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CHEMISTRY
STANDARD LEVEL
PAPER 2

Candidate session number

Monday 19 May 2014 (afternoon)

1 hour 15 minutes

Examination code

2	2	1	4	–	6	1	1	1

INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all questions.
- Section B: answer one question.
- Write your answers in the 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]*.

22 pages

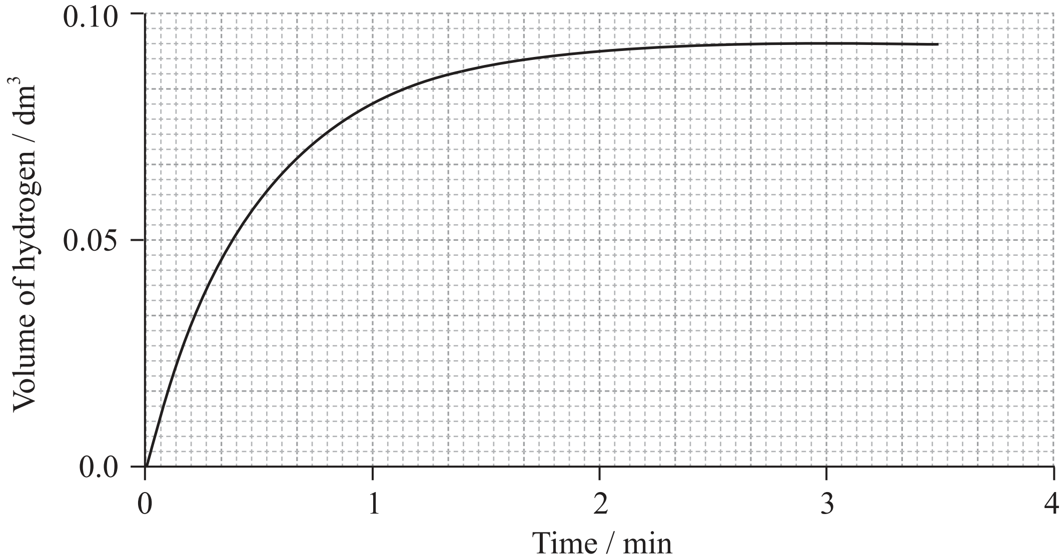
SECTION A

*Answer **all** questions. Write your answers in the boxes provided.*

1. (a) 0.100 g of magnesium ribbon is added to 50.0 cm^3 of 1.00 mol dm^{-3} sulfuric acid to produce hydrogen gas and magnesium sulfate.

$$Mg(s) + H_2SO_4(aq) \rightarrow H_2(g) + MgSO_4(aq)$$

(i) The graph shows the volume of hydrogen produced against time under these experimental conditions.



Sketch two curves, labelled **I** and **II**, to show how the volume of hydrogen produced (under the same temperature and pressure) changes with time when:

I. using the same mass of magnesium powder instead of a piece of magnesium ribbon;

II. 0.100 g of magnesium ribbon is added to 50 cm^3 of 0.500 mol dm^{-3} sulfuric acid. *[2]*

(ii) Outline why it is better to measure the volume of hydrogen produced against time rather than the loss of mass of reactants against time. *[1]*

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(Question 1 continued)

(b) Magnesium sulfate can exist in either the hydrated form or in the anhydrous form. Two students wished to determine the enthalpy of hydration of anhydrous magnesium sulfate. They measured the initial and the highest temperature reached when anhydrous magnesium sulfate, $MgSO_4(s)$, was dissolved in water. They presented their results in the following table.

mass of anhydrous magnesium sulfate / g	3.01
volume of water / cm^3	50.0
initial temperature / °C	17.0
highest temperature / °C	26.7

(i) Calculate the amount, in mol, of anhydrous magnesium sulfate. *[1]*

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(ii) Calculate the enthalpy change, ΔH_1, for anhydrous magnesium sulfate dissolving in water, in $kJ\,mol^{-1}$. State your answer to the correct number of significant figures. *[2]*

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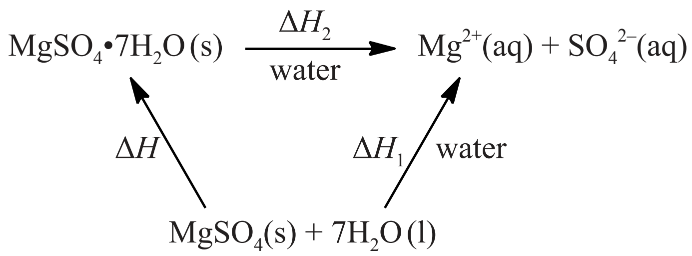
(Question 1 continued)

(c) The students repeated the experiment using 6.16 g of solid hydrated magnesium sulfate, $MgSO_4 \cdot 7H_2O(s)$, and 50.0 cm^3 of water. They found the enthalpy change, ΔH_2, to be +18 $kJ\,mol^{-1}$.

The enthalpy of hydration of solid anhydrous magnesium sulfate is difficult to determine experimentally, but can be determined using the diagram below.



(i) Determine the enthalpy change, ΔH, in $kJ\,mol^{-1}$, for the hydration of solid anhydrous magnesium sulfate, $MgSO_4$. *[1]*

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(ii) The literature value for the enthalpy of hydration of anhydrous magnesium sulfate is –103 $kJ\,mol^{-1}$. Calculate the percentage difference between the literature value and the value determined from experimental results, giving your answer to **one** decimal place. (If you did not obtain an answer for the experimental value in (c)(i) then use the value of –100 $kJ\,mol^{-1}$, but this is **not** the correct value.) *[1]*

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(Question 1 continued)

(d) Another group of students experimentally determined an enthalpy of hydration of $-95\,kJ\,mol^{-1}$. Outline two reasons which may explain the variation between the experimental and literature values. *[2]*

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(e) Magnesium sulfate is one of the products formed when acid rain reacts with dolomitic limestone. This limestone is a mixture of magnesium carbonate and calcium carbonate.

(i) State the equation for the reaction of sulfuric acid with magnesium carbonate. *[1]*

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(ii) Deduce the Lewis (electron dot) structure of the carbonate ion, giving the shape and the oxygen-carbon-oxygen bond angle. *[3]*

Lewis (electron dot) structure:

Shape:

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Bond angle:

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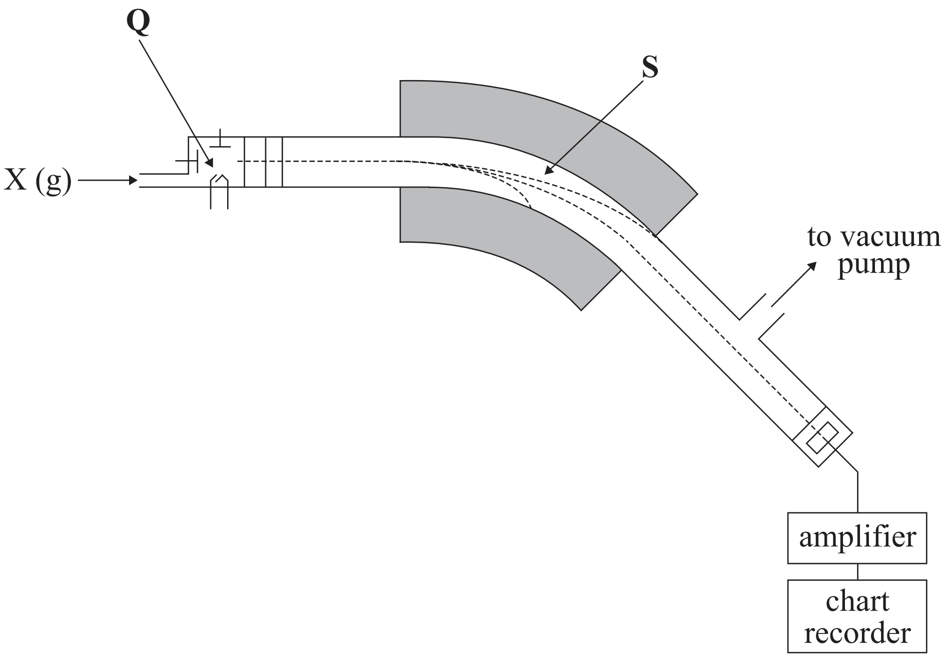
2. Magnesium has three stable isotopes, ^{24}Mg, ^{25}Mg and ^{26}Mg. The relative abundance of each isotope is 78.99%, 10.00% and 11.01% respectively, and can be determined using a mass spectrometer.



(a) Describe the processes occurring at stage **Q** and stage **S**. *[4]*

Q:

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S:

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(Question 2 continued)

(b) (i) Define the term *relative atomic mass*. *[1]*

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(ii) Calculate, showing your working, the relative atomic mass, A_r, of magnesium, giving your answer to **two** decimal places. *[2]*

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3. An equilibrium occurs between nitrogen dioxide, $NO_2(g)$, and dinitrogen tetroxide, $N_2O_4(g)$.

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H = -58\,kJ$$

(a) Deduce the equilibrium constant expression, K_c, for this reaction. *[1]*

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(b) Explain the effect on the position of the equilibrium and on the value of K_c when:

(i) pressure is decreased and temperature is kept constant. *[2]*

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(ii) temperature is increased and pressure is kept constant. *[2]*

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4. Consider the following three organic compounds: butane, $CH_3CH_2CH_2CH_3$; propanal, CH_3CH_2CHO; and ethanoic acid, CH_3COOH.

(a) Deduce the order of **increasing** solubility in water of the three compounds. *[1]*

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(b) Explain your reasoning. *[3]*

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SECTION B

*Answer **one** question. Write your answers in the boxes provided.*

5. Periodic trends enable chemists to predict the behaviour of related compounds.

(a) (i) State the equation for the reaction of sodium metal with water. *[1]*

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(ii) Describe **two** changes that could be observed during the reaction. *[2]*

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(iii) Predict the relative reaction rates of lithium, sodium and potassium with water. *[1]*

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(Question 5 continued)

(b) Chlorine gas, $Cl_2(g)$, is bubbled through separate solutions of aqueous bromine, $Br_2(aq)$, and potassium bromide, $KBr(aq)$.

(i) Predict any changes that may be observed in each case. *[2]*

$Br_2(aq)$:

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$KBr(aq)$:

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(ii) State the half-equations for the reactions that occur. *[2]*

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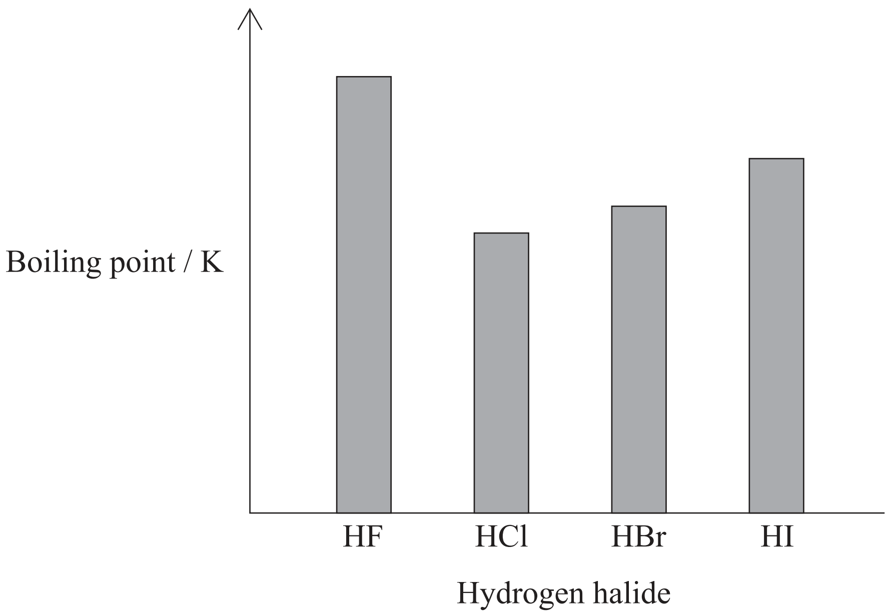
(Question 5 continued)

(c) The hydrogen halides do not show perfect periodicity. A bar chart of boiling points shows that the boiling point of hydrogen fluoride, HF, is much higher than periodic trends would indicate.



(i) Explain why the boiling point of HF is much higher than the boiling points of the other hydrogen halides. *[1]*

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(ii) Explain the trend in the boiling points of HCl, HBr and HI. *[2]*

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(Question 5 continued)

(d) Explain why the ionic radius of a chloride ion is greater than the atomic radius of a chlorine atom. *[1]*

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(e) Na_2O and SO_3 are two oxides of period 3 elements.

(i) Na_2O does not conduct electricity in the solid state but it does when molten. Pure SO_3 does not conduct electricity in either the solid or liquid states. Explain these facts. *[3]*

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(ii) State the acid-base natures of Na_2O and SO_3. *[1]*

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(Question 5 continued)

(iii) State equations for the reactions of Na_2O and SO_3 with water. *[2]*

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(iv) Identify a source of SO_3 and describe the effect of SO_3 pollution on the environment. *[2]*

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6. Oxidation and reduction can be defined in terms of electron transfer or oxidation numbers.

(a) Define *oxidation* in terms of electron transfer. *[1]*

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(b) Alcohols with the molecular formula C_4H_9OH occur as four structural isomers. Three of the isomers can be oxidized with acidified potassium dichromate solution to form compounds with the molecular formula C_4H_8O. The half-equation for the dichromate ion is:

$$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightleftharpoons 2Cr^{3+}(aq) + 7H_2O(l)$$

(i) Deduce the oxidation number of chromium in $Cr_2O_7^{2-}$. *[1]*

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(ii) Deduce the half-equation for the oxidation of the alcohol C_4H_9OH. *[1]*

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(iii) Deduce the overall equation for the redox reaction. *[1]*

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(This question continues on the following page)

(Question 6 continued)

(iv) Two of the isomers with the molecular formula C_4H_9OH can be oxidized further to form compounds with the molecular formula $C_4H_8O_2$. Deduce the structural formulas of these two isomers. *[2]*

(v) One isomer cannot be oxidized by acidified potassium dichromate solution. Deduce its structural formula, state its name and identify it as a primary, secondary or tertiary alcohol. *[3]*

Name: . . . .

Alcohol: . . . .

(vi) All isomers of the alcohol C_4H_9OH undergo complete combustion. State an equation for the complete combustion of C_4H_9OH. *[2]*

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(Question 6 continued)

(c) Electrolysis has made it possible to obtain reactive metals from their ores.

(i) Draw a labelled electrolytic cell for the electrolysis of molten potassium bromide, KBr. Include the direction of electron flow, the positive electrode (anode) and the negative electrode (cathode), the location of oxidation and reduction, and the electrolyte. *[4]*

(ii) Deduce a half-equation for the reaction that occurs at each electrode. *[2]*

Positive electrode (anode):

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Negative electrode (cathode):

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(This question continues on the following page)

(Question 6 continued)

(iii) Describe how current is conducted in a molten electrolyte. *[1]*

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(d) A reactivity series can be experimentally determined by adding the metals W, X, Y and Z to solutions of these metal ions. The following reactions were observed:

$$W^{2+}(aq) + X(s) \rightarrow W(s) + X^{2+}(aq)$$
$$Y(s) + W^{2+}(aq) \rightarrow Y^{2+}(aq) + W(s)$$
$$Z^{2+}(aq) + W(s) \rightarrow Z(s) + W^{2+}(aq)$$
$$Y(s) + X^{2+}(aq) \rightarrow Y^{2+}(aq) + X(s)$$

(i) Deduce the order of reactivity of these four metals, from the least to the most reactive. *[1]*

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(ii) A voltaic cell is made by connecting a half-cell of X in XCl_2(aq) to a half-cell of Z in ZCl_2(aq). Deduce the overall equation for the reaction taking place when the cell is operating. *[1]*

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7. (a) Outline how electrical conductivity can be used to distinguish between a $0.200\ mol\ dm^{-3}$ solution of ethanoic acid, CH_3COOH, and a $0.200\ mol\ dm^{-3}$ solution of hydrochloric acid, HCl. *[1]*

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(b) $25.0\ cm^3$ of $0.200\ mol\ dm^{-3}$ ethanoic acid were added to $30.0\ cm^3$ of a $0.150\ mol\ dm^{-3}$ sodium hydrogencarbonate solution, $NaHCO_3(aq)$.

(i) State an equation for the reaction of ethanoic acid with a solution of sodium hydrogencarbonate. *[1]*

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(ii) Determine which is the limiting reagent. Show your working. *[2]*

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(This question continues on the following page)

(Question 7 continued)

(iii) Calculate the mass, in g, of carbon dioxide produced. *[2]*

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(c) The molar mass of a volatile organic liquid, **X**, can be determined experimentally by allowing it to vaporize completely at a controlled temperature and pressure. 0.348 g of **X** was injected into a gas syringe maintained at a temperature of 90 °C and a pressure of 1.01×10^5 Pa. Once it had reached equilibrium, the gas volume was measured as $95.0\,cm^3$.

(i) Determine the amount, in mol, of **X** in the gas syringe. *[3]*

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(ii) Calculate the molar mass of **X**. *[1]*

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(Question 7 continued)

(d) Bromoethane, CH_3CH_2Br, undergoes a substitution reaction to form ethanol, CH_3CH_2OH.

(i) Identify the reagent necessary for this reaction to occur. *[1]*

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(ii) Deduce the mechanism for the reaction using equations and curly arrows to represent the movement of electron pairs. *[3]*

(e) (i) Bromoethane, CH_3CH_2Br, can be formed from ethene, CH_2CH_2. Identify the reagent(s) and conditions used. *[2]*

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(This question continues on the following page)

(Question 7 continued)

(ii) Determine the enthalpy change, in kJ mol^{-1}, for this reaction, using Table 10 of the Data Booklet. *[3]*

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(f) Bromoethene, CH_2CHBr, can undergo polymerization. Draw a section of this polymer that contains six carbon atoms. *[1]*

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