



Cambridge International AS & A Level

CHEMISTRY

9701/11

Paper 1 Multiple Choice

May/June 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.

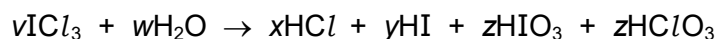
INFORMATION

- 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.

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



- 1 ICl_3 reacts with water in a redox reaction.



What are the numbers v , x and z in the correctly balanced equation?

	v	x	z
A	2	8	1
B	2	5	1
C	3	8	1
D	3	5	1

- 2 The rate of the reaction between a reactive metal and an excess of a dilute acid is investigated.

The total volume of hydrogen gas produced is recorded every 30 seconds for 3 minutes.

time/s	total volume of hydrogen gas/ cm^3
0	0
30	64
60	105
90	132
120	151
150	161
180	167

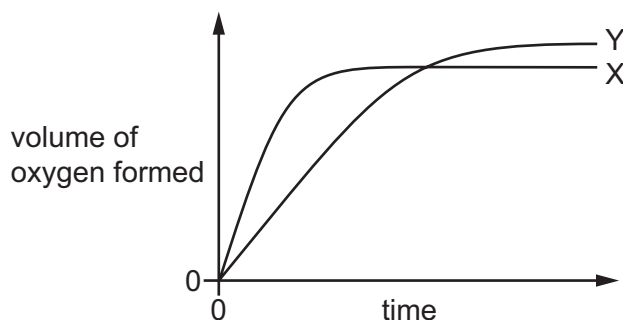
The average rate of reaction during the first 30 seconds is P .

The average rate of reaction during the last 30 seconds is Q .

What is the value of $P - Q$?

- A** $1.21 \text{ cm}^3 \text{ s}^{-1}$ **B** $1.93 \text{ cm}^3 \text{ s}^{-1}$ **C** $2.13 \text{ cm}^3 \text{ s}^{-1}$ **D** $3.43 \text{ cm}^3 \text{ s}^{-1}$

- 3 In the diagram, curve X was obtained by measuring the volume of oxygen produced during the decomposition of 100 cm^3 of 1.0 mol dm^{-3} hydrogen peroxide. A catalyst of manganese(IV) oxide was used.



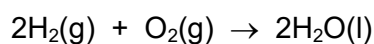
Which alteration to the original experimental conditions would produce curve Y?

- A** adding more manganese(IV) oxide
B adding some 0.1 mol dm^{-3} hydrogen peroxide
C adding water
D raising the temperature
- 4 The first seven ionisation energies of an element between lithium and neon in the Periodic Table are shown.

1310 3390 5320 7450 11 000 13 300 71 000 kJ mol^{-1}

What is the outer electronic configuration of the element?

- A** $2s^2$ **B** $2s^2 2p^1$ **C** $2s^2 2p^4$ **D** $2s^2 2p^6$
- 5 The reaction of hydrogen with oxygen is shown.



Which expression corresponds to the standard enthalpy change of this reaction?

- A** $2 \times \Delta H_f^\circ(\text{H}_2\text{O})$
B $\Delta H_c^\circ(\text{H}_2\text{O}) - \Delta H_c^\circ(\text{H}_2)$
C $\Delta H_c^\circ(\text{H}_2)$
D $2 \times \Delta H_f^\circ(\text{H}_2\text{O}) + 2 \times \Delta H_c^\circ(\text{H}_2)$

- 6 P is a compound that burns in an excess of oxygen to give carbon dioxide and water only.

2.20 g of P contains 1.20 g of carbon and 0.20 g of hydrogen.

When P is added to a solution of sodium carbonate, bubbles of gas are seen.

What is P?

- A CH_3CHO
- B $\text{CH}_3\text{CO}_2\text{H}$
- C $\text{CH}_3\text{COCH}_2\text{CH}_2\text{OH}$
- D $\text{CH}_3\text{CH}_2\text{CH}_2\text{CO}_2\text{H}$

- 7 Substance W has the physical properties shown.

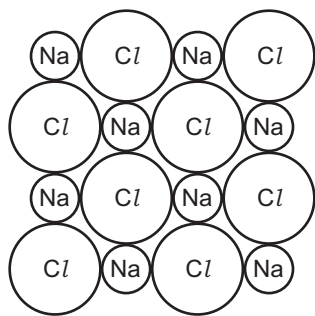
m.p./°C	b.p./°C	electrical conductivity		
		of solid	of liquid	in water
2072	2980	poor	good	insoluble

What is substance W?

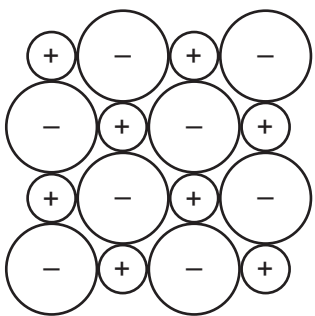
- A aluminium oxide
- B iron
- C silicon dioxide
- D sodium fluoride

8 Which diagram represents the lattice structure of sodium chloride?

A



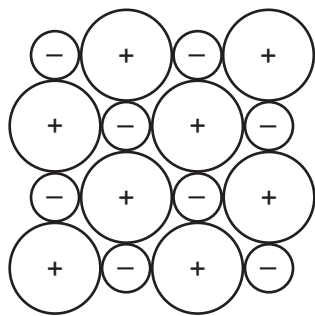
B



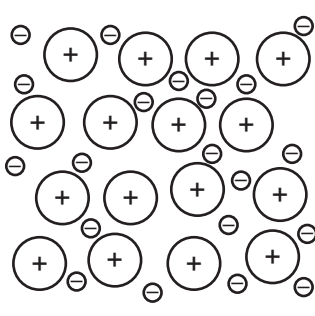
key

Cl = chlorine atom
 Na = sodium atom
 - = chloride ion
 + = sodium ion

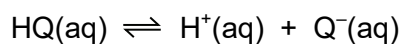
C



D



9 An aqueous solution X contains substance HQ which behaves as a weak acid.



The soluble salt NaQ is added to X.

What happens to the $[\text{H}^+(\text{aq})]$ and the pH in X?

	$[\text{H}^+(\text{aq})]$	pH
A	decreases	decreases
B	decreases	increases
C	increases	decreases
D	increases	increases

- 10 Dinitrogen tetroxide, N_2O_4 , decomposes reversibly.



An equilibrium mixture of N_2O_4 and NO_2 gases is placed in a closed container under standard conditions.

$$K_c = 1.15 \times 10^{-1} \text{ mol dm}^{-3}$$

The conditions are changed.

Under the new conditions, $K_c = 1.70 \times 10^{-3} \text{ mol dm}^{-3}$.

Which change in conditions occurs?

- A The pressure increases.
 - B The pressure decreases.
 - C The temperature increases.
 - D The temperature decreases.
- 11 50 cm^3 of 1.0 mol dm^{-3} H_2SO_4 is added to 100 cm^3 of 1.0 mol dm^{-3} NaOH in an insulated vessel.

Both solutions are at a temperature of 20°C before mixing. After mixing, the temperature rises and the highest temperature reached is 29°C .

Assume that:

- all the energy released in the reaction goes into raising the temperature of the aqueous reaction mixture
- the specific heat capacity of the mixture is $4.2 \text{ J cm}^{-3} \text{ K}^{-1}$.

What is the value of the enthalpy of neutralisation determined from this experiment?

- A $-113.4 \text{ kJ mol}^{-1}$
- B $-56.7 \text{ kJ mol}^{-1}$
- C $-37.8 \text{ kJ mol}^{-1}$
- D $-18.9 \text{ kJ mol}^{-1}$

- 12** Barium dithionate, $\text{BaS}_2\text{O}_6 \cdot 2\text{H}_2\text{O}$, is soluble in water.

$\text{S}_2\text{O}_6^{2-}$ ions slowly decompose in acidic solution.



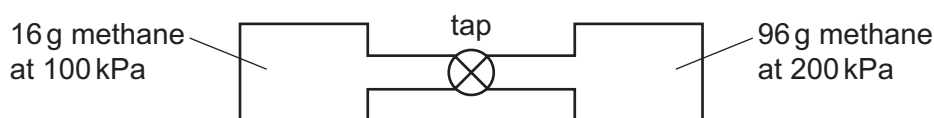
3.513 g of $\text{BaS}_2\text{O}_6 \cdot 2\text{H}_2\text{O}$ is dissolved in water in a 100 cm^3 volumetric flask and the solution made up to the mark with $\text{HCl}(\text{aq})$.

At time x min, a white precipitate of mass 0.661 g is present in the flask.

What is the concentration of BaS_2O_6 in the volumetric flask at time x min?

- A** $0.0077\text{ mol dm}^{-3}$
B $0.0090\text{ mol dm}^{-3}$
C 0.077 mol dm^{-3}
D 0.090 mol dm^{-3}
- 13** The diagram shows two containers of methane connected by a closed tap.

Each container has a volume of 1.00 m^3 .



The tap is opened. The temperature of the system is changed to 800 K.

The system reaches constant pressure.

What is the pressure of methane within the system?

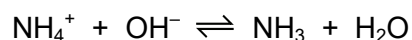
- A** 23.3 kPa **B** 46.6 kPa **C** 186 kPa **D** 372 kPa
- 14** Which statement about a 3p orbital is correct?
- A** It can hold a maximum of six electrons.
B It has the highest energy of the orbitals with principal quantum number 3.
C It is at a higher energy level than a 3s orbital but has the same shape.
D It is occupied by one electron in an isolated phosphorus atom.

15 In which pair do both species:

- have the same shape
- have the same number of covalent bonds?

- A** methane and the ammonium ion
B carbon dioxide and nitrogen
C boron trifluoride and ammonia
D water and oxygen

16 A reaction involving ammonium ions is shown.



Four statements about this reaction are listed.

- 1 The ammonium ions are reduced.
- 2 In the reverse reaction, ammonia acts as a Brønsted–Lowry base.
- 3 The ammonium ion and the ammonia molecule have the same bond angle.
- 4 This reaction is **not** a redox reaction.

Which statements are correct?

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

17 Which reduction process occurs on the surface of a catalytic converter?

- A** reduction of carbon dioxide and nitrogen oxides
B reduction of carbon dioxide only
C reduction of nitrogen oxides only
D reduction of carbon monoxide

18 Three statements about the halogens, chlorine, bromine and iodine and their compounds are listed.

- 1 The halogen with the highest boiling point has atoms which form the strongest bond to hydrogen.
- 2 The halogen with the strongest instantaneous dipole (id–id) attractions forms the most thermally stable hydrogen halide.
- 3 The most volatile element most rapidly oxidises hydrogen.

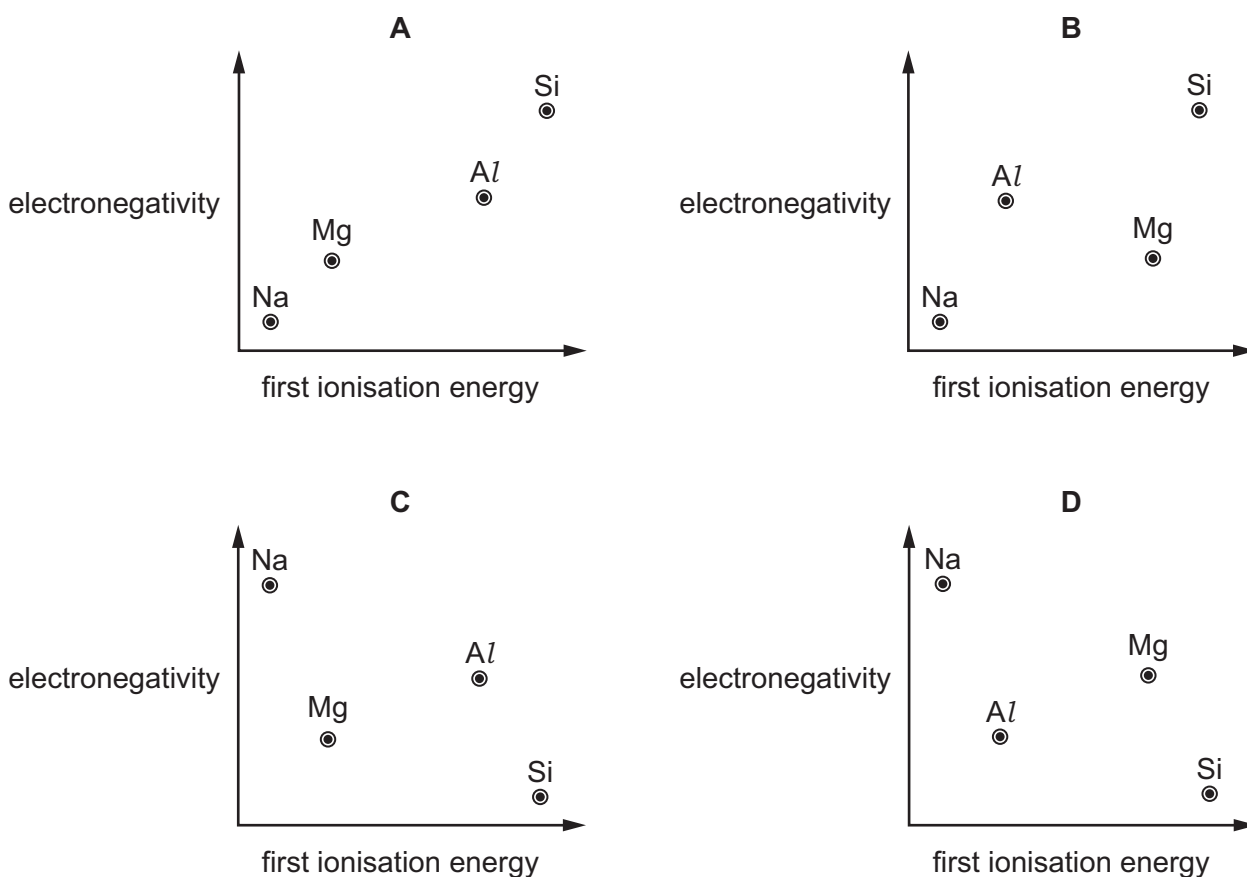
Which statements are correct?

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

19 Which reagent or reagents and conditions will oxidise chlorine, Cl_2 , into a compound containing chlorine in the +5 oxidation state?

- A $\text{AgNO}_3(\text{aq})$ followed by $\text{NH}_3(\text{aq})$ at room temperature
- B concentrated H_2SO_4 at room temperature
- C cold dilute $\text{NaOH}(\text{aq})$
- D hot concentrated $\text{NaOH}(\text{aq})$

20 Which diagram shows the electronegativity of the elements Na, Mg, Al and Si plotted against their first ionisation energies?



21 Radium is an element below barium in Group 2 of the Periodic Table.

Which equation shows what happens when solid radium nitrate, $\text{Ra}(\text{NO}_3)_2$, is heated strongly?

- A $2\text{Ra}(\text{NO}_3)_2(\text{s}) \rightarrow 2\text{RaO}(\text{s}) + 4\text{NO}_2(\text{g}) + \text{O}_2(\text{g})$
- B $2\text{Ra}(\text{NO}_3)_2(\text{s}) \rightarrow 2\text{RaO}(\text{s}) + 2\text{N}_2(\text{g}) + 5\text{O}_2(\text{g})$
- C $\text{Ra}(\text{NO}_3)_2(\text{s}) \rightarrow \text{RaO}(\text{s}) + \text{N}_2\text{O}(\text{g}) + 2\text{O}_2(\text{g})$
- D $4\text{Ra}(\text{NO}_3)_2(\text{s}) \rightarrow 2\text{Ra}_2\text{O}(\text{s}) + 8\text{NO}_2(\text{g}) + 3\text{O}_2(\text{g})$

22 The table shows some data for the elements in Period 3 of the Periodic Table.

	melting point / K	electrical conductivity
sodium	371	good
magnesium	922	good
aluminium	933	good
silicon	1693	poor
phosphorus	317	does not conduct
sulfur	386	does not conduct
chlorine	172	does not conduct
argon	84	does not conduct

Which statements are correct?

- 1 All the elements in the table with a giant structure have a higher melting point than each of the elements in the table with a simple molecular structure.
- 2 Magnesium has a higher melting point than sodium because it has more delocalised electrons and stronger electrostatic attraction between the delocalised electrons and the metal ions.
- 3 Phosphorus and sulfur do **not** conduct electricity because they are simple molecular solids at room conditions.

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

23 Each mineral listed behaves as a mixture of two carbonate compounds. They can be used as fire retardants because they decompose in the heat, producing CO_2 . This gas smothers the fire.

barytocalcite, $\text{BaCa}(\text{CO}_3)_2$

dolomite, $\text{CaMg}(\text{CO}_3)_2$

huntite, $\text{Mg}_3\text{Ca}(\text{CO}_3)_4$

What is the order of effectiveness as fire retardants, from best to worst?

	best	→	worst
A	dolomite	barytocalcite	huntite
B	dolomite	huntite	barytocalcite
C	huntite	barytocalcite	dolomite
D	huntite	dolomite	barytocalcite

- 24** Compound X contains two Period 3 elements, Y and Z.

Compound X reacts with water to form only two products: a slightly soluble hydroxide and compound Q.

Q is a compound of element Z and hydrogen.

Compound Q burns in moist air to produce an oxide and water. The oxidation number of element Z in the oxide is +5.

Which row identifies element Y and element Z?

	element Y	element Z
A	Mg	P
B	Na	S
C	Na	P
D	Mg	S

- 25** Three reagents are listed.

- 1 aqueous sodium carbonate
- 2 LiAlH_4
- 3 water

Which reagents react with pure ethanoic acid to give a solution containing ethanoate ions?

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

- 26** Complete combustion of compound T produces carbon dioxide and water only. Compound T produces steamy fumes with PCl_5 . Compound T does not give any visible product with 2,4-dinitrophenylhydrazine reagent.

What can be deduced with certainty from this information?

- A** Compound T is a carboxylic acid.
B Compound T is a hydrocarbon.
C Compound T is an alcohol.
D Compound T is **not** an aldehyde.

27 Information about carbonyl compound X is given.

- Compound X reacts with LiAlH_4 to produce a secondary alcohol.
- Compound X reacts with alkaline $\text{I}_2(\text{aq})$ to give a yellow precipitate.

What is compound X?

- A butanal
- B butanone
- C ethanal
- D pentan-3-one

28 An organic compound J reacts with an excess of sodium to produce an organic ion with a charge of -3 . J reacts with an excess of $\text{NaOH}(\text{aq})$ to produce an organic ion with a charge of -1 .

What is the structural formula of J?

- A $\text{HOCH}_2\text{CH}(\text{OH})\text{CH}_2\text{CO}_2\text{H}$
- B $\text{HO}_2\text{CCH}(\text{OH})\text{CH}_2\text{CHO}$
- C $\text{HO}_2\text{CCH}(\text{OH})\text{CH}_2\text{CO}_2\text{H}$
- D $\text{HOCH}_2\text{COCH}_2\text{CHO}$

29 Which formula represents the organic compound formed by the reaction of propanoic acid with methanol in the presence of concentrated sulfuric acid as a catalyst?

- A $\text{CH}_3\text{CH}_2\text{COCH}_3$
- B $\text{CH}_3\text{CH}_2\text{CO}_2\text{CH}_3$
- C $\text{CH}_3\text{CO}_2\text{CH}_2\text{CH}_3$
- D $\text{CH}_3\text{CH}_2\text{CH}_2\text{CO}_2\text{CH}_3$

30 Structural isomerism and stereoisomerism should be considered when answering this question.

2,5-dibromohexane is heated under reflux with ethanolic KOH.

How many isomeric compounds are formed with molecular formula C_6H_{10} ?

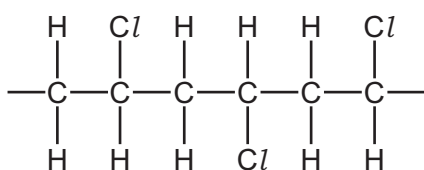
- A 3 B 5 C 6 D 7

- 31 Considering **only** structural isomers, what is the number of alcohols of each type with the formula $C_5H_{12}O$?

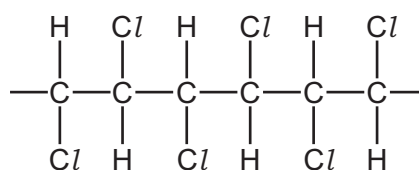
	primary	secondary	tertiary
A	3	3	2
B	4	2	2
C	4	3	1
D	5	2	1

- 32 Which structure represents part of the polymer chain of PVC?

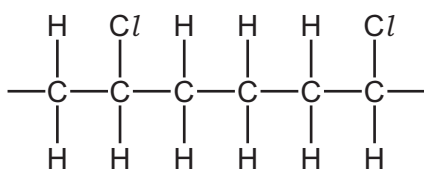
A



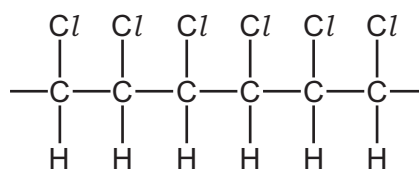
B



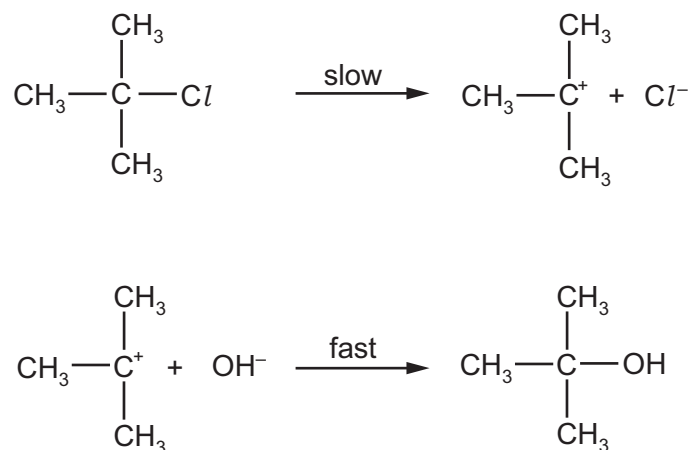
C



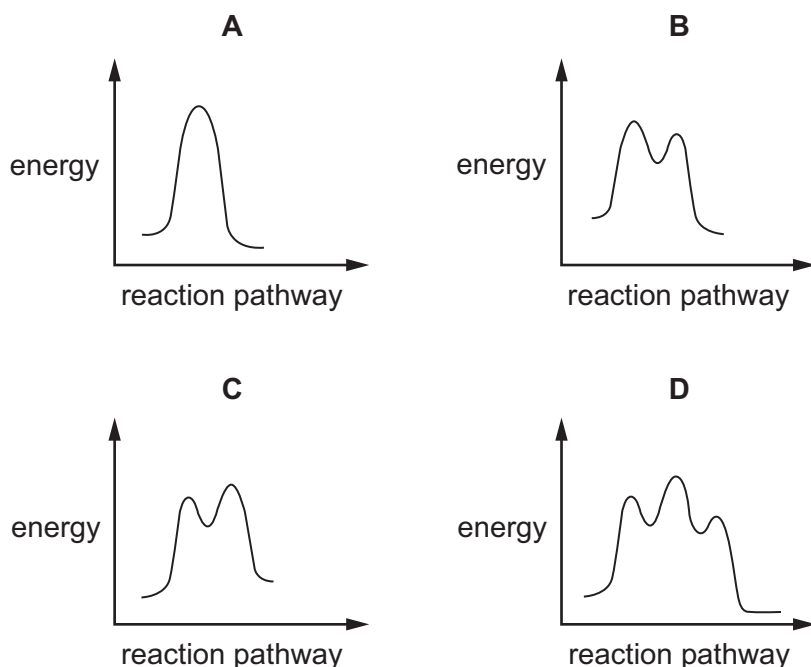
D



33 A possible mechanism for the exothermic hydrolysis of 2-chloro-2-methylpropane is shown.



Which diagram represents the reaction pathway diagram for this mechanism?



34 Compound W contains atoms of carbon, nitrogen and hydrogen.

Compound W reacts with HCl(aq) to produce propanoic acid.

Which row is correct?

	functional group in compound W	name of compound W
A	amine	ethylamine
B	nitrile	ethanenitrile
C	amine	propylamine
D	nitrile	propanenitrile

35 Two reactions are described.

- 1 2-bromo-2-methylbutane heated with NaOH(aq)
- 2 2-chloro-2-methylbutane heated with NaOH(aq)

In both reactions, the conditions are the same and NaOH(aq) is in excess.

30.18 g of 2-bromo-2-methylbutane forms 12.32 g of product X.

[M_r : 2-bromo-2-methylbutane, 150.9; 2-chloro-2-methylbutane, 106.5]

Which row is correct?

	percentage yield of product X / %	relative rate of reaction
A	41	1 is faster than 2
B	41	2 is faster than 1
C	70	1 is faster than 2
D	70	2 is faster than 1

36 An alkene P reacts with an excess of hot concentrated acidified $\text{KMnO}_4(\text{aq})$.

Methylpropanoic acid is the only organic product.

What is alkene P?

- A** 2,5-dimethylhex-3-ene
- B** 2-methylbut-2-ene
- C** methylpropene
- D** oct-4-ene, C_8H_{16}

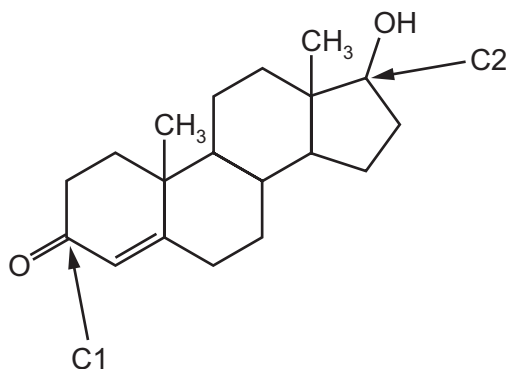
37 Three substances are listed.

- 1 butane
- 2 hydrogen
- 3 hydrogen bromide

Which substances are possible products of the free-radical substitution reaction between ethane and bromine?

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

38 The structure of the testosterone molecule is shown.

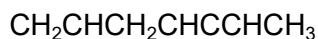


Which statements are correct?

- 1 Carbon atoms C1 and C2 can be oxidised with acidified $\text{K}_2\text{Cr}_2\text{O}_7$.
- 2 There are fewer than 27 hydrogen atoms in one testosterone molecule.
- 3 There are six chiral carbon atoms in one testosterone molecule.

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

39 The structural formula of hept-1,4,5-triene is shown.



How many of the carbon atoms in one molecule of hept-1,4,5-triene are sp^2 hybridised?

A 4 **B** 5 **C** 6 **D** 7

40 Hydrocarbon X is saturated. Each molecule contains one ring of carbon atoms.

The mass spectrum of hydrocarbon X is measured.

The peak representing the M^+ ion is 14 mm high.

The peak representing the $[\text{M}+1]^+$ ion is 0.77 mm high.

What is the m/e value for the M^+ ion of X?

A 56 **B** 58 **C** 70 **D** 72

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Important values, constants and standards

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

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The Periodic Table of Elements

Group																		
1	2	1 Hhydrogen1.0										13	14	15	16	17	18	
		Key atomic number atomic symbol name relative atomic mass																
3 Li lithium 6.9	4 Be beryllium 9.0																	
11 Na sodium 23.0	12 Mg magnesium 24.3																	
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 oganeson —

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	euroium	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
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	—

actinoids



Cambridge International AS & A Level

CHEMISTRY

9701/12

Paper 1 Multiple Choice

May/June 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.

This document has **16** pages.



1 Consider the following statements.

- 1 Silicon dioxide has a higher melting point than sulfur dioxide.
- 2 Ammonia has a higher boiling point than phosphine, PH_3 .

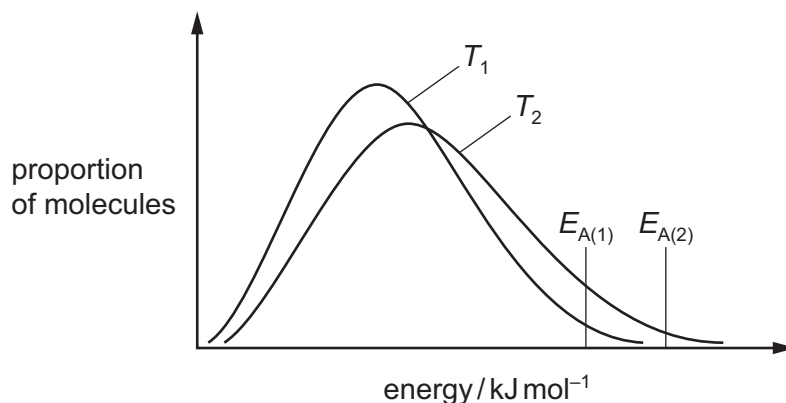
Which statements are correct?

- A** both statement 1 and statement 2
B statement 1 only
C statement 2 only
D neither statement 1 nor statement 2

2 How many neutrons are contained in an atom of iron with a mass number of 60?

- A** 26 **B** 30 **C** 34 **D** 60

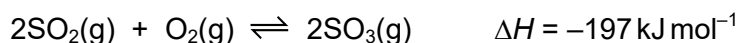
3 The diagram shows a Boltzmann distribution of molecular energies for a gaseous reaction at two different temperatures and two different activation energies.



Which combination of temperature and activation energy will give the highest reaction rate?

- A** T_1 and $E_{A(1)}$ **B** T_1 and $E_{A(2)}$ **C** T_2 and $E_{A(2)}$ **D** T_2 and $E_{A(1)}$

- 4 The reaction between sulfur dioxide and oxygen has the equation shown.



1.0 mol of SO_2 and 1.0 mol of O_2 are placed in a closed container and heated to a constant temperature.

At this temperature, 0.8 mol of SO_3 are present in the equilibrium mixture.

Which statement is correct?

- A** The equilibrium partial pressure of SO_2 is greater than the equilibrium partial pressure of O_2 .
B K_p has units of mol dm^{-3} .
C At a lower temperature, the equilibrium amount of SO_3 is lower than 0.8 mol.
D The mole fraction of SO_3 is less than 0.8.

- 5 'Red lead' is a red pigment with the formula Pb_3O_4 . Every formula unit of 'red lead' is the same.

Each formula unit contains three lead ions and four oxide ions. Lead has two different oxidation states in 'red lead'.

What are the oxidation states of lead in 'red lead'?

- A** +1 and +2 **B** +1 and +3 **C** +2 and +4 **D** +2 and +6
- 6 Some standard enthalpy of combustion data are given.

substance	standard enthalpy change of combustion / kJ mol^{-1}
$\text{C}(\text{s})$	-394
$\text{H}_2(\text{g})$	-286
$\text{CH}_3\text{OH}(\text{l})$	-726

Using these data, what is the enthalpy change of formation of methanol?

- A** -240 kJ mol^{-1} **B** -46 kJ mol^{-1} **C** 46 kJ mol^{-1} **D** 240 kJ mol^{-1}
- 7 Which row is correct?

	smallest bond angle	→	largest bond angle
A	H_2O	NH_3	BF_3
B	BF_3	NH_3	H_2O
C	NH_3	H_2O	BF_3
D	H_2O	BF_3	NH_3

- 8 In the Haber process, the reaction between the two gaseous reactants requires the use of a catalyst that contains a transition element.

What is the metal and in which mole ratio do the gases react?

	metal	mole ratio
A	Fe	1:2
B	Fe	1:3
C	V	1:2
D	V	1:3

- 9 Aqueous hydrogen peroxide, H_2O_2 , decomposes into water and oxygen in the presence of a suitable catalyst.

50 cm^3 of a 0.50 mol dm^{-3} solution of hydrogen peroxide produced 120 cm^3 of oxygen in 2.0 minutes.

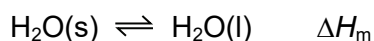
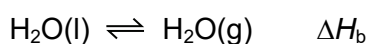
The volume of gas was measured at room conditions.

What is the average rate of decomposition of hydrogen peroxide during this 2.0 minute period?

- A** $0.000083\text{ mol dm}^{-3}\text{ s}^{-1}$
B $0.00083\text{ mol dm}^{-3}\text{ s}^{-1}$
C $0.0017\text{ mol dm}^{-3}\text{ s}^{-1}$
D $0.10\text{ mol dm}^{-3}\text{ s}^{-1}$
- 10 The average intermolecular forces in water are much stronger than the average intermolecular forces in steam.

The average intermolecular forces in ice are slightly stronger than the average intermolecular forces in water.

Enthalpy changes are associated with the equilibrium processes shown.



Which statements are correct?

- 1 ΔH_b and ΔH_m are both negative.
- 2 ΔH_b is greater than ΔH_m .
- 3 The intermolecular forces in ice and water are of the same type.

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

- 11 An experiment is carried out to determine the value of x in hydrated lithium hydroxide, $\text{LiOH} \cdot x\text{H}_2\text{O}$. A sample of the solid is heated in a crucible over a Bunsen flame.

Complete dehydration takes place; decomposition does **not** occur.

mass of empty crucible / g = Q

mass of crucible with $\text{LiOH} \cdot x\text{H}_2\text{O}$ / g = R

mass of crucible and residue after heating / g = S

Which equation gives the correct value of x ?

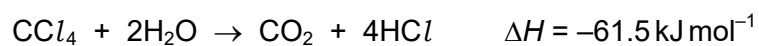
- A $\frac{S-R}{18}$ B $\frac{R-S}{18}$ C $\frac{23.9(R-S)}{18(S-Q)}$ D $\frac{23.9(S-R)}{18(S-Q)}$

- 12 A sample of an ideal gas occupies 240 cm^3 at 37°C and 100 kPa .

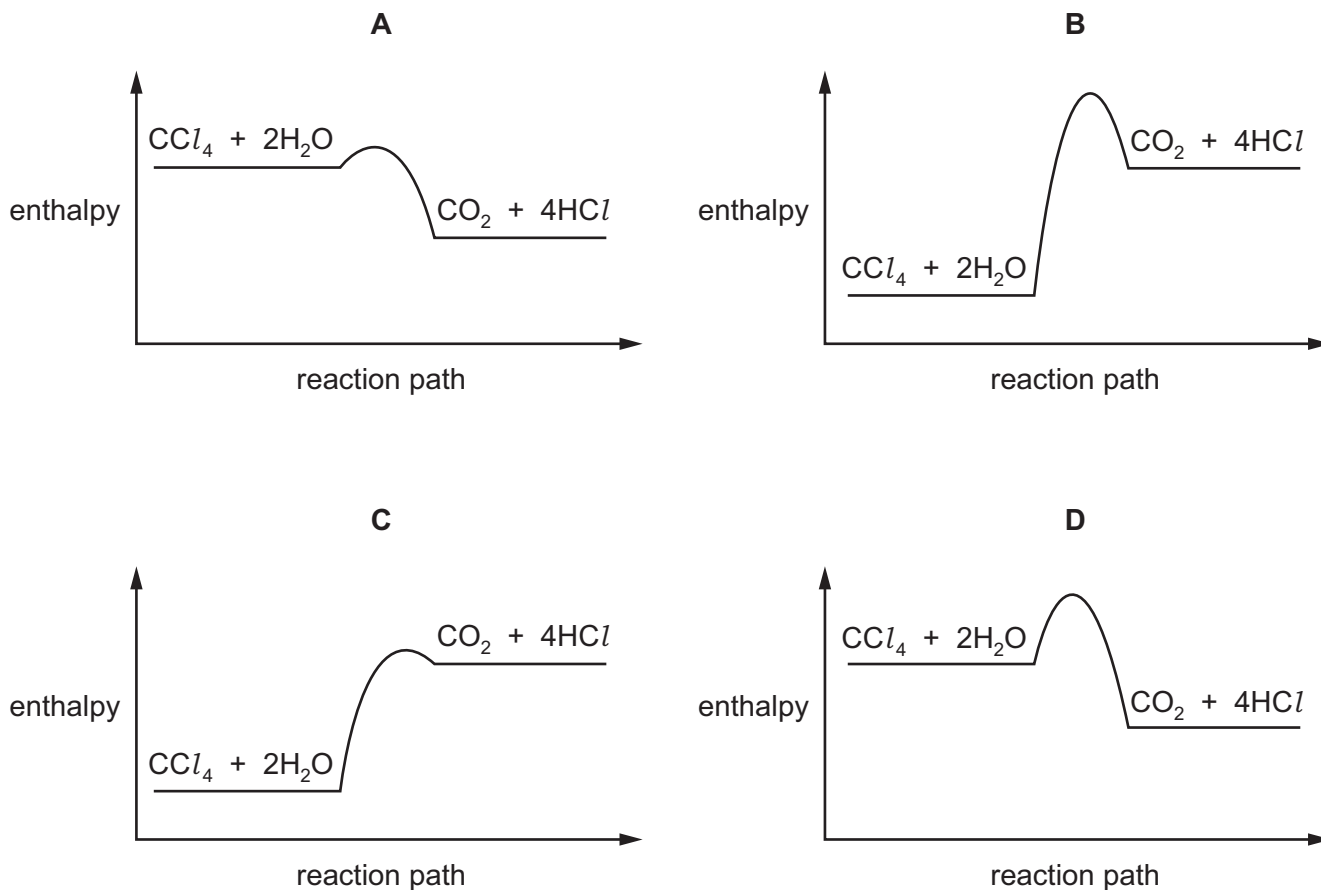
How many moles of gas are present in the sample?

- A 9.32×10^{-6} B 9.32×10^{-3} C 0.0781 D 78.1

- 13 Under certain conditions, CCl_4 and H_2O react as shown. The activation energy for the reaction is $+62 \text{ kJ mol}^{-1}$.



Which enthalpy profile diagram best fits this reaction?

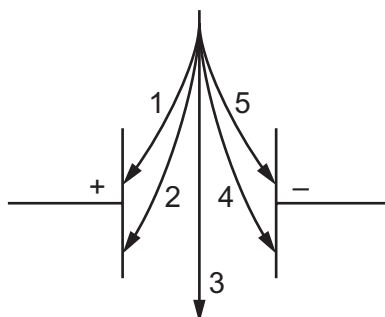


- 14** A helium ion contains two protons, two neutrons and one electron.

This helium ion and a proton are passed separately through a uniform electric field.

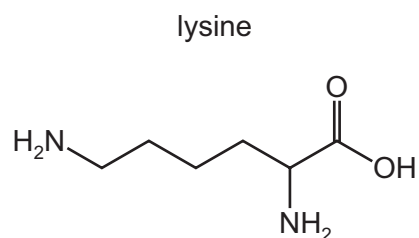
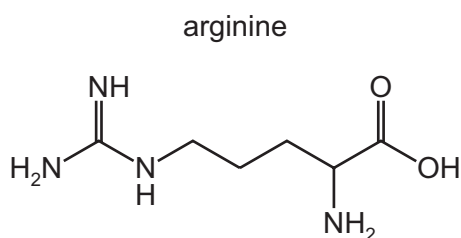
The particles are travelling at the same velocity.

Which arrow describes the path of each particle?



	helium ion	proton
A	1	2
B	2	1
C	4	5
D	5	4

- 15** The skeletal formulae of arginine and lysine are shown.



Which row is correct?

	substance	empirical formula	M_r
A	arginine	$C_3H_7N_2O$	174
B	arginine	$C_3H_8N_2O$	176
C	lysine	C_3H_7NO	144
D	lysine	C_3H_8NO	146

- 16** The oxide and chloride of an element X are separately mixed with water. The two resulting solutions have the same effect on litmus.

What could element X be?

- A** Al **B** Ca **C** Na **D** P

- 17** Why do the halogens become less volatile as Group 17 is descended?

- A** The halogen–halogen bond energy decreases.
B The halogen–halogen bond energy increases.
C The number of electrons in each molecule increases.
D The van der Waals' forces between molecules become weaker.

- 18** Compound M is a white solid. It is the chloride of a Period 3 element.

Information about some reactions starting with compound M is given in the table.

reaction	observation
compound M + non-polar solvent	colourless solution
compound M added a little at a time to water	steamy fumes, Q colourless solution, R
fumes Q tested with moist blue litmus paper	paper turns red
solution R + a few drops of NaOH(aq) + excess NaOH(aq)	white precipitate dissolves to give a colourless solution

What is compound M?

- A** aluminium chloride
B magnesium chloride
C phosphorus pentachloride
D sodium chloride
- 19** Which statement about strontium and its compounds is correct?
- A** Strontium hydroxide is more soluble than barium hydroxide.
B Strontium sulfate is more soluble than magnesium sulfate.
C Strontium nitrate has a lower thermal stability than calcium nitrate.
D Strontium is a stronger reducing agent than magnesium.

- 20** Sodium bromide is warmed with concentrated sulfuric acid.

Which row describes the change in the oxidation number of the sulfur and the role of the bromide ions in the reaction?

	change in oxidation number of sulfur	role of bromide ions
A	+6 to +4	oxidising agent
B	+6 to +4	reducing agent
C	+4 to 0	oxidising agent
D	+4 to 0	reducing agent

- 21** A reaction occurs when ammonium chloride is added to calcium hydroxide.

What is the role of the ammonium ions in this reaction?

- A** acid
- B** base
- C** oxidising agent
- D** reducing agent

- 22** Elements Y and Z are both in Period 3. Element Y has the smallest atomic radius in Period 3.

There are only two elements in Period 3 that have a lower melting point than element Z.

Elements Y and Z react together to form compound R.

Which compound could be R?

- A** MgCl_2 **B** MgS **C** Na_2S **D** PCl_3

- 23** 1.0g of each of four different compounds of Group 2 elements are thermally decomposed. The residue in each decomposition is the oxide of the Group 2 element.

The volume of gas produced from each reaction is measured at room conditions.

Which substance produces the greatest volume of gas?

- A** calcium carbonate
- B** calcium nitrate
- C** strontium carbonate
- D** strontium nitrate

24 Sulfur dioxide in the atmosphere can form acid rain. This occurs in two steps.

- 1 oxidation of SO_2 to SO_3
- 2 formation of dilute H_2SO_4

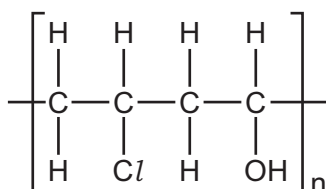
Which row identifies the atmospheric catalyst for step 1 and the reagent for step 2?

	catalyst	reagent
A	O_2	H_2O
B	O_2	O_2
C	NO_2	H_2O
D	NO_2	O_2

25 Which statement about the mechanism of an $\text{S}_{\text{N}}1$ reaction of a halogenoalkane is correct?

- A** A nucleophile is substituted by an electrophile.
- B** One intermediate is formed from two reacting molecules.
- C** The intermediate is stabilised by adjacent alkyl groups.
- D** The intermediate is uncharged.

26 The repeat unit of a polymer is shown.



Three statements about this polymer are listed.

- 1 Its disposal is hazardous because it produces toxic gases when burned.
- 2 Two different monomers are used to make this polymer.
- 3 The monomer for this polymer is 3-chlorobut-2-ene-1-ol.

Which statements are correct?

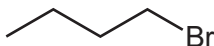
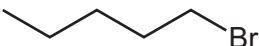
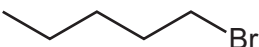
- A** 1 and 2
- B** 1 and 3
- C** 1 only
- D** 2 only

- 27 Methanoic acid, HCO_2H , has acidic properties similar to those of other carboxylic acids. In addition, it can be oxidised by the same oxidising agents that are capable of oxidising aldehydes.

Which pair consists of two compounds that will give the same observations with Fehling's reagent?

- A HCO_2H and $\text{CH}_3\text{CO}_2\text{H}$
 B HCO_2H and $\text{CH}_3\text{CO}_2\text{CH}_3$
 C HCO_2H and $\text{CH}_3\text{CH}_2\text{COCH}_3$
 D HCO_2H and $\text{CH}_3\text{CH}_2\text{CHO}$

- 28 Which row gives pentanenitrile as one product?

	halogenoalkane	reagents and conditions
A		heat with HCN
B		heat with KCN using ethanol as solvent
C		heat with HCN
D		heat with KCN using ethanol as solvent

- 29 An ester, $\text{R}'\text{CO}_2\text{R}''$, is hydrolysed in alkaline conditions. R' and R'' are different alkyl groups.

Which row identifies the two products formed?

	product 1	product 2
A	$\text{R}'\text{CO}_2\text{H}$	$\text{R}''\text{OH}$
B	$\text{R}'\text{CO}_2^-$	$\text{R}''\text{OH}$
C	$\text{R}'\text{CO}_2\text{H}$	$\text{R}''\text{O}^-$
D	$\text{R}'\text{CO}_2^-$	$\text{R}''\text{O}^-$

- 30 Which compound **cannot** be oxidised by acidified potassium dichromate(VI) solution but **does** react with sodium metal?

- A $(\text{CH}_3)_3\text{COH}$
 B $\text{CH}_3\text{COCH}_2\text{CH}_3$
 C $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$
 D $\text{CH}_3\text{CH}_2\text{CH}(\text{OH})\text{CH}_3$

- 31** Butan-2-one reacts with alkaline $I_2(aq)$. An excess of dilute sulfuric acid is then added to the reaction mixture.

The organic products of this reaction sequence are triiodomethane and product M.

What is product M?

- A** ethanoate ion
- B** ethanoic acid
- C** propanoate ion
- D** propanoic acid

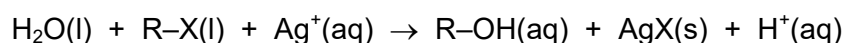
- 32** Four reagents are listed.

- 1 aqueous KCl
- 2 dilute HCl
- 3 liquid $SOCl_2$
- 4 solid PCl_5

Which reagents, when added to ethanol, will rapidly produce a gas that turns blue litmus red?

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

- 33** Four drops of 1-chlorobutane, 1-bromobutane and 1-iodobutane are put separately into three test-tubes containing 1.0 cm^3 of aqueous silver nitrate at 60°C . In each case, a hydrolysis reaction occurs.



R represents C_4H_9 and X represents the halogen atom.

The rate of formation of cloudiness in the test-tubes is in the order $RCI < RBr < RI$.

Why is this?

- A** The bond energy of $R-X$ decreases from RCI to RI .
- B** The first ionisation energy of the halogen decreases from Cl to I .
- C** The solubility of $AgX(s)$ decreases from $AgCl$ to AgI .
- D** The $R-X$ bond polarity decreases from RCI to RI .

- 34 Propanoic acid reacts with LiAlH_4 to give organic product P.

Methanoic acid reacts with organic product P, in the presence of a few drops of concentrated sulfuric acid, to give organic product Q.

What are the skeletal formulae of the two organic products?

	organic product P	organic product Q
A		
B		
C		
D		

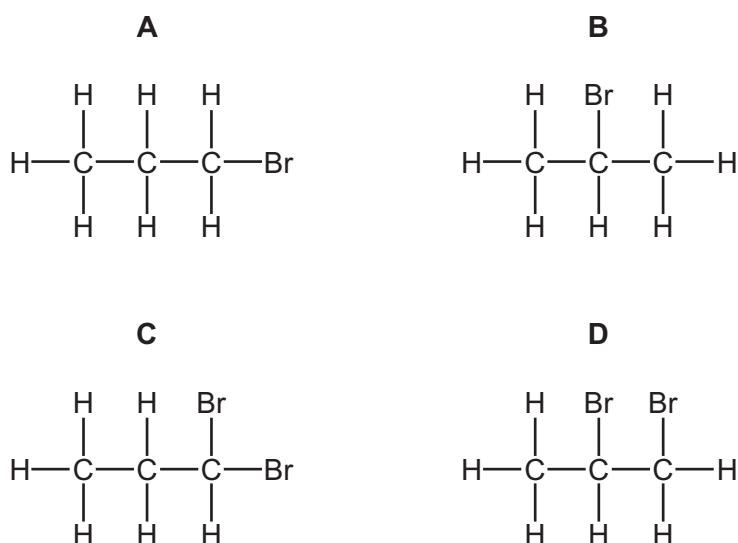
- 35 Samples of the gases CH_3Cl and Cl_2 are mixed together and irradiated with ultraviolet light.

Which compound is produced by a termination step in the reaction?

- A** HCl **B** $\text{CH}_2=\text{CH}_2$ **C** $\text{CH}_2\text{ClCH}_2\text{Cl}$ **D** H_2

- 36 Propan-1-ol, $\text{C}_3\text{H}_7\text{OH}$, is dehydrated by passing its vapour over hot aluminium oxide to give a hydrocarbon.

Which structural formula represents the product obtained when the hydrocarbon reacts with bromine?



37 Alkane S has molecular formula C_4H_{10} .

S reacts with $Cl_2(g)$ in the presence of sunlight to produce only two different monochloroalkanes, C_4H_9Cl . Both of these monochloroalkanes are treated with hot ethanolic KOH. They both produce the same alkene T, and no other organic products.

What is produced when T is treated with hot concentrated acidified $KMnO_4$?

- A CO_2 and $CH_3CH_2CO_2H$
- B CO_2 and CH_3COCH_3
- C HCO_2H and CH_3COCH_3
- D CH_3CO_2H only

38 Including structural isomers and stereoisomers, how many isomers are there of $C_2H_2Br_2$?

- A 2 B 3 C 4 D 5

39 Which compound exhibits stereoisomerism?

- A 1,1-dichloropropene
- B 2,3-dichloropropene
- C 1,2-dichloropropane
- D 1,3-dichloropropane

40 The mass spectrum of CH_3Cl shows a molecular ion peak, M^+ , at the m/e value of 50 with a relative abundance of 18.0%.

Other peaks are present in the mass spectrum.

What is seen in the mass spectrum at the m/e value of 52?

- A a peak with relative abundance of 4.5%
- B a peak with relative abundance of 6.0%
- C a peak with relative abundance of 18.0%
- D a peak with relative abundance of 54.0%

Important values, constants and standards

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

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The Periodic Table of Elements

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



Cambridge International AS & A Level

CHEMISTRY

9701/13

Paper 1 Multiple Choice

May/June 2025

1 hour 15 minutes

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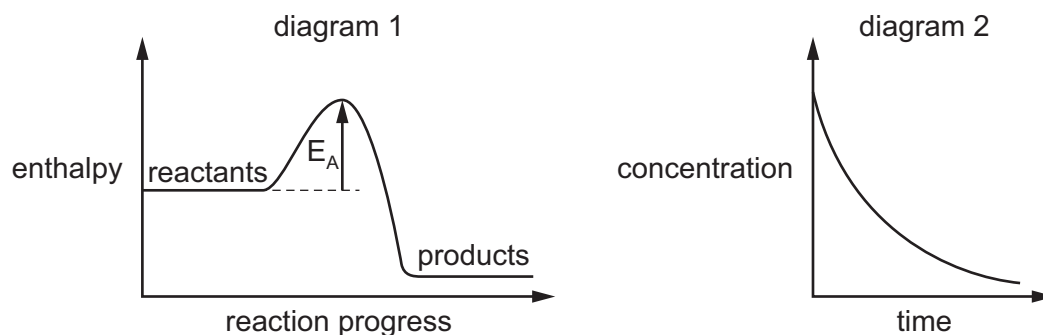
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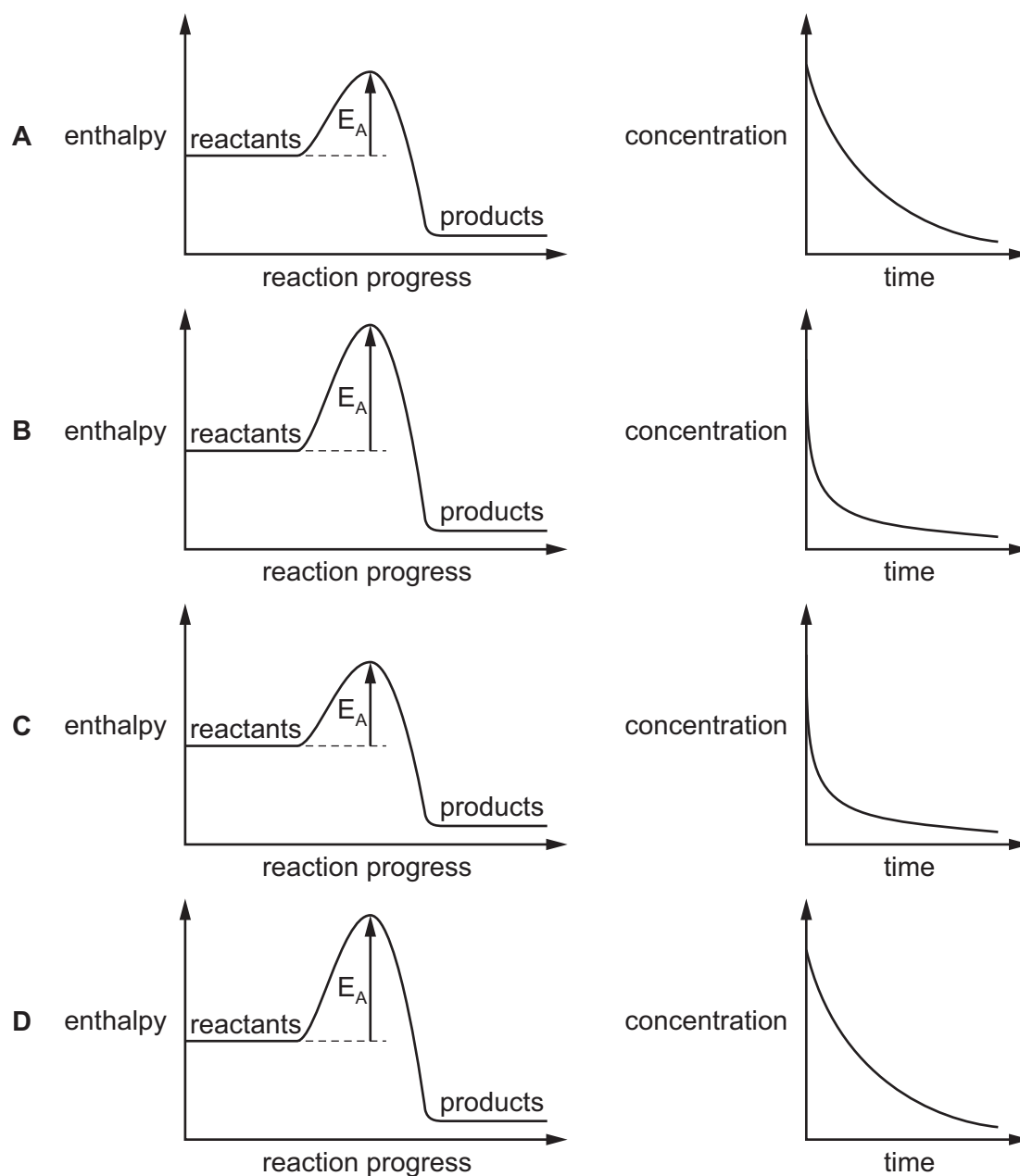
- 1** Which isolated gaseous atom has a total of five electrons occupying spherically shaped orbitals?
- A** sodium
 - B** fluorine
 - C** boron
 - D** potassium

2 Diagram 1 shows the reaction pathway for a reaction.

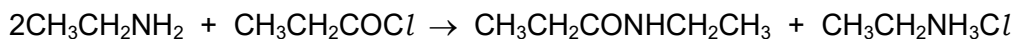
Diagram 2 shows a graph of concentration of reactant against time for the same reaction.



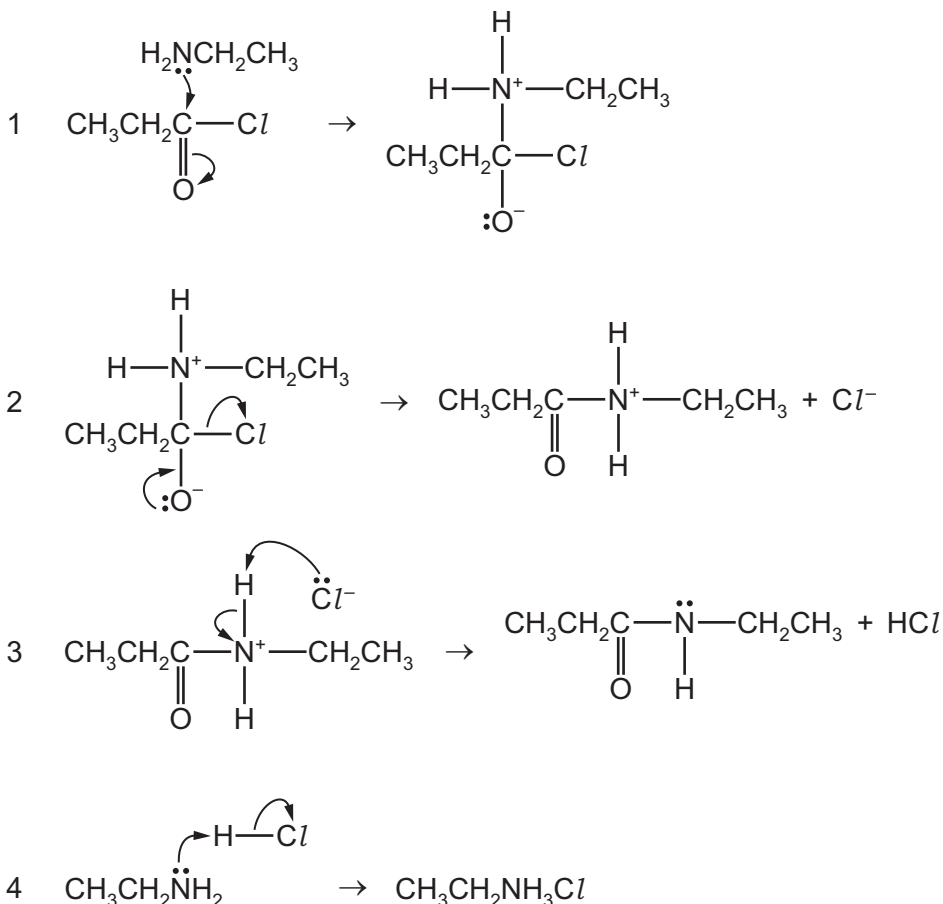
Which diagrams, drawn to the same scale, show the effect of increased temperature on this reaction?



- 3 The equation shows the overall reaction between an amine and an acid chloride.



The four steps in the mechanism are as follows.



Which steps are Brønsted–Lowry acid–base reactions?

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

- 4 Chromium is present in compound X.

- Two moles of compound X react with exactly 3 moles of silicon.
- The only products of this reaction are 4 moles of chromium and 3 moles of a silicon compound in which the oxidation state of the silicon is +4.
- Chromium and silicon are the only elements that change their oxidation states in this reaction.

What could be the identity of compound X?

- A** Cr_2O_3 **B** Cr_2H_6 **C** Cr_2H_4 **D** Cr_2O_4

- 5 The reversible reaction shown is in equilibrium at a temperature of 450 °C.



The table shows the equilibrium concentrations in the reaction mixture.

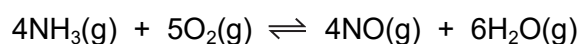
H_2	I_2	HI
1.02 mol dm^{-3}	0.02 mol dm^{-3}	0.98 mol dm^{-3}

The temperature of the reaction mixture is increased at constant volume.

The concentration of one of the components **falls** to 0.80 mol dm^{-3} at equilibrium under these conditions.

What is the concentration of H_2 in the new equilibrium mixture?

- A 0.80 mol dm^{-3}
 B 0.93 mol dm^{-3}
 C 1.11 mol dm^{-3}
 D 1.20 mol dm^{-3}
- 6 The first stage in the industrial production of nitric acid from ammonia can be represented by the following equation.



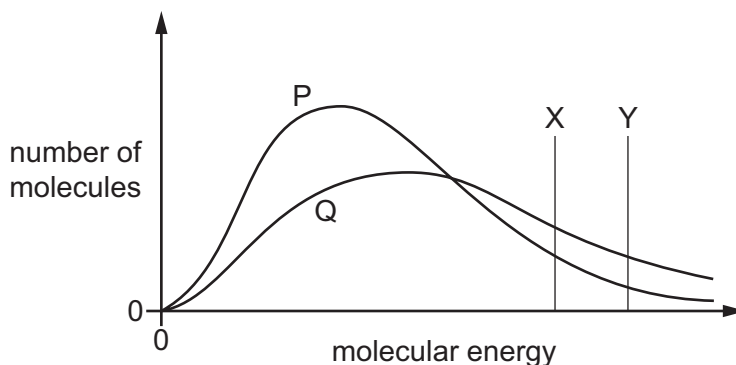
Using the following standard enthalpy change of formation data, what is the value of the standard enthalpy change, $\Delta H^\ominus$, for this reaction?

compound	$\Delta H_f^\ominus / \text{kJ mol}^{-1}$
$\text{NH}_3(\text{g})$	-46.1
$\text{NO}(\text{g})$	+90.3
$\text{H}_2\text{O}(\text{g})$	-241.8

- A $+905.2 \text{ kJ mol}^{-1}$
 B $-105.4 \text{ kJ mol}^{-1}$
 C $-905.2 \text{ kJ mol}^{-1}$
 D $-1274.0 \text{ kJ mol}^{-1}$

- 7 The gaseous compound Z decomposes on heating.

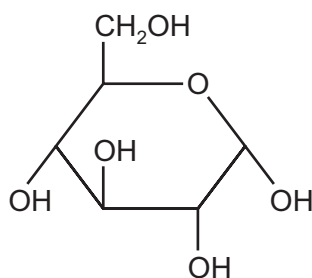
In the diagram, Boltzmann distributions for Z at two different temperatures, P and Q, are shown. The lines X and Y indicate activation energies for the decomposition of Z with and without a catalyst.



Which curve and which line describe the decomposition of Z at a higher temperature and with a catalyst present?

	higher temperature	catalyst present
A	P	X
B	P	Y
C	Q	X
D	Q	Y

- 8 The structure of a molecule found in food is shown.



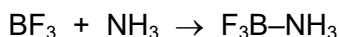
Four statements about the molecule are listed.

- 1 This molecule contains only σ bonds.
- 2 This molecule contains both σ and π bonds.
- 3 The six-membered ring is planar.
- 4 The six-membered ring is non-planar.

Which two statements are correct?

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

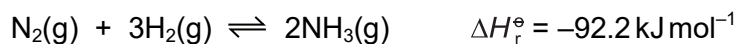
- 9 In which substance are covalent bonds broken as it melts?
- A silicon(IV) oxide
B ice
C iodine
D ethanol
- 10 Why is the second ionisation energy of sodium larger than the second ionisation energy of magnesium?
- A The attraction between the nucleus and the outer electron is greater in Na^+ than in Mg^+ .
B The nuclear charge of Na^+ is greater than that of Mg^+ .
C The outer electron of Na^+ is more shielded than the outer electron of Mg^+ .
D The outer electron of Na is in the same orbital as the outer electron of Mg.
- 11 BF_3 reacts with NH_3 to form a single compound with a simple molecular structure.



Which row describes how the bond angles change during the reaction?

	F–B–F bond angle	H–N–H bond angle
A	decreases	decreases
B	decreases	increases
C	increases	decreases
D	increases	increases

- 12 The equation for the reaction of nitrogen with hydrogen is shown.



Which statement is correct?

- A $\Delta H_r^\ominus$ is measured at 298 °C.
B $\Delta H_r^\ominus$ is measured at 101 kPa.
C $\Delta H_r^\ominus$ represents the standard enthalpy change for the formation of ammonia gas.
D $\Delta H_r^\ominus$ represents the enthalpy change when 1.0 mol of $\text{N}_2(\text{g})$ reacts with 1.0 mol of $\text{H}_2(\text{g})$.

- 13 Hydrogen peroxide, H_2O_2 , decomposes into water and oxygen when a suitable catalyst is added.

20.0cm^3 of aqueous hydrogen peroxide decomposes to produce 600cm^3 of oxygen at room conditions.

What is the concentration of the aqueous hydrogen peroxide?

- A 5.00mol dm^{-3}
- B 2.50mol dm^{-3}
- C 1.25mol dm^{-3}
- D 0.625mol dm^{-3}

- 14 When 0.15g of an organic compound is vaporised, it occupies a volume of 65.0cm^3 at 405K and $1.00 \times 10^5\text{Pa}$.

Using the expression $pV = nRT$, which expression should be used to calculate the relative molecular mass, M_r , of the compound?

- A $\frac{0.15 \times 65 \times 10^{-6} \times 1 \times 10^5}{8.31 \times 405}$
- B $\frac{0.15 \times 8.31 \times 405}{1 \times 10^5 \times 65 \times 10^{-3}}$
- C $\frac{0.15 \times 65 \times 10^{-3} \times 1 \times 10^5}{8.31 \times 405}$
- D $\frac{0.15 \times 8.31 \times 405}{1 \times 10^5 \times 65 \times 10^{-6}}$

- 15 A washing powder contains sodium hydrogencarbonate, NaHCO_3 , as one of the ingredients.

In a titration, a solution containing 1.00g of this washing powder requires 7.15cm^3 of 0.100mol dm^{-3} sulfuric acid for complete reaction. The sodium hydrogencarbonate is the only ingredient that reacts with the acid.

What is the percentage by mass of sodium hydrogencarbonate in the washing powder?

- A 3.0%
- B 6.0%
- C 12.0%
- D 24.0%

16 The flow chart shows some reactions of nitrogen compounds.



Which row identifies gas 1 and salt 2?

	gas 1	salt 2
A	ammonia	ammonium nitrate
B	ammonia	sodium nitrate
C	nitrogen dioxide	ammonium nitrate
D	nitrogen dioxide	sodium nitrate

17 Mixing aqueous silver nitrate and aqueous sodium chloride produces a precipitate.

Addition of which reagent to the mixture gives a colourless solution?

- A** aqueous ammonia
- B** aqueous potassium iodide
- C** dilute hydrochloric acid
- D** dilute nitric acid

18 Which statement is correct?

- A** Barium oxide reacts with water at room temperature to form barium hydroxide and hydrogen.
- B** Calcium oxide does **not** react with water at room temperature.
- C** Magnesium hydroxide reacts with steam to form magnesium oxide and hydrogen.
- D** Strontium oxide reacts with water at room temperature to form strontium hydroxide only.

19 Which statement about the properties of halogens and hydrogen halides is correct?

- A** A chloride ion is a stronger reducing agent than an iodide ion.
- B** Chlorine is more volatile than bromine because chlorine has stronger intermolecular forces.
- C** Hydrogen bromide is more thermally stable than hydrogen iodide because it has a stronger covalent bond.
- D** Iodine is less reactive than bromine because iodine has weaker covalent bonds.

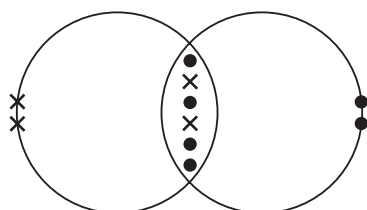
20 Three statements about the chemical periodicity of Period 3 oxides are listed.

- 1 The maximum oxidation state of the Period 3 elements in their oxides increases from sodium to phosphorus, then decreases from phosphorus to sulfur.
- 2 The oxides from sodium to aluminium dissolve in water without hydrolysis; from silicon to sulfur they are hydrolysed by water.
- 3 The structure and bonding changes from giant ionic to giant covalent to simple molecular.

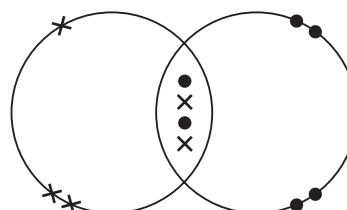
Which statements are correct?

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

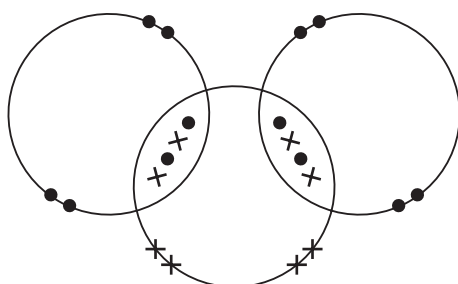
21 Which dot-and-cross diagrams represent molecules that can react with unburned hydrocarbons to form peroxyacetyl nitrate, PAN, a component of photochemical smog?



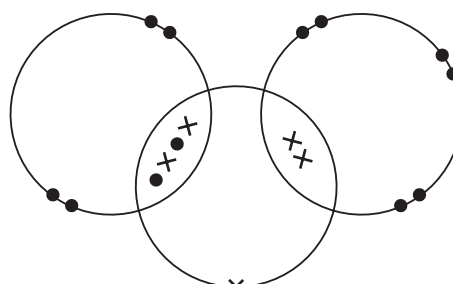
1



2



3



4

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

22 Which set of three elements contains a single element that has **both** the highest melting point **and** the lowest electrical conductivity of the three elements in the set?

- A** magnesium, aluminium and silicon
B aluminium, silicon and phosphorus
C sodium, magnesium and aluminium
D silicon, phosphorus and chlorine

23 In which row do the particles increase in size?

	smallest	→	largest
A	N	O	F
B	N^{3-}	O^{2-}	F^-
C	Na^+	Mg^{2+}	Al^{3+}
D	Na^+	Ne	F^-

24 W, X, Y and Z are Group 2 elements barium, calcium, magnesium and strontium but not in that order.

W reacts faster with dilute hydrochloric acid than Y.

The hydroxide of X is less soluble in water than the hydroxide of W.

The sulfate of Y is the most soluble of the sulfates of W, X, Y and Z.

The carbonate of Z decomposes more slowly than the carbonate of W at the same temperature.

What is the M_r of the nitrate of W?

- A** 148.3 **B** 164.1 **C** 211.6 **D** 261.3

25 Polymer J has repeat unit $-\text{[CH(C}_2\text{H}_5\text{)CH(CH}_3\text{)]}-$.

Polymer K has repeat unit $-\text{[CH(CH}_3\text{)CH(CH}_3\text{)]}-$.

Which row is correct?

	monomer from which polymer J is produced	monomer from which polymer K is produced
A	pent-1-ene	but-1-ene
B	pent-1-ene	but-2-ene
C	pent-2-ene	but-1-ene
D	pent-2-ene	but-2-ene

26 0.200 mol ethanenitrile reacts with an excess of dilute sodium hydroxide. The reaction produces organic compound S and ammonia gas only.

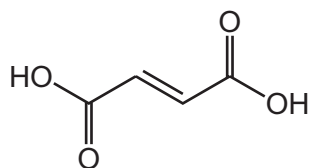
The reaction has an 80.0% yield.

Which mass of S is produced?

- A** 9.60 g **B** 13.1 g **C** 15.4 g **D** 16.4 g

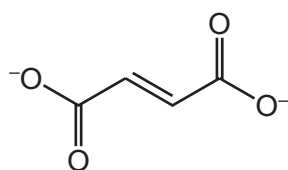
27 The structure of butenedioic acid is shown.

butenedioic acid

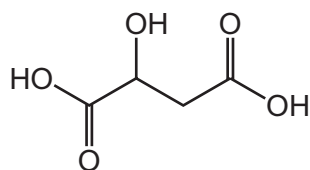


When an excess of NaOH(aq) is added to butenedioic acid, which organic product is formed?

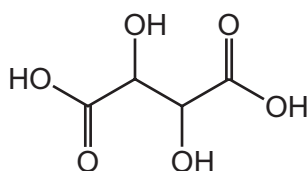
A



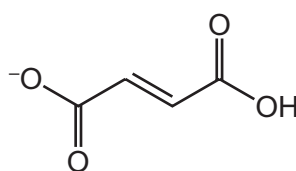
B



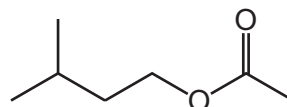
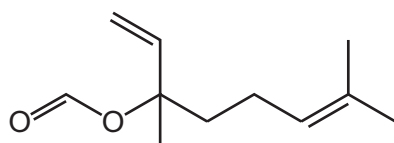
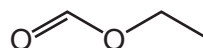
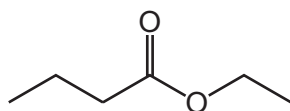
C



D



28 Four organic compounds are shown.



A mixture of these four compounds reacts with hot aqueous sodium hydroxide.

The products of this reaction are acidified.

Which organic acids are present in the products?

- A** butanoic, ethanoic and propanoic acids
- B** butanoic, ethanoic and methanoic acids
- C** ethanoic, 3-methylbutanoic and propanoic acids
- D** methanoic, 3-methylbutanoic and propanoic acids

- 29 Ethanal reacts with KCN dissolved in liquid HCN. This reaction involves the formation of an intermediate.

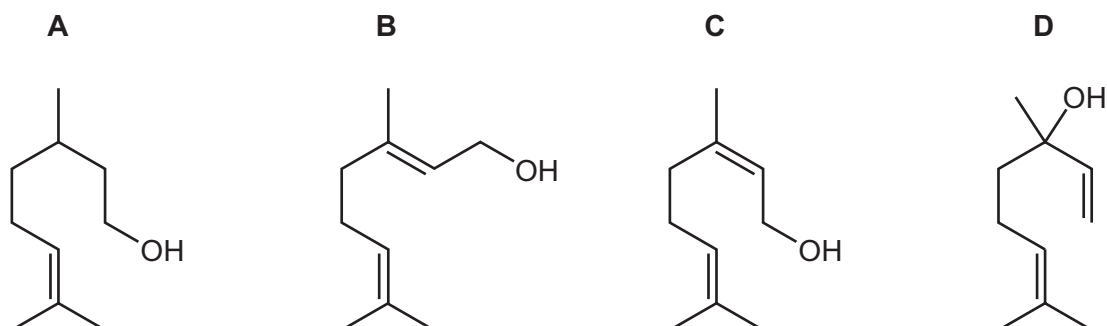
Which statement is correct?

- A HCN does **not** have any lone pairs of electrons and so CN^- is the catalyst.
 - B The $\text{O}^{\delta-}$ of $\text{C}=\text{O}$ attacks K^+ in a nucleophilic attack.
 - C A proton from HCN is transferred to the intermediate.
 - D The reaction is a nucleophilic substitution.
- 30 What is formed when propanone is heated under reflux with a solution of NaBH_4 ?
- A propan-2-ol
 - B propan-1-ol
 - C propanal
 - D propane

- 31 The compounds shown are all produced by plants.

Each compound is warmed with acidified $\text{K}_2\text{Cr}_2\text{O}_7$.

Which compound will give a different observation to the other three?

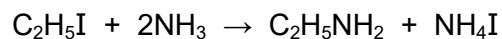


- 32 Structural and stereoisomerism should be considered when answering this question.

How many alcohols with the molecular formula $\text{C}_5\text{H}_{12}\text{O}$ give a yellow precipitate with alkaline $\text{I}_2(\text{aq})$?

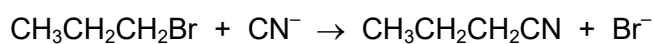
- A 2 B 3 C 4 D 5

- 33 An amine is produced in the following reaction.



What is the mechanism?

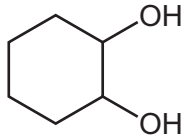
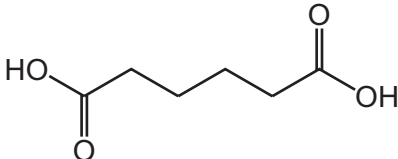
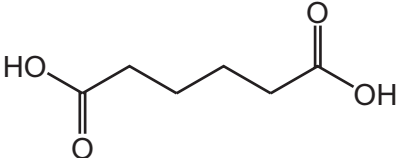
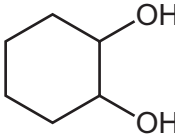
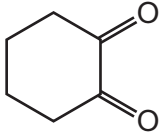
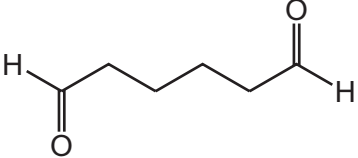
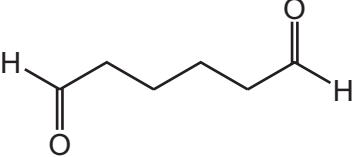
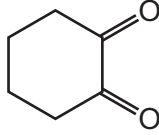
- A** electrophilic addition
B free-radical substitution
C nucleophilic addition
D nucleophilic substitution
- 34 The reaction shown can be used to lengthen a carbon chain.



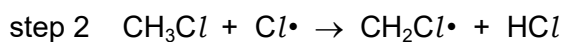
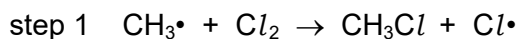
Which row shows the correct reagent and conditions for this reaction?

	reagent	conditions
A	KCN	heat under reflux in dilute sulfuric acid
B	KCN	heat under reflux in ethanol
C	HCN	heat under reflux in dilute sulfuric acid
D	HCN	heat under reflux in ethanol

- 35 Which row shows the products formed when cyclohexene reacts with acidified KMnO_4 under different conditions?

	product formed on reaction with cold, dilute acidified KMnO_4	product formed on reaction with hot, concentrated acidified KMnO_4
A		
B		
C		
D		

- 36 Two steps in the free-radical substitution reaction between methane and chlorine are shown.

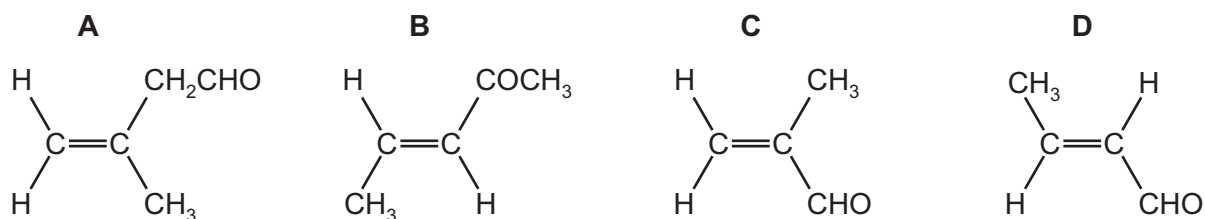


Which statement is correct?

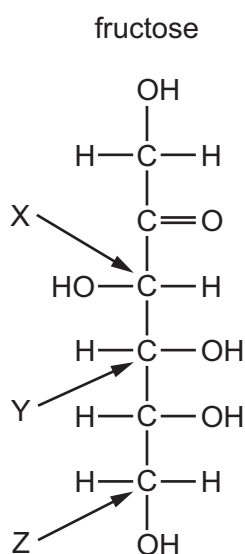
- A Step 1 is initiation and step 2 is propagation.
- B Step 1 is propagation and step 2 is termination.
- C Step 1 is initiation and step 2 is termination.
- D Both steps are propagation.

- 37 Compound P displays cis/trans isomerism and gives a red-brown precipitate with Fehling's solution.

What is P?



- 38 Fructose is a sugar with more than one chiral centre. The fructose molecule is shown with X, Y and Z indicating three carbon atoms.



Which carbon atoms are chiral centres?

- A** X, Y and Z **B** X and Y only **C** X only **D** Y only
- 39 An organic compound, T, contains only one functional group.

Compound T has the empirical formula $\text{C}_2\text{H}_4\text{O}$.

Some functional groups are listed.

- 1 alcohol
- 2 aldehyde
- 3 ester
- 4 ketone

Which functional groups are possible for compound T?

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

40 The mass spectrum of an organic compound has the following features.

- The molecular ion peak is at $m/e = 60$. This peak has a relative intensity = 100.
- There is a peak at $m/e = 61$, which has a relative intensity = 2.2.
- There is **no** fragment peak at $m/e = 17$.
- There is a fragment peak at $m/e = 31$.

What could be the identity of the organic compound?

- A methyl methanoate, HCOOCH_3
- B methoxyethane, $\text{CH}_3\text{OC}_2\text{H}_5$
- C ethanoic acid, CH_3COOH
- D propan-2-ol, $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$

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Important values, constants and standards

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

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Cambridge International AS & A Level

CHEMISTRY

9701/14

Paper 1 Multiple Choice

May/June 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.

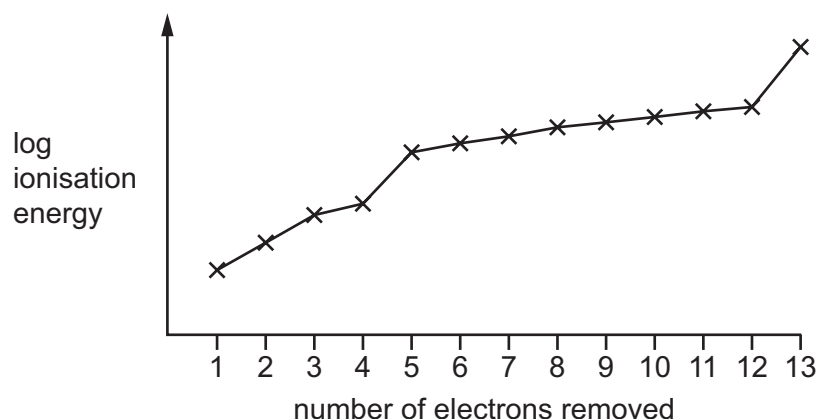
INFORMATION

- 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.

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



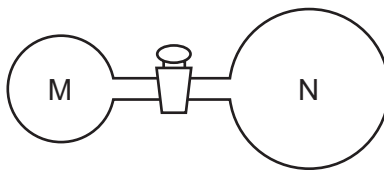
- 1 The diagram shows the logarithm of the first 13 ionisation energies of an element.



Which statement is correct?

- A** A proton is lost for each successive ionisation energy.
- B** The element is aluminium.
- C** The element is silicon.
- D** The element has only one outer electron.
- 2 What is the empirical formula of butanoic acid?
- A** C_2H_4O **B** C_3H_6O **C** C_4H_8O **D** $C_5H_{10}O$
- 3 In which pair is the bond angle in the first species smaller than the smallest bond angle in the second species?
- A** CH_4 and SF_6
- B** CO_2 and BF_3
- C** H_2O and H_3O^+
- D** NH_4^+ and NH_3

- 4 Two glass vessels, M and N, are connected by a closed valve.



M contains helium at 20°C at a pressure of 1×10^5 Pa. N has been evacuated, and has three times the volume of M.

The valve is opened and the temperature of the whole apparatus is raised to 100°C.

What is the final pressure in the system?

- A 3.18×10^4 Pa
 B 4.24×10^4 Pa
 C 1.25×10^5 Pa
 D 5.09×10^5 Pa
- 5 Solid sulfur consists of molecules made up of eight atoms covalently bonded together.

The bonding in sulfur dioxide is O=S=O.

enthalpy change of combustion of S_8 , $\Delta H_c^\circ S_8(s) = -2376 \text{ kJ mol}^{-1}$

energy required to break 1.0 mol $S_8(s)$ into gaseous atoms = 2232 kJ mol^{-1}

O=O bond enthalpy = 496 kJ mol^{-1}

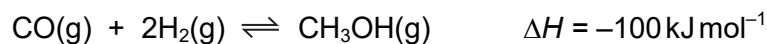
Using these data, what is the value of the S=O bond enthalpy?

- A 239 kJ mol^{-1} B 257 kJ mol^{-1} C 319 kJ mol^{-1} D 536 kJ mol^{-1}
- 6 In this question, the average oxidation state of sulfur in $\underline{S}_2O_3^{2-}$ and sulfur in $\underline{S}_2O_4^{2-}$ should be used.

In which reaction does the underlined element have the largest increase in oxidation state?

- A $3\underline{Cr}O_4^{3-}(aq) + 8H^+(aq) \rightarrow 2CrO_4^{2-}(aq) + Cr^{3+}(aq) + 4H_2O(l)$
 B $2\underline{N}O_2(g) + H_2O(l) \rightarrow HNO_3(aq) + HNO_2(aq)$
 C $\underline{S}_2O_3^{2-}(aq) + 2H^+(aq) \rightarrow S(s) + SO_2(g) + H_2O(l)$
 D $2\underline{S}_2O_4^{2-}(aq) + H_2O(l) \rightarrow S_2O_3^{2-}(aq) + 2HSO_3^-(aq)$

- 7 Methanol, CH_3OH , is made industrially from carbon monoxide and hydrogen in the equilibrium reaction shown.



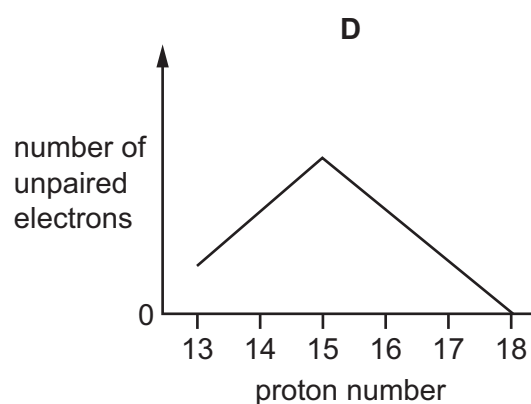
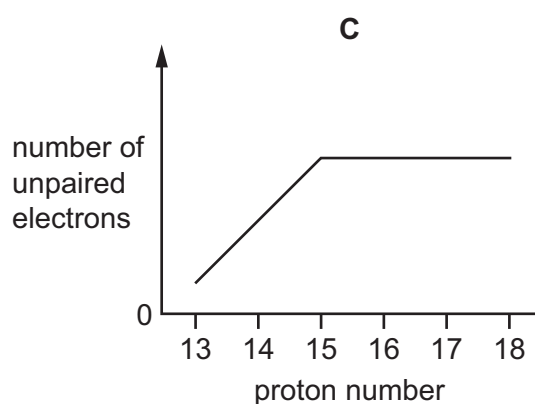
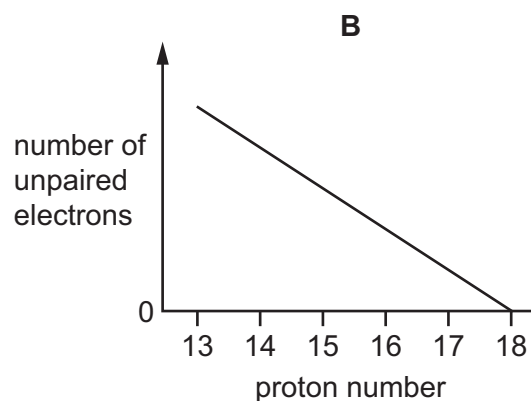
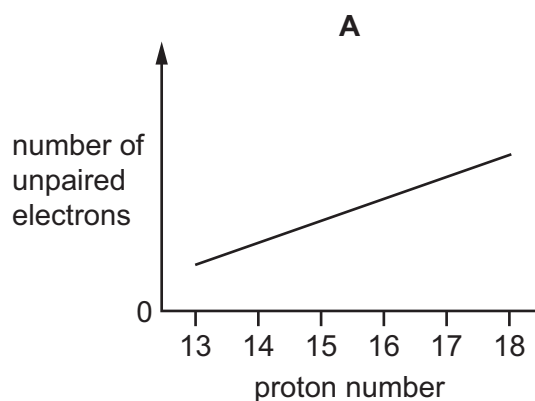
Which statement about this equilibrium is correct?

- A K_p for the process is $\frac{p_{\text{CH}_3\text{OH}}}{p_{\text{CO}} \times p_{\text{H}_2}}$.
- B An increase in pressure increases the equilibrium yield of methanol.
- C An increase in temperature increases the equilibrium yield of methanol.
- D The addition of an effective catalyst increases the equilibrium yield of methanol.
- 8 The distribution of molecular energies in an ideal gas can be represented in a Boltzmann distribution.

Which change in conditions leads to a **larger** value for the number of molecules that have the most probable energy?

- A keeping the temperature constant but decreasing the pressure
- B keeping the pressure constant but decreasing the temperature
- C keeping the temperature constant but increasing the pressure
- D keeping the pressure constant but increasing the temperature

- 9 Which graph represents the number of unpaired electrons in the atoms of six elements in Period 3 of the Periodic Table?



- 10 A 69.0 g sample of nitrogen dioxide is placed in a reaction vessel.

The initial pressure of the nitrogen dioxide is P . An effective catalyst is then added and the nitrogen dioxide begins to decompose into its elements.

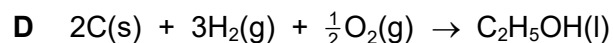
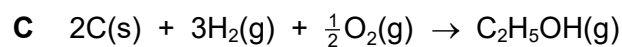
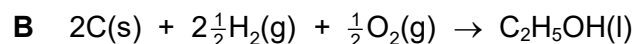
After ten minutes, the total pressure is $1.1P$.

What is the mass of oxygen molecules in the reaction vessel after ten minutes?

- A** 4.80 g **B** 9.60 g **C** 38.4 g **D** 48.0 g
- 11 Which statement about the molecule PF_5 is correct?
- A** Every F–P–F bond angle is 90° .
- B** The central atom in the molecule does **not** have a lone pair of electrons.
- C** The molecule has an overall dipole moment.
- D** The shape of the molecule is octahedral.
- 12 Which solid compound has both ionic and covalent bonding but **not** coordinate bonding?

- A** Al_2Cl_6 **B** CH_3COONa **C** MgCl_2 **D** NH_4Cl

13 Which equation represents the standard enthalpy change of formation, $\Delta H_f^\ominus$, for ethanol?



14 When K_2MnO_4 reacts with concentrated hydrochloric acid, the products include chlorine molecules and MnCl_2 . All of the manganese atoms are reduced to MnCl_2 .

Both Mn and Cl change their oxidation numbers during the reaction. No other element is oxidised or reduced.

Using these changes in oxidation number, how many moles of chlorine will be produced when 1.0 mol of K_2MnO_4 reacts with an excess of hydrochloric acid?

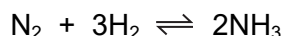
A 2.0 mol

B 2.5 mol

C 3.0 mol

D 4.0 mol

15 A nitrogen–hydrogen mixture, initially in the mole ratio of 1 : 3, reaches equilibrium with ammonia when 50% of the nitrogen has reacted. The total final pressure is p .



What is the partial pressure of ammonia in the equilibrium mixture?

A $\frac{p}{6}$

B $\frac{p}{4}$

C $\frac{p}{3}$

D $\frac{p}{2}$

- 16** Propyl methanoate is hydrolysed with NaOH(aq) at 20 °C to form two products, X and Y. Product X is an alcohol.

Data from the experiment is shown.

time / s	[X] / mol dm ⁻³
0	0.000
40	0.004
80	0.007
120	0.010
180	0.015
240	0.019
300	0.022

Which row is correct?

	average rate of reaction between 240 and 300 s	product Y
A	$5.00 \times 10^{-5} \text{ mol dm}^{-3} \text{ s}^{-1}$	HCOONa
B	$5.00 \times 10^{-5} \text{ mol dm}^{-3} \text{ s}^{-1}$	HCOOH
C	$7.33 \times 10^{-5} \text{ mol dm}^{-3} \text{ s}^{-1}$	HCOONa
D	$7.33 \times 10^{-5} \text{ mol dm}^{-3} \text{ s}^{-1}$	HCOOH

17 The table shows the numbers of bond pairs and lone pairs in four different species.

Which row is correct?

	species	total number of bond pairs	total number of lone pairs
A	nitrogen molecule	3	1
B	ammonia molecule	4	1
C	ammonium ion	4	0
D	hydroxide ion	1	4

18 Which row is correct?

	property	explanation
A	AgI dissolves in aqueous ammonia more readily than AgCl does	AgI reacts with aqueous ammonia
B	HCl decomposes more readily than HI does	Cl is more electronegative than I
C	I ₂ has a higher melting point than Cl ₂	I ₂ has stronger van der Waals' forces than Cl ₂
D	I ₂ is a stronger oxidising agent than Cl ₂	an I atom loses electrons more readily than a Cl atom

19 Substance J reacts with water. A gas is given off and the pH of the solution increases. The solution is then reacted with sulfuric acid and a white precipitate forms.

What could be substance J?

- A** barium
- B** barium oxide
- C** magnesium
- D** magnesium oxide

- 20** Compound L has empirical formula NH. It decomposes on gentle heating to produce ammonia and compound M only. An aqueous solution of compound L is a good conductor of electricity.

Which row could be correct?

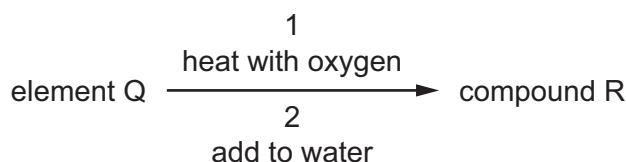
	identity of M	species present in L(aq)
A	N_2H_4	N^{3-} and H^+
B	N_2H_4	NH_4^+ and NH_2^-
C	HN_3	NH_3 and HN_3
D	HN_3	NH_4^+ and N_3^-

- 21** X, Y and Z are elements in Period 3 of the Periodic Table. The results of some experiments carried out with compounds of these elements are shown.

element	result of adding the oxide of the element to $\text{H}_2\text{O}(\text{l})$	result of adding the chloride of the element to $\text{H}_2\text{O}(\text{l})$	result of adding the oxide of the element to $\text{HCl}(\text{aq})$
X	no reaction	hydrolyses	forms chloride salt
Y	forms hydroxide	dissolves	forms chloride salt
Z	forms acid	hydrolyses	hydrolyses

Which statement is correct?

- A** Element X is Al and element Y is Mg.
B Element X is Si and element Y is Na.
C Element Y is Al and element Z is P.
D Element Y is Na and element Z is Al.
- 22** The flow diagram shows two successive reactions starting from element Q. Element Q is either calcium or barium.



Element Q forms a nitrate that is less thermally stable than strontium nitrate.

What is the identity of compound R?

- A** CaO **B** $\text{Ca}(\text{OH})_2$ **C** BaO **D** $\text{Ba}(\text{OH})_2$

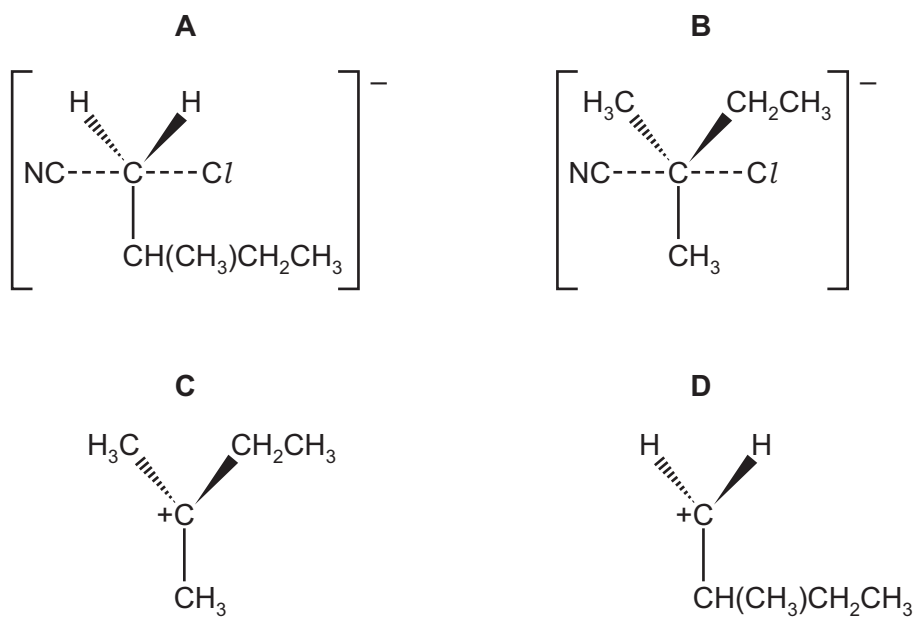
- 23 Which anions are formed when chlorine is passed into cold aqueous potassium hydroxide?
- A Cl^- and ClO^-
 - B Cl^- and ClO_3^-
 - C Cl^- and ClO_4^-
 - D ClO^- and ClO_3^-
- 24 What increases for each successive element in Period 3 from sodium to sulfur?
- A the highest oxidation number of the element seen in an oxide
 - B the melting point of the elements
 - C the number of occupied orbitals in the atom
 - D the pH of the solutions of the chlorides in water
- 25 Which statement about an ammonium ion is correct?
- A All of the H–N–H bond angles in the ion are 90° .
 - B All of the H–N–H bond angles in the ion are 107° .
 - C The ion contains a N–H dative covalent bond which is weaker than the other three N–H covalent bonds.
 - D The ion will react with a base as it is a weak acid.
- 26 An alcohol, U, is reacted with hot acidified $\text{K}_2\text{Cr}_2\text{O}_7$ solution. The organic product of the reaction contains 58.8% C, 9.8% H and 31.4% O by mass.
- What is the identity of alcohol U?
- A 2-methylbutan-2-ol
 - B 3-methylbutan-2-ol
 - C pentan-1-ol
 - D propan-1-ol

27 Which row shows a primary, a secondary and a tertiary alcohol?

	primary	secondary	tertiary
A	$\begin{array}{c} \text{CH}_2\text{OH} \\ \\ \text{CH}_2 \\ \\ \text{CH}_3 \end{array}$	$\begin{array}{c} \text{CH}_2\text{OH} \\ \\ \text{CHOH} \\ \\ \text{CH}_3 \end{array}$	$\begin{array}{c} \text{CH}_2\text{OH} \\ \\ \text{CHOH} \\ \\ \text{CH}_2\text{OH} \end{array}$
B	$\begin{array}{c} \text{CH}_2\text{OH} \\ \\ \text{CH}_3-\text{C}-\text{H} \\ \\ \text{CH}_3 \end{array}$	$\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3-\text{C}-\text{OH} \\ \\ \text{CH}_3 \end{array}$	$\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3-\text{C}-\text{H} \\ \\ \text{CH}_2\text{OH} \end{array}$
C	$\begin{array}{c} \text{CH}_2\text{OH} \\ \\ \text{CH}_3-\text{C}-\text{H} \\ \\ \text{H} \end{array}$	$\begin{array}{c} \text{CH}_2\text{OH} \\ \\ \text{CH}_3-\text{C}-\text{CH}_2\text{OH} \\ \\ \text{H} \end{array}$	$\begin{array}{c} \text{CH}_2\text{OH} \\ \\ \text{CH}_3-\text{C}-\text{CH}_2\text{OH} \\ \\ \text{CH}_2\text{OH} \end{array}$
D	$\begin{array}{c} \text{H} \\ \\ \text{CH}_3-\text{C}-\text{OH} \\ \\ \text{H} \end{array}$	$\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3-\text{C}-\text{OH} \\ \\ \text{H} \end{array}$	$\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3-\text{C}-\text{OH} \\ \\ \text{CH}_3 \end{array}$

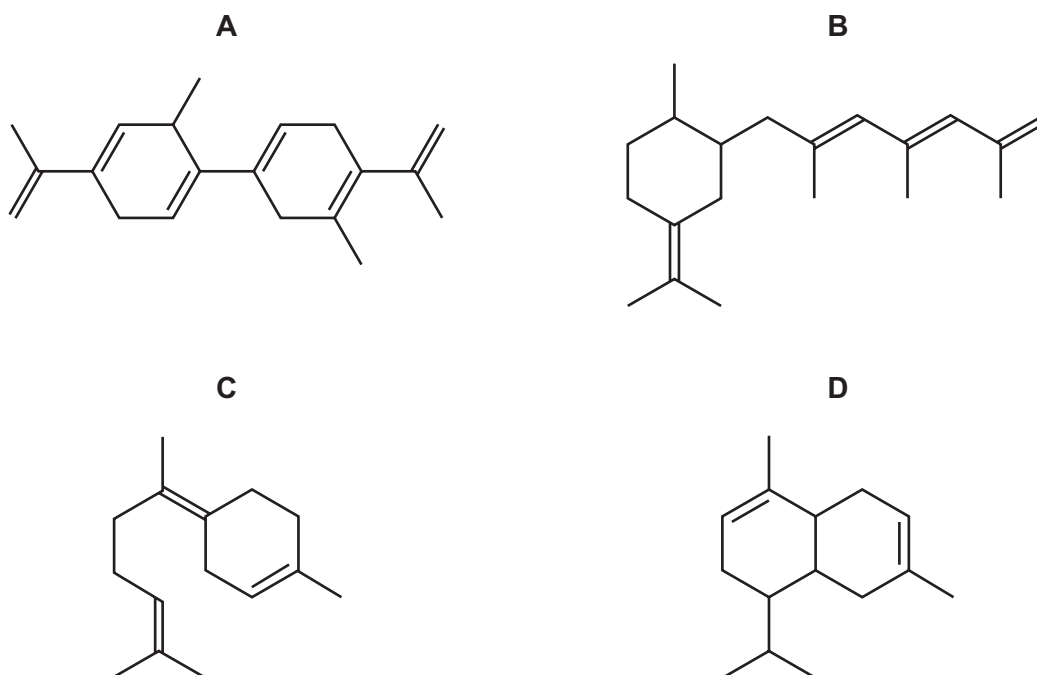
28 1-chloro-2-methylbutane reacts with sodium cyanide in a nucleophilic substitution reaction.

What is the most likely intermediate or transition state in this reaction?

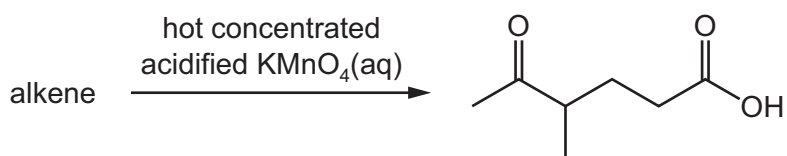


- 29 When 0.010 mol of a hydrocarbon X reacts with 720 cm³ of hydrogen at room conditions, an alkane is formed.

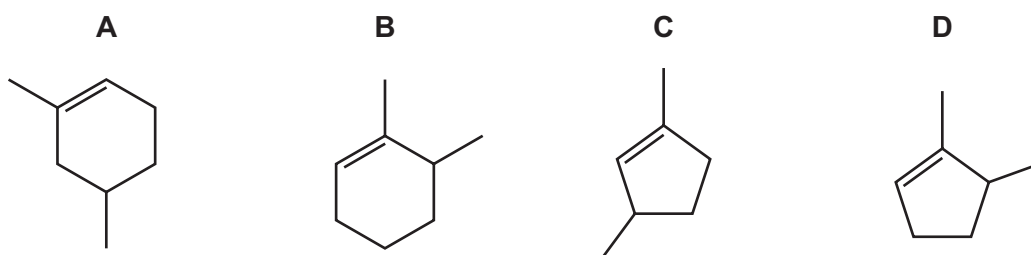
What is hydrocarbon X?



- 30 An alkene reacts with hot concentrated acidified KMnO₄ to produce a single organic product as shown.

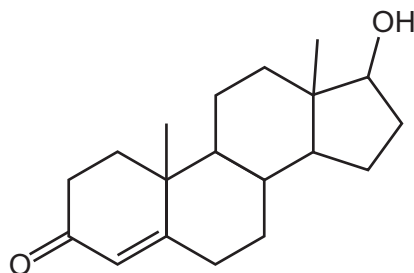


What is the structure of the alkene?



- 31 Testosterone is an optically active organic molecule.

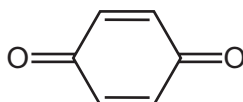
testosterone



How many chiral centres are there in one molecule of testosterone?

- A 5 B 6 C 7 D 8
- 32 Quinone is an unsaturated molecule.

quinone



Which statement about quinone is correct?

- A Quinone is non-planar and has an overall dipole moment.
 B Quinone is non-planar and does **not** have an overall dipole moment.
 C Quinone is planar and has an overall dipole moment.
 D Quinone is planar and does **not** have an overall dipole moment.
- 33 Which reagent would react with 1-bromopropane to give the highest yield of propene?
- A ammonia
 B aqueous potassium hydroxide
 C potassium cyanide
 D ethanolic sodium hydroxide
- 34 Acidified potassium dichromate(VI), $K_2Cr_2O_7$, is added to propan-1-ol and the mixture is immediately distilled. The distillate is treated with HCN in the presence of KCN.

What is the organic product?

- A $CH_3C(CN)(OH)CH_3$
 B $CH_3CH_2CH_2CO_2H$
 C $CH_3CH_2CH(OH)CN$
 D $CH_3CH_2CH_2CN$

- 35** Compound Q gives positive results when tested separately with alkaline $I_2(aq)$ and with Tollens' reagent.

What is compound Q?

- A** $CHOCH_2CH_2CHO$
B CH_3CH_2COCHO
C CH_3COCH_2CHO
D $CH_3COCOCH_3$

- 36** Structural isomerism and stereoisomerism should be considered when answering this question.

How many isomeric esters of methanoic acid can be made with the molecular formula $C_5H_{10}O_2$?

- A** 2 **B** 3 **C** 4 **D** 5

- 37** The juice of one lemon reacts completely with 120 cm^3 of 0.50 mol dm^{-3} sodium carbonate solution.

The formula of citric acid is $HOOCCH_2C(OH)(COOH)CH_2COOH$.

No sodium carbonate is left unreacted.

What is the amount of citric acid in one lemon assuming that it is the only acid in the sample?

- A** 0.02 mol **B** 0.04 mol **C** 0.06 mol **D** 0.09 mol

- 38** Separate samples of 1-bromopropane are used in two different reactions.

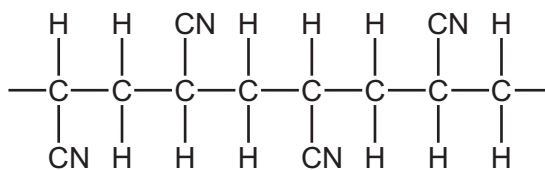
reaction 1 1-bromopropane is converted into compound X by heating it under pressure with ammonia in ethanol.

reaction 2 1-bromopropane is converted into compound Y. Compound Y undergoes hydrolysis to form butanoic acid.

Which row identifies compound X and describes the reagents used in reaction 2 to make compound Y?

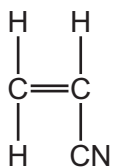
	identity of compound X	reagents for reaction 2
A	$CH_3CH_2CH_2NH_2$	$HCN(aq)$
B	$CH_3CH_2CH_2NH_2$	KCN dissolved in ethanol
C	$CH_3CH_2CH_2OH$	$HCN(aq)$
D	$CH_3CH_2CH_2OH$	KCN dissolved in ethanol

39 The diagram shows part of a polymer chain.

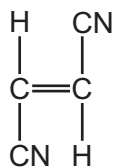


Which monomer would form this polymer?

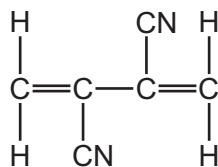
A



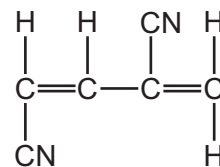
B



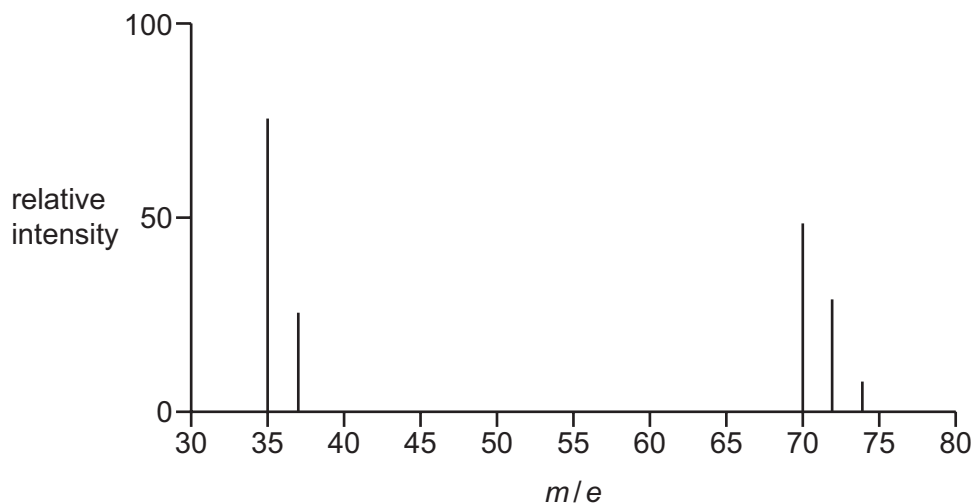
C



D



40 The mass spectrum of element Z is shown.



What is element Z?

- A** arsenic
- B** chlorine
- C** gallium
- D** tungsten

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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 J g ⁻¹ K ⁻¹)

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The Periodic Table of Elements

Group																		
1	2	1 Hhydrogen1.0										13	14	15	16	17	18	
		Key atomic number atomic symbol name relative atomic mass																
3 Li lithium 6.9	4 Be beryllium 9.0																	
11 Na sodium 23.0	12 Mg magnesium 24.3																	
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8	
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium —	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3	
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids		72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium —	85 At astatine —	86 Rn radon —
87 Fr francium —	88 Ra radium —	89–103 actinoids		104 Rf rutherfordium —	105 Db dubnium —	106 Sg seaborgium —	107 Bh bohrium —	108 Hs hassium —	109 Mt meitnerium —	110 Ds darmstadtium —	111 Rg roentgenium —	112 Cn copernicium —	113 Nh nihonium —	114 Fl flerovium —	115 Mc moscovium —	116 Lv livermorium —	117 Ts tennessine —	118 Og oganesson —

lanthanoids

57	La lanthanum 138.9	58	Ce cerium 140.1	59	Pr praseodymium 140.9	60	Nd neodymium 144.2	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
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 —

actinoids