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**Chemistry**  
**Higher level**  
**Paper 1**

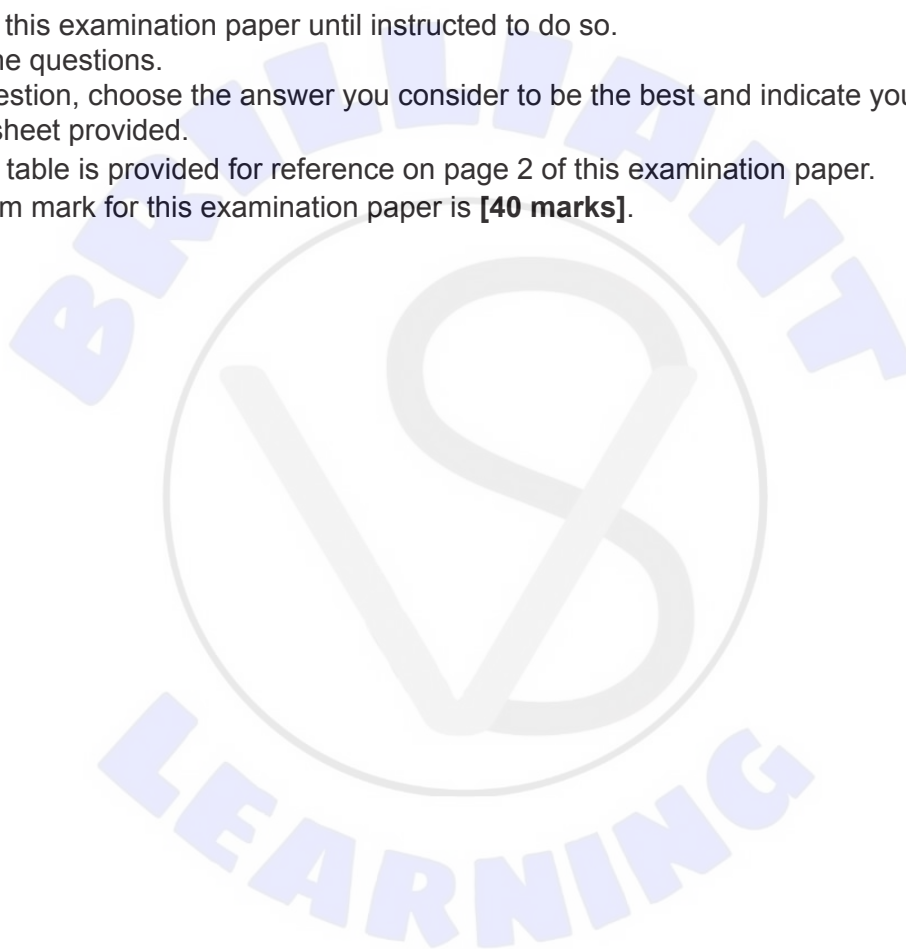
Wednesday 18 May 2022 (afternoon)

1 hour

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**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
	Atomic number																	
	Element																	
	Relative atomic mass																	
1	1 <b>H</b> 1.01																	2 <b>He</b> 4.00
2	3 <b>Li</b> 6.94	4 <b>Be</b> 9.01															9 <b>F</b> 19.00	10 <b>Ne</b> 20.18
3	11 <b>Na</b> 22.99	12 <b>Mg</b> 24.31															17 <b>Cl</b> 35.45	18 <b>Ar</b> 39.95
4	19 <b>K</b> 39.10	20 <b>Ca</b> 40.08	21 <b>Sc</b> 44.96	22 <b>Ti</b> 47.87	23 <b>V</b> 50.94	24 <b>Cr</b> 52.00	25 <b>Mn</b> 54.94	26 <b>Fe</b> 55.85	27 <b>Co</b> 58.93	28 <b>Ni</b> 58.69	29 <b>Cu</b> 63.55	30 <b>Zn</b> 65.38	31 <b>Ga</b> 69.72	32 <b>Ge</b> 72.63	33 <b>As</b> 74.92	34 <b>Se</b> 78.96	35 <b>Br</b> 79.90	36 <b>Kr</b> 83.90
5	37 <b>Rb</b> 85.47	38 <b>Sr</b> 87.62	39 <b>Y</b> 88.91	40 <b>Zr</b> 91.22	41 <b>Nb</b> 92.91	42 <b>Mo</b> 95.96	43 <b>Tc</b> (98)	44 <b>Ru</b> 101.07	45 <b>Rh</b> 102.91	46 <b>Pd</b> 106.42	47 <b>Ag</b> 107.87	48 <b>Cd</b> 112.41	49 <b>In</b> 114.82	50 <b>Sn</b> 118.71	51 <b>Sb</b> 121.76	52 <b>Te</b> 127.60	53 <b>I</b> 126.90	54 <b>Xe</b> 131.29
6	55 <b>Cs</b> 132.91	56 <b>Ba</b> 137.33	57 † <b>La</b> 138.91	72 <b>Hf</b> 178.49	73 <b>Ta</b> 180.95	74 <b>W</b> 183.84	75 <b>Re</b> 186.21	76 <b>Os</b> 190.23	77 <b>Ir</b> 192.22	78 <b>Pt</b> 195.08	79 <b>Au</b> 196.97	80 <b>Hg</b> 200.59	81 <b>Tl</b> 204.38	82 <b>Pb</b> 207.2	83 <b>Bi</b> 208.98	84 <b>Po</b> (209)	85 <b>At</b> (210)	86 <b>Rn</b> (222)
7	87 <b>Fr</b> (223)	88 <b>Ra</b> (226)	89 ‡ <b>Ac</b> (227)	104 <b>Rf</b> (267)	105 <b>Db</b> (268)	106 <b>Sg</b> (269)	107 <b>Bh</b> (270)	108 <b>Hs</b> (269)	109 <b>Mt</b> (278)	110 <b>Ds</b> (281)	111 <b>Rg</b> (281)	112 <b>Cn</b> (285)	113 <b>Unt</b> (286)	114 <b>Uug</b> (289)	115 <b>Uup</b> (288)	116 <b>Uuh</b> (293)	117 <b>Uus</b> (294)	118 <b>Uuo</b> (294)

†

58 <b>Ce</b> 140.12	59 <b>Pr</b> 140.91	60 <b>Nd</b> 144.24	61 <b>Pm</b> (145)	62 <b>Sm</b> 150.36	63 <b>Eu</b> 151.96	64 <b>Gd</b> 157.25	65 <b>Tb</b> 158.93	66 <b>Dy</b> 162.50	67 <b>Ho</b> 164.93	68 <b>Er</b> 167.26	69 <b>Tm</b> 168.93	70 <b>Yb</b> 173.05	71 <b>Lu</b> 174.97
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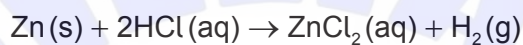
90 <b>Th</b> 232.04	91 <b>Pa</b> 231.04	92 <b>U</b> 238.03	93 <b>Np</b> (237)	94 <b>Pu</b> (244)	95 <b>Am</b> (243)	96 <b>Cm</b> (247)	97 <b>Bk</b> (247)	98 <b>Cf</b> (251)	99 <b>Es</b> (252)	100 <b>Fm</b> (257)	101 <b>Md</b> (258)	102 <b>No</b> (259)	103 <b>Lr</b> (262)
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1. 2.67 g of lead (II) carbonate is decomposed by heating until constant mass.



What is the final mass of solid?

- A. 0.44 g  
B. 2.23 g  
C. 2.67 g  
D. 3.11 g
2. 0.02 mol of zinc is added to 10.0 cm<sup>3</sup> of 1.0 mol dm<sup>-3</sup> hydrochloric acid.



How many moles of hydrogen are produced?

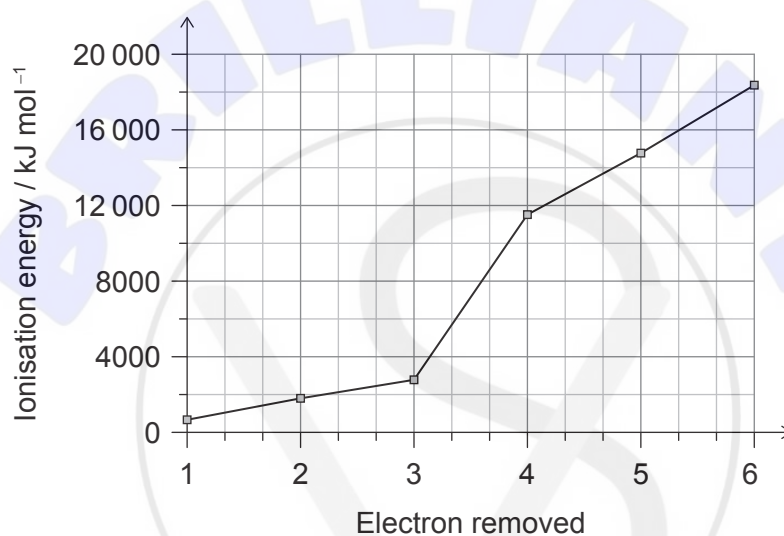
- A. 0.005  
B. 0.01  
C. 0.02  
D. 0.04
3. 8.8 g of an oxide of nitrogen contains 3.2 g of oxygen. What is the empirical formula of the compound?
- A. N<sub>2</sub>O<sub>5</sub>  
B. N<sub>2</sub>O  
C. NO<sub>2</sub>  
D. NO

Turn over

4. Naturally occurring gallium consists of the isotopes  $^{71}\text{Ga}$  and  $^{69}\text{Ga}$ . What is the approximate percentage abundance of  $^{69}\text{Ga}$ ?

$$M_r(\text{Ga}) = 69.72.$$

- A. 40 %  
B. 50 %  
C. 60 %  
D. 75 %
5. The graph shows the first six ionization energies of an element.



In which group is the element?

- A. 13  
B. 14  
C. 15  
D. 16

6. Which gases are acidic?

- I. nitrogen dioxide
- II. carbon dioxide
- III. sulfur dioxide

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

7. Which of the following is the electron configuration of a metallic element?

- A.  $[\text{Ne}] 3s^2 3p^2$
- B.  $[\text{Ne}] 3s^2 3p^4$
- C.  $[\text{Ne}] 3s^2 3p^6 3d^3 4s^2$
- D.  $[\text{Ne}] 3s^2 3p^6 3d^{10} 4s^2 4p^5$

8. Why is hydrated copper (II) sulfate blue?

- A. Blue light is emitted when electrons return to lower d-orbitals.
- B. Light complimentary to blue is absorbed when electrons return to lower d-orbitals.
- C. Blue light is emitted when electrons are promoted between d-orbitals.
- D. Light complimentary to blue is absorbed when electrons are promoted between d-orbitals.

9. A compound consists of the ions  $\text{Ca}^{2+}$  and  $\text{PO}_4^{3-}$ . What are the name and formula of the compound?

	Name	Formula
A.	calcium phosphorus oxide	$\text{CaPO}_4$
B.	calcium phosphorus oxide	$\text{Ca}_3(\text{PO}_4)_2$
C.	calcium phosphate	$\text{CaPO}_4$
D.	calcium phosphate	$\text{Ca}_3(\text{PO}_4)_2$

Turn over

10. What is the explanation for the high melting point of sodium chloride?
- The covalent bond between sodium and chlorine atoms is strong.
  - Electrostatic attraction between sodium and chloride ions is strong.
  - Intermolecular forces in sodium chloride are strong.
  - Delocalized electrons cause strong bonding in sodium chloride.
11. For which species can resonance structures be drawn?
- HCOOH
  - HCOO<sup>-</sup>
  - CH<sub>3</sub>OH
  - H<sub>2</sub>CO<sub>3</sub>
12. In which compound are all carbon atoms sp<sup>3</sup> hybridized?
- C<sub>2</sub>H<sub>2</sub>
  - C<sub>2</sub>H<sub>2</sub>Cl<sub>2</sub>
  - C<sub>2</sub>Cl<sub>4</sub>
  - C<sub>2</sub>Cl<sub>6</sub>
13. What are the electron domain and molecular geometries of the XeF<sub>4</sub> molecule?

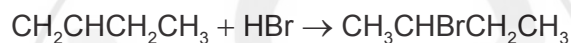
	Electron domain geometry	Molecular geometry
A.	tetrahedral	planar
B.	tetrahedral	tetrahedral
C.	octahedral	planar
D.	octahedral	tetrahedral

14. The energy from burning 0.250 g of ethanol causes the temperature of 150 cm<sup>3</sup> of water to rise by 10.5 °C. What is the enthalpy of combustion of ethanol, in kJ mol<sup>-1</sup>?

Specific heat capacity of water: 4.18 Jg<sup>-1</sup> K<sup>-1</sup>.

- A.  $\frac{150 \times 4.18 \times 10.5}{\frac{0.250}{46.08}}$
- B.  $\frac{150 \times 4.18 \times 10.5}{\frac{0.250}{46.08} \times 1000}$
- C.  $\frac{150 \times 4.18 \times (273 + 10.5)}{\frac{0.250}{46.08}}$
- D.  $\frac{150 \times 4.18 \times (273 + 10.5)}{\frac{0.250}{46.08} \times 1000}$

15. What is the enthalpy change of the following reaction?



Substance	$\Delta H_f^\ominus / \text{kJ mol}^{-1}$
CH <sub>2</sub> CHCH <sub>2</sub> CH <sub>3</sub>	0.1
HBr	-36.3
CH <sub>3</sub> CHBrCH <sub>2</sub> CH <sub>3</sub>	-156.0

- A. -119.6 kJ
- B. +119.6 kJ
- C. -119.8 kJ
- D. +119.8 kJ
16. Which compound has the largest value of lattice enthalpy?
- A. Na<sub>2</sub>O
- B. K<sub>2</sub>O
- C. Na<sub>2</sub>S
- D. K<sub>2</sub>S

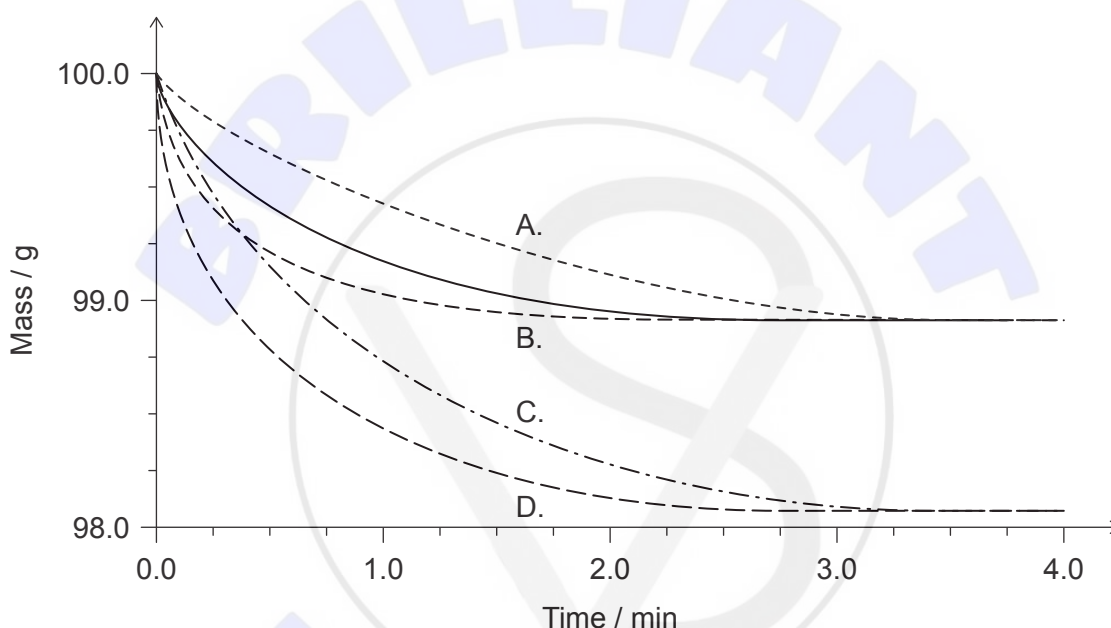
Turn over

17. In which reaction does entropy decrease?

- A.  $\text{NaCl(s)} \rightarrow \text{NaCl(aq)}$
- B.  $\text{Zn(s)} + \text{H}_2\text{SO}_4\text{(aq)} \rightarrow \text{ZnSO}_4\text{(aq)} + \text{H}_2\text{(g)}$
- C.  $\text{NH}_3\text{(g)} + \text{HCl(g)} \rightarrow \text{NH}_4\text{Cl(s)}$
- D.  $\text{CuCO}_3\text{(s)} \rightarrow \text{CuO(s)} + \text{CO}_2\text{(g)}$

18. A sample of calcium carbonate reacts with excess hydrochloric acid in a beaker. The solid line shows how the mass of the beaker changes with time.

Which dashed line represents the results obtained when the acid concentration is doubled?



19. A student was investigating rates of reaction. In which of the following cases would a colorimeter show a change in absorbance?

- A.  $\text{KBr(aq)} + \text{Cl}_2\text{(aq)}$
- B.  $\text{Cu(s)} + \text{Na}_2\text{SO}_4\text{(aq)}$
- C.  $\text{HCl(aq)} + \text{NaOH(aq)}$
- D.  $\text{(CH}_3\text{)}_3\text{COH(aq)} + \text{K}_2\text{Cr}_2\text{O}_7\text{(aq)}$

20. The table shows data for the hydrolysis of a halogenoalkane, RCl.

[NaOH] / mol dm <sup>-3</sup>	[RCl] / mol dm <sup>-3</sup>	Rate / mol dm <sup>-3</sup> s <sup>-1</sup>
0.1	0.01	$5.0 \times 10^{-7}$
0.2	0.01	$1.0 \times 10^{-6}$
0.2	0.02	$1.9 \times 10^{-6}$

Which statements are correct?

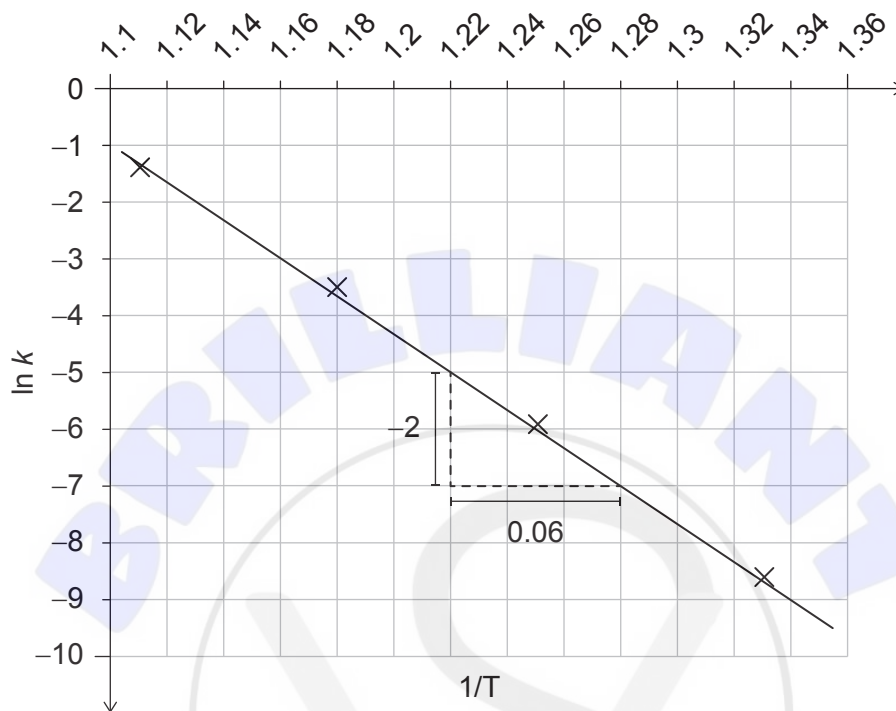
- I. The reaction is first order with respect to RCl.
  - II. The reaction is second order overall.
  - III. The reaction proceeds by an S<sub>N</sub>2 mechanism.
- A. I and II only
  - B. I and III only
  - C. II and III only
  - D. I, II and III



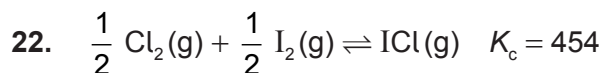
Turn over

21. What is the activation energy according to the following plot of the linear form of the Arrhenius equation?

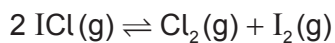
Arrhenius equation:  $k = Ae^{\frac{-E_a}{RT}}$ .



- A.  $E_a = \frac{2 \times 8.31}{0.06}$
- B.  $E_a = \frac{-2 \times 8.31}{0.06}$
- C.  $E_a = e^{\frac{2 \times 8.31}{0.06}}$
- D.  $E_a = e^{\frac{-2 \times 8.31}{0.06}}$



What is the  $K_c$  value for the reaction below?



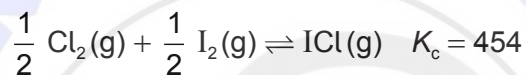
A.  $2 \times 454$

B.  $\frac{1}{2 \times 454}$

C.  $454^2$

D.  $\frac{1}{454^2}$

23. At equilibrium, the concentrations of chlorine and iodine are both  $0.02 \text{ mol dm}^{-3}$ .



What is the concentration of iodine monochloride, ICl?

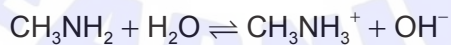
A.  $\frac{454}{0.02}$

B.  $454 \times 0.02$

C.  $\frac{454}{0.04}$

D.  $454 \times 0.04$

24. Which species are acids in the equilibrium below?



A.  $\text{CH}_3\text{NH}_2$  and  $\text{H}_2\text{O}$

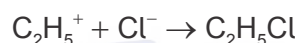
B.  $\text{H}_2\text{O}$  and  $\text{CH}_3\text{NH}_3^+$

C.  $\text{H}_2\text{O}$  and  $\text{OH}^-$

D.  $\text{CH}_3\text{NH}_2$  and  $\text{CH}_3\text{NH}_3^+$

Turn over

25. Which  $0.01 \text{ mol dm}^{-3}$  aqueous solution has the highest pH?
- A. HCl
  - B.  $\text{H}_2\text{SO}_4$
  - C. NaOH
  - D.  $\text{NH}_3$
26. Which statement explains the Lewis acid–base nature of the chloride ion in this reaction?



- A. Lewis base because it donates a pair of electrons
  - B. Lewis base because it accepts a pair of electrons
  - C. Lewis acid because it donates a pair of electrons
  - D. Lewis acid because it accepts a pair of electrons
27. In which set are the salts arranged in order of increasing pH?
- A.  $\text{HCOONH}_4 < \text{KBr} < \text{NH}_4\text{Br} < \text{HCOOK}$
  - B.  $\text{KBr} < \text{NH}_4\text{Br} < \text{HCOOK} < \text{HCOONH}_4$
  - C.  $\text{NH}_4\text{Br} < \text{HCOONH}_4 < \text{KBr} < \text{HCOOK}$
  - D.  $\text{HCOOK} < \text{KBr} < \text{HCOONH}_4 < \text{NH}_4\text{Br}$
28. In which of the following species would sulfur be reduced if converted to  $\text{SCl}_2$ ?
- A.  $\text{S}_2\text{O}_3^{2-}$
  - B.  $\text{H}_2\text{S}$
  - C. S
  - D.  $\text{SO}_2$

29. How many electrons are needed when the following half-equation is balanced using the lowest possible whole numbers?



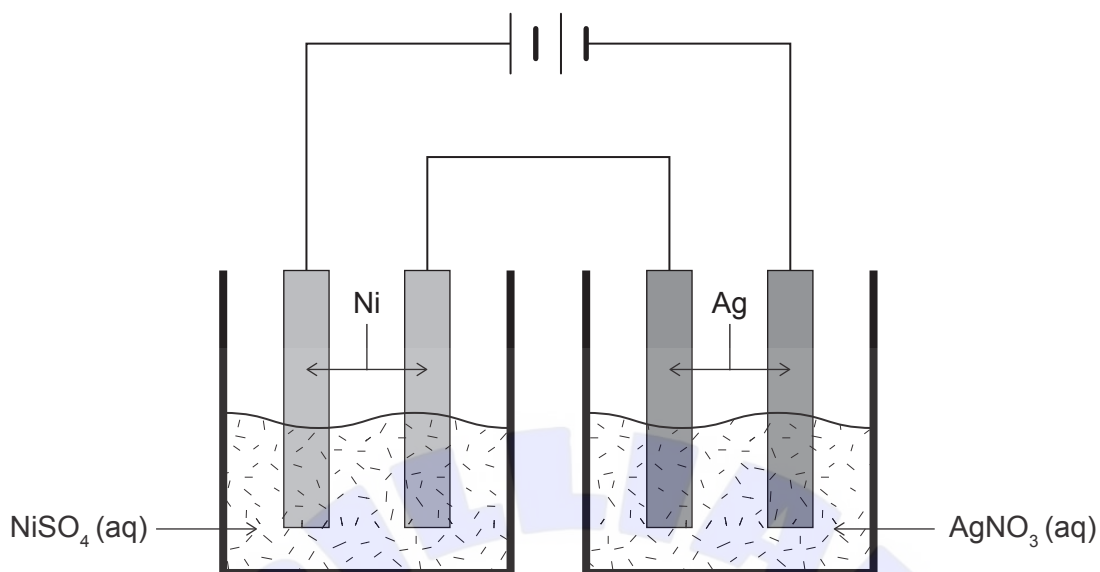
- A. 1  
 B. 2  
 C. 3  
 D. 5
30. What are the products when dilute aqueous copper (II) nitrate is electrolysed using platinum electrodes?

$$E^\ominus (\text{Cu} | \text{Cu}^{2+}) = -0.34 \text{V.}$$

	<b>Anode (positive electrode)</b>	<b>Cathode (negative electrode)</b>
A.	O <sub>2</sub> (g)	Cu(s)
B.	O <sub>2</sub> (g)	H <sub>2</sub> (g)
C.	Cu(s)	O <sub>2</sub> (g)
D.	H <sub>2</sub> (g)	Cu(s)

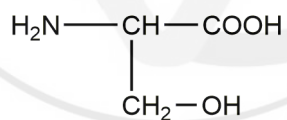
Turn over

31. In the electrolysis apparatus shown, 0.59 g of Ni is deposited on the cathode of the first cell.



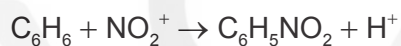
What is the mass of Ag deposited on the cathode of the second cell?

- A. 0.54 g
  - B. 0.59 g
  - C. 1.08 g
  - D. 2.16 g
32. Which functional groups are present in serine?



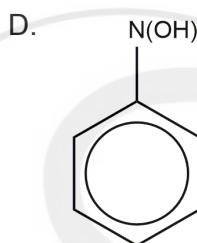
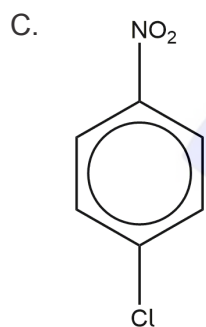
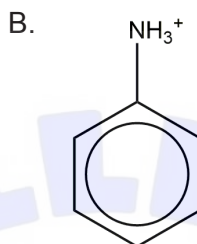
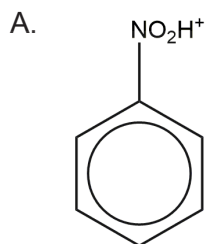
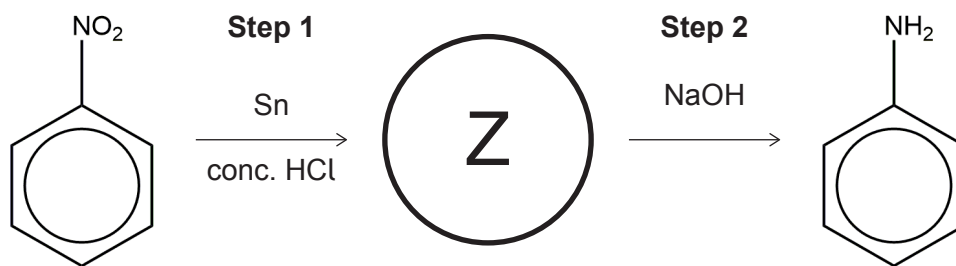
- A. nitro, carbonyl and carboxyl
- B. amino, hydroxyl and carbonyl
- C. nitro, carboxyl and hydroxyl
- D. amino, carboxyl and hydroxyl

33. Which compounds are members of the same homologous series?
- A. propanal, propanone, propanoic acid
- B. propane, propene, propyne
- C. hexan-1-ol, hexan-2-ol, hexan-3-ol
- D. ethanol, propan-1-ol, butan-1-ol
34. Which reagents and conditions are best for converting propan-1-ol into propanoic acid?
- A. Reflux with acidified potassium dichromate (VI)
- B. Reflux with  $\text{LiAlH}_4$
- C. Distil with acidified potassium dichromate (VI)
- D. Distil with  $\text{LiAlH}_4$
35. What are the type of reaction and role of the nitronium ion,  $\text{NO}_2^+$ , in the following reaction?

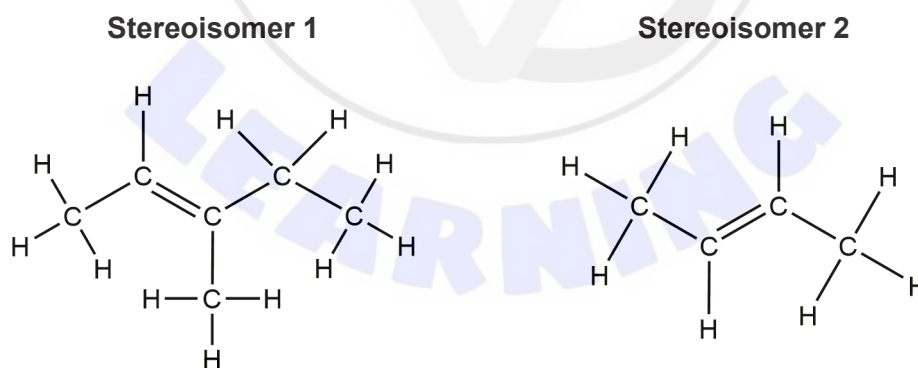


	Type of reaction	Role of $\text{NO}_2^+$
A.	substitution	electrophile
B.	addition	electrophile
C.	substitution	nucleophile
D.	addition	nucleophile

36. What is molecule Z that is formed in step 1 of this synthetic route?

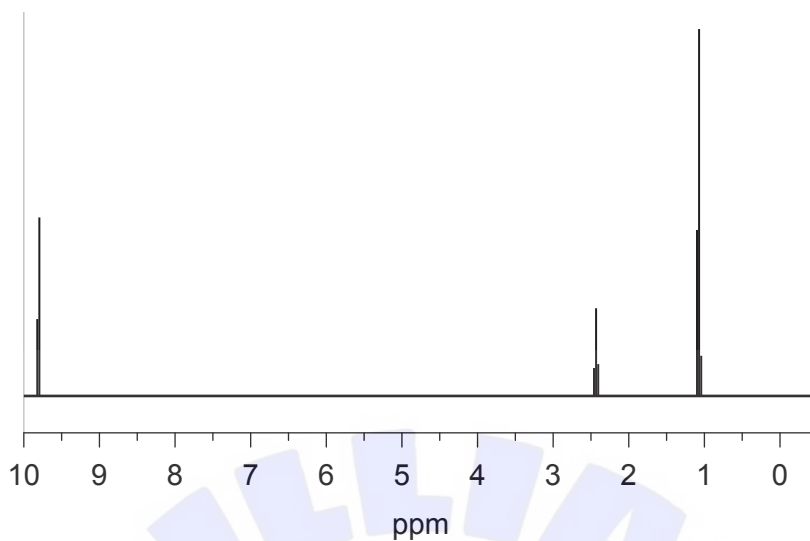


37. What are the E/Z designations of these stereoisomers?



	Stereoisomer 1	Stereoisomer 2
A.	E	E
B.	E	Z
C.	Z	E
D.	Z	Z

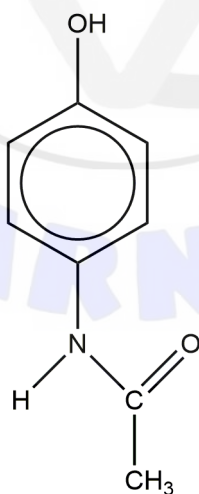
38. Which compound produces the following  $^1\text{H}$  NMR spectrum?



- A. propanal
- B. propanone
- C. propane
- D. methlypropane

39. What is the index of hydrogen deficiency (IHD) of this molecule?

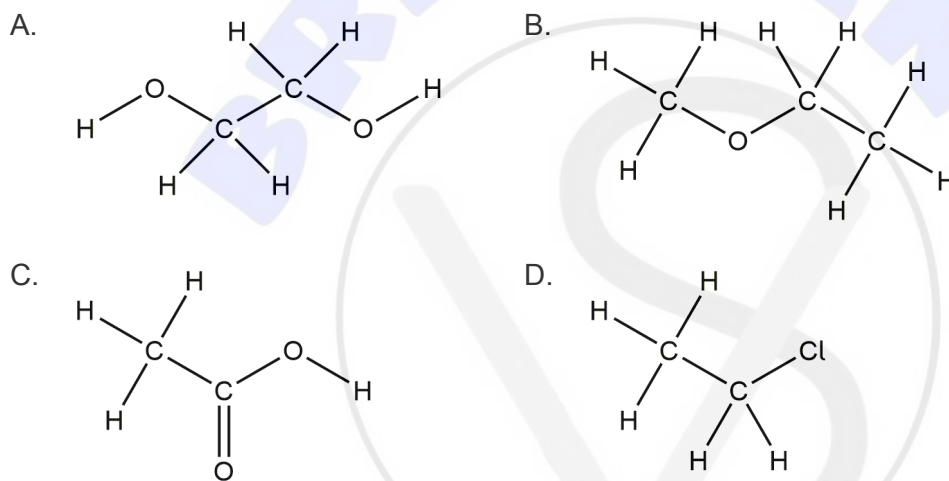
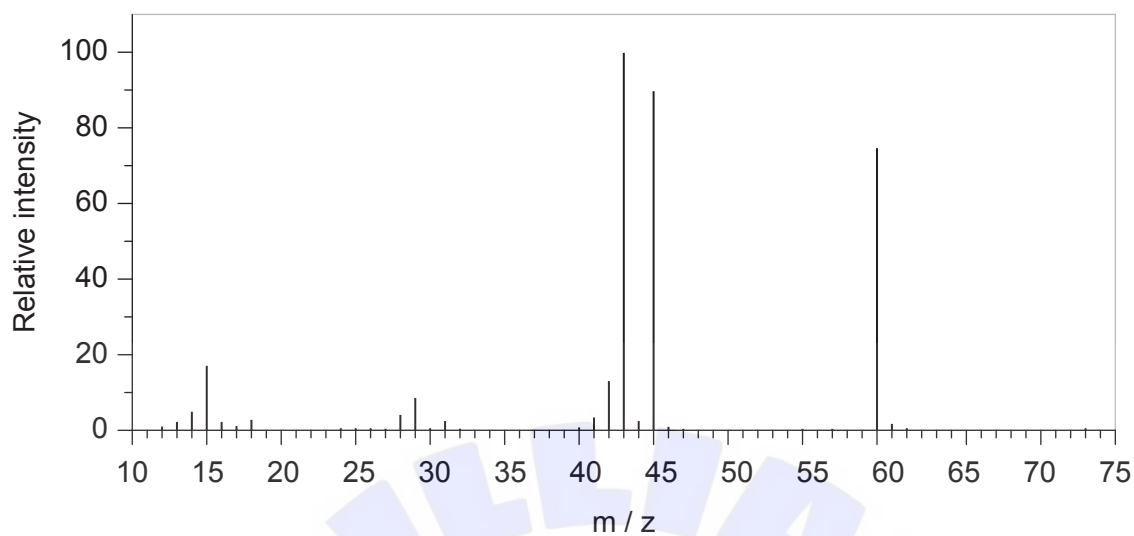
**Paracetamol (acetaminophen)**



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

Turn over

40. Which compound produces this mass spectrum?





**References:**

5. Ionization energies of the elements (data page) Available at: [https://en.wikipedia.org/wiki/Ionization\\_energies\\_of\\_the\\_elements\\_\(data\\_page\)](https://en.wikipedia.org/wiki/Ionization_energies_of_the_elements_(data_page)) Text is available under the Creative Commons Attribution-ShareAlike License 3.0 (CC BY-SA 3.0) <https://creativecommons.org/licenses/by-sa/3.0/deed.en>.
38. Spectral Database for Organic Compounds, SDBS. SDBS Compounds and Spectral Search. [graph] Available at: <https://sdbs.db.aist.go.jp> [Accessed 3 January 2019].
40. Spectral Database for Organic Compounds, SDBS. SDBS Compounds and Spectral Search. [graph] Available at: <https://sdbs.db.aist.go.jp> [Accessed 3 January 2019].

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