Cambridge Assessment International Education

Cambridge International AS & A Level

CHEMISTRY **9701/13**

Paper 1 Multiple Choice **October/November 2023**

1 hour 15 minutes

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)

4187055194

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.

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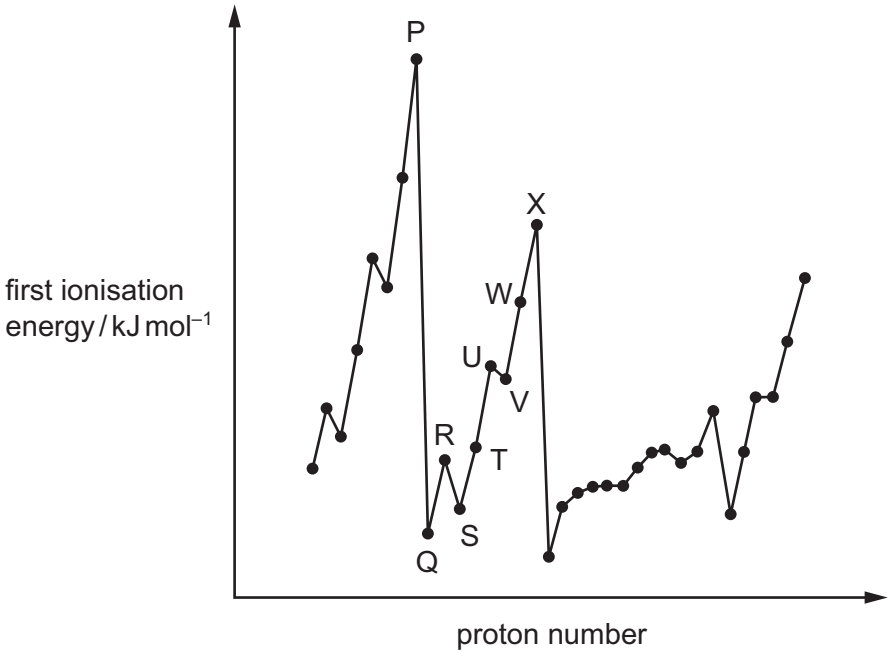
1 Sodium azide, NaN_3 is an explosive used to inflate airbags in cars when they crash. It consists of positive sodium ions and negative azide ions.

What are the numbers of electrons in the sodium ion and the azide ion?

	sodium ion	azide ion
A	10	20
B	10	22
C	12	20
D	12	22

2 The graph shows the variation of the first ionisation energy with proton number for some elements. The letters used are **not** the actual symbols for the elements.



Which statement about the elements is correct?

A P and X are in the same period in the Periodic Table.

B The general increase from Q to X is due to increasing atomic radius.

C The small decrease from R to S is due to decreased shielding.

D The small decrease from U to V is due to repulsion between paired electrons.

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3 Aluminium carbide, Al_4C_3, reacts readily with aqueous sodium hydroxide. The two products of the reaction are $NaAlO_2$ and a hydrocarbon. Water molecules are also involved as reactants.

What is the formula of the hydrocarbon?

A CH_4 **B** C_2H_6 **C** C_3H_8 **D** C_6H_{12}

4 A sample of 35.6 g of hydrated sodium carbonate contains 25.84% sodium ions by mass.

When this sample is heated, anhydrous sodium carbonate and water are formed.

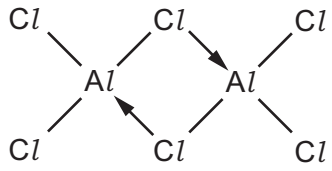
Which mass of water is given off?

A 7.2 g **B** 10.6 g **C** 14.4 g **D** 21.2 g

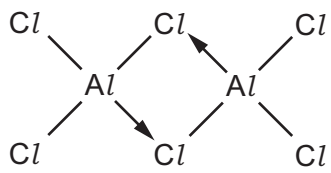
5 Solid aluminium chloride sublimes at 178 °C.

Which structure best represents the species in the vapour at this temperature?

A



B



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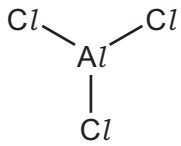

D

$Al^{3+}(Cl^-)_3$

6 Which row is correct?

	shape of H_3O^+	shape of SCl_2
A	pyramidal	non-linear
B	pyramidal	linear
C	trigonal planar	non-linear
D	trigonal planar	linear

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[Turn over

7 When an evacuated tube of volume 400 cm^3 is filled with gas at 300 K and 101 kPa, the mass of the tube increases by 0.65 g.

Assume the gas behaves as an ideal gas.

What is the identity of the gas?

A argon

B helium

C krypton

D neon

8 Nitrogen, N_2, and carbon monoxide, CO, both have M_r = 28.

The boiling point of N_2 is 77 K.

The boiling point of CO is 82 K.

What could be responsible for this difference in boiling points?

A CO molecules have a permanent dipole; the N_2 molecules are **not** polar.

B N_2 has σ and π bonding; CO has σ bonding only.

C N_2 has a strong N≡N bond; CO has a C=O bond.

D The CO molecule has more electrons than the N_2 molecule.

9 Which statement about enthalpy changes is correct?

A Enthalpy changes of reaction are always negative.

B Enthalpy changes of combustion are always positive.

C Enthalpy changes of formation are always positive.

D Enthalpy changes of neutralisation are always negative.

10 What is the definition of standard enthalpy change of neutralisation, $\Delta H^{\ominus}_{neut}$?

A $\Delta H^{\ominus}_{r}$ when one mole of an aqueous acid is neutralised by an aqueous alkali

B $\Delta H^{\ominus}_{r}$ when one mole of an aqueous alkali is neutralised by an aqueous acid

C $\Delta H^{\ominus}_{r}$ when one mole of an aqueous acid is neutralised by one mole of an aqueous alkali

D $\Delta H^{\ominus}_{r}$ when an aqueous acid and an aqueous alkali react together to produce one mole of water

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11 HOCl(aq) is the molecule that kills bacteria when chlorine is added to water.

The following reaction produces this molecule.

$$Cl_2(g) + H_2O(l) \rightleftharpoons HOCl(aq) + H^+(aq) + Cl^-(aq)$$

Which statement about this reaction is correct?

A Chlorine is both oxidised and reduced.

B Chlorine is oxidised but **not** reduced.

C Hydrogen is both oxidised and reduced.

D Hydrogen is oxidised but **not** reduced.

12 Nitrogen dioxide, NO_2, exists in equilibrium with dinitrogen tetroxide, N_2O_4.

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H = -57\,kJ\,mol^{-1}$$

Which conditions give the greatest percentage of $N_2O_4(g)$ at equilibrium?

	pressure	temperature
A	high	high
B	high	low
C	low	high
D	low	low

13 When an equimolar mixture of H_2 and I_2 react, the mole fraction of HI in the final mixture is x.

What is the equilibrium constant, K_p, for the reaction?

A $\dfrac{x^2}{(1-x)^2}$

B $\dfrac{x^2}{(1-2x)^2}$

C $\dfrac{4x^2}{(1-x)^2}$

D $\dfrac{4x^2}{(1-2x)^2}$

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[Turn over

14 In reaction 1, a student measures the initial rate of production of $CO_2(g)$ when $CuCO_3(s)$ is added to 50 cm^3 of 0.1 mol dm^{-3} $HNO_3(aq)$.

In reaction 2, the student repeats the experiment using 50 cm^3 of 0.5 mol dm^{-3} $HNO_3(aq)$ and the same mass of $CuCO_3(s)$.

In reaction 1 and reaction 2, the acid is in excess and samples of the same $CuCO_3$ powder are used.

Which row is correct?

	$\frac{\text{rate of reaction 1}}{\text{rate of reaction 2}}$	$\frac{\text{initial number of effective collisions in reaction 1 per second}}{\text{initial number of effective collisions in reaction 2 per second}}$
A	greater than 1	greater than 1
B	greater than 1	less than 1
C	less than 1	greater than 1
D	less than 1	less than 1

15 The forward reaction of a reversible reaction is exothermic and has an activation energy of +30 kJ mol^{-1}.

The reverse reaction proceeds by a mechanism that is the exact reverse of the mechanism of the forward reaction.

Which statement about the activation energy of the reverse reaction is correct?

A The activation energy for the reverse reaction is equal to –30 kJ mol^{-1}.

B The activation energy for the reverse reaction is greater than 0 kJ mol^{-1} but less than +30 kJ mol^{-1}.

C The activation energy for the reverse reaction is equal to +30 kJ mol^{-1}.

D The activation energy for the reverse reaction is greater than +30 kJ mol^{-1}.

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16 X, Y and Z are elements all found within Groups 13, 14 and 15 of the Periodic Table.

X is in the same group in the Periodic Table as Y.

Y and Z are in Period 3.

The first ionisation energy of X is greater than the first ionisation energy of Y.

The melting point of Z is less than the melting point of Y.

Y and Z both form chlorides which are white solids. These white solids react with water to produce solutions with a pH of less than 4.

Which row of the table shows the possible identities of X and Y?

	X	Y
A	B	A*l*
B	Ge	Si
C	As	P
D	N	P

17 Which row about silicon, Si, and magnesium, Mg, and their ions is correct?

	comparison of silicon and magnesium	explanation
A	Si has a greater atomic radius than Mg.	Si has electrons in 3p orbitals. Mg has electrons in the 3s orbital only.
B	Si has a lower electrical conductivity than Mg.	Si has 4 delocalised electrons per atom. Mg only has 2 delocalised electrons per atom.
C	Si has a lower melting point than Mg.	Si has covalent bonding. Mg has metallic bonding.
D	The radius of Si^{4+} is smaller than the radius of Mg^{2+}.	Si has a greater nuclear charge than Mg.

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[Turn over

18 Bromocresol green is an acid-base indicator. Below a pH of 3.8 it is yellow. Above a pH of 5.4 it is blue. Between these values it is green.

Bromocresol green is added to the aqueous solution formed when the chloride of element T is added to water. The colour becomes yellow.

When an excess of the solid oxide of element U is slowly added to this yellow solution, the indicator turns green then blue.

Which row could identify element T and element U?

	element T	element U
A	silicon	sodium
B	silicon	phosphorus
C	magnesium	sodium
D	magnesium	phosphorus

19 Which row correctly describes the separate reactions of calcium and strontium with water?

	substance reduced	substance oxidised	more vigorous reaction
A	calcium or strontium	water	calcium + water
B	calcium or strontium	water	strontium + water
C	water	calcium or strontium	calcium + water
D	water	calcium or strontium	strontium + water

20 L and M are both compounds of Group 2 elements.

L and M are both soluble in water.

When solutions of L and M are mixed, a white precipitate is formed.

What could be L and M?

A barium chloride and magnesium sulfate

B barium sulfate and magnesium chloride

C barium nitrate and magnesium chloride

D barium carbonate and magnesium nitrate

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21 A 5.00 g sample of an anhydrous Group 2 metal nitrate loses 3.29 g in mass when heated strongly.

Which metal is present?

A magnesium

B calcium

C strontium

D barium

22 In this question, Q represents an atom of chlorine, bromine or iodine.

Which explanation for the variation in volatility down Group 17 is correct?

A Instantaneous dipole–induced dipole forces between molecules become stronger.

B Permanent dipole–permanent dipole forces between molecules become stronger.

C The bond energy of the Q_2 molecules decreases.

D The first ionisation energy $Q(g) \rightarrow Q^+(g) + e^-$ decreases.

23 Which statement about the halogens or halide ions is correct?

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

B Bromine does **not** oxidise chloride ions when added to sodium chloride solution.

C Fluorine atoms form cations by accepting electrons when they react.

D Chloride ions are stronger reducing agents than iodide ions.

24 If ammonium cyanate is heated in the absence of air, the only product of the reaction is urea, $CO(NH_2)_2$. No other products are formed in the reaction.

What is the formula of the cyanate ion present in ammonium cyanate?

A CON_2^- **B** CON_2^{2-} **C** OCN^- **D** OCN^{2-}

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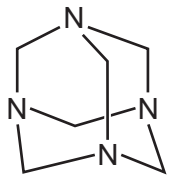
[Turn over

25 Hexamine is a crystalline solid used as a fuel in portable stoves.

The diagram shows its skeletal structure.

hexamine

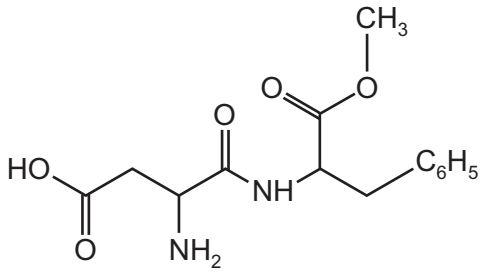


What is the empirical formula of hexamine?

A CH_2N **B** $C_3H_6N_2$ **C** $C_4H_8N_4$ **D** $C_6H_{12}N_4$

26 The compound *aspartame* is widely used as a sweetener in 'diet' soft drinks.

aspartame



Aspartame is chiral. (There are no chiral carbon atoms in C_6H_5.)

How many chiral carbon atoms are present in a molecule of *aspartame*?

A 1 **B** 2 **C** 3 **D** 4

27 How many σ and π bonds are in the molecule $HCCCH_2CH_2CHC(CH_3)_2$?

A 17 σ 3 π **B** 17 σ 5 π **C** 18 σ 4 π **D** 19 σ 3 π

28 The hydrocarbon $C_{17}H_{36}$ can be cracked.

Which compound is the **least** likely to be produced in this reaction?

A C_3H_8 **B** C_4H_8 **C** C_8H_{16} **D** $C_{16}H_{34}$

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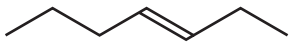
29 Which compound has an M_r of 84 and will react with HBr to give a product with an M_r of 164.9?

A



B



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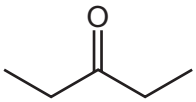
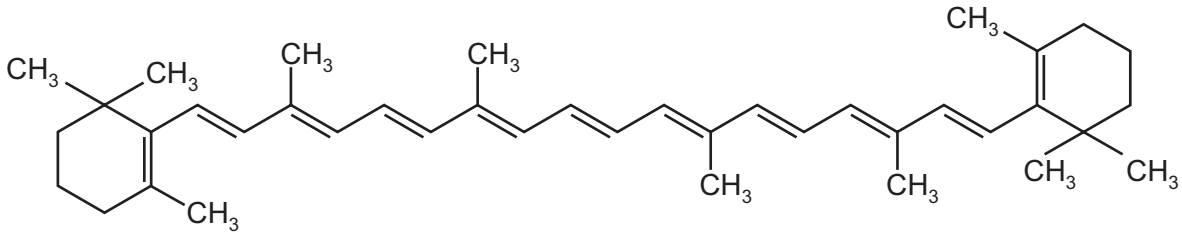


D



30 β-carotene is responsible for the orange colour of carrots.

β-carotene



β-carotene is oxidised by hot, concentrated, acidified $KMnO_4$.

When an individual molecule of β-carotene is oxidised in this way, many product molecules are formed.

How many of these product molecules contain a ketone functional group?

A 4 **B** 6 **C** 9 **D** 11

31 1,1-dichloropropane reacts with aqueous sodium hydroxide in a series of steps to give propanal.

$$CH_3CH_2CHCl_2 \xrightarrow{NaOH(aq)} CH_3CH_2CHO$$

Which term describes the first step of this reaction?

A addition

B elimination

C oxidation

D substitution

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32 Propanoic acid can be made from bromoethane using a two-stage synthesis.

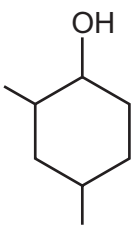
Which pair of reagents is most suitable?

	reagent for stage 1	reagent for stage 2
A	hydrogen cyanide	aqueous sodium hydroxide
B	aqueous sodium hydroxide	excess acidified potassium dichromate(VI)
C	ethanolic sodium hydroxide	acidified potassium manganate(VII)
D	potassium cyanide	dilute hydrochloric acid

33 Alcohol X gives a yellow precipitate with alkaline I_2(aq).

What is the structure of X?

A



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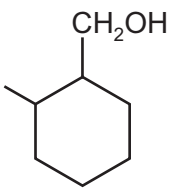
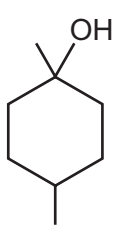


C



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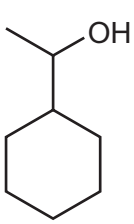

34 When ethanol reacts with sodium metal, ethoxide ions, $CH_3CH_2O^-$, are produced.

When water reacts with sodium metal, OH^- ions are produced.

Which statement about these reactions and the ethoxide ion is correct?

A At the same temperature, the rate of reaction between sodium and ethanol is greater than that between sodium and water.

B $CH_3CH_2O^-$ is a stronger base than OH^- due to the electron-donating effect of the ethyl group.

C The negative charge on the oxygen in an ethoxide ion is delocalised.

D It is easier to deprotonate ethanol as it is more acidic than water.

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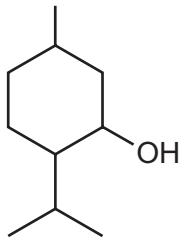
35 Menthol is a naturally occurring alcohol.

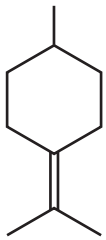
menthol



When menthol is heated with concentrated sulfuric acid it reacts. The products formed include compound T.

What is the structure of compound T?

A



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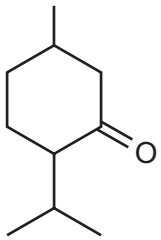

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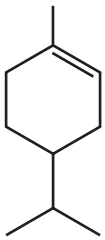

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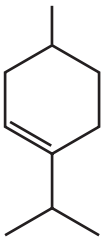
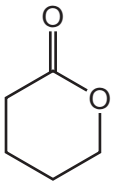


36 Which compound will produce a yellow-orange precipitate when added to 2,4-dinitrophenylhydrazine?

A



B



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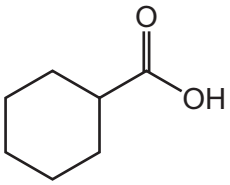

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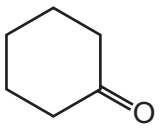

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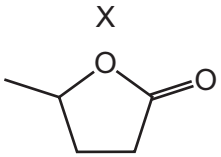
37 Ethanal, CH_3CHO, undergoes an addition reaction with HCN in the presence of CN^- ions.

Which row identifies the type of reaction and the name of the product formed?

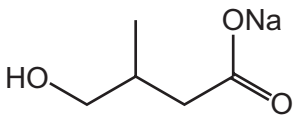
	type of reaction	name of product
A	electrophilic addition	2-hydroxypropanenitrile
B	electrophilic addition	2-hydroxyethanenitrile
C	nucleophilic addition	2-hydroxypropanenitrile
D	nucleophilic addition	2-hydroxyethanenitrile

38 The structure of compound X is shown.



What is produced when X is heated with NaOH(aq)?

A



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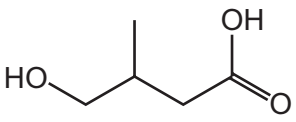

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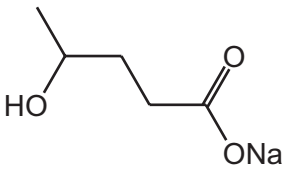

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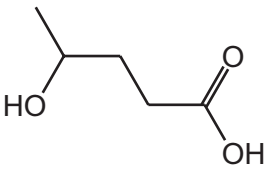
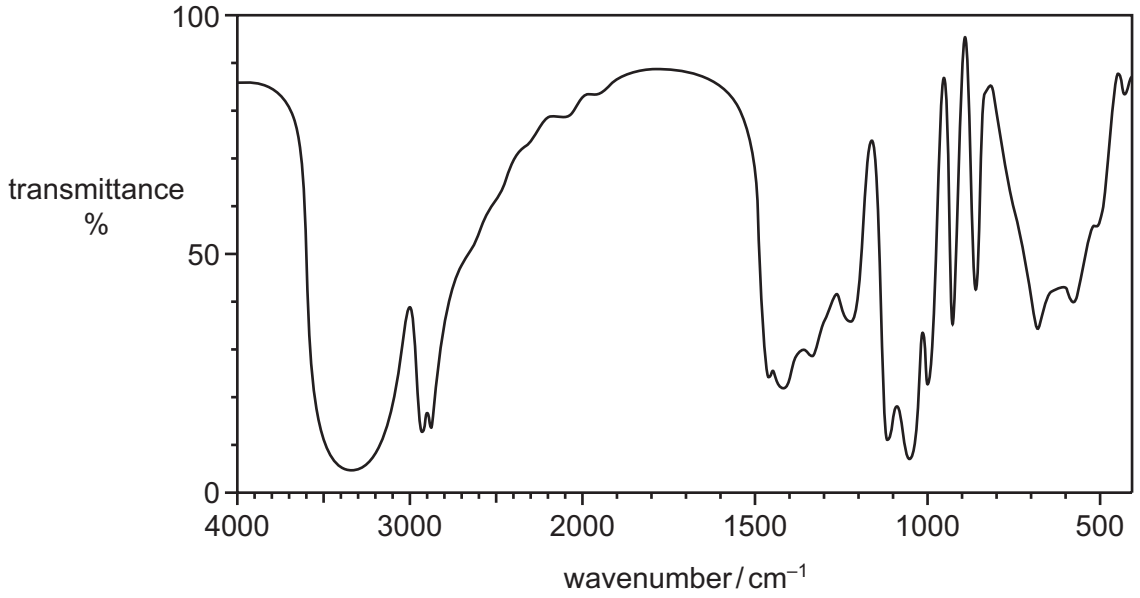


39 The infrared spectrum of compound L is shown.



bond	functional groups 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	2850–2950
N–H	amine, amide	3300–3500
O–H	carboxyl hydroxy	2500–3000 3200–3600

What is the structure of L?

A $HOCH_2COCH_2OH$

B $HOCH_2CH(OH)CHO$

C $HOCH_2CH(OH)CH_2OH$

D $HOCH_2CH_2COOH$

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[Turn over

40 In the mass spectrum of compound J, the ratio of the height of the M +1 ion peak to the height of the M + ion peak is 4 : 91.

Compound J forms a carboxylic acid when heated with acidified $K_2Cr_2O_7$.

What is compound J?

A butanal

B butanone

C propan-1-ol

D propanenitrile

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Important values, constants and standards

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

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The Periodic Table of Elements

Group																	
1	2											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 –

Key

atomic number
atomic symbol
name
relative atomic mass

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 –

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