Cambridge Assessment International Education

Cambridge International AS & A Level

CHEMISTRY **9701/11**

Paper 1 Multiple Choice **October/November 2025**

1 hour 15 minutes

You must answer on the multiple choice answer sheet.

4120668224

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 **16** pages.

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1 What is the electronic configuration for the particle $^{27}_{13}Al^{+}$?

A $1s^2 2s^2 2p^6 3s^1 3p^1$

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

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

D $1s^2 2s^2 2p^6 3s^2 3p^6 3d^7 4s^1$

2 The data in the table gives the 5th to the 10th ionisation energies of three elements from Period 3 of the Periodic Table.

element	ionisation energy / kJ mol^{-1}					
	5th	6th	7th	8th	9th	10th
X	6274	21 269	25 398	29 855	35 868	40 960
Y	7012	8 496	27 107	31 671	36 579	43 140
Z	6542	9 362	11 018	33 606	38 601	43 963

What are the correct identities of these three elements?

	element X	element Y	element Z
A	Na	Mg	A*l*
B	Mg	A*l*	Si
C	P	S	C*l*
D	S	C*l*	Ar

3 What contains 9.03×10^{23} oxygen atoms?

A 0.25 mol aluminium oxide

B 0.75 mol sulfur dioxide

C 1.5 mol sulfur trioxide

D 3.0 mol water

4 Methane and steam react to produce hydrogen.

$$CH_4(g) + 2H_2O(g) \rightarrow CO_2(g) + 4H_2(g)$$

0.80 g of methane and 1.35 g of steam react. One of the reactants is used up.

Which volume of hydrogen, measured at room conditions, will be produced?

A 1.80 dm^3 **B** 3.60 dm^3 **C** 4.80 dm^3 **D** 7.20 dm^3

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5 Which statement explains why sodium and potassium have different melting points?

A The attraction between cations and delocalised electrons is stronger in sodium.

B The attraction between cations and anions is stronger in sodium.

C The attraction between atoms is stronger in sodium.

D The attraction between nuclei and shared electron pairs is stronger in sodium.

6 NH_3 and HCN react together to form NH_4CN, an ionic compound.

Which row states the number of coordinate bonds and the number of π bonds in one formula unit of NH_4CN?

	number of coordinate bonds	number of π bonds
A	0	2
B	1	2
C	0	3
D	1	3

7 When 1.0 mol of ethanoic acid, CH_3COOH, in aqueous solution is neutralised by an excess of aqueous sodium hydroxide, 55 kJ mol^{-1} of energy is released.

Which statement about this reaction is correct?

A The reaction is exothermic because only bond breaking takes place.

B The reaction is exothermic because only bond forming takes place.

C The reaction is exothermic because more energy is given out in breaking bonds than is taken in to form bonds.

D The reaction is exothermic because more energy is given out in forming bonds than is taken in to break bonds.

8 In an experiment, 1.60 g of a fuel is burnt. 45.0% of the energy released is absorbed by 200 g of water. The temperature of the water rises from 18.0 °C to 66.0 °C.

What is the total energy released per gram of fuel burnt?

A 25 100 J **B** 55 700 J **C** 89 200 J **D** 143 000 J

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9 Sulfite ions, SO_3^{2-}, react separately with zinc and with manganese dioxide.

a, *b*, *c*, *d*, *w*, *x*, *y* and *z* are all whole numbers.

$$a SO_3^{2-}(aq) + b H_2O(l) + Zn(s) \rightarrow Zn^{2+}(aq) + c OH^-(aq) + d S_2O_4^{2-}(aq)$$

$$MnO_2(s) + w SO_3^{2-}(aq) + x H^+(aq) \rightarrow Mn^{2+}(aq) + y S_2O_6^{2-}(aq) + z H_2O(l)$$

Which numbers are correct for *a*, *b*, *w* and *x*?

	a	*b*	*w*	*x*
A	1	2	2	4
B	2	2	2	4
C	1	2	4	2
D	2	2	4	2

10 Which equation shows hydrogen acting as an oxidising agent?

A $H_2 + 2K \rightarrow 2K^+H^-$

B $H_2 + I_2 \rightarrow 2HI$

C $H_2 + Cu_2S + ZnO \rightarrow 2Cu + ZnS + H_2O$

D $3H_2 + N_2 \rightarrow 2NH_3$

11 1.00 g of nitrogen gas is stored in a 2.00 dm^3 vessel at 40.0 °C.

What is the pressure in the vessel?

A 5940 Pa **B** 11 900 Pa **C** 46 400 Pa **D** 92 900 Pa

12 One molecule of haemoglobin, Hb, can bind with four molecules of oxygen according to the equation shown.

$$Hb(aq) + 4O_2(aq) \rightleftharpoons Hb(O_2)_4(aq)$$

When the equilibrium concentration of O_2 is 7.6×10^{-6} mol dm^{-3}, the equilibrium concentrations of Hb and $Hb(O_2)_4$ are equal.

What is the numerical value of K_c for this equilibrium?

A 3.0×10^{20} **B** 1.3×10^{5} **C** 7.6×10^{-6} **D** 3.3×10^{-21}

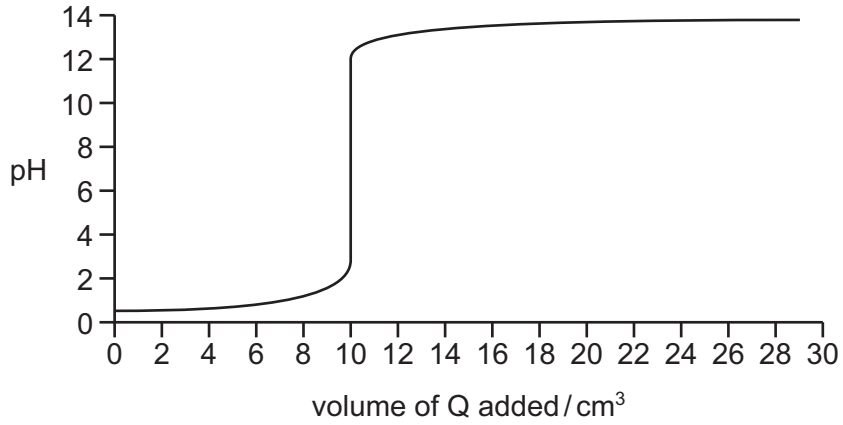
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13 Aqueous acid P and aqueous alkali Q have the same concentration.

$20\,cm^3$ of P is added to a conical flask.

Q is slowly added to the flask and the volume of Q and the pH are recorded.

The pH titration curve is shown.



Which row gives the identity of P and Q?

	P	Q
A	HCl	NaOH
B	H_2SO_4	NH_3
C	HCl	$Ba(OH)_2$
D	CH_3COOH	$Sr(OH)_2$

14 Photochromic glass, used for sunglasses, darkens when exposed to bright light and becomes more transparent again when the light is less bright. The darkness of the glass is due to the presence of silver atoms.

The following reactions are involved.

reaction 1 $Ag^+ + Cl^- \rightleftharpoons Ag + Cl$

reaction 2 $Cu^+ + Cl \rightarrow Cu^{2+} + Cl^-$

reaction 3 $Cu^{2+} + Ag \rightarrow Cu^+ + Ag^+$

Which statement about these reactions is correct?

A Cu^+ and Cu^{2+} ions act as catalysts.

B Cu^+ ions act as an oxidising agent in reaction 2.

C Reaction 3 increases the darkness of the glass.

D Silver atoms are reduced in reaction 3.

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15 The reversible reaction between methanol and ethanoic acid liquids is catalysed by adding a small volume of concentrated sulfuric acid.

Two statements about this reaction are listed.

1 The sulfuric acid is a homogeneous catalyst.

2 The sulfuric acid lowers the activation energy of the reverse reaction.

Which statements are correct?

A both 1 and 2

B 1 only

C 2 only

D neither 1 nor 2

16 The atomic radii and ionic radii for three elements in Period 3 are shown.

	atomic radius / nm	ionic radius / nm
element X	0.118	0.053
element Y	0.099	0.180
element Z	0.160	0.072

Using this data, which statement is correct?

A Element X has lower electrical conductivity than element Y.

B Element Y has a higher melting point than element X.

C Element Y and element Z react to form an ionic compound.

D Element Z forms ionic compounds by gaining electrons.

17 Three equations are listed. *x*, *y* and *z* are all whole numbers.

1 $x\mathrm{A}l + y\mathrm{O_2} \rightarrow z\mathrm{A}l_2\mathrm{O_3}$

2 $x\mathrm{Mg} + y\mathrm{O_2} \rightarrow z\mathrm{MgO}$

3 $x\mathrm{Na} + y\mathrm{O_2} \rightarrow z\mathrm{Na_2O}$

Which equations can be balanced if $x = 4$ and $z = 2$?

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

18 Which oxide has a simple structure rather than a giant structure?

A MgO **B** $\mathrm{A}l_2\mathrm{O_3}$ **C** $\mathrm{SiO_2}$ **D** $\mathrm{P_4O_{10}}$

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19 The trends seen in Group 2 can be used to predict the properties of radium and its compounds.

Which statement is correct?

A Radium has the highest second ionisation energy of the elements in Group 2.

B Radium hydroxide is the least soluble of the hydroxides of the elements in Group 2.

C Radium carbonate has the lowest thermal stability of the carbonates of the elements in Group 2.

D Radium reacts faster with water than the other elements in Group 2.

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

Which compound will produce the greatest volume of gas?

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

21 Equation 1 and equation 2 show two different reactions of halide ion Q^- with concentrated sulfuric acid.

equation 1 $H_2SO_4 + Q^- \rightarrow HSO_4^- + HQ$

equation 2 $H_2SO_4 + 2Q^- + 2H^+ \rightarrow SO_2 + Q_2 + 2H_2O$

What is Q?

A Cl^- or Br^- **B** Br^- or I^- **C** Cl^- only **D** I^- only

22 What happens when iodine solution is added to a solution of sodium bromide?

A A reaction occurs without changes in oxidation state.

B Bromide ions are oxidised; iodine atoms are reduced.

C Bromide ions are reduced; iodine atoms are oxidised.

D No reaction occurs.

23 Which statement is correct?

A Nitrogen is unreactive due to the absence of lone pairs in the molecule.

B Aqueous ammonia contains both $NH_3(aq)$ and $NH_4^+(aq)$. The $NH_4^+(aq)$ ion is a Brønsted–Lowry acid.

C High temperatures are needed to supply the energy to break the strong double bonds in nitrogen molecules when they react.

D Atmospheric SO_2 reacts with unburnt hydrocarbons to form a component of photochemical smog.

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24 When dry ammonia and hydrogen chloride gases are mixed, a solid white ionic compound is formed.

Two statements are listed.

1 The formation of the ionic compound is a redox reaction.

2 During the formation of the ionic compound, the H–N–H bond angle increases.

Which statements are correct?

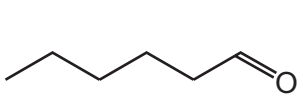
A both 1 and 2

B 1 only

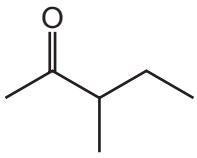
C 2 only

D neither 1 nor 2

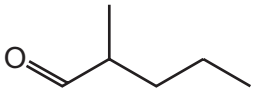
25 The diagrams show skeletal formulas of some isomers of $C_6H_{12}O$.



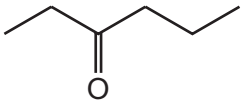
1



2



3



4

Which statement is correct?

A 1 and 3 are chain isomers of each other and positional isomers of each other.

B 2 and 3 are functional group isomers of each other and both have a chiral centre.

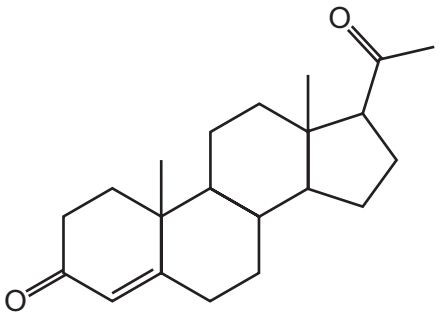
C 1 and 4 are functional group isomers of each other and both have a chiral centre.

D 2 and 4 are positional isomers of each other and functional group isomers of each other.

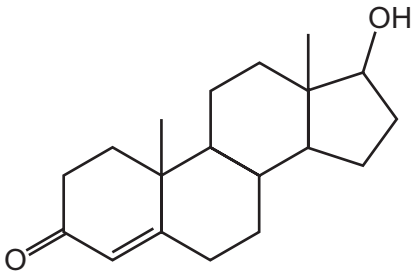
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26 The skeletal formulas of two compounds are shown.

progesterone



testosterone



Which statements about progesterone and testosterone are correct?

A They both contain a ketone group, and they both have geometrical isomers due to the C=C bond.

B They have the same molecular formula, and they both have geometrical isomers.

C They have the same number of chiral carbons, and they have the same molecular formula.

D They have the same number of chiral carbons, and they both contain a ketone group.

27 Which intermediate ion forms in the greatest amount during the addition of HBr to propene?

A $CH_3CH^+CH_3$

B $CH_3CH_2CH_2^+$

C $CH_3CH^-CH_2Br$

D $CH_3CHBrCH_2^-$

28 Two hydrocarbons, $R–CH_3$ and $R'–CH_3$, react separately with bromine in the presence of ultraviolet light. One of these hydrocarbons is unsaturated.

In each case, free radical substitution reactions occur.

R is $CH_3CHC(CH_3)$.

R' is $CH_3CH(CH_3)CH_2$.

Which row is correct?

	a propagation stage for the saturated hydrocarbon	a termination stage for the unsaturated hydrocarbon
A	$R–CH_2• + Br• \rightarrow R–CH_2Br$	$R'–CH_2• + Br• \rightarrow R'–CH_2Br$
B	$R–CH_2• + Br_2 \rightarrow R–CH_2Br + Br•$	$R'–CH_2• + Br_2 \rightarrow R'–CH_2Br + Br•$
C	$R'–CH_3 + Br• \rightarrow R'–CH_2• + HBr$	$2R–CH_2• \rightarrow R–CH_2CH_2–R$
D	$2R'–CH_2• \rightarrow R'–CH_2CH_2–R'$	$R–CH_3 + Br• \rightarrow R–CH_2• + HBr$

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29 The fumes from the exhausts of petrol-burning cars contain the following pollutants.

1 unburnt hydrocarbons

2 nitrogen dioxide

3 carbon monoxide

Which pollutants are removed by oxidation in a catalytic converter?

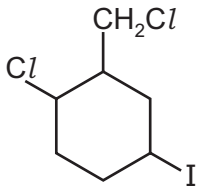
A 1, 2 and 3 **B** 1 and 2 only **C** 1 and 3 only **D** 2 and 3 only

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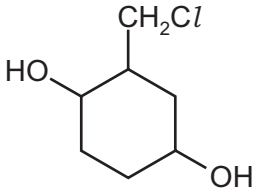
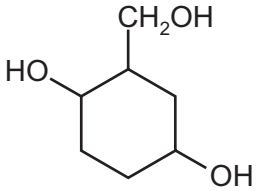
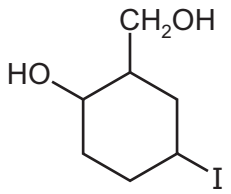
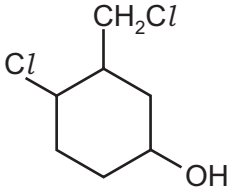
30 Compound X, $C_7H_{11}IC\mathit{l}_2$, is dissolved in ethanol and the solution mixed with warm aqueous silver nitrate.

A precipitate is seen immediately.

compound X



What is the colour of this precipitate and what is the structural formula of the **first** organic product?

	colour of the precipitate	structural formula of the **first** organic product
A	cream	
B	cream	
C	white	
D	yellow	

31 1,4-dibromobutane reacts with an excess of ethanolic sodium hydroxide until no further reaction takes place.

What is the relative formula mass of the major organic product?

A 54 **B** 56 **C** 74 **D** 90

32 A small section of a polymer produced from two monomers is shown.

$$–CH_2–C(CH_3)_2–CH(CH_3)–CH_2–$$

What are the two monomers?

A but-1-ene and propene

B but-2-ene and propene

C ethene and pent-2-ene

D methylpropene and propene

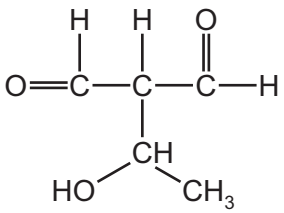
33 The balanced equation for the reaction of X with an excess of acidified $K_2Cr_2O_7$ is shown.

$$X + 3[O] \rightarrow Y + H_2O$$

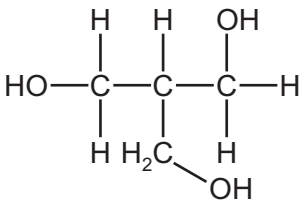
Compound Y is the only organic product of the reaction.

Which compound is X?

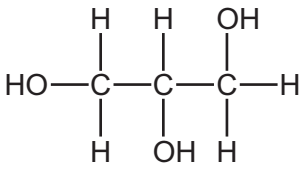
A



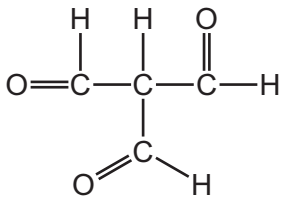
B



C



D



34 Three mixtures are heated under reflux.

Which mixtures will produce sodium propanoate as one product?

1 $CH_3CH_2CHO + NaBH_4(aq)$

2 $CH_3CH_2CH_2OH + Na(s)$

3 $CH_3CH_2CN + NaOH(aq)$

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

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35 Which compound is a product of the hydrolysis of $CH_3CO_2CH_2C_2H_5$ using aqueous sodium hydroxide?

A $CH_3CO_2^-Na^+$

B CH_3CO_2H

C $C_2H_5CH_2O^-Na^+$

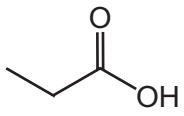
D $C_2H_5CH_2CO_2^-Na^+$

36 Compound Q reacts when heated with HCN in the presence of a catalyst to produce compound R.

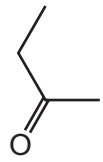
Molecules of compound R each contain four carbon atoms.

What is compound Q?

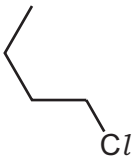
A



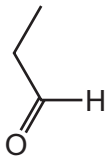
B



C



D



37 The table shows the reagents and products of three reactions.

	reagents	products
1	ethanoic acid + Na_2CO_3	$CH_3CO_2Na + H_2O + CO_2$
2	ethanoic acid + Mg	$(CH_3CO_2)_2Mg + H_2O$
3	ethanoic acid + CH_3OH	$CH_3CO_2CH_3 + H_2O$

Which rows are correct?

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

38 Seven aldehydes and ketones

- contain only **one** oxygen atom per molecule
- have four or fewer carbon atoms in their structures.

Alkaline I_2(aq) is added to each of these carbonyl compounds separately.

How many of these carbonyl compounds produce a yellow precipitate with alkaline I_2(aq)?

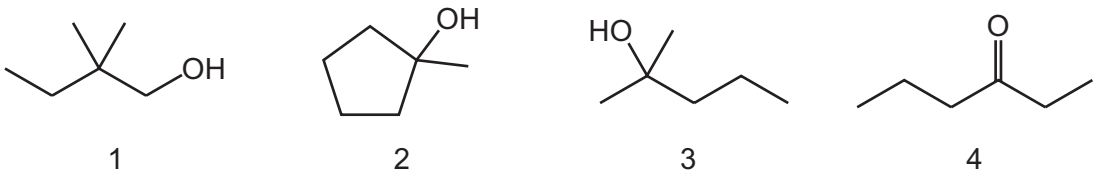
A 1 **B** 2 **C** 3 **D** 4

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39 Some properties of compound X are listed.

- 1.0 mol X reacts with exactly 8.5 mol oxygen when completely combusted.
- X does **not** react when heated with acidified $KMnO_4$.

What are the possible identities of X?



1 2 3 4

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

40 A sample of magnesium contains the isotopes ^{24}Mg, ^{25}Mg and ^{26}Mg only.

The percentage abundance of ^{25}Mg and ^{26}Mg is the same.

The relative atomic mass of magnesium in the sample is 24.3.

What is the percentage abundance of ^{24}Mg?

A 10% **B** 20% **C** 60% **D** 80%

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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	$L = 6.02 \times 10^{23}\,\text{mol}^{-1}$
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	3	4	5	6	7	8	9	10	11	12	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 144.2	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 –

Cambridge Assessment International Education

Cambridge International AS & A Level

CHEMISTRY **9701/12**

Paper 1 Multiple Choice **October/November 2025**

1 hour 15 minutes

You must answer on the multiple choice answer sheet.

0883971175

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

INSTRUCTIONS

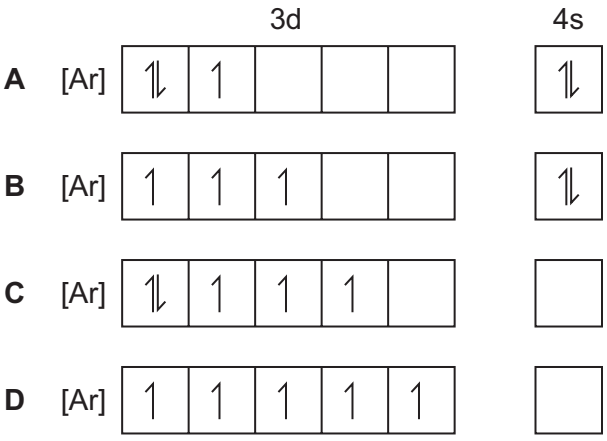
- There are **forty** questions on this paper. Answer **all** questions.
- For each question there are four possible answers **A**, **B**, **C** and **D**. Choose the **one** you consider correct and record your choice in soft pencil on the multiple choice answer sheet.
- Follow the instructions on the 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.

IB25 11_9701_12/5RP
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1 What is the electrons in boxes notation for the Fe^{3+} ion?



2 Which equation has an energy change that is equal to the first ionisation energy of bromine?

A $Br(g) \rightarrow Br^+(g) + e^-$

B $Br(g) \rightarrow Br^-(g) - e^-$

C $\frac{1}{2}Br_2(g) \rightarrow Br^+(g) + e^-$

D $\frac{1}{2}Br_2(g) \rightarrow Br^-(g) - e^-$

3 The reaction of hydrogen sulfide with sulfur dioxide gives sulfur as one of the products.

The two relevant redox equations are shown.

$$H_2S(aq) \rightleftharpoons S(s) + 2H^+(aq) + 2e^-$$

$$SO_2(aq) + 4H^+(aq) + 4e^- \rightleftharpoons S(s) + 2H_2O(l)$$

How many moles of hydrogen sulfide are needed to react with sulfur dioxide to produce 1 mol of sulfur?

A $\frac{1}{3}$ mol **B** $\frac{2}{3}$ mol **C** $\frac{3}{2}$ mol **D** 2 mol

4 Which statement is correct?

A The relative atomic mass of a ^{35}Cl atom is 35.5.

B The relative molecular mass of O_2 is 16.0.

C The relative formula mass of $CaCO_3$ is 100.1.

D The relative isotopic mass of a ^{24}Mg atom is 24.3.

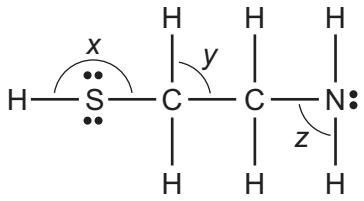
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5 The bonding between two atoms of nitrogen in an N_2 molecule involves the hybridisation of atomic orbitals to form sp orbitals.

Which row is correct?

	formation of the σ bond between the nitrogen atoms in N_2	type of orbital which contains the lone pair of electrons on each nitrogen atom in N_2
A	an sp orbital from one atom overlaps with an sp orbital of the other atom	p
B	an sp orbital from one atom overlaps with an sp orbital of the other atom	sp
C	an s orbital from one atom overlaps with a p orbital of the other atom	p
D	an s orbital from one atom overlaps with a p orbital of the other atom	sp

6 Three bond angles are labelled on the molecule shown.



: represents a lone pair of electrons

What is the order of **decreasing** size of the bond angles *x*, *y* and *z*?

	largest ⟶		smallest
A	*x*	*y*	*z*
B	*x*	*z*	*y*
C	*y*	*z*	*x*
D	*z*	*y*	*x*

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7 X and Y are different elements in Period 3.

Atoms of X and Y each have only one completely filled orbital in their highest occupied energy sub-shell.

Y has a greater first ionisation energy than X.

Which row shows the structure and bonding in X and Y?

	X	Y
A	giant metallic	giant metallic
B	giant metallic	simple molecular
C	giant covalent	simple molecular
D	simple molecular	simple molecular

8 A pure sample of a gas has a density of $2.62\,g\,dm^{-3}$ at 101 000 Pa and 25 °C. The gas behaves ideally under these conditions.

Which expression gives the M_r of the gas?

A $\dfrac{101000 \times 0.001}{2.62 \times 8.31 \times 25}$

B $\dfrac{101000 \times 0.001}{2.62 \times 8.31 \times 298}$

C $\dfrac{2.62 \times 8.31 \times 25}{101000 \times 0.001}$

D $\dfrac{2.62 \times 8.31 \times 298}{101000 \times 0.001}$

9 When 0.47 g of a hydrocarbon is completely burnt in air, the energy released heats 200 g of water from 23.7 °C to 41.0 °C.

What is the amount of energy absorbed, in Joules, by the water?

A $0.47 \times 4.18 \times 17.3$

B $0.47 \times 4.18 \times (273 + 17.3)$

C $200 \times 4.18 \times 17.3$

D $200 \times 4.18 \times (273 + 17.3)$

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10 One commercially available 'heat pad' contains iron, activated carbon and water. The 'heat pad' is activated by air. This causes the pad to get hotter.

Which statement describes the chemical reaction occurring in the 'heat pad' when it is exposed to air?

A The reaction is endothermic and iron gains electrons.

B The reaction is endothermic and iron loses electrons.

C The reaction is exothermic and iron gains electrons.

D The reaction is exothermic and iron loses electrons.

11 In which substance is the average oxidation number of sulfur the highest?

A S_8 **B** $Na_2S_4O_6$ **C** $Na_2S_2O_3$ **D** SO_2Cl_2

12 An equilibrium can be represented by the equation shown.

$$P(aq) + Q(aq) \rightleftharpoons 2R(aq) + S(aq)$$

In a certain mixture, of volume 1.0 dm^3, the equilibrium concentration of Q is 10 mol dm^{-3}.

What will be the new equilibrium concentration of Q if 5.0 mol of pure Q is completely dissolved in the mixture?

A 15 mol dm^{-3}

B between 10 mol dm^{-3} and 15 mol dm^{-3}

C 10 mol dm^{-3}

D between 5.0 mol dm^{-3} and 10 mol dm^{-3}

13 In the Contact process, sulfur dioxide and oxygen react to form sulfur trioxide.

In the Haber process, nitrogen and hydrogen react to form ammonia.

Which statement about these processes is correct?

A K_p for the Haber process has no unit.

B In the Contact process, the value of K_p falls when pressure is increased at constant T.

C The Haber process uses a homogeneous catalyst.

D When V_2O_5 is used in the Contact process, the position of equilibrium is unchanged.

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14 $20.0\,cm^3$ of hydrogen peroxide decomposes to water and oxygen in the presence of a suitable catalyst.

$160\,cm^3$ of oxygen, measured at room conditions, is produced in 5.00 minutes.

What is the average rate of decomposition of hydrogen peroxide during this reaction period?

A $2.22 \times 10^{-5}\,mol\,s^{-1}$

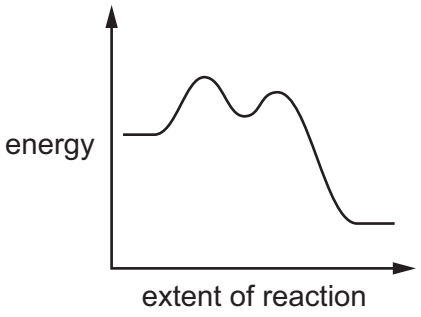
B $4.44 \times 10^{-5}\,mol\,s^{-1}$

C $1.76 \times 10^{-4}\,mol\,s^{-1}$

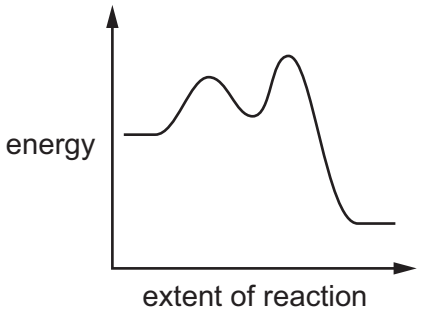
D $2.67 \times 10^{-3}\,mol\,s^{-1}$

15 Which reaction pathway diagram shows an endothermic reaction that occurs in two steps and in which the second step of the reaction is likely to be faster than the first?

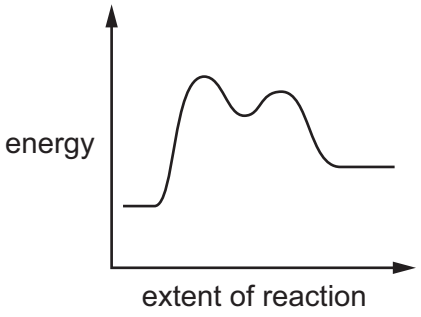
A



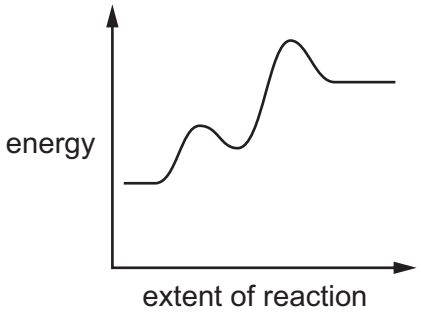
B



C



D



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16 Oxides of nitrogen, NO_x, are involved in formation of photochemical smog and acid rain.

Which oxides of nitrogen are involved in each of these processes?

	photochemical smog		acid rain	
	NO	NO_2	NO	NO_2
A	✓	✓	✓	✓
B	✗	✓	✗	✓
C	✓	✓	✗	✓
D	✗	✓	✓	✓

17 Sodium and sulfur react together to form sodium sulfide, Na_2S.

How do the atomic radius and ionic radius of sodium compare with those of sulfur?

	atomic radius	ionic radius
A	sulfur is greater	sodium is greater
B	sulfur is greater	sulfur is greater
C	sodium is greater	sodium is greater
D	sodium is greater	sulfur is greater

18 Compound X is an oxide of a Period 3 element.

Compound X is a white solid at 25 °C. It reacts with water to form an acidic solution.

What is compound X?

A aluminium oxide

B silicon dioxide

C sulfur dioxide

D phosphorus(V) oxide

19 When heated, magnesium nitrate decomposes.

Which equation for the thermal decomposition of magnesium nitrate is correct?

A $Mg(NO_3)_2 \rightarrow MgO + NO_2 + NO + O_2$

B $2Mg(NO_3)_2 \rightarrow 2MgO + 4NO + 3O_2$

C $2Mg(NO_3)_2 \rightarrow 2MgO + 4NO_2 + O_2$

D $3Mg(NO_3)_2 \rightarrow Mg_2N_3 + MgO + 3NO + 7O_2$

20 R is the aqueous solution of an ionic compound.

- A white precipitate is formed when R is added to $Sr(NO_3)_2(aq)$.
- No visible reaction is seen when R is added to dilute $HNO_3(aq)$.

What is the anion present in compound R?

A Cl^- **B** SO_4^{2-} **C** HCO_3^- **D** CO_3^{2-}

21 In an experiment, 0.600 mol of chlorine gas, Cl_2, is reacted with an excess of hot aqueous sodium hydroxide. One of the products is $NaClO_3$.

Which mass of $NaClO_3$ is formed?

A 21.3 g **B** 44.7 g **C** 63.9 g **D** 128 g

22 X and Y are sodium salts of Group 17 elements.

When X reacts with concentrated sulfuric acid, hydrogen sulfide, H_2S, is produced.

When Y reacts with concentrated sulfuric acid, there is no change in the oxidation number of the sulfur.

Which statement is correct?

A Aqueous X reduces aqueous bromine.

B Aqueous Y reacts with aqueous silver nitrate to give a precipitate which is insoluble in concentrated aqueous ammonia.

C X and Y react separately with concentrated sulfuric acid to produce halogens.

D When X reacts with concentrated sulfuric acid, six halide ions are needed to reduce one sulfur atom to H_2S.

23 Element E is in Period 3. It forms a chloride which reacts with a small amount of water to produce a white precipitate and steamy fumes. This precipitate is soluble in NaOH(aq) and in $HCl(aq)$.

What is element E?

A magnesium

B aluminium

C silicon

D phosphorus

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24 Four reaction mixtures are listed.

1 $(NH_4)_2SO_4(aq)$ and NaOH

2 $NH_4Cl(aq)$ and $Ba(OH)_2$

3 $NH_4Cl(aq)$ and Na_2O

4 $(NH_4)_3PO_4(aq)$ and HCl

Which reaction mixtures produce ammonia as a product?

A 1, 2 and 3 **B** 1 and 2 only **C** 2 and 3 only **D** 3 and 4 only

25 Two statements about a molecule of methanal are given.

1 It is planar.

2 It contains three σ bonds.

Which statements are correct?

A both 1 and 2

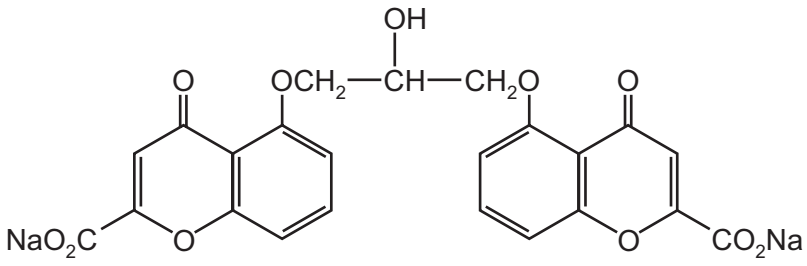
B 1 only

C 2 only

D neither 1 nor 2

26 The structure of disodium cromoglycate is shown.

disodium cromoglycate



How many chiral centres are there in this molecule?

A 0 **B** 1 **C** 2 **D** 3

27 What is the major product when 2-methylpent-2-ene reacts with hydrogen bromide?

A 1-bromo-2-methylpentane

B 2-bromo-2-methylpentane

C 3-bromo-2-methylpentane

D 4-bromo-2-methylpentane

28 Pent-2-ene is reacted with cold, dilute, acidified manganate(VII) ions.

What is the major product?

A $CH_3CH_2CH(OH)CH(OH)CH_3$

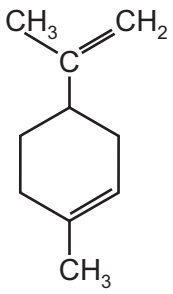
B $CH_3CH_2COCOCH_3$

C a mixture of $CH_3CH_2CH(OH)CH_2CH_3$ and $CH_3CH_2CH_2CH(OH)CH_3$

D CH_3CH_2COOH and CH_3COOH

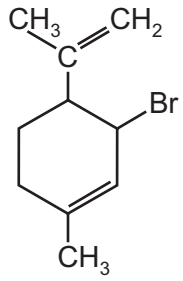
29 Limonene is an oil formed in the peel of citrus fruits.

limonene

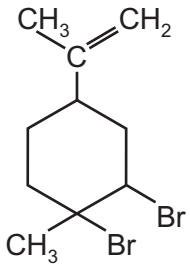


Which product is formed when an excess of bromine, $Br_2(l)$, reacts with limonene at room temperature in the dark?

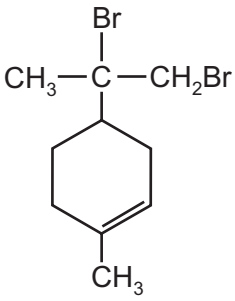
A



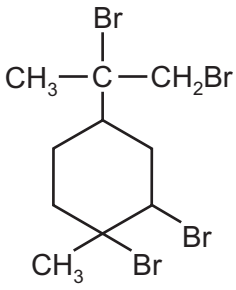
B



C



D



30 Which reaction mixture produces a nitrile?

A halogenoalkane with KCN in ethanol

B halogenoalkane with NH_3 in ethanol

C ketone with 2,4-DNPH

D carboxylic acid with NH_3 in water

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31 Which reaction is classified as S_N1?

A the reaction of 1-chloropropane with ammonia in ethanol

B the reaction of 1-chloropropane with potassium hydroxide in ethanol

C the reaction of 2-chloro-2-methylpropane with potassium cyanide in ethanol

D the reaction of 2-chloro-2-methylpropane with potassium hydroxide in ethanol

32 Which reaction mixture produces a primary alcohol as the major product?

A propanone with $NaBH_4$

B propene with steam in the presence of H_3PO_4

C butanoic acid with $LiAlH_4$

D ethene with hot concentrated acidified $KMnO_4$

33 $HOCH_2CHO$ is heated under reflux with an excess of acidified $K_2Cr_2O_7$ until there is no further reaction.

What is the final product of this reaction?

A HOOCCHO

B $HOCH_2COOH$

C HOOCCOOH

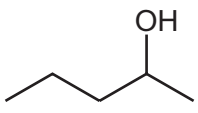
D $HOOCCH_2COOH$

34 An organometallic lithium compound, RLi, contains the nucleophile R^-.

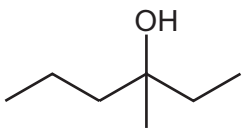
CH_3CH_2Li reacts with pentan-2-one. The mechanism is nucleophilic addition. The first step produces an anion which is then protonated to form the final product.

Which organic product is formed?

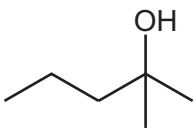
A



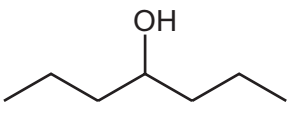
B



C

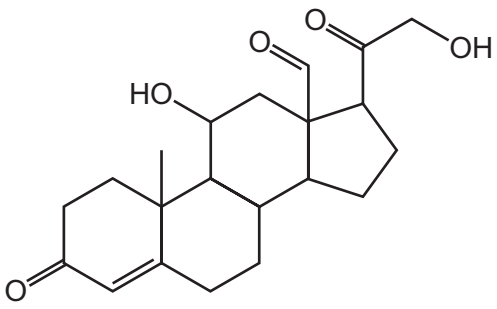


D



35 The structure of a naturally occurring compound, Q, is shown.

compound Q



Compound Q is heated under reflux with an excess of acidified $KMnO_4$.

Organic product R is formed.

Which row is correct?

	results of tests with compound Q	results of tests with organic product R
A	orange precipitate with 2,4-DNPH and no reaction with alkaline I_2(aq)	yellow precipitate with alkaline I_2(aq) and no reaction with Fehling's reagent
B	red precipitate with Fehling's reagent and no reaction with alkaline I_2(aq)	orange precipitate with 2,4-DNPH and no reaction with alkaline I_2(aq)
C	yellow precipitate with alkaline I_2(aq) and orange precipitate with 2,4-DNPH	no reaction with alkaline I_2(aq) and no reaction with Fehling's reagent
D	yellow precipitate with alkaline I_2(aq) and red precipitate with Fehling's reagent	yellow precipitate with alkaline I_2(aq) and orange precipitate with 2,4-DNPH

36 Which organic starting material could be used in a single reaction to produce propanoic acid?

A ethanenitrile

B propan-2-ol

C propanal

D propyl ethanoate

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37 In four separate reactions, W, X, Y and Z, 1 mol of an organic compound reacts with an excess of a reagent.

	organic compound	reagent
W	$(CH_2COOH)_2$	Na
X	$CH_3CH(OH)CH_2COOH$	Na_2CO_3
Y	$CH_3CH(OH)CH_2COOH$	NaOH
Z	$CH(OH)(COOH)CH_2COOH$	Na

The volume of any gas produced is collected and measured. All gas volumes are measured at the same temperature and pressure.

What is the order of the reactions from greatest total volume of gas collected to least total volume of gas collected?

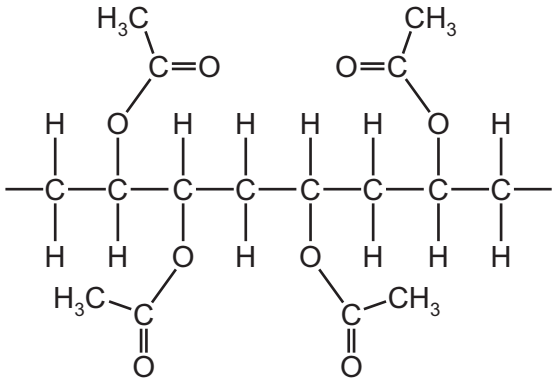
	greatest volume → least volume			
A	W	Y	Z	X
B	W	Z	Y	X
C	Z	W	X	Y
D	Z	X	W	Y

38 Butylamine can be produced by the reaction of butanenitrile with hydrogen in the presence of a suitable catalyst.

Which volume of hydrogen, measured at room conditions, is required to react completely with 0.500 g of butanenitrile?

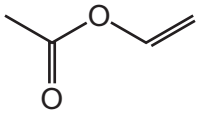
A 145 cm^3 **B** 174 cm^3 **C** 289 cm^3 **D** 348 cm^3

39 A section of an addition polymer is shown.

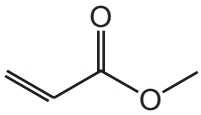


Which monomer is used to make this polymer?

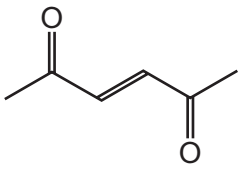
A



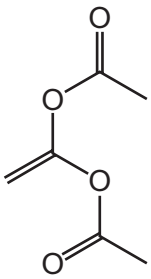
B



C



D



40 The purity of a compound can be determined using infrared spectroscopy.

The table gives the characteristic infrared absorption frequencies for some selected bonds.

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 3200–3650

Propan-2-ol is made by hydration of propene. A sample of the product is obtained.

Which feature of the infrared spectrum of the product would show that **no** propene remains in the product?

A absorption in the 2900 cm^{-1} region

B strong absorption below 1000 cm^{-1}

C the lack of absorption at or near 1250 cm^{-1}

D the lack of absorption at or near 1550 cm^{-1}

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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	$L = 6.02 \times 10^{23}\,\text{mol}^{-1}$
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	3	4	5	6	7	8	9	10	11	12	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 144.2	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 –

Cambridge Assessment International Education

Cambridge International AS & A Level

CHEMISTRY **9701/13**

Paper 1 Multiple Choice **October/November 2025**

1 hour 15 minutes

You must answer on the multiple choice answer sheet.

1620770458

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 **16** pages.

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1 What is the electronic configuration for the particle $^{27}_{13}Al^{+}$?

A $1s^2 2s^2 2p^6 3s^1 3p^1$

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

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

D $1s^2 2s^2 2p^6 3s^2 3p^6 3d^7 4s^1$

2 The data in the table gives the 5th to the 10th ionisation energies of three elements from Period 3 of the Periodic Table.

element	ionisation energy / kJ mol^{-1}					
	5th	6th	7th	8th	9th	10th
X	6274	21 269	25 398	29 855	35 868	40 960
Y	7012	8 496	27 107	31 671	36 579	43 140
Z	6542	9 362	11 018	33 606	38 601	43 963

What are the correct identities of these three elements?

	element X	element Y	element Z
A	Na	Mg	Al
B	Mg	Al	Si
C	P	S	Cl
D	S	Cl	Ar

3 What contains 9.03×10^{23} oxygen atoms?

A 0.25 mol aluminium oxide

B 0.75 mol sulfur dioxide

C 1.5 mol sulfur trioxide

D 3.0 mol water

4 Methane and steam react to produce hydrogen.

$$CH_4(g) + 2H_2O(g) \rightarrow CO_2(g) + 4H_2(g)$$

0.80 g of methane and 1.35 g of steam react. One of the reactants is used up.

Which volume of hydrogen, measured at room conditions, will be produced?

A 1.80 dm^3 **B** 3.60 dm^3 **C** 4.80 dm^3 **D** 7.20 dm^3

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5 Which statement explains why sodium and potassium have different melting points?

A The attraction between cations and delocalised electrons is stronger in sodium.

B The attraction between cations and anions is stronger in sodium.

C The attraction between atoms is stronger in sodium.

D The attraction between nuclei and shared electron pairs is stronger in sodium.

6 NH_3 and HCN react together to form NH_4CN, an ionic compound.

Which row states the number of coordinate bonds and the number of π bonds in one formula unit of NH_4CN?

	number of coordinate bonds	number of π bonds
A	0	2
B	1	2
C	0	3
D	1	3

7 When 1.0 mol of ethanoic acid, CH_3COOH, in aqueous solution is neutralised by an excess of aqueous sodium hydroxide, 55 kJ mol^{-1} of energy is released.

Which statement about this reaction is correct?

A The reaction is exothermic because only bond breaking takes place.

B The reaction is exothermic because only bond forming takes place.

C The reaction is exothermic because more energy is given out in breaking bonds than is taken in to form bonds.

D The reaction is exothermic because more energy is given out in forming bonds than is taken in to break bonds.

8 In an experiment, 1.60 g of a fuel is burnt. 45.0% of the energy released is absorbed by 200 g of water. The temperature of the water rises from 18.0 °C to 66.0 °C.

What is the total energy released per gram of fuel burnt?

A 25 100 J **B** 55 700 J **C** 89 200 J **D** 143 000 J

9 Sulfite ions, SO_3^{2-}, react separately with zinc and with manganese dioxide.

a, *b*, *c*, *d*, *w*, *x*, *y* and *z* are all whole numbers.

$$a SO_3^{2-}(aq) + b H_2O(l) + Zn(s) \rightarrow Zn^{2+}(aq) + c OH^-(aq) + d S_2O_4^{2-}(aq)$$

$$MnO_2(s) + w SO_3^{2-}(aq) + x H^+(aq) \rightarrow Mn^{2+}(aq) + y S_2O_6^{2-}(aq) + z H_2O(l)$$

Which numbers are correct for *a*, *b*, *w* and *x*?

	a	*b*	*w*	*x*
A	1	2	2	4
B	2	2	2	4
C	1	2	4	2
D	2	2	4	2

10 Which equation shows hydrogen acting as an oxidising agent?

A $H_2 + 2K \rightarrow 2K^+H^-$

B $H_2 + I_2 \rightarrow 2HI$

C $H_2 + Cu_2S + ZnO \rightarrow 2Cu + ZnS + H_2O$

D $3H_2 + N_2 \rightarrow 2NH_3$

11 1.00 g of nitrogen gas is stored in a 2.00 dm^3 vessel at 40.0 °C.

What is the pressure in the vessel?

A 5940 Pa **B** 11 900 Pa **C** 46 400 Pa **D** 92 900 Pa

12 One molecule of haemoglobin, Hb, can bind with four molecules of oxygen according to the equation shown.

$$Hb(aq) + 4O_2(aq) \rightleftharpoons Hb(O_2)_4(aq)$$

When the equilibrium concentration of O_2 is 7.6×10^{-6} mol dm^{-3}, the equilibrium concentrations of Hb and $Hb(O_2)_4$ are equal.

What is the numerical value of K_c for this equilibrium?

A 3.0×10^{20} **B** 1.3×10^{5} **C** 7.6×10^{-6} **D** 3.3×10^{-21}

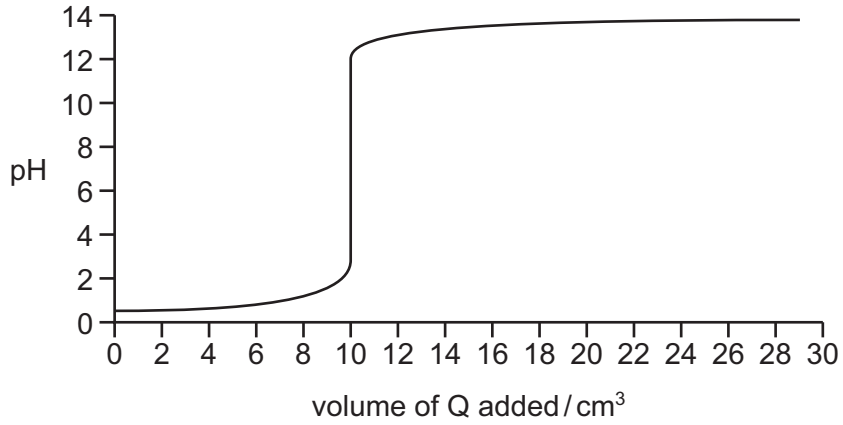
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13 Aqueous acid P and aqueous alkali Q have the same concentration.

$20\,cm^3$ of P is added to a conical flask.

Q is slowly added to the flask and the volume of Q and the pH are recorded.

The pH titration curve is shown.



Which row gives the identity of P and Q?

	P	Q
A	HCl	NaOH
B	H_2SO_4	NH_3
C	HCl	$Ba(OH)_2$
D	CH_3COOH	$Sr(OH)_2$

14 Photochromic glass, used for sunglasses, darkens when exposed to bright light and becomes more transparent again when the light is less bright. The darkness of the glass is due to the presence of silver atoms.

The following reactions are involved.

reaction 1 $Ag^+ + Cl^- \rightleftharpoons Ag + Cl$

reaction 2 $Cu^+ + Cl \rightarrow Cu^{2+} + Cl^-$

reaction 3 $Cu^{2+} + Ag \rightarrow Cu^+ + Ag^+$

Which statement about these reactions is correct?

A Cu^+ and Cu^{2+} ions act as catalysts.

B Cu^+ ions act as an oxidising agent in reaction 2.

C Reaction 3 increases the darkness of the glass.

D Silver atoms are reduced in reaction 3.

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15 The reversible reaction between methanol and ethanoic acid liquids is catalysed by adding a small volume of concentrated sulfuric acid.

Two statements about this reaction are listed.

1 The sulfuric acid is a homogeneous catalyst.

2 The sulfuric acid lowers the activation energy of the reverse reaction.

Which statements are correct?

A both 1 and 2

B 1 only

C 2 only

D neither 1 nor 2

16 The atomic radii and ionic radii for three elements in Period 3 are shown.

	atomic radius / nm	ionic radius / nm
element X	0.118	0.053
element Y	0.099	0.180
element Z	0.160	0.072

Using this data, which statement is correct?

A Element X has lower electrical conductivity than element Y.

B Element Y has a higher melting point than element X.

C Element Y and element Z react to form an ionic compound.

D Element Z forms ionic compounds by gaining electrons.

17 Three equations are listed. *x*, *y* and *z* are all whole numbers.

1 $x\mathrm{A}l + y\mathrm{O_2} \rightarrow z\mathrm{A}l_2\mathrm{O_3}$

2 $x\mathrm{Mg} + y\mathrm{O_2} \rightarrow z\mathrm{MgO}$

3 $x\mathrm{Na} + y\mathrm{O_2} \rightarrow z\mathrm{Na_2O}$

Which equations can be balanced if $x = 4$ and $z = 2$?

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

18 Which oxide has a simple structure rather than a giant structure?

A MgO **B** $\mathrm{A}l_2\mathrm{O_3}$ **C** $\mathrm{SiO_2}$ **D** $\mathrm{P_4O_{10}}$

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19 The trends seen in Group 2 can be used to predict the properties of radium and its compounds.

Which statement is correct?

A Radium has the highest second ionisation energy of the elements in Group 2.

B Radium hydroxide is the least soluble of the hydroxides of the elements in Group 2.

C Radium carbonate has the lowest thermal stability of the carbonates of the elements in Group 2.

D Radium reacts faster with water than the other elements in Group 2.

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

Which compound will produce the greatest volume of gas?

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

21 Equation 1 and equation 2 show two different reactions of halide ion Q^- with concentrated sulfuric acid.

equation 1 $H_2SO_4 + Q^- \rightarrow HSO_4^- + HQ$

equation 2 $H_2SO_4 + 2Q^- + 2H^+ \rightarrow SO_2 + Q_2 + 2H_2O$

What is Q?

A Cl^- or Br^- **B** Br^- or I^- **C** Cl^- only **D** I^- only

22 What happens when iodine solution is added to a solution of sodium bromide?

A A reaction occurs without changes in oxidation state.

B Bromide ions are oxidised; iodine atoms are reduced.

C Bromide ions are reduced; iodine atoms are oxidised.

D No reaction occurs.

23 Which statement is correct?

A Nitrogen is unreactive due to the absence of lone pairs in the molecule.

B Aqueous ammonia contains both $NH_3(aq)$ and $NH_4^+(aq)$. The $NH_4^+(aq)$ ion is a Brønsted–Lowry acid.

C High temperatures are needed to supply the energy to break the strong double bonds in nitrogen molecules when they react.

D Atmospheric SO_2 reacts with unburnt hydrocarbons to form a component of photochemical smog.

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24 When dry ammonia and hydrogen chloride gases are mixed, a solid white ionic compound is formed.

Two statements are listed.

1 The formation of the ionic compound is a redox reaction.

2 During the formation of the ionic compound, the H–N–H bond angle increases.

Which statements are correct?

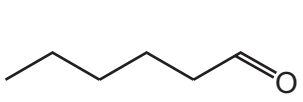
A both 1 and 2

B 1 only

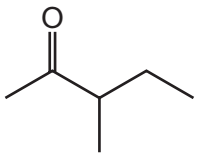
C 2 only

D neither 1 nor 2

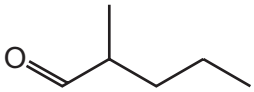
25 The diagrams show skeletal formulas of some isomers of $C_6H_{12}O$.



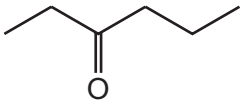
1



2



3



4

Which statement is correct?

A 1 and 3 are chain isomers of each other and positional isomers of each other.

B 2 and 3 are functional group isomers of each other and both have a chiral centre.

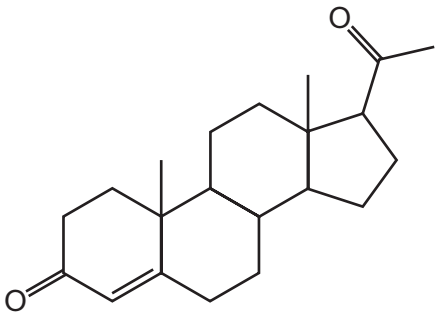
C 1 and 4 are functional group isomers of each other and both have a chiral centre.

D 2 and 4 are positional isomers of each other and functional group isomers of each other.

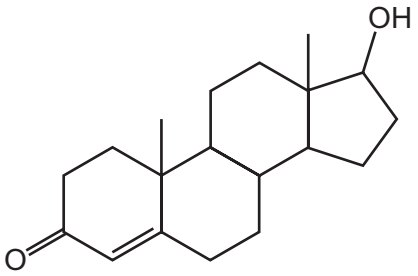
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26 The skeletal formulas of two compounds are shown.

progesterone



testosterone



Which statements about progesterone and testosterone are correct?

A They both contain a ketone group, and they both have geometrical isomers due to the C=C bond.

B They have the same molecular formula, and they both have geometrical isomers.

C They have the same number of chiral carbons, and they have the same molecular formula.

D They have the same number of chiral carbons, and they both contain a ketone group.

27 Which intermediate ion forms in the greatest amount during the addition of HBr to propene?

A $CH_3CH^+CH_3$

B $CH_3CH_2CH_2^+$

C $CH_3CH^-CH_2Br$

D $CH_3CHBrCH_2^-$

28 Two hydrocarbons, $R–CH_3$ and $R'–CH_3$, react separately with bromine in the presence of ultraviolet light. One of these hydrocarbons is unsaturated.

In each case, free radical substitution reactions occur.

R is $CH_3CHC(CH_3)$.

R' is $CH_3CH(CH_3)CH_2$.

Which row is correct?

	a propagation stage for the saturated hydrocarbon	a termination stage for the unsaturated hydrocarbon
A	$R–CH_2• + Br• \rightarrow R–CH_2Br$	$R'–CH_2• + Br• \rightarrow R'–CH_2Br$
B	$R–CH_2• + Br_2 \rightarrow R–CH_2Br + Br•$	$R'–CH_2• + Br_2 \rightarrow R'–CH_2Br + Br•$
C	$R'–CH_3 + Br• \rightarrow R'–CH_2• + HBr$	$2R–CH_2• \rightarrow R–CH_2CH_2–R$
D	$2R'–CH_2• \rightarrow R'–CH_2CH_2–R'$	$R–CH_3 + Br• \rightarrow R–CH_2• + HBr$

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29 The fumes from the exhausts of petrol-burning cars contain the following pollutants.

1 unburnt hydrocarbons

2 nitrogen dioxide

3 carbon monoxide

Which pollutants are removed by oxidation in a catalytic converter?

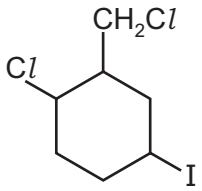
A 1, 2 and 3 **B** 1 and 2 only **C** 1 and 3 only **D** 2 and 3 only

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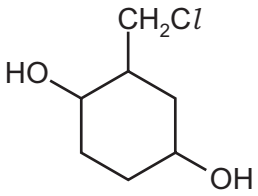
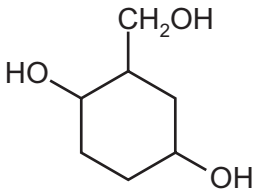
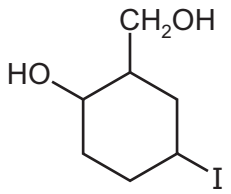
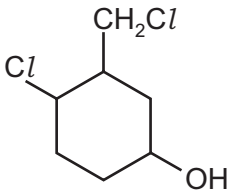
30 Compound X, $C_7H_{11}IC\mathit{l}_2$, is dissolved in ethanol and the solution mixed with warm aqueous silver nitrate.

A precipitate is seen immediately.

compound X



What is the colour of this precipitate and what is the structural formula of the **first** organic product?

	colour of the precipitate	structural formula of the **first** organic product
A	cream	
B	cream	
C	white	
D	yellow	

31 1,4-dibromobutane reacts with an excess of ethanolic sodium hydroxide until no further reaction takes place.

What is the relative formula mass of the major organic product?

A 54 **B** 56 **C** 74 **D** 90

32 A small section of a polymer produced from two monomers is shown.

$$–CH_2–C(CH_3)_2–CH(CH_3)–CH_2–$$

What are the two monomers?

A but-1-ene and propene

B but-2-ene and propene

C ethene and pent-2-ene

D methylpropene and propene

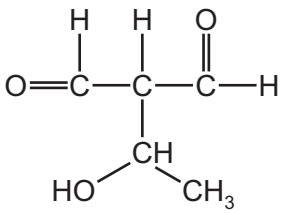
33 The balanced equation for the reaction of X with an excess of acidified $K_2Cr_2O_7$ is shown.

$$X + 3[O] \rightarrow Y + H_2O$$

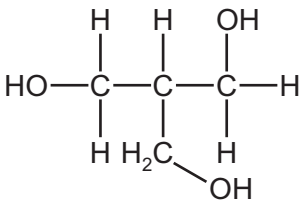
Compound Y is the only organic product of the reaction.

Which compound is X?

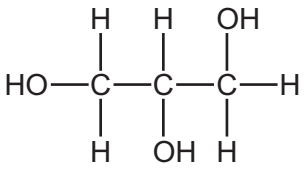
A



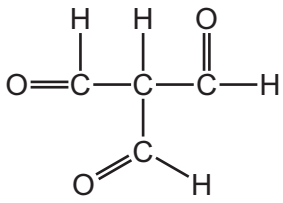
B



C



D



34 Three mixtures are heated under reflux.

Which mixtures will produce sodium propanoate as one product?

1 $CH_3CH_2CHO + NaBH_4(aq)$

2 $CH_3CH_2CH_2OH + Na(s)$

3 $CH_3CH_2CN + NaOH(aq)$

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

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35 Which compound is a product of the hydrolysis of $CH_3CO_2CH_2C_2H_5$ using aqueous sodium hydroxide?

A $CH_3CO_2^-Na^+$

B CH_3CO_2H

C $C_2H_5CH_2O^-Na^+$

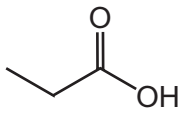
D $C_2H_5CH_2CO_2^-Na^+$

36 Compound Q reacts when heated with HCN in the presence of a catalyst to produce compound R.

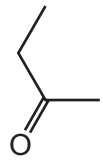
Molecules of compound R each contain four carbon atoms.

What is compound Q?

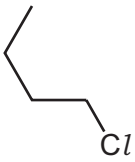
A



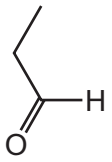
B



C



D



37 The table shows the reagents and products of three reactions.

	reagents	products
1	ethanoic acid + Na_2CO_3	$CH_3CO_2Na + H_2O + CO_2$
2	ethanoic acid + Mg	$(CH_3CO_2)_2Mg + H_2O$
3	ethanoic acid + CH_3OH	$CH_3CO_2CH_3 + H_2O$

Which rows are correct?

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

38 Seven aldehydes and ketones

- contain only **one** oxygen atom per molecule
- have four or fewer carbon atoms in their structures.

Alkaline I_2(aq) is added to each of these carbonyl compounds separately.

How many of these carbonyl compounds produce a yellow precipitate with alkaline I_2(aq)?

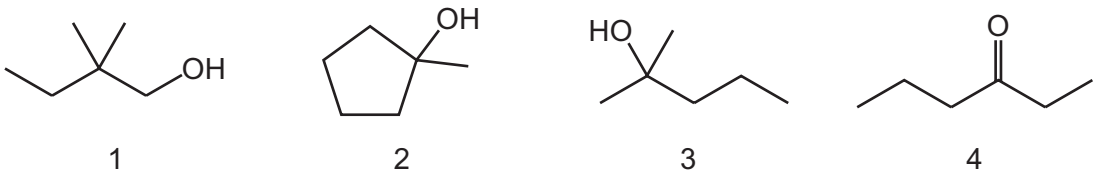
A 1 **B** 2 **C** 3 **D** 4

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39 Some properties of compound X are listed.

- 1.0 mol X reacts with exactly 8.5 mol oxygen when completely combusted.
- X does **not** react when heated with acidified $KMnO_4$.

What are the possible identities of X?



1 2 3 4

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

40 A sample of magnesium contains the isotopes ^{24}Mg, ^{25}Mg and ^{26}Mg only.

The percentage abundance of ^{25}Mg and ^{26}Mg is the same.

The relative atomic mass of magnesium in the sample is 24.3.

What is the percentage abundance of ^{24}Mg?

A 10% **B** 20% **C** 60% **D** 80%

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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	$L = 6.02 \times 10^{23}\,\text{mol}^{-1}$
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	3	4	5	6	7	8	9	10	11	12	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 144.2	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 –

Cambridge Assessment International Education

Cambridge International AS & A Level

CHEMISTRY **9701/14**

Paper 1 Multiple Choice **October/November 2025**

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.

IB25 11_9701_14/4RP
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[Turn over

1 Helium forms an ion $^{3}_{2}He^{+}$.

Three statements about this ion are listed.

1 It contains two protons.

2 It contains three neutrons.

3 It contains one electron.

Which statements are correct?

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

2 The table shows the first five ionisation energies of element X.

element	ionisation energy / kJ mol^{-1}				
	1st	2nd	3rd	4th	5th
X	736	1450	7740	10 500	13 600

Element X is in Period 3 of the Periodic Table.

What is element X?

A sodium

B magnesium

C silicon

D argon

3 Methanethiol, CH_3SH, burns as shown.

$$CH_3SH + 3O_2 \rightarrow CO_2 + SO_2 + 2H_2O$$

A sample of 10 cm^3 of methanethiol gas was reacted with 60 cm^3 of oxygen. Both samples were measured at room conditions.

What would be the final volume of the resultant mixture of gases measured at room temperature?

A 20 cm^3 **B** 30 cm^3 **C** 50 cm^3 **D** 70 cm^3

4 A solution containing 4.4 g of an organic acid is exactly neutralised by 25.0 cm^3 of 2.0 mol dm^{-3} sodium hydroxide. The acid has one COOH group in each molecule.

What is the empirical formula of the acid?

A CH_2O **B** C_2H_4O **C** $C_3H_6O_3$ **D** $C_4H_8O_2$

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5 In which set do all the molecules have all their atoms arranged in one plane?

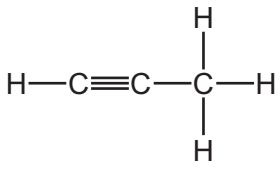
A $AlCl_3$, BF_3, PH_3

B $AlCl_3$, CO_2, NH_3

C BF_3, C_2H_4, C_3H_6

D C_2H_4, CO_2, H_2O

6 The diagram shows the bonding in a molecule of propyne.



Which types of hybridisation are shown by the carbon atoms in propyne?

A sp, sp^2 and sp^3

B sp and sp^3 only

C sp^2 and sp^3 only

D sp^2 only

7 The boiling point of water, H_2O, is higher than that of hydrogen sulfide, H_2S.

Which statement explains this difference in boiling points?

A The bond energy of O–H is greater than the bond energy of S–H.

B The intermolecular forces in H_2O are weaker than the intermolecular forces in H_2S.

C The S–H bond in H_2S is longer than the O–H bond in H_2O.

D There is significant intermolecular hydrogen bonding in H_2O but **not** in H_2S.

8 Which row describes silicon dioxide?

	electrical conductivity in liquid state	solubility in water
A	non-conductor	insoluble
B	non-conductor	soluble
C	conductor	insoluble
D	conductor	soluble

9 The data shown are needed for this question.

$\Delta H_f^\ominus(P_4O_{10}(s)) = -3012\,kJ\,mol^{-1}$

$\Delta H_f^\ominus(H_2O(l)) = -286\,kJ\,mol^{-1}$

$\Delta H_f^\ominus(H_3PO_4(s)) = -1279\,kJ\,mol^{-1}$

What is $\Delta H^\ominus$ for the reaction shown?

$$P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(s)$$

A $-9844\,kJ\,mol^{-1}$

B $-388\,kJ\,mol^{-1}$

C $-97\,kJ\,mol^{-1}$

D $+2019\,kJ\,mol^{-1}$

10 In an experiment to measure the enthalpy change of neutralisation of hydrochloric acid, $20\,cm^3$ of solution containing 0.04 mol of HC*l* is placed in a plastic cup of negligible heat capacity.

A $20\,cm^3$ sample of aqueous sodium hydroxide containing 0.04 mol of NaOH, at the same initial temperature, is added and the temperature rises by 15 K.

If the heat capacity per unit volume of the final solution is $4.2\,J\,K^{-1}\,cm^{-3}$, what is the enthalpy change of neutralisation of hydrochloric acid?

A $\frac{20 \times 4.2 \times 15}{0.04}\,J\,mol^{-1}$

B $40 \times 4.2 \times 15 \times 0.08\,J\,mol^{-1}$

C $\frac{40 \times 4.2 \times 15}{0.04}\,J\,mol^{-1}$

D $\frac{20 \times 4.2 \times 15}{0.08}\,J\,mol^{-1}$

11 Acidified potassium manganate(VII) reacts with iron(II) ethanedioate, FeC_2O_4.

The reactions taking place are shown.

$$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$$

$$Fe^{2+} \rightarrow Fe^{3+} + e^-$$

$$C_2O_4^{2-} \rightarrow 2CO_2 + 2e^-$$

How many moles of iron(II) ethanedioate react with **one** mole of potassium manganate(VII)?

A 0.60 **B** 1.67 **C** 2.50 **D** 5.00

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12 Nitrogen dioxide decomposes on heating according to the equation shown.

$$2NO_2(g) \rightleftharpoons 2NO(g) + O_2(g)$$

When 4 mol of nitrogen dioxide were put into a 1 dm^3 container and heated to a constant temperature, the equilibrium mixture contained 0.8 mol of oxygen.

What is the value of the equilibrium constant, K_c, at the temperature of the experiment?

A $\frac{0.8^2 \times 0.8}{4^2}$ **B** $\frac{1.6 \times 0.8}{2.4^2}$ **C** $\frac{1.6^2 \times 0.8}{4^2}$ **D** $\frac{1.6^2 \times 0.8}{2.4^2}$

13 One particle of X reacts with one particle of Y in a single-step reaction to produce two particles of Z.

This reaction is exothermic and reversible.

$$X + Y \rightleftharpoons 2Z$$

Three statements about the forward and reverse reactions are listed.

1 The activation energy of the forward reaction is equal to the activation energy of the reverse reaction.

2 At equilibrium, the frequency of collisions between one particle of X and one particle of Y is equal to the frequency of collisions between two particles of Z.

3 At equilibrium, the frequency of effective collisions between one particle of X and one particle of Y is equal to the frequency of effective collisions between two particles of Z.

Which statements are correct?

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

14 When two aqueous solutions are mixed, the reaction between them is very slow.

An effective catalyst is added to the mixture without any change in temperature.

Which statement about this catalyst is correct?

A It increases the average energy of the reactant particles.

B It changes the distribution of energies of the reactant particles.

C It allows a greater number of reactant particles to react per unit time.

D It increases the number of reactant particles with the most probable energy.

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15 A mixture of gases reacts faster as its temperature increases.

Which row explains this?

	the activation energy remains unchanged	more particles have energy equal to or above the activation energy	there is an increase in the rate of successful collisions
A	false	false	false
B	true	true	true
C	false	true	true
D	true	false	false

16 A student investigated the chloride of a Period 3 element. This is what the student wrote down as their observations.

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

What can be deduced from these observations?

A At least one of the recorded observations is **not** correct.

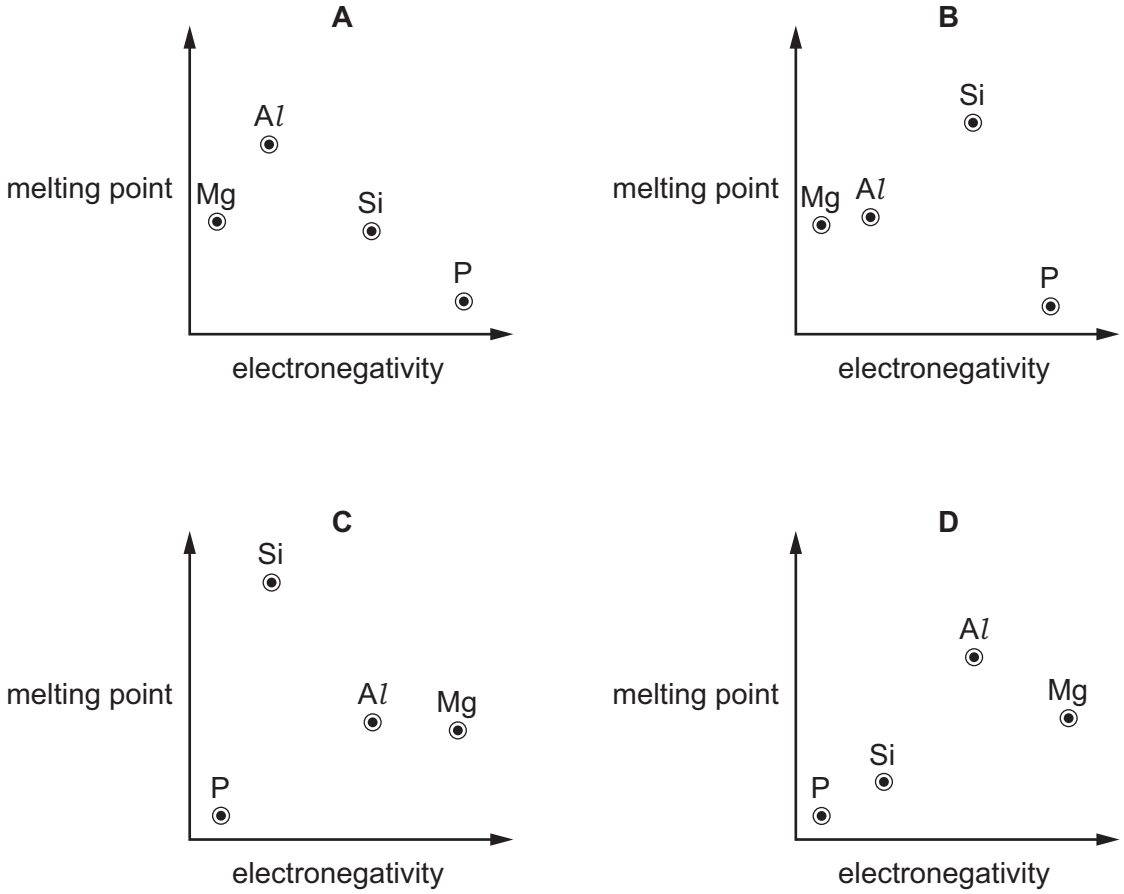
B The compound was magnesium chloride, $MgCl_2$.

C The compound was phosphorus pentachloride, PCl_5.

D The compound was sodium chloride, $NaCl$.

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17 Which graph shows the relative melting points of the elements Mg, A*l*, Si and P plotted against their relative electronegativities?



18 Caesium and barium are in Period 6 of the Periodic Table.

Which row is correct?

	the larger ionic radius	the higher melting point
A	Ba^{2+}	barium
B	Ba^{2+}	caesium
C	Cs^{+}	barium
D	Cs^{+}	caesium

19 Magnesium nitrate, $Mg(NO_3)_2$, will decompose when heated to give a white solid and a mixture of gases. One of the gases released is oxygen.

29.7 g of anhydrous magnesium nitrate is heated until no further reaction takes place.

Which mass of oxygen is produced?

A 3.2 g **B** 6.4 g **C** 12.8 g **D** 19.2 g

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20 Which row shows the trends in the named properties going down the Group 2 nitrates?

	thermal stability	volume of gas produced, measured at room conditions, when 1.0 g of anhydrous solid nitrate is thermally decomposed
A	increases	increases
B	increases	decreases
C	decreases	increases
D	decreases	decreases

21 X, Y and Z are three aqueous solutions. Equal volumes of pairs of the solutions are mixed and observations noted.

X mixed with Y shows no reaction.

X mixed with Z shows an immediate reaction.

Z mixed with Y shows no reaction.

What are X, Y and Z?

	X	Y	Z
A	Br_2(aq)	I_2(aq)	HBr(aq)
B	Cl_2(aq)	I_2(aq)	HBr(aq)
C	HCl(aq)	HI(aq)	Br_2(aq)
D	HCl(aq)	Br_2(aq)	HBr(aq)

22 An excess of chlorine gas is bubbled into hot potassium hydroxide solution.

Which chlorine-containing species are present in the final solution?

A Cl^- and ClO^-

B Cl^- and ClO_3^-

C ClO^- and ClO_3^-

D ClO_3^- only

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23 The oxides of nitrogen, NO and NO_2, act as pollutants in the Earth's atmosphere in a number of different ways.

Three statements about the oxides of nitrogen are listed.

1 They react with oxygen and water vapour to form nitric acid, a constituent of acid rain.

2 They react with carbon monoxide to form photochemical smog.

3 They catalyse the oxidation of sulfur dioxide in the formation of sulfuric acid, another constituent of acid rain.

Which statements are correct?

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

24 Which reagent, when mixed with ammonium sulfate and then heated, liberates ammonia?

A aqueous bromine

B dilute hydrochloric acid

C aqueous calcium hydroxide

D potassium dichromate(VI) in acidic solution

25 Two hydrocarbons, $CH_3CHC(CH_3)CH_3$ and $CH_3CH(CH_3)CH_2CH_3$, react separately with chlorine in the presence of ultraviolet light.

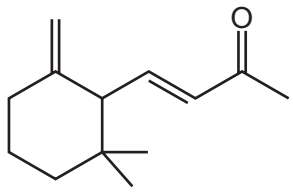
In each reaction, free-radical substitution occurs.

Which row is correct?

	identity of the hydrocarbon that can also undergo electrophilic addition	a termination stage of the free-radical substitution of the saturated hydrocarbon
A	$CH_3CHC(CH_3)CH_3$	$CH_3CH(CH_3)CH_2CH_2\bullet + Cl\bullet \rightarrow CH_3CH(CH_3)CH_2CH_2Cl$
B	$CH_3CHC(CH_3)CH_3$	$CH_3CHC(CH_3)CH_2\bullet + Cl\bullet \rightarrow CH_3CHC(CH_3)CH_2Cl$
C	$CH_3CH(CH_3)CH_2CH_3$	$CH_3CH(CH_3)CH_2CH_2\bullet + Cl\bullet \rightarrow CH_3CH(CH_3)CH_2CH_2Cl$
D	$CH_3CH(CH_3)CH_2CH_3$	$CH_3CHC(CH_3)CH_2\bullet + Cl\bullet \rightarrow CH_2CHC(CH_3)CH_2Cl$

26 The structure of the compound γ-ionone is shown.

γ-ionone



Including γ-ionone, how many stereoisomers exist with this molecular formula?

A 1 **B** 2 **C** 4 **D** 8

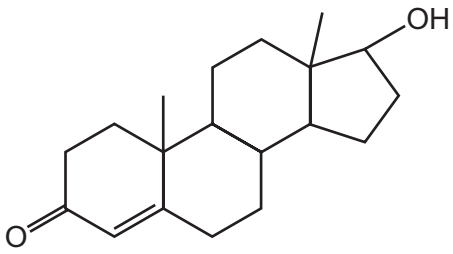
27 Structural and stereoisomerism should be considered when answering this question.

A mixture of 1-chlorobutane and 2-chlorobutane is heated with an excess of NaOH in ethanol.

How many different organic molecules will be produced?

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

28 The diagram shows the skeletal formula of the hormone testosterone.



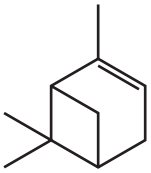
What is the molecular formula of testosterone?

A $C_{19}H_{28}O_2$ **B** $C_{17}H_{22}O_2$ **C** $C_{17}H_{24}O_2$ **D** $C_{19}H_{26}O_2$

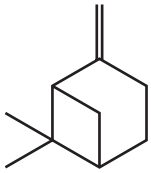
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29 Pinenes are unsaturated compounds. The structures of two pinenes are shown.

α-pinene



β-pinene



A mixture of these two pinenes reacts with hot concentrated acidified $KMnO_4$.

What are the molecular formulae of the organic products?

A $C_9H_{14}O$ and $C_{10}H_{16}O_3$

B $C_9H_{14}O$ and $C_{10}H_{14}O_4$

C $C_9H_{16}O_2$ and $C_{10}H_{16}O_3$

D $C_9H_{16}O_2$ and $C_{10}H_{14}O_4$

30 An organic ion containing a carbon atom with a negative charge is called a carbanion.

An organic ion containing a carbon atom with a positive charge is called a carbocation.

The reaction between NaOH(aq) and 1-bromobutane proceeds by an S_N2 mechanism.

What is the first step in the mechanism?

A attack by a nucleophile on a carbon atom with a partial positive charge

B heterolytic bond fission followed by attack by an electrophile on a carbanion

C heterolytic bond fission followed by attack by a nucleophile on a carbocation

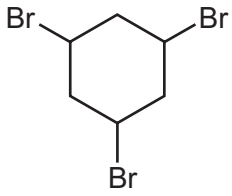
D homolytic bond fission followed by attack by a nucleophile on a carbocation

31 2-chloropropane and 2-bromopropane react separately with aqueous NaOH.

Which row is correct?

	comparison of rates of reaction	explanation of the difference in reaction rates
A	2-chloropropane reacts faster	chlorine is more reactive than bromine
B	2-chloropropane reacts faster	the C–C*l* bond is more polar than the C–Br bond
C	2-bromopropane reacts faster	the first ionisation energy of bromine is lower than chlorine's
D	2-bromopropane reacts faster	the C–Br bond is weaker than the C–C*l* bond

32 The diagram shows the structure of compound X.



X

X undergoes hydrolysis to form product Y in which all of the bromine atoms are replaced by hydroxyl groups. Product Z is formed by oxidation of Y.

Two suggestions are listed.

1 Y is a secondary alcohol.

2 Z is a ketone.

Which suggestions are correct?

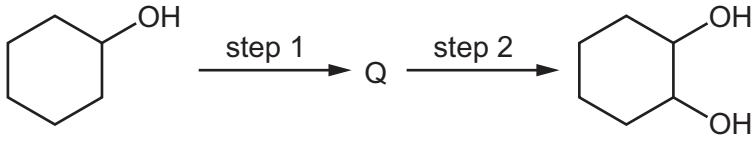
A both 1 and 2

B 1 only

C 2 only

D neither 1 nor 2

33 Cyclohexanol is converted to cyclohexane-1,2-diol via a two-step synthesis that proceeds via intermediate Q.



Which row identifies the type of reaction in step 1 and in step 2?

	step 1	step 2
A	dehydration	oxidation
B	dehydration	nucleophilic substitution
C	reduction	oxidation
D	reduction	nucleophilic substitution

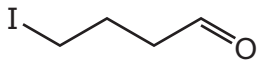
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34 Three tests were performed on an unknown organic compound.

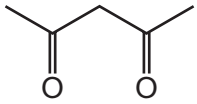
test reagent	test result
2,4-DNPH reagent	orange ppt
Tollens' reagent	no change
alkaline I_2(aq)	yellow ppt

What is the organic compound tested?

A



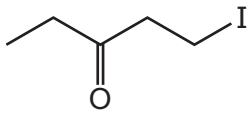
B



C



D



35 Butanone, $CH_3CH_2COCH_3$, and HCN mixed with a little KCN react together in a nucleophilic addition reaction.

Which description of the mechanism of this nucleophilic addition reaction is correct?

A The π bond pair of C=O accepts H^+ from HCN and then CN^- acts as a nucleophile.

B A π bond pair from CN^- attacks the δ+ C and HCN then donates H^+ to O.

C The lone pair on O accepts H^+ from HCN and then CN^- acts as a nucleophile.

D A lone pair from CN^- attacks the δ+ C and then O^- accepts H^+ from HCN.

36 The structural formula of compound P is $CH_3CH_2COOCH_2CH_3$.

P can be formed by reacting together two organic compounds in the presence of a suitable catalyst.

Which pair of compounds could react together to produce P?

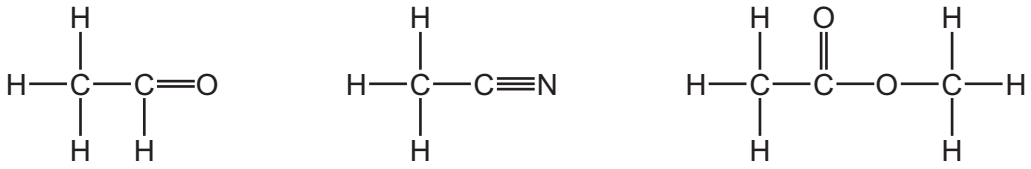
A ethanoic acid and propanoic acid

B ethanoic acid and propan-1-ol

C ethanol and propanoic acid

D ethanol and propan-1-ol

37 The structures of three organic compounds are shown.



1 2 3

Which compounds produce ethanoic acid when heated with HCl(aq)?

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

38 When bromoethane, C_2H_5Br, is heated with NaOH in ethanol, which type of reaction occurs?

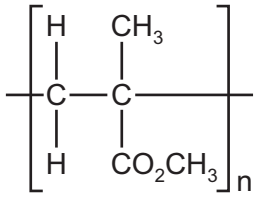
A electrophilic substitution

B elimination

C nucleophilic substitution, mainly via an S_N1 mechanism

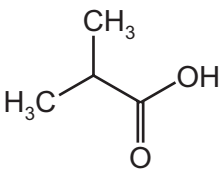
D nucleophilic substitution, mainly via an S_N2 mechanism

39 PMMA is a rigid polymer. The repeat unit of PMMA is shown.

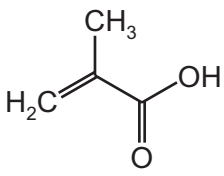


Which monomer is used to make PMMA?

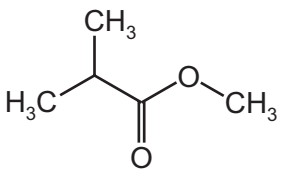
A



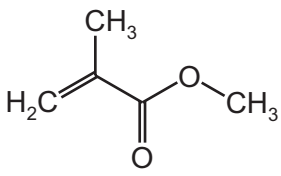
B



C



D



40 A sample of gallium contains two isotopes only.

In every 10 atoms in the sample, there are 6 that have 38 neutrons and 4 that have 40 neutrons.

What is the relative atomic mass, A_r, of the gallium in the sample?

A 69.7 **B** 69.8 **C** 70.0 **D** 70.2

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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	$L = 6.02 \times 10^{23}\,\text{mol}^{-1}$
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	3	4	5	6	7	8	9	10	11	12	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 144.2	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 –