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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	7

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 class studied the equilibrium established when ethanoic acid and ethanol react together in the presence of a strong acid, using propanone as an inert solvent. The equation is given below.

$$CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$$

One group made the following **initial mixture**:

Liquid	Volume / cm^3
Ethanoic acid	5.00 ± 0.05
Ethanol	5.00 ± 0.05
$6.00\,mol\,dm^{-3}$ aqueous hydrochloric acid	1.00 ± 0.02
Propanone	39.0 ± 0.5

(a) The density of ethanoic acid is $1.05\,g\,cm^{-3}$. Determine the amount, in mol, of ethanoic acid present in the initial mixture. *[3]*

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(b) The hydrochloric acid does not appear in the balanced equation for the reaction. State its function. *[1]*

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(Question 1 continued)

(c) Identify the liquid whose volume has the greatest percentage uncertainty. *[1]*

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(d) After one week, a $5.00 \pm 0.05\,cm^3$ sample of the final equilibrium mixture was pipetted out and titrated with $0.200\,mol\,dm^{-3}$ aqueous sodium hydroxide to determine the amount of ethanoic acid remaining. The following titration results were obtained:

Titration number	1	2	3
Initial reading / cm^3 ± 0.05	1.20	0.60	14.60
Final reading / cm^3 ± 0.05	28.80	26.50	40.70
Titre / cm^3	27.60	25.90	26.10

(i) Calculate the absolute uncertainty of the titre for Titration 1 ($27.60\,cm^3$). *[1]*

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(ii) Suggest the average volume of alkali, required to neutralize the $5.00\,cm^3$ sample, that the student should use. *[1]*

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(Question 1 continued)

(iii) 23.00 cm^3 of this 0.200 $mol\,dm^{-3}$ aqueous sodium hydroxide reacted with the ethanoic acid in the 5.00 cm^3 sample. Determine the amount, in mol, of ethanoic acid present in the 50.0 cm^3 of final equilibrium mixture. *[2]*

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(e) Referring back to your answer for part (a), calculate the percentage of ethanoic acid converted to ethyl ethanoate. *[1]*

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(f) Deduce the equilibrium constant expression for the reaction. *[1]*

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(g) Outline how you could establish that the system had reached equilibrium at the end of one week. *[1]*

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(Question 1 continued)

(h) Outline why changing the temperature has only a very small effect on the value of the equilibrium constant for this equilibrium. *[1]*

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(i) Outline how adding some ethyl ethanoate to the initial mixture would affect the amount of ethanoic acid converted to product. *[2]*

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(j) Propanone is used as the solvent because one compound involved in the equilibrium is insoluble in water. Identify this compound and explain why it is insoluble in water. *[2]*

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(k) Suggest **one** other reason why using water as a solvent would make the experiment less successful. *[1]*

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2. Boron is most often encountered as a component in borosilicate glass (heat resistant glass). The naturally occurring element contains two stable isotopes, $^{10}_{5}B$ and $^{11}_{5}B$.

(a) State the number of protons, neutrons and electrons in an atom of $^{11}_{5}B$.

	Protons	**Neutrons**	**Electrons**
$^{11}_{5}B$			

[1]

(b) The relative atomic mass of boron is 10.8, to three significant figures. Calculate the percentage of $^{10}_{5}B$ in the naturally occurring element. *[2]*

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(c) Isotopes of boron containing 7 and 8 neutrons also exist. Suggest why releasing isotopes containing more neutrons than the stable isotope into the environment can be dangerous. *[1]*

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(d) (i) State the formula of the compound that boron forms with fluorine. *[1]*

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(Question 2 continued)

(ii) Explain why this compound acts as a Lewis acid. *[2]*

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3. Hydrocarbons, such as nonane, C_9H_{20}, are essential as fuels and as raw materials.

(a) State a balanced equation for the complete combustion of nonane. *[2]*

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(b) Combustion also often forms carbon and carbon monoxide. Outline what **reaction conditions** result in these being produced. *[1]*

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(c) Propene, which can be obtained from nonane, can be polymerized.

(i) State the type of polymerization that occurs. *[1]*

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(ii) Draw the structure of a segment of the polymer containing **six** carbon atoms. *[1]*

SECTION B

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

4. Group 7 of the periodic table contains a number of reactive elements such as chlorine, bromine and iodine.

(a) (i) Describe the colour change that occurs when aqueous chlorine is added to aqueous sodium bromide. *[1]*

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(ii) Outline, with the help of a chemical equation, why this reaction occurs. *[2]*

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(b) The colour change in the reaction between aqueous chlorine and aqueous sodium iodide is very similar, but it differs with an excess of aqueous chlorine. Describe the appearance of the reaction mixture when **excess** aqueous chlorine has been added to aqueous sodium iodide. *[1]*

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(Question 4 continued)

(c) Bleaches in which chlorine is the active ingredient are the most common, although some environmental groups have concerns about their use. In aqueous chlorine the equilibrium below produces chloric(I) acid (hypochlorous acid), HOCl, the active bleach.

$$Cl_2(aq) + H_2O(l) \rightleftharpoons HOCl(aq) + H^+(aq) + Cl^-(aq)$$

(i) Chloric(I) acid is a weak acid, but hydrochloric acid is a strong acid. Outline how this is indicated in the equation above. *[1]*

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(ii) State a balanced equation for the reaction of chloric(I) acid with water. *[1]*

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(iii) Outline, in terms of the equilibrium above, why it is dangerous to use an acidic toilet cleaner in combination with this kind of bleach. *[2]*

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(iv) Suggest why a covalent molecule, such as chloric(I) acid, is readily soluble in water. *[2]*

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(Question 4 continued)

(v) Draw the Lewis (electron dot) structure of chloric(I) acid. *[1]*

(vi) Predict the H–O–Cl bond angle in this molecule and explain this in terms of the valence shell electron pair repulsion (VSEPR) theory. *[3]*

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(d) Aqueous sodium chlorate(I), NaOCl, the most common active ingredient in chlorine based bleaches, oxidizes coloured materials to colourless products while being reduced to the chloride ion. It will also oxidize sulfur dioxide to the sulfate ion.

(i) Deduce the coefficients required to balance the half-equations given below. *[2]*

$$\_\_\_\ ClO^- + \_\_\_\ H^+ + \_\_\_\ e^- \rightleftharpoons \_\_\_\ H_2O + \_\_\_\ Cl^-$$

$$\_\_\_\ SO_4^{2-} + \_\_\_\ H^+ + \_\_\_\ e^- \rightleftharpoons \_\_\_\ SO_2 + \_\_\_\ H_2O$$

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(Question 4 continued)

(ii) State the initial and final oxidation numbers of both chlorine and sulfur in the equations in part (i). *[2]*

Element	Initial oxidation number	Final oxidation number
Chlorine		
Sulfur		

(iii) Use the half-equations to deduce the balanced equation for the reaction between the chlorate(I) ion and sulfur dioxide. *[2]*

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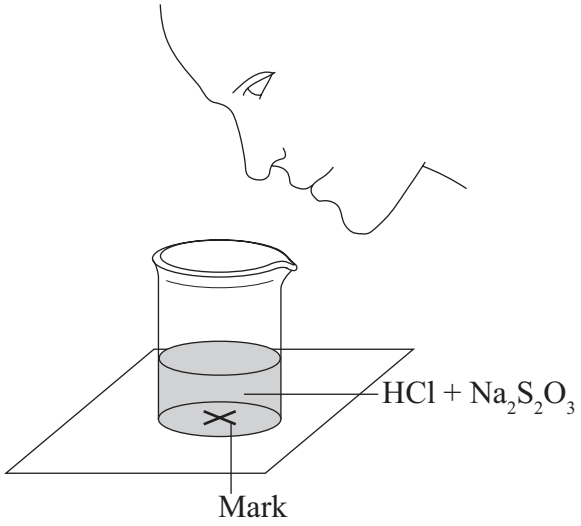
5. A group of students investigated the rate of the reaction between aqueous sodium thiosulfate and hydrochloric acid according to the equation below.

$$Na_2S_2O_3(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + SO_2(g) + S(s) + H_2O(l)$$

The two reagents were rapidly mixed together in a beaker and placed over a mark on a piece of paper. The time taken for the precipitate of sulfur to obscure the mark when viewed through the reaction mixture was recorded.



Initially they measured out $10.0\,cm^3$ of $0.500\,mol\,dm^{-3}$ hydrochloric acid and then added $40.0\,cm^3$ of $0.0200\,mol\,dm^{-3}$ aqueous sodium thiosulfate. The mark on the paper was obscured 47 seconds after the solutions were mixed.

(a) The teacher made up $2.50\,dm^3$ of the sodium thiosulfate solution using sodium thiosulfate pentahydrate crystals, $Na_2S_2O_3 \cdot 5H_2O$. Calculate the required mass of these crystals. *[3]*

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(Question 5 continued)

(b) The teacher asked the students to measure the effect of halving the concentration of sodium thiosulfate on the rate of reaction.

(i) State the volumes of the liquids that should be mixed. *[1]*

Liquid	$0.500\,mol\,dm^{-3}$ HCl	$0.0200\,mol\,dm^{-3}$ $Na_2S_2O_3$	Water
Volume / cm^3			

(ii) State why it is important that the students use a similar beaker for both reactions. *[1]*

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(iii) Explain, in terms of the collision theory, how decreasing the concentration of sodium thiosulfate would affect the time taken for the mark to be obscured. *[2]*

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(Question 5 continued)

(c) (i) Sketch and label, indicating an approximate activation energy, the Maxwell–Boltzmann energy distribution curves for two temperatures, T_1 and T_2 ($T_2 > T_1$), at which the rate of reaction would be significantly different. *[3]*

(ii) Explain why increasing the temperature of the reaction mixture would significantly increase the rate of the reaction. *[3]*

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(Question 5 continued)

(d) The teacher asked the students to devise another technique to measure the rate of this reaction.

(i) One group suggested recording how long it takes for the pH of the solution to change by one unit. Calculate the initial pH of the original reaction mixture. *[2]*

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(ii) Deduce the percentage of hydrochloric acid that would have to be used up for the pH to change by one unit. *[1]*

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(Question 5 continued)

(e) Another group suggested collecting the sulfur dioxide and drawing a graph of the volume of gas against time.

(i) Calculate the volume of sulfur dioxide, in cm^3, that the original reaction mixture would produce if it were collected at 1.00×10^5 Pa and 300 K. *[3]*

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(ii) Suggest why it is better to use a gas syringe rather than collecting the gas in a measuring cylinder over water. *[1]*

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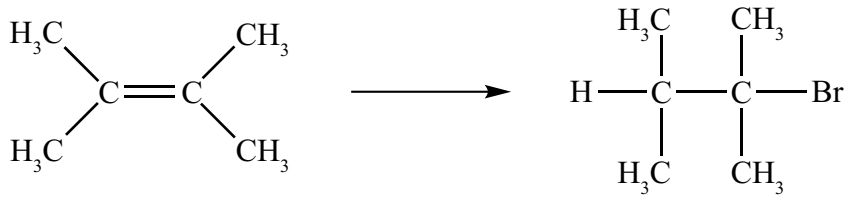
6. Alkenes, such as **A** (shown below), are important intermediates in the petrochemical industry because they undergo addition reactions to produce a wide variety of products, such as the conversion shown below.



A **B**

(a) Applying IUPAC rules, state the name of **A**. *[1]*

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(b) State the reagent required to convert **A** into **B**. *[1]*

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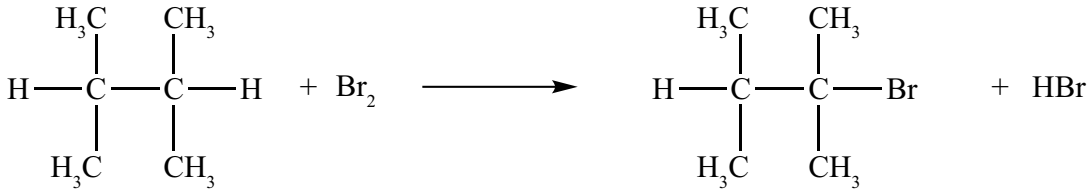
(Question 6 continued)

(c) Another way to make **B** is the reaction shown below.



(i) State the conditions required for this reaction to occur. *[1]*

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(ii) Outline why it would give a poor yield of the desired product. *[1]*

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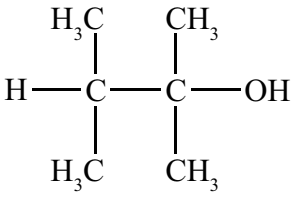
(d) **B** can be converted into **C**.



C

(i) State the reagent required. *[1]*

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(Question 6 continued)

(ii) Explain the mechanism of this reaction, using curly arrows to represent the movement of electron pairs. *[3]*

(e) **A** can also be converted into **C** without going via **B**. State the reagent and conditions required. *[2]*

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(f) (i) State why **C** is **not** readily oxidized by acidified potassium dichromate(VI). *[1]*

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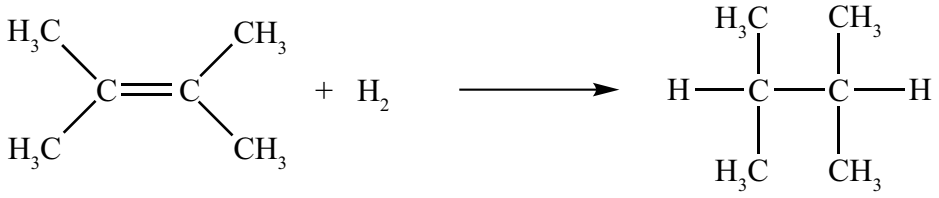
(Question 6 continued)

(ii) Deduce the structural formula of an isomer of **C** that could be oxidized to a carboxylic acid by this reagent. *[1]*

(g) In the gas phase, **A** reacts with hydrogen to form **D**.



A **D**

(i) State the conditions required for this reaction to occur. *[1]*

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(ii) State the homologous series to which **D** belongs. *[1]*

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(This question continues on the following page)

(Question 6 continued)

(iii) Determine the enthalpy change, in kJ mol^{-1}, for the reaction of **A** with hydrogen, using Table 10 of the Data Booklet, and state whether the reaction is exothermic or endothermic. *[4]*

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(iv) The standard enthalpy change of combustion of **A** is $-4000\,kJ\,mol^{-1}$. Calculate the amount of **A**, in mol, that would have to be burned to raise the temperature of 1 dm^3 of water from $20\,^{\circ}C$ to $100\,^{\circ}C$. *[2]*

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