

**Chemistry**  
**Standard level**  
**Paper 2**

Thursday 14 May 2015 (afternoon)

Candidate session number

1 hour 15 minutes

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**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]**.

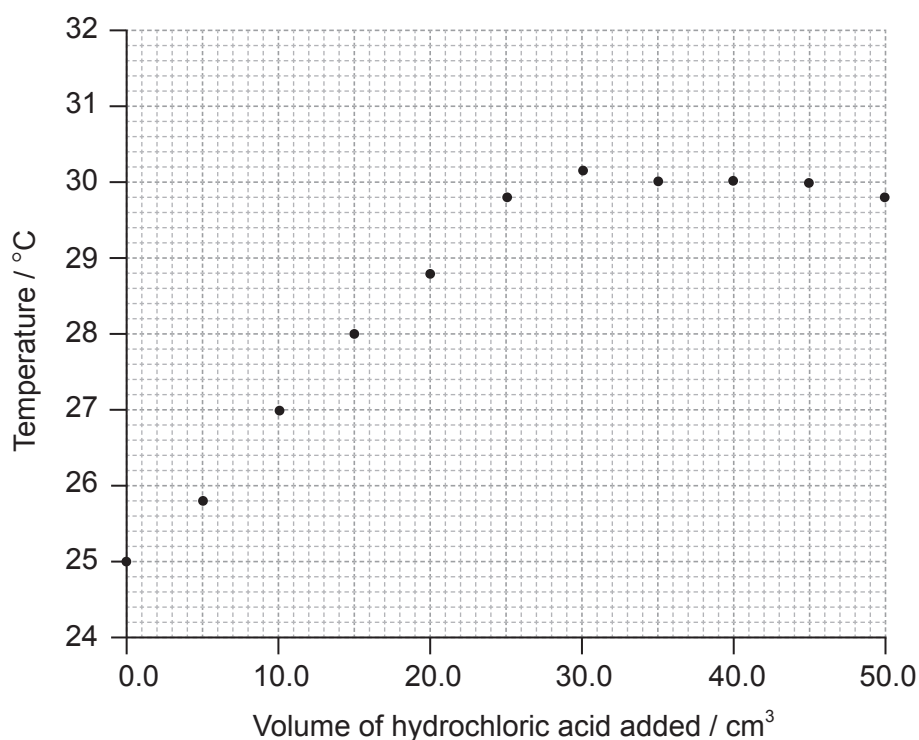


### Section A

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

1. A student carried out an experiment to determine the concentration of a hydrochloric acid solution and the enthalpy change of the reaction between aqueous sodium hydroxide and this acid by thermometric titration.

She added  $5.0\text{ cm}^3$  portions of hydrochloric acid to  $25.0\text{ cm}^3$  of  $1.00\text{ mol dm}^{-3}$  sodium hydroxide solution in a glass beaker until the total volume of acid added was  $50.0\text{ cm}^3$ , measuring the temperature of the mixture each time. Her results are plotted in the graph below.



The initial temperature of both solutions was the same.

- (a) (i) By drawing appropriate lines, determine the volume of hydrochloric acid required to completely neutralize the  $25.0\text{ cm}^3$  of sodium hydroxide solution. [2]

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**(Question 1 continued)**

- (ii) Determine the concentration of the hydrochloric acid, including units. [2]

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- (b) (i) Determine the change in temperature,  $\Delta T$ . [1]

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- (ii) Calculate the enthalpy change, in  $\text{kJ mol}^{-1}$ , for the reaction of hydrochloric acid and sodium hydroxide solution. [3]

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- (iii) The accepted theoretical value from the literature of this enthalpy change is  $-58 \text{ kJ mol}^{-1}$ . Calculate the percentage error correct to **two** significant figures. [1]

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(Question 1 continued)

- (iv) Suggest the major source of error in the experimental procedure **and** an improvement that could be made to reduce it.

[2]

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2. A sample of vaporized elemental magnesium is introduced into a mass spectrometer. One of the ions that reaches the detector is  $^{26}\text{Mg}^+$ .

- (a) Calculate the number of protons, neutrons and electrons in the  $^{26}\text{Mg}^+$  ion. [2]

Protons: ..... Neutrons: ..... Electrons: .....
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- (b) Outline how the  $\text{Mg}^+$  ion is formed in the mass spectrometer. [1]

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- (c) Describe how  $\text{Mg}^+$  is accelerated in the mass spectrometer. [1]

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- (d) The sample contained the three isotopes  $^{24}\text{Mg}$ ,  $^{25}\text{Mg}$  and  $^{26}\text{Mg}$ . The relative percentage abundances of  $^{25}\text{Mg}$  and  $^{26}\text{Mg}$  are 10.00% and 11.01% respectively. Calculate the relative atomic mass ( $A_r$ ) of magnesium, accurate to **two** decimal places. [2]

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3. Electrolysis is an important industrial process used to obtain very reactive elements from their common ores.

(a) Molten magnesium chloride can be electrolysed using inert graphite electrodes at 800 °C.

(i) Describe, using a labelled diagram, the essential components of this electrolytic cell. [2]

(ii) Deduce the half-equations, including state symbols, for the reactions occurring at each electrode. (The melting points of  $\text{MgCl}_2$  and  $\text{Mg}$  are 714 °C and 649 °C respectively.) [3]

Positive electrode (anode):

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Negative electrode (cathode):

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(Question 3 continued)

(b) Outline why solid magnesium chloride does not conduct electricity. [1]

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(c) Aluminium can also be obtained by electrolysis. Suggest **one** reason why aluminium is often used instead of iron by engineers. [1]

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4. (a) State **two** features of a homologous series. [2]

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- (b) Ethane, a member of the homologous series of alkanes, can react with bromine. Explain the free-radical mechanism of this reaction, including any necessary reaction conditions. [4]

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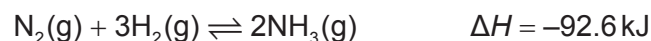




**Section B**

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

5. When nitrogen gas and hydrogen gas are allowed to react in a closed container, the following equilibrium is established.



- (a) Outline **two** characteristics of a reversible reaction in a state of dynamic equilibrium. [2]

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- (b) Deduce the equilibrium constant expression,  $K_c$ , for the reaction. [1]

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- (c) Predict, with a reason, how each of the following changes affects the position of equilibrium. [2]

The volume of the container is increased.  
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Ammonia is removed from the equilibrium mixture.  
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**(Question 5 continued)**

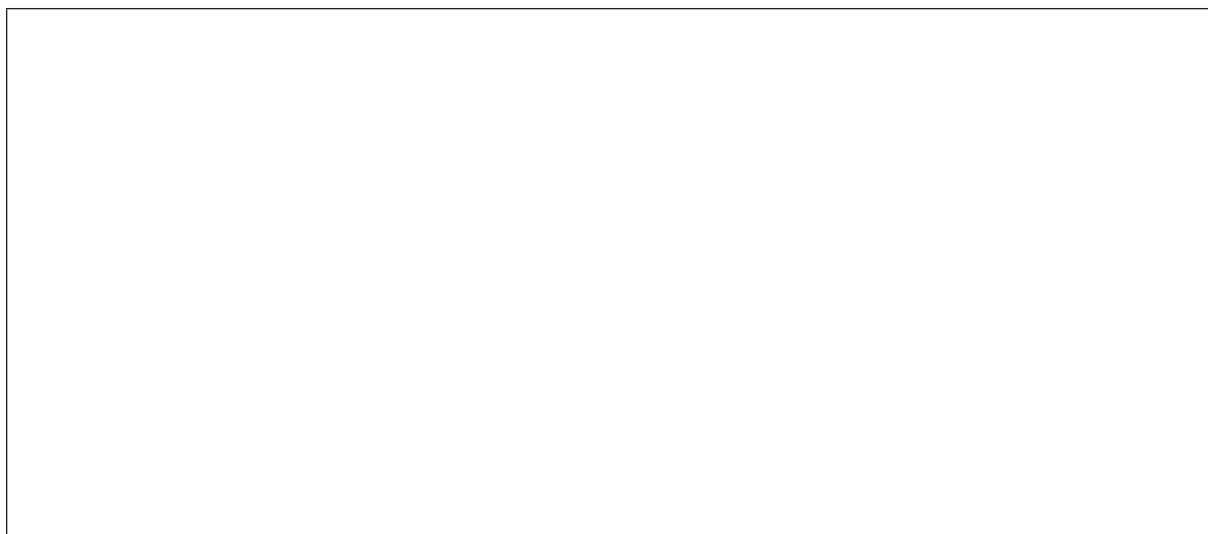
- (d) (i) Define the term *activation energy*,  $E_a$ . [1]

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- (ii) Ammonia is manufactured by the Haber process in which iron is used as a catalyst. Explain the effect of a catalyst on the rate of reaction. [2]

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- (iii) Sketch the Maxwell–Boltzmann energy distribution curve for a reaction, labelling both axes and showing the activation energy with and without a catalyst. [2]



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**(Question 5 continued)**

(e) Typical conditions used in the Haber process are 500 °C and 200 atm, resulting in approximately 15% yield of ammonia.

(i) Explain why a temperature lower than 500 °C is **not** used. [2]

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(ii) Outline why a pressure higher than 200 atm is **not** often used. [1]

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(f) (i) Define the term *base* according to the Lewis theory. [1]

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(ii) Define the term *weak base* according to the Brønsted–Lowry theory. [1]

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**(Question 5 continued)**

- (iii) Deduce the formulas of conjugate acid-base pairs in the reaction below.



Acid	Conjugate base
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- (iv) Outline an experiment and its results which could be used to distinguish between a strong base and a weak base. [3]

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6. (a) (i) Draw the Lewis (electron dot) structure of chloromethane. [1]

- (ii) Predict the shape of the chloromethane molecule and the H-C-H bond angle. [2]

Shape:

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Bond angle:

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- (iii) Explain why chloromethane is a polar molecule. [2]

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- (iv) Methanol has a lower molar mass than chloromethane. Explain why the boiling point of methanol is higher than that of chloromethane. [2]

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**(Question 6 continued)**

- (b) (i) State the equation for the reaction between potassium and chlorine. [1]

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- (ii) Outline the nature of the metallic bonding present in potassium. [1]

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- (iii) Describe the covalent bond present in the chlorine molecule and how it is formed. [2]

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- (iv) Describe the ionic bonding present in potassium chloride and how the ions are formed. [2]

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**(Question 6 continued)**

- (v) Potassium also reacts with water to form hydrogen gas. Determine the volume, in  $\text{cm}^3$ , of hydrogen gas that could theoretically be produced at 273 K and  $1.01 \times 10^5 \text{ Pa}$  when 0.0587 g of potassium reacts with excess water. [3]

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- (c) (i) Identify the acid-base character of the oxides of each of the elements from sodium to chlorine in period 3. [2]

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- (ii) State the equations for the separate reactions of sodium oxide and phosphorus(V) oxide with water. [2]

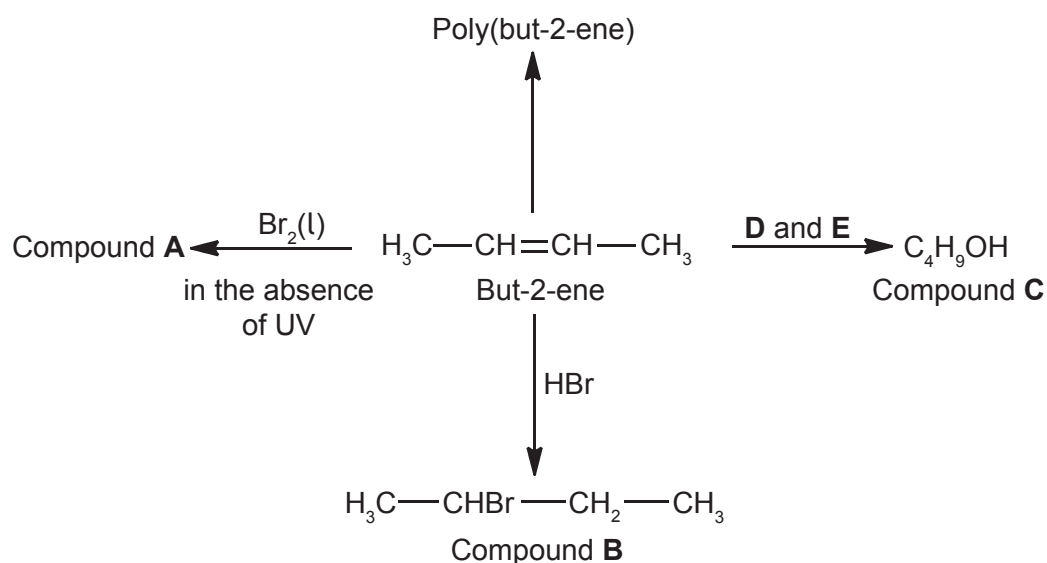
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7. Some reactions of but-2-ene are given below.



(a) (i) Deduce the full structural formula of compound **A**. [1]

(ii) Apply IUPAC rules to name compound **A**. [1]

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(iii) Describe the colour change observed when excess but-2-ene reacts with bromine to form compound **A**. [1]

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**(Question 7 continued)**

- (b) State the names of the reagents **D** and **E**. [2]

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- (c) (i) Outline **two** reasons why the polymerization of alkenes is of economic importance. [2]

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- (ii) Identify the structure of the repeating unit of poly(but-2-ene). [1]

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**(Question 7 continued)**

(d) Compound **C**,  $C_4H_9OH$ , can also be formed directly from compound **B**,  $CH_3CHBrCH_2CH_3$ .

(i) State the reagent and the conditions required for this reaction. [1]

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(ii) State the name of the type of reaction occurring in this conversion. [1]

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(e) Compound **C** can be oxidized by acidified potassium dichromate(VI) to form compound **F**.

(i) State the name of the functional group present in compound **F**. [1]

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(ii) Deduce the structural formula of an alcohol which is a structural isomer of compound **C** and **cannot** be oxidized by acidified potassium dichromate(VI). [1]

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**(Question 7 continued)**

- (f) Explain why but-2-ene is more volatile than compound **C**,  $C_4H_9OH$ . [2]

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- (g) (i) Define the term *average bond enthalpy*. [2]

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- (ii) Deduce the equation for the complete combustion of compound **C**. [1]

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- (iii) Determine the enthalpy change,  $\Delta H$ , in  $\text{kJ mol}^{-1}$ , for the complete combustion of compound **C** when all reactants and products are in the gaseous state, using table 10 of the data booklet. [3]

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Answers written on this page  
will not be marked.

