Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Standard level
Paper 2

Thursday 14 May 2015 (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.
- 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]**.

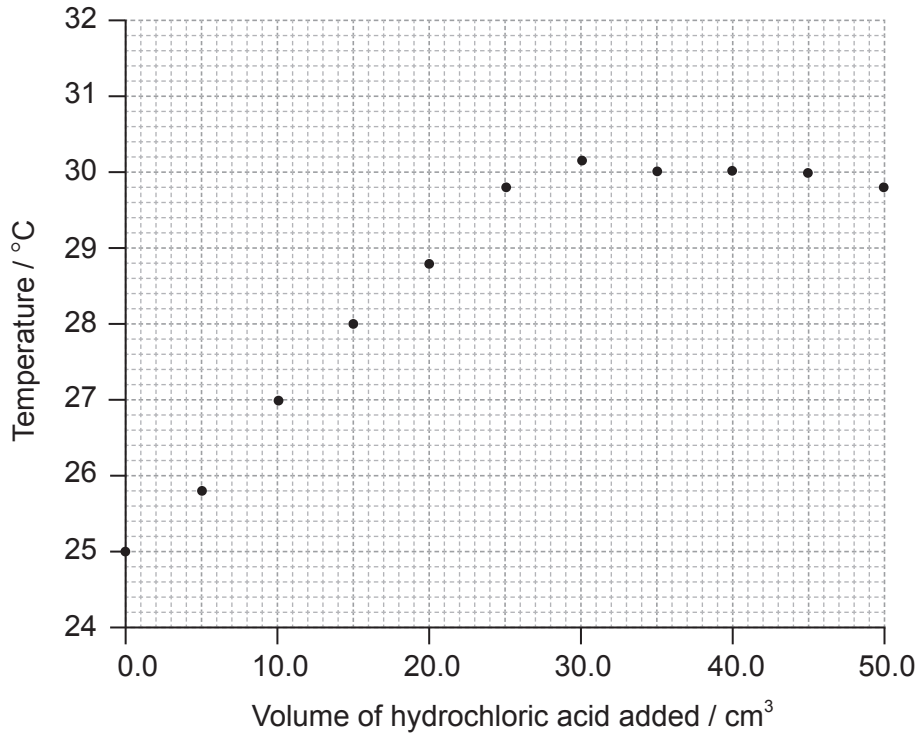
2215–6117

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 cm^3 portions of hydrochloric acid to 25.0 cm^3 of 1.00 $mol\,dm^{-3}$ sodium hydroxide solution in a glass beaker until the total volume of acid added was 50.0 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 cm^3 of sodium hydroxide solution. [2]

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(This question continues on the following page)

(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, ΔT. [1]

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(ii) Calculate the enthalpy change, in $kJ\,mol^{-1}$, 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 $-58\,kJ\,mol^{-1}$. Calculate the percentage error correct to **two** significant figures. [1]

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(This question continues on the following page)

(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 $^{26}Mg^{+}$.

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

Protons:

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Neutrons:

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Electrons:

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(b) Outline how the Mg^{+} ion is formed in the mass spectrometer. [1]

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

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(d) The sample contained the three isotopes ^{24}Mg, ^{25}Mg and ^{26}Mg. The relative percentage abundances of ^{25}Mg and ^{26}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 $MgCl_2$ and Mg are 714 °C and 649 °C respectively.) [3]

Positive electrode (anode):

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Negative electrode (cathode):

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(This question continues on the following page)

(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.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92.6\,kJ$$

(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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(This question continues on the following page)

(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]

(This question continues on the following page)

(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.

$$CH_3NH_2(aq) + H_2O(l) \rightleftharpoons CH_3NH_3^+(aq) + OH^-(aq)$$ [2]

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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(This question continues on the following page)

(Question 6 continued)

(v) Potassium also reacts with water to form hydrogen gas. Determine the volume, in cm^3, of hydrogen gas that could theoretically be produced at 273 K and 1.01×10^5 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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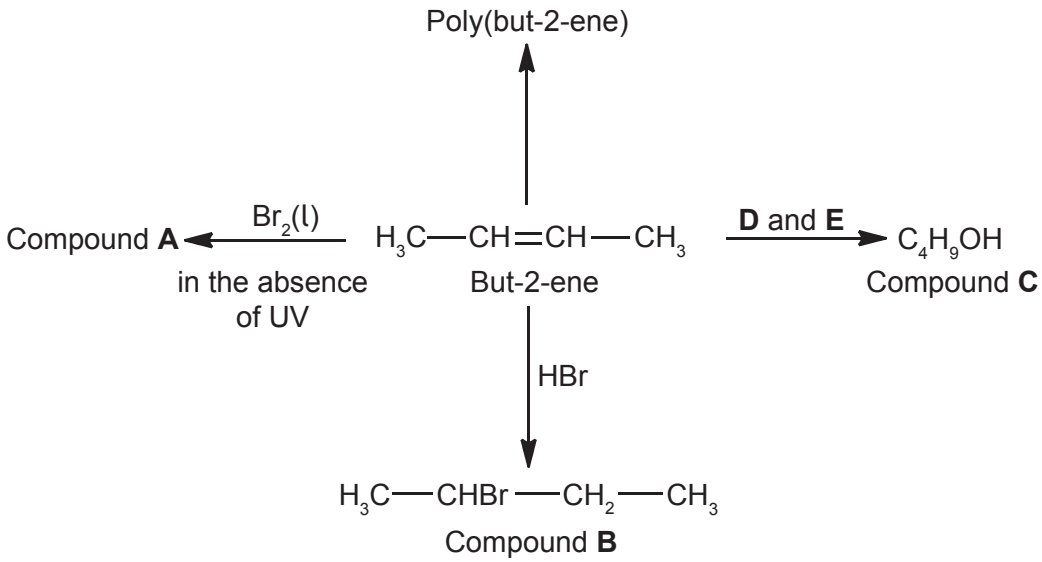
7. Some reactions of but-2-ene are given below.



(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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(This question continues on the following page)

(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]

(This question continues on the following page)

(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]

(This question continues on the following page)

(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, ΔH, in $kJ\,mol^{-1}$, 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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Please **do not** write on this page.

Answers written on this page
will not be marked.