Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
9	
TOTAL	

General Certificate of Education
Advanced Subsidiary Examination
June 2011

Chemistry CHEM2

Unit 2 Chemistry in Action

Friday 27 May 2011 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.
- 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 accurate scientific terminology.

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

Section A

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

1 The rate of a chemical reaction is influenced by the size of the activation energy. Catalysts are used to increase the rates of chemical reactions but are not used up in the reactions.

1 (a) Give the meaning of the term *activation energy*.

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(2 marks)

1 (b) Explain how a catalyst increases the rate of a reaction.

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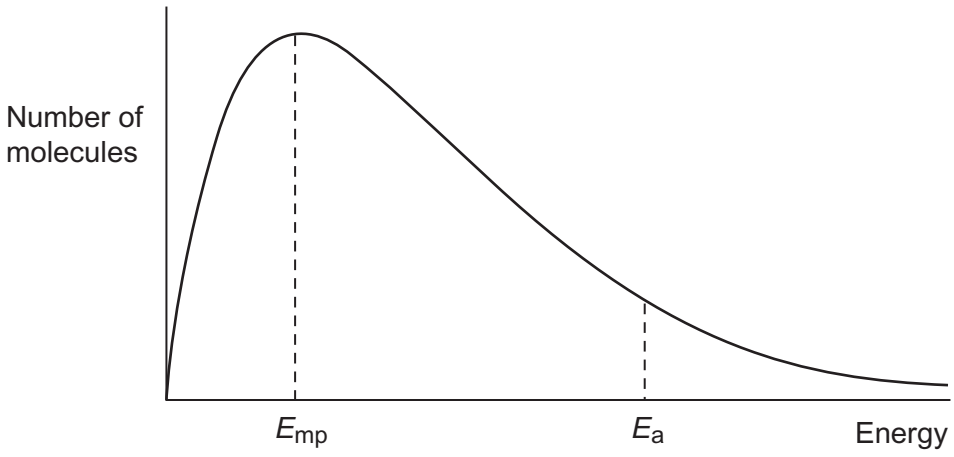
(2 marks)

1 (c) The diagram below shows the Maxwell–Boltzmann distribution of molecular energies, at a constant temperature, in a gas at the start of a reaction.
On this diagram the most probable molecular energy at this temperature is shown by the symbol E_{mp}
The activation energy is shown by the symbol E_a



To answer the questions **1 (c) (i)** to **1 (c) (iv)**, you should use the words **increases**, **decreases** or **stays the same**. You may use each of these answers once, more than once or not at all.

1 (c) (i) State how, if at all, the value of the most probable energy (E_{mp}) changes as the total number of molecules is increased at constant temperature.

.....

(1 mark)

1 (c) (ii) State how, if at all, the number of molecules with the most probable energy (E_{mp}) changes as the temperature is decreased without changing the total number of molecules.

.....

(1 mark)

1 (c) (iii) State how, if at all, the number of molecules with energy greater than the activation energy (E_a) changes as the temperature is increased without changing the total number of molecules.

.....

(1 mark)

1 (c) (iv) State how, if at all, the area under the molecular energy distribution curve changes as a catalyst is introduced without changing the temperature or the total number of molecules.

.....

(1 mark)

1 (d) For each of the following reactions, identify a catalyst and name the organic product of the reaction.

1 (d) (i) The fermentation of an aqueous solution of glucose.

Catalyst .....

Name of organic product .....

(2 marks)

1 (d) (ii) The hydration of but-2-ene.

Catalyst .....

Name of organic product .....

(2 marks)

12

2 This question is about the extraction of titanium from titanium(IV) oxide by a two-stage process.
The first stage in the process produces titanium(IV) chloride. In the second stage, titanium(IV) chloride is converted into titanium.
The enthalpy change for the second stage can be determined using Hess's Law.

2 (a) Give **one** reason why titanium is **not** extracted directly from titanium(IV) oxide using carbon.

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(1 mark)

2 (b) Give the meaning of the term *enthalpy change*.

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(1 mark)

2 (c) State Hess's Law.

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(1 mark)

2 (d) Define the term *standard enthalpy of formation*.

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(3 marks)

2 (e) The following standard enthalpy of formation data refer to the second stage in the extraction of titanium.

	$TiCl_4(g)$	Na(l)	NaCl(s)	Ti(s)
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	–720	+3	–411	0

2 (e) (i) State why the value for the standard enthalpy of formation of Na(l) is **not** zero.

.....

.....

(1 mark)

2 (e) (ii) Use data from the table to calculate a value for the standard enthalpy change of the following reaction.

$$TiCl_4(g) + 4Na(l) \longrightarrow 4NaCl(s) + Ti(s)$$

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.....

(3 marks)

2 (e) (iii) State the role of sodium in this reaction.

.....

(1 mark)

11

Turn over ▶

3 (a) Give the **formula** of a Group 2 metal hydroxide used in agriculture.

.....

(1 mark)

3 (b) Identify a sodium halide that does **not** undergo a redox reaction when added as a solid to concentrated sulfuric acid.

.....

(1 mark)

3 (c) Chlorine gas reacts with cold dilute sodium hydroxide solution to form sodium chloride and another chlorine-containing compound, **X**.
Give the **formula** of **X**.

.....

(1 mark)

3 (d) Give the **formula** of the substance responsible for the orange colour when chlorine gas is bubbled through an aqueous solution of sodium bromide.

.....

(1 mark)

3 (e) Solid sodium iodide undergoes a redox reaction with concentrated sulfuric acid.
Give the **formula** for each of the following in this reaction.

Formula of the solid reduction product .....

Formula of the oxidation product .....

(2 marks)

3 (f) Draw the structure of each of the following organic compounds.

3 (f) (i) The hydrocarbon that is a chain isomer of methylpropene, but does **not** exhibit E–Z stereoisomerism.

(1 mark)

3 (f) (ii) The alcohol that is a position isomer of butan-2-ol.

(1 mark)

3 (f) (iii) The hydrocarbon that has a peak, due to its molecular ion, at $m/z = 44$ in its mass spectrum.

(1 mark)

3 (f) (iv) The bromoalkane that reacts with sodium cyanide to produce propanenitrile.

(1 mark)

10

4 Metals are usually extracted from oxides.
Some of these oxides occur naturally. Other oxides are made by roasting sulfide ores in air, producing sulfur dioxide as a by-product.
For the extraction of some metals, the oxide needs to be converted into a chloride.

4 (a) The ore molybdenite contains molybdenum disulfide (MoS_2).
The first stage in the extraction of molybdenum is to roast the ore in air to form molybdenum oxide (MoO_3) and sulfur dioxide.

4 (a) (i) Write an equation for the first stage in this extraction.

.....

(1 mark)

4 (a) (ii) The release of sulfur dioxide into the atmosphere causes environmental problems and wastes a valuable resource. Identify **one** environmental problem and identify **one** use for the sulfur dioxide.

Environmental problem .....

.....

.....

Use for sulfur dioxide .....

.....

.....

(2 marks)

4 (a) (iii) Pure molybdenum is formed in the second stage by the reduction of MoO_3 using hydrogen.
Write an equation for this reaction.

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(1 mark)

4 (a) (iv) State **one** risk in using hydrogen gas in metal extractions.

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(1 mark)

4 (b) Calcium is an expensive metal. It is extracted by the electrolysis of molten calcium chloride.

4 (b) (i) State why calcium chloride must be molten for electrolysis to occur.

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(1 mark)

4 (b) (ii) Write an equation for the reaction that takes place at the negative electrode during this electrolysis.

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(1 mark)

4 (b) (iii) Identify the major cost in this extraction of calcium.

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(1 mark)

8

Turn over for the next question

5 A sample of nitrogen dioxide gas (NO_2) was prepared by the reaction of copper with concentrated nitric acid.

5 (a) (i) Balance the equation for the reaction of copper with concentrated nitric acid.

$$Cu + \ldots\ldots HNO_3 \longrightarrow Cu(NO_3)_2 + \ldots\ldots NO_2 + \ldots\ldots H_2O$$

(1 mark)

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

HNO_3 .....

NO_2 .....

(2 marks)

5 (a) (iii) Deduce the half-equation for the conversion of HNO_3 into NO_2 in this reaction.

.....

(1 mark)

5 (b) The following equilibrium is established between colourless dinitrogen tetraoxide gas (N_2O_4) and dark brown nitrogen dioxide gas.

$$N_2O_4(g) \rightleftharpoons 2NO_2(g) \qquad \Delta H = +58\,kJ\,mol^{-1}$$

5 (b) (i) Give two features of a reaction at equilibrium.

Feature 1 .....

.....

.....

.....

Feature 2 .....

.....

.....

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(2 marks)

5 (b) (ii) Use Le Chatelier's principle to explain why the mixture of gases becomes darker in colour when the mixture is heated at constant pressure.

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(2 marks)

5 (b) (iii) Use Le Chatelier's principle to explain why the amount of NO_2 decreases when the pressure is increased at constant temperature.

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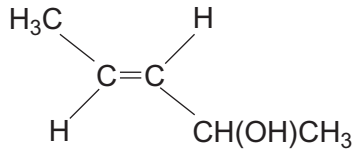
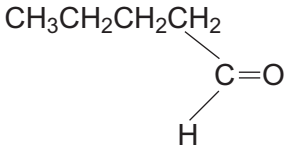
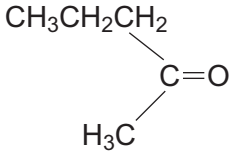
(2 marks)

10

Turn over for the next question

6 The table below shows the structures of three isomers with the molecular formula $C_5H_{10}O$

Isomer **1** 	(*E*)-pent-3-en-2-ol
Isomer **2** 	pentanal
Isomer **3** 	

6 (a) Complete the table by naming Isomer **3**. *(1 mark)*

6 (b) State the type of structural isomerism shown by these three isomers.

.....

(1 mark)

6 (c) The compound (*Z*)-pent-3-en-2-ol is a stereoisomer of (*E*)-pent-3-en-2-ol.

6 (c) (i) Draw the structure of (*Z*)-pent-3-en-2-ol.

(1 mark)

6 (c) (ii) Identify the feature of the double bond in (*E*)-pent-3-en-2-ol and that in (*Z*)-pent-3-en-2-ol that causes these two compounds to be stereoisomers.

.....

(1 mark)

6 (d) A chemical test can be used to distinguish between separate samples of Isomer **2** and Isomer **3**.
Identify a suitable reagent for the test.
State what you would observe with Isomer **2** and with Isomer **3**.

Test reagent .....

Observation with Isomer **2** .....

.....

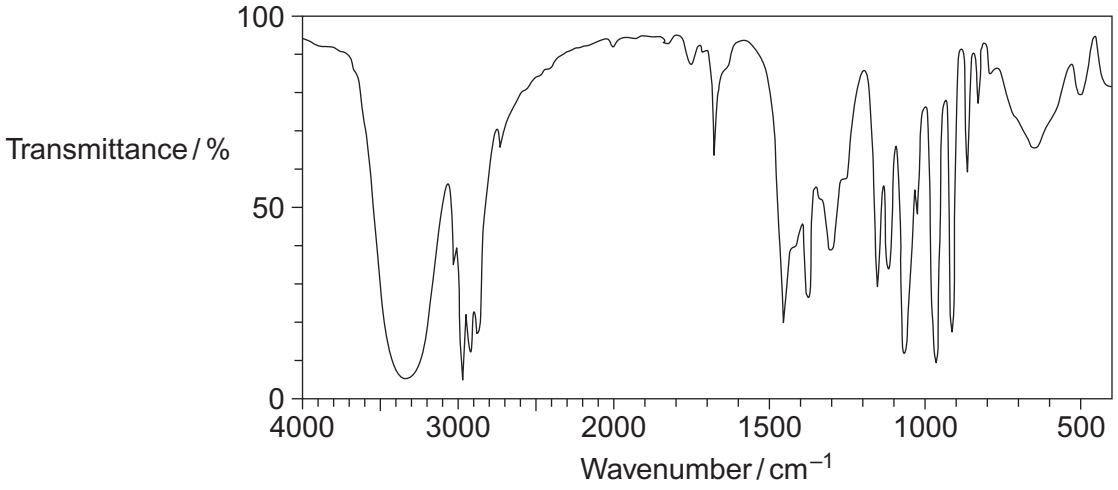
Observation with Isomer **3** .....

.....

(3 marks)

Question 6 continues on the next page

6 (e) The following is the infrared spectrum of one of the isomers **1**, **2** or **3**.



6 (e) (i) Deduce which of the isomers (**1**, **2** or **3**) would give this infrared spectrum.
You may find it helpful to refer to **Table 1** on the Data Sheet.

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(1 mark)

6 (e) (ii) Identify two features of the infrared spectrum that support your deduction.
In each case, identify the functional group responsible.

Feature 1 and functional group .....

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Feature 2 and functional group .....

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(2 marks)

10

Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

7 Halogens are used to make halogenated organic compounds.

7 (a) The refrigerant used in air conditioners is a mixture of fluorinated alkanes.
These compounds are made by fluorination reactions.
The mechanism for the reaction of fluorine with an alkane or with a fluoroalkane is a free-radical substitution similar to the reaction of chlorine with methane.

7 (a) (i) Write the overall equation for the reaction of fluorine with methane to form trifluoromethane (CHF_3).

.....

(1 mark)

7 (a) (ii) Write equations for the following steps in the mechanism for the reaction of fluorine with trifluoromethane (CHF_3) to form tetrafluoromethane (CF_4).

Initiation step

.....

First propagation step

.....

Second propagation step

.....

A termination step leading to the formation of hexafluoroethane.

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(4 marks)

7 (b) Chlorofluorocarbons (CFCs) were used as refrigerants.
In the upper atmosphere, ultra-violet radiation breaks bonds in the CFCs to produce a reactive intermediate that catalyses the decomposition of ozone.

7 (b) (i) An example of a CFC is 1,1,1-trichloro-2,2-difluoroethane.
Draw the displayed formula of this CFC.

(1 mark)

7 (b) (ii) Identify a bond in a CFC that is broken by ultra-violet radiation to produce a reactive intermediate.
Give the name of this reactive intermediate that catalyses the decomposition of ozone.
Write an overall equation for this decomposition of ozone.

Bond broken .....

Name of the reactive intermediate .....

Overall equation

.....

(3 marks)

9

Turn over for the next question

Section B

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

8 (a) Some scientists thought that the waste water from a waste disposal factory contained **two** sodium halides.

They tested a sample of the waste water.

They added three reagents, one after the other, to the same test tube containing the waste water.

The table below shows their results.

Reagent added	Observations
1. Silver nitrate solution (acidified with dilute nitric acid)	A cream precipitate formed
2. Dilute ammonia solution	A yellow precipitate remained
3. Concentrated ammonia solution	The yellow precipitate did not dissolve

8 (a) (i) Identify the yellow precipitate that did **not** dissolve in concentrated ammonia solution.
Write the **simplest** ionic equation for the formation of this precipitate from silver ions and the correct halide ion.
Identify the other sodium halide that must be present in this mixture of two sodium halides.

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(3 marks)

8 (a) (ii) Give **one** reason why the silver nitrate solution was acidified before it was used in this test.

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(1 mark)

8 (a) (iii) The method that the scientists used could **not** detect one type of halide ion.
Identify this halide ion.
Give **one** reason for your answer.

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(2 marks)

8 (b) The scientists thought that the waste water also contained dissolved barium ions.
An aqueous solution of sodium sulfate can be used to test for the presence of dissolved barium ions.

Write the **simplest** ionic equation for the reaction between barium ions and sulfate ions to form barium sulfate.

State what is observed in this reaction.

Give a use for barium sulfate in medicine and explain why this use is possible, given that solutions containing barium ions are poisonous.

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(4 marks)

Question 8 continues on the next page

8 (c) The scientists also analysed the exhaust gases from an incinerator used to destroy waste poly(ethene).
Mass spectrometry showed that there was a trace gas with a precise M_r = 28.03176 in the exhaust gases from the incinerator.

The table below contains some precise relative atomic mass data.

Atom	Precise relative atomic mass
^{12}C	12.00000
^{1}H	1.00794
^{16}O	15.99491

Use the data to show that the trace gas is ethene. Show your working.

Suggest why both ethene and carbon monoxide might have been identified as the trace gas if the scientists had used relative atomic masses to a precision of only one decimal place.

Write an equation for the incomplete combustion of ethene to form carbon monoxide and water only.

Ethene is used to make poly(ethene).
Draw the displayed formula for the repeating unit of poly(ethene).
Name this type of polymer.

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(5 marks)

15

9 Organic reaction mechanisms help chemists to understand how the reactions of organic compounds occur.
The following conversions illustrate a number of different types of reaction mechanism.

9 (a) When 2-bromopentane reacts with ethanolic KOH, two structurally isomeric alkenes are formed.

9 (a) (i) Name and outline a mechanism for the conversion of 2-bromopentane into pent-2-ene as shown below.

$$CH_3CH_2CH_2CHBrCH_3 \xrightarrow{\text{ethanolic KOH}} CH_3CH_2CH{=}CHCH_3$$

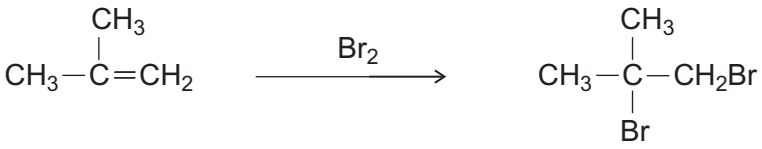
(4 marks)

9 (a) (ii) Draw the structure of the other structurally isomeric alkene produced when 2-bromopentane reacts with ethanolic KOH.

(1 mark)

Question 9 continues on the next page

9 (b) Name and outline a mechanism for the following conversion.



(5 marks)

9 (c) Name and outline a mechanism for the following conversion.

$$CH_3CH_2CH_2Br \xrightarrow{NH_3} CH_3CH_2CH_2NH_2$$

(5 marks)

15

END OF QUESTIONS

There are no questions printed on this page

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