reaction I, ... ,

reaction II. ..... .

(ii) What *type of reaction* is reaction II? .....

(iii) Suggest a reason why chlorobenzene is much less reactive than 1-chlorohexane.

.....

.....

[4]

(b) Phenylamine can be made from benzene by the following two reactions.

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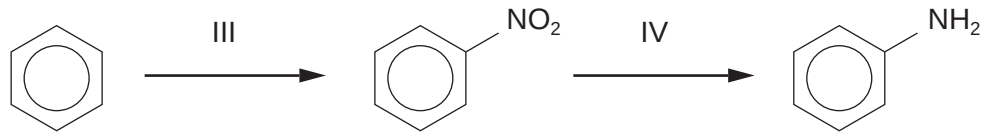

(i) Suggest reagents and conditions for

reaction III, ... ,

reaction IV. ..... .

(ii) State the *type of reaction* for

reaction III, ... ,

reaction IV. ..... .

[5]

(c) Suggest a reagent that could be used to distinguish phenylamine from hexylamine.

reagent and conditions .....

observation with phenylamine .....

observation with hexylamine.....

[2]

[Turn over

(d) Phenylamine is used to make azo dyes. In the following boxes draw the structural formula of the intermediate **D** and of the azo dye **E**.

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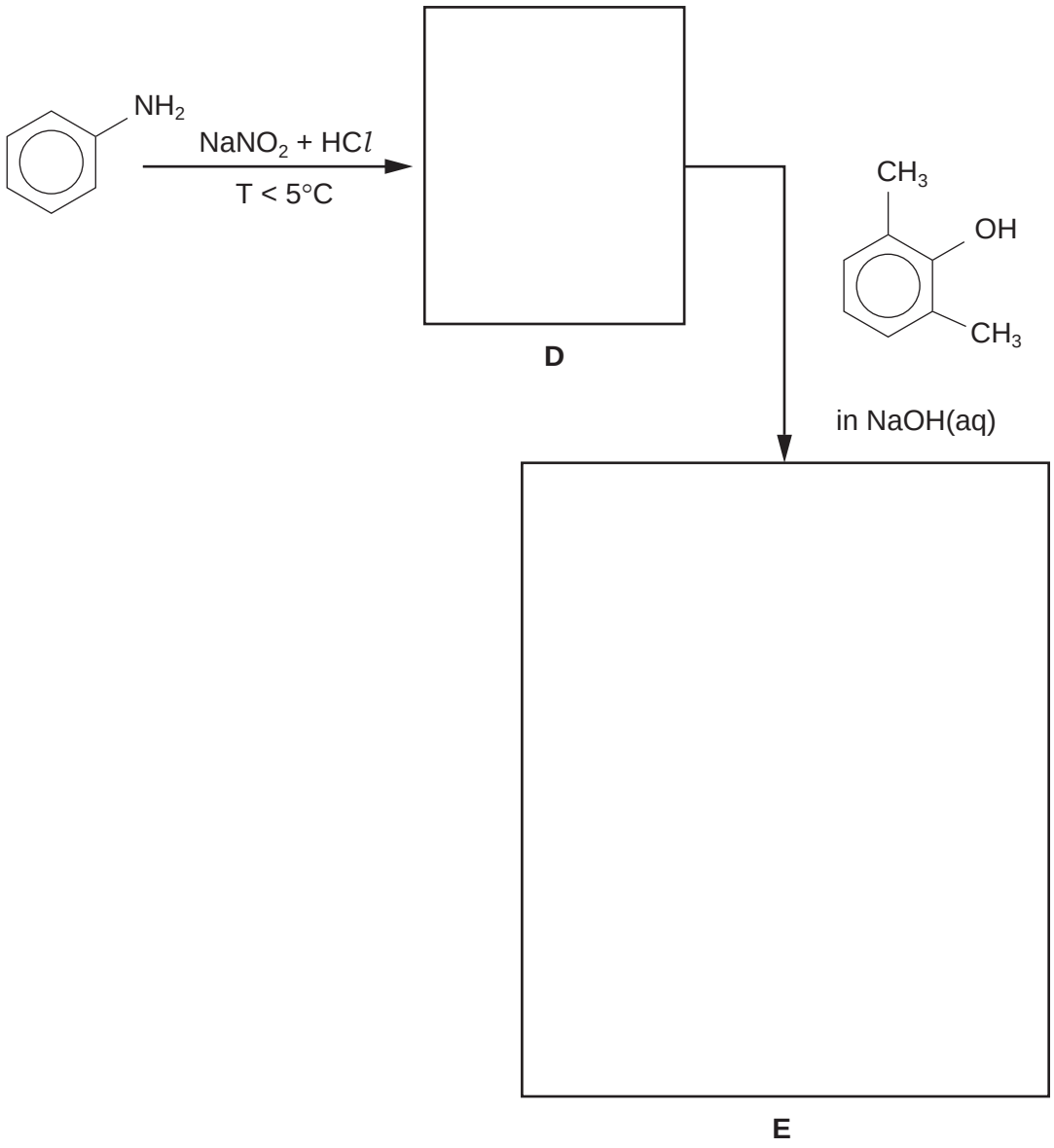


D

E

[2]

[Total: 13]

Section B

For Examiner's Use

Answer **all** questions in the spaces provided.

7 Metals play a vital part in biochemical systems. In this question you need to consider why some metals are essential to life, whilst others are toxic.

(a) For each of the metals, state where it might be found in a living organism, and what its chemical role is.

iron location in organism .....

role .....

.....

sodium location in organism .....

role .....

.....

zinc location in organism .....

role .....

.....

[6]

(b) Heavy metals such as mercury are toxic, and it is important that these do not enter the food chain.

(i) Give a possible source of mercury in the environment.

.....

(ii) Describe and explain **two** reasons why mercury is toxic, using diagrams and/or equations to help your explanation.

.....

.....

.....

[4]

[Total : 10]

8 A large number of organic compounds are soluble in both water and non-aqueous solvents such as hexane. If such a compound is shaken with a mixture of water and the non-aqueous solvent, it will dissolve in both solvents depending on the solubility in each.

For Examiner's Use

(a) (i) State what is meant by the term *partition coefficient*.

.....

.....

(ii) When 100 cm^3 of an aqueous solution containing 0.50 g of an organic compound **X** was shaken with 20 cm^3 of hexane, it was found that 0.40 g of **X** was extracted into the hexane.

Calculate the partition coefficient of **X** between hexane and water.

(iii) If **two** 10 cm^3 portions of hexane were used instead of a single 20 cm^3 portion, calculate the total amount of **X** extracted and compare this with the amount extracted using one 20 cm^3 portion.

[5]

For Examiner's Use

(b) PCBs are highly toxic compounds released into the atmosphere when some plastics are burned at insufficiently high temperatures. In recent years PCB residues have been found in the breast milk of Inuit mothers in northern Canada. Foods, such as oily fish, seal and whale meat, which are high in fat, form an important part of the Inuit diet.

(i) Suggest why berries and drinking water are not contaminated by PCBs in the same way that oily fish, seal and whale meat are.

.....

.....

.....

(ii) Based on the information provided, what can you say about the partition coefficient between fat and water for PCB residues?

.....

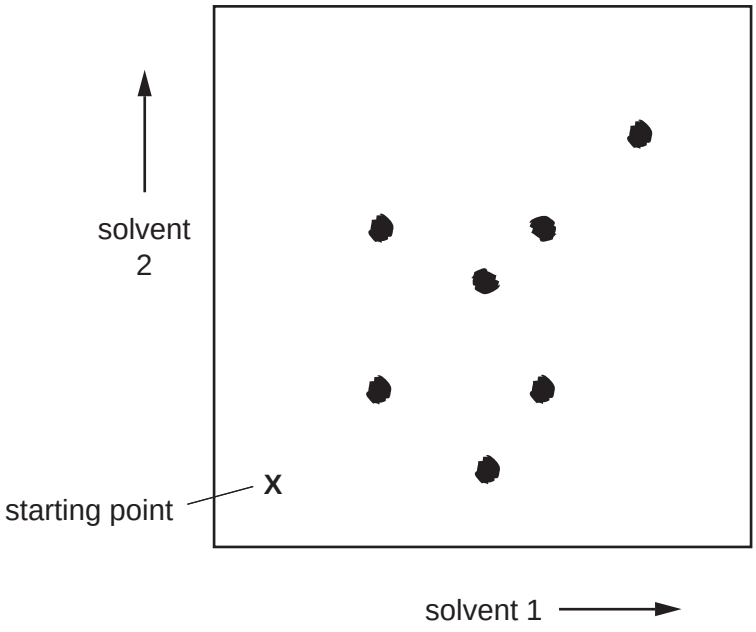
.....

.....

[3]

(c) The diagram shows the result of two-way paper chromatography.

For Examiner's Use



(i) How many spots were there after the first solvent had been used?

.....

(ii) Circle the spot that moved very little in solvent 2, but moved a greater distance in solvent 1.

(iii) Draw a square around the spot that could be separated from the rest by using **only** solvent 1.

[3]

[Total: 11]

9 **(a)** Spider silk is a natural polymer which has an exceptional strength for its weight. *Kevlar* is a man-made polymer designed to have similar properties. It has a wide variety of uses from sporting equipment to bullet-proof vests.

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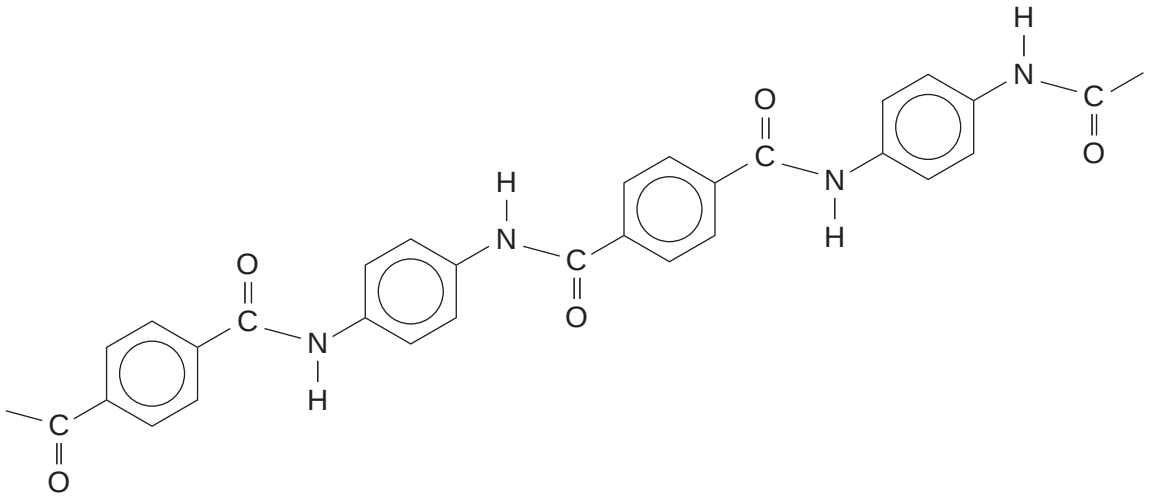


Kevlar

(i) In *Kevlar*, the polymer strands line up to form strong sheets with bonds between the strands.

On the diagram above, draw part of a second polymer chain showing how bonds could be formed between the chains.

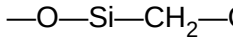
(ii) Suggest what type of bonds these are.

.....

(iii) Draw **two** possible monomer molecules for making the polymer *Kevlar*.

[5]

(b) The transport of oil by sea has resulted in a number of oil spills in recent years. As well as a waste of a valuable resource, these have caused major environmental problems. Traditional sorbent materials absorb water and sink. Researchers have developed new sorbent materials to help collect the spilled oil. The sorbent consists of a material called 'hydrophobic aerogels'. This is a network of silicon(IV) oxide with some of the silicon atoms attached to fluorine-containing groups.



The introduction of these fluorine-containing groups allows the oil to be absorbed but not the water. Tests show that these materials can absorb more than 200 times their mass of oil without sinking.

(i) Suggest what the word **hydrophobic** means.

.....

(ii) Suggest why the fluorine-containing groups allow oil to pass through but not water molecules.

.....

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.....

.....

(iii) Suggest another important fluorine-containing polymer that repels water-containing materials.

.....

[4]

[Total: 9]

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