



UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education Advanced Level

CANDIDATE
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CHEMISTRY

9701/41

Paper 4 Structured Questions

May/June 2013

2 hours

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 soft 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.

Electronic calculators may be used.

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	
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4	
5	
6	
7	
8	
Total	

This document consists of **15** printed pages and **1** blank page.



Section A

For
Examiner's
UseAnswer **all** the questions in the spaces provided.

- 1 (a) What is meant by the term *standard electrode potential*, SEP?

.....

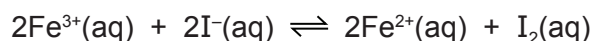
.....

[2]

- (b) Draw a fully labelled diagram of the apparatus you could use to measure the SEP of the $\text{Fe}^{3+}/\text{Fe}^{2+}$ electrode.

[5]

- (c) The reaction between Fe^{3+} ions and I^- ions is an equilibrium reaction.



- (i) Use the *Data Booklet* to calculate the $E_{\text{cell}}^{\ominus}$ for this reaction.

.....

- (ii) Hence state, with a reason, whether there will be more products or more reactants at equilibrium.

.....

.....

- (iii) Write the expression for K_c for this reaction, and state its units.

$$K_c =$$

units

An experiment was carried out using solutions of $\text{Fe}^{3+}(\text{aq})$ and $\text{I}^{-}(\text{aq})$ of equal concentrations. 100 cm^3 of each solution were mixed together, and allowed to reach equilibrium.

The concentrations at equilibrium of $\text{Fe}^{3+}(\text{aq})$ and $\text{I}_2(\text{aq})$ were as follows.

$$[\text{Fe}^{3+}(\text{aq})] = 2.0 \times 10^{-4} \text{ mol dm}^{-3}$$

$$[\text{I}_2(\text{aq})] = 1.0 \times 10^{-2} \text{ mol dm}^{-3}$$

- (iv) Use these data, together with the equation given in (c), to calculate the concentrations of $\text{Fe}^{2+}(\text{aq})$ and $\text{I}^{-}(\text{aq})$ at equilibrium.

$$[\text{Fe}^{2+}(\text{aq})] = \dots\dots\dots \text{mol dm}^{-3}$$

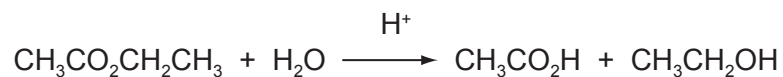
$$[\text{I}^{-}(\text{aq})] = \dots\dots\dots \text{mol dm}^{-3}$$

- (v) Calculate the K_c for this reaction.

$$K_c = \dots\dots\dots [8]$$

[Total: 15]

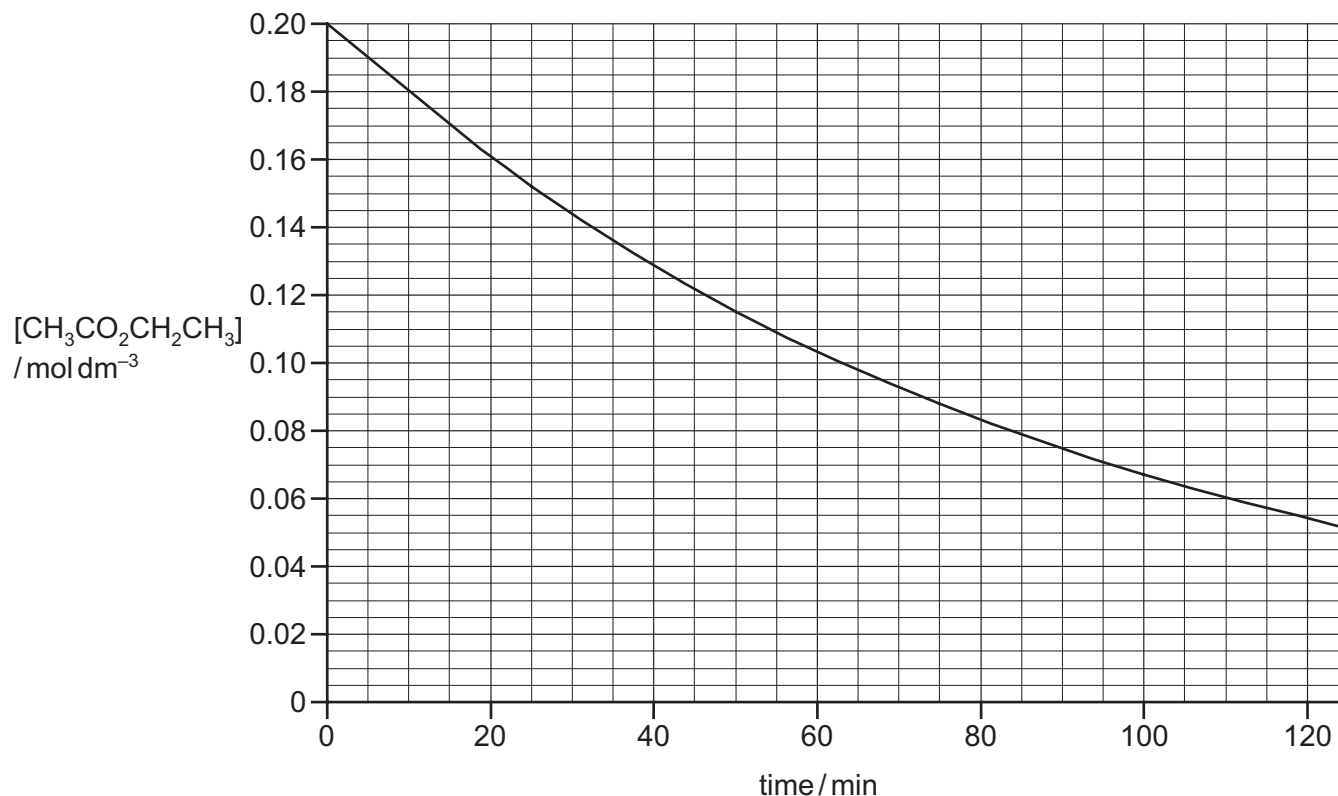
- 2 Ethyl ethanoate is hydrolysed slowly by water in the following acid-catalysed reaction.



The concentration of ethyl ethanoate was determined at regular time intervals as the reaction progressed.

Two separate experiments were carried out, with different HCl concentrations.

The following graph shows the results of an experiment using $[\text{HCl}] = 0.1 \text{ mol dm}^{-3}$.



- (a) When the experiment was carried out using $[\text{HCl}] = 0.2 \text{ mol dm}^{-3}$, the following results were obtained.

time / min	$[\text{CH}_3\text{CO}_2\text{CH}_2\text{CH}_3] / \text{mol dm}^{-3}$
0	0.200
10	0.160
25	0.115
50	0.067
75	0.038
100	0.022
125	0.013

- (i) Plot these data on the axes above, and draw a line of best fit.

- (ii) Use one of the graphs to show that the reaction is first order with respect to $\text{CH}_3\text{CO}_2\text{CH}_2\text{CH}_3$.

Show all your working, and show clearly any construction lines you draw on the graphs.

- (iii) Use the graphs to calculate the order of reaction with respect to HCl .

Show all your working, and show clearly any construction lines you draw on the graphs.

- (iv) Write the rate equation for this reaction, and calculate the value of the rate constant.

rate =

[7]

- (b) (i) Why is it **not** possible to determine the order of reaction with respect to water in this experiment?

.....
.....

- (ii) Although $[\text{CH}_3\text{CO}_2\text{CH}_2\text{CH}_3]$ decreases during each experiment, $[\text{HCl}]$ remains the same as its initial value.

Why is this?

.....
.....

[2]

[Total: 9]

3 (a) (i) What is meant by the *density* of a substance?

.....

(ii) Use data from the *Data Booklet* to explain why the density of iron is greater than that of calcium.

.....

.....

.....

[3]

(b) In general, reactions of the compounds of transition elements can be classified under one or more of the following headings.

acid-base

ligand exchange

precipitation

redox

Choose the most suitable heading to describe each of the following reactions, by placing a tick (✓) in the appropriate column in the table below.

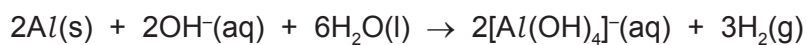
Only one tick should be placed against each reaction.

reaction	acid-base	ligand exchange	precipitation	redox
$[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{NH}_3 \rightarrow [\text{Cu}(\text{NH}_3)_4]^{2+} + 6\text{H}_2\text{O}$				
$[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{HCl} \rightarrow [\text{CuCl}_4]^{2-} + 4\text{H}^+ + 6\text{H}_2\text{O}$				
$2\text{FeCl}_2 + \text{Cl}_2 \rightarrow 2\text{FeCl}_3$				
$[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow \text{Fe}(\text{OH})_2 + 6\text{H}_2\text{O}$				
$2\text{Fe}(\text{OH})_2 + \frac{1}{2}\text{O}_2 + \text{H}_2\text{O} \rightarrow 2\text{Fe}(\text{OH})_3$				
$\text{CrO}_3 + 2\text{HCl} \rightarrow \text{CrO}_2\text{Cl}_2 + \text{H}_2\text{O}$				
$\text{Cr}(\text{H}_2\text{O})_3(\text{OH})_3 + \text{OH}^- \rightarrow [\text{Cr}(\text{H}_2\text{O})_2(\text{OH})_4]^- + \text{H}_2\text{O}$				
$[\text{Cr}(\text{OH})_4]^- + 1\frac{1}{2}\text{H}_2\text{O}_2 + \text{OH}^- \rightarrow \text{CrO}_4^{2-} + 4\text{H}_2\text{O}$				

[8]

- (c) Alloys of aluminium, titanium and vanadium are used in aerospace and marine equipment, and in medicine.

When a powdered sample of one such alloy is heated with an excess of aqueous NaOH, only the aluminium reacts, according to the following equation.



Reacting 100 g of alloy in this way produced 8.0 dm³ of hydrogen, measured under room conditions.

Calculate the percentage by mass of aluminium in the alloy.

percentage = ... %
[3]

[Total: 14]

- 4 Because of the lack of reactivity of the nitrogen molecule, extreme conditions need to be used to synthesise ammonia from nitrogen in the Haber process.

(a) Suggest an explanation for the lack of reactivity of the nitrogen molecule, N_2 .

.....
.....

[1]

(b) Under conditions of high temperature, nitrogen and oxygen react together to give oxides of nitrogen.

(i) Write an equation for a possible reaction between nitrogen and oxygen.

.....

(ii) State **two** situations, one natural and one as a result of human activities, in which nitrogen and oxygen react together.

.....
.....

(iii) What is the main environmental effect of the presence of nitrogen oxides in the atmosphere?

.....

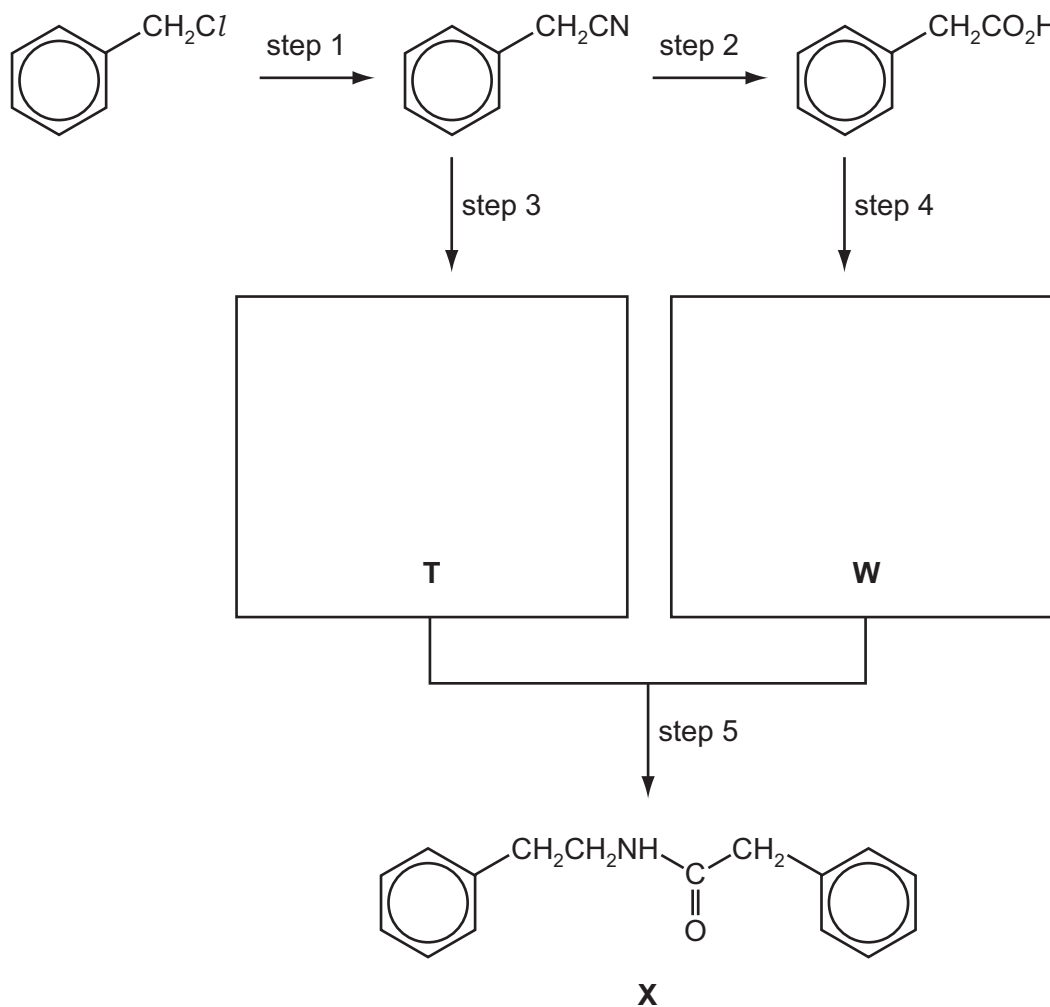
[4]

(c) Describe and explain how the basicities of ethylamine and phenylamine compare to that of ammonia.

.....
.....
.....
.....
.....

[4]

- (d) Compound **X** is a useful intermediate in the synthesis of pharmaceuticals.
X can be synthesised from chloromethylbenzene according to the following scheme.



- (i) What *type of reaction* is each of the following?

step 1

step 2

- (ii) Suggest reagents and conditions for

step 1, ...

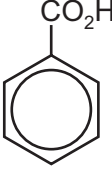
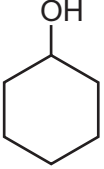
step 2.

- (iii) Draw the structures of the intermediates **T** and **W** in the boxes above.

[6]

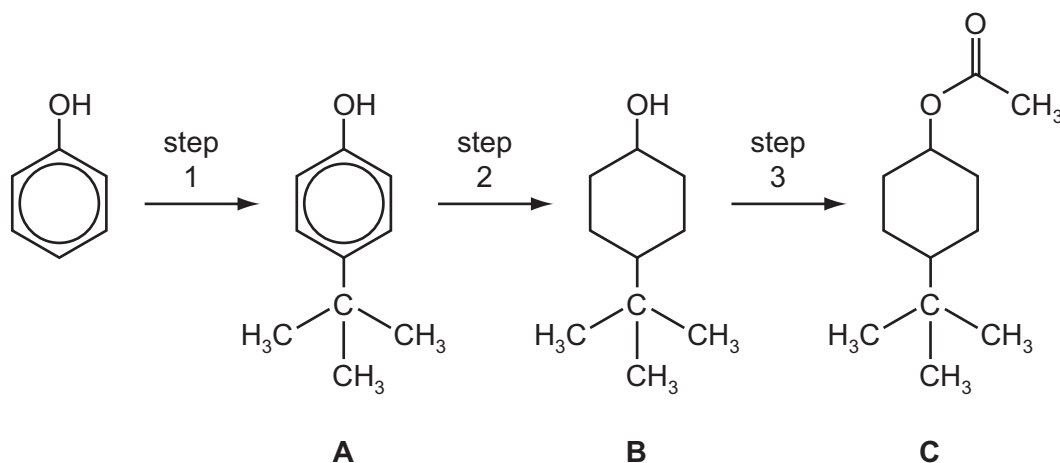
[Total: 15]

- 5 (a) A series of experiments is carried out in which the reagent shown at the top of the column of the table is mixed, in turn, with each of the reagents at the side. Complete the following table by writing in each box the formula of any gas produced. Write **x** in the box if no gas is produced. The first column has been completed as an illustration.

	H_2O			
Na	H_2			
KOH(aq)	x			
$\text{Na}_2\text{CO}_3(\text{aq})$	x			

[5]

- (b) Compound **C** is responsible for the pleasant aroma of apples. It can be prepared from phenol by the following 3-step synthesis.



- (i) The only by-product of step 1 is HCl . Suggest the reagent that was used to react with phenol to produce compound **A**.
-
- (ii) What *type of reaction* is occurring in step 2?
-
- (iii) What reagents and conditions are required for step 3?
-
- (iv) State the reagent and conditions needed to convert **C** back to **B**, the reverse of step 3.
-

[5]

- (c) (i) Either compound **A** or compound **B**, or both, react with the following reagents. For each reagent draw the structure of the organic product formed with **A**, and with **B**. If no reaction occurs, write 'no reaction' in the relevant box.

reagent and conditions	product with A	product with B
an excess of $\text{Br}_2(\text{aq})$		
heat with HBr		
pass vapour over heated Al_2O_3		
heat with acidified $\text{K}_2\text{Cr}_2\text{O}_7$		

- (ii) Choose **one** of the above reactions to enable you to distinguish between **A** and **B**.

State below the observations you would make with each compound.

reagent	observation with A	observation with B

[7]

[Total: 17]

Section B

For
Examiner's
UseAnswer **all** the questions in the spaces provided.

- 6 There are two important polymerisations that occur within living organisms – protein synthesis and the formation of DNA.

- (a) Complete the table placing a tick (✓) in the correct column to indicate in which process each substance could be used.

substance	protein synthesis	formation of DNA
adenine		
alanine		
aspartate		
phosphate		

[3]

- (b) Proteins and DNA form different helical structures. Briefly describe the bonding that maintains the shape of each of these helical structures.

protein

.....

.....

DNA

.....

.....

[4]

- (c) Describe the differences in bonding in the *primary* and *tertiary* structures of proteins. Your answer should include reference both to the nature of the bonding and the types of amino acid causing it.

.....

.....

.....

.....

.....

[3]

[Total: 10]

- 7 Modern methods of analysis have had far-reaching effects on a number of branches of science including medicine, forensic science, environmental monitoring and archaeology.

(a) Outline, in simple terms, the technique of DNA fingerprinting.

.....

.....

.....

.....

.....

.....

[4]

(b) Complete the table by indicating whether the items can be used for DNA fingerprinting. Use a tick (✓) for items which can be used for DNA fingerprinting and a cross (x) for items which cannot.

item for testing	suitable for DNA fingerprinting
human hair	
piece of a flint tool	
piece of Iron Age pot	
piece of Roman leather	

[3]

(c) Various forms of chromatography can be used to separate and analyse mixtures. HPLC (high performance liquid chromatography) can be used to separate each of the following mixtures. State another method of chromatography which would separate each mixture.

insecticides in a sample of water

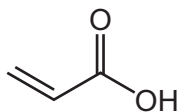
dyes present in a foodstuff

drug residue in an athlete's urine

[3]

[Total: 10]

- 8 In recent years there has been a lot of interest in polymers in the form of gels that absorb aqueous materials. One of the largest uses of these polymers is in disposable nappies (diapers). The gel which is used in this case is a polymer of propenoic acid.



propenoic acid

- (a) (i) Draw a section of the polymer of propenoic acid showing **two** repeat units.

- (ii) By what type of chemical reaction is this polymer formed?

.....

- (iii) By what type of bonding is water held on the polymer?

.....

[3]

- (b) For some disposable nappies (diapers), the monomer is a mixture of propenoic acid and sodium propenoate. The properties of the polymer are influenced by the proportion of sodium salt in the monomer mixture.

- (i) Suggest and explain how the difference in the structure of this polymer compared to one formed only from propenoic acid might affect the water absorbing properties of the polymer.

.....

.....

.....

- (ii) Suggest a property the polymer should have in order to be used in disposable products.

.....

[3]

- (c) A variation on the gel used for disposable nappies (diapers) containing more sodium propenoate has been used to treat soils contaminated by heavy metals such as lead (Pb^{2+}) and cadmium (Cd^{2+}). Suggest why the gel is effective.

.....

.....

.....

[2]

- (d) Another variation on this type of polymer is used in hair gels. In these, the polymer chains are cross-linked by a compound known as pentaerythritol.



pentaerythritol

- (i) By what type of chemical reaction are the cross-links in this polymer formed?

.....

- (ii) It is important that the gel should be easily washed out of hair. What is it about the structure of the polymer that allows this to happen?

.....

[2]

[Total: 10]

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CHEMISTRY

9701/42

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2 hours

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For Examiner's Use

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Total	

This document consists of **16** printed pages and **4** blank pages.



Section A

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

For
Examiner's
Use

- 1 A bromoalkane, R–Br, is hydrolysed by aqueous sodium hydroxide.

(a) (i) Write a balanced equation for this reaction.

.....

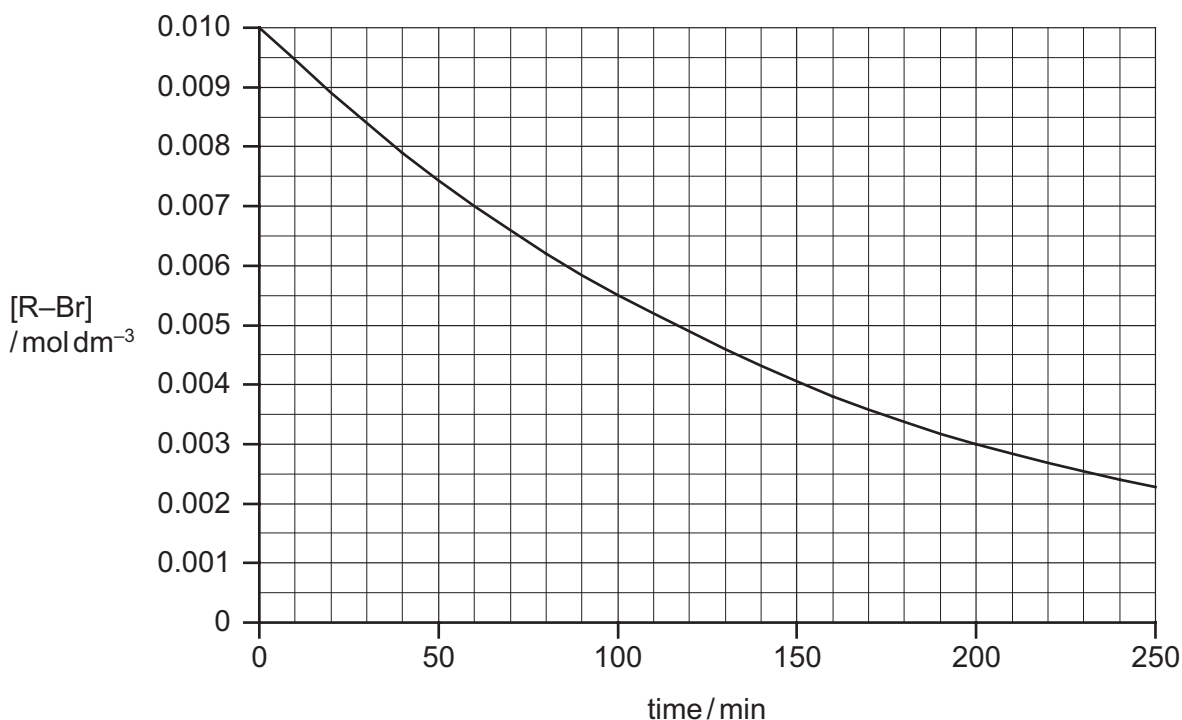
(ii) What *type of reaction* is this?

.....

[2]

- (b) The concentration of bromoalkane was determined at regular time intervals as the reaction progressed.

Two separate experiments were carried out, with different NaOH concentrations. The graph below shows the results of an experiment using $[\text{NaOH}] = 0.10 \text{ mol dm}^{-3}$.



When the experiment was repeated using $[\text{NaOH}] = 0.15 \text{ mol dm}^{-3}$, the following results were obtained.

time / min	$[\text{R-Br}] / \text{mol dm}^{-3}$
0	0.0100
40	0.0070
80	0.0049
120	0.0034
160	0.0024
200	0.0017
240	0.0012

- (i) Plot these data on the axes above, and draw a line of best fit.

- (ii) Use one of the graphs to confirm that the reaction is first order with respect to R–Br. Show all your working, and show clearly any construction lines you draw.

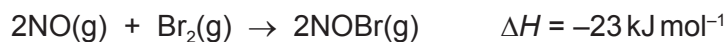
- (iii) Use the graphs to calculate the order of reaction with respect to NaOH. Show all your working, and show clearly any construction lines you draw on the graphs.

- (iv) Write the rate equation for this reaction, and calculate the value of the rate constant.

rate =

[7]

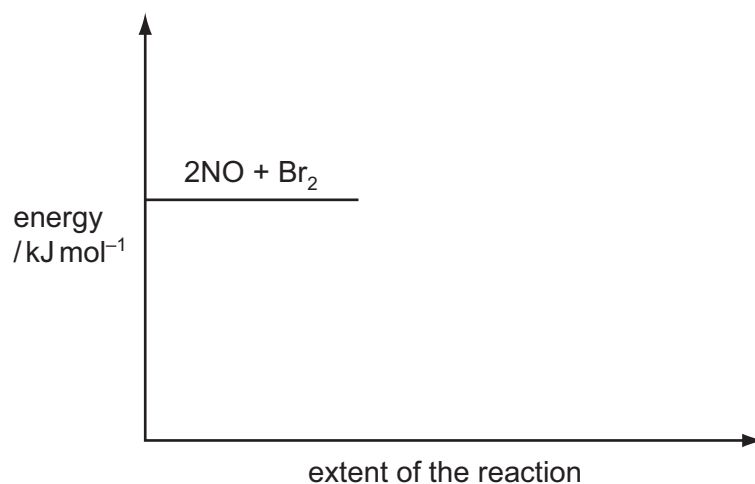
- (c) Nitric oxide, NO, and bromine vapour react together according to the following equation.



The reaction has an activation energy of +5.4 kJ mol⁻¹.

Use the following axes to sketch a fully-labelled reaction pathway diagram for this reaction.

Include all numerical data on your diagram.



[2]

[Total: 11]

- 2 (a) (i) With the aid of a fully-labelled diagram, describe the standard hydrogen electrode.

- (ii) Use the *Data Booklet* to calculate the standard cell potential for the reaction between Cr^{2+} ions and $\text{Cr}_2\text{O}_7^{2-}$ ions in acid solution, and construct a balanced equation for the reaction.

$$E_{\text{cell}}^{\circ} = \dots\dots\dots \text{V}$$

equation

- (iii) Describe what you would see if a blue solution of Cr^{2+} ions was added to an acidified solution of $\text{Cr}_2\text{O}_7^{2-}$ ions until reaction was complete.

.....
.....

[8]

- (b) A buffer solution is to be made using 1.00 mol dm^{-3} ethanoic acid, $\text{CH}_3\text{CO}_2\text{H}$, and 1.00 mol dm^{-3} sodium ethanoate, $\text{CH}_3\text{CO}_2\text{Na}$.

Calculate to the nearest 1 cm^3 the volumes of each solution that would be required to make 100 cm^3 of a buffer solution with pH 5.50.

Clearly show all steps in your working.

$$K_a(\text{CH}_3\text{CO}_2\text{H}) = 1.79 \times 10^{-5} \text{ mol dm}^{-3}$$

volume of $1.00 \text{ mol dm}^{-3} \text{ CH}_3\text{CO}_2\text{H} = \dots\dots\dots \text{cm}^3$

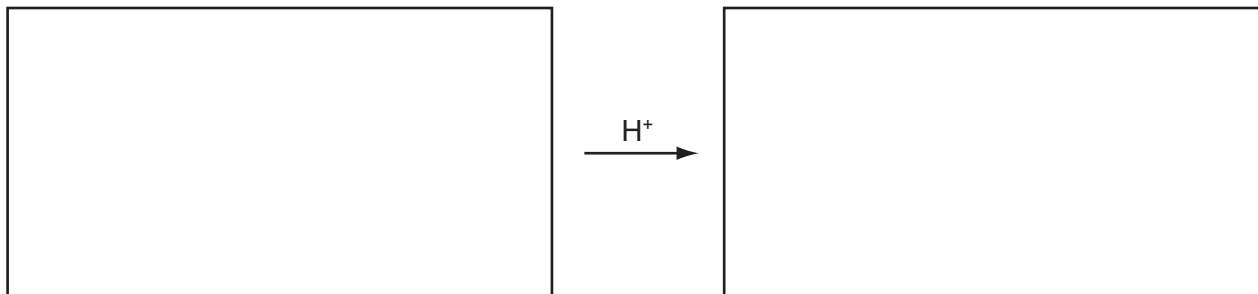
volume of $1.00 \text{ mol dm}^{-3} \text{ CH}_3\text{CO}_2\text{Na} = \dots\dots\dots \text{cm}^3$
[4]

- (c) Write an equation to show the reaction of this buffer solution with each of the following.

(i) added HCl

(ii) added NaOH
[2]

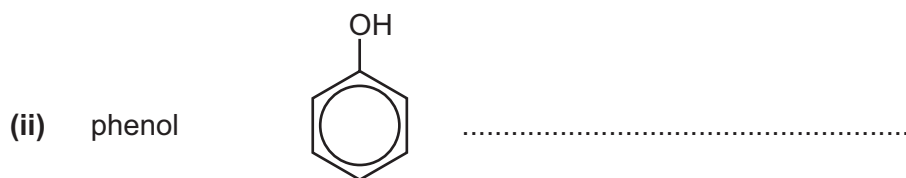
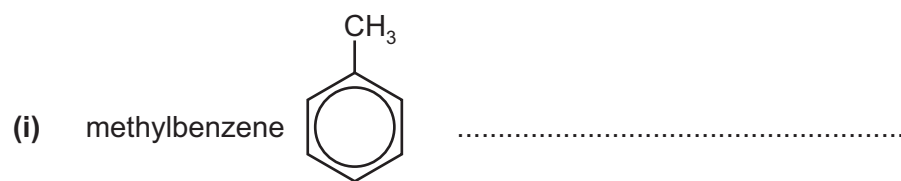
- (d) Choose **one** reaction in organic chemistry that is catalysed by an acid, and write the structural formulae of the reactants and products in the boxes below.



[3]

[Total: 17]

- 3 (a) Describe the reagents and conditions required to form a nitro compound from the following.

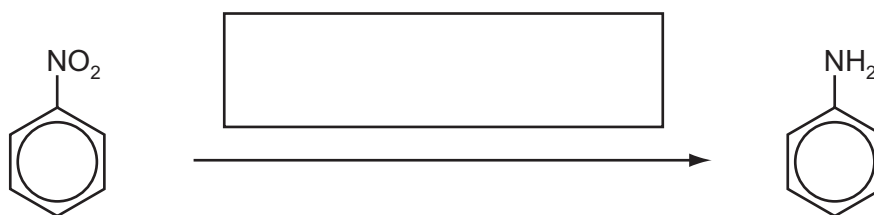


[3]

- (b) Draw the structure of the intermediate organic ion formed during the nitration of benzene.

[1]

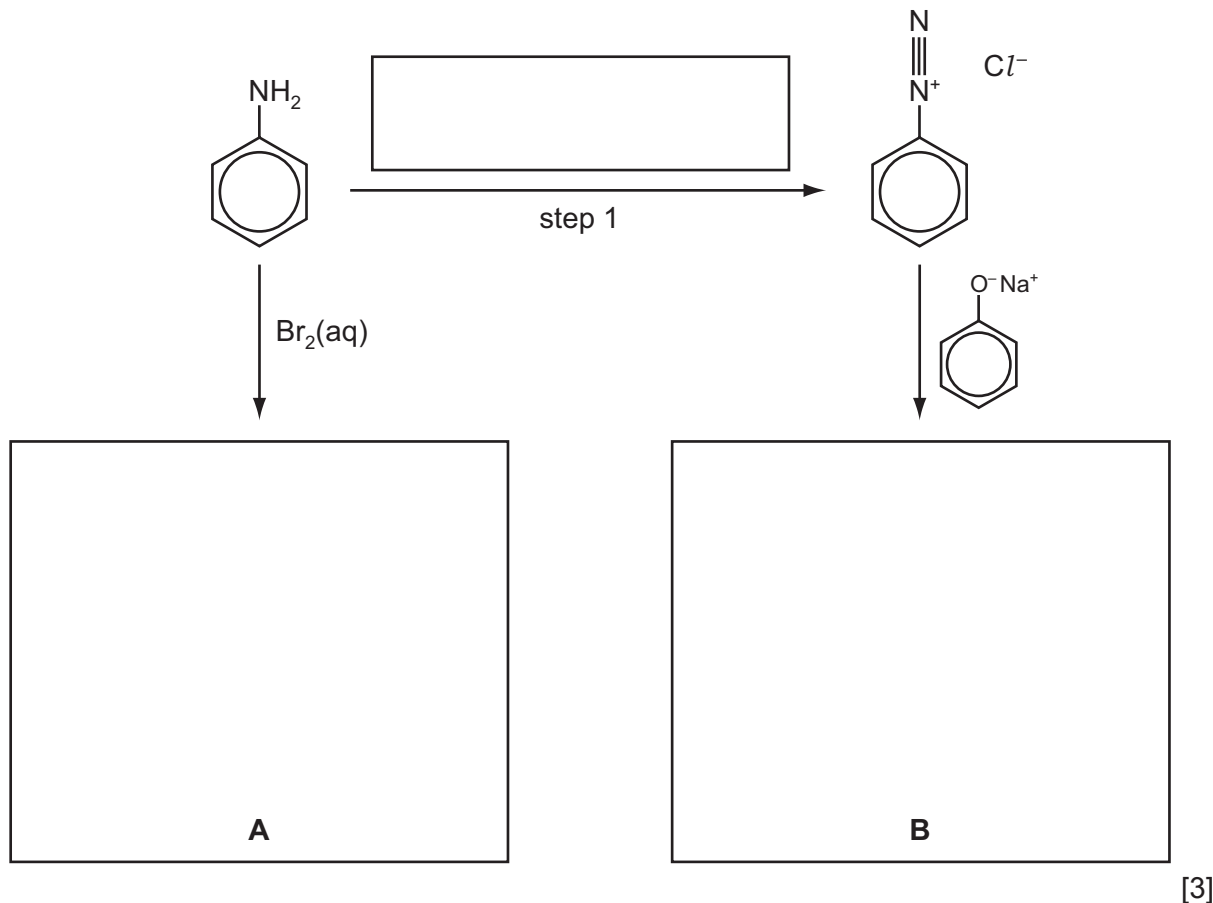
- (c) In the box over the arrow below, write the reagents needed to convert nitrobenzene into phenylamine.



[1]

(d) Phenylamine can be converted into the organic compounds **A** and **B**.

- (i) Suggest the structural formulae of **A** and **B** in the boxes below.
- (ii) Suggest suitable reagents and conditions for step 1, and write them in the box over the arrow.



[3]

(e) When phenylamine is treated with propanoyl chloride a white crystalline compound, **C**, $\text{C}_9\text{H}_{11}\text{NO}$, is formed.

- (i) Name the functional group formed in this reaction.
- (ii) Calculate the percentage by mass of nitrogen in **C**.

percentage = ... %

(iii) Draw the structural formula of **C**.

[3]

[Total: 11]

- 4 (a) (i) Suggest why transition elements show variable oxidation states in their compounds whereas s-block elements like calcium do not.

.....

- (ii) Calculate the oxidation number of the metal in each of the following ions.

VO_2^+

CrF_6^{2-}

MnO_4^{2-}

[4]

- (b) Explain why transition element complexes are often coloured whereas compounds of s-block elements such as calcium and sodium are not.

.....

[4]

- (c) SO_2 and MnO_4^- react together in acidic solution.

- (i) Use the *Data Booklet* to construct a balanced equation for this reaction.

.....

- (ii) Describe the colour change you would see when $\text{SO}_2(\text{aq})$ is added to a sample of acidified KMnO_4 until the SO_2 is in excess.

from to

[3]

- (d) Describe the observations you would make when $\text{NH}_3(\text{aq})$ is added gradually to a solution containing Cu^{2+} ions, until the NH_3 is in an excess.

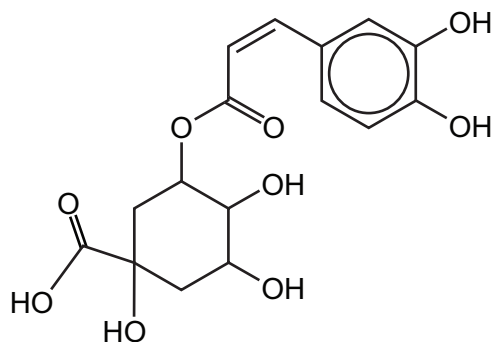
.....

[3]

[Total: 14]

5 Coffee beans contain chlorogenic acid.

For
Examiner's
Use



chlorogenic acid

(a) (i) Draw circles around any chiral centres in the above structure.

(ii) Write down the molecular formula of chlorogenic acid.

.....

(iii) How many moles of $\text{H}_2(\text{g})$ will be evolved when 1 mol of chlorogenic acid reacts with an excess of sodium metal?

.....

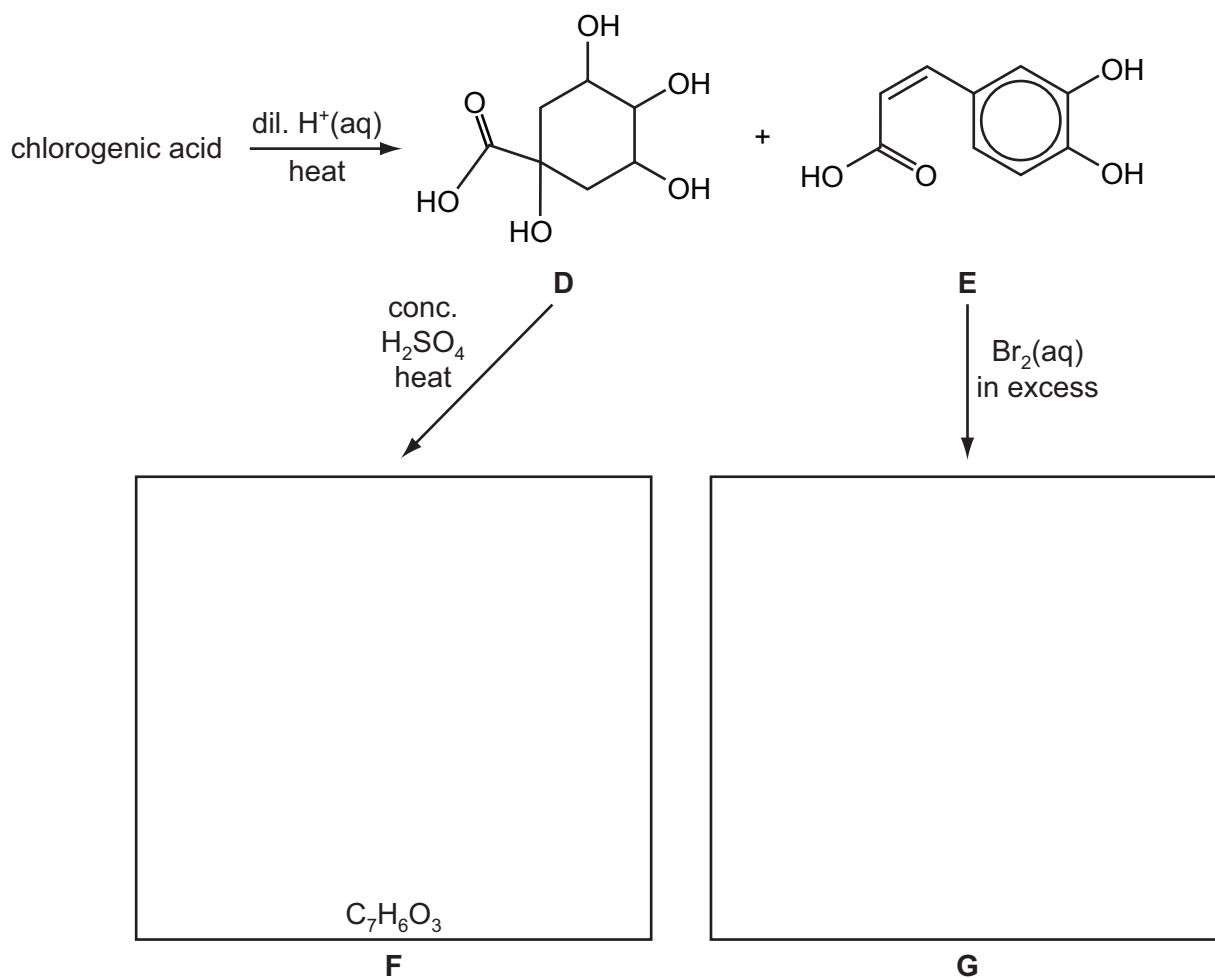
(iv) How many moles of $\text{NaOH}(\text{aq})$ will react with 1 mol of chlorogenic acid under each of the following conditions?

in the cold

on heating

[6]

- (b) On heating with dilute aqueous acid, chlorogenic acid produces two compounds, **D** and **E**.



- (i) What *type of reaction* is chlorogenic acid undergoing when **D** and **E** are formed?

.....

When compound **D** is heated with concentrated H₂SO₄, compound **F**, C₇H₆O₃, is formed.

Compound **F** evolves CO₂(g) when treated with Na₂CO₃(aq), and decolourises Br₂(aq), giving a white precipitate. It does not, however, decolourise cold dilute acidified KMnO₄.

When compound **E** is treated with an excess of Br₂(aq), compound **G** is produced.

- (ii) If the test with cold dilute acidified KMnO₄ had been positive, which functional group would this have shown to be present in **F**?

.....

- (iii) **Name** the functional groups in compound **F** that would react with the following.

Na₂CO₃(aq) Br₂(aq)

- (iv) Suggest structures for compounds **F** and **G** and draw them in the relevant boxes above.

- (v) Compound **E** is one of a pair of stereoisomers.

What type of stereoisomerism is shown by compound **E**?

.....

- (vi) Draw the structure of the other stereoisomer in the box below.



[8]

- (c) Calculate the volume of 0.1 mol dm^{-3} NaOH that is needed to react completely with 0.1 g of compound **E**.

volume = ... cm^3
[3]

[Total: 17]

Section B

For
Examiner's
UseAnswer **all** the questions in the spaces provided.

- 6 There are two important polymerisations that occur within living organisms – protein synthesis and the formation of DNA.

- (a) Complete the table by placing a tick (✓) in the correct column to indicate in which process each substance could be used.

substance	protein synthesis	formation of DNA
cysteine		
cytosine		
glutamine		
guanine		

[3]

- (b) DNA consists of a double helical structure.

- (i) Describe the bonding between the two strands in DNA and state which part of each strand is joined by it.

.....

.....

- (ii) How does the strength of this bonding relate to the mechanism of the replication of DNA?

.....

.....

[4]

- (c) Some diseases are caused by changes in the structure of proteins. Explain the genetic basis of these changes.

.....

.....

.....

.....

[3]

[Total: 10]

- 7 The techniques of mass spectrometry and NMR spectroscopy are useful in determining the structures of organic compounds.

(a) The three peaks of highest mass in the mass spectrum of organic compound **L** correspond to masses of 142, 143 and 144.

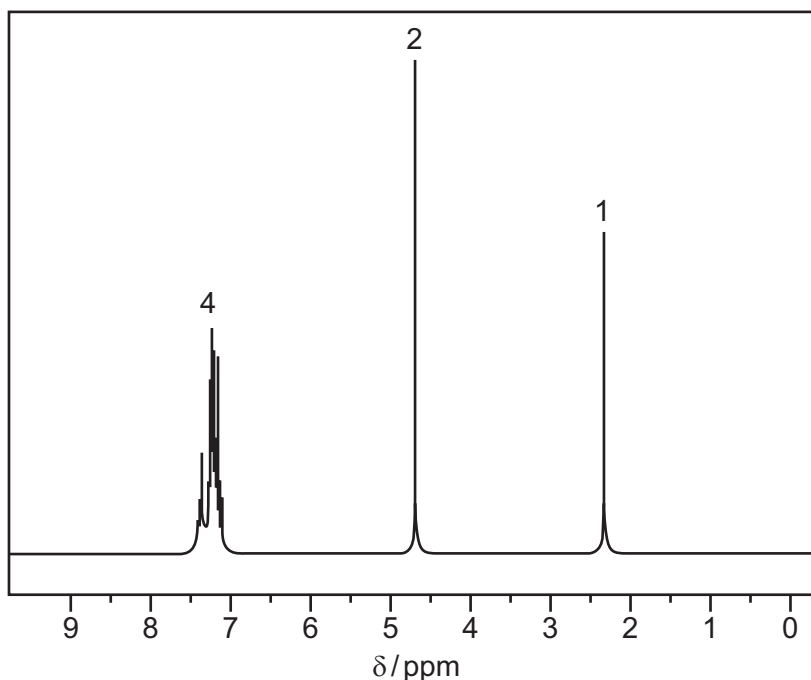
The ratio of the heights of the $M:M+1$ peaks is 43.3:3.35, and the ratio of heights of the $M:M+2$ peaks is 43.3:14.1.

(i) Use the data to calculate the number of carbon atoms present in **L**.

(ii) Explain what element is indicated by the $M+2$ peak.

.....
.....

Compound **L** reacts with sodium metal. The NMR spectrum of compound **L** is given below.



(iii) What does the NMR spectrum tell you about the number of protons in **L** and their chemical environments?

.....
.....

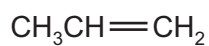
- (iv) Use the information given and your answers to (i), (ii) and (iii) to deduce a structure for **L**.
Explain how you arrive at your answer.

structure of **L**

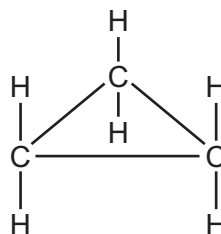


[7]

- (b) The molecular formula C_3H_6 represents the compounds propene and cyclopropane.



propene



cyclopropane

- (i) Suggest **one** difference in the fragmentation patterns of the mass spectra of these compounds.

.....

- (ii) Suggest **two** differences in the NMR spectra of these compounds.

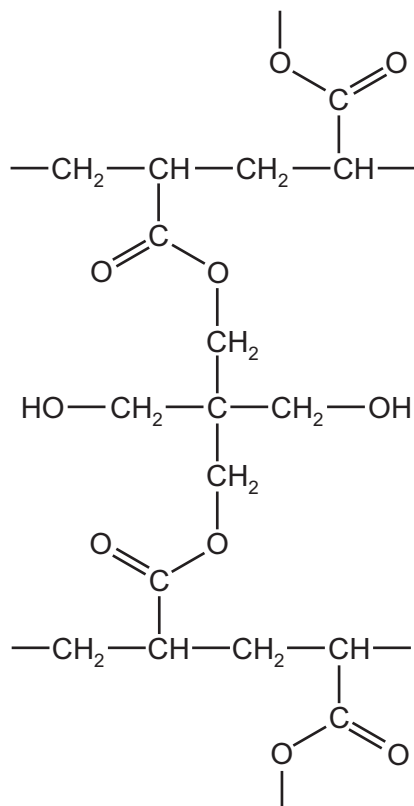
.....

[3]

[Total: 10]

- 8 In recent years there has been considerable interest in a range of polymers known as 'hydrogels'. These polymers are hydrophilic and can absorb large quantities of water.

(a) The diagram shows part of the structure of a hydrogel.



The hydrogel is formed from chains of one polymer which are cross-linked using another molecule.

(i) Draw the structure of the monomer used in the polymer chains.

(ii) State the type of polymerisation used to form these chains.

.....

.....

(iii) Draw the structure of the molecule used to cross-link the polymer chains.

- (iv) During the cross-linking, a small molecule is formed as a by-product. Identify this molecule.

.....
[5]

- (b) Once a hydrogel has absorbed water, it can be dried and re-used many times. Explain why this is possible, referring to the structure on the opposite page.

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

- (c) Not every available side chain in the polymer is cross-linked, and the amount of cross-linking affects the properties of the hydrogel.

- (i) The amount of cross-linking has little effect on the ability of the gel to absorb water. Suggest why this is the case.

.....
.....
.....

- (ii) Suggest **one** property of the hydrogel that will change if more cross-linking takes place. Explain how the increased cross-linking brings about this change.

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

[Total: 10]

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CHEMISTRY

9701/43

Paper 4 Structured Questions

May/June 2013

2 hours

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 soft 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.

Electronic calculators may be used.

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	
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7	
8	
Total	

This document consists of **15** printed pages and **1** blank page.



Section A

For
Examiner's
UseAnswer **all** the questions in the spaces provided.

- 1 (a) What is meant by the term *standard electrode potential*, SEP?

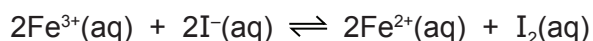
.....

[2]

- (b) Draw a fully labelled diagram of the apparatus you could use to measure the SEP of the $\text{Fe}^{3+}/\text{Fe}^{2+}$ electrode.

[5]

- (c) The reaction between Fe^{3+} ions and I^- ions is an equilibrium reaction.



- (i) Use the *Data Booklet* to calculate the $E_{\text{cell}}^{\ominus}$ for this reaction.

.....

- (ii) Hence state, with a reason, whether there will be more products or more reactants at equilibrium.

.....

- (iii) Write the expression for K_c for this reaction, and state its units.

$$K_c =$$

units

An experiment was carried out using solutions of $\text{Fe}^{3+}(\text{aq})$ and $\text{I}^{-}(\text{aq})$ of equal concentrations. 100 cm^3 of each solution were mixed together, and allowed to reach equilibrium.

The concentrations at equilibrium of $\text{Fe}^{3+}(\text{aq})$ and $\text{I}_2(\text{aq})$ were as follows.

$$[\text{Fe}^{3+}(\text{aq})] = 2.0 \times 10^{-4} \text{ mol dm}^{-3}$$

$$[\text{I}_2(\text{aq})] = 1.0 \times 10^{-2} \text{ mol dm}^{-3}$$

- (iv) Use these data, together with the equation given in (c), to calculate the concentrations of $\text{Fe}^{2+}(\text{aq})$ and $\text{I}^{-}(\text{aq})$ at equilibrium.

$$[\text{Fe}^{2+}(\text{aq})] = \dots\dots\dots \text{mol dm}^{-3}$$

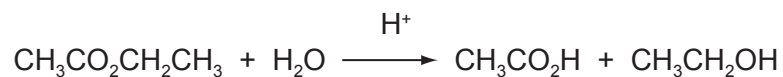
$$[\text{I}^{-}(\text{aq})] = \dots\dots\dots \text{mol dm}^{-3}$$

- (v) Calculate the K_c for this reaction.

$$K_c = \dots\dots\dots [8]$$

[Total: 15]

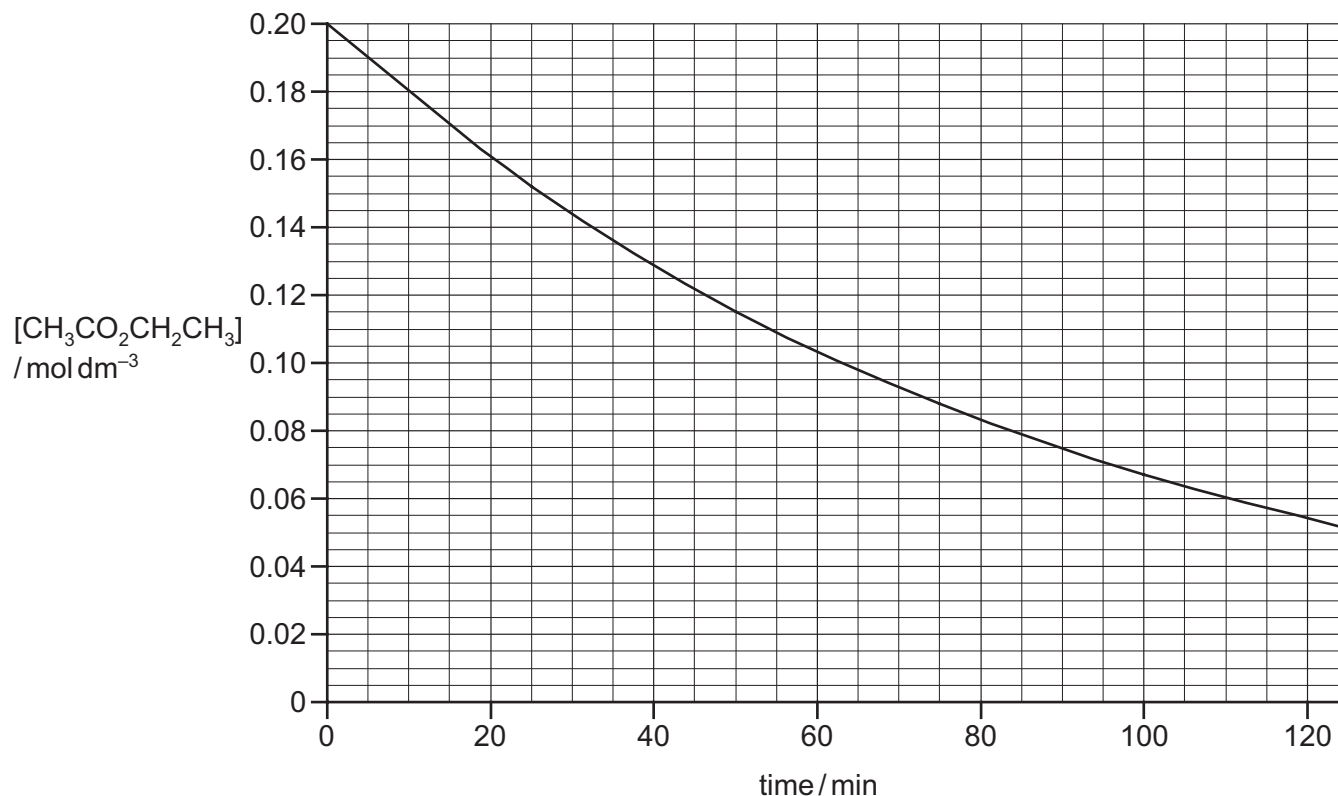
- 2 Ethyl ethanoate is hydrolysed slowly by water in the following acid-catalysed reaction.



The concentration of ethyl ethanoate was determined at regular time intervals as the reaction progressed.

Two separate experiments were carried out, with different HCl concentrations.

The following graph shows the results of an experiment using $[\text{HCl}] = 0.1 \text{ mol dm}^{-3}$.



- (a) When the experiment was carried out using $[\text{HCl}] = 0.2 \text{ mol dm}^{-3}$, the following results were obtained.

time / min	$[\text{CH}_3\text{CO}_2\text{CH}_2\text{CH}_3] / \text{mol dm}^{-3}$
0	0.200
10	0.160
25	0.115
50	0.067
75	0.038
100	0.022
125	0.013

- (i) Plot these data on the axes above, and draw a line of best fit.

- (ii) Use one of the graphs to show that the reaction is first order with respect to $\text{CH}_3\text{CO}_2\text{CH}_2\text{CH}_3$.

Show all your working, and show clearly any construction lines you draw on the graphs.

- (iii) Use the graphs to calculate the order of reaction with respect to HCl .

Show all your working, and show clearly any construction lines you draw on the graphs.

- (iv) Write the rate equation for this reaction, and calculate the value of the rate constant.

rate =

[7]

- (b) (i) Why is it **not** possible to determine the order of reaction with respect to water in this experiment?

.....
.....

- (ii) Although $[\text{CH}_3\text{CO}_2\text{CH}_2\text{CH}_3]$ decreases during each experiment, $[\text{HCl}]$ remains the same as its initial value.

Why is this?

.....
.....

[2]

[Total: 9]

3 (a) (i) What is meant by the *density* of a substance?

.....

(ii) Use data from the *Data Booklet* to explain why the density of iron is greater than that of calcium.

.....

.....

.....

[3]

(b) In general, reactions of the compounds of transition elements can be classified under one or more of the following headings.

acid-base

ligand exchange

precipitation

redox

Choose the most suitable heading to describe each of the following reactions, by placing a tick (✓) in the appropriate column in the table below.

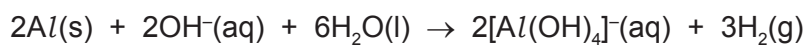
Only one tick should be placed against each reaction.

reaction	acid-base	ligand exchange	precipitation	redox
$[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{NH}_3 \rightarrow [\text{Cu}(\text{NH}_3)_4]^{2+} + 6\text{H}_2\text{O}$				
$[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{HCl} \rightarrow [\text{CuCl}_4]^{2-} + 4\text{H}^+ + 6\text{H}_2\text{O}$				
$2\text{FeCl}_2 + \text{Cl}_2 \rightarrow 2\text{FeCl}_3$				
$[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow \text{Fe}(\text{OH})_2 + 6\text{H}_2\text{O}$				
$2\text{Fe}(\text{OH})_2 + \frac{1}{2}\text{O}_2 + \text{H}_2\text{O} \rightarrow 2\text{Fe}(\text{OH})_3$				
$\text{CrO}_3 + 2\text{HCl} \rightarrow \text{CrO}_2\text{Cl}_2 + \text{H}_2\text{O}$				
$\text{Cr}(\text{H}_2\text{O})_3(\text{OH})_3 + \text{OH}^- \rightarrow [\text{Cr}(\text{H}_2\text{O})_2(\text{OH})_4]^- + \text{H}_2\text{O}$				
$[\text{Cr}(\text{OH})_4]^- + 1\frac{1}{2}\text{H}_2\text{O}_2 + \text{OH}^- \rightarrow \text{CrO}_4^{2-} + 4\text{H}_2\text{O}$				

[8]

- (c) Alloys of aluminium, titanium and vanadium are used in aerospace and marine equipment, and in medicine.

When a powdered sample of one such alloy is heated with an excess of aqueous NaOH, only the aluminium reacts, according to the following equation.



Reacting 100 g of alloy in this way produced 8.0 dm³ of hydrogen, measured under room conditions.

Calculate the percentage by mass of aluminium in the alloy.

percentage = ... %
[3]

[Total: 14]

- 4 Because of the lack of reactivity of the nitrogen molecule, extreme conditions need to be used to synthesise ammonia from nitrogen in the Haber process.

(a) Suggest an explanation for the lack of reactivity of the nitrogen molecule, N_2 .

.....
.....

[1]

(b) Under conditions of high temperature, nitrogen and oxygen react together to give oxides of nitrogen.

(i) Write an equation for a possible reaction between nitrogen and oxygen.

.....

(ii) State **two** situations, one natural and one as a result of human activities, in which nitrogen and oxygen react together.

.....
.....

(iii) What is the main environmental effect of the presence of nitrogen oxides in the atmosphere?

.....

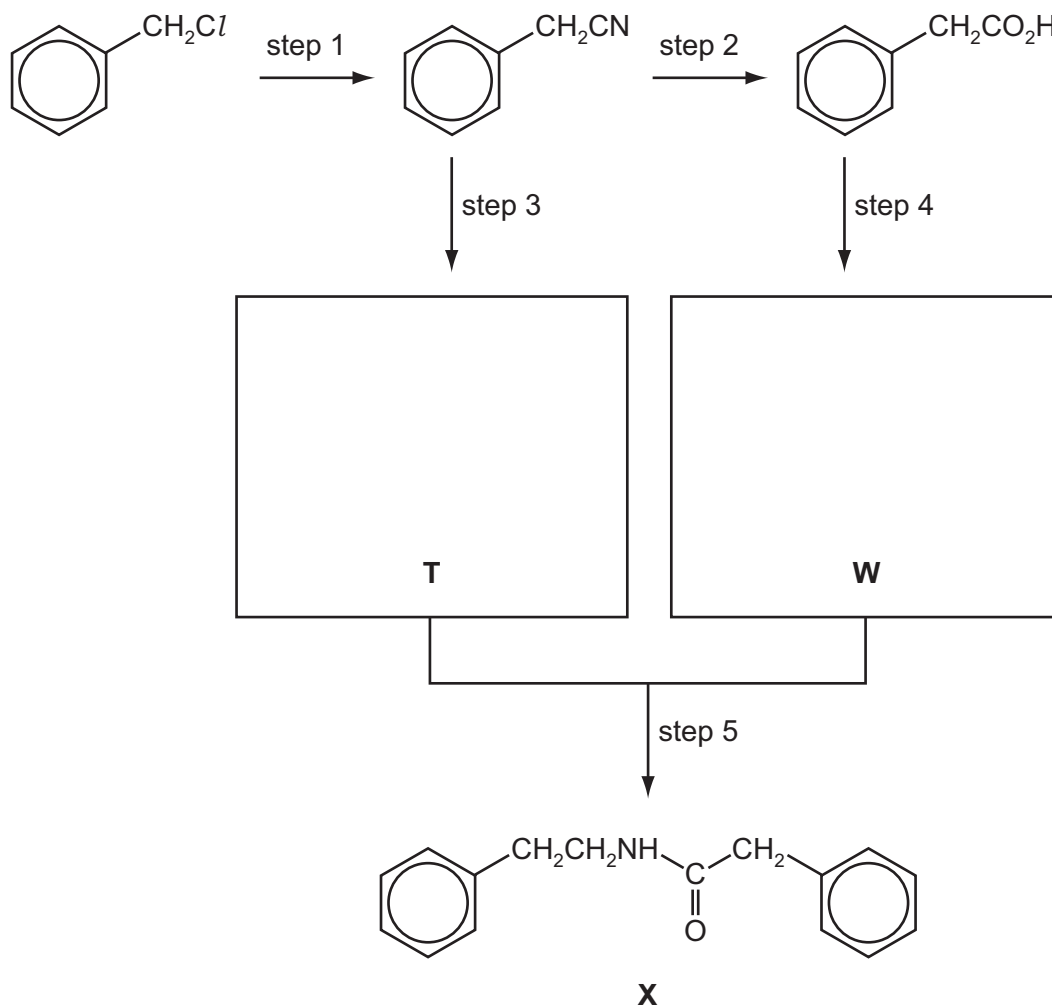
[4]

(c) Describe and explain how the basicities of ethylamine and phenylamine compare to that of ammonia.

.....
.....
.....
.....
.....

[4]

- (d) Compound **X** is a useful intermediate in the synthesis of pharmaceuticals.
X can be synthesised from chloromethylbenzene according to the following scheme.



- (i) What *type of reaction* is each of the following?

step 1

step 2

- (ii) Suggest reagents and conditions for

step 1, ...

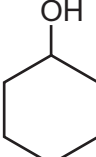
step 2.

- (iii) Draw the structures of the intermediates **T** and **W** in the boxes above.

[6]

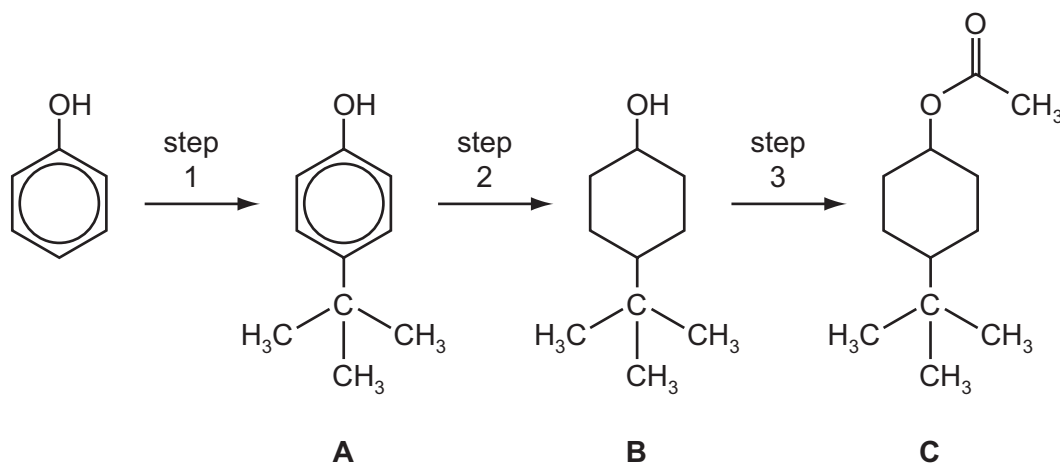
[Total: 15]

- 5 (a) A series of experiments is carried out in which the reagent shown at the top of the column of the table is mixed, in turn, with each of the reagents at the side. Complete the following table by writing in each box the formula of any gas produced. Write **x** in the box if no gas is produced. The first column has been completed as an illustration.

	H_2O			
Na	H_2			
KOH(aq)	x			
$\text{Na}_2\text{CO}_3(\text{aq})$	x			

[5]

- (b) Compound **C** is responsible for the pleasant aroma of apples. It can be prepared from phenol by the following 3-step synthesis.



- (i) The only by-product of step 1 is HCl . Suggest the reagent that was used to react with phenol to produce compound **A**.
-
- (ii) What *type of reaction* is occurring in step 2?
-
- (iii) What reagents and conditions are required for step 3?
-
- (iv) State the reagent and conditions needed to convert **C** back to **B**, the reverse of step 3.
-

[5]

- (c) (i) Either compound **A** or compound **B**, or both, react with the following reagents. For each reagent draw the structure of the organic product formed with **A**, and with **B**. If no reaction occurs, write 'no reaction' in the relevant box.

reagent and conditions	product with A	product with B
an excess of $\text{Br}_2(\text{aq})$		
heat with HBr		
pass vapour over heated Al_2O_3		
heat with acidified $\text{K}_2\text{Cr}_2\text{O}_7$		

- (ii) Choose **one** of the above reactions to enable you to distinguish between **A** and **B**.

State below the observations you would make with each compound.

reagent	observation with A	observation with B

[7]

[Total: 17]

Section B

For
Examiner's
UseAnswer **all** the questions in the spaces provided.

- 6 There are two important polymerisations that occur within living organisms – protein synthesis and the formation of DNA.

- (a) Complete the table placing a tick (✓) in the correct column to indicate in which process each substance could be used.

substance	protein synthesis	formation of DNA
adenine		
alanine		
aspartate		
phosphate		

[3]

- (b) Proteins and DNA form different helical structures. Briefly describe the bonding that maintains the shape of each of these helical structures.

protein

.....

.....

DNA

.....

.....

[4]

- (c) Describe the differences in bonding in the *primary* and *tertiary* structures of proteins. Your answer should include reference both to the nature of the bonding and the types of amino acid causing it.

.....

.....

.....

.....

.....

[3]

[Total: 10]

- 7 Modern methods of analysis have had far-reaching effects on a number of branches of science including medicine, forensic science, environmental monitoring and archaeology.

(a) Outline, in simple terms, the technique of DNA fingerprinting.

.....

.....

.....

.....

.....

.....

[4]

(b) Complete the table by indicating whether the items can be used for DNA fingerprinting. Use a tick (✓) for items which can be used for DNA fingerprinting and a cross (x) for items which cannot.

item for testing	suitable for DNA fingerprinting
human hair	
piece of a flint tool	
piece of Iron Age pot	
piece of Roman leather	

[3]

(c) Various forms of chromatography can be used to separate and analyse mixtures. HPLC (high performance liquid chromatography) can be used to separate each of the following mixtures. State another method of chromatography which would separate each mixture.

insecticides in a sample of water

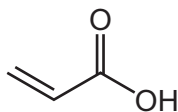
dyes present in a foodstuff

drug residue in an athlete's urine

[3]

[Total: 10]

- 8 In recent years there has been a lot of interest in polymers in the form of gels that absorb aqueous materials. One of the largest uses of these polymers is in disposable nappies (diapers). The gel which is used in this case is a polymer of propenoic acid.



propenoic acid

- (a) (i) Draw a section of the polymer of propenoic acid showing **two** repeat units.

- (ii) By what type of chemical reaction is this polymer formed?

.....

- (iii) By what type of bonding is water held on the polymer?

.....

[3]

- (b) For some disposable nappies (diapers), the monomer is a mixture of propenoic acid and sodium propenoate. The properties of the polymer are influenced by the proportion of sodium salt in the monomer mixture.

- (i) Suggest and explain how the difference in the structure of this polymer compared to one formed only from propenoic acid might affect the water absorbing properties of the polymer.

.....

.....

.....

- (ii) Suggest a property the polymer should have in order to be used in disposable products.

.....

[3]

- (c) A variation on the gel used for disposable nappies (diapers) containing more sodium propenoate has been used to treat soils contaminated by heavy metals such as lead (Pb^{2+}) and cadmium (Cd^{2+}). Suggest why the gel is effective.

.....

.....

.....

[2]

- (d) Another variation on this type of polymer is used in hair gels. In these, the polymer chains are cross-linked by a compound known as pentaerythritol.



pentaerythritol

- (i) By what type of chemical reaction are the cross-links in this polymer formed?

.....

- (ii) It is important that the gel should be easily washed out of hair. What is it about the structure of the polymer that allows this to happen?

.....

[2]

[Total: 10]

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