Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Standard level
Paper 2

Wednesday 16 May 2018 (afternoon)

1 hour 15 minutes

Candidate session number

Instructions to candidates

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **chemistry data booklet** is required for this paper.
- The maximum mark for this examination paper is **[50 marks]**.

2218–6117

Answer **all** questions. Answers must be written within the answer boxes provided.

1. A student determined the percentage of the active ingredient magnesium hydroxide, $Mg(OH)_2$, in a 1.24 g antacid tablet.

The antacid tablet was added to 50.00 cm^3 of 0.100 mol dm^{-3} sulfuric acid, which was in excess.

(a) Calculate the amount, in mol, of H_2SO_4. [1]

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(b) Formulate the equation for the reaction of H_2SO_4 with $Mg(OH)_2$. [1]

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(c) The excess sulfuric acid required 20.80 cm^3 of 0.1133 mol dm^{-3} NaOH for neutralization.

Calculate the amount of excess acid present. [1]

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(d) Calculate the amount of H_2SO_4 that reacted with $Mg(OH)_2$. [1]

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(Question 1 continued)

(e) Determine the mass of $Mg(OH)_2$ in the antacid tablet. [2]

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(f) Calculate the percentage by mass of magnesium hydroxide in the 1.24 g antacid tablet to three significant figures. [1]

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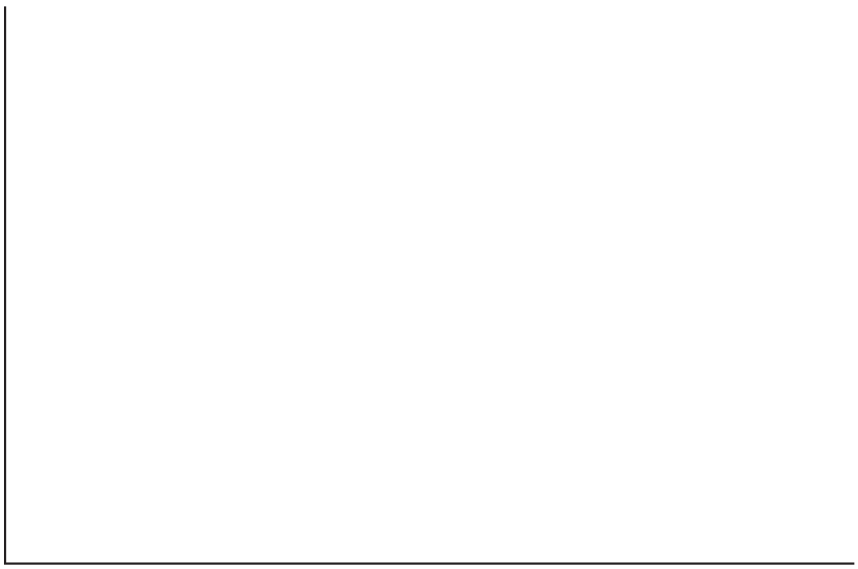
2. Graphing is an important tool in the study of rates of chemical reactions.

(a) Sketch a Maxwell–Boltzmann distribution curve for a chemical reaction showing the activation energies with and without a catalyst. [3]



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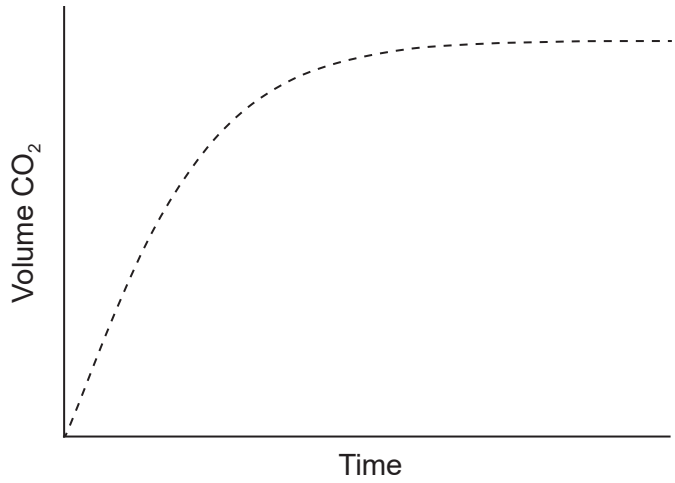
(Question 2 continued)

(b) Excess hydrochloric acid is added to lumps of calcium carbonate. The graph shows the volume of carbon dioxide gas produced over time.



(i) Sketch a curve on the graph to show the volume of gas produced over time if the same mass of crushed calcium carbonate is used instead of lumps. All other conditions remain constant. [1]

(ii) State and explain the effect on the rate of reaction if ethanoic acid of the same concentration is used in place of hydrochloric acid. [2]

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(c) Outline why pH is more widely used than $[H^+]$ for measuring relative acidity. [1]

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(d) Outline why H_3PO_4/HPO_4^{2-} is not a conjugate acid-base pair. [1]

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3. The emission spectrum of an element can be used to identify it.

(a) (i) Draw the first four energy levels of a hydrogen atom on the axis, labelling n = 1, 2, 3 and 4. [1]

(ii) Draw the lines, on your diagram, that represent the electron transitions to n = 2 in the emission spectrum. [1]

(b) Elements show trends in their physical properties across the periodic table.

(i) Outline why atomic radius decreases across period 3, sodium to chlorine. [1]

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(ii) Outline why the ionic radius of K^+ is smaller than that of Cl^-. [2]

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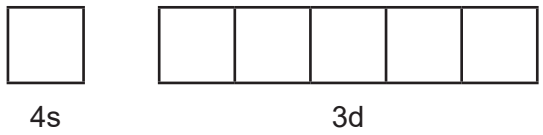
(Question 3 continued)

(c) (i) Copper is widely used as an electrical conductor.

Draw arrows in the boxes to represent the electronic configuration of copper in the 4s and 3d orbitals. [1]



(ii) Impure copper can be purified by electrolysis. In the electrolytic cell, impure copper is the anode (positive electrode), pure copper is the cathode (negative electrode) and the electrolyte is copper(II) sulfate solution.

Formulate the half-equation at each electrode. [2]

Anode (positive electrode):

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Cathode (negative electrode):

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(iii) Outline where and in which direction the electrons flow during electrolysis. [1]

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4. Enthalpy changes depend on the number and type of bonds broken and formed.

(a) Hydrogen gas can be formed industrially by the reaction of natural gas with steam.

$$CH_4(g) + H_2O(g) \rightarrow 3H_2(g) + CO(g)$$

Determine the enthalpy change, ΔH, for the reaction, in kJ, using section 11 of the data booklet.

Bond enthalpy for C≡O: 1077 kJ mol^{-1} [3]

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(b) The table lists the standard enthalpies of formation, $\Delta H_f^{\ominus}$, for some of the species in the reaction above.

	$CH_4(g)$	$H_2O(g)$	$CO(g)$	$H_2(g)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	–74.0	–242	–111	

(i) Outline why no value is listed for $H_2(g)$. [1]

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(ii) Determine the value of $\Delta H^{\ominus}$, in kJ, for the reaction using the values in the table. [1]

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(Question 4 continued)

(iii) Outline why the value of enthalpy of reaction calculated from bond enthalpies is less accurate. [1]

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5. A mixture of 1.00 mol $SO_2(g)$, 2.00 mol $O_2(g)$ and 1.00 mol $SO_3(g)$ is placed in a 1.00 dm^3 container and allowed to reach equilibrium.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

(a) Distinguish between the terms reaction quotient, *Q,* and equilibrium constant, K_c. [1]

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(b) The equilibrium constant, K_c, is 0.282 at temperature T.

Deduce, showing your work, the direction of the initial reaction. [2]

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6. Some physical properties of molecular substances result from the different types of forces between their molecules.

(a) (i) Explain why the hydrides of group 16 elements (H_2O, H_2S, H_2Se and H_2Te) are polar molecules. [2]

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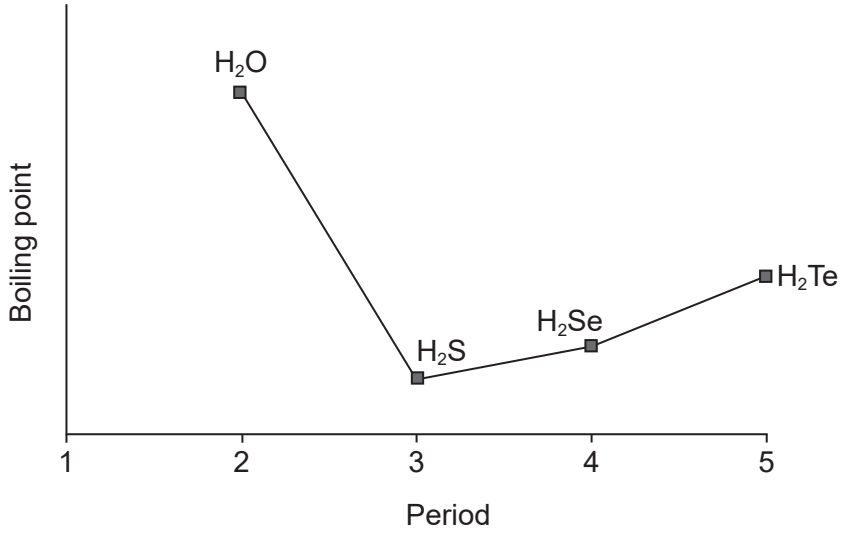
(ii) The graph shows the boiling points of the hydrides of group 16 elements.



Explain the increase in the boiling point from H_2S to H_2Te. [2]

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(Question 6 continued)

(b) Lewis structures show electron domains and are used to predict molecular geometry.

Deduce the electron domain geometry and the molecular geometry for the NH_2^- ion. [2]

Electron domain geometry:

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Molecular geometry:

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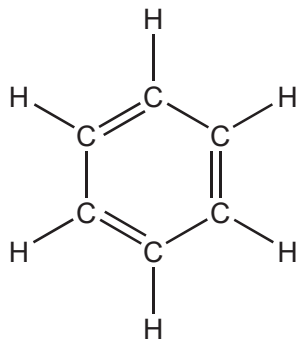
7. The structure of an organic molecule can help predict the type of reaction it can undergo.

(a) The Kekulé structure of benzene suggests it should readily undergo addition reactions.



Discuss two pieces of evidence, **one** physical and **one** chemical, which suggest this is not the structure of benzene. [2]

Physical evidence:

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Chemical evidence:

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(Question 7 continued)

(b) (i) Formulate the ionic equation for the oxidation of propan-1-ol to the corresponding aldehyde by acidified dichromate(VI) ions. Use section 24 of the data booklet. [2]

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(ii) The aldehyde can be further oxidized to a carboxylic acid.

Outline how the experimental procedures differ for the synthesis of the aldehyde and the carboxylic acid. [2]

Aldehyde:

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Carboxylic acid:

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(c) Improvements in instrumentation have made identification of organic compounds routine.

The empirical formula of an unknown compound containing a phenyl group was found to be C_4H_4O. The molecular ion peak in its mass spectrum appears at m/z = 136.

(i) Deduce the molecular formula of the compound. [1]

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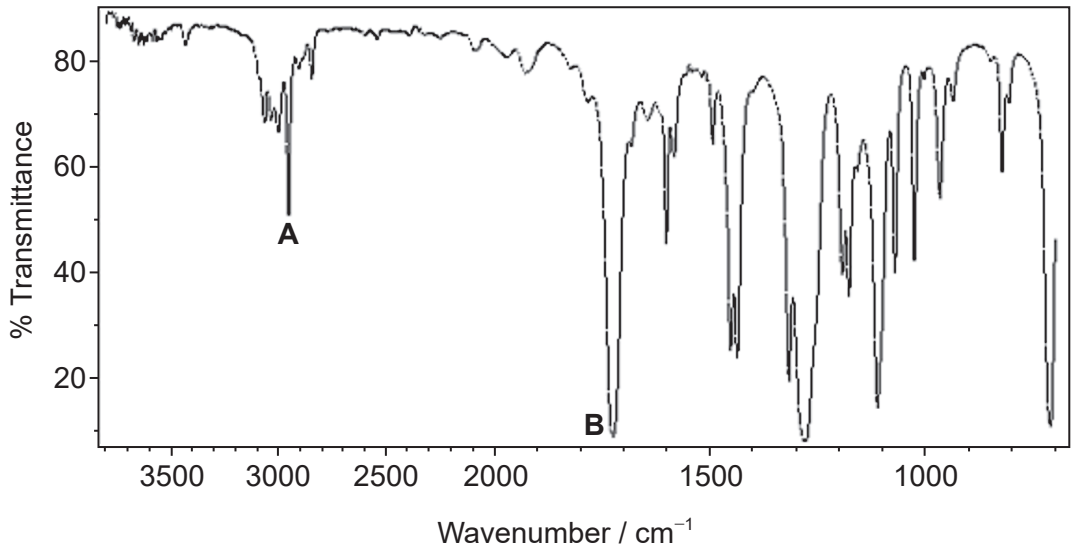
(Question 7 continued)

(ii) Identify the bonds causing peaks **A** and **B** in the IR spectrum of the unknown compound using section 26 of the data booklet. [1]



[Source: Food and Agriculture Organization of the United Nations, http://www.fao.org/fileadmin/user_upload/jecfa/img/851.gif. Reproduced with permission]

A:

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B:

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(iii) Deduce full structural formulas of **two** possible isomers of the unknown compound, both of which are esters. [2]

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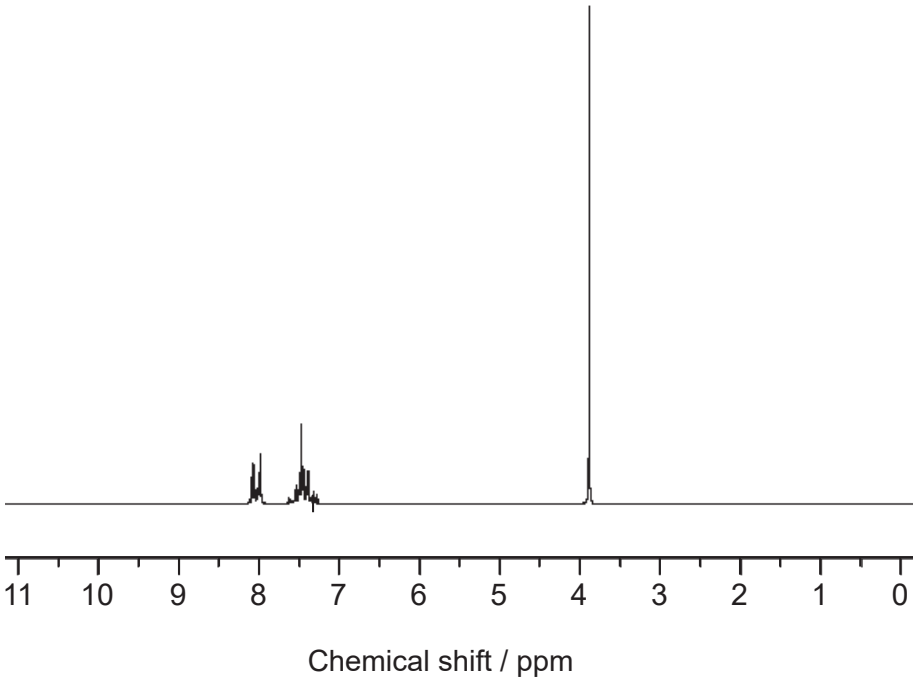
(Question 7 continued)

(iv) Deduce the formula of the unknown compound based on its ^{1}H NMR spectrum using section 27 of the data booklet. [1]



[Source: SDBS, National Institute of Advanced Industrial Science and Technology.]

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