

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 <https://ibo.org/become-an-ib-school/ib-publishing/licensing/applying-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 suivante : <https://ibo.org/become-an-ib-school/ib-publishing/licensing/applying-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: <https://ibo.org/become-an-ib-school/ib-publishing/licensing/applying-for-a-license/>.

Chemistry
Standard level
Paper 2

Thursday 5 November 2020 (afternoon)

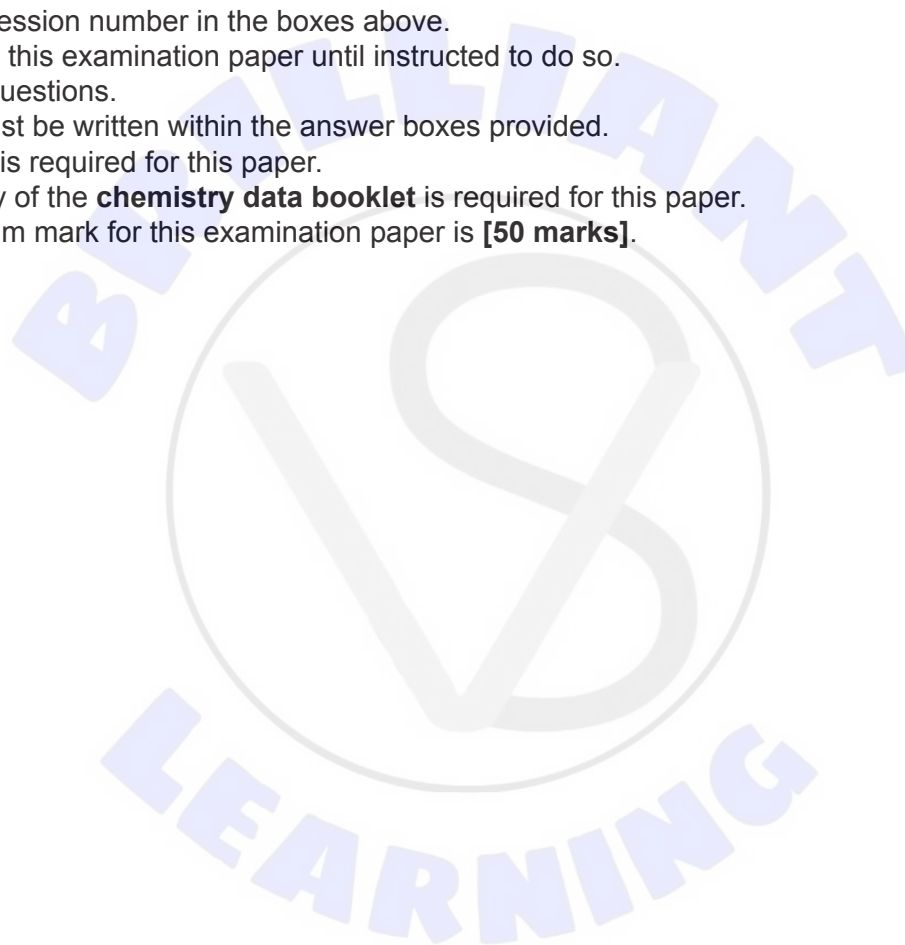
Candidate session number

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. Chlorine undergoes many reactions.

(a) (i) State the full electron configuration of the chlorine atom. [1]

.....
.....

(ii) State, giving a reason, whether the chlorine atom or the chloride ion has a larger radius. [1]

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

(iii) Outline why the chlorine atom has a smaller atomic radius than the sulfur atom. [2]

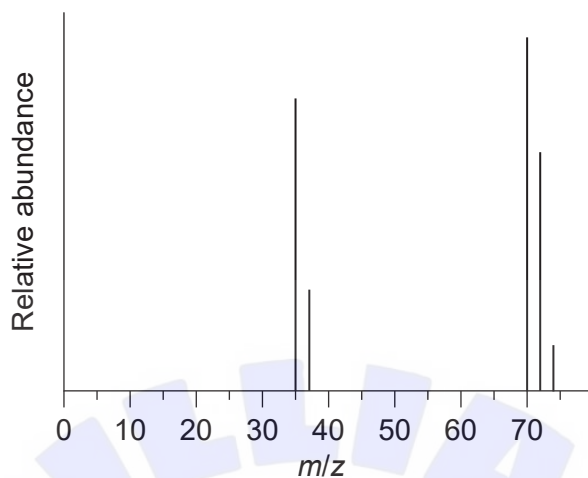
.....
.....
.....
.....

(This question continues on the following page)



(Question 1 continued)

(iv) The mass spectrum of chlorine is shown.



Outline the reason for the two peaks at $m/z = 35$ and 37 . [1]

.....

.....

(v) Explain the presence and relative abundance of the peak at $m/z = 74$. [2]

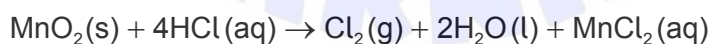
.....

.....

.....

.....

(b) 2.67 g of manganese(IV) oxide was added to 200.0 cm³ of 2.00 mol dm⁻³ HCl.



(i) Calculate the amount, in mol, of manganese(IV) oxide added. [1]

.....

.....

(This question continues on the following page)



(Question 1 continued)

(ii) Determine the limiting reactant, showing your calculations. [2]

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

(iii) Determine the excess amount, in mol, of the other reactant. [1]

.....
.....

(iv) Calculate the volume of chlorine, in dm^3 , produced if the reaction is conducted at standard temperature and pressure (STP). Use section 2 of the data booklet. [1]

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

(v) State the oxidation state of manganese in MnO_2 and MnCl_2 . [2]

MnO_2 :
.....
 MnCl_2 :
.....

(vi) Deduce, referring to oxidation states, whether MnO_2 is an oxidizing or reducing agent. [1]

.....
.....

(This question continues on the following page)



(Question 1 continued)

(c) Chlorine gas reacts with water to produce hypochlorous acid and hydrochloric acid.



(i) Hypochlorous acid is considered a weak acid. Outline what is meant by the term weak acid. [1]

.....
.....

(ii) State the formula of the conjugate base of hypochlorous acid. [1]

.....

(iii) Calculate the concentration of $\text{H}^+(\text{aq})$ in a $\text{HClO}(\text{aq})$ solution with a $\text{pH} = 3.61$. [1]

.....
.....

(d) (i) State the type of reaction occurring when ethane reacts with chlorine to produce chloroethane. [1]

.....

(ii) Predict, giving a reason, whether ethane or chloroethane is more reactive. [1]

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

(This question continues on the following page)



(Question 1 continued)

- (iii) Write the equation for the reaction of chloroethane with a dilute aqueous solution of sodium hydroxide. [1]

.....
.....

- (iv) Deduce the nucleophile for the reaction in d(iii). [1]

.....

- (v) Ethoxyethane (diethyl ether) can be used as a solvent for this conversion. Draw the structural formula of ethoxyethane. [1]

.....

- (vi) Deduce the number of signals and their chemical shifts in the ^1H NMR spectrum of ethoxyethane. Use section 27 of the data booklet. [2]

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

(This question continues on the following page)



(Question 1 continued)

(e) CCl_2F_2 is a common chlorofluorocarbon, CFC.

(i) Calculate the percentage by mass of chlorine in CCl_2F_2 . [2]

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

(ii) Comment on how international cooperation has contributed to the lowering of CFC emissions responsible for ozone depletion. [1]

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

2. Compound **A** is in equilibrium with compound **B**.



(a) Predict the electron domain and molecular geometries around the **oxygen** atom of molecule **A** using VSEPR. [2]

Electron domain geometry:
.....

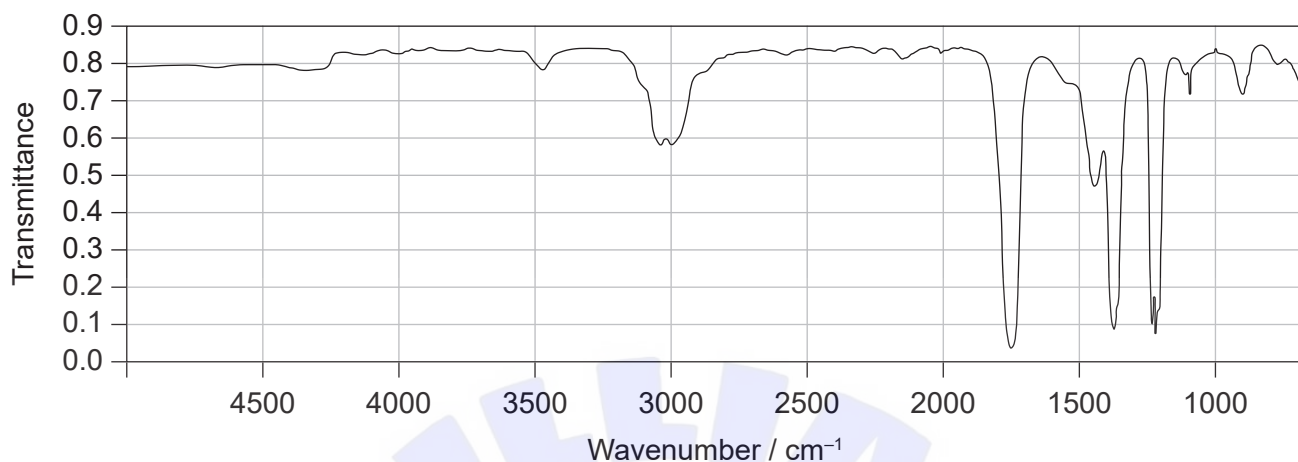
Molecular geometry:
.....

(This question continues on the following page)



(Question 2 continued)

(b) The IR spectrum of one of the compounds is shown:



Deduce, giving a reason, the compound producing this spectrum.

[1]

.....

.....

.....

(c) Compound **A** and **B** are isomers. Draw two other structural isomers with the formula C_3H_6O .

[2]

.....

.....

(This question continues on the following page)



(Question 2 continued)

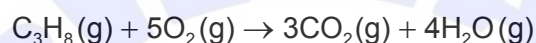
- (d) The equilibrium constant, K_c , for the conversion of **A** to **B** is 1.0×10^8 in water at 298 K.

Deduce, giving a reason, which compound, **A** or **B**, is present in greater concentration when equilibrium is reached.

[1]

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

3. An equation for the combustion of propane is given below.



- (a) Determine the standard enthalpy change, ΔH^\ominus , for this reaction, using section 11 of the data booklet.

[3]

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

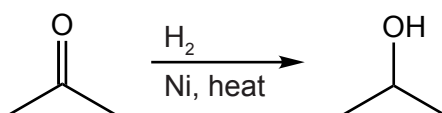
- (b) Calculate the standard enthalpy change, ΔH^\ominus , for this reaction using section 12 of the data booklet.

[2]

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



4. Nickel catalyses the conversion of propanone to propan-2-ol.



(a) Outline how a catalyst increases the rate of reaction.

[1]

.....

.....

.....

(b) Explain why an increase in temperature increases the rate of reaction.

[2]

.....

.....

.....

.....

(c) Discuss, referring to intermolecular forces present, the relative volatility of propanone and propan-2-ol.

[3]

.....

.....

.....

.....

.....

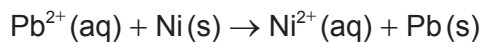
.....

(This question continues on the following page)



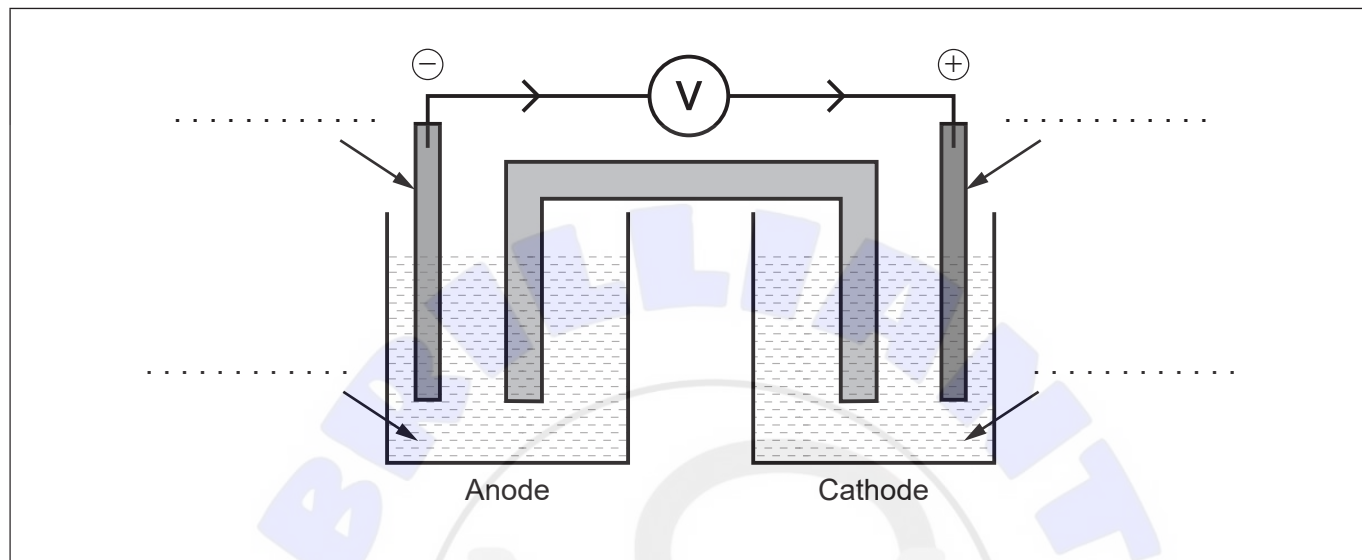
(Question 4 continued)

(d) (i) The diagram shows an unlabelled voltaic cell for the reaction



Label the diagram with the species in the equation.

[1]



(ii) Suggest a metal that could replace nickel in a new half-cell and reverse the electron flow. Use section 25 of the data booklet.

[1]

.....

(iii) Describe the bonding in metals.

[2]

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

(iv) Nickel alloys are used in aircraft gas turbines. Suggest a physical property altered by the addition of another metal to nickel.

[1]

.....
.....





References:

- 1.(a)(iv)** NIST Mass Spectrometry Data Center Collection © 2014 copyright by the U.S. Secretary of Commerce on behalf of the United States of America. All rights reserved.
- 2.(b)** COBLENTZ SOCIETY. Collection © 2018 copyright by the U.S. Secretary of Commerce on behalf of the United States of America. All rights reserved.

