

© International Baccalaureate Organization 2022

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 2022

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, 2022

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/>.

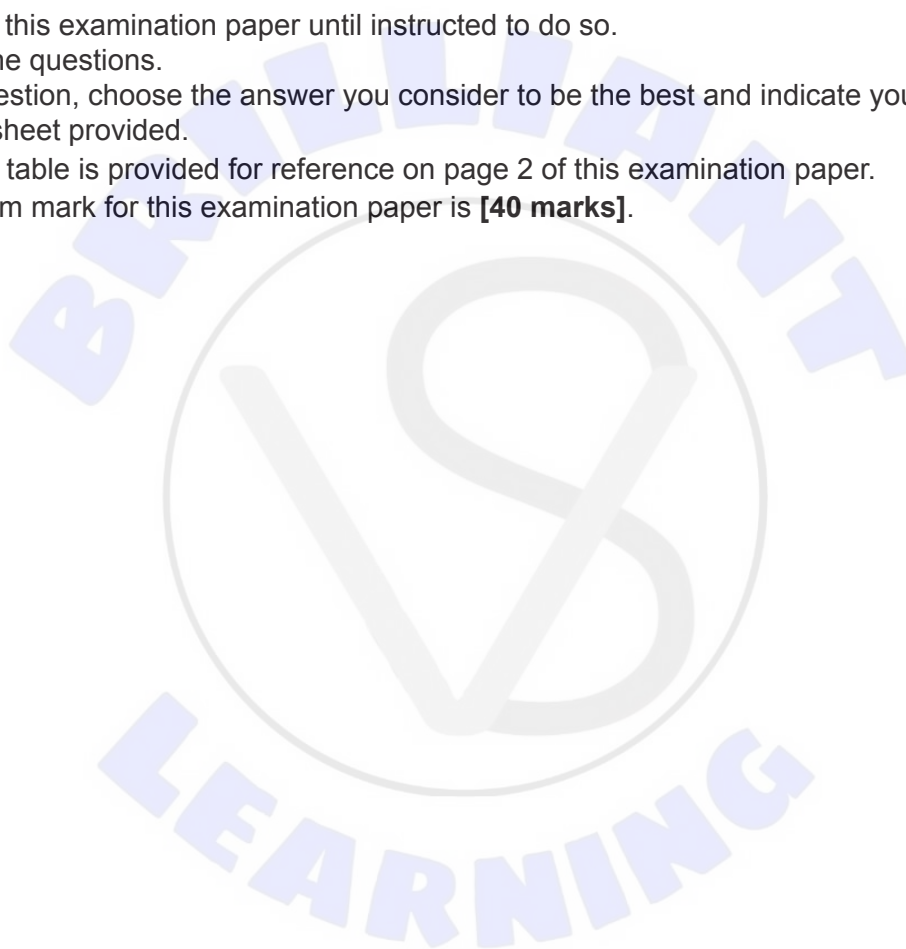
Chemistry
Higher level
Paper 1

Wednesday 18 May 2022 (afternoon)

1 hour

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 **[40 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	Atomic number																	
2	3 Li 6.94	4 Be 9.01	Element																
3	11 Na 22.99	12 Mg 24.31	Relative atomic mass																
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 Uut (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. What is the concentration of chloride ions, in mol dm^{-3} , in a solution formed by mixing 200 cm^3 of 1 mol dm^{-3} HCl with 200 cm^3 of 5 mol dm^{-3} NaCl?

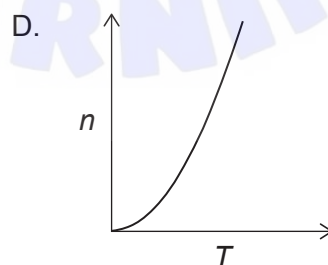
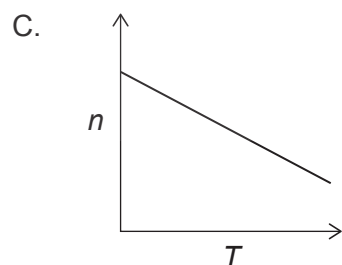
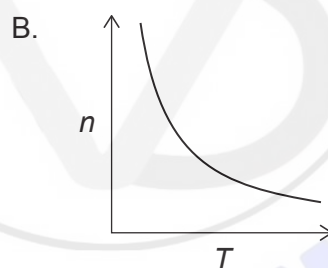
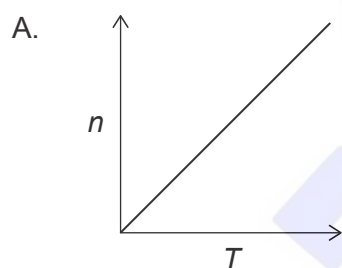
- A. 1
- B. 2
- C. 3
- D. 6

2. 30g of an organic compound produces 44g CO_2 and 18g H_2O as the only combustion products. Which of the following is the empirical formula for this compound?

$$M_r \text{CO}_2 = 44 \quad M_r \text{H}_2\text{O} = 18$$

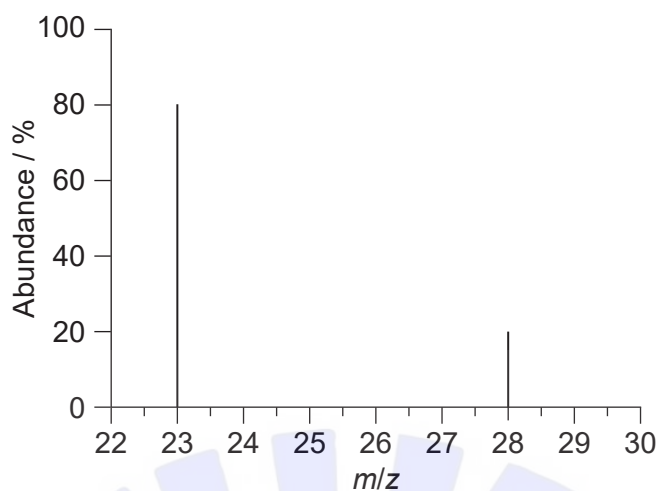
- A. CH_2
- B. CH_3
- C. CHO
- D. CH_2O

3. Which graph represents the relationship between the amount of gas, n , and the absolute temperature, T , with all other variables in the ideal gas equation, $PV = nRT$, held constant?



Turn over

4. What is the relative atomic mass of an element with the following mass spectrum?



- A. 23
- B. 24
- C. 25
- D. 28

5. What is the correct order for **increasing** first ionization energy?

- A. Na < Mg < Al
- B. Na < Al < Mg
- C. Al < Mg < Na
- D. Al < Na < Mg

6. Which are the most reactive elements of the alkali metals and halogens?

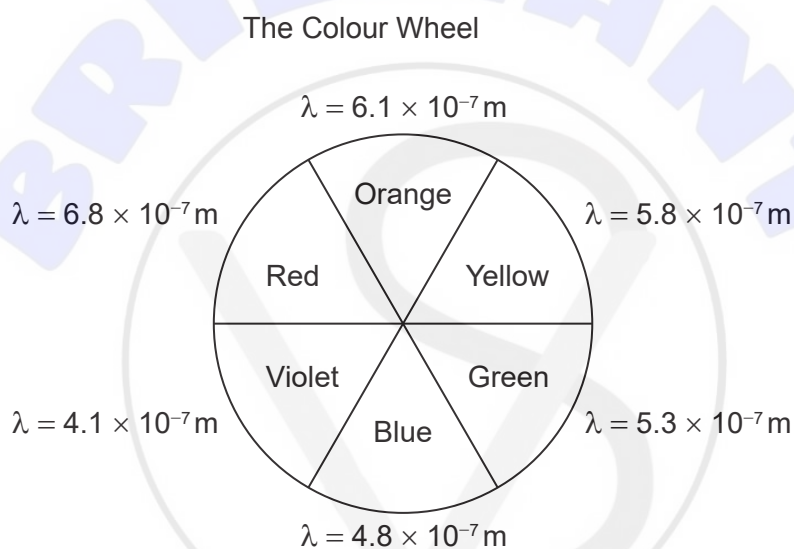
- A. Lithium and fluorine
- B. Lithium and iodine
- C. Caesium and fluorine
- D. Caesium and iodine

7. Which of these ions are likely to be paramagnetic?

- I. Ti^{3+}
- II. Cr^{3+}
- III. Fe^{3+}

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

8. $[\text{Cr}(\text{OH}_2)_6]^{3+}$ is violet and $[\text{Cr}(\text{NH}_3)_6]^{3+}$ is yellow. What is correct?

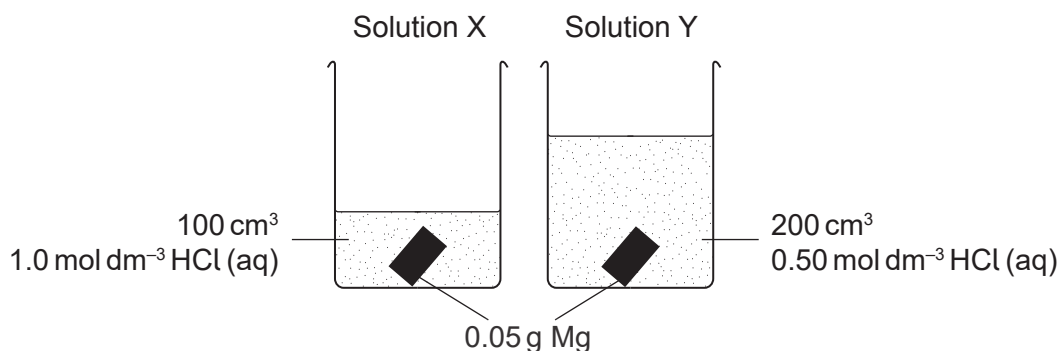


	Wavelength of light absorbed by $[\text{Cr}(\text{OH}_2)_6]^{3+}$	d-level splitting caused by H_2O compared to NH_3 ligands
A.	$\lambda = 5.8 \times 10^{-7} \text{ m}$	$\text{H}_2\text{O} > \text{NH}_3$
B.	$\lambda = 5.8 \times 10^{-7} \text{ m}$	$\text{H}_2\text{O} < \text{NH}_3$
C.	$\lambda = 4.1 \times 10^{-7} \text{ m}$	$\text{H}_2\text{O} > \text{NH}_3$
D.	$\lambda = 4.1 \times 10^{-7} \text{ m}$	$\text{H}_2\text{O} < \text{NH}_3$

Turn over

9. In which of the following compounds does ionic bonding predominate?
- A. HCl
 - B. NaF
 - C. NH_4Br
 - D. NaOH
10. What is the main interaction between liquid CH_4 molecules?
- A. London (dispersion) forces
 - B. Dipole–dipole forces
 - C. Hydrogen bonding
 - D. Covalent bonding
11. What is the formal charge of the oxygen atom in H_3O^+ ?
- A. –2
 - B. –1
 - C. 0
 - D. +1
12. What is the molecular geometry of SF_4 ?
- A. Tetrahedral
 - B. Trigonal bipyramidal
 - C. See-saw
 - D. Square planar

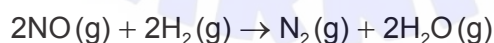
13. Which statement is correct about identical pieces of magnesium added to two solutions, X and Y, containing hydrochloric acid at the same temperature?



- A. Solution X will reach a higher maximum temperature.
 B. Solution Y will reach a higher maximum temperature.
 C. Solutions X and Y will have the same temperature rise.
 D. It is not possible to predict whether X or Y will have the higher maximum temperature because we cannot identify the limiting reactant.
14. Which equation represents hydration enthalpy?
- A. $\text{Na}^+(\text{g}) \rightarrow \text{Na}^+(\text{aq})$
 B. $\text{Na}^+(\text{aq}) \rightarrow \text{Na}^+(\text{g})$
 C. $\text{NaCl}(\text{s}) \rightarrow \text{NaCl}(\text{aq})$
 D. $\text{NaCl}(\text{aq}) \rightarrow \text{NaCl}(\text{s})$
15. What are the signs of ΔH and ΔS for a reaction that is non-spontaneous at low temperatures but spontaneous at high temperatures?

	ΔH	ΔS
A.	-	-
B.	-	+
C.	+	-
D.	+	+

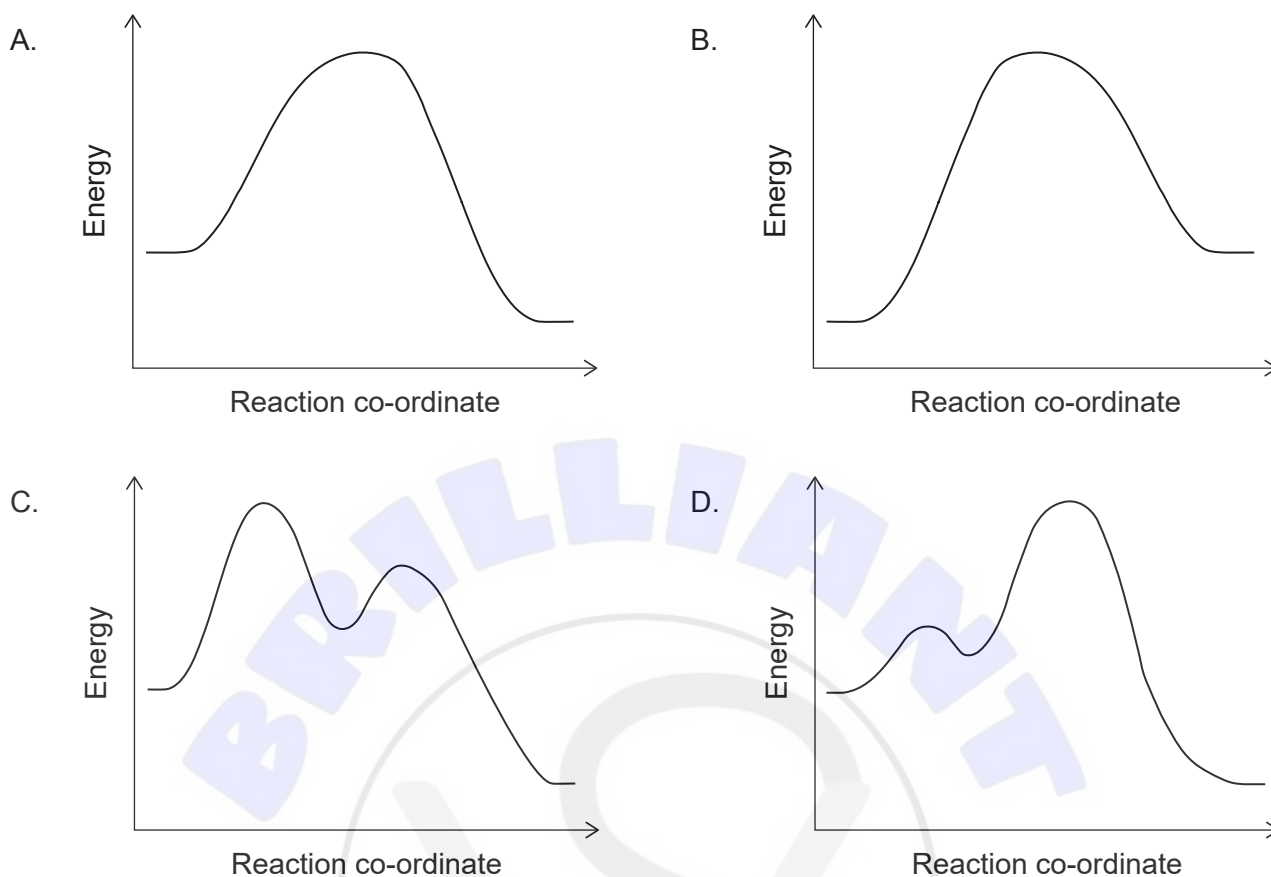
16. Which equation represents the bond enthalpy for H-Br in hydrogen bromide?
- A. $\text{HBr(g)} \rightarrow \text{H}^+(\text{g}) + \text{Br}^-(\text{g})$
- B. $\text{HBr(g)} \rightarrow \text{H(g)} + \text{Br(g)}$
- C. $\text{HBr(g)} \rightarrow \frac{1}{2}\text{H}_2(\text{g}) + \frac{1}{2}\text{Br}_2(\text{l})$
- D. $\text{HBr(g)} \rightarrow \frac{1}{2}\text{H}_2(\text{g}) + \frac{1}{2}\text{Br}_2(\text{g})$
17. Which term in the expression $\Delta G^\ominus = \Delta H^\ominus - T\Delta S^\ominus$ is an indirect measure of the entropy change of the surroundings when divided by T?
- A. ΔG^\ominus
- B. ΔH^\ominus
- C. ΔS^\ominus
- D. $-T\Delta S^\ominus$
18. Why does a reaction for a sample of gases, at constant temperature, occur faster at higher pressure?
- A. Collisions are more frequent.
- B. Collisions are more energetic.
- C. High pressure lowers activation energy.
- D. The reaction is more exothermic at high pressure.
19. What is correct about the rate of disappearance of NO?



$$\text{rate} = k[\text{H}_2][\text{NO}]^2$$

- A. It equals half the rate of disappearance of H_2 .
- B. It equals the rate of disappearance of H_2 .
- C. It equals twice the rate of disappearance of H_2 .
- D. It equals four times the rate of disappearance of H_2 .

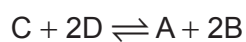
20. Which energy profile diagram represents an exothermic S_N1 reaction?



21. Which factor influences the value of the pre-exponential factor, A, in the Arrhenius equation,

$$k = Ae^{-\frac{E_a}{RT}}$$

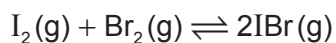
- A. Nature of reactants
 - B. Temperature of reaction
 - C. Activation energy of reaction
 - D. Overall order of the reaction
22. The equilibrium constant, K_c , for the reaction $2A + 4B \rightleftharpoons 2C + 4D$ has a value of 4.0. What is the value of K_c for the reaction below at the same temperature?



- A. 0.25
- B. 0.50
- C. 1.0
- D. 16

Turn over

23. 0.50 mol of $I_2(g)$ and 0.50 mol of $Br_2(g)$ are placed in a closed flask. The following equilibrium is established.

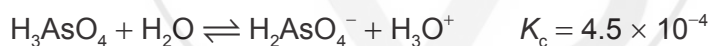


The equilibrium mixture contains 0.80 mol of $IBr(g)$. What is the value of K_c ?

- A. 0.64
 B. 1.3
 C. 2.6
 D. 64
24. What happens to the amount of hydroxide ions and hydroxide ion concentration when water is added to a solution of $NH_3(aq)$?

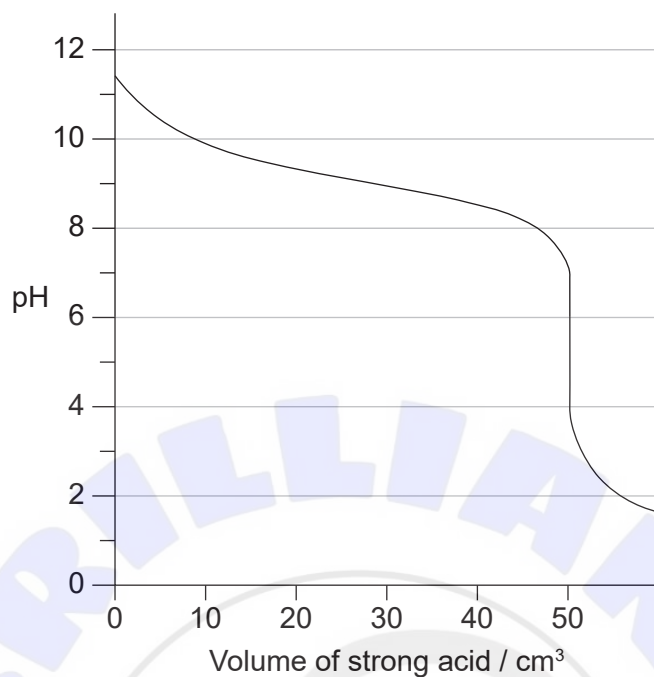
	$n(OH^-)$	$[OH^-]$
A.	Increases	Increases
B.	Decreases	Decreases
C.	Increases	Decreases
D.	Decreases	Increases

25. What is the strongest acid in the equation below?



- A. H_3AsO_4
 B. H_2O
 C. $H_2AsO_4^-$
 D. H_3O^+

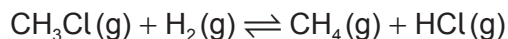
26. A weak base is titrated with a strong acid. Which value of pK_b can be estimated from this titration curve?



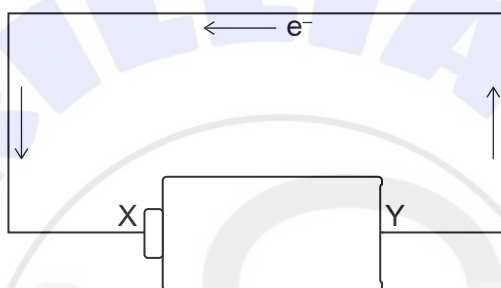
- A. 11.3
 B. 9.2
 C. 4.8
 D. 1.8
27. Which species are **both** Lewis and Brønsted–Lowry bases?
- I. CN^-
 II. OH^-
 III. NH_3
- A. I and II only
 B. I and III only
 C. II and III only
 D. I, II and III

Turn over

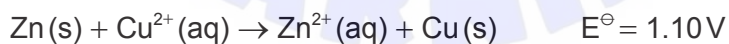
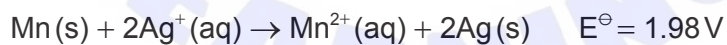
28. Which combination best describes what is happening to chloromethane, CH_3Cl , in the equation below?



- A. Oxidation and addition
 B. Oxidation and substitution
 C. Reduction and addition
 D. Reduction and substitution
29. The arrows represent electron flow in the diagram. What does terminal X on the battery represent?



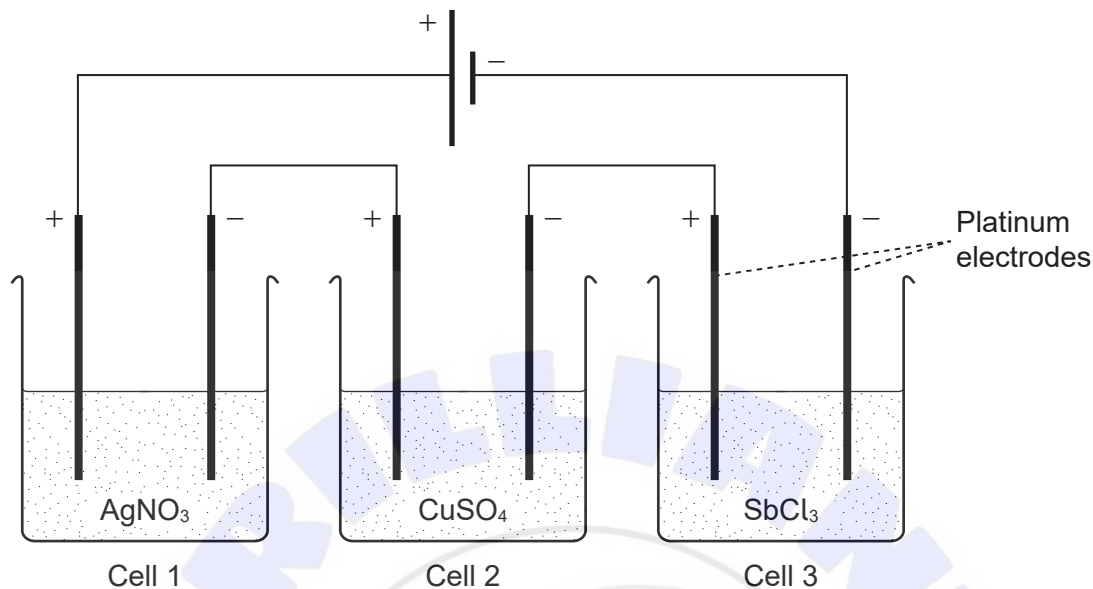
- A. Anode and positive terminal
 B. Anode and negative terminal
 C. Cathode and positive terminal
 D. Cathode and negative terminal
30. Which E^\ominus value, in V, for the reaction $\text{Mn}(\text{s}) + \text{Zn}^{2+}(\text{aq}) \rightarrow \text{Mn}^{2+}(\text{aq}) + \text{Zn}(\text{s})$ can be deduced from the following equations?



- A. 0.42
 B. 1.34
 C. 2.62
 D. 3.54

31. What is the order of **increasing** mass deposited by this electrolytic cell?

A_r Ag = 108, Cu = 64, Sb = 122



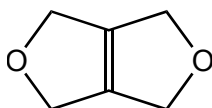
- A. Ag < Cu < Sb
 - B. Sb < Ag < Cu
 - C. Cu < Ag < Sb
 - D. Cu < Sb < Ag
32. Which sequence of reagents converts propene to propanone?

	First reagent added	2nd reagent added to product	3rd reagent added to product of 2nd reaction
A.	HCl	NaOH	KMnO ₄
B.	HCl	KMnO ₄	NaOH
C.	KMnO ₄	HCl	NaOH
D.	KMnO ₄	NaOH	HCl

Turn over

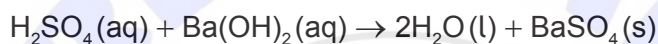
33. How many dichlorinated butane isomers can be formed by the halogenation of $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$ with excess Cl_2 in the presence of UV light?
- A. 4
B. 6
C. 8
D. 10
34. Which is a homologous series?
- A. C_2H_4 , C_3H_5 , C_4H_6
B. C_2H_2 , C_3H_4 , C_4H_6
C. C_2H_2 , C_2H_4 , C_2H_6
D. C_2H_2 , C_4H_4 , C_6H_6
35. Which reaction involves homolytic fission?
- A. $\text{CH}_4 + \text{Cl}_2$
B. $\text{CH}_3\text{Br} + \text{NaOH}$
C. $(\text{CH}_3)_3\text{CBr} + \text{NaOH}$
D. $\text{C}_6\text{H}_6 + \text{HNO}_3 + \text{H}_2\text{SO}_4$
36. Which structure represents a repeating unit of a polymer formed from propene?
- A. $-\text{CH}_2-\text{CH}(\text{CH}_3)-$
B. $-\text{CH}_2-\text{CH}_2-\text{CH}_2-$
C. $-\text{CH}(\text{CH}_3)-\text{CH}(\text{CH}_3)-$
D. $-\text{CH}_2-\text{CH}_2-$
37. What is the product of the reaction of propanal with lithium aluminium hydride, LiAlH_4 ?
- A. Propanoic acid
B. Propanone
C. Propan-1-ol
D. Propan-2-ol

38. How many signals are observed in the ^1H NMR spectrum of this compound?

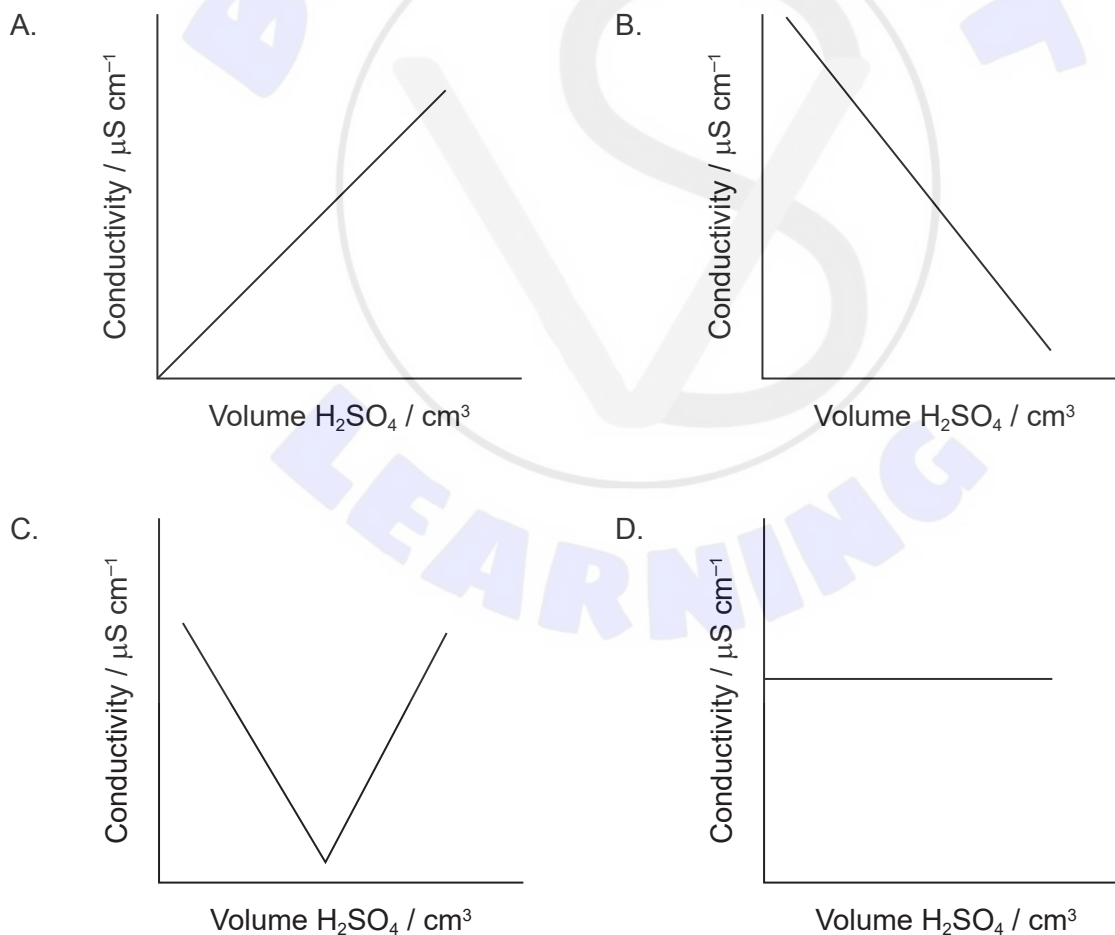


- A. 1
- B. 2
- C. 3
- D. 4

39. 20 cm^3 of 1 mol dm^{-3} sulfuric acid was added dropwise to 20 cm^3 of 1 mol dm^{-3} barium hydroxide producing a precipitate of barium sulfate.



Which graph represents a plot of conductivity against volume of acid added?



Turn over

40. Given equimolar concentrations, which substance would produce the strongest signal in a ^1H NMR spectrum?
- A. $(\text{CH}_3)_3\text{CH}$
 - B. C_6H_6
 - C. C_8H_{18}
 - D. $\text{Si}(\text{CH}_3)_4$
-



References:

© International Baccalaureate Organization 2022