Cambridge Assessment

A Level

Chemistry A

Session:	2010 June
Type:	Question paper
Code:	H034-H434
Units:	F321; F322; F324; F325

THIS IS A NEW SPECIFICATION

OCR
RECOGNISING ACHIEVEMENT

ADVANCED SUBSIDIARY GCE

CHEMISTRY A

Atoms, Bonds and Groups

F321

Candidates answer on the Question Paper

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

Other Materials Required:
- Scientific calculator

Friday 21 May 2010
Afternoon

Duration: 1 hour

OCE/22845

F321

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. If additional space is required, you should use the lined pages at the end of this booklet. The question number(s) must be clearly shown.

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 A* 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 **60**.
- This document consists of **16** pages. Any blank pages are indicated.

Answer **all** the questions.

1 Tin mining was common practice on Dartmoor in pre-Roman times. Most of the tin extracted was mixed with copper to produce bronze.

(a) The table below shows the sub-atomic particles of an isotope of tin.

isotope	protons	neutrons	electrons
^{118}Sn			

(i) Complete the table. **[1]**

(ii) In terms of sub-atomic particles, how would atoms of ^{120}Sn differ from atoms of ^{118}Sn?

.....

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

(b) The relative atomic mass of tin is 118.7.

Define the term *relative atomic mass*.

.....

.....

.....

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

(c) A bronze-age shield found on Dartmoor contained 2.08 kg of tin.

Calculate the number of tin atoms in this bronze shield.
Give your answer to **three** significant figures.

answer = ... **[2]**

(d) Tin ore, known as cassiterite, contains an oxide of tin. This oxide contains 78.8% tin by mass. Calculate the empirical formula of this oxide. You must show your working.

answer = ... **[2]**

[Total: 9]

2 Chemicals called 'acids' have been known throughout history. The word acid comes from the Latin 'acidus' meaning sour. Dilute sulfuric acid, H_2SO_4, is a common laboratory acid.

(a) (i) State the formulae of two ions released when sulfuric acid is in aqueous solution.

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

(ii) A student adds a sample of solid potassium carbonate, K_2CO_3, to an excess of dilute sulfuric acid.

Describe what the student would **see** and write the equation for the reaction which takes place.

.....

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

(b) Dilute sulfuric acid reacts with alkalis such as sodium hydroxide.

Solid sodium hydroxide is known as caustic soda. It has a household use as a drain cleaner.

A student believes a box of caustic soda has been accidentally contaminated.

- To prove this, the student dissolves 2.00 g of the impure caustic soda in water and the solution is made up to 250 cm^3.
- 25.0 cm^3 of this solution of caustic soda is neutralised by 24.60 cm^3 of 0.100 mol dm^{-3} dilute sulfuric acid.

$$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

(i) Calculate the amount, in moles, of H_2SO_4 used.

answer = ... mol **[1]**

(ii) Determine the amount, in moles, of NaOH in the 25.0 cm^3 used.

answer = ... mol **[1]**

(iii) Calculate the percentage, by mass, of NaOH in the impure caustic soda.

answer = ... **[3]**

[Total: 10]

3 In an atom the electrons occupy sub-shells in order of increasing energy.

(a) Complete the table below to show the order in which the next two sub-shells are filled.

1s	2s	2p	3s	3p	4s		

increasing energy $\rightarrow$

[1]

(b) Sub-shells are made up of orbitals.

(i) What is meant by an *orbital*?

.....

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

(ii) State the total number of electrons occupying the p orbitals in one chlorine atom.

answer = ... **[1]**

(c) How many electrons are there in one ion of Ca^{2+}?

answer = ... **[1]**

(d) The successive ionisation energies of aluminium are shown in the table below. Some of these ionisations involve the removal of an electron from an s sub-shell.

ionisation energy / kJ mol^{-1}	578	1817	2745	11 578	14 831	18 378	23 296	27 460	31 862	38 458	42 655
ionisation number	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th

(i) State **all** the ionisation numbers that involve the removal of an electron from s sub-shells.

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

(ii) Write the equation that represents the third ionisation energy of A*l*.
Include state symbols.

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

[Total: 8]

4 In the Periodic Table, the chemistry of elements in a group can often be predicted from the chemistry of just one element in the group.

(a) Ions of Group 7 elements take part in displacement reactions. These reactions can be used to compare the reactivities of the elements within Group 7.

A student adds aqueous solutions of halogens to test-tubes containing solutions of halide ions. The resulting mixtures are then shaken with cyclohexane, an organic solvent.

One of the student's results is shown in the table.

experiment number	experiment details	colour seen within the organic solvent
1	addition of Cl_2(aq) to I^-(aq) ions	
2	addition of Cl_2(aq) to Br^-(aq) ions	orange
3	addition of Br_2(aq) to Cl^-(aq) ions	

(i) Complete the table to show the expected colours. **[2]**

(ii) Write the ionic equation for the reaction taking place in experiment 2.

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

(iii) These three experiments alone are unable to confirm the order of reactivity for Cl_2, Br_2 and I_2.

Suggest **one** further displacement reaction which could be carried out to confirm the order of reactivity of Cl_2, Br_2 and I_2.

.....

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

(b) Chlorine gas reacts with water as shown below.

$$Cl_2(g) + H_2O(l) \longrightarrow HClO(aq) + HCl(aq)$$

(i) Using oxidation numbers, explain why this reaction is an example of disproportionation.

.....

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

(ii) State **one** benefit for public health, of the reaction between chlorine gas and water.

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

(c) Group 2 elements and compounds show periodic trends. One trend is shown by the effect of heat upon Group 2 carbonates.

A student carried out an experiment to find out the volume of carbon dioxide obtained by heating a weighed sample of magnesium carbonate.

The student placed a 1.47 g sample of $MgCO_3$ into a test-tube and heated it until there was no further change in mass.

The following reaction took place.

$$MgCO_3(s) \rightarrow MgO(s) + CO_2(g)$$

(i) What type of reaction is this?

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

(ii) What volume of CO_2, in dm^3, would have been given off when measured at room temperature and pressure?

The molar mass of $MgCO_3$ = 84.3 g mol^{-1}

answer = ...dm^3 **[2]**

(iii) The student repeated the experiment a further three times, using the same number of moles of $CaCO_3$, $SrCO_3$ and $BaCO_3$.

What trend in the behaviour of the Group 2 carbonates would be observed by the student?

.....

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

[Total: 12]

5 This question is about elements in Period 2 of the Periodic Table.

(a) Lithium has a giant metallic structure and a boiling point of 1342 °C.

Describe, with the aid of a labelled diagram, the structure and bonding in lithium and explain why lithium has a high boiling point.

.....

.....

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

(b) Fluorine is a gas at room temperature and has a very low boiling point of –188 °C.

(i) Draw a '*dot-and-cross*' diagram to show the bonding in a fluorine molecule. Show the outer electrons only.

[1]

(ii) Explain why fluorine has a low boiling point.

.....

.....

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

(c) Fluorine reacts with lithium at room temperature to form a white crystalline solid, lithium fluoride. Lithium fluoride is a good conductor of electricity when molten but not when solid.

(i) Draw a '*dot-and-cross*' diagram to show the bonding in lithium fluoride.
Show the outer electrons only.

[2]

(ii) Explain why lithium fluoride conducts electricity when molten but **not** when solid.

.....

.....

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

(d) Fluorine reacts with boron, B, to form the fluoride BF_3.

(i) Suggest an equation for this reaction.

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

(ii) Name the shape of, and state the bond angles in, a BF_3 molecule.

Explain why BF_3 has this shape.

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

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

(e) Nitrogen can also form a fluoride, NF_3, which has a permanent dipole.

Explain why NF_3 has a permanent dipole.

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

(f) Describe and explain the trend in atomic radii of the elements Li to F across Period 2 of the Periodic Table.

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

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

[Total: 21]

END OF QUESTION PAPER

ADDITIONAL PAGE

If additional space is required, you should use the lined pages below. The question number(s) must be clearly shown.

ADDITIONAL PAGE

ADDITIONAL PAGE

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ADVANCED SUBSIDIARY GCE

CHEMISTRY A

Chains, Energy and Resources

F322

Candidates answer on the Question Paper

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

Other Materials Required:
- Scientific calculator

Monday 7 June 2010
Morning

Duration: 1 hour 45 minutes

OCE/22979

F322

Candidate Forename		Candidate Surname	

Centre Number						Candidate Number				

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- A copy of the *Data Sheet for Chemistry A* 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 **100**.
- This document consists of **24** pages. Any blank pages are indicated.

Answer **all** the questions.

1 The alkanes are an homologous series of hydrocarbons.
The table shows information about some straight chain alkanes.

alkane	molecular formula	boiling point / °C
methane	CH_4	–164
ethane	C_2H_6	–89
propane	C_3H_8	–42
butane	C_4H_{10}	–1

(a) (i) What is meant by an *homologous series*?

.....

.....

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

(ii) Explain why the boiling points increase down the alkane homologous series.

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

(b) Alkynes are another homologous series of hydrocarbons.
The table gives the molecular formulae of the first five straight chain alkynes.

alkyne	molecular formula
ethyne	C_2H_2
propyne	C_3H_4
but-1-yne	C_4H_6
	C_5H_8
hex-1-yne	C_6H_{10}

(i) Suggest the name of a straight chain alkyne with the molecular formula C_5H_8.

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

(ii) Deduce the general formula for an alkyne.

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

(iii) The alkynes contain the C≡C functional group.

Suggest the displayed formula for propyne.

[1]

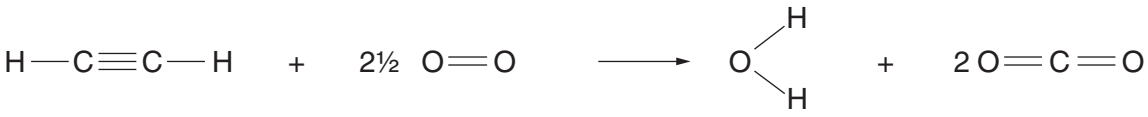
(iv) Hex-1-yne has many cyclic structural isomers.

Draw the skeletal structure of one of these cyclic structural isomers.

[1]

(c) Ethyne is commonly called acetylene.
It is used in an oxy-acetylene flame which is hot enough to cut through steel.

Ethyne completely combusts as shown in the equation below.



Calculate the enthalpy change of combustion of ethyne using the average bond enthalpies in the table below.

bond	average bond enthalpy / kJ mol^{-1}
C–H	+415
C≡C	+837
O=O	+498
C=O	+805
O–H	+464

enthalpy change of combustion = ... kJ mol^{-1} **[3]**

(d) Ethyne is formed when water reacts with calcium carbide, CaC_2.

$$CaC_2(s) + 2H_2O(l) \longrightarrow Ca(OH)_2(s) + C_2H_2(g)$$

The standard enthalpy change of this reaction can be determined indirectly using standard enthalpy changes of formation.

(i) What is meant by the term *standard enthalpy change of formation*, $\Delta H_f^{\ominus}$?
You should state the standard conditions in your answer.

.....

.....

.....

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

(ii) Standard enthalpy changes of formation are shown in the table below.

substance	**standard enthalpy change of formation, $\Delta H_f^{\ominus}$ / kJ mol^{-1}**
$CaC_2(s)$	−60
$H_2O(l)$	–286
$Ca(OH)_2(s)$	–987
$C_2H_2(g)$	+227

Calculate the standard enthalpy change of the reaction:

$$CaC_2(s) + 2H_2O(l) \longrightarrow Ca(OH)_2(s) + C_2H_2(g)$$

standard enthalpy change of reaction = ... kJ mol^{-1} **[3]**

(e) A factory makes ethyne gas from calcium carbide, CaC_2.
One of the waste products is calcium hydroxide.

$$CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2$$

Each day 1.00×10^6 grams of calcium carbide are used and 3.60×10^5 dm^3 of ethyne gas, measured at room temperature and pressure, is manufactured.

(i) Calculate the atom economy for this process using the relative formula masses in the table below.

compound	relative formula mass
CaC_2	64.1
H_2O	18.0
$Ca(OH)_2$	74.1
C_2H_2	26.0

atom economy = ……... % **[2]**

(ii) Calculate the amount, in moles, of CaC_2 used each day.

amount of CaC_2 = ……mol **[1]**

(iii) Calculate the amount, in moles, of C_2H_2 made each day.

amount of C_2H_2 = ……mol **[1]**

(iv) Calculate the percentage yield of C_2H_2.

percentage yield = …….. % **[1]**

(v) Comment on the percentage yield and the atom economy of this process in terms of sustainability.

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

[Total: 23]

2 Petrol and diesel are both complex mixtures of hydrocarbons used as fuels in transport.

(a) Petrol contains some branched chain alkanes.
The number of carbon atoms per molecule varies between five and nine.

Name one branched chain alkane with between five and nine carbon atoms.

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

(b) When petrol burns in an internal combustion engine the exhaust gases contain CO_2, CO, NO, N_2, O_2, H_2O and unburnt hydrocarbons.

(i) What effect does the absorption of infrared radiation have on the bonds in CO_2 molecules in the atmosphere?

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

(ii) Why is CO present in the exhaust gases?

.....

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

(iii) Both NO and CO are atmospheric pollutants.

For each pollutant, describe one environmental problem.

NO .....

.....

CO .....

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

(c) Most cars are fitted with a catalytic converter which catalyses the exothermic reaction between NO and CO to form two less harmful gases.

(i) Name the two gases formed and write an equation for this reaction.

.....

.....

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

(ii) NO and CO react very slowly without a catalyst.
The catalyst in a catalytic converter increases the rate of reaction.

Explain, using an enthalpy profile diagram and the Boltzmann distribution model, how the use of a catalyst increases the rate of reaction.

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..... **[7]**

(d) Many lorries and some cars use diesel powered engines.
Biodiesel is being developed as a substitute for diesel from crude oil.

Biodiesel is a methyl ester of a long chain carboxylic acid.
The flow chart shows how it is produced.

plants $\rightarrow$ plant oil $\rightarrow$ long chain carboxylic acids $\rightarrow$ biodiesel

Describe the benefits and disadvantages of changing from diesel to biodiesel.

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

[Total: 17]

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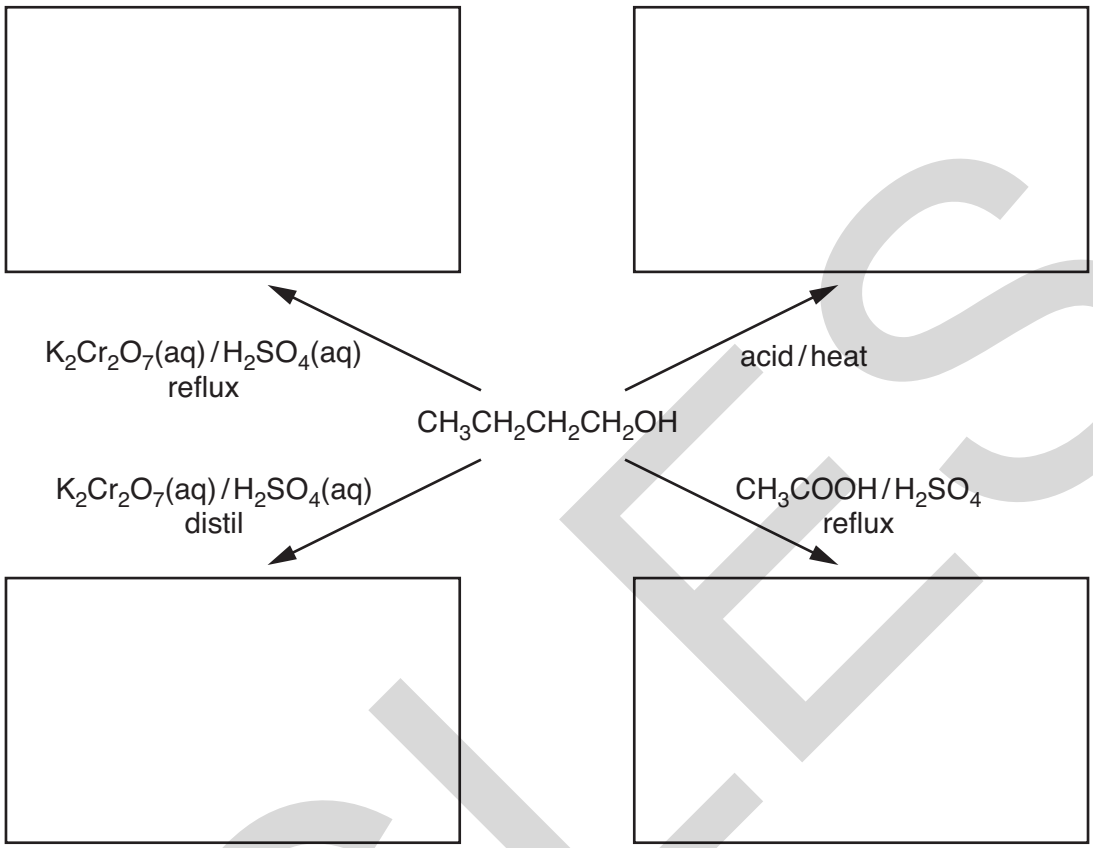
3 Alcohols are used in the industrial production of many organic compounds.

(a) Complete the flowchart below to show the organic product formed in each of the reactions of butan-1-ol.



[4]

(b) Butan-1-ol can be prepared by the alkaline hydrolysis of 1-iodobutane.

$$CH_3CH_2CH_2CH_2I + OH^- \longrightarrow CH_3CH_2CH_2CH_2OH + I^-$$

The reaction mixture is gently heated for 20 minutes.

(i) The curly arrow model is used in reaction mechanisms to show the movement of electron pairs.

Use the curly arrow model to outline the mechanism for the alkaline hydrolysis of 1-iodobutane.

In your answer, include the name of the mechanism, the type of bond fission and relevant dipoles.

name of mechanism .....

type of bond fission ..... **[5]**

(ii) A student decides to prepare butan-1-ol by the alkaline hydrolysis of 1-chlorobutane.

Suggest, with reasons, any change in the conditions from those used in the alkaline hydrolysis of 1-iodobutane.

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.....

.....

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

[Total: 11]

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4 Infrared spectroscopy and mass spectrometry are used to identify substances.

(a) Police use breathalysers to detect ethanol in the breath of drivers.

(i) Some modern breathalysers use infrared spectroscopy.

Suggest **two** characteristic infrared absorptions that could be used to identify the presence of ethanol vapour.

1 ..... cm^{-1}

2 ..... cm^{-1} **[2]**

(ii) Some older breathalysers used the redox reaction between acidified dichromate(VI) ions and ethanol. A colour change was seen which indicated the presence of ethanol in the breath.

What is the colour change that would be seen in this breathalyser if ethanol was present in the breath?

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

(iii) Give an equation to show the reaction between acidified dichromate(VI) ions and ethanol.

Use [O] to represent the acidified dichromate(VI) ions, the oxidising agent.

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

(b) Infrared spectroscopy and mass spectrometry are used in the search for organic molecules in outer space.

Compound **A** has been analysed by infrared spectroscopy.

Image removed due to third party copyright restrictions

wavenumber / cm^{-1}

The mass spectrum of compound **A** is shown below.

Image removed due to third party copyright restrictions

(i) A research chemist concludes that compound **A** is a hydrocarbon.

What evidence is there to support this conclusion?

.....

.....

.....

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

(ii) How does the mass spectrum confirm that compound **A** has a molecular formula of C_4H_{10}?

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

(iii) Draw the structural isomers of C_4H_{10}.

[1]

(iv) Identify the fragment ions that give rise to the following peaks in the mass spectrum.

m/z 15 is …….

m/z 29 is …….

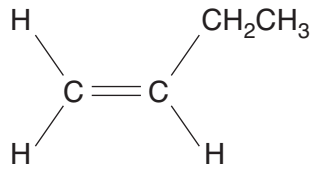
m/z 43 is ……. **[3]**

(v) Use your answer to part **(iv)** to identify which of the isomers in part **(iii)** is compound **A**. Explain your reasoning.

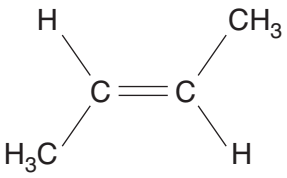
[1]

[Total: 13]

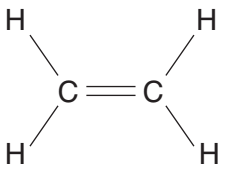
5 Alkenes **B**, **C**, **D**, **E** and **F** are shown below.



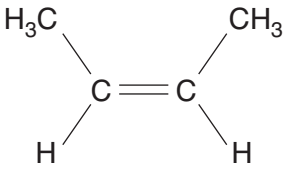
B



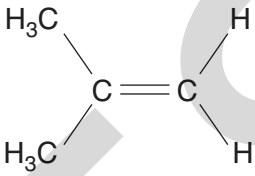
C



D



E



F

You will have to refer to these alkenes throughout the question.

(a) Describe, using the orbital overlap model, how the π-bond in alkene **D** is formed.

[2]

(b) Many alkenes show *E*/*Z* isomerism.

(i) Explain why *E*/*Z* isomerism is shown in some alkenes.

.....

.....

.....

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

(ii) Which **two** alkenes are a pair of *E*/*Z* isomers?

Choose from **B**, **C**, **D**, **E** and **F**.

…….. and ……. **[1]**

(c) What is the main organic product of the reaction between alkene **D** and steam in the presence of a phosphoric acid catalyst?

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

(d) Describe and explain the reaction of hydrogen bromide, HBr, with alkene **B** and with alkene **D**.

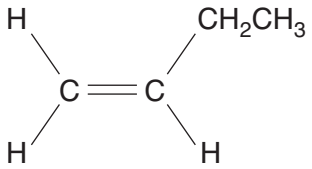
Include in your answer

- equations and structures of the products,
- why one of these alkenes gives just one product but the other gives more than one product,
- the reaction mechanism for the reaction with alkene **D** using the curly arrow model showing any relevant dipoles.

*Your answer needs to be clear and well organised using appropriate examples from the chemistry of alkenes **B** and **D**.*

[9]

(e) Alkenes are a major source of polymers.
Alkene **B** can be polymerised.



B

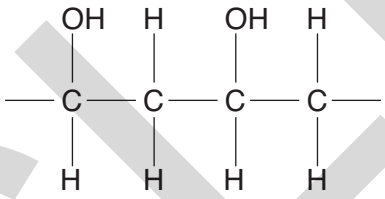
(i) Draw a section of the resultant polymer showing **two** repeat units.

[1]

(ii) Give the name of this polymer.

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

(f) Poly(ethenol) is a very unusual polymer because it can dissolve in water under certain conditions.



(i) Suggest why poly(ethenol) can dissolve in water.

.....

.....

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

(ii) Waste poly(ethenol) does not cause many environmental problems.
Other polymers such as poly(ethene), PVC or PTFE cause significant environmental problems.

Outline **two** ways in which waste polymers can be processed to reduce their environmental impact.

.....

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

[Total: 21]

6 An important reaction in the manufacture of nitric acid is the catalytic oxidation of ammonia.

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H = -909 \text{ kJ mol}^{-1}$$

(a) Low pressures and low temperatures would give the maximum equilibrium yield of NO.

Explain why.

.....

.....

.....

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

(b) The actual conditions used in the catalytic oxidation of ammonia include 900 °C and an increase in pressure.

Suggest why these conditions are a compromise.

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

(c) A factory makes 2.50×10^5 mol of NO a day.

(i) How much energy is released every day?

energy released = ... kJ **[1]**

(ii) Suggest how this energy can be used to reduce the cost of making NO.

.....

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

[Total: 7]

7 Compound **G** was extracted from the leaves of a plant. A sample of **G** was analysed by a research chemist. A summary of the chemist's results is shown in the table.

type of analysis	**evidence**
infrared spectroscopy	absorptions at 1080, 1720 and a very broad absorption at 2900 cm^{-1}
percentage composition by mass	C, 26.7%; H, 2.22%; O, 71.1%
volumetric analysis	0.00105 mol of **G** has a mass of 0.0945 g

Use this information to suggest a possible structure for compound **G**.

In your answer, you should make clear how your explanation is linked to the evidence.

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..... **[8]**

[Total: 8]

END OF QUESTION PAPER

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THIS IS A NEW SPECIFICATION

OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE

CHEMISTRY A

Rings, Polymers and Analysis

F324

Candidates answer on the Question Paper

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

Other Materials Required:
- Scientific calculator

Monday 28 June 2010
Morning

Duration: 1 hour

OCE/15373

F 3 2 4

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. If additional space is required, you should use the lined pages at the end of the booklet. The question number(s) must be clearly shown.

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 A* 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 **60**.
- This document consists of **16** pages. Any blank pages are indicated.

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Answer **all** the questions.

1 Benzene is an important industrial chemical and is used in a wide range of manufacturing processes. Over time our understanding of the structure and bonding of benzene has changed and various models have been proposed.

(a) In 1865, Kekulé proposed a model for the structure and bonding of benzene, but there is considerable evidence to suggest that Kekulé's model may not be correct. Scientists have proposed alternative models for the structure and bonding of benzene.

Explain the evidence that led scientists to doubt the model proposed by Kekulé.

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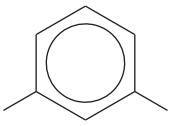
..... **[3]**

(b) Sudan II is an azo dye which was used as a colourant in chilli powder. However, scientists advised the Food Standards Agency that Sudan II was linked to an increased risk of cancer and it is now no longer used as a food colourant.

The flowchart below shows how Sudan II could be prepared in the laboratory from 1,3-dimethylbenzene.

(i) Draw the structures of the organic compounds **A**, **B**, **C** and **D** in the boxes below. Display the functional group in compound **C**.



1,3-dimethylbenzene

HNO_3, H_2SO_4

compound A

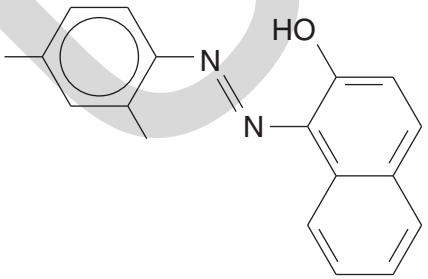
Sn, conc. HC*l*, heat

compound B

$NaNO_2$, HC*l*(aq)
below 10 °C

compound C

alkaline solution of compound **D**



Sudan II

compound D

[4]

(ii) Compound **A** is formed by reacting 1,3-dimethylbenzene with HNO_3 and H_2SO_4.

Explain, with the aid of curly arrows, the mechanism for the formation of compound **A**.

Your answer should clearly show the role of H_2SO_4 as a catalyst.

[5]

(iii) Deduce how many **other** structural isomers of compound **A** could have been formed from the mononitration of 1,3-dimethylbenzene.

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

[Total: 13]

2 A student was researching the development of polymers and discovered three polyesters, PET, PEN and PGA, that are used in the manufacture of plastic bottles.

(a) The student discovered that the first polyester developed was Terylene which is also known as poly(ethylene terephthalate) or PET.

PET can be made by reacting benzene-1,4-dicarboxylic acid with ethane-1,2-diol.

(i) Draw the **displayed** formula of the repeat unit in PET.

[2]

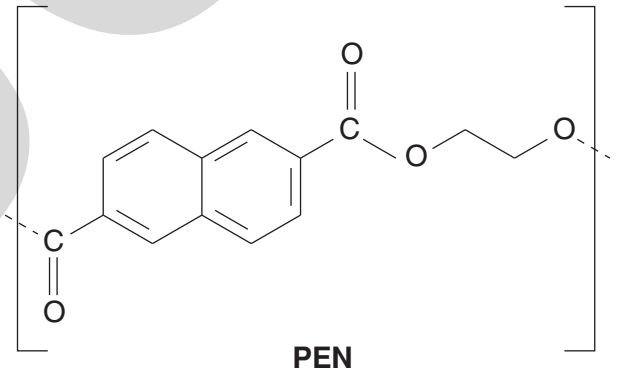
(ii) The industrial manufacture of PET involves two main stages. The first stage, known as 'pre-polymerisation', forms compound **F** with molecular formula $C_{12}H_{14}O_6$.

Draw the structure of compound **F**.

[1]

(b) PEN is a new kind of polyester. PEN is rigid at high temperature whereas PET readily softens.

The repeat unit of PEN is shown below.



PEN

(i) What is the empirical formula of the repeat unit in PEN?

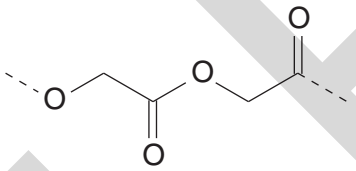
..... **[1]**

(ii) Draw the structures of **two** monomers that could be used to make PEN.

[2]

(c) Polyglycolic acid, PGA, is a polymer that is being developed as an inner coating for PET bottles.

A short section of PGA is shown below.



PGA

(i) Compared with other synthetic polymers, PGA can be easily hydrolysed.

Draw the skeletal formula of the organic product formed from the complete hydrolysis of PGA by NaOH(aq).

[2]

(ii) Explain why scientists now think that polymers such as PGA are better for the environment than hydrocarbon-based polymers.

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

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

[Total: 9]

3 A student was given three compounds, an aldehyde, a ketone, and a carboxylic acid.

(a) The student carried out the same two chemical tests on each compound. This allowed her to distinguish between all three compounds.

- Describe two suitable tests that the student could have used.
- Show how the observations would allow her to distinguish between the compounds.

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

(b) Explain how the student could use infrared spectroscopy to confirm which compound is a carboxylic acid.

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

(c) The aldehyde has the molecular formula $C_5H_{10}O$.

The ^1H NMR spectrum of the aldehyde contains a doublet at $\delta = 0.9$ ppm with a relative peak area of six compared with the aldehyde proton.

Analyse this information to deduce the structure of the aldehyde. Explain your reasoning.

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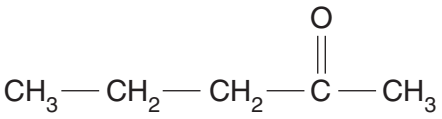
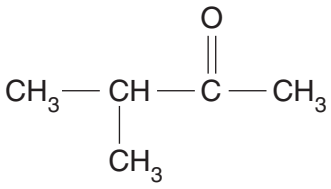
..... **[3]**

(d) The ketone also has the molecular formula $C_5H_{10}O$. There are three structural isomers of this formula that are ketones.

(i) Two of these isomers are shown below.

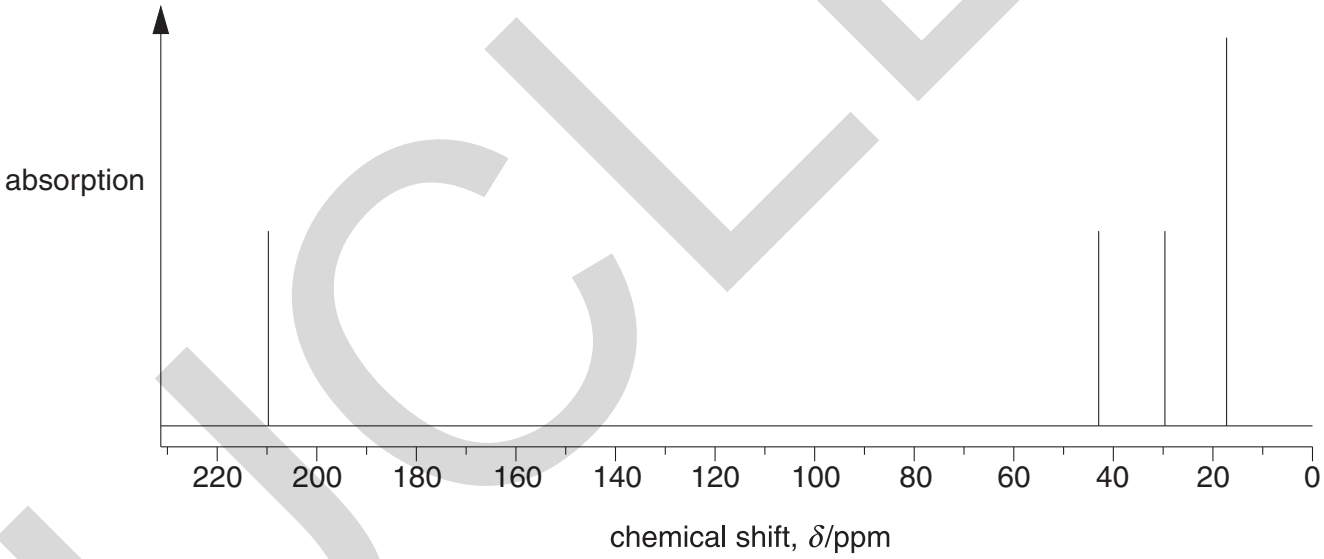
Draw the structural formula of the third structural isomer in the box below.

		
ketone 1	**ketone 2**	**ketone 3**

[1]

(ii) The ^{13}C NMR spectrum of the ketone given to the student is shown below.

- Use the spectrum to identify the ketone. Explain your reasoning.
- Identify the carbon responsible for the peak at $\delta = 210$ ppm.



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[Total: 12]

4 Two esters, $CH_3(CH_2)_2COO(CH_2)_3CH_3$ and $CH_3(CH_2)_2COOCH_2CH_3$, contribute to the odour of pineapple. A food scientist analysed a sample of pineapple essence by separating the two esters using gas chromatography, GC, and measuring their retention times.

(a) (i) State what is meant by *retention time*.

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

(ii) Explain the possible limitations of GC in separating the two esters.

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

(iii) Give the systematic name for the ester $CH_3(CH_2)_2COO(CH_2)_3CH_3$.

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

(b) The unsaturated ester, ethyl deca-2,4-dienoate contributes to the flavour of pears.

(i) Draw the structure of this ester.

[2]

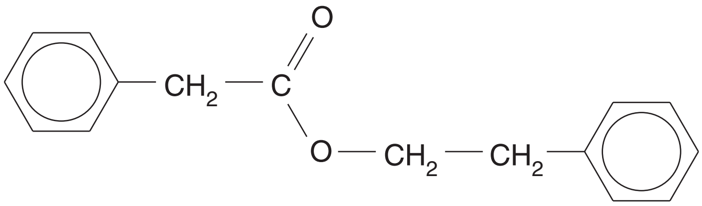
(ii) When pears ripen, ethyl deca-2,4-dienoate is formed following the breakdown of triglycerides.

Draw the general structure of a triglyceride with any functional groups fully displayed.

You can use 'R' to represent the carbon chains.

[1]

(c) The food scientist decided to synthesise the ester shown below, for possible use as a flavouring.



The **only** organic compound available to the food scientist was phenylethanal ($C_6H_5CH_2CHO$).

Explain how the food scientist was able to synthesise this ester using only phenylethanal and standard laboratory reagents.

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

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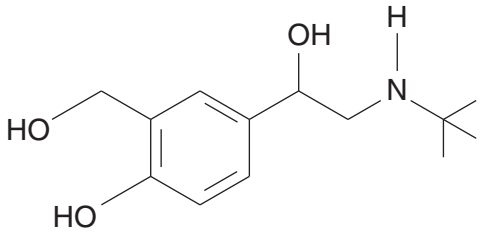
[Total: 13]

5 Hydroxyamines are organic compounds containing hydroxyl and amino functional groups.

(a) Salbutamol is a hydoxyamine used in the treatment of asthma and bronchitis. Salbutamol is an example of a chiral drug.

(i) Draw a circle around the chiral carbon in the structure of salbutamol shown below.



salbutamol

[1]

(ii) Suggest possible problems of making a chiral drug such as salbutamol and describe **two** ways that the pharmaceutical industry might overcome these problems.

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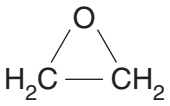
..... **[4]**

(b) Monoethanolamine, MEA, $H_2NCH_2CH_2OH$, is a hydroxyamine that is used in aqueous solution as a gas scrubber to remove acidic gases from emissions in incinerators.

MEA is prepared industrially by reacting ammonia with epoxyethane.



epoxyethane

(i) Write an equation for the industrial preparation of MEA.

[1]

(ii) During the manufacture of MEA, a compound with molecular formula $C_4H_{11}NO_2$ is also formed.

Draw the structure of the compound with molecular formula $C_4H_{11}NO_2$.

[1]

(c) The combustion of some polymers produces emissions containing toxic acidic gases such as HC*l* and H_2S. MEA can remove HC*l* and H_2S from the emissions.

Give the formula of the organic salts formed when MEA removes:

(i) HC*l*,

[1]

(ii) H_2S.

[1]

TURN OVER FOR QUESTION 5 PARTS (d) AND (e)

(d) MEA, $H_2NCH_2CH_2OH$, can be oxidised to form an α-amino acid.

(i) Explain what is meant by an α-amino acid.

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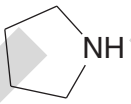
..... **[1]**

(ii) Write an equation for the oxidation of MEA to form an α-amino acid.

Use [O] to represent the oxidising agent.

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

(e) Isomers **F** and **G** are hydroxyamines each with the molecular formula $C_4H_{11}NO$.

- Isomer **F** can be dehydrated to form the cyclic compound 

- Isomer **G** has two chiral centres.

Identify and draw the structural isomers **F** and **G**.

isomer F	**isomer G**

[2]

[Total: 13]

END OF QUESTION PAPER

ADDITIONAL PAGE

If additional space is required, you should use the lined pages below. The question number(s) must be clearly shown.

ADDITIONAL PAGE

THIS IS A NEW SPECIFICATION

OCR
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ADVANCED GCE

CHEMISTRY A

Equilibria, Energetics and Elements

F325

Candidates answer on the Question Paper

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

Other Materials Required:
- Scientific calculator

Thursday 17 June 2010
Afternoon

Duration: 1 hour 45 minutes

OCE/11144

F 3 2 5

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. Additional paper may be used if necessary but you must clearly show your Candidate Number, Centre Number and question number(s).

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 A* 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 **100**.
- This document consists of **20** pages. Any blank pages are indicated.

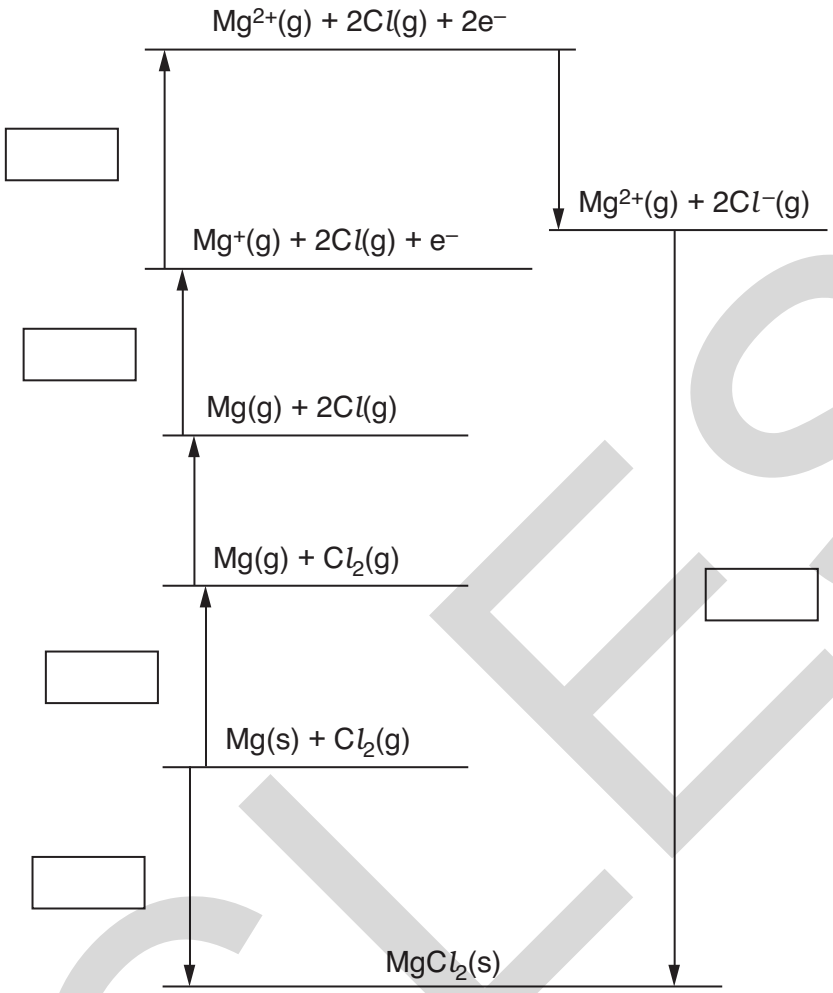
Answer **all** the questions.

1 Lattice enthalpy can be used as a measure of ionic bond strength. Lattice enthalpies are determined indirectly using an enthalpy cycle called a Born–Haber cycle.

The table below shows the enthalpy changes that are needed to determine the lattice enthalpy of magnesium chloride, $MgCl_2$.

letter	enthalpy change	energy/ kJ mol^{-1}
A	1st electron affinity of chlorine	–349
B	1st ionisation energy of magnesium	+736
C	atomisation of chlorine	+150
D	formation of magnesium chloride	–642
E	atomisation of magnesium	+76
F	2nd ionisation energy of magnesium	+1450
G	lattice enthalpy of magnesium chloride	

(a) On the cycle below, write the correct letter in each empty box.



[3]

(b) Use the Born–Haber cycle to calculate the lattice enthalpy of magnesium chloride.

answer = ... $kJ\,mol^{-1}$ **[2]**

(c) Magnesium chloride has stronger ionic bonds than sodium chloride.

Explain why.

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

[Total: 8]

2 In the presence of acid, $H^+(aq)$, aqueous bromate(V) ions, $BrO_3^-(aq)$, react with aqueous bromide ions, $Br^-(aq)$, to produce bromine, $Br_2(aq)$.

A student carried out an investigation into the kinetics of this reaction.

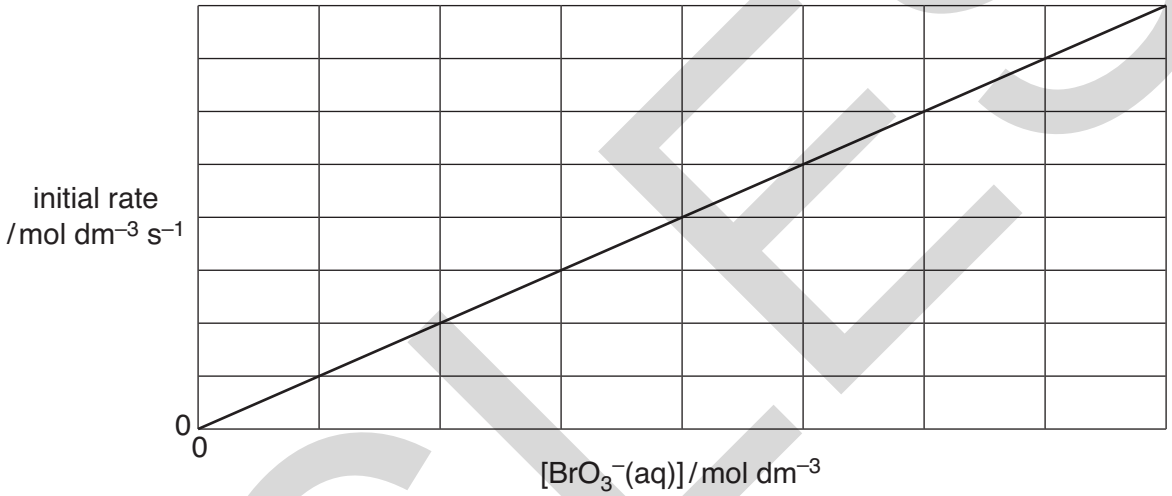
(a) Balance the ionic equation for this reaction.

$$BrO_3^- + \ldots\ldots Br^- + \ldots\ldots H^+ \longrightarrow \ldots\ldots Br_2 + \ldots\ldots H_2O$$

[1]

(b) The student investigated how different concentrations of $BrO_3^-(aq)$ affect the initial rate of the reaction.

A graph of initial rate against $[BrO_3^-(aq)]$ is shown below.



The student then investigated how different concentrations of $Br^-(aq)$ and $H^+(aq)$ affect the initial rate of the reaction.

The results are shown below.

$[BrO_3^-(aq)]$ / mol dm^{-3}	$[Br^-(aq)]$ / mol dm^{-3}	$[H^+(aq)]$ / mol dm^{-3}	initial rate / mol dm^{-3} s^{-1}
5.0×10^{-2}	1.5×10^{-1}	3.1×10^{-1}	1.19×10^{-5}
5.0×10^{-2}	3.0×10^{-1}	3.1×10^{-1}	2.38×10^{-5}
5.0×10^{-2}	1.5×10^{-1}	6.2×10^{-1}	4.76×10^{-5}

- Using the results from the student's experiments, what conclusions can be drawn about the kinetics of this reaction? Justify your reasoning.

- Calculate the rate constant for this reaction, including the units.

In your answer you should make clear how your conclusions fit with the experimental results.

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[Total: 10]

3 The chemicals that we call 'acids' have been known for thousands of years. However, modern theories of acids have been developed comparatively recently. It wasn't until the early 1900s that the concept of dissociation became accepted by the scientific community and the concept of pH was introduced.

A student carried out a series of experiments with acids and alkalis.

(a) Propanoic acid, CH_3CH_2COOH, is a naturally occurring weak acid. The equation for the dissociation of propanoic acid is shown below.

$$CH_3CH_2COOH(aq) \rightleftharpoons H^+(aq) + CH_3CH_2COO^-(aq)$$

The student wanted to prove that propanoic acid is a weak acid. The student had access to a pH meter and 0.100 mol dm^{-3} propanoic acid.

- Explain how the student could prove that propanoic acid is a weak acid by taking a single pH measurement.
- Show how the student could then calculate the acid dissociation constant, K_a, for propanoic acid.

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

(b) The student measured the pH of a solution of sodium hydroxide at 25 °C.
The measured pH was 13.46.

Calculate the concentration of the aqueous sodium hydroxide.

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

(c) A student made a buffer solution by mixing an excess of propanoic acid to an aqueous solution of sodium hydroxide at 25 °C. This buffer solution contains an equilibrium system that minimises changes in pH when small amounts of acids and alkalis are added.

- Explain why a buffer solution formed when an excess of propanoic acid was mixed with aqueous sodium hydroxide.

- Explain how this buffer solution controls pH when an acid or an alkali is added.

In your answer you should explain how the equilibrium system allows the buffer solution to control the pH.

[7]

(d) A student added nitric acid to propanoic acid. A reaction took place to form an equilibrium mixture containing two acid–base pairs.

Complete the equilibrium below and label the two conjugate acid–base pairs.

$HNO_3 + CH_3CH_2COOH \rightleftharpoons$ ..... + ...

[2]

(e) Finally, the student reacted an aqueous solution of propanoic acid with a reactive metal and with a carbonate.

(i) Write an equation for the reaction of aqueous propanoic acid with magnesium.

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

(ii) Write an ionic equation for the reaction of aqueous propanoic acid with aqueous sodium carbonate.

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

[Total: 17]

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QUESTION 4 STARTS ON PAGE 10

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4 Electrochemical cells have been developed as a convenient and portable source of energy.

The essential components of any electrochemical cell are two redox systems, one providing electrons and the other accepting electrons. The tendency to lose or gain electrons can be quantified using values called standard electrode potentials.

Standard electrode potentials for seven redox systems are shown in **Table 4.1**.
You may need to use this information throughout this question.

Table 4.1

redox system	equation	$E^{\ominus}$/V
1	$2H^+(aq) + 2e^- \rightleftharpoons H_2(g)$	0
2	$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77
3	$SO_4^{2-}(aq) + 2H^+(aq) + 2e^- \rightleftharpoons SO_3^{2-}(aq) + H_2O(l)$	+0.17
4	$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	+0.34
5	$Cl_2(aq) + 2e^- \rightleftharpoons 2Cl^-(aq)$	+1.36
6	$O_2(g) + 4H^+(aq) + 4e^- \rightleftharpoons 2H_2O(l)$	+1.23
7	$I_2(aq) + 2e^- \rightleftharpoons 2I^-(aq)$	+0.54

(a) An electrochemical cell can be made based on redox systems 2 and 4.

(i) Draw a labelled diagram to show how this cell can be set up in the laboratory.

[3]

(ii) State the charge carriers that transfer current

through the wire, ...

through the solution. ..... **[1]**

(iii) Write down the overall cell reaction.

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

(iv) Write down the cell potential.

cell potential ..... V **[1]**

(b) Select from **Table 4.1**,

(i) a species which oxidises $Fe^{2+}(aq)$ to $Fe^{3+}(aq)$,

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

(ii) a species which reduces $Fe^{3+}(aq)$ to $Fe^{2+}(aq)$ but does **not** reduce $Ag^{+}(aq)$ to Ag(s).

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

(c) Fuel cells are a type of electrochemical cell being developed as a potential source of energy in the future.

- State **one** important difference between a fuel cell and a conventional electrochemical cell.
- Write the equation for the overall reaction that takes place in a hydrogen fuel cell.
- State **two** ways that hydrogen might be stored as a fuel for cars.
- Suggest why some people consider that the use of hydrogen as a fuel for cars consumes more energy than using fossil fuels such as petrol and diesel.

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

[Total: 13]

5 Ammonia is one of our most important chemicals, produced in enormous quantities because of its role in the production of fertilisers.

Much of this ammonia is manufactured from nitrogen and hydrogen gases using the Haber process. The equilibrium is shown below.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92\,kJ\,mol^{-1}$$

(a) (i) Write an expression for K_c for this equilibrium.

[1]

(ii) Deduce the units of K_c for this equilibrium.

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

(b) A research chemist was investigating methods to improve the synthesis of ammonia from nitrogen and hydrogen at 500 °C.

- The chemist mixed together nitrogen and hydrogen and pressurised the gases so that their total gas volume was 6.0 dm^3.
- The mixture was allowed to reach equilibrium at constant temperature and without changing the total gas volume.
- The equilibrium mixture contained 7.2 mol N_2 and 12.0 mol H_2.
- At 500 °C, the numerical value of K_c for this equilibrium is 8.00×10^{-2}.

Calculate the amount, in mol, of ammonia present in the equilibrium mixture at 500 °C.

equilibrium amount of NH_3 = ... mol **[4]**

(c) The research chemist doubled the pressure of the equilibrium mixture whilst keeping all other conditions the same. As expected the equilibrium yield of ammonia increased.

(i) Explain in terms of le Chatelier's principle why the equilibrium yield of ammonia increased.

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

(ii) Explain in terms of K_c why the equilibrium yield of ammonia increased.

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

(d) For the industrial manufacture of ammonia, nitrogen and hydrogen gases are required in large quantities from readily available resources.

Various methods have been developed to obtain hydrogen gas for this process.

(i) Much of the hydrogen is obtained by reacting together natural gas (methane) and steam.

Construct an equation for this reaction.

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

(ii) Natural gas is a fossil fuel and the annual production of ammonia accounts for about 2% of all methane consumption. In the future, as fossil fuels become more depleted, the use of methane for ammonia production may become too expensive.

Suggest another process that might be used in the future to obtain hydrogen gas for the Haber process.

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

(e) In the industrial production of ammonia, a temperature in the range 400–500 °C is used.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92\,kJ\,mol^{-1}$$

Standard entropies of $N_2(g)$, $H_2(g)$ and $NH_3(g)$ are given in the table below.

substance	$N_2(g)$	$H_2(g)$	$NH_3(g)$
S **/ J K^{-1} mol^{-1}**	191	131	192

(i) Show that the formation of ammonia from nitrogen and hydrogen gases should be feasible at room temperature (25 °C).

[6]

(ii) Explain, in terms of entropy, why this reaction is **not** feasible at very high temperatures.

.....

.....

.....

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

(iii) Suggest why a temperature of 400–500 °C is used for ammonia production, despite the reaction being feasible at room temperature.

.....

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

[Total: 22]

6 Chromium shows typical properties of a transition element. The element's name comes from the Greek word 'Chroma' meaning colour because of its many colourful compounds.

(a) Write down the electron configuration of

(i) a Cr atom, ... **[1]**

(ii) a Cr^{3+} ion. ..... **[1]**

(b) An acidified solution containing orange $Cr_2O_7^{2-}$ ions reacts with zinc in a redox reaction to form a solution containing Zn^{2+} ions and blue Cr^{2+} ions.

The unbalanced half-equations are shown below.

$$Zn \longrightarrow Zn^{2+} + e^-$$

$$Cr_2O_7^{2-} + H^+ + e^- \longrightarrow Cr^{2+} + H_2O$$

Balance these equations and construct an overall equation for this reaction.

.....

.....

.....

.....

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

(c) Aqueous solutions of Cr^{3+} ions contain ruby-coloured $[Cr(H_2O)_6]^{3+}$ complex ions. If an excess of concentrated ammonia solution is added, the solution changes to a violet colour as the hexaammine chromium(III) complex ion forms.

(i) What type of reaction has taken place?

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

(ii) Suggest an equation for this reaction.

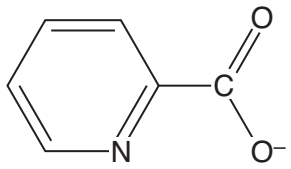
..... **[2]**

(d) Chromium picolinate, $Cr(C_6H_4NO_2)_3$, is a bright red complex, used as a nutritional supplement to prevent or treat chromium deficiency in the human body.

In this complex,

- chromium has the +3 oxidation state,
- picolinate ions, $C_6H_4NO_2^-$, act as bidentate ligands.

The structure of the picolinate ion is shown below.



$Cr(C_6H_4NO_2)_3$ exists as a mixture of stereoisomers.

(i) What is meant by the term *ligand*?

.....

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

(ii) How is the picolinate ion able to act as a **bidentate** ligand?

.....

.....

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

(iii) Why does $Cr(C_6H_4NO_2)_3$ exist as a mixture of stereoisomers?
Draw diagrams of the stereoisomers as part of your answer.

.....

.....

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

(e) Compound **A** is an orange ionic compound of chromium with the percentage composition by mass N, 11.11%; H, 3.17%; Cr, 41.27%; O, 44.45%. Compound **A** does **not** have water of crystallisation.

On gentle heating, compound **A** decomposes to form three products, **B**, **C** and water.
B is a green oxide of chromium with a molar mass of 152.0 g mol^{-1}.
C is a gas. At RTP, each cubic decimetre of **C** has a mass of 1.17 g.

In the steps below, show all your working.

- Calculate the empirical formula of compound **A**.
- Deduce the ions that make up the ionic compound **A**.
- Identify substances **B** and **C**.
- Write an equation for the decomposition of compound **A** by heat.

[8]

[Total: 22]

TURN OVER FOR QUESTION 7

7 Redox titrations using $KMnO_4$ in acidic conditions can be used to analyse reducing agents. Acidified $KMnO_4$ is a strong oxidising agent, readily removing electrons:

$$MnO_4^- + 8H^+ + 5e^- \longrightarrow Mn^{2+} + 4H_2O$$

A student analysed a solution of hydrogen peroxide, $H_2O_2(aq)$, using a redox titration with $KMnO_4$ under acidic conditions. Under these conditions, H_2O_2 is a reducing agent.

The overall equation for the reaction is given below.

$$2MnO_4^- + 6H^+ + 5H_2O_2 \longrightarrow 2Mn^{2+} + 8H_2O + 5O_2$$

(a) Deduce the simplest whole number half-equation for the oxidation of H_2O_2 under these conditions.

[2]

(b) The student diluted 25.0 cm^3 of a solution of hydrogen peroxide with water and made the solution up to 250.0 cm^3. The student titrated 25.0 cm^3 of this solution with 0.0200 mol dm^{-3} $KMnO_4$ under acidic conditions. The volume of $KMnO_4$(aq) required to reach the end-point was 23.45 cm^3.

- Calculate the concentration, in g dm^{-3}, of the **undiluted** hydrogen peroxide solution.
- What volume of oxygen gas, measured at RTP, would be produced during this titration?

[6]

[Total: 8]

END OF QUESTION PAPER

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