Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
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8	
9	
10	
11	
TOTAL	

General Certificate of Education
Advanced Subsidiary Examination
June 2013

Chemistry CHEM2

Unit 2 Chemistry in Action

Tuesday 4 June 2013 1.30 pm to 3.15 pm

For this paper you must have:
- the Periodic Table/Data Sheet, provided as an insert (enclosed)
- a calculator.

Time allowed
- 1 hour 45 minutes

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 100.
- You are expected to use a calculator, where appropriate.
- The Periodic Table/Data Sheet is provided as an insert.
- Your answers to the questions in **Section B** should be written in continuous prose, where appropriate.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use scientific terminology accurately.

Advice
- You are advised to spend about 1 hour 15 minutes on **Section A** and about 30 minutes on **Section B**.

There are no questions printed on this page

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ANSWER IN THE SPACES PROVIDED

Section A

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

1 Sulfuric acid is manufactured by the Contact Process.

1 (a) In this process, sulfur dioxide reacts with oxygen.
The equation for the equilibrium that is established is

$$SO_2(g) + \tfrac{1}{2}O_2(g) \rightleftharpoons SO_3(g) \qquad \Delta H = -98\ kJ\ mol^{-1}$$

1 (a) (i) State and explain the effect of a **decrease** in temperature on the equilibrium yield of SO_3

Effect of a decrease in temperature on yield .....

Explanation .....

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(3 marks)

(Extra space) .....

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1 (a) (ii) Give **two** features of a reaction at equilibrium.

Feature 1 .....

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Feature 2 .....

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(2 marks)

Question 1 continues on the next page

1 (b) Write an equation for the reaction of concentrated sulfuric acid with potassium bromide to form potassium hydrogensulfate and hydrogen bromide.

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(1 mark)

1 (c) Bromine is one of the products formed when concentrated sulfuric acid reacts with hydrogen bromide.

Write an equation for this reaction.
State the role of sulfuric acid in this reaction.

Equation

.....

Role of sulfuric acid .....

(3 marks)

1 (d) Concentrated sulfuric acid is used in a two-stage process to convert 2-methylpropene into 2-methylpropan-2-ol.

Stage **1** $(CH_3)_2C{=}CH_2 + H_2SO_4 \longrightarrow (CH_3)_2C(OSO_2OH)CH_3$

Stage **2** $(CH_3)_2C(OSO_2OH)CH_3 + H_2O \longrightarrow (CH_3)_2C(OH)CH_3 + H_2SO_4$

1 (d) (i) Name and outline a mechanism for Stage **1** of this conversion.

Name of mechanism .....

Mechanism

(5 marks)

1 (d) (ii) Deduce the type of reaction in Stage **2** of this conversion.

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(1 mark)

1 (d) (iii) State the overall role of sulfuric acid in this conversion.

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(1 mark)

16

Turn over for the next question

2 The following pairs of compounds can be distinguished by simple test-tube reactions.

For each pair, give a suitable reagent that could be added separately to each compound to distinguish between them.
Describe what you would observe in each case.

2 (a) AgBr(s) and AgI(s)

Reagent .....

Observation with AgBr(s) .....

.....

Observation with AgI(s) .....

.....

(3 marks)

2 (b) HCl(aq) and HNO_3(aq)

Reagent .....

Observation with HCl(aq) .....

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Observation with HNO_3(aq) .....

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(3 marks)

2 (c) Cyclohexane and cyclohexene

Reagent .....

Observation with cyclohexane .....

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Observation with cyclohexene .....

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(3 marks)

2 (d) Butanal and butanone

Reagent .....

Observation with butanal .....

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Observation with butanone .....

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(3 marks)

12

Turn over for the next question

There are no questions printed on this page

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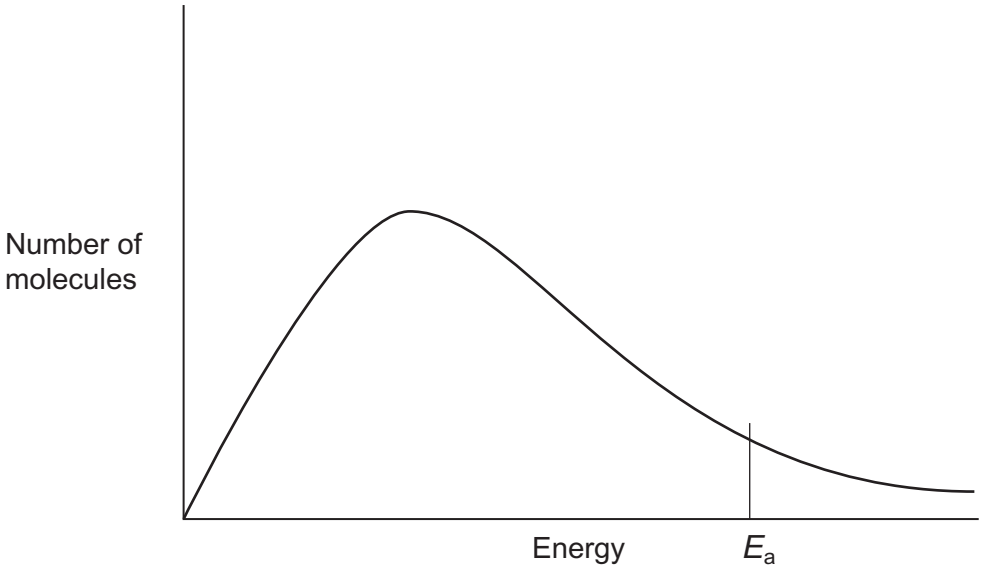
ANSWER IN THE SPACES PROVIDED

3 The diagram shows the Maxwell–Boltzmann distribution for a sample of gas at a fixed temperature.
E_a is the activation energy for the decomposition of this gas.



E_{mp} is the most probable value for the energy of the molecules.

3 (a) On the appropriate axis of this diagram, mark the value of E_{mp} for **this** distribution.

On this diagram, sketch a new distribution for the same sample of gas at a **lower** temperature.

(3 marks)

3 (b) With reference to the Maxwell–Boltzmann distribution, explain why a decrease in temperature decreases the rate of decomposition of this gas.

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(2 marks)

5

4 The price of copper is increasing as supplies of high-grade ores start to run out. The mineral covellite (CuS), found in low-grade ores, is a possible future source of copper.

4 (a) When copper is extracted from covellite, a reaction occurs between copper(II) sulfide and nitric acid to form a dilute solution of copper(II) sulfate.

4 (a) (i) Balance the equation for this reaction.

$3CuS(s) + \ldots\ldots HNO_3(aq) \longrightarrow \ldots\ldots CuSO_4(aq) + \ldots\ldots NO(g) + \ldots\ldots H_2O(l)$

(1 mark)

4 (a) (ii) Give the oxidation state of nitrogen in each of the following.

HNO_3 .....

NO .....

(2 marks)

4 (a) (iii) Deduce the redox half-equation for the reduction of the nitrate ion in acidified solution to form nitrogen monoxide and water.

.....

(1 mark)

4 (a) (iv) Deduce the redox half-equation for the oxidation of the sulfide ion in aqueous solution to form the sulfate ion and $H^+(aq)$ ions.

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(1 mark)

4 (b) Use your knowledge of metal reactivity to state and explain a low-cost method for the extraction of copper from a dilute aqueous solution of copper(II) sulfate.
Write the **simplest ionic** equation for the reaction that occurs during this extraction process.

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Simplest ionic equation

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(4 marks)

9

Turn over for the next question

5 Haloalkanes are used in the synthesis of other organic compounds.

5 (a) Hot concentrated ethanolic potassium hydroxide reacts with 2-bromo-3-methylbutane to form two alkenes that are structural isomers of each other. The major product is 2-methylbut-2-ene.

5 (a) (i) Name and outline a mechanism for the conversion of 2-bromo-3-methylbutane into 2-methylbut-2-ene according to the equation.

$$(CH_3)_2CHCHBrCH_3 + KOH \longrightarrow (CH_3)_2C{=}CHCH_3 + KBr + H_2O$$

Name of mechanism .....

Mechanism

(4 marks)

5 (a) (ii) Draw the **displayed formula** for the other isomer that is formed.

(1 mark)

5 (a) (iii) State the type of structural isomerism shown by these two alkenes.

.....

(1 mark)

5 (b) A small amount of another organic compound, **X**, can be detected in the reaction mixture formed when hot concentrated ethanolic potassium hydroxide reacts with 2-bromo-3-methylbutane.
Compound **X** has the molecular formula $C_5H_{12}O$ and is a secondary alcohol.

5 (b) (i) Draw the **displayed formula** for **X**.

(1 mark)

5 (b) (ii) Suggest **one** change to the reaction conditions that would increase the yield of **X**.

.....

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(1 mark)

5 (b) (iii) State the type of mechanism for the conversion of 2-bromo-3-methylbutane into **X**.

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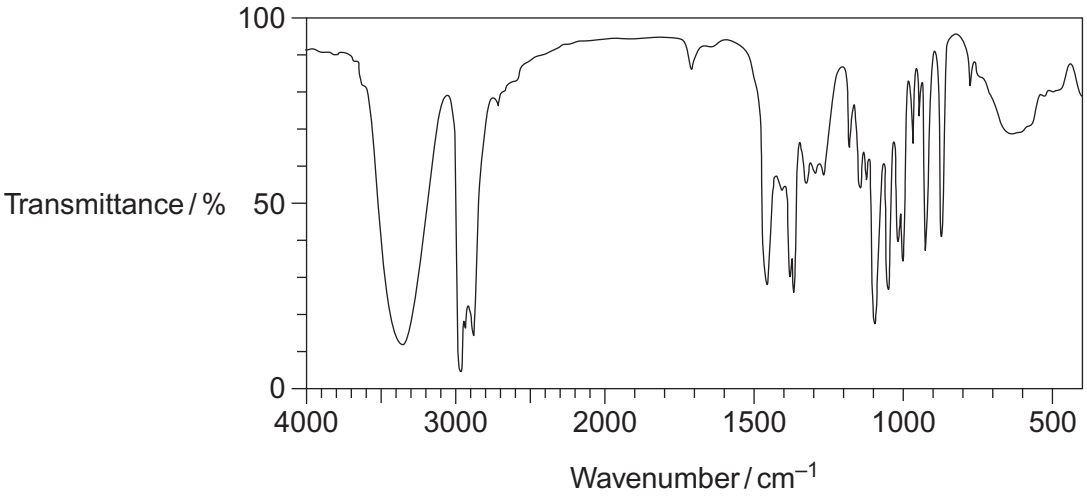
(1 mark)

5 (b) (iv) Identify **one** feature of this infrared spectrum of a pure sample of **X** that may be used to confirm that **X** is an alcohol.
You may find it helpful to refer to **Table 1** on the Data Sheet.



Feature .....

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(1 mark)

10

6 (a) Chlorine displaces iodine from aqueous potassium iodide.

6 (a) (i) Write the **simplest ionic** equation for this reaction.

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(1 mark)

6 (a) (ii) Give **one** observation that you would make when this reaction occurs.

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(1 mark)

6 (b) In bright sunlight, chlorine reacts with water to form oxygen as one of the products. Write an equation for this reaction.

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(1 mark)

6 (c) Explain why chlorine has a lower boiling point than bromine.

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(2 marks)

(Extra space) .....

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7 Chlorine can be used to make chlorinated alkanes such as dichloromethane.

7 (a) Write an equation for each of the following steps in the mechanism for the reaction of chloromethane (CH_3Cl) with chlorine to form dichloromethane (CH_2Cl_2).

Initiation step

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First propagation step

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Second propagation step

.....

The termination step that forms a compound with empirical formula CH_2Cl

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(4 marks)

7 (b) When chlorinated alkanes enter the upper atmosphere, carbon–chlorine bonds are broken. This process produces a reactive intermediate that catalyses the decomposition of ozone. The overall equation for this decomposition is

$$2O_3 \rightleftharpoons 3O_2$$

7 (b) (i) Name the type of reactive intermediate that acts as a catalyst in this reaction.

.....

(1 mark)

7 (b) (ii) Write **two** equations to show how this intermediate is involved as a catalyst in the decomposition of ozone.

Equation 1 .....

Equation 2 .....

(2 marks)

7

There are no questions printed on this page

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ANSWER IN THE SPACES PROVIDED

8 In each of the following questions, you should draw the structure of the compound in the space provided.

8 (a) Draw the structure of the alkene that would form 1,2-dibromo-3-methylbutane when reacted with bromine.

(1 mark)

8 (b) Draw the structure of the alcohol with molecular formula $C_4H_{10}O$ that is resistant to oxidation by acidified potassium dichromate(VI).

(1 mark)

8 (c) Draw the structure of the alkene that has a peak, due to its molecular ion, at $m/z = 42$ in its mass spectrum.

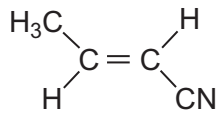
(1 mark)

8 (d) Draw the structure of the organic product with $M_r = 73$, made from the reaction between 2-bromobutane and ammonia.

(1 mark)

4

9 The alkene (*E*)-but-2-enenitrile is used to make acrylic plastics.
The structure of (*E*)-but-2-enenitrile is



9 (a) (i) Draw the structure of (*Z*)-but-2-enenitrile.

(1 mark)

9 (a) (ii) Identify the feature of the double bond in the E and Z isomers that causes them to be stereoisomers.

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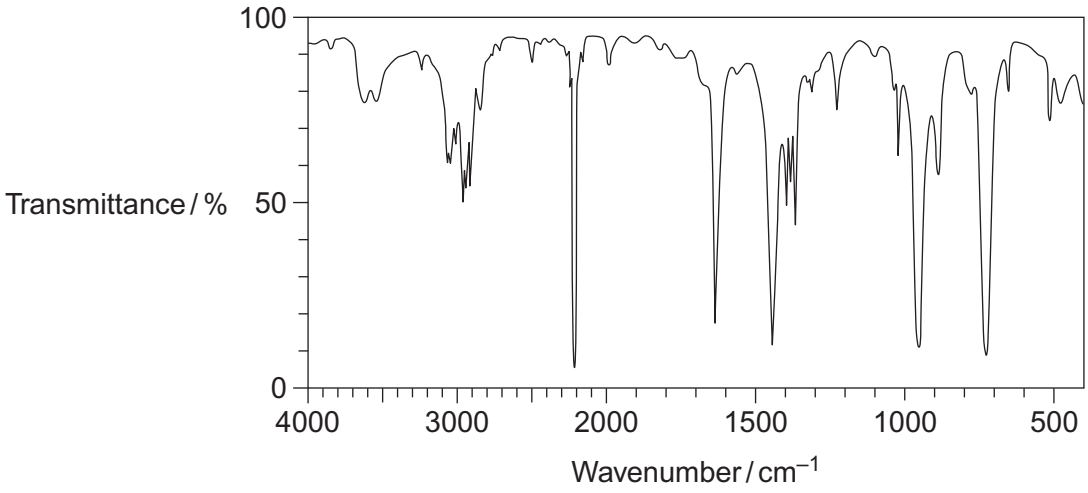
(1 mark)

9 (b) Draw the repeating unit of the polyalkene formed by addition polymerisation of (*E*)-but-2-enenitrile.

(1 mark)

9 (c) Consider the infrared spectrum of (*E*)-but-2-enenitrile.



Identify **two** features of the infrared spectrum that support the fact that this is the infrared spectrum for but-2-enenitrile.
You may find it helpful to refer to **Table 1** on the Data Sheet.

Feature 1 .....

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Feature 2 .....

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(2 marks)

5

Turn over for the next question

Section B

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

10 Ethanol is an important industrial compound.

10 (a) Ethanol can be produced by the hydration of ethene.
The equation for the equilibrium that is established is

$$H_2C{=}CH_2(g) + H_2O(g) \rightleftharpoons CH_3CH_2OH(g) \qquad \Delta H = -42\,kJ\,mol^{-1}$$

The operating conditions for the process are a temperature of 300 ºC and a pressure of 7 MPa.
Under these conditions, the conversion of ethene into ethanol is 5%.

10 (a) (i) Identify the catalyst used in this process.
Deduce how an overall yield of 95% is achieved in this process without changing the operating conditions.

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(2 marks)

10 (a) (ii) Use your knowledge of equilibrium reactions to explain why a manufacturer might consider using an excess of steam in this process, under the same operating conditions.

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(3 marks)

10 (a) (iii) At pressures higher than 7 MPa, some of the ethene reacts to form a solid with a relative molecular mass greater than 5000

Deduce the identity of this solid.

Give **one** other reason for **not** operating this process at pressures higher than 7 MPa. Do **not** include safety reasons.

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(2 marks)

10 (b) Write an equation for the reaction that has an enthalpy change that is the standard enthalpy of formation of ethanol.

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(2 marks)

10 (c) When ethanol is used as a fuel, it undergoes combustion.

10 (c) (i) Define the term *standard enthalpy of combustion*.

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(3 marks)

Question 10 continues on the next page

10 (c) (ii) Consider these bond enthalpy data.

	C—H	C—C	C—O	O=O	C=O	O—H
Bond enthalpy / kJ mol^{-1}	412	348	360	496	805	463

Use these data and the equation to calculate a value for the enthalpy of combustion of gaseous ethanol.

$$CH_3CH_2OH(g) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(g)$$

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(3 marks)

10 (d) Gaseous ethanol can be used to convert hot copper(II) oxide into copper.

10 (d) (i) Deduce the role of ethanol in this reaction.

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(1 mark)

10 (d) (ii) Draw the structure of the organic compound with M_r = 60 that is produced in this reaction.

(1 mark)

17

11 Group 2 metals and their compounds are used commercially in a variety of processes.

11 (a) Strontium is extracted from strontium oxide (SrO) by heating a mixture of powdered strontium oxide and powdered aluminium.

Consider these standard enthalpies of formation.

	SrO(s)	$Al_2O_3(s)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	– 590	– 1669

$$3SrO(s) + 2Al(s) \longrightarrow 3Sr(s) + Al_2O_3(s)$$

Use these data and the equation to calculate the standard enthalpy change for this extraction of strontium.

The use of powdered strontium oxide and powdered aluminium increases the surface area of the reactants.
Suggest **one** reason why this increases the reaction rate.

Suggest **one** major reason why this method of extracting strontium is expensive.

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(5 marks)

Question 11 continues on the next page

11 (b) Explain why calcium has a higher melting point than strontium.

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(2 marks)

11 (c) Magnesium is used in fireworks. It reacts rapidly with oxygen, burning with a bright white light. Magnesium reacts slowly with cold water.

Write an equation for the reaction of magnesium with oxygen.

Write an equation for the reaction of magnesium with cold water.

Give a medical use for the magnesium compound formed in the reaction of magnesium with cold water.

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(3 marks)

10

END OF QUESTIONS