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CHEMISTRY
STANDARD LEVEL
PAPER 2

Candidate session number

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Thursday 16 May 2013 (afternoon)

1 hour 15 minutes

Examination code

2	2	1	3	–	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]*.

SECTION A

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

1. A student decided to determine the molecular mass of a solid monoprotic acid, HA, by titrating a solution of a known mass of the acid.

The following recordings were made.

Mass of bottle / g ± 0.001 g	1.737
Mass of bottle + acid HA / g ± 0.001 g	2.412

(a) Calculate the mass of the acid and determine its absolute and percentage uncertainty. *[2]*

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(b) This known mass of acid, HA, was then dissolved in distilled water to form a 100.0 cm^3 solution in a volumetric flask. A 25.0 cm^3 sample of this solution reacted with 12.1 cm^3 of a 0.100 mol dm^{-3} NaOH solution. Calculate the molar mass of the acid. *[3]*

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(Question 1 continued)

(c) The percentage composition of HA is 70.56% carbon, 23.50% oxygen and 5.94% hydrogen. Determine its empirical formula. *[2]*

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(d) A solution of HA is a weak acid. Distinguish between a *weak acid* and a *strong acid*. *[1]*

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(e) Describe an experiment, other than measuring the pH, to distinguish HA from a strong acid of the same concentration and describe what would be observed. *[2]*

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2. Table 8 of the Data Booklet shows the atomic and ionic radii of the elements.

(a) Describe and explain the trend in atomic radius across period 3. *[3]*

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(b) A student formulates the following hypothesis: "If phosphorus were to form a positive ion, P^{3+}, its ionic radius would probably be between 110×10^{-12} m and 212×10^{-12} m." Evaluate this hypothesis. *[2]*

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3. Both sodium and sodium chloride can conduct electricity.

(a) Compare how electric current passes through sodium and sodium chloride by completing the table below. *[3]*

	Sodium	**Sodium chloride**
State of matter	. . . . .	. . . . .
Particles that conduct the current	. . . . .	. . . . .
Reaction occurring	. . . . .	. . . . .

(This question continues on the following page)

(Question 3 continued)

(b) Sodium can be obtained by electrolysis from molten sodium chloride. Describe, using a diagram, the essential components of this electrolytic cell. *[3]*

(c) State **one** example that shows the economic importance of electrolysis. *[1]*

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4. Ethanedioic acid (oxalic acid), $(COOH)_2$, reacts with acidified potassium permanganate solution, $KMnO_4$, according to the following equation.

$$5(COOH)_2(aq) + 2MnO_4^-(aq) + 6H^+(aq) \rightarrow 10CO_2(g) + 2Mn^{2+}(aq) + 8H_2O(l)$$

The reaction is a redox reaction.

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

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(b) Calculate the change in oxidation numbers of carbon and manganese. *[2]*

Carbon:

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Manganese:

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(c) Identify the oxidizing and reducing agents. *[1]*

Oxidizing agent:

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Reducing agent:

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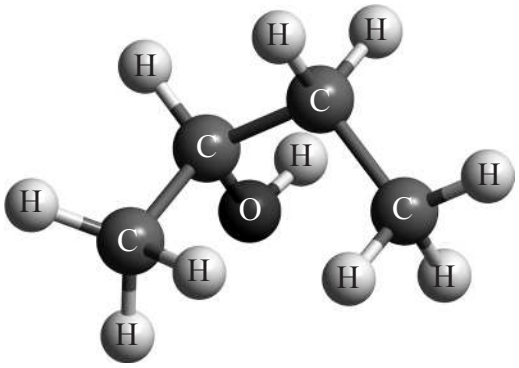
5. The following diagram shows the three-dimensional structure of a molecule.



(a) Apply IUPAC rules to state the name of this molecule. *[1]*

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(b) Deduce the structural formula of **two** isomers of the molecule above with the same functional group. *[2]*

(c) Describe, using an equation, the oxidation by acidified potassium dichromate(VI) of the substance shown in the diagram. Use the symbol [O] to represent the oxidizing agent. *[1]*

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SECTION B

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

6. The element boron has two naturally occurring isotopes, ^{10}B and ^{11}B.

(a) (i) Define the term *isotopes of an element*. *[1]*

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(ii) Calculate the percentage abundance of **each** isotope, given that the relative atomic mass of B is 10.81. *[2]*

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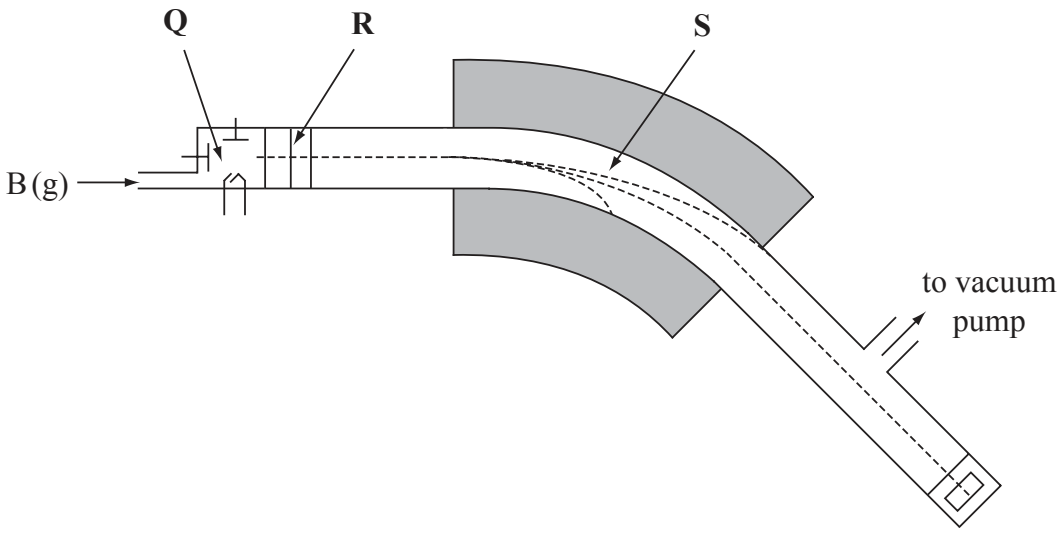
(Question 6 continued)

(b) The percentage abundance of the isotopes of boron can be determined with a mass spectrometer. The diagram shows the operation of a mass spectrometer.



(i) State the names of stages **R** and **S**. *[1]*

R: . . . . . .

S: . . . . . .

(ii) Deduce the number of protons, neutrons and the electron arrangement of the main ion of ^{11}B formed in stage **Q**. *[2]*

Protons:

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Neutrons:

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Electron arrangement:

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(This question continues on the following page)

(Question 6 continued)

(iii) Identify the species that is used as the scale for the mass of the isotopes. *[1]*

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(c) (i) Deduce the Lewis structures of NH_3 and BF_3. *[2]*

NH_3 BF_3

(ii) Describe how covalent bonds are formed. *[1]*

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(iii) Compare the shapes of the two molecules and explain the difference using valence shell electron pair repulsion theory (VSEPR). *[4]*

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(Question 6 continued)

(iv) Predict and explain whether the molecules NH_3 and BF_3 are polar molecules. *[2]*

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(d) (i) Define an *acid* according to the Lewis theory. *[1]*

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(ii) State and explain the acid–base character of NH_3 and BF_3 according to the Lewis theory. *[3]*

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7. To determine the enthalpy change of combustion of methanol, CH_3OH, 0.230 g of methanol was combusted in a spirit burner. The heat released increased the temperature of 50.0 cm^3 of water from 24.5 °C to 45.8 °C.

(a) (i) Calculate the enthalpy change of combustion of methanol. *[4]*

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(ii) Using the theoretical value in Table 12 of the Data Booklet, discuss the experimental results, including **one** improvement that could be made. *[3]*

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(Question 7 continued)

(b) Methanol can be produced according to the following equation.

$$CO(g) + 2H_2(g) \rightarrow CH_3OH(l)$$

Calculate the standard enthalpy change of this reaction using the following data:

I: $2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(l)$ $\Delta H^{\ominus} = -1452\,kJ\,mol^{-1}$

II: $2CO(g) + O_2(g) \rightarrow 2CO_2(g)$ $\Delta H^{\ominus} = -566\,kJ\,mol^{-1}$

III: $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$ $\Delta H^{\ominus} = -572\,kJ\,mol^{-1}$ *[3]*

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(This question continues on the following page)

(Question 7 continued)

(c) The manufacture of gaseous methanol from CO and H_2 involves an equilibrium reaction.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H^{\ominus} < 0$$

(i) Outline the characteristics of a chemical equilibrium. *[2]*

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

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(iii) Identify **one** other important industrial synthesis that is an equilibrium reaction. *[1]*

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(This question continues on the following page)

(Question 7 continued)

(d) State and explain the effect of the following changes on the equilibrium position of the reaction in part (c).

(i) Increase in temperature. *[2]*

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(ii) Increase in pressure. *[2]*

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(iii) Addition of a catalyst. *[2]*

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8. Ethene belongs to the homologous series of the alkenes.

(a) (i) Outline **three** features of a homologous series. *[3]*

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(ii) Describe a test to distinguish ethene from ethane, including what is observed in **each** case. *[2]*

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(iii) Bromoethane can be produced either from ethene or from ethane. State an equation for **each** reaction. *[2]*

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(This question continues on the following page)

(Question 8 continued)

(b) A bromoalkane, C_4H_9Br, reacts with a warm, aqueous sodium hydroxide solution, NaOH.

(i) State the equation for the reaction of C_4H_9Br with NaOH. *[1]*

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(ii) Suggest what would happen to the pH of the solution as the reaction proceeds. *[1]*

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(c) The time taken to produce a certain amount of product using different initial concentrations of C_4H_9Br and NaOH is measured. The results are shown in the following table.

Reaction	**$[C_4H_9Br]$ / 10^{-2} mol dm^{-3}**	**[NaOH] / 10^{-3} mol dm^{-3}**	***t* / s**
A	1.0	2.0	46
B	2.0	2.0	23
C	2.0	4.0	23

(i) Deduce the effect of the concentration of C_4H_9Br and NaOH on the rate of reaction. *[2]*

C_4H_9Br:

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NaOH:

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(This question continues on the following page)

(Question 8 continued)

(ii) Suggest why **warm** sodium hydroxide solution is used. *[1]*

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(iii) Deduce whether C_4H_9Br is a primary or tertiary halogenoalkane. *[2]*

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(iv) Determine the structural formula of C_4H_9Br. *[1]*

(v) Describe, using an equation, how C_4H_9Br can be converted into $C_4H_8Br_2$. *[1]*

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(This question continues on the following page)

(Question 8 continued)

(d) Explain the mechanism for the reaction in (c) of C_4H_9Br with NaOH, using curly arrows to represent the movement of electron pairs. *[4]*