Cambridge Assessment International Education

Cambridge International AS & A Level

CHEMISTRY **9701/11**

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)

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.

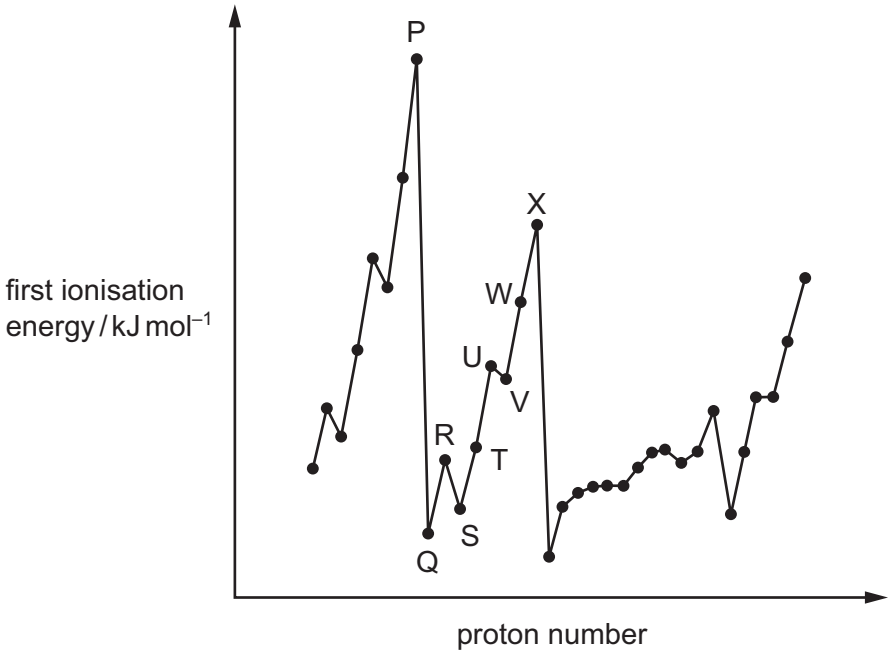
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1 Sodium azide, NaN_3 is an explosive used to inflate airbags in cars when they crash. It consists of positive sodium ions and negative azide ions.

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.

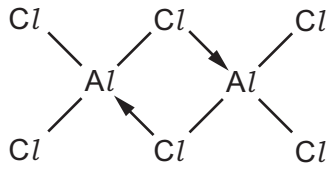
Which mass of water is given off?

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

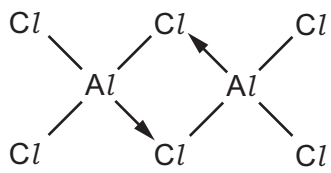
5 Solid aluminium chloride sublimes at 178 °C.

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

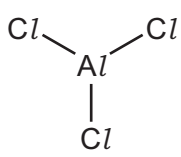
A



B



C



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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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?

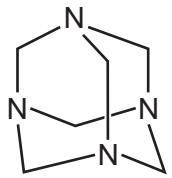
A CON_2^- **B** CON_2^{2-} **C** OCN^- **D** OCN^{2-}

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

The diagram shows its skeletal structure.

hexamine

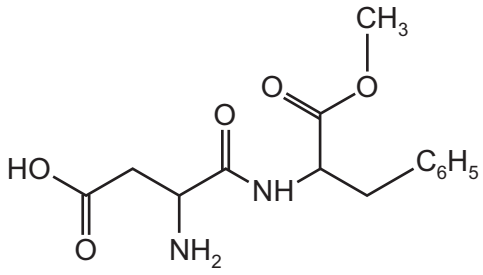


What is the empirical formula of hexamine?

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.

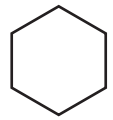
Which compound is the **least** likely to be produced in this reaction?

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

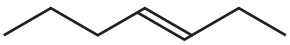
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29 Which compound has an M_r of 84 and will react with HBr to give a product with an M_r of 164.9?

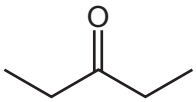
A



B



C

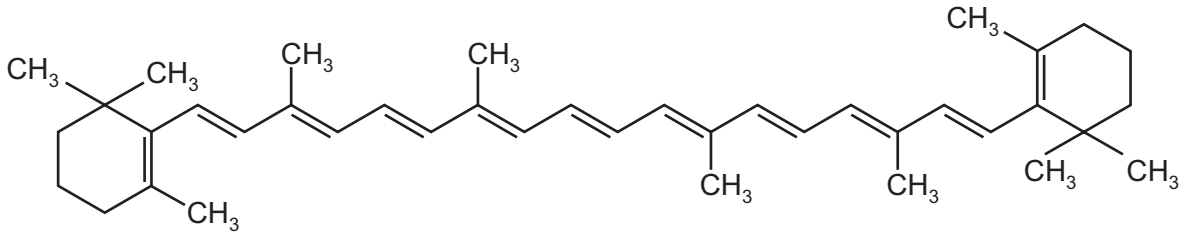


D



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.

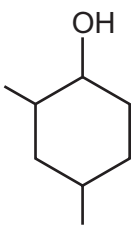
Which pair of reagents is most suitable?

	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

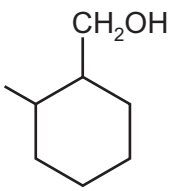
33 Alcohol X gives a yellow precipitate with alkaline I_2(aq).

What is the structure of X?

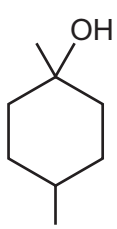
A



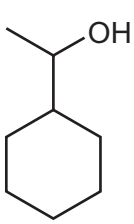
B



C



D



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.

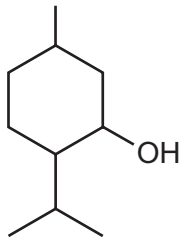
C The negative charge on the oxygen in an ethoxide ion is delocalised.

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.

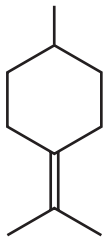
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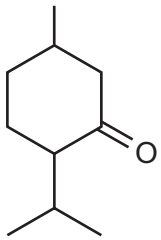
When menthol is heated with concentrated sulfuric acid it reacts. The products formed include compound T.

What is the structure of compound T?

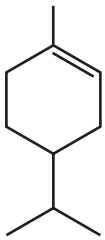
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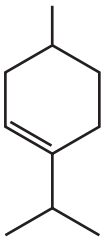
B



C

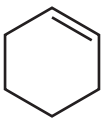


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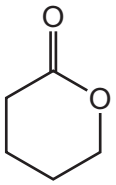


36 Which compound will produce a yellow-orange precipitate when added to 2,4-dinitrophenylhydrazine?

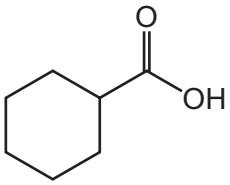
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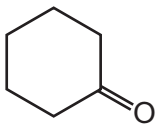
B



C



D



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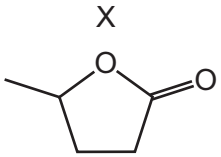
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37 Ethanal, CH_3CHO, undergoes an addition reaction with HCN in the presence of CN^- ions.

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

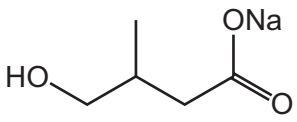
	type of reaction	name of product
A	electrophilic addition	2-hydroxypropanenitrile
B	electrophilic addition	2-hydroxyethanenitrile
C	nucleophilic addition	2-hydroxypropanenitrile
D	nucleophilic addition	2-hydroxyethanenitrile

38 The structure of compound X is shown.

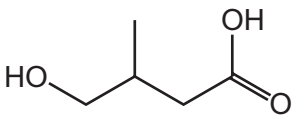


What is produced when X is heated with NaOH(aq)?

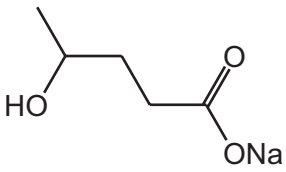
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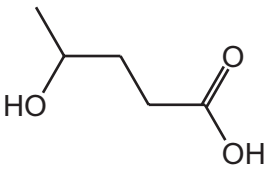
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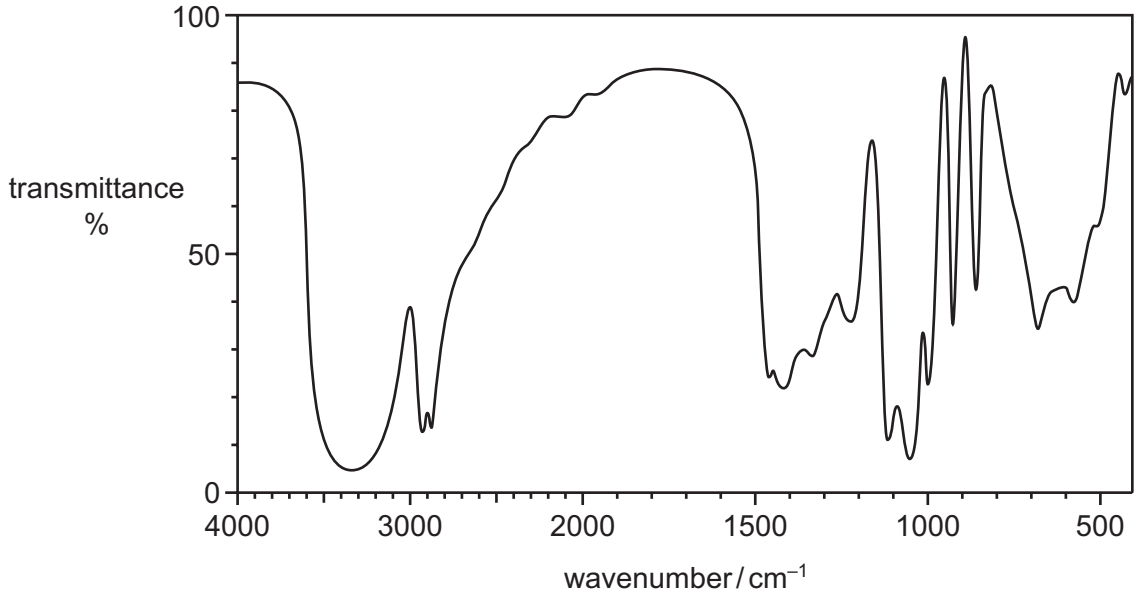


D



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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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CHEMISTRY **9701/12**

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)

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.

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[Turn over

1 Which particle contains 8 protons, 9 neutrons and 10 electrons?

A $^{16}_{8}O^{-}$ **B** $^{16}_{8}O^{2-}$ **C** $^{17}_{8}O^{-}$ **D** $^{17}_{8}O^{2-}$

2 The second ionisation energy of oxygen is greater than the second ionisation energy of fluorine.

Which factor explains this difference?

A The atomic radius of an oxygen atom is smaller than that of fluorine.

B The covalent bond in a fluorine molecule is weaker than the bond in an oxygen molecule.

C A spin-paired electron is removed from fluorine but **not** from oxygen.

D Fluorine has more electrons in total than oxygen. This causes a greater shielding of the nuclear attraction in fluorine.

3 Zinc reacts with concentrated nitric acid giving three products only: zinc nitrate, an oxide of nitrogen and water.

3.0 moles of zinc react with 8.0 moles of nitric acid. Zinc nitrate contains Zn^{2+} ions.

What could be the formula of the oxide of nitrogen?

A N_2O **B** NO **C** N_2O_3 **D** NO_2

4 A 3.7 g sample of copper(II) carbonate is added to 25 cm^3 of 2.0 mol dm^{-3} hydrochloric acid.

Which volume of gas is produced at room conditions?

A 0.60 dm^3 **B** 0.72 dm^3 **C** 1.20 dm^3 **D** 2.40 dm^3

5 Ammonium ions, NH_4^+, are formed when ammonia gas reacts with hydrogen chloride gas.

Which statement about the changes that occur in this reaction is correct?

A The dipole moment of an ammonium ion is greater than the dipole moment of an ammonia molecule.

B The H–N–H bond angle decreases when an ammonium ion is formed.

C The hybridisation of nitrogen does **not** change.

D There is electron transfer from nitrogen to chlorine.

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6 Which feature is present in both ethene and poly(ethene)?

A bond angles of 109.5°

B π covalent bonds

C σ covalent bonds

D sp^3 orbitals

7 Two compounds of boron are sodium borohydride, $NaBH_4$, and boron trifluoride, BF_3.

What are the shapes of the borohydride ion and the boron trifluoride molecule?

	borohydride ion	boron trifluoride
A	square planar	pyramidal
B	square planar	trigonal planar
C	tetrahedral	pyramidal
D	tetrahedral	trigonal planar

8 In an experiment, 0.100 mol of propan-1-ol is burnt completely in 12.0 dm^3 of oxygen, measured at room conditions.

What is the final volume of gas, measured at room conditions?

A 7.20 dm^3 **B** 8.40 dm^3 **C** 16.80 dm^3 **D** 18.00 dm^3

9 At a temperature of 2500 K and a pressure of 1.00×10^{-4} Pa, a sample of 0.321 g of sulfur vapour has a volume of 2.08×10^6 m^3.

What is the molecular formula of sulfur under these conditions?

A S **B** S_2 **C** S_4 **D** S_8

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[Turn over

10 In the structure of solid SiO_2

each silicon atom is bonded to x oxygen atoms

each oxygen atom is bonded to y silicon atoms

each bond is a z type bond.

What is the correct combination of x, y and z in these statements?

	x	y	z
A	2	1	covalent
B	2	1	ionic
C	4	2	covalent
D	4	2	ionic

11 Nitric acid is made industrially by the oxidation of ammonia. The overall equation for the process is shown.

equation 1 $\quad NH_3 + 2O_2 \rightarrow HNO_3 + H_2O$

The process happens in three stages. The equations and enthalpy changes for these stages are given.

stage 1 $\quad 4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O \quad \Delta H = -904\,kJ\,mol^{-1}$

stage 2 $\quad 2NO + O_2 \rightarrow 2NO_2 \quad \Delta H = -114\,kJ\,mol^{-1}$

stage 3 $\quad 4NO_2 + O_2 + 2H_2O \rightarrow 4HNO_3 \quad \Delta H = -348\,kJ\,mol^{-1}$

What is the enthalpy change of the process shown in equation 1?

A $-1480\,kJ\,mol^{-1}$

B $-370\,kJ\,mol^{-1}$

C $-341.5\,kJ\,mol^{-1}$

D $+82\,kJ\,mol^{-1}$

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12 Chlorine reacts with sodium bromide.

$$\tfrac{1}{2}Cl_2 + NaBr \rightarrow NaCl + \tfrac{1}{2}Br_2$$

Which words correctly describe this reaction?

1 redox

2 displacement

3 disproportionation

A 1, 2 and 3

B 1 and 2 only

C 1 only

D 2 only

13 The equation for the reaction between aqueous copper ions and aqueous iodide ions is as follows.

$$2Cu^{2+}(aq) + 4I^{-}(aq) \rightarrow 2CuI(s) + I_2(aq)$$

What is the change in oxidation state of copper?

A +2 to –1 **B** +2 to 0 **C** +2 to +1 **D** +4 to +2

14 A mixture of the three gases, oxygen, nitrogen and argon, is at a total pressure of 500 kPa. There is a total of 1.2 moles of gas in the mixture.

If the oxygen gas alone occupied the entire volume of the mixture, it would exert a pressure of 150 kPa.

At room conditions the amount of nitrogen gas in the mixture would occupy a volume of 5.76 dm^3.

What is the partial pressure of the argon gas in the mixture?

A 150 kPa

B 200 kPa

C 250 kPa

D 300 kPa

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15 0.200 mol of sulfur dioxide and 0.200 mol of oxygen are placed in a 1.00 dm^3 sealed container. The gases are allowed to react until equilibrium is reached.

$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$

At equilibrium there is 0.100 mol of SO_3 in the container.

What is the value of K_c?

A 0.150 $mol\,dm^{-3}$

B 0.800 $mol\,dm^{-3}$

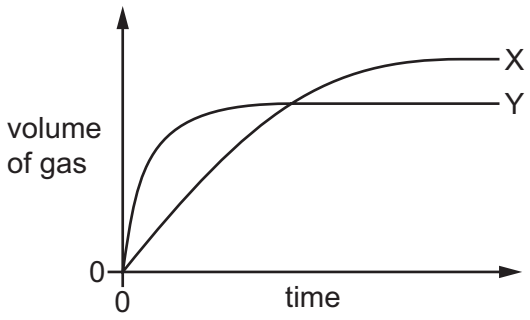
C 1.25 $mol^{-1}\,dm^3$

D 6.67 $mol^{-1}\,dm^3$

16 The decomposition of hydrogen peroxide in the presence of MnO_2 produces water and oxygen gas.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

The volume of gas collected when 0.2 g of MnO_2 is added to two different hydrogen peroxide solutions at 20 °C is shown on the graph as curves X and Y.

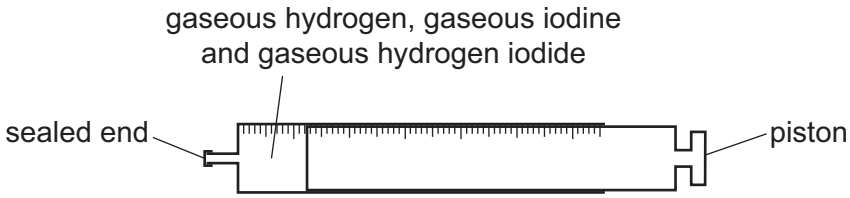


Which row shows the conditions that will result in curves X and Y?

	curve X			curve Y		
	volume of H_2O_2 / cm^3	concentration of H_2O_2 / $mol\,dm^{-3}$	form of MnO_2	volume of H_2O_2 / cm^3	concentration of H_2O_2 / $mol\,dm^{-3}$	form of MnO_2
A	50	0.1	lumps	50	0.2	powder
B	25	0.2	powder	25	0.1	lumps
C	50	0.1	lumps	20	0.2	powder
D	20	0.2	powder	40	0.1	lumps

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17 The diagram shows a gas syringe with a free-moving piston. The syringe contains gaseous hydrogen, gaseous iodine and gaseous hydrogen iodide at equilibrium.



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

Three changes are listed.

1 increasing the total pressure by adding an inert gas and keeping the volume constant

2 increasing the pressure by adding more gaseous hydrogen iodide and keeping the volume constant

3 decreasing the volume by pushing the piston to the left

Which changes will result in an equilibrium position at which the rate of the forward reaction has increased?

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

18 Which row gives the best description of the variations in the melting points and the first ionisation energies of the elements in Period 3 from sodium to argon?

	melting points	first ionisation energies
A	increase up to a peak at aluminium then decrease	generally decrease
B	increase up to a peak at aluminium then decrease	generally increase
C	increase up to a peak at silicon then decrease	generally decrease
D	increase up to a peak at silicon then decrease	generally increase

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[Turn over

19 X and Y are atoms of different elements in Period 3 of the Periodic Table. Neither X nor Y is argon.

X is a non-metal.

X has a greater atomic radius than Y.

Which statement is correct?

A X has more occupied electron shells than Y.

B X has more protons in each atom than Y.

C X has the same number of outer electrons in each atom as Y.

D Y is a non-metal.

20 Four mixtures are added to four separate 50 cm^3 samples of water and stirred.

Which mixture results in a solution with the highest pH?

A 1.0 g of aluminium oxide and 1.0 g of aluminium chloride

B 1.0 g of magnesium oxide and 1.0 g of magnesium chloride

C 1.0 g of phosphorus oxide and 1.0 g of phosphorus chloride

D 1.0 g of silicon dioxide and 1.0 g of silicon chloride

21 What happens when a piece of magnesium ribbon is placed in cold water?

A A vigorous effervescence occurs.

B Bubbles of gas form slowly on the magnesium.

C The magnesium floats on the surface of the water and reacts quickly.

D The magnesium glows and a white solid is produced.

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22 The table gives some data for compounds of two elements from Group 2 of the Periodic Table.

element	decomposition temperature of carbonate / °C	solubility of sulfate in mol / 100 g of water	solubility of hydroxide in mol / 100 g of water
calcium	840	4.66×10^{-3}	1.53×10^{-3}
Z	?	?	2.00×10^{-5}

What is the missing data for element Z?

	decomposition temperature of carbonate / °C	solubility of sulfate in mol / 100 g of water
A	350	1.83×10^{-1}
B	350	7.11×10^{-5}
C	1100	1.83×10^{-1}
D	1100	7.11×10^{-5}

23 Q is a mixture of two compounds of Group 2 elements.

Q undergoes thermal decomposition to produce a white solid and only two gaseous products. One of the gaseous products relights a glowing splint.

What could be the components of mixture Q?

A $MgCl_2$ and $CaCO_3$

B $MgCO_3$ and $Ca(NO_3)_2$

C $Mg(NO_3)_2$ and $Ca(NO_3)_2$

D MgO and CaO

24 Iodine has a higher melting point than chlorine.

What is the reason for this?

A Iodine has stronger covalent bonds than chlorine.

B Iodine molecules have stronger permanent dipoles than chlorine molecules.

C Iodine is more volatile than chlorine.

D Iodine has stronger instantaneous dipole–induced dipole forces than chlorine.

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25 When concentrated sulfuric acid is added to solid sodium chloride, HCl is formed but **not** Cl_2.

When concentrated sulfuric acid is added to solid sodium iodide, I_2 is formed.

Which statement explains these observations?

A Sulfuric acid is an oxidising agent and chloride ions are more easily oxidised than iodide ions.

B Sulfuric acid is an oxidising agent and iodide ions are more easily oxidised than chloride ions.

C Sulfuric acid is a reducing agent and chloride ions are more easily reduced than iodide ions.

D Sulfuric acid is a reducing agent and iodide ions are more easily reduced than chloride ions.

26 NaOH(aq) is added to NH_4Cl(aq). The mixture is warmed.

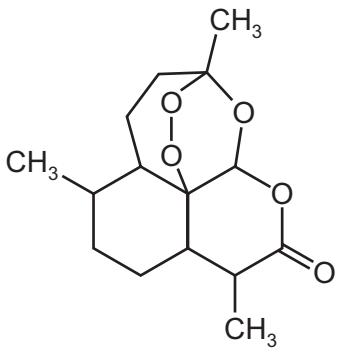
The gas that is produced turns damp red litmus paper blue.

Which row is correct?

	behaviour of the ammonium ion in NH_4Cl	behaviour of the water present on the litmus paper
A	Brønsted–Lowry acid	Brønsted–Lowry base
B	Brønsted–Lowry acid	Brønsted–Lowry acid
C	Brønsted–Lowry base	Brønsted–Lowry acid
D	Brønsted–Lowry base	Brønsted–Lowry base

27 Artemisinin is a powerful anti-malarial drug.

artemisinin



How many chiral centres are there in each molecule of artemisinin?

A 4 **B** 6 **C** 7 **D** 8

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28 Which row shows the correct name and classification of the halogenoalkane shown?

$CH_3(CH_2)_2CBr(CH_3)CH_2CH_3$

	name	classification of halogenoalkane
A	3-bromo-3-methylhexane	secondary
B	3-bromo-3-methylhexane	tertiary
C	3-bromo-4-methylhexane	tertiary
D	4-bromo-5-methylhexane	secondary

29 How many geometrical (cis/trans) isomers are there of hex-2,4-diene, $CH_3CH=CHCH=CHCH_3$?

A none; hex-2,4-diene does **not** show geometric isomerism

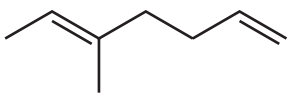
B 2

C 3

D 4

30 The structure of compound X is shown.

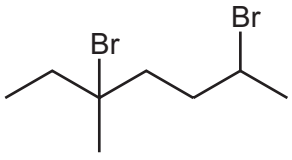
compound X



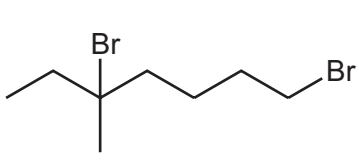
One mole of compound X reacts completely with two moles of hydrogen bromide.

What is the structure of the major product of this reaction?

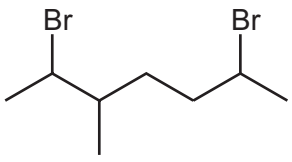
A



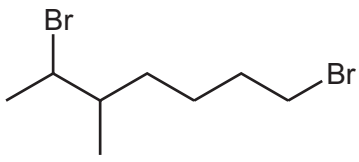
B



C



D



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31 The formulae of three compounds are shown.

C_3H_7CHO $C_2H_5COCH_3$ $CH_2CHCH_2CH_2OH$

Only one of these compounds will decolourise bromine water. Only one of these compounds will produce a silver mirror with Tollens' reagent.

Which row shows the correct results?

	decolourises bromine water	forms a silver mirror with Tollens' reagent
A	C_3H_7CHO	$C_2H_5COCH_3$
B	$C_2H_5COCH_3$	C_3H_7CHO
C	$CH_2CHCH_2CH_2OH$	$C_2H_5COCH_3$
D	$CH_2CHCH_2CH_2OH$	C_3H_7CHO

32 Which list contains a compound that is **not** made during the free radical substitution of methane with chlorine?

A CH_3Cl, CCl_4, C_2H_6

B Cl_2, CH_2Cl_2, CCl_4

C CH_3Cl, CH_2Cl_2, $CHCl_3$

D CH_3Cl, $CHCl_3$, $C_2H_2Cl_2$

33 Propanoic acid can be used to make propene by a two-stage synthesis.

Which row shows suitable reagents for this synthesis?

	reagent for first stage	reagent for second stage
A	$LiAlH_4$	conc. H_2SO_4
B	$LiAlH_4$	NaOH in ethanol
C	$NaBH_4$	conc. H_2SO_4
D	$NaBH_4$	NaOH in ethanol

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34 Which alcohol reacts with alkaline I_2(aq) to produce ethanoate ions?

A ethanol

B methylpropan-2-ol

C propan-2-ol

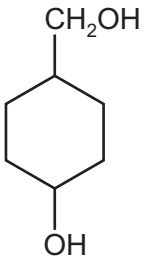
D butan-2-ol

35 Heating compound X, $C_7H_{14}O_2$, under reflux with an excess of acidified potassium dichromate(VI) produces compound Y.

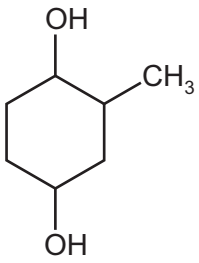
Compound Y produces hydrogen gas with sodium metal and forms orange crystals with 2,4-DNPH reagent.

What could X be?

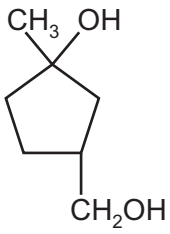
A



B



C



D

$(CH_3)_2C(OH)CH_2CH_2CH_2CHO$

36 Which reaction takes place by a nucleophilic addition mechanism?

A propene reacting with hydrogen bromide

B 2-bromopropane reacting with sodium hydroxide in ethanol

C propanone reacting with hydrogen cyanide

D methane reacting with chlorine

37 Three equations are shown.

1 $CH_3COOH + MgCO_3 \rightarrow CH_3COOMg + CO_2 + H_2O$

2 $CH_3CH_2COOH + Na \rightarrow CH_3CH_2COONa + \frac{1}{2}H_2$

3 $CH_3CH_2COOH + 2Ba(OH)_2 \rightarrow CH_3CH_2COOBa_2 + 2H_2O$

Which of the equations are correct?

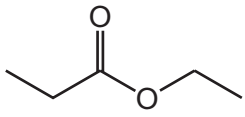
A 1, 2 and 3 **B** 1 and 2 only **C** 2 only **D** 3 only

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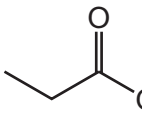
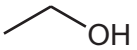
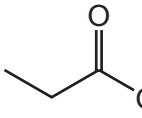
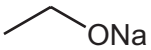
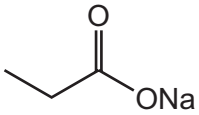
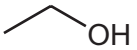
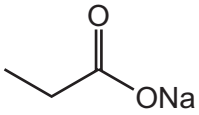
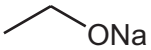
38 How many esters with the molecular formula $C_5H_{10}O_2$ can be made by reacting a primary alcohol with a carboxylic acid?

A 4 **B** 5 **C** 6 **D** 8

39 The diagram shows an ester. It is heated under reflux with an excess of NaOH(aq).



Which row shows the 2 products of the reaction?

	product 1	product 2
A		
B		
C		
D		

40 Oxygen has three stable isotopes, ^{16}O, ^{17}O and ^{18}O. All three isotopes are present in a sample of oxygen gas, O_2, which was analysed using a mass spectrometer.

How many peaks associated with the O_2^+ ion would be expected?

A 3 **B** 5 **C** 6 **D** 9

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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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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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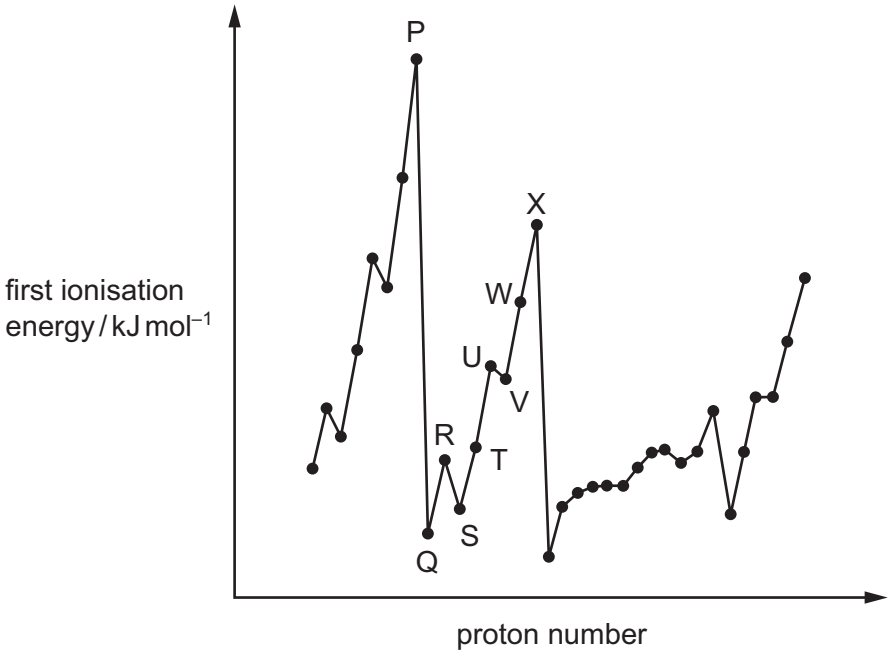
[Turn over

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.

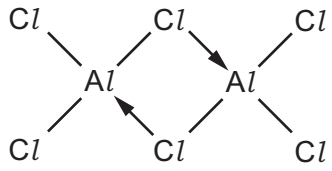
Which mass of water is given off?

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

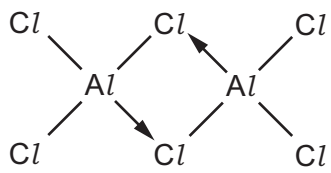
5 Solid aluminium chloride sublimes at 178 °C.

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

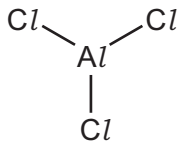
A



B



C



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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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?

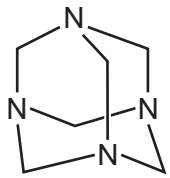
A CON_2^- **B** CON_2^{2-} **C** OCN^- **D** OCN^{2-}

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

The diagram shows its skeletal structure.

hexamine

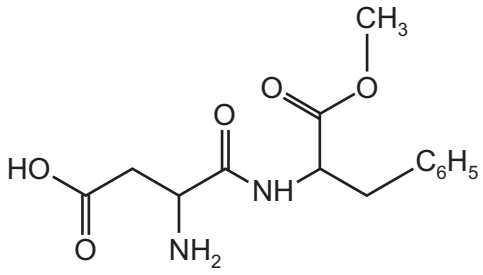


What is the empirical formula of hexamine?

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** $C_{16}H_{34}$

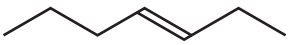
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29 Which compound has an M_r of 84 and will react with HBr to give a product with an M_r of 164.9?

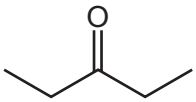
A



B



C

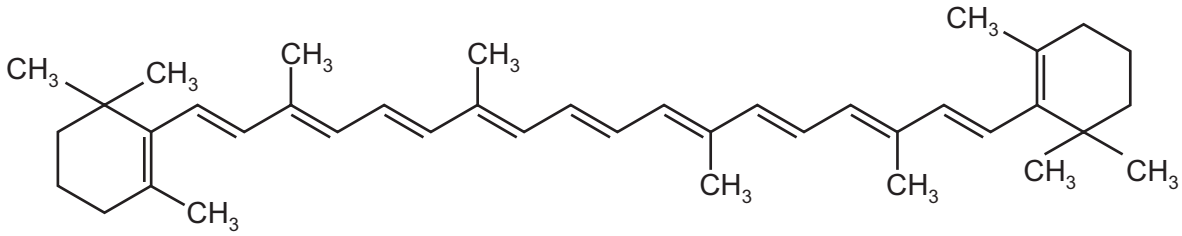


D



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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[Turn over

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

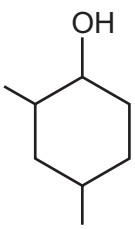
Which pair of reagents is most suitable?

	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

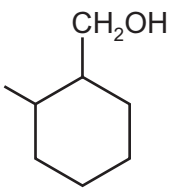
33 Alcohol X gives a yellow precipitate with alkaline I_2(aq).

What is the structure of X?

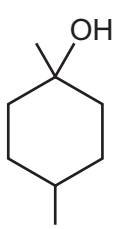
A



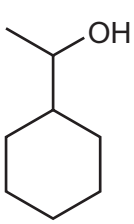
B



C



D



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.

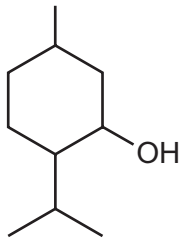
C The negative charge on the oxygen in an ethoxide ion is delocalised.

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.

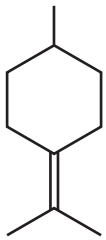
menthol



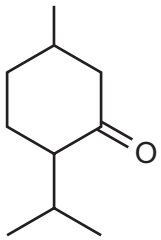
When menthol is heated with concentrated sulfuric acid it reacts. The products formed include compound T.

What is the structure of compound T?

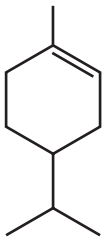
A



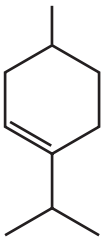
B



C



D

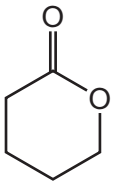


36 Which compound will produce a yellow-orange precipitate when added to 2,4-dinitrophenylhydrazine?

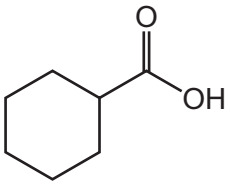
A



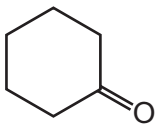
B



C



D



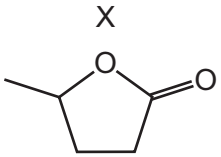
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37 Ethanal, CH_3CHO, undergoes an addition reaction with HCN in the presence of CN^- ions.

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

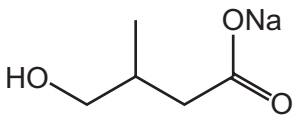
	type of reaction	name of product
A	electrophilic addition	2-hydroxypropanenitrile
B	electrophilic addition	2-hydroxyethanenitrile
C	nucleophilic addition	2-hydroxypropanenitrile
D	nucleophilic addition	2-hydroxyethanenitrile

38 The structure of compound X is shown.

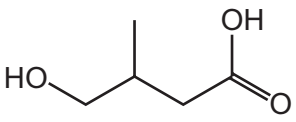


What is produced when X is heated with NaOH(aq)?

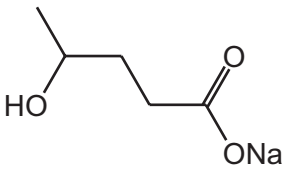
A



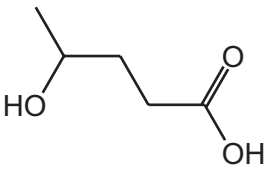
B



C

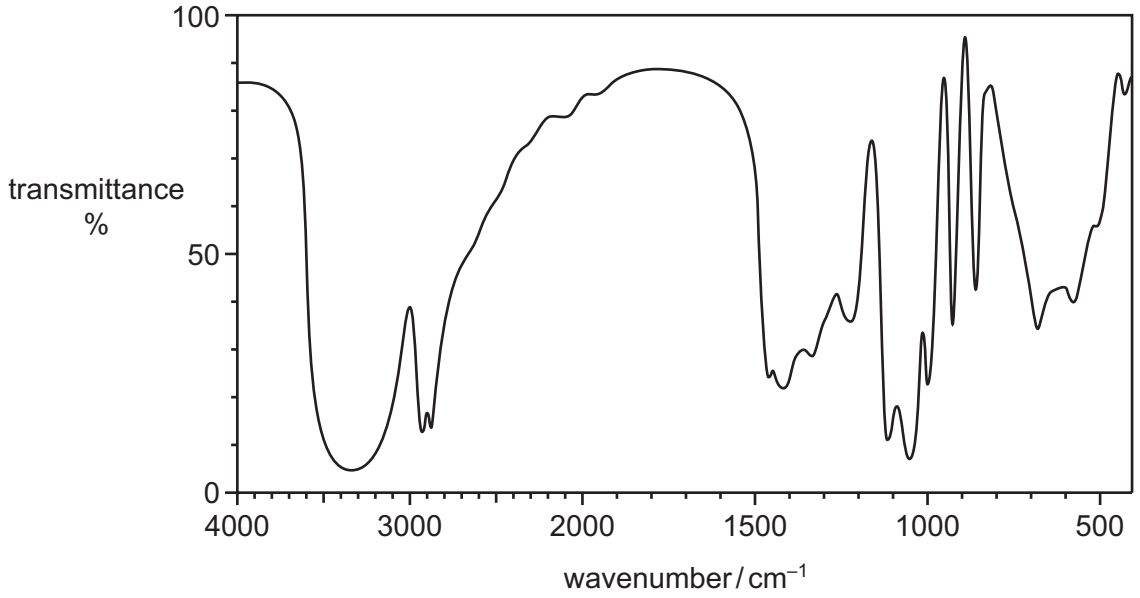


D



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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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