

© International Baccalaureate Organization 2021

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 2021

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, 2021

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 1

Friday 14 May 2021 (morning)

45 minutes

Instructions to candidates

- Do not open this examination paper until instructed to do so.
- Answer all the questions.
- For each question, choose the answer you consider to be the best and indicate your choice on the answer sheet provided.
- The periodic table is provided for reference on page 2 of this examination paper.
- The maximum mark for this examination paper is **[30 marks]**.

The Periodic Table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18			
1	1 H 1.01	<table border="1"> <tr> <td>Atomic number</td> </tr> <tr> <td>Element</td> </tr> <tr> <td>Relative atomic mass</td> </tr> </table>																Atomic number	Element	Relative atomic mass	2 He 4.00
Atomic number																					
Element																					
Relative atomic mass																					
2	3 Li 6.94	4 Be 9.01																	9 F 19.00	10 Ne 20.18	
3	11 Na 22.99	12 Mg 24.31																	17 Cl 35.45	18 Ar 39.95	
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.63	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.90			
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.96	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29			
6	55 Cs 132.91	56 Ba 137.33	57 † La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)			
7	87 Fr (223)	88 Ra (226)	89 † Ac (227)	104 Rf (267)	105 Db (268)	106 Sg (269)	107 Bh (270)	108 Hs (269)	109 Mt (278)	110 Ds (281)	111 Rg (281)	112 Cn (285)	113 Unt (286)	114 Uug (289)	115 Uup (288)	116 Uuh (293)	117 Uus (294)	118 Uuo (294)			
†	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.05	71 Lu 174.97							
‡	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)							

1. Which contains the most atoms of oxygen?
 - A. 64 g of O₂
 - B. 1.2×10^{24} molecules of O₂
 - C. 64 g of C₃H₅O₃
 - D. 1.2×10^{24} molecules of C₃H₅O₃

2. What is the resulting concentration, in mol dm⁻³, when 1.0 cm³ of 0.500 mol dm⁻³ nitric acid solution is diluted to 50.0 cm³ with water?
 - A. 0.002
 - B. 0.01
 - C. 0.04
 - D. 0.1

3. What volume of oxygen, in dm³ at STP, is needed when 5.8 g of butane undergoes complete combustion?

$2\text{C}_4\text{H}_{10}(\text{g}) + 13\text{O}_2(\text{g}) \rightarrow 8\text{CO}_2(\text{g}) + 10\text{H}_2\text{O}(\text{l})$

A. $2 \times \frac{5.8}{12.01 \times 4 + 1.01 \times 10} \times 13 \times 22.7$

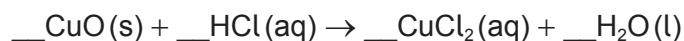
B. $\frac{5.8}{12.01 \times 4 + 1.01 \times 10} \times \frac{13}{2} \times 22.7$

C. $\frac{5.8}{12.01 \times 4 + 1.01 \times 10} \times \frac{2}{13} \times 22.7$

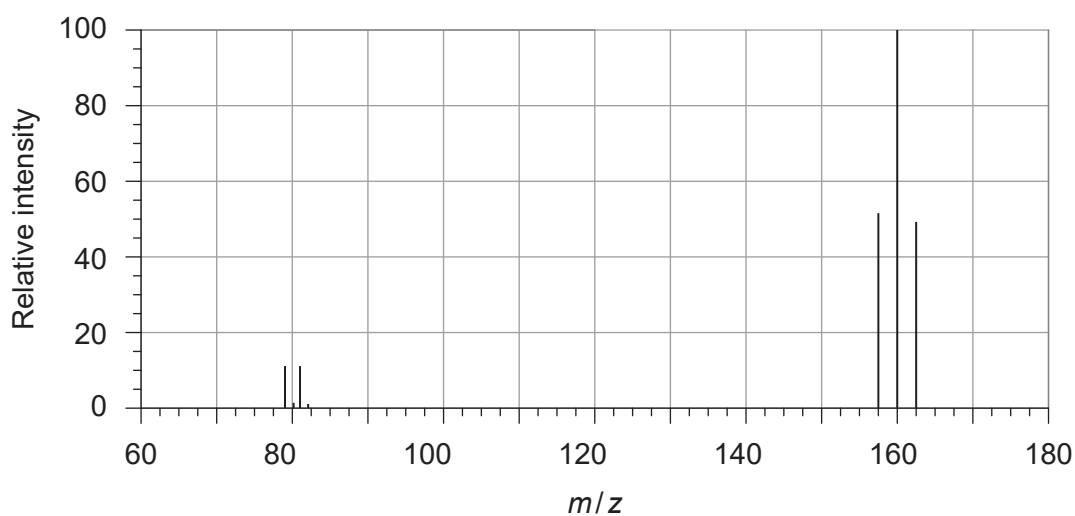
D. $\frac{5.8}{12.01 \times 4 + 1.01 \times 10} \times \frac{13}{2} \times \frac{22.7}{1000}$

Turn over

4. What is the coefficient of HCl(aq) when the equation is balanced using the smallest possible whole numbers?



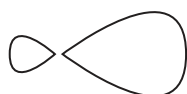
- A. 1
 B. 2
 C. 3
 D. 4
5. What is the relative molecular mass of bromine, according to the following mass spectrum?



- A. $\frac{158 \times 52 + 160 \times 100 + 162 \times 48}{52 + 100 + 48}$
- B. $\frac{158 \times 52 + 160 \times 100 + 162 \times 48}{158 + 160 + 162}$
- C. $\frac{79 \times 11 + 81 \times 11 + 158 \times 52 + 160 \times 100 + 162 \times 48}{11 + 11 + 52 + 100 + 48}$
- D. $\frac{79 \times 11 + 81 \times 11}{11 + 11}$

6. Which represents a *p* orbital?

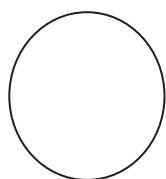
A.



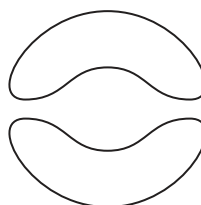
C.



B.



D.



7. Which species has the same electron configuration as argon?

A. Br^-

B. Ca^{2+}

C. Al^{3+}

D. Si^{4+}

8. Which trend is correct, going down group 1?

A. Melting point increases

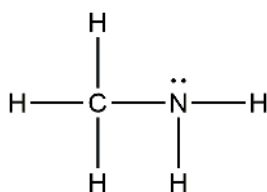
B. Reactivity decreases

C. First ionisation energy increases

D. Electronegativity decreases

Turn over

9. The Lewis structure of methylamine is shown.



What is the molecular geometry around N?

- A. Square planar
- B. Tetrahedral
- C. Trigonal planar
- D. Trigonal pyramidal
10. Which compound contains both ionic and covalent bonds?
- A. MgO
- B. CH_2Cl_2
- C. CH_3COOH
- D. NaOH
11. Which substance is most likely to be ionic?

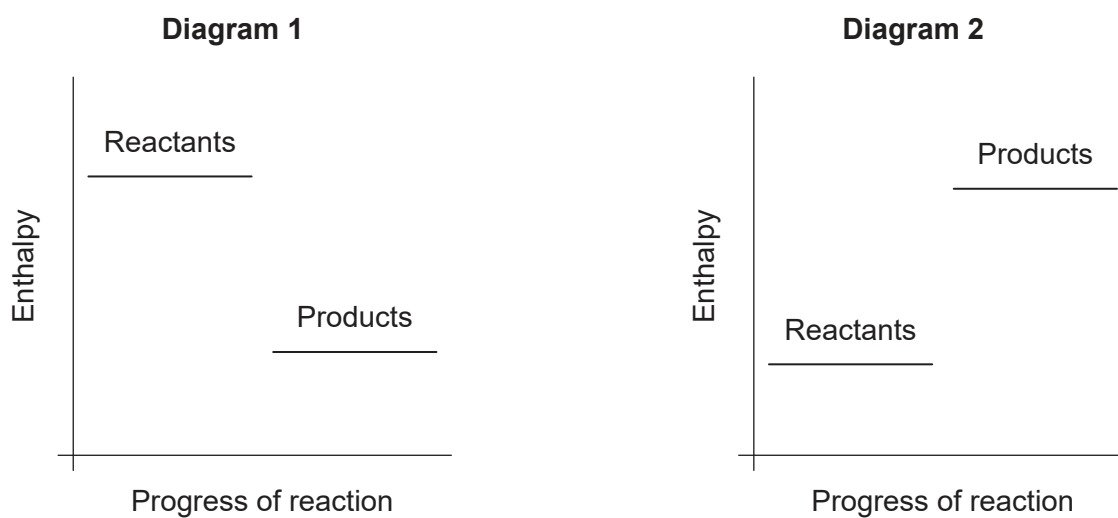
	Melting point	Solubility in hexane	Electrical conductivity of solid
A.	High	Low	High
B.	Low	Low	Low
C.	Low	High	Low
D.	High	Low	Low

12. Along which series is the bond angle increasing?

- A. NH_3 H_2O CH_4
- B. CH_4 NH_3 H_2O
- C. H_2O NH_3 CH_4
- D. H_2O CH_4 NH_3

13. When sodium carbonate powder is added to ethanoic acid, the beaker becomes cooler.

Possible enthalpy diagrams are shown.



Which correctly describes the reaction?

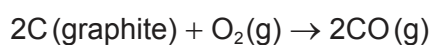
	Enthalpy diagram	Reaction
A.	1	Endothermic
B.	1	Exothermic
C.	2	Endothermic
D.	2	Exothermic

Turn over

14. What is the enthalpy change, in J, when 5g of water is heated from 10°C to 18°C?

Specific heat capacity of water: $4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$

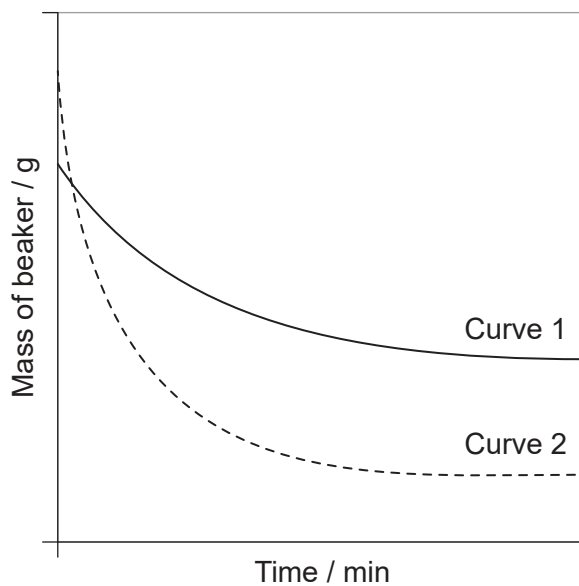
- A. $5 \times 4.18 \times 8$
 B. $5 \times 10^{-3} \times 4.18 \times 8$
 C. $5 \times 4.18 \times (273 + 8)$
 D. $5 \times 10^{-3} \times 4.18 \times (273 + 8)$
15. What is the enthalpy change of the reaction, in kJ?



Substance	$\Delta H_{\text{combustion}}^{\ominus} / \text{kJ mol}^{-1}$
C (graphite)	–394
CO (g)	–283

- A. $-394 - 283$
 B. $2(-394) + 2(-283)$
 C. $-394 + 283$
 D. $2(-394) + 2(283)$

16. Curve 1 shows the mass change when marble chips are added to excess hydrochloric acid in an open beaker.

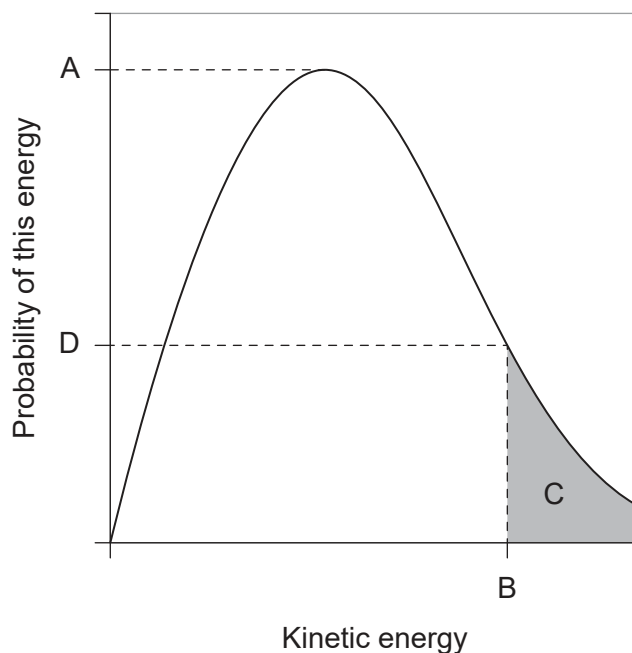


Which changes would produce curve 2?

- A. Powdering the marble chips and heating
- B. Powdering the marble chips and doubling their mass
- C. Doubling the volume of acid and heating
- D. Doubling the acid concentration and powdering the marble chips

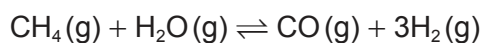
Turn over

17. On the following Maxwell-Boltzmann distribution, which letter represents activation energy?



- A. A
- B. B
- C. C
- D. D

18. Which changes produce the greatest increase in the percentage conversion of methane?



	Pressure	Proportion of H ₂ O (g)
A.	Doubled	Halved
B.	Doubled	Doubled
C.	Halved	Doubled
D.	Halved	Halved

19. Which is amphiprotic?

- A. NH_4^+
- B. PO_4^{3-}
- C. H_2O
- D. H_3O^+

20. Which solution has a pH of 9?

- A. $1.0 \times 10^{-9} \text{ mol dm}^{-3} \text{ HCl (aq)}$
- B. $1.0 \times 10^{-5} \text{ mol dm}^{-3} \text{ KOH (aq)}$
- C. $1.0 \times 10^{-9} \text{ mol dm}^{-3} \text{ KOH (aq)}$
- D. $1.0 \times 10^{-5} \text{ mol dm}^{-3} \text{ HCl (aq)}$

21. A student performed displacement reactions using metals W and X and solutions of salts of metals W, X, Y and Z. The results are summarized in the table.

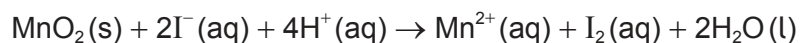
		Salt solution			
		W^{2+}	X^{2+}	Y^{2+}	Z^{2+}
Metal	W		No reaction	No reaction	No reaction
	X	Reaction		Reaction	No reaction

Which of the four metals is most reactive?

- A. W
- B. X
- C. Y
- D. Z

Turn over

22. What is correct for this redox reaction?



	Reduced	Reducing agent
A.	$\text{MnO}_2(\text{s})$	$\text{I}^-(\text{aq})$
B.	$\text{I}^-(\text{aq})$	$\text{H}^+(\text{aq})$
C.	$\text{I}^-(\text{aq})$	$\text{MnO}_2(\text{s})$
D.	$\text{H}^+(\text{aq})$	$\text{I}^-(\text{aq})$

23. Which statements are correct for electrolysis?

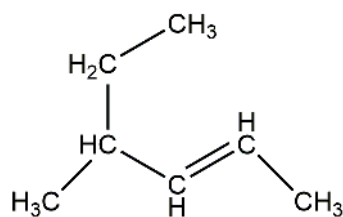
- I. An exothermic reaction occurs.
- II. Oxidation occurs at the anode (positive electrode).
- III. The reaction is non-spontaneous.

- A. I and II only
- B. I and III only
- C. II and III only
- D. I, II and III

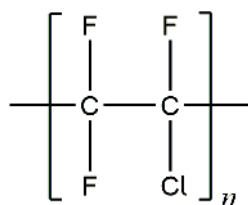
24. Which series is in order of increasing boiling point?

- A. $\text{CH}_2\text{CH}_2\text{CH}_3\text{OH}$ CH_3COCH_3 $\text{CH}_3\text{CH}_2\text{CH}_3$
- B. $\text{CH}_3\text{CH}_2\text{CH}_3$ CH_3COCH_3 $\text{CH}_2\text{CH}_2\text{CH}_3\text{OH}$
- C. CH_3COCH_3 $\text{CH}_2\text{CH}_2\text{CH}_3\text{OH}$ $\text{CH}_3\text{CH}_2\text{CH}_3$
- D. $\text{CH}_3\text{CH}_2\text{CH}_3$ $\text{CH}_2\text{CH}_2\text{CH}_3\text{OH}$ CH_3COCH_3

25. What is the name of this compound, applying IUPAC rules?



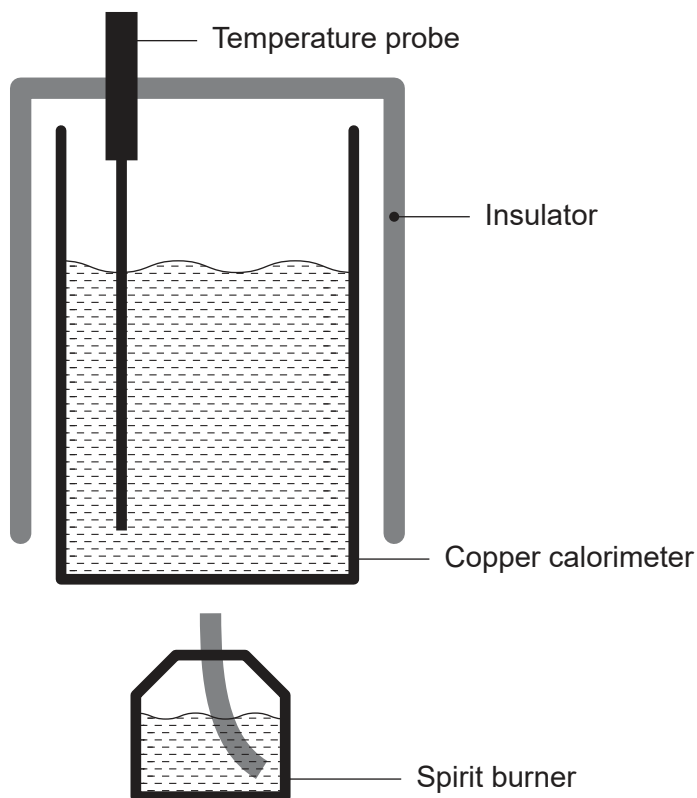
- A. 4-methylhex-2-ene
 B. 4-ethylpent-2-ene
 C. 2-ethylpent-3-ene
 D. 3-methylhex-4-ene
26. What is formed in a propagation step of the substitution reaction between bromine and ethane?
- A. $\text{CH}_3\text{CH}_2\cdot$
 B. $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$
 C. $\text{H}\cdot$
 D. Br^-
27. Which monomer would produce the polymer shown?



- A. $\text{CF}_3\text{CCl}_2\text{F}$
 B. CF_3CClHF
 C. CF_2CClF
 D. CF_2CF_2

Turn over

28. The enthalpy of combustion of a fuel was determined using the calorimeter shown. The final result was lower than the literature value.



Which factors could have contributed to this error?

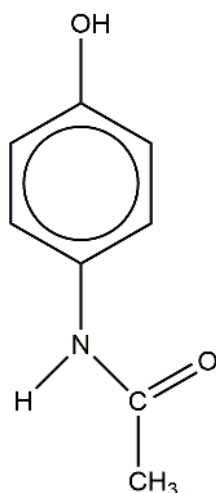
- I. Not all heat from the combustion was transferred to the calorimeter.
 - II. Incomplete combustion occurred.
 - III. The temperature probe touched the bottom of the calorimeter.
- A. I and II only
 - B. I and III only
 - C. II and III only
 - D. I, II and III

29. Burette readings for a titration are shown.

Burette readings / $\text{cm}^3 \pm 0.05 \text{ cm}^3$	Trial 1	Trial 2	Trial 3
Final	11.35	24.60	11.70
Initial	0.20	13.50	0.50

What is the mean titre?

- A. $11.1 \text{ cm}^3 \pm 0.1 \text{ cm}^3$
- B. $11.15 \text{ cm}^3 \pm 0.05 \text{ cm}^3$
- C. $11.2 \text{ cm}^3 \pm 0.05 \text{ cm}^3$
- D. $11.2 \text{ cm}^3 \pm 0.1 \text{ cm}^3$
30. Determine the index of hydrogen deficiency (IHD) of paracetamol.



- A. 3
- B. 4
- C. 5
- D. 6
-

References:

5. 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.

All other texts, graphics and illustrations © International Baccalaureate Organization 2021