Channel: CHEMISTRY
Paper: 2 Theory
Cambridge Ordinary Level

October/November 2017
1 hour 30 minutes

Candidates answer on the Question Paper.
No Additional Materials are required.

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 an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO NOT WRITE IN ANY BARCODES.

Section A
Answer all questions.
Write your answers in the spaces provided in the Question Paper.

Section B
Answer any three questions.
Write your answers in the spaces provided in the Question Paper.

Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.
A copy of the Periodic Table is printed on page 20.

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.

This document consists of 19 printed pages and 1 blank page.
Section A

Answer all the questions in this section in the spaces provided.

The total mark for this section is 45.

A1 (a) Choose from the following elements to answer the questions.

- calcium
- chlorine
- chromium
- copper
- krypton
- nitrogen
- oxygen
- sodium
- sulfur

Each element may be used once, more than once or not at all.

Which element:

(i) is a monatomic gas,
.......................................................................................................................... [1]

(ii) makes up 78% of dry air,
.......................................................................................................................... [1]

(iii) has an oxide which reacts with the impurities in a blast furnace to form slag,
.......................................................................................................................... [1]

(iv) forms aqueous ions with a 2+ charge which give a dark blue solution on addition of excess aqueous ammonia,
.......................................................................................................................... [1]

(v) reacts with propane in the presence of ultraviolet light by a substitution reaction?
.......................................................................................................................... [1]
(b) Complete the table to show the number of electrons and number of neutrons in the sulfur atom and in the magnesium ion.

<table>
<thead>
<tr>
<th></th>
<th>number of electrons</th>
<th>number of neutrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{33}\text{S}_{16}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^{25}\text{Mg}^{2+}_{12}$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

[Total: 9]
A2 Copper(II) sulfate is an ionic compound.

(a) Describe the arrangement of the ions and the type of attractive forces between the ions in solid copper(II) sulfate.

arrangement ..........................................................................................................................

type of attractive forces .........................................................................................................

(b) Explain why solid copper(II) sulfate does not conduct electricity but aqueous copper(II) sulfate does conduct.

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

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

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

(c) When aqueous copper(II) sulfate is electrolysed using platinum electrodes, copper(II) ions are reduced to copper at the negative electrode. Oxygen is formed at the positive electrode by loss of electrons from hydroxide ions.

(i) State the source of the hydroxide ions.

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

(ii) Complete the equation for the reaction at the positive electrode.

\[ \ldots \text{OH}^- \rightarrow \text{O}_2 + \ldots \text{H}_2\text{O} + \ldots \text{........} \] [1]

(iii) Suggest why hydroxide ions and not sulfate ions are discharged at the positive electrode.

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

(d) (i) Give the formulae of the four ions present in aqueous copper(II) sulfate.

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

(ii) Suggest why the solution becomes acidic as the electrolysis proceeds.

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

(iii) Suggest why the blue colour of the aqueous copper(II) sulfate fades as the electrolysis proceeds.

.............................................................................................................................................[1]
(e) Draw a ‘dot-and-cross’ diagram of an oxygen molecule.

Show only the outer shell electrons.
A3 The diagram shows the structure of a metal.

![Diagram of metal structure]

Key
+ metal ion
– electron

(a) Refer to this structure to explain why

(i) metals are malleable,
...........................................................................................................................................
...............................................................................................................................................[2]

(ii) metals conduct electricity.
...............................................................................................................................................[1]

(b) The table shows the ease with which different metal oxides can be reduced.

<table>
<thead>
<tr>
<th>metal oxide</th>
<th>ease of reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>calcium oxide</td>
<td>not reduced by carbon at 1800 °C</td>
</tr>
<tr>
<td>iron(III) oxide</td>
<td>reduced by carbon at 650 °C</td>
</tr>
<tr>
<td>silver oxide</td>
<td>reduced by heating without carbon</td>
</tr>
<tr>
<td>titanium(IV) oxide</td>
<td>reduced by carbon at 1800 °C but not at 650 °C</td>
</tr>
</tbody>
</table>

Use the information in the table to place the metals calcium, iron, silver and titanium in order of their reactivity.

least reactive   most reactive

[1]
(c) Iron(III) oxide can be reduced by carbon monoxide.

\[ \text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2 \]

(i) Calculate the maximum mass of iron that can be formed when 14.4 g of iron(III) oxide is reduced by excess carbon monoxide.

Give your answer to three significant figures.

mass of iron = ....................................................... g [3]

(ii) Calculate the maximum volume of carbon dioxide, in dm\(^3\), produced by this reaction, at room temperature and pressure.

volume of carbon dioxide = .................................................. dm\(^3\) [2]

[Total: 9]
A4 The structure of malic acid is shown.

(a) Malic acid is a carboxylic acid because it contains a \(-\text{COOH}\) group.

Malic acid also contains an \(-\text{OH}\) group.

Name the homologous series of compounds which contain the \(-\text{OH}\) group.

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

(b) A diester of malic acid has the formula shown.

\[
\text{H}_2\text{C}_3\text{OOC–CH(OH)–CH}_2–\text{COOC}_3\text{H}_7
\]

What reagent and conditions are needed to make this diester from malic acid?

reagent ........................................................................................................................................

conditions ...................................................................................................................................

(c) When heated, malic acid forms fumaric acid.

\[
\text{HOOC–CH(OH)–CH}_2–\text{COOH} \rightarrow \text{HOOC–CH=CH–COOH} + \text{H}_2\text{O}
\]

malic acid fumaric acid

How can aqueous malic acid and aqueous fumaric acid be distinguished when aqueous bromine is added to a sample of each?

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

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

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

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

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

...................................................................................................................................................
(d) The structure of compound A is shown.

\[
\begin{array}{c}
\text{H} \quad \text{H} \\
\text{C} \quad \text{C} \\
\text{COOH} \quad \text{OH}
\end{array}
\]

Compound A can undergo two types of polymerisation.

(i) Name these two types of polymerisation.

1. .......................................................................................................................................

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

(ii) For one of these types of polymerisation, draw a section of the polymer to show two repeat units.

[2] [Total: 9]
A5 Hydrocarbons undergo complete combustion to form carbon dioxide and water.

(a) Construct the equation for the complete combustion of butane, $\text{C}_4\text{H}_{10}$.

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

(b) The combustion of butane is exothermic.

Explain in terms of bond making and bond breaking why this reaction is exothermic.

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

(c) Petroleum (crude oil) fractions contain hydrocarbons.

Give one use of the paraffin (kerosene) fraction.

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

[Total: 5]
Section B

Answer three questions from this section in the spaces provided.

The total mark for this section is 30.

B6 Ethanoic acid is a weak acid.

(a) What is meant by the term *weak acid*?

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

(b) Ethanoic acid reacts with ethanol to form ethyl ethanoate.

The reaction is exothermic.

\[
\text{CH}_3\text{COOH} + \text{C}_2\text{H}_5\text{OH} \rightleftharpoons \text{CH}_3\text{COOC}_2\text{H}_5 + \text{H}_2\text{O}
\]

Describe and explain the effect, if any, on the position of equilibrium when

(i) the concentration of ethanol is increased,

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

(ii) the temperature is increased.

..............................................................................................................................................................................
..............................................................................................................................................................................
..............................................................................................................................................................................[2]
(c) The table shows some properties of four carboxylic acids.

<table>
<thead>
<tr>
<th>carboxylic acid</th>
<th>formula</th>
<th>melting point /°C</th>
<th>boiling point /°C</th>
<th>density in the liquid state in g/cm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>methanoic acid</td>
<td>HCOOH</td>
<td>8.5</td>
<td>100.7</td>
<td>1.22</td>
</tr>
<tr>
<td>ethanoic acid</td>
<td>CH₃COOH</td>
<td>16.7</td>
<td>118.0</td>
<td>1.05</td>
</tr>
<tr>
<td>propanoic acid</td>
<td>C₂H₅COOH</td>
<td>−20.7</td>
<td>141.1</td>
<td></td>
</tr>
<tr>
<td>butanoic acid</td>
<td>C₃H₇COOH</td>
<td>−4.4</td>
<td>165.6</td>
<td>0.96</td>
</tr>
</tbody>
</table>

(i) How does the boiling point change as the number of carbon atoms in the formula of the carboxylic acids increases?

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

(ii) Estimate the density, in g/cm³, of liquid propanoic acid.

density .............................................. g/cm³ [1]

(iii) What is the physical state of ethanoic acid at 15.0 °C? Explain your answer.

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

(iv) Why is it difficult to predict the melting point of pentanoic acid, C₄H₉COOH, using only the information from the table?

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

(v) Draw the structure of propanoic acid showing all of the atoms and all of the bonds.

[1]

[Total: 10]
B7 Some properties of the Group IV elements are shown in the table.

<table>
<thead>
<tr>
<th>element</th>
<th>melting point $^\circ$C</th>
<th>relative electrical conductivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>carbon (diamond)</td>
<td>3550</td>
<td>non-conductor</td>
</tr>
<tr>
<td>silicon</td>
<td>1410</td>
<td>poor conductor</td>
</tr>
<tr>
<td>germanium</td>
<td>937</td>
<td>poor conductor</td>
</tr>
<tr>
<td>tin</td>
<td>232</td>
<td>conductor</td>
</tr>
<tr>
<td>lead</td>
<td>328</td>
<td>conductor</td>
</tr>
</tbody>
</table>

(a) (i) Explain in terms of structure and bonding why diamond has such a high melting point.

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

(ii) Use the information in the table to suggest how the type of structure and bonding in carbon (diamond) differs from the type of structure and bonding in tin. Explain your answer.

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

(iii) Lead oxide is an amphoteric oxide.

What is the meaning of the term *amphoteric oxide*?

...........................................................................................................................................[1]
(b) A sample containing 64.5 g of a chloride of germanium contains 42.6 g of chlorine.

(i) Deduce the empirical formula of this chloride.

empirical formula ...........................................................[3]

(ii) This chloride of germanium has a boiling point of 87 °C.

Predict the structure and bonding of this chloride.

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

[Total: 10]
B8 Concentrated aqueous ammonia is used to make fertilisers such as ammonium phosphate, \((\text{NH}_4)_3\text{PO}_4\).

(a) Calculate the percentage by mass of nitrogen in ammonium phosphate.

........................................ % by mass [2]

(b) Explain why farmers spread nitrogen-containing fertilisers on their fields.

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

(c) Describe a test for ammonia.

test ............................................................................................................................................

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

(d) Explain why adding calcium hydroxide to the soil at the same time as ammonium phosphate results in loss of nitrogen from the soil.

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

............................................................................................................................................[2]
(e) Aqueous ammonia reacts with dilute sulfuric acid.

$$2\text{NH}_3(\text{aq}) + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow (\text{NH}_4)_2\text{SO}_4(\text{aq})$$

A student titrates 20.0 cm$^3$ of aqueous ammonia with 0.150 mol/dm$^3$ sulfuric acid.

10.5 cm$^3$ of sulfuric acid is required to neutralise the aqueous ammonia.

Calculate the concentration, in mol/dm$^3$, of the aqueous ammonia.

concentration of aqueous ammonia = ........................................... mol/dm$^3$ [3]

[Total: 10]
B9 Cyclopropane is converted to propene when heated.

\[
\begin{align*}
\text{H}_2\text{C} & \quad \text{CH}_2 \\
\text{H}_2\text{C} & \quad \text{CH}_2 \\
\text{cyclopropane} & \quad \text{CH}_3\text{CH} = \text{CH}_2
\end{align*}
\]

(a) Explain why cyclopropane and propene are isomers.

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

(b) The graph shows how the concentration of propene in this reaction changes with time.

Describe how the rate of this reaction changes with time. Explain your answer by referring to the graph.

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

(c) Describe and explain the effect of increasing the concentration of cyclopropane on the rate of this reaction.

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

(d) Describe and explain the effect of decreasing the temperature on the rate of this reaction.

..................................................................................................................................................
..................................................................................................................................................
..................................................................................................................................................
..................................................................................................................................................[2]
(e) Propene undergoes addition reactions. Two addition reactions of propene are shown in the diagram.

Complete the diagram to show the missing name, formula and conditions.

\[ \text{propene } \text{CH}_3\text{CH} = \text{CH}_2 \]

+ steam  \quad + \text{H}_2  \quad \text{conditions}

1. ..............................

2. ..............................

\[ \text{name } \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \]

\[ \text{formula } \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \]

\[ \text{propane } \text{CH}_3\text{CH}_2\text{CH}_3 \]

[3]

[Total: 10]
The Periodic Table of Elements

<table>
<thead>
<tr>
<th>Group</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Key</td>
<td>atomic number</td>
<td>atomic symbol</td>
<td>name</td>
<td>relative atomic mass</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>He</td>
<td>helium</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Li</td>
<td>lithium</td>
<td>7</td>
<td>Be</td>
<td>beryllium</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Na</td>
<td>sodium</td>
<td>23</td>
<td>Mg</td>
<td>magnesium</td>
<td>24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>K</td>
<td>potassium</td>
<td>39</td>
<td>Ca</td>
<td>calcium</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>Rb</td>
<td>rubidium</td>
<td>85</td>
<td>Sr</td>
<td>strontium</td>
<td>88</td>
<td></td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>Cs</td>
<td>caesium</td>
<td>133</td>
<td>Ba</td>
<td>barium</td>
<td>137</td>
<td></td>
<td></td>
</tr>
<tr>
<td>87</td>
<td>Fr</td>
<td>francium</td>
<td>–</td>
<td>Ra</td>
<td>radium</td>
<td>–</td>
<td></td>
<td></td>
</tr>
<tr>
<td>57</td>
<td>La</td>
<td>lanthanum</td>
<td>139</td>
<td>Ce</td>
<td>cerium</td>
<td>140</td>
<td></td>
<td></td>
</tr>
<tr>
<td>58</td>
<td>Pr</td>
<td>praseodymium</td>
<td>141</td>
<td>Nd</td>
<td>neodymium</td>
<td>144</td>
<td></td>
<td></td>
</tr>
<tr>
<td>61</td>
<td>Sm</td>
<td>samarium</td>
<td>–</td>
<td>Eu</td>
<td>europium</td>
<td>152</td>
<td></td>
<td></td>
</tr>
<tr>
<td>89</td>
<td>Ac</td>
<td>actinium</td>
<td>–</td>
<td>Th</td>
<td>thorium</td>
<td>232</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The volume of one mole of any gas is 24 dm$^3$ at room temperature and pressure (r.t.p.).