Diploma Programme
Programme du diplôme
Programa del Diploma

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]**.

2222 – 6107

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 **Element** Relative atomic mass														2 **He** 4.00
2	3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
3	11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	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. 2.67 g of lead (II) carbonate is decomposed by heating until constant mass.

$$PbCO_3(s) \rightarrow PbO(s) + CO_2(g)$$

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^3 of 1.0 mol dm^{-3} hydrochloric acid.

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

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_2O_5

B. N_2O

C. NO_2

D. NO

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

M_r(Ga) = 69.72.

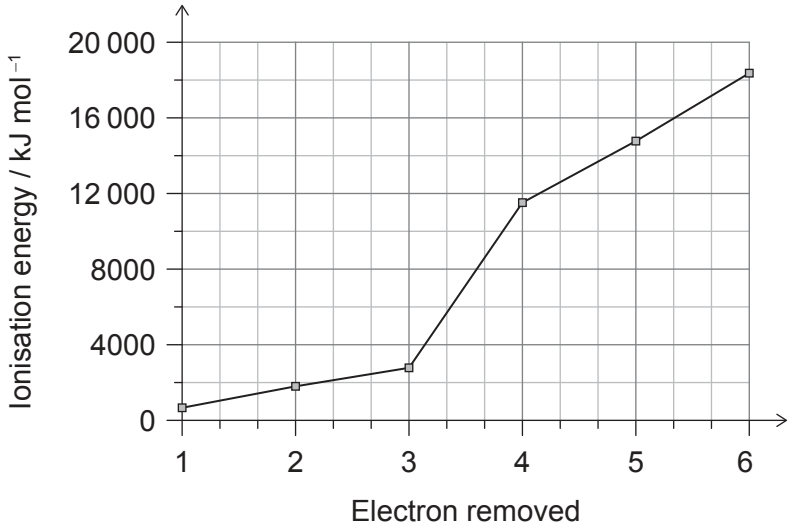
A. 40 %

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. [Ne] $3s^2\ 3p^2$

B. [Ne] $3s^2\ 3p^4$

C. [Ne] $3s^2\ 3p^6\ 3d^3\ 4s^2$

D. [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 Ca^{2+} and PO_4^{3-}. What are the name and formula of the compound?

	Name	Formula
A.	calcium phosphorus oxide	$CaPO_4$
B.	calcium phosphorus oxide	$Ca_3(PO_4)_2$
C.	calcium phosphate	$CaPO_4$
D.	calcium phosphate	$Ca_3(PO_4)_2$

10. What is the explanation for the high melting point of sodium chloride?

A. The covalent bond between sodium and chlorine atoms is strong.

B. Electrostatic attraction between sodium and chloride ions is strong.

C. Intermolecular forces in sodium chloride are strong.

D. Delocalized electrons cause strong bonding in sodium chloride.

11. For which species can resonance structures be drawn?

A. HCOOH

B. $HCOO^-$

C. CH_3OH

D. H_2CO_3

12. In which compound are all carbon atoms sp^3 hybridized?

A. C_2H_2

B. $C_2H_2Cl_2$

C. C_2Cl_4

D. C_2Cl_6

13. What are the electron domain and molecular geometries of the XeF_4 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^3 of water to rise by 10.5 °C. What is the enthalpy of combustion of ethanol, in kJ mol^{-1}?

Specific heat capacity of water: 4.18 $J g^{-1} K^{-1}$.

A. $\dfrac{150 \times 4.18 \times 10.5}{\dfrac{0.250}{46.08}}$

B. $\dfrac{150 \times 4.18 \times 10.5}{\dfrac{0.250}{46.08} \times 1000}$

C. $\dfrac{150 \times 4.18 \times (273 + 10.5)}{\dfrac{0.250}{46.08}}$

D. $\dfrac{150 \times 4.18 \times (273 + 10.5)}{\dfrac{0.250}{46.08} \times 1000}$

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

$$CH_2CHCH_2CH_3 + HBr \rightarrow CH_3CHBrCH_2CH_3$$

Substance	$\Delta H_f^{\ominus}$ / kJ mol^{-1}
$CH_2CHCH_2CH_3$	0.1
HBr	–36.3
$CH_3CHBrCH_2CH_3$	–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_2O

B. K_2O

C. Na_2S

D. K_2S

17. In which reaction does entropy decrease?

A. $NaCl(s) \rightarrow NaCl(aq)$

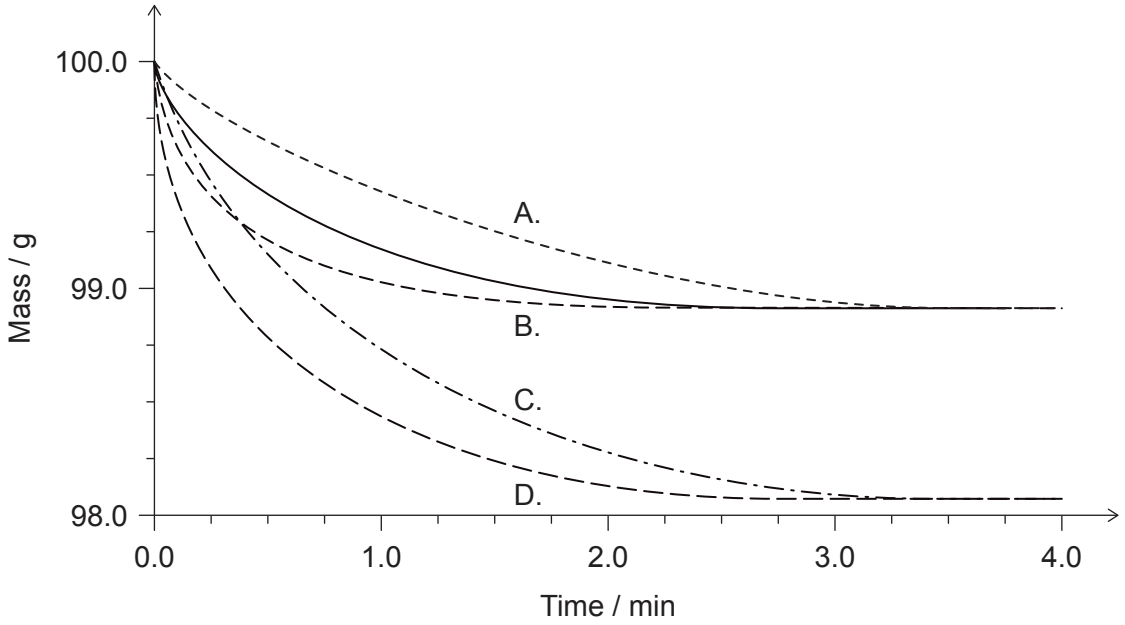
B. $Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$

C. $NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$

D. $CuCO_3(s) \rightarrow CuO(s) + CO_2(g)$

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. $KBr(aq) + Cl_2(aq)$

B. $Cu(s) + Na_2SO_4(aq)$

C. $HCl(aq) + NaOH(aq)$

D. $(CH_3)_3COH(aq) + K_2Cr_2O_7(aq)$

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

[NaOH] / mol dm^{-3}	**[RCl] / mol dm^{-3}**	**Rate / mol dm^{-3} s^{-1}**
0.1	0.01	5.0×10^{-7}
0.2	0.01	1.0×10^{-6}
0.2	0.02	1.9×10^{-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_N2 mechanism.

A. I and II only

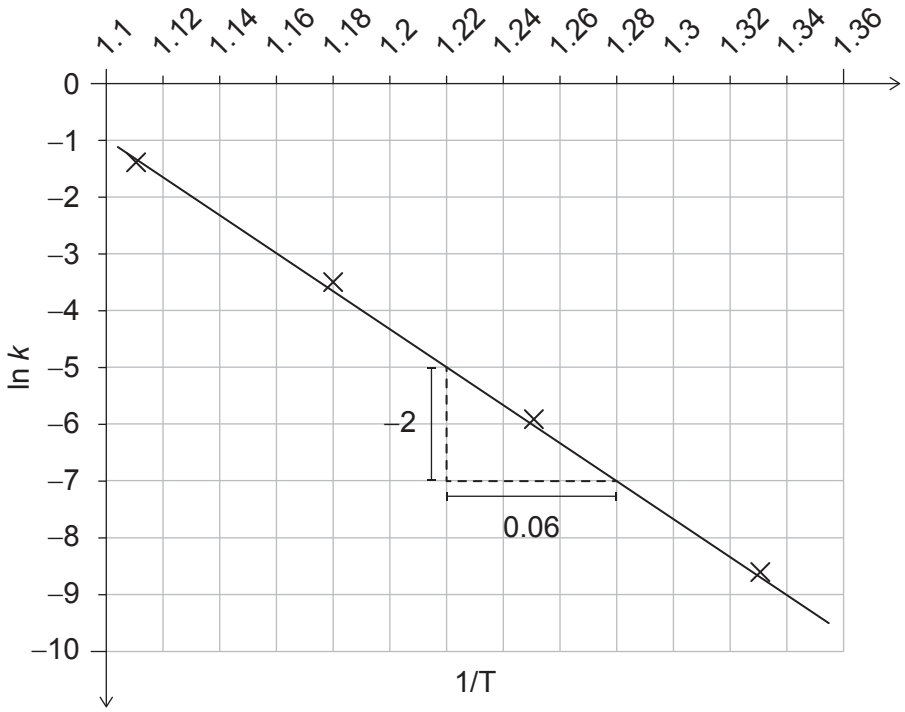
B. I and III only

C. II and III only

D. I, II and III

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

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



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. $E_a = e^{\frac{-2 \times 8.31}{0.06}}$

22. $\frac{1}{2}\ Cl_2(g) + \frac{1}{2}\ I_2(g) \rightleftharpoons ICl(g) \quad K_c = 454$

What is the K_c value for the reaction below?

$$2\ ICl(g) \rightleftharpoons Cl_2(g) + I_2(g)$$

A. 2×454

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 mol dm^{-3}.

$$\frac{1}{2}\ Cl_2(g) + \frac{1}{2}\ I_2(g) \rightleftharpoons ICl(g) \quad K_c = 454$$

What is the concentration of iodine monochloride, ICl?

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

B. 454×0.02

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

D. 454×0.04

24. Which species are acids in the equilibrium below?

$$CH_3NH_2 + H_2O \rightleftharpoons CH_3NH_3^+ + OH^-$$

A. CH_3NH_2 and H_2O

B. H_2O and $CH_3NH_3^+$

C. H_2O and OH^-

D. CH_3NH_2 and $CH_3NH_3^+$

25. Which 0.01 mol dm^{-3} aqueous solution has the highest pH?

A. HCl

B. H_2SO_4

C. NaOH

D. NH_3

26. Which statement explains the Lewis acid–base nature of the chloride ion in this reaction?

$$C_2H_5^+ + Cl^- \rightarrow C_2H_5Cl$$

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. $HCOONH_4 < KBr < NH_4Br < HCOOK$

B. $KBr < NH_4Br < HCOOK < HCOONH_4$

C. $NH_4Br < HCOONH_4 < KBr < HCOOK$

D. $HCOOK < KBr < HCOONH_4 < NH_4Br$

28. In which of the following species would sulfur be reduced if converted to SCl_2?

A. $S_2O_3^{2-}$

B. H_2S

C. S

D. SO_2

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

$$\_\_\ NO_3^-(aq) + \_\_\ H^+(aq) + \_\_\ e^- \rightarrow \_\_\ NO(g) + \_\_\ H_2O(l)$$

A. 1

B. 2

C. 3

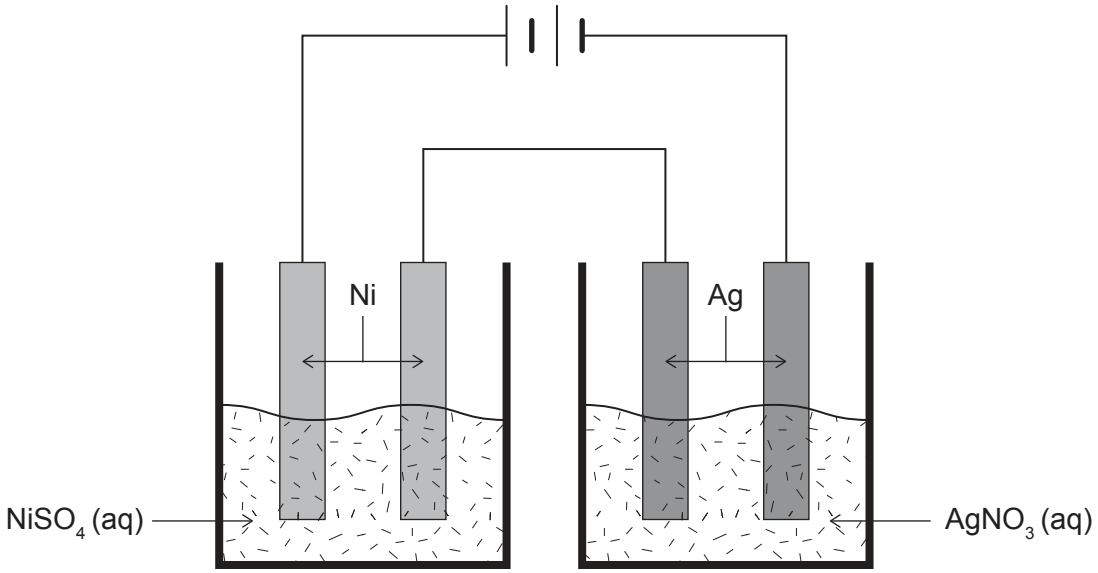
D. 5

30. What are the products when dilute aqueous copper (II) nitrate is electrolysed using platinum electrodes?

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

	Anode (positive electrode)	Cathode (negative electrode)
A.	$O_2(g)$	$Cu(s)$
B.	$O_2(g)$	$H_2(g)$
C.	$Cu(s)$	$O_2(g)$
D.	$H_2(g)$	$Cu(s)$

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?

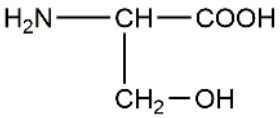
A. 0.54 g

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 $LiAlH_4$

C. Distil with acidified potassium dichromate (VI)

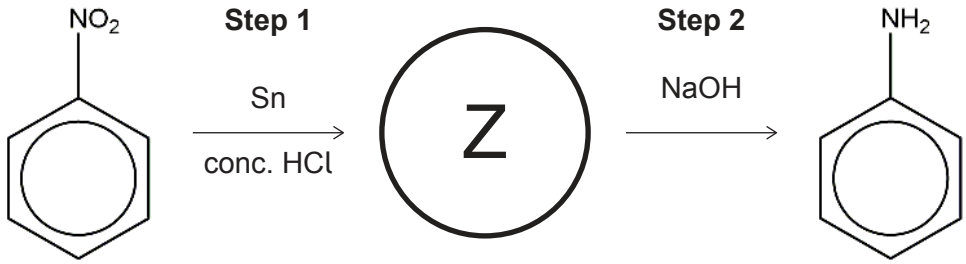
D. Distil with $LiAlH_4$

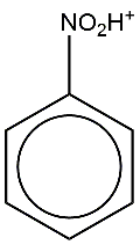
35. What are the type of reaction and role of the nitronium ion, NO_2^+, in the following reaction?

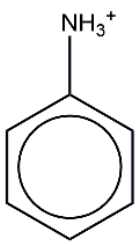
$$C_6H_6 + NO_2^+ \rightarrow C_6H_5NO_2 + H^+$$

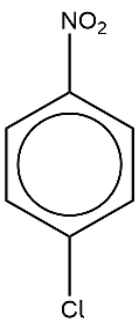
	Type of reaction	Role of NO_2^+
A.	substitution	electrophile
B.	addition	electrophile
C.	substitution	nucleophile
D.	addition	nucleophile

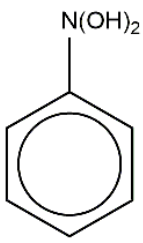
36. What is molecule Z that is formed in step 1 of this synthetic route?



A. 

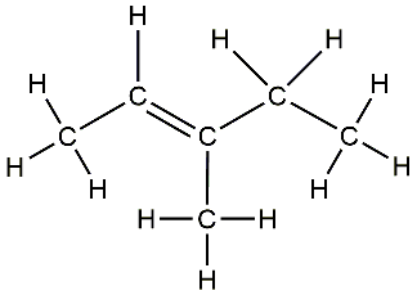
B. 

C. 

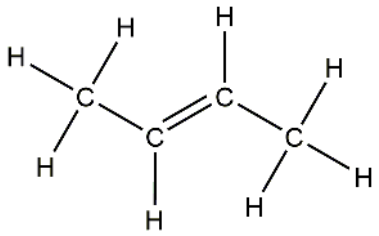
D. 

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

Stereoisomer 1

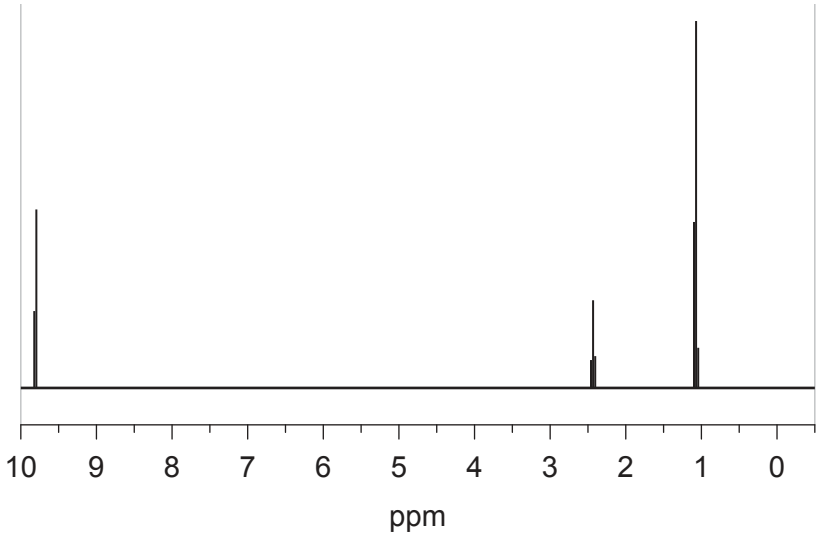


Stereoisomer 2



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

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



A. propanal

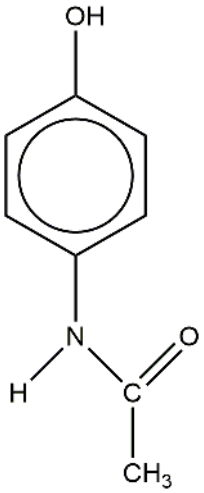
B. propanone

C. propane

D. methlypropane

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

Paracetamol (acetaminophen)



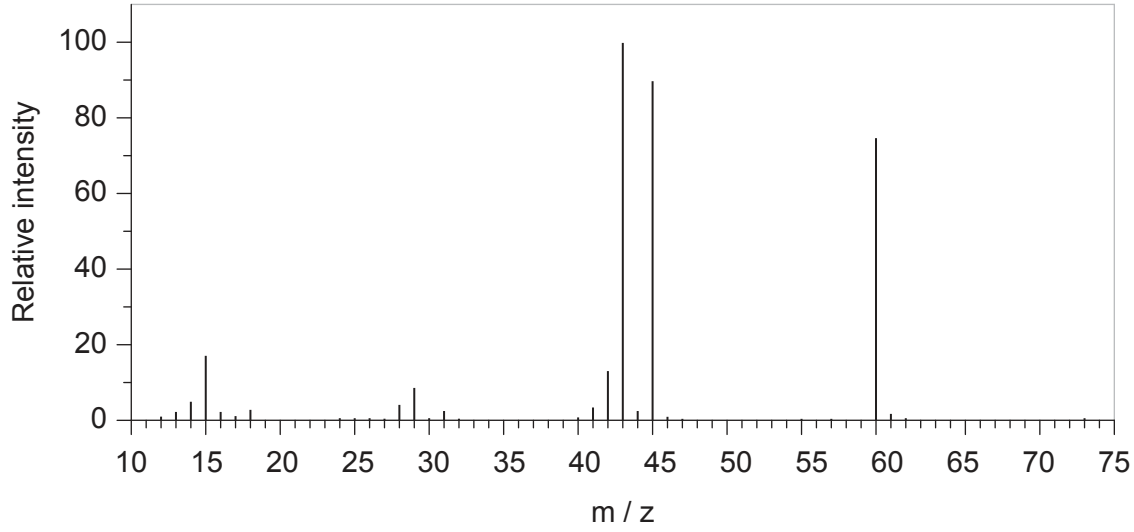
A. 3

B. 4

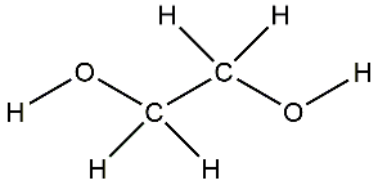
C. 5

D. 6

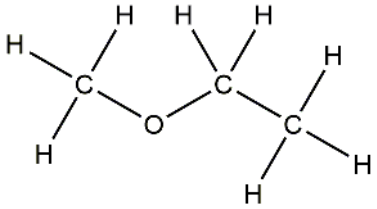
40. Which compound produces this mass spectrum?



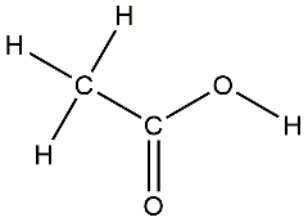
A.



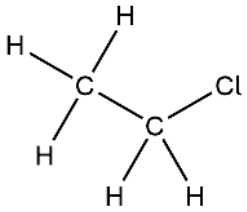
B.



C.



D.



References:

5. Ionization energies of the elements (data page) Available at: 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].