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

Wednesday 22 May 2019 (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.
- Answer all questions.
- Answers must be written within the answer 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]**.



Answer **all** questions. Answers must be written within the answer boxes provided.

1. Xylene is a derivative of benzene. One isomer is 1,4-dimethylbenzene.



- (a) State the number of  $^1\text{H}$  NMR signals for this isomer of xylene and the ratio in which they appear. [2]

Number of signals:

.....

Ratio:

.....

- (b) Draw the structure of one other isomer of xylene which retains the benzene ring. [1]

(This question continues on the following page)





2. Benzoic acid,  $C_6H_5COOH$ , is another derivative of benzene.

(a) Draw the structure of the conjugate base of benzoic acid showing **all** the atoms and **all** the bonds. [1]

(b) (i) The pH of an aqueous solution of benzoic acid at 298 K is 2.95. Determine the concentration of hydroxide ions in the solution, using section 2 of the data booklet. [2]

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(ii) Formulate the equation for the complete combustion of benzoic acid in oxygen using only integer coefficients. [2]

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(This question continues on the following page)



**(Question 2 continued)**

- (c) Suggest how benzoic acid,  $M_r = 122.13$ , forms an apparent dimer,  $M_r = 244.26$ , when dissolved in a non-polar solvent such as hexane. [1]

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**3. This question is about compounds of sodium.**

- (a) (i) Describe the structure and bonding in solid sodium oxide. [2]

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- (ii) Write equations for the separate reactions of solid sodium oxide and solid phosphorus(V) oxide with excess water and differentiate between the solutions formed. [3]

Sodium oxide,  $\text{Na}_2\text{O}$ :

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Phosphorus(V) oxide,  $\text{P}_4\text{O}_{10}$ :

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Differentiation:

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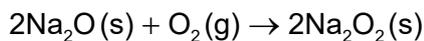
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**(Question 3 continued)**

- (b) Sodium peroxide, Na<sub>2</sub>O<sub>2</sub>, is formed by the reaction of sodium oxide with oxygen.



Calculate the percentage yield of sodium peroxide if 5.00 g of sodium oxide produces 5.50 g of sodium peroxide.

[2]

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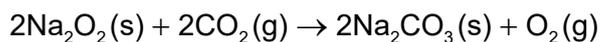
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- (c) Sodium peroxide is used in diving apparatus to produce oxygen from carbon dioxide.



- (i) Determine the enthalpy change,  $\Delta H$ , in kJ, for this reaction using data from the table and section 12 of the data booklet.

[3]

	$\Delta H_f / \text{kJ mol}^{-1}$
Na <sub>2</sub> O <sub>2</sub> (s)	-510.9
Na <sub>2</sub> CO <sub>3</sub> (s)	-1130.7

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**(Question 3 continued)**

(ii) Outline why bond enthalpy values are not valid in calculations such as that in (c)(i). [1]

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(d) The reaction of sodium peroxide with excess water produces hydrogen peroxide and one other sodium compound. Suggest the formula of this compound. [1]

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(e) State the oxidation number of carbon in sodium carbonate,  $\text{Na}_2\text{CO}_3$ . [1]

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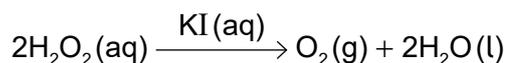
4. This question is about peroxides.

- (a) Suggest why many chemicals, including hydrogen peroxide, are kept in brown bottles instead of clear colourless bottles. [1]

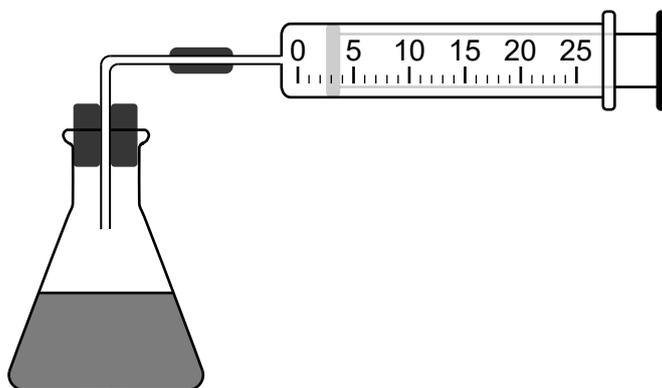
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- (b) Hydrogen peroxide decomposes to water and oxygen when a catalyst such as potassium iodide, KI, is added.



- (i) In a laboratory experiment solutions of potassium iodide and hydrogen peroxide were mixed and the volume of oxygen generated was recorded. The volume was adjusted to 0 at t = 0.



The data for the first trial is given below.

Time / s	Volume of O <sub>2</sub> (g) / cm <sup>3</sup>
100	2.5
300	6.5
500	11.0
700	15.0

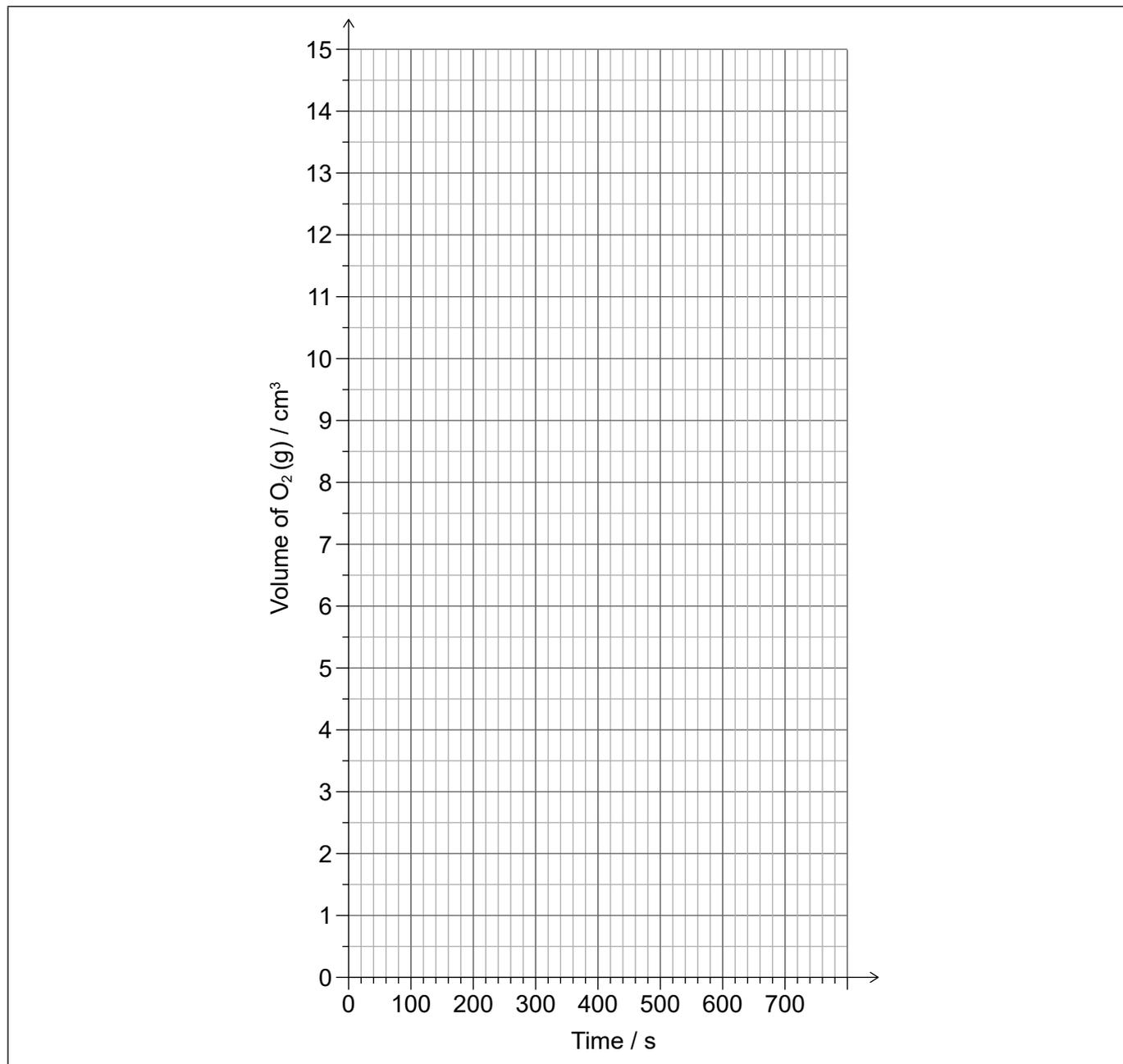
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(Question 4 continued)

Plot a graph on the axes below and from it determine the average rate of formation of oxygen gas in  $\text{cm}^3 \text{O}_2(\text{g}) \text{s}^{-1}$ .

[3]



Average rate of reaction:

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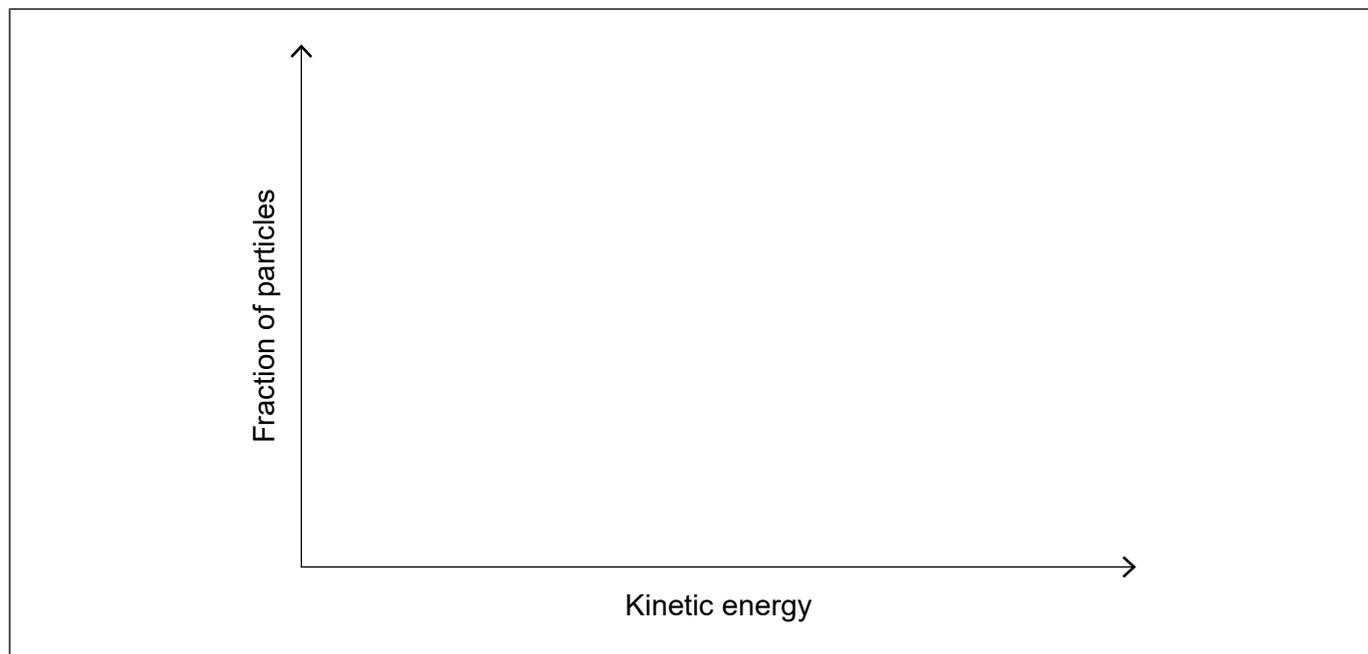
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**(Question 4 continued)**

- (ii) Additional experiments were carried out at an elevated temperature. On the axes below, sketch Maxwell–Boltzmann energy distribution curves at two temperatures  $T_1$  and  $T_2$ , where  $T_2 > T_1$ . [2]



- (iii) Apart from a greater frequency of collisions, explain, by annotating your graphs in (b)(ii), why an increased temperature causes the rate of reaction to increase. [2]

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- (iv)  $MnO_2$  is another possible catalyst for the reaction. State the IUPAC name for  $MnO_2$ . [1]

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**(This question continues on the following page)**



**(Question 4 continued)**

- (c) Comment on why peracetic acid,  $\text{CH}_3\text{COOOH}$ , is always sold in solution with ethanoic acid and hydrogen peroxide.



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- (d) Sodium percarbonate,  $2\text{Na}_2\text{CO}_3 \cdot 3\text{H}_2\text{O}_2$ , is an adduct of sodium carbonate and hydrogen peroxide and is used as a cleaning agent.

$$M_r(2\text{Na}_2\text{CO}_3 \cdot 3\text{H}_2\text{O}_2) = 314.04$$

Calculate the percentage by mass of hydrogen peroxide in sodium percarbonate, giving your answer to two decimal places. [2]

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5. Both vinegar (a dilute aqueous solution of ethanoic acid) and bleach are used as cleaning agents.

(a) Outline why ethanoic acid is classified as a weak acid.

[1]

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(b) A solution of bleach can be made by reacting chlorine gas with a sodium hydroxide solution.



Suggest, with reference to Le Châtelier's principle, why it is dangerous to mix vinegar and bleach together as cleaners.

[3]

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(c) Bleach reacts with ammonia, also used as a cleaning agent, to produce the poisonous compound chloramine,  $\text{NH}_2\text{Cl}$ .

(i) Draw a Lewis (electron dot) structure of chloramine.

[1]

(This question continues on the following page)



**(Question 5 continued)**

(ii) Deduce the molecular geometry of chloramine and estimate its H–N–H bond angle. [2]

Molecular geometry:  
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H–N–H bond angle:  
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6. This question is about iron.

(a) State the nuclear symbol notation,  ${}^A_ZX$ , for iron-54. [1]

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(b) Mass spectrometry analysis of a sample of iron gave the following results:

	% abundance
Fe-54	5.84
Fe-56	91.68
Fe-57	2.17
Fe-58	0.31

Calculate the relative atomic mass,  $A_r$ , of this sample of iron to two decimal places. [2]

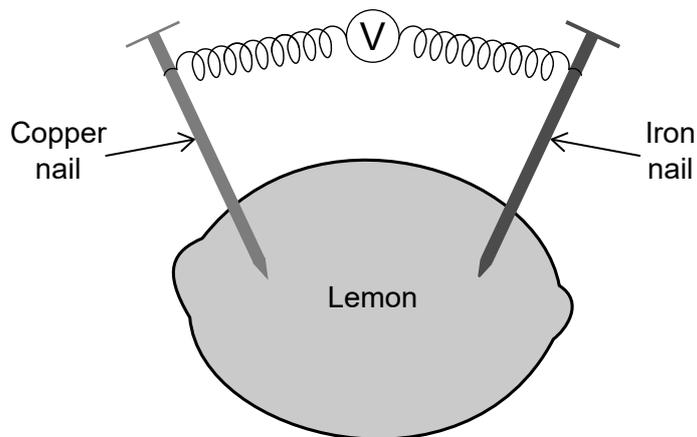
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**(Question 6 continued)**

(c) An iron nail and a copper nail are inserted into a lemon.



Explain why a potential is detected when the nails are connected through a voltmeter. [2]

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