Cambridge International AS & A Level

CHEMISTRY **9701/12**

Paper 1 Multiple Choice **February/March 2022**

1 hour 15 minutes

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You must answer on the multiple choice answer sheet.

You will need: Multiple choice answer sheet
Soft clean eraser
Soft pencil (type B or HB is recommended)

INSTRUCTIONS

- There are **forty** questions on this paper. Answer **all** questions.
- For each question there are four possible answers **A**, **B**, **C** and **D**. Choose the **one** you consider correct and record your choice in soft pencil on the multiple choice answer sheet.
- Follow the instructions on the multiple choice answer sheet.
- Write in soft pencil.
- Write your name, centre number and candidate number on the multiple choice answer sheet in the spaces provided unless this has been done for you.
- Do **not** use correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.

INFORMATION

- The total mark for this paper is 40.
- Each correct answer will score one mark.
- Any rough working should be done on this question paper.
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.

This document has **20** pages. Any blank pages are indicated.

1 The first ionisation energy of potassium, K, is 418 $kJ\,mol^{-1}$. The first ionisation energy of strontium, Sr, is 548 $kJ\,mol^{-1}$.

Which statement helps to explain why Sr has a greater first ionisation energy than K?

A The charge on a Sr nucleus is greater than the charge on a K nucleus.

B The outer electron in a Sr atom experiences greater shielding than the outer electron in a K atom.

C The outer electron in a Sr atom experiences spin-pair repulsion.

D The outer electron in a Sr atom is further from the nucleus than the outer electron in a K atom.

2 What is the electronic configuration of Mg^{2+}?

A $1s^2\ 2s^2\ 2p^6$

B $1s^2\ 2s^2\ 2p^6\ 3s^2$

C $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$

D $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^2\ 4s^2$

3 Compound X contains the elements C, H and O only.

2.00 g of X produces 4.00 g of carbon dioxide and 1.63 g of water when completely combusted.

What is the empirical formula of X?

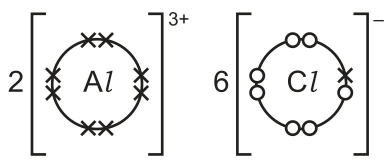
A CHO_2 **B** C_2H_2O **C** C_2H_4O **D** CH_2O_2

4 For which molecule is the dipole moment zero?

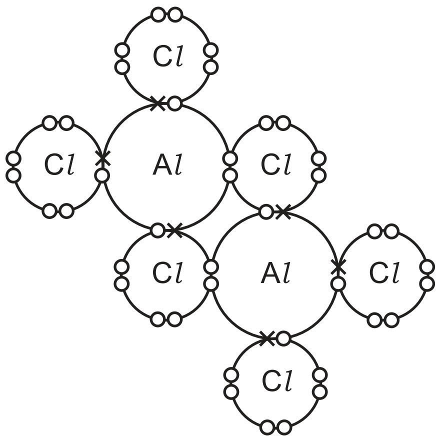
A CH_3Cl **B** CH_2Cl_2 **C** $CHCl_3$ **D** CCl_4

5 Which dot-and-cross diagram is correct for Al_2Cl_6?

A

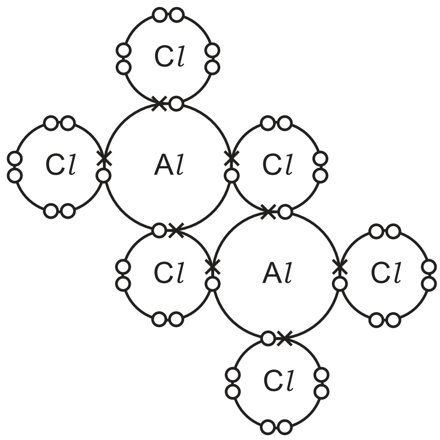


B

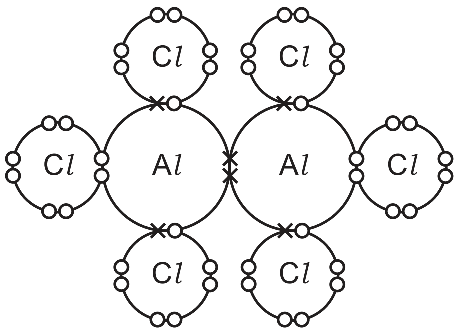


key
× = electrons from Al
○ = electrons from Cl

C



D



6 The boiling points of some hydrogen halides are shown.

hydrogen halide	boiling point / K
H–Cl	188
H–Br	206
H–I	238

What is the explanation for the trend in boiling point for the hydrogen halides from HCl to HI?

A The bond energies of the hydrogen halides increase from HCl to HI.

B There is an increase in the strength of the intermolecular forces of attraction from HCl to HI.

C The intermolecular hydrogen bonds become stronger from HCl to HI.

D There is an increase in the bond polarity from HCl to HI.

7 Elements X, Y and Z are all in the first two periods of the Periodic Table.

Their Pauling electronegativity values, E_N, are shown.

element	E_N
X	1.0
Y	2.1
Z	4.0

Substances exist with formulae XZ, YZ and Z_2.

Which row puts these substances in order of increasing melting point?

	lowest melting point	$\longrightarrow$	highest melting point
A	XZ	YZ	Z_2
B	XZ	Z_2	YZ
C	Z_2	YZ	XZ
D	Z_2	XZ	YZ

8 The equation for reaction 1 is shown.

reaction 1 $\quad C_6H_{12}O_6 \rightarrow 2CO_2 + 2C_2H_5OH$

	$\Delta H^{\ominus}_{c}$ / kJ mol^{-1}
$C_6H_{12}O_6$	a
C_2H_5OH	b

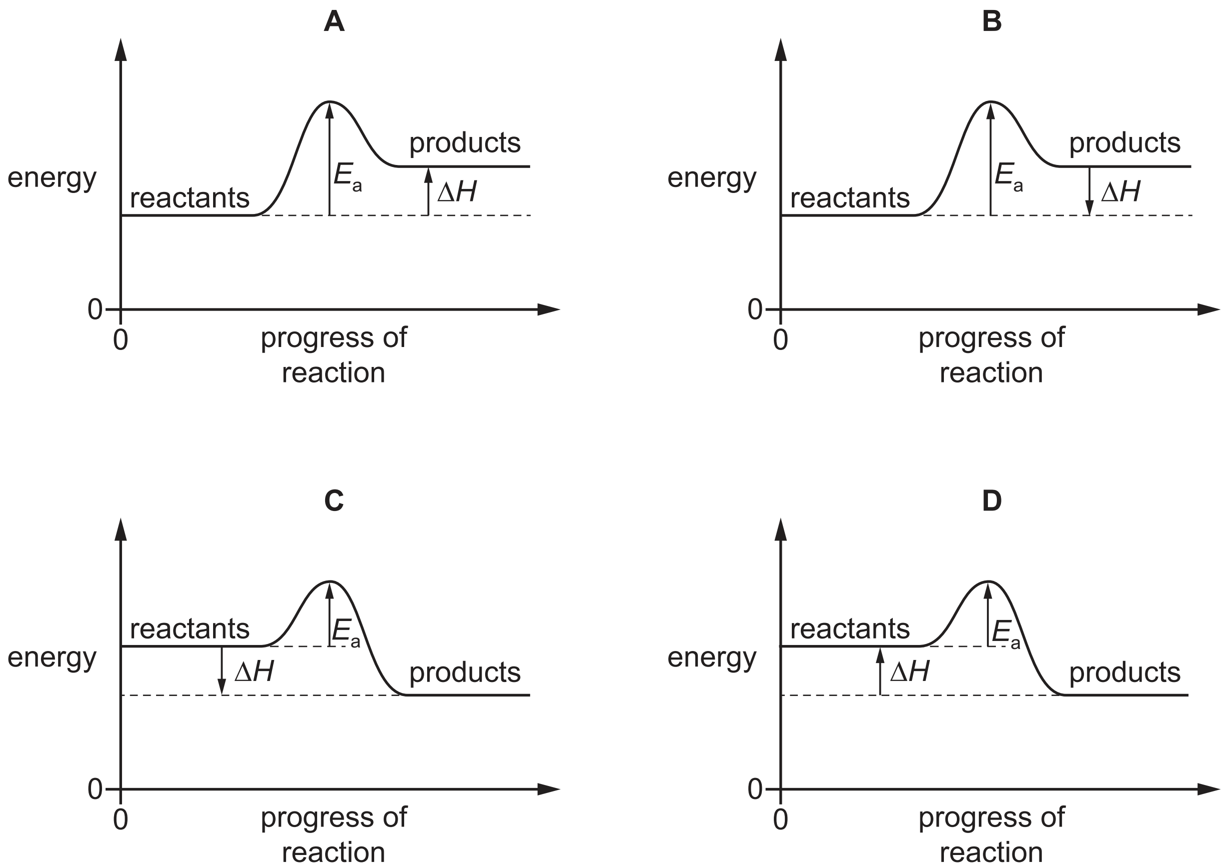
What is the correct expression for the enthalpy change of reaction 1?

A $a + b$ **B** $a - b$ **C** $a + 2b$ **D** $a - 2b$

9 Nitrogen monoxide is an atmospheric pollutant that is formed inside car engines by an endothermic reaction between nitrogen and oxygen.

$$N_2(g) + O_2(g) \rightarrow 2NO(g)$$

Which diagram correctly represents the energy profile for this reaction?



10 Two half-equations are shown.

$$MnO_4^- + 2H_2O + 3e^- \rightarrow MnO_2 + 4OH^-$$

$$2OH^- + SO_3^{2-} \rightarrow SO_4^{2-} + H_2O + 2e^-$$

The equation for the reaction between manganate(VII) ions and sulfite ions is shown.

$$uMnO_4^- + vH_2O + wSO_3^{2-} \rightarrow xMnO_2 + ySO_4^{2-} + zOH^-$$

Which statements are correct?

1 $u = x = z$

2 Manganese is reduced to oxidation state +4.

3 Sulfur is oxidised from oxidation state +4 to +6.

A 1, 2 and 3 **B** 1 and 2 only **C** 1 and 3 only **D** 2 and 3 only

11 Hydrogen peroxide, H_2O_2, decomposes to form water and oxygen.

The reaction is catalysed by bromide ions.

step 1 $2Br^-(aq) + H_2O_2(aq) + 2H^+(aq) \rightarrow 2H_2O(l) + Br_2(aq)$

step 2 $H_2O_2(aq) + Br_2(aq) \rightarrow 2Br^-(aq) + 2H^+(aq) + O_2(g)$

Which row is correct?

	type of catalyst	in step 1
A	heterogeneous	bromide ions are oxidised
B	heterogeneous	bromide ions are reduced
C	homogeneous	bromide ions are oxidised
D	homogeneous	bromide ions are reduced

12 Hydrogen and iodine react to form hydrogen iodide in an exothermic reaction. The equation is shown.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

A $1\,m^3$ reaction vessel contains H_2, I_2 and HI gases at equilibrium. The temperature is changed such that the total pressure in the $1\,m^3$ vessel doubles.

What is the effect on the value of K_p and on the position of equilibrium?

	effect on the value of K_p	effect on the position of equilibrium
A	decreases	moves left
B	increases	moves right
C	no change	moves left
D	no change	no change

13 Diethylzinc, $(C_2H_5)_2Zn$, is added to NaOH(aq). Two reactions occur.

reaction 1 $(C_2H_5)_2Zn + H_2O \rightarrow ZnO + 2C_2H_6$

reaction 2 $H_2O + ZnO + 2OH^- \rightarrow Zn(OH)_4^{2-}$

In these reactions, which compounds act as Brønsted–Lowry acids?

	reaction 1	reaction 2
A	$(C_2H_5)_2Zn$	H_2O
B	H_2O	H_2O
C	H_2O	ZnO
D	the reaction is not acid / base	ZnO

14 Which statement about atoms and molecules is correct?

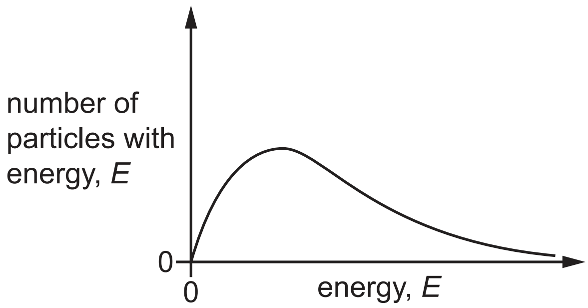
A The molecular formula of a compound is the simplest whole number ratio of atoms of each element in the compound.

B One mole of any substance contains 6×10^{23} atoms.

C The relative atomic mass of an element is the ratio of the average mass of one atom of the element to the mass of an atom of carbon-12.

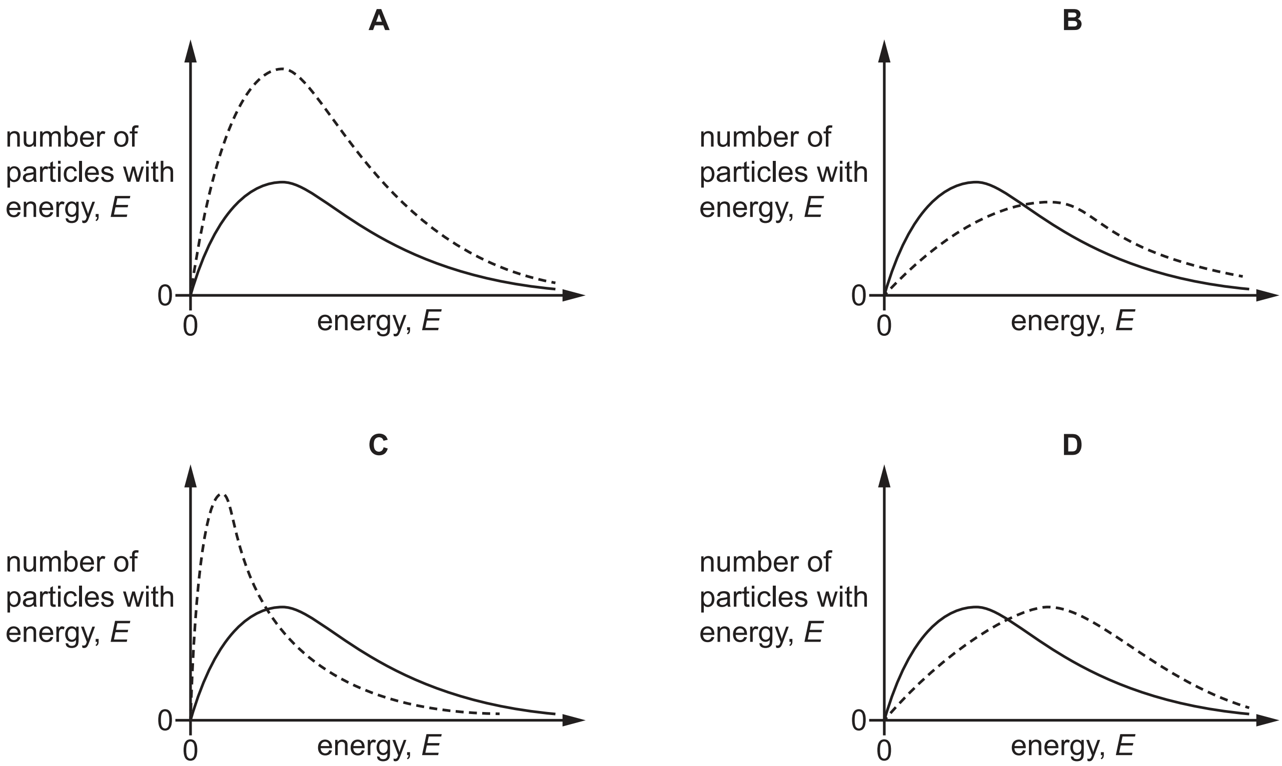
D The relative formula mass of a compound is the sum of the individual atomic masses of all the atoms in the formula.

15 The Boltzmann distribution for one mole of a gas at temperature T is shown.



One mole of the same gas is added, and the gas remains at temperature T.

Which dotted curve shows the distribution with the added gas?



16 In the reaction shown, the concentrations of both X and Y are reduced to half of their original values whilst keeping the total volume of the solution constant.

$$X(aq) + Y(aq) \rightarrow XY(aq)$$

Simultaneously the temperature is increased from 298 K to 348 K.

Which prediction is definitely true?

A A smaller proportion of collisions between particles of X and particles of Y will be successful.

B The average kinetic energy of particles of X and particles of Y will increase.

C The rate of the reaction will be unaffected.

D The frequency of collisions between particles of X and particles of Y will halve.

17 A student investigated the chloride of a Period 3 element. This is what the student wrote down as a record.

> The compound was a white crystalline solid. It dissolved easily in water to give a solution of pH 12. When placed in a test-tube and heated in a roaring Bunsen flame, the compound melted after several minutes heating.

What can be deduced from this record?

A At least one of the recorded observations is incorrect.

B The compound was magnesium chloride, $MgCl_2$.

C The compound was phosphorus pentachloride, PCl_5.

D The compound was sodium chloride, $NaCl$.

18 The elements in Period 3 and their compounds show trends across the period from sodium to chlorine.

Which row is correct?

	electronegativity of the elements	acid / base behaviour of the oxides of the elements
A	decreases	basic → amphoteric → acidic
B	decreases	acidic → amphoteric → basic
C	increases	basic → amphoteric → acidic
D	increases	acidic → amphoteric → basic

19 The table shows the melting points of SiO_2 and P_4O_6.

oxide	SiO_2	P_4O_6
melting point / K	1883	297

Which statement explains the difference between the melting points of SiO_2 and P_4O_6?

A The bonding of the oxides changes from ionic to covalent.

B The metallic character of the elements decreases across Period 3.

C The oxidation number of the element increases from Si to P.

D The structure changes from giant molecular to simple molecular.

20 Equal masses of $CaCO_3$, $Ca(NO_3)_2$, $BaCO_3$ and $Ba(NO_3)_2$ are thermally decomposed. The volume of gas produced in each experiment is measured under the same conditions.

Which compound will produce the greatest volume of gas?

A $CaCO_3$ **B** $Ca(NO_3)_2$ **C** $BaCO_3$ **D** $Ba(NO_3)_2$

21 Which row gives correct comparisons between the solubilities of calcium hydroxide and barium hydroxide and the thermal stabilities of calcium carbonate and barium carbonate?

	solubility		thermal stability	
	calcium hydroxide	barium hydroxide	calcium carbonate	barium carbonate
A	higher	lower	higher	lower
B	higher	lower	lower	higher
C	lower	higher	higher	lower
D	lower	higher	lower	higher

22 Which statement relating to the elements in Group 17 and their compounds is correct?

A Bromine will reduce KI to form iodine.

B Iodide ions react to form a white precipitate when added to silver nitrate solution.

C Bromide ions react to form a white precipitate when added to silver nitrate solution.

D Chlorine reacts with hydrogen to form a colourless gas.

23 An excess of chlorine was bubbled into $100\,cm^3$ of hot $6.0\,mol\,dm^{-3}$ sodium hydroxide.

How many moles of sodium chloride would be produced in the reaction?

A 0.30 **B** 0.50 **C** 0.60 **D** 0.72

24 The product of the Contact process is Z.

Which reaction or process leads to the formation of a gas that can neutralise an aqueous solution of Z?

A atmospheric lightning

B combustion of fuel in an internal combustion engine

C the Haber process

D thermal decomposition of Group 2 nitrates

25 When ammonia, NH_3, is dissolved in water, a small concentration of ammonium ions, NH_4^+, is formed.

Which row is correct?

	number of electrons in one ammonium ion	change of the H–N–H angle from ammonia to the ammonium ion
A	8	decreases
B	8	increases
C	10	decreases
D	10	increases

26 In this question, alkenes and cyclic alkanes should be considered.

How many **structural** isomers of C_4H_8 are there?

A 3 **B** 4 **C** 5 **D** 6

27 Which compound will decolourise $Br_2(aq)$?

A $CH_3CH_2CH_2CH_2CH_2CO_2H$

B $CH_3CH_2CH_2CH_2CH_2CHO$

C $CH_3CHCHCH_2CH_2CH_2OH$

D $CH_3CH_2CH_2CO_2CH_2CH_3$

28 Alkenes react with aqueous hydrogen bromide. The reaction proceeds via an intermediate carbocation. The more stable the intermediate, the faster the reaction.

Which sequence correctly shows an **increase** in the speed of reaction of the alkenes with hydrogen bromide?

A ethene, propene, 2-methylpropene

B 2-methylpropene, ethene, propene

C propene, ethene, 2-methylpropene

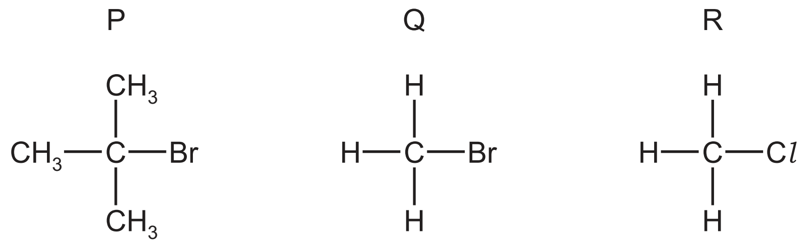
D propene, 2-methylpropene, ethene

29 A reaction occurs when a sample of 1-chloropropane is heated under reflux with sodium hydroxide dissolved in ethanol.

Which row is correct?

	type of reaction	name of product
A	elimination	propan-1-ol
B	elimination	propene
C	substitution	propan-1-ol
D	substitution	propene

30 The diagram shows the structures of three halogenoalkanes.



P, Q and R can all be hydrolysed.

Which row is correct?

	relative speed of hydrolysis		mechanism of hydrolysis	
	Q	R	P	Q
A	fast	slow	S_N1	S_N2
B	fast	slow	S_N2	S_N1
C	slow	fast	S_N1	S_N2
D	slow	fast	S_N2	S_N1

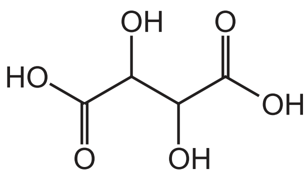
31 A sample of 2.30 g of ethanol is mixed with an excess of aqueous acidified potassium dichromate(VI). The reaction mixture is boiled under reflux for one hour. The required organic product is then collected by distillation. The yield of product is 60.0%.

Which mass of product is collected?

A 1.32 g **B** 1.38 g **C** 1.80 g **D** 3.00 g

32 The structure of tartaric acid is shown.

tartaric acid



Four moles of substance X react with one mole of tartaric acid.

What could be substance X?

A sodium

B sodium carbonate

C sodium hydrogencarbonate

D sodium hydroxide

33 Which compound gives both:

- an orange precipitate with 2,4-DNPH reagent
- **and** a yellow precipitate with alkaline I_2(aq)?

A ethanol

B methanal

C propanal

D propanone

34 A student suggests two uses of $LiAlH_4$.

reaction 1 $\quad CH_3{-}CH{=}CH_2 \xrightarrow{LiAlH_4} CH_3{-}CH_2{-}CH_3$

reaction 2 $\quad CH_3CO_2H \xrightarrow{LiAlH_4} CH_3CH_2OH$

Which reactions would give the product shown?

A both reactions

B reaction 1 only

C reaction 2 only

D neither reaction

35 Compound X contains a single ester group.

X contains 27.6% by mass of oxygen.

Which pair of products could be produced by the hydrolysis of X?

A butan-1-ol and ethanoic acid

B ethanol and propanoic acid

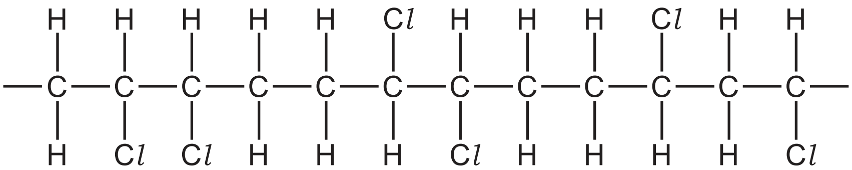
C methanol and methanoic acid

D propan-2-ol and butanoic acid

36 What is the least number of carbon atoms in a non-cyclic alkane molecule that has a chiral centre?

A 7 **B** 8 **C** 9 **D** 10

37 A molecule of a polymer contains the sequence shown.



Which monomer could produce this polymer by addition polymerisation?

A $CHCl{=}CHCl$

B $CH_2{=}CHCl$

C $CH_3CCl{=}CHCl$

D $CH_3CCl{=}CH_2$

38 Compound Y is heated with a mild oxidising agent. One of the products of the reaction reacts with hydrogen cyanide forming 2-hydroxybutanenitrile.

What is compound Y?

A butan-1-ol

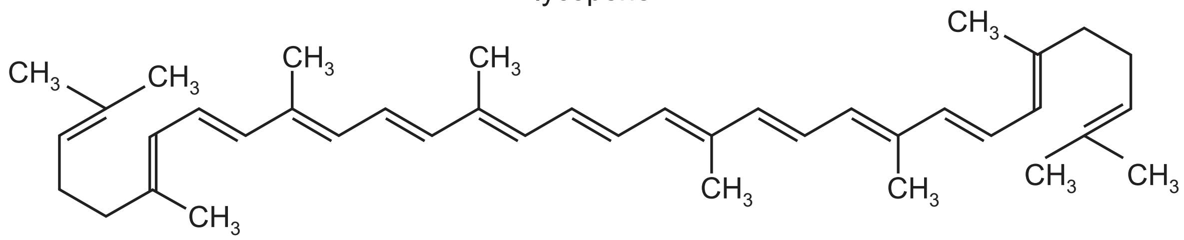
B butan-2-ol

C propan-1-ol

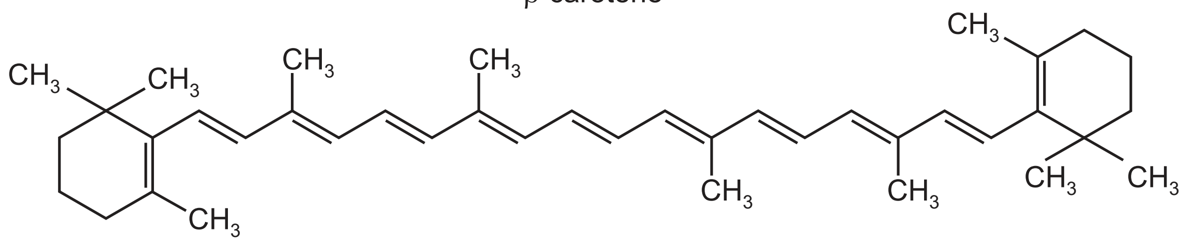
D propan-2-ol

39 The diagrams show the structures of lycopene and β-carotene.

lycopene



β-carotene



When lycopene is converted into β-carotene, what is the gain or loss of hydrogen atoms per molecule?

A 4 gained

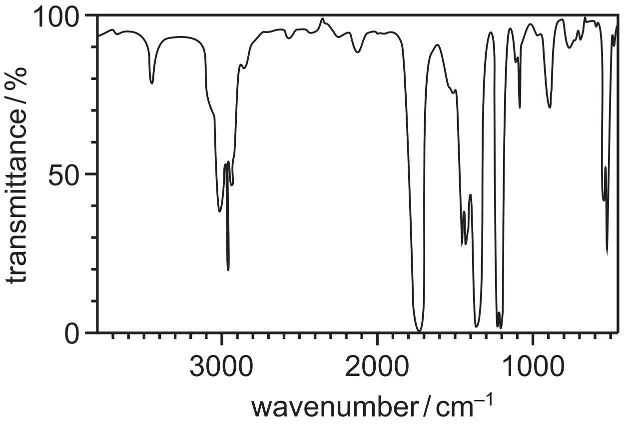
B 2 gained

C no change

D 2 lost

40 Which diagram shows the infrared spectrum of a compound that contains both a C=O and an O–H group?

A



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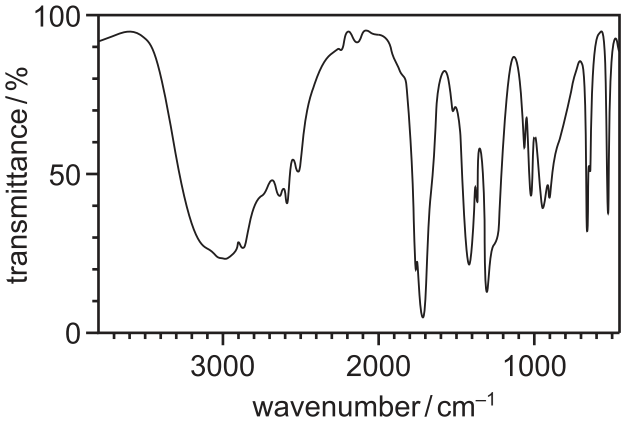

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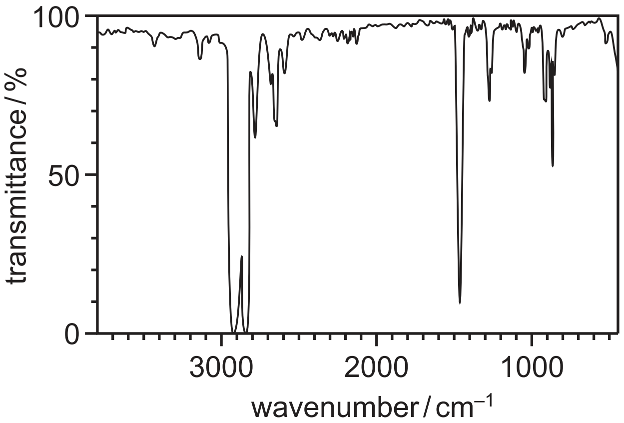

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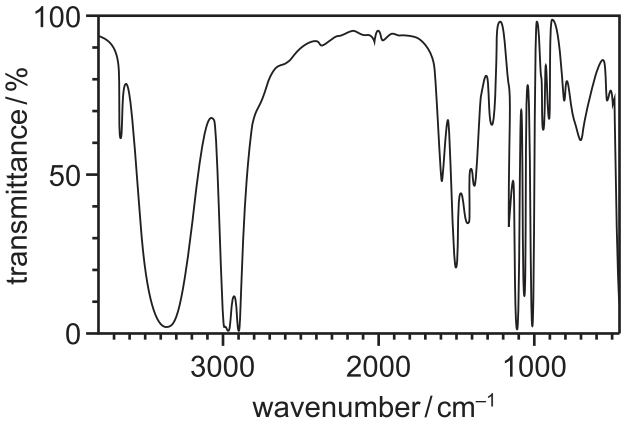

bond	functional group containing the bond	characteristic infrared absorption range (in wavenumbers) / cm^{-1}
C–O	hydroxy, ester	1040–1300
C=C	aromatic compound, alkene	1500–1680
C=O	amide carbonyl, carboxyl ester	1640–1690 1670–1740 1710–1750
C≡N	nitrile	2200–2250
C–H	alkane	2850–3100
N–H	amine, amide	3300–3500
O–H	carboxyl hydroxy	2500–3000 3200–3650

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Important values, constants and standards

molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
Faraday constant	$F = 9.65 \times 10^{4}\,\mathrm{C\,mol^{-1}}$
Avogadro constant	$L = 6.022 \times 10^{23}\,\mathrm{mol^{-1}}$
electronic charge	$e = -1.60 \times 10^{-19}\,\mathrm{C}$
molar volume of gas	$V_m = 22.4\,\mathrm{dm^3\,mol^{-1}}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0\,\mathrm{dm^3\,mol^{-1}}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14}\,\mathrm{mol^2\,dm^{-6}}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18\,\mathrm{kJ\,kg^{-1}\,K^{-1}}$ ($4.18\,\mathrm{J\,g^{-1}\,K^{-1}}$)

The Periodic Table of Elements

Key

atomic number
atomic symbol
name
relative atomic mass

Group 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
							1 H hydrogen 1.0										2 He helium 4.0
3 Li lithium 6.9	4 Be beryllium 9.0											5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2
11 Na sodium 23.0	12 Mg magnesium 24.3											13 Al aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium –	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids	72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium –	85 At astatine –	86 Rn radon –
87 Fr francium –	88 Ra radium –	89–103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –	113 Nh nihonium –	114 Fl flerovium –	115 Mc moscovium –	116 Lv livermorium –	117 Ts tennessine –	118 Og oganesson –

lanthanoids	57 La lanthanum 138.9	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.4	61 Pm promethium –	62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9	66 Dy dysprosium 162.5	67 Ho holmium 164.9	68 Er erbium 167.3	69 Tm thulium 168.9	70 Yb ytterbium 173.1	71 Lu lutetium 175.0
actinoids	89 Ac actinium –	90 Th thorium 232.0	91 Pa protactinium 231.0	92 U uranium 238.0	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –