

© International Baccalaureate Organization 2024

All rights reserved. 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 the prior written permission from the IB. Additionally, the license tied with this product prohibits 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, whether fee-covered or not, is prohibited and is a criminal offense.

More information on how to request written permission in the form of a license can be obtained from <https://ibo.org/become-an-ib-school/ib-publishing/licensing/applying-for-a-license/>.

© Organisation du Baccalauréat International 2024

Tous droits réservés. 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 préalable de l'IB. De plus, la licence associée à ce produit interdit toute utilisation 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, moyennant paiement ou non, est interdite et constitue une infraction pénale.

Pour plus d'informations sur la procédure à suivre pour obtenir une autorisation écrite sous la forme d'une licence, rendez-vous à l'adresse <https://ibo.org/become-an-ib-school/ib-publishing/licensing/applying-for-a-license/>.

© Organización del Bachillerato Internacional, 2024

Todos los derechos reservados. 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 la previa autorización por escrito del IB. Además, la licencia vinculada a este producto prohíbe el uso 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—, ya sea incluido en tasas o no, está prohibido y constituye un delito.

En este enlace encontrará más información sobre cómo solicitar una autorización por escrito en forma de licencia: <https://ibo.org/become-an-ib-school/ib-publishing/licensing/applying-for-a-license/>.

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

5 November 2024

**Zone A** morning | **Zone B** morning | **Zone C** morning

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]**.



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

Answers written on this page  
will not be marked.

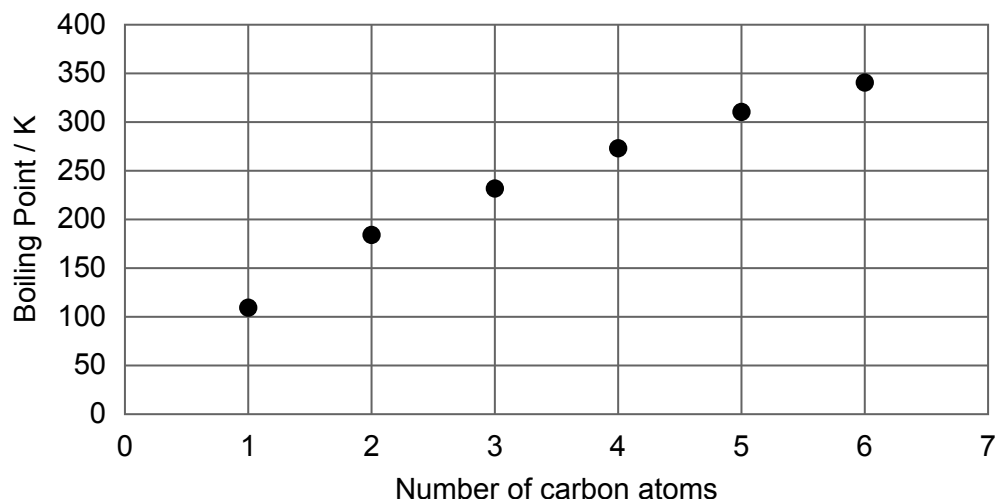


Answer **all** questions. Answers must be written within the answer boxes provided.

1. Alkanes are commonly occurring organic compounds.

(a) The first four straight chain alkanes are gases at room temperature.

Boiling points of straight chain alkanes



(i) Explain why the boiling point increases from methane to propane.

[2]

.....

.....

.....

.....

.....

(ii) Explain why the volume occupied by a sample of propane increases sharply when the sample is heated up from 200 to 250 K at constant pressure.

[2]

.....

.....

.....

.....

.....

(This question continues on the following page)



**(Question 1 continued)**

(iii) Calculate the volume, in  $\text{dm}^3$ , occupied by 6.45 g of propane gas at 100 kPa and  $15^\circ\text{C}$ .

[2]

.....

.....

.....

.....

.....

(iv) Outline why the volume occupied by propane (g) at very high pressure is higher than the value calculated using  $PV = nRT$ .

[2]

.....

.....

.....

.....

.....

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



**(Question 1 continued)**

(b) Ethane can be converted to chloroethane by reacting with chlorine gas,  $\text{Cl}_2(\text{g})$ , in the presence of UV light.

(i) State the type of reaction and the name of the mechanism by which it occurs. [1]

.....  
.....

(ii) Explain the reaction mechanism by writing equations for each step. [4]

One initiation step: .....

Two propagation steps: .....

.....

One termination step: .....

(c) Chloroethane can be converted to ethanol. Identify the reagent and conditions necessary for this reaction to occur. [2]

Reagent: .....

Conditions: .....



2. Potassium, K, and potassium chloride, KCl, both form lattice structures in the solid state.

(a) Predict, with a reason, the electrical conductivity of K(s) and KCl(s). [2]

K(s): .....

.....

.....

KCl(s): .....

.....

.....

(b) An electrolytic cell is made using inert electrodes and molten potassium chloride, KCl(l). State the half equation for the reaction occurring at each electrode. [2]

Anode (positive electrode): .....

.....

Cathode (negative electrode): .....

.....

(c) State the number of each type of subatomic particle in the potassium ion,  ${}_{19}^{41}\text{K}^+$ . [1]

Protons: .....

Electrons: .....

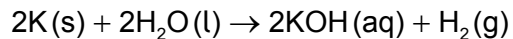
Neutrons: .....

(This question continues on the following page)



**(Question 2 continued)**

(d) Potassium reacts with water to produce potassium hydroxide.



(i) Calculate the enthalpy of reaction, in  $\text{kJ mol}^{-1}$ , when 1 mol of potassium reacts with water. Use section 12 of the data booklet.  $\Delta H_f$  of  $\text{KOH(aq)}$  is  $-481.8 \text{ kJ mol}^{-1}$ . [3]

.....

.....

.....

.....

.....

(ii) Describe the difference between the reactions of sodium and potassium with water. [1]

.....

.....

.....

(iii) Demonstrate, with an equation, the acid-base nature of  $\text{K}_2\text{O(s)}$ . [1]

.....





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

Answers written on this page  
will not be marked.



3. Sulfur trioxide is an important compound in industry.

(a) Sulfur trioxide has more than one possible Lewis (electron dot) structure.

(i) Sketch a Lewis (electron dot) structure for  $\text{SO}_3$  which obeys the octet rule. [1]

(ii) Predict the length of each S to O bond in pm. Use section 10 of the data booklet. [1]

.....

.....

.....

.....

(iii) State the molecular geometry and the O-S-O bond angle in  $\text{SO}_3$ . [2]

Molecular geometry: .....

Bond angle: .....

(b) Suggest why atmospheric  $\text{SO}_3(\text{g})$  is an environmental concern. [1]

.....

.....

.....

(This question continues on the following page)

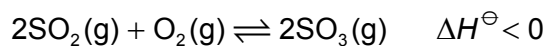


**(Question 3 continued)**

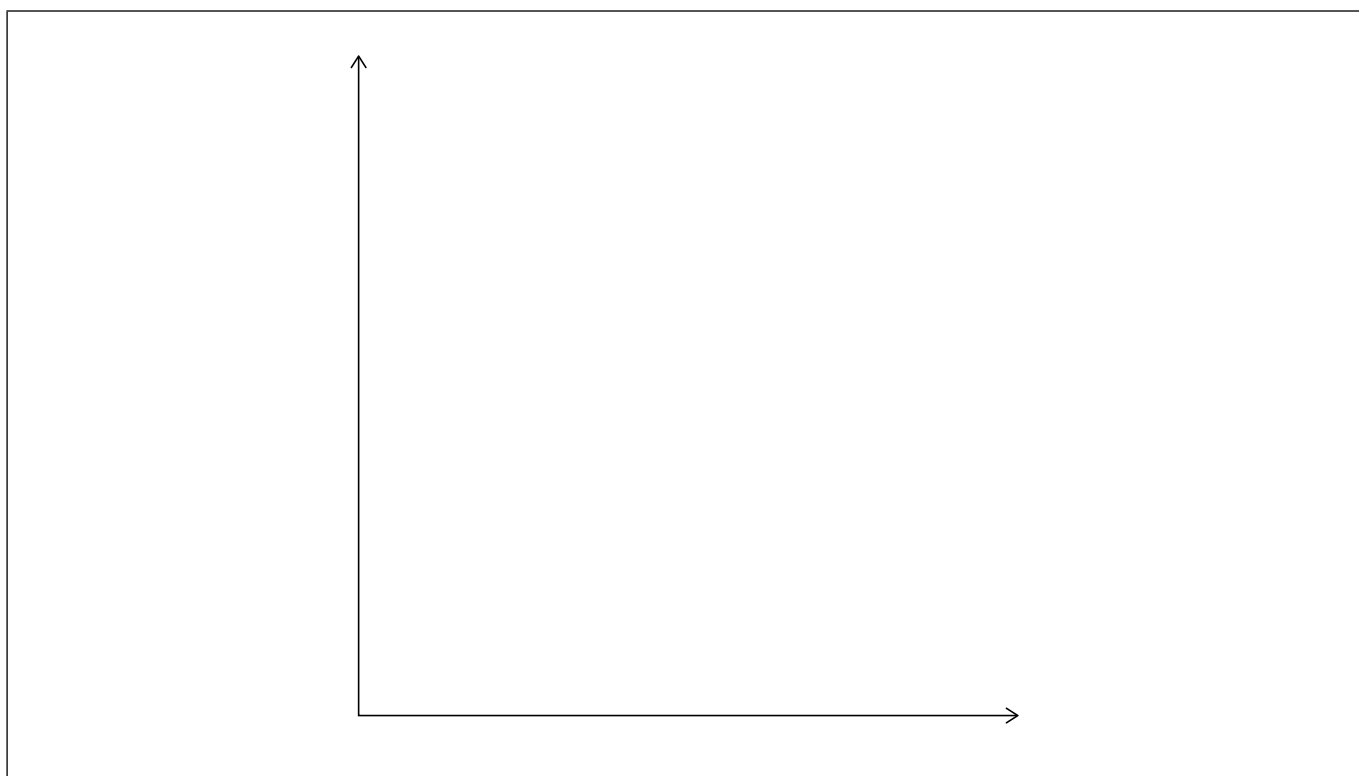
- (c) State the name of a post-combustion method used to lower the quantity of SO<sub>3</sub>(g) released to the atmosphere. [1]

.....

- (d) SO<sub>3</sub>(g) is made using the contact process.



- (i) Sketch a potential energy profile for this reaction on the axes provided. Label  $E_a$  and include labels on the axes. [3]



- (ii) Explain why increasing the temperature increases the rate of reaction. [2]

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

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



**(Question 3 continued)**

- (iii) Vanadium pentoxide,  $V_2O_5$ , is used as a catalyst. Explain how a catalyst increases the rate of a reaction. [2]

.....

.....

.....

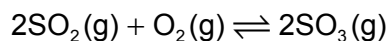
.....

- (iv) During the reaction,  $V_2O_5$  changes to  $V_2O_4$ . Identify the oxidation states of vanadium in each compound. [1]

$V_2O_5$ : .....

$V_2O_4$ : .....

- (v) State the equilibrium constant expression,  $K_c$ , for the production of  $SO_3$ . [1]



.....

.....

- (vi) Outline, with a reason, the effect of increasing the pressure on the position of equilibrium. [1]

.....

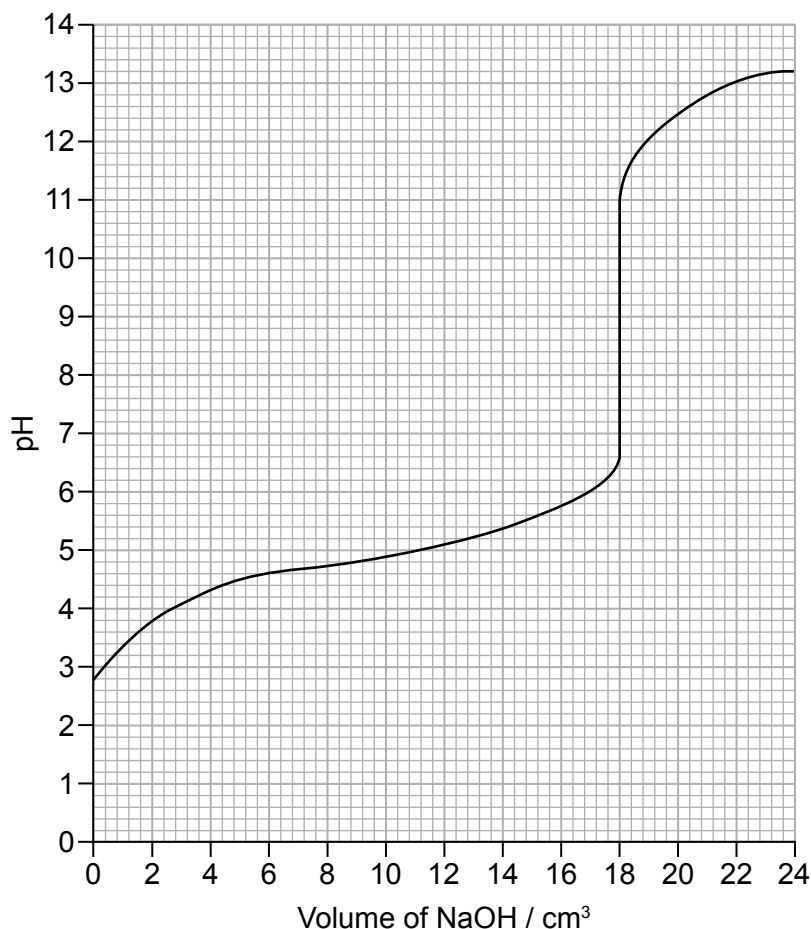
.....

.....



4. Propanoic acid is a weak acid.

(a) A 20.00 cm<sup>3</sup> sample of 0.150 mol dm<sup>-3</sup> propanoic acid, CH<sub>3</sub>CH<sub>2</sub>COOH(aq), was titrated with a solution of sodium hydroxide, NaOH(aq), giving the pH curve shown.



Determine the concentration, in mol dm<sup>-3</sup>, of the NaOH(aq) used in the titration.

[2]

.....

.....

.....

.....

.....

(b) Predict the number of signals and the ratio of areas under the signals in the <sup>1</sup>H NMR spectrum of propanoic acid, CH<sub>3</sub>CH<sub>2</sub>COOH.

[2]

Number of signals: .....

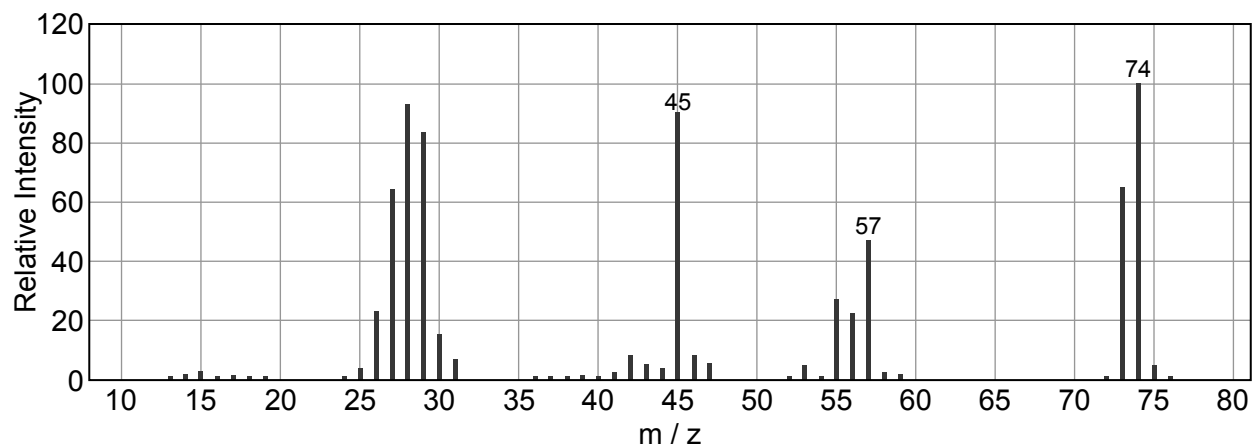
Ratio of areas: .....

(This question continues on the following page)



(Question 4 continued)

(c) The mass spectrum of propanoic acid is shown.



(i) The molar mass of propanoic acid is  $74.09 \text{ g mol}^{-1}$ . Suggest why there are two smaller peaks with higher  $m/z$  value than 74. [1]

.....

.....

.....

(ii) Identify the fragments with  $m/z$  57 and 45. Use section 28 of the data booklet. [2]

$m/z$  57: .....

$m/z$  45: .....

(d) Outline how samples of propanoic acid and a strong acid of the same concentration can be distinguished from each other. [2]

Method: .....

.....

Observation: .....

.....



**Disclaimer:**

Content used in IB assessments is taken from authentic, third-party sources. The views expressed within them belong to their individual authors and/or publishers and do not necessarily reflect the views of the IB.

**References:**

4.(c)(i) Used with permission. © United States of America as represented by the Secretary of Commerce.

**All other texts, graphics and illustrations © International Baccalaureate Organization 2024**



16EP14

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

Answers written on this page  
will not be marked.



16EP15



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

Answers written on this page  
will not be marked.



16EP16