

No part of this product may be reproduced in any form or by any electronic or mechanical means, including information storage and retrieval systems, without written permission from the IB.

Additionally, the license tied with this product prohibits commercial use of any selected files or extracts from this product. Use by third parties, including but not limited to publishers, private teachers, tutoring or study services, preparatory schools, vendors operating curriculum mapping services or teacher resource digital platforms and app developers, is not permitted and is subject to the IB's prior written consent via a license. More information on how to request a license can be obtained from <http://www.ibo.org/contact-the-ib/media-inquiries/for-publishers/guidance-for-third-party-publishers-and-providers/how-to-apply-for-a-license>.

Aucune partie de ce produit ne peut être reproduite sous quelque forme ni par quelque moyen que ce soit, électronique ou mécanique, y compris des systèmes de stockage et de récupération d'informations, sans l'autorisation écrite de l'IB.

De plus, la licence associée à ce produit interdit toute utilisation commerciale de tout fichier ou extrait sélectionné dans ce produit. L'utilisation par des tiers, y compris, sans toutefois s'y limiter, des éditeurs, des professeurs particuliers, des services de tutorat ou d'aide aux études, des établissements de préparation à l'enseignement supérieur, des fournisseurs de services de planification des programmes d'études, des gestionnaires de plateformes pédagogiques en ligne, et des développeurs d'applications, n'est pas autorisée et est soumise au consentement écrit préalable de l'IB par l'intermédiaire d'une licence. Pour plus d'informations sur la procédure à suivre pour demander une licence, rendez-vous à l'adresse <http://www.ibo.org/fr/contact-the-ib/media-inquiries/for-publishers/guidance-for-third-party-publishers-and-providers/how-to-apply-for-a-license>.

No se podrá reproducir ninguna parte de este producto de ninguna forma ni por ningún medio electrónico o mecánico, incluidos los sistemas de almacenamiento y recuperación de información, sin que medie la autorización escrita del IB.

Además, la licencia vinculada a este producto prohíbe el uso con fines comerciales de todo archivo o fragmento seleccionado de este producto. El uso por parte de terceros —lo que incluye, a título enunciativo, editoriales, profesores particulares, servicios de apoyo académico o ayuda para el estudio, colegios preparatorios, desarrolladores de aplicaciones y entidades que presten servicios de planificación curricular u ofrezcan recursos para docentes mediante plataformas digitales— no está permitido y estará sujeto al otorgamiento previo de una licencia escrita por parte del IB. En este enlace encontrará más información sobre cómo solicitar una licencia: <http://www.ibo.org/es/contact-the-ib/media-inquiries/for-publishers/guidance-for-third-party-publishers-and-providers/how-to-apply-for-a-license>.

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

Wednesday 22 May 2019 (afternoon)

Candidate session number

1 hour 15 minutes

--	--	--	--	--	--	--	--	--	--

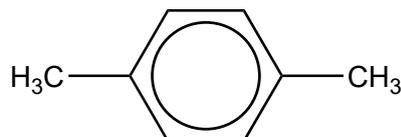
**Instructions to candidates**

- 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]

.....

.....

.....

.....

.....

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

.....

.....

.....

(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]

.....

.....

.....

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

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

.....

.....

.....

.....

.....

- (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,  $\text{Na}_2\text{O}$ :

.....

.....

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

.....

.....

Differentiation:

.....

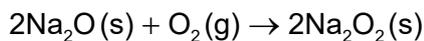
.....

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



**(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]

.....

.....

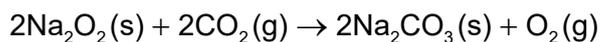
.....

.....

.....

.....

- (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

.....

.....

.....

.....

.....

.....

.....

.....

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



**(Question 3 continued)**

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

.....  
.....

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

.....  
.....

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

.....  
.....



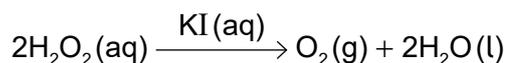
4. This question is about peroxides.

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

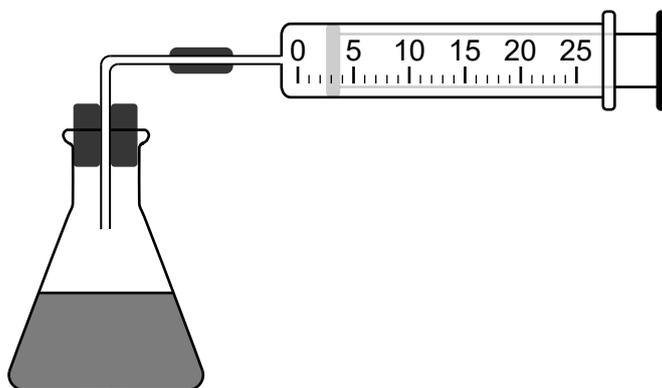
.....

.....

- (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

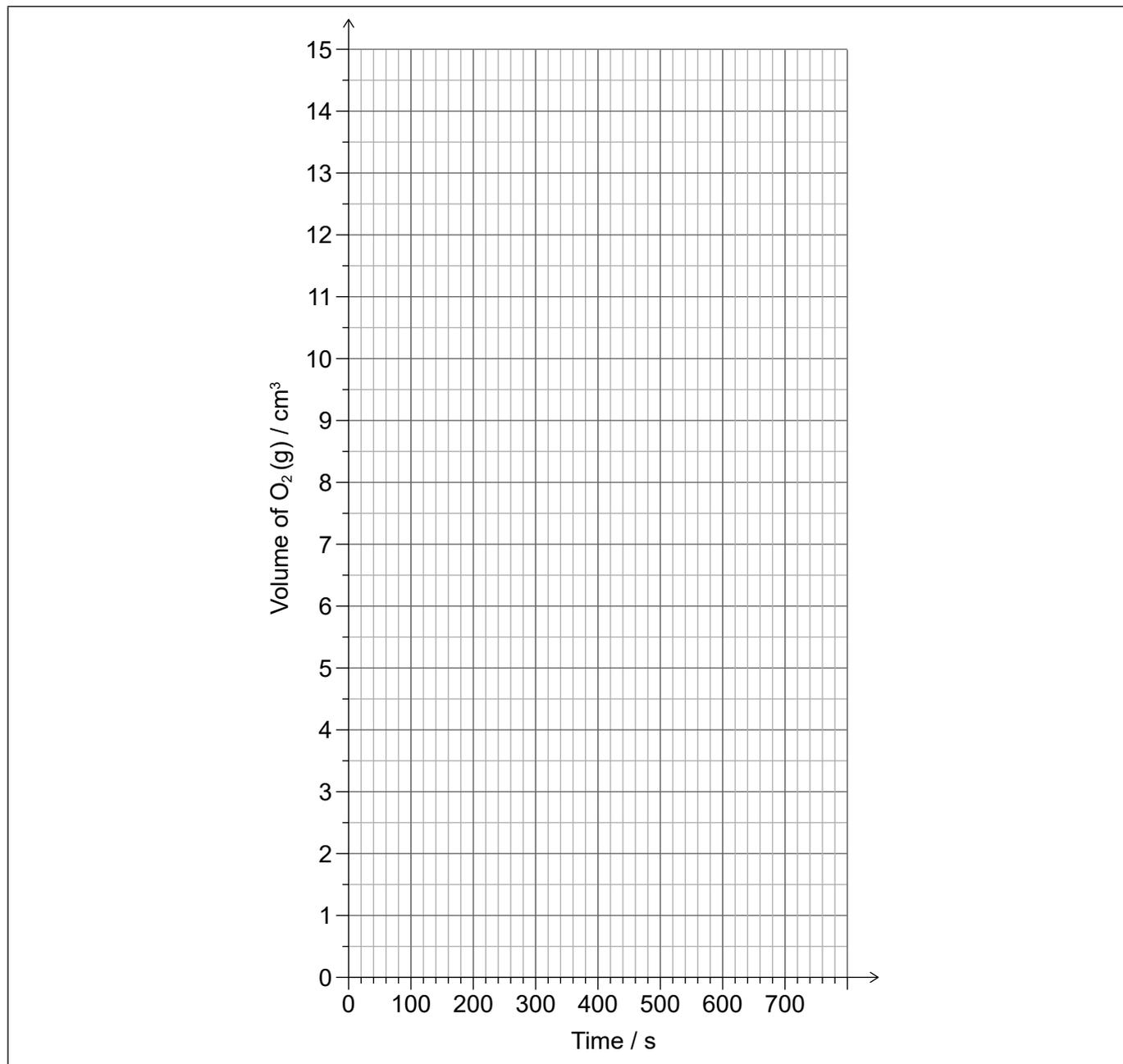
(This question continues on the following page)



(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:

.....

.....

.....

.....

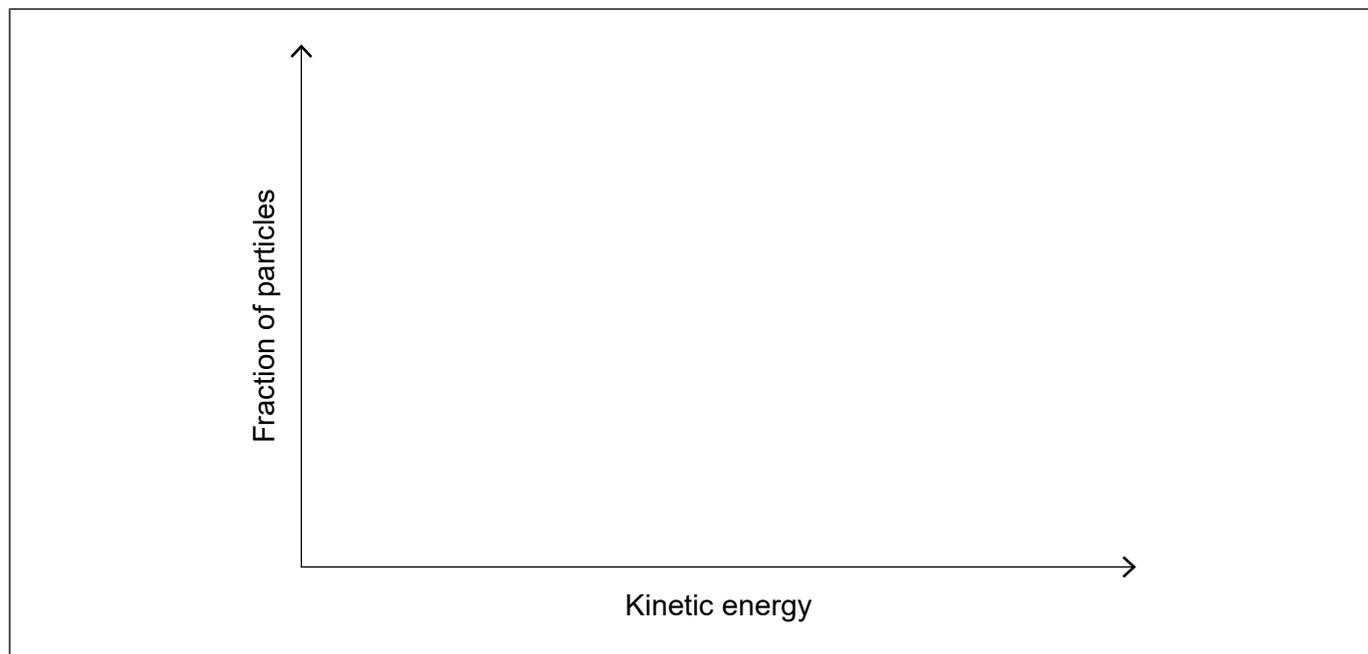
(This question continues on the following page)



16EP09

**(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]

.....  
.....  
.....

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

.....  
.....

**(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.



.....

.....

.....

- (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]

.....

.....

.....

.....

.....



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]

.....  
.....

(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]

.....  
.....  
.....  
.....  
.....

(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:  
.....

H–N–H bond angle:  
.....

6. This question is about iron.

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

.....  
.....

(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]

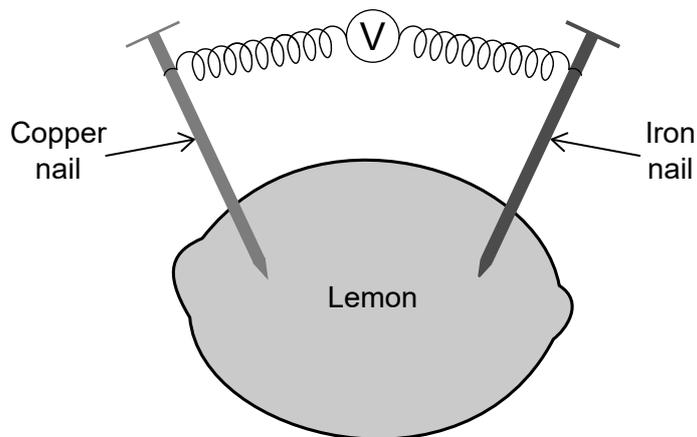
.....  
.....  
.....  
.....  
.....

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



**(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]

.....

.....

.....

.....

.....



Please **do not** write on this page.

Answers written on this page  
will not be marked.



Please **do not** write on this page.

Answers written on this page  
will not be marked.

