Cambridge Assessment International Education

Cambridge International AS & A Level

CHEMISTRY **9701/13**

Paper 1 Multiple Choice **October/November 2024**

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.

[Turn over

1 In this question Q is used to represent a halogen atom.

Magnesium and calcium each form a compound with chlorine and a compound with bromine.

One of these compounds contains:

- the element in Group 2 with the higher first ionisation energy **and**
- the element in Group 17 with the higher Q–Q bond energy.

What is the formula of this compound?

A $MgCl_2$ **B** $MgBr_2$ **C** $CaCl_2$ **D** $CaBr_2$

2 Compound X contains two elements, Y and Z.

Element Y is in Period 2 of the Periodic Table. In one atom of element Y, the p sub-shell has all three orbitals occupied; only one of these three orbitals is fully occupied.

Element Z is in Period 3 of the Periodic Table. In one atom of element Z, the p sub-shell has only two orbitals occupied.

What is the formula of compound X?

A CCl_4 **B** $SiCl_4$ **C** SiO_2 **D** SO_2

3 Glauber's salt consists of crystals of hydrated sodium sulfate, $Na_2SO_4 \cdot xH_2O$, which can be used for the manufacture of detergents.

When a sample of Glauber's salt was heated, 1.91 g of water was removed leaving 1.51 g of anhydrous Na_2SO_4.

What is the value of x in $Na_2SO_4 \cdot xH_2O$?

A 1 **B** 8.85 **C** 10 **D** 11.25

4 What contains the greatest number of the named particles?

A 6.0 dm^3 of argon atoms at room conditions

B 6.0 g of carbon dioxide molecules

C 6.0 g of magnesium atoms

D 6.0 g of water molecules

5 Phosphorus forms a compound with hydrogen called phosphine, PH_3. This compound can react with a hydrogen ion, H^+.

Which type of interaction occurs between PH_3 and H^+?

A dative covalent bond

B dipole–dipole forces

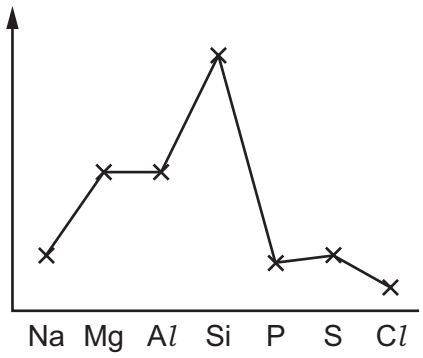
C hydrogen bond

D ionic bond

6 The graphs show trends in four physical properties of elements in Period 3, excluding argon.

Which graph has electronegativity on the *y*-axis?

A



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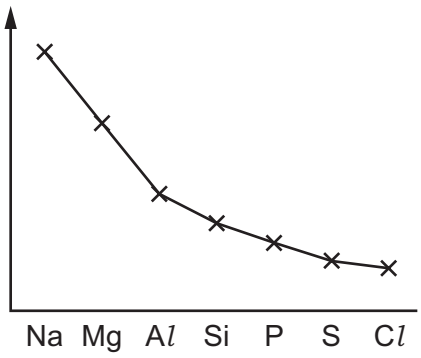

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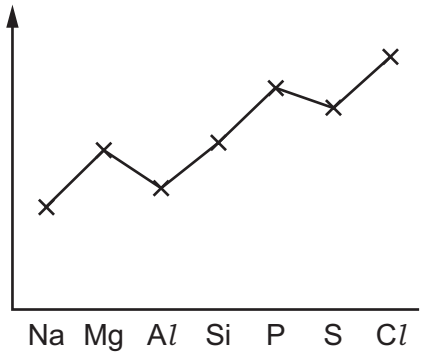

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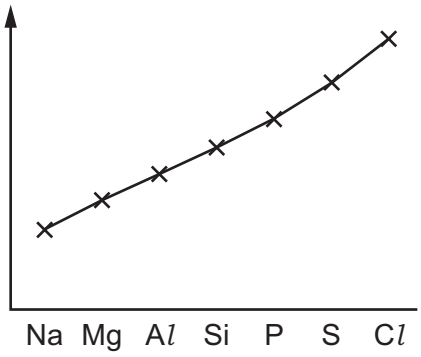


7 The element tin exists in two forms, grey tin and white tin.

Some properties of grey tin and white tin are shown.

	grey tin	white tin
boiling point / K	2543	2533
electrical conductivity	none in solid or liquid	good in solid and liquid
malleability	brittle	malleable

Which structural change might take place when grey tin changes to white tin?

A giant covalent to giant ionic

B giant covalent to giant metallic

C giant ionic to giant covalent

D giant ionic to giant metallic

8 Which solid has a simple molecular lattice?

A calcium fluoride

B nickel

C silicon(IV) oxide

D sulfur

9 The standard enthalpy change of combustion of carbon is –394 kJ mol^{-1}.

The standard enthalpy change of combustion of hydrogen is –286 kJ mol^{-1}.

The standard enthalpy change of formation of butane is –129 kJ mol^{-1}.

What is the standard enthalpy change of combustion of butane?

A –551 kJ mol^{-1}

B –2877 kJ mol^{-1}

C –3135 kJ mol^{-1}

D –4307 kJ mol^{-1}

10 Three processes are described.

1 $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

2 $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$

3 $NH_3(g) \rightarrow NH_3(l)$

Which statement is correct?

A None of the processes have a positive enthalpy change.

B Only process 1 has a positive enthalpy change.

C Only process 2 has a positive enthalpy change.

D Only process 3 has a positive enthalpy change.

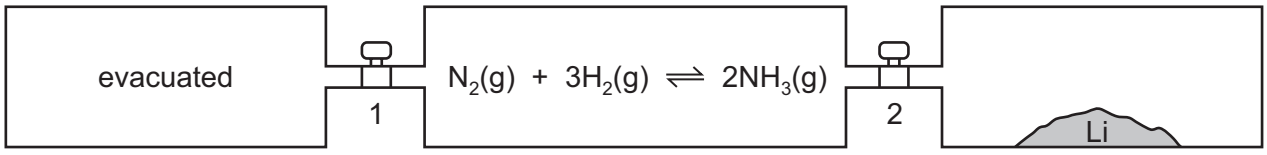
11 In alkaline solution, MnO_4^- ions oxidise SO_3^{2-} ions to SO_4^{2-} ions. The MnO_4^- ions are reduced to MnO_2.

What is the ratio of the two ions in the balanced chemical equation for this reaction?

	MnO_4^-	SO_3^{2-}
A	2	3
B	3	2
C	4	7
D	7	4

12 Lithium reacts with nitrogen at room temperature to form solid Li_3N.

Three vessels of equal volume are connected by taps 1 and 2 as shown.



At the start, taps 1 and 2 are closed, the left-hand vessel is evacuated, the middle vessel has the indicated reaction at equilibrium and the right-hand vessel contains lithium only.

Which action would allow the equilibrium mixture to contain the **most** ammonia?

A Keep both taps 1 and 2 closed.

B Open both taps 1 and 2.

C Open tap 1 only.

D Open tap 2 only.

[Turn over

13 When 0.20 mol of hydrogen gas and 0.15 mol of iodine gas are heated at 723 K until equilibrium is established, the equilibrium mixture contains 0.26 mol of hydrogen iodide.

The equation for the reaction is as follows.

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

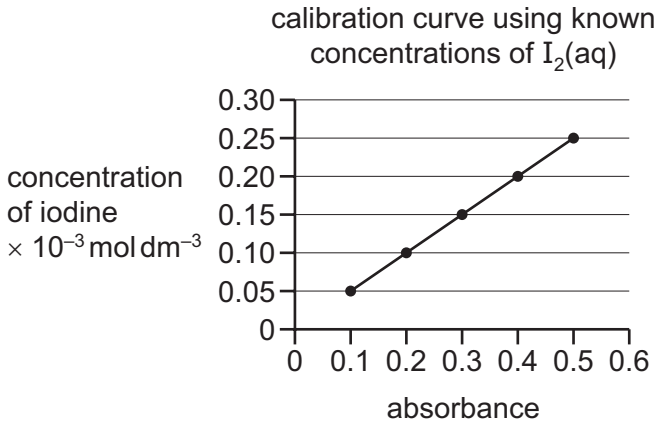
What is the correct expression for the equilibrium constant K_c?

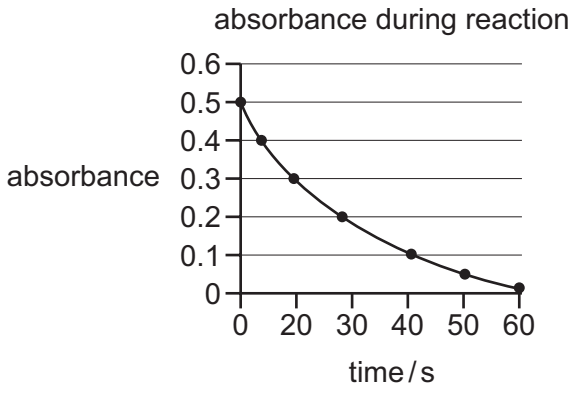
A $\dfrac{2 \times 0.26}{0.20 \times 0.15}$ **B** $\dfrac{(2 \times 0.26)^2}{0.20 \times 0.15}$ **C** $\dfrac{(0.26)^2}{0.07 \times 0.02}$ **D** $\dfrac{(0.26)^2}{0.13 \times 0.13}$

14 In acidic conditions, iodine reacts with propanone in a substitution reaction.

$$CH_3COCH_3(aq) + I_2(aq) \rightarrow CH_3COCH_2I(aq) + HI(aq)$$

The kinetics of the reaction are investigated using a colorimeter. As the I_2 reacts, the yellow / brown colour of the $I_2(aq)$ fades to colourless, changing the absorbance of the solution. Known concentrations of $I_2(aq)$ are used to prepare a calibration curve graph and the absorbance is then measured as the reaction proceeds.





What is the rate of reaction at 20 s?

A 5×10^{-6} mol dm^{-3} s^{-1}

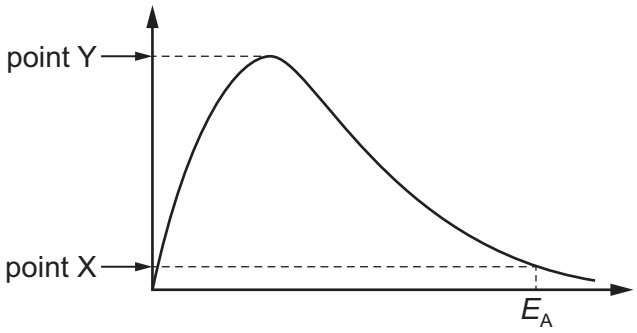
B 1×10^{-5} mol dm^{-3} s^{-1}

C 5×10^{-3} mol dm^{-3} s^{-1}

D 1×10^{-2} mol dm^{-3} s^{-1}

15 The diagram shows a Boltzmann distribution curve.

The axes are not labelled.



Points X and Y are points on the vertical axis.

What is represented by both points X and Y?

	point X	point Y
A	number of molecules with energy equal to E_A	largest number of molecules with the same energy
B	number of molecules with energy equal to or greater than E_A	largest number of molecules with the same energy
C	number of molecules with energy equal to E_A	the amount of energy of the greatest number of molecules
D	number of molecules with energy equal to or greater than E_A	the amount of energy of the greatest number of molecules

16 What are the acid–base nature and structure of SO_2?

	acid–base nature	structure
A	acidic	giant covalent lattice
B	acidic	simple molecular
C	basic	giant covalent lattice
D	basic	simple molecular

[Turn over

17 Elements X and Y are in Period 3 of the Periodic Table. Element X is either phosphorus or sulfur. Element Y is either sodium or magnesium.

Element X forms an oxide that reacts with water to give a solution containing the aqueous anion XO_4^{2-}.

One mole of element Y reacts with one mole of chlorine molecules. At the end of the reaction, all of the element Y and all of the chlorine molecules have been used up.

What are elements X and Y?

	X	Y
A	phosphorus	sodium
B	phosphorus	magnesium
C	sulfur	sodium
D	sulfur	magnesium

18 Q is a semi-conductor. The chloride of Q reacts with water to form white fumes and an acidic solution.

Which Period 3 element is Q?

A magnesium

B aluminium

C silicon

D phosphorus

19 V and W are two compounds. Each one contains a different Group 2 element.

A sample of each solid is added to water, shaken, and the pH of the resulting solution is measured.

compound	V	W
pH	13.6	9.4

Which row could identify V and W?

	V	W
A	$BaSO_4$	$MgSO_4$
B	$MgSO_4$	$BaSO_4$
C	$Ba(OH)_2$	$Mg(OH)_2$
D	$Mg(OH)_2$	$Ba(OH)_2$

20 Compound L decomposes on heating. One of the products is gas M.

M reacts with unburned hydrocarbons to form peroxyacetyl nitrate, PAN.

What could be the formula of L?

A $CaNO_3$ **B** $Ca(NO_3)_2$ **C** $MgCO_3$ **D** $Mg(CO_3)_2$

21 In reaction 1, concentrated sulfuric acid is added to potassium chloride and the fumes produced are bubbled into aqueous potassium iodide solution.

In reaction 2, potassium chloride is dissolved in aqueous ammonia and this is then added to aqueous silver nitrate.

What are the observations for reactions 1 and 2?

	observation for reaction 1	observation for reaction 2
A	brown solution	colourless solution
B	brown solution	white precipitate
C	colourless solution	colourless solution
D	colourless solution	white precipitate

22 The table refers to the hydrogen halides.

Which row is correct?

	oxidation	thermal stability
A	easier to oxidise down the group	increases down the group
B	more difficult to oxidise down the group	increases down the group
C	easier to oxidise down the group	decreases down the group
D	more difficult to oxidise down the group	decreases down the group

23 7.5 g of nitrogen monoxide reacts with 7.0 g of carbon monoxide on the surface of the catalytic converter in the exhaust system of a car.

What is the total volume of the product gases measured at room conditions?

A $3.0\,dm^3$ **B** $6.0\,dm^3$ **C** $9.0\,dm^3$ **D** $12.0\,dm^3$

24 Three statements about ammonia molecules and ammonium ions are given.

1 In aqueous solution, ammonia molecules form coordinate bonds with hydroxide ions.

2 Ammonium ions are Brønsted–Lowry acids.

3 The H–N–H bond angle is larger in the ammonium ion than in the ammonia molecule.

Which statements are correct?

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

25 Ethene reacts with steam in the presence of sulfuric acid.

$$C_2H_4 + H_2O \rightarrow CH_3CH_2OH$$

Which type of reaction is this?

A acid–base

B addition

C hydrolysis

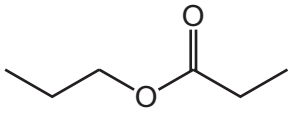
D substitution

26 Compound Z has the molecular formula $C_4H_8O_2$.

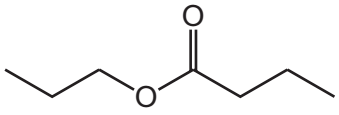
Compound Z reacts with propan-1-ol in the presence of concentrated H_2SO_4.

The diagram shows the skeletal formulae of three compounds, S, T and U.

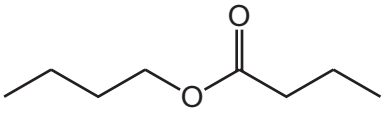
S



T



U

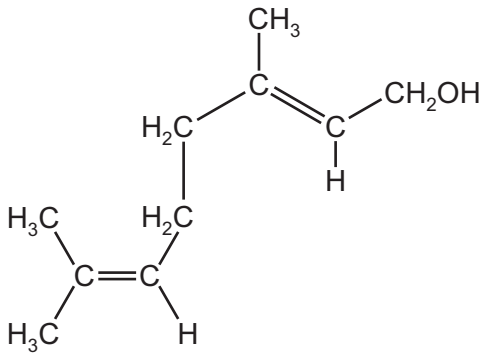


What are the possible skeletal formulae of the products of the reaction between compound Z and propan-1-ol?

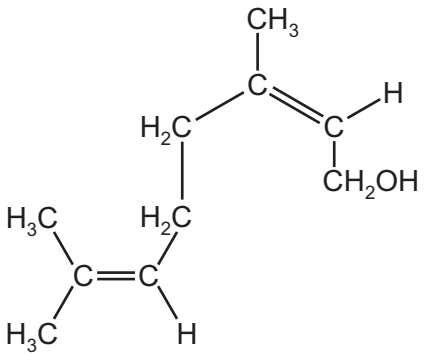
A S and T **B** U only **C** S and U **D** T only

27 Geraniol and nerol are isomers of each other.

geraniol



nerol



Which type of isomerism is shown here?

A chain

B geometrical (cis / trans)

C optical

D positional

28 Which compound has the greatest number of stereoisomers?

A 2-methylhex-2-ene

B 3-methylhex-2-ene

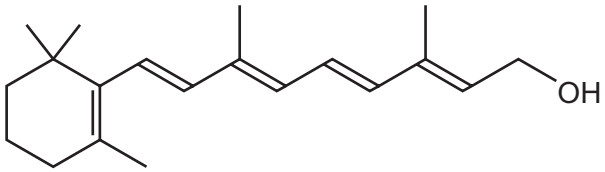
C 4-methylhex-2-ene

D 5-methylhex-2-ene

[Turn over

29 Vitamin A contains retinol.

retinol



Under appropriate conditions, acidified $KMnO_4(aq)$ can be used to break C=C bonds.

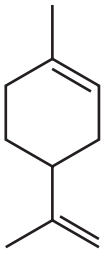
After these bonds have been broken, further oxidation of the fragments may occur.

Under which conditions is the acidified $KMnO_4(aq)$ used and what do the final oxidation products include?

	conditions	final oxidation products
A	cold, dilute	aldehydes and carboxylic acids
B	cold, dilute	ketones and carboxylic acids
C	hot, concentrated	aldehydes and carboxylic acids
D	hot, concentrated	ketones and carboxylic acids

30 The structure of limonene is shown.

limonene



What are the number of moles of carbon dioxide and water produced when a sample of limonene is completely combusted in oxygen?

	number of moles of carbon dioxide	number of moles of water
A	4	3
B	5	4
C	5	8
D	9	7

31 The reaction of chlorine with methane is carried out in the presence of light.

What is the function of the light?

A to break the C–H bonds in methane

B to break the chlorine molecules into atoms

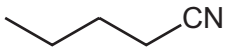
C to break the chlorine molecules into ions

D to heat the mixture

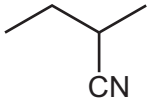
32 When X is added to NaOH(aq) and heated under reflux, pentan-2-ol is made.

Which organic product is made when X is heated with a solution of KCN dissolved in ethanol?

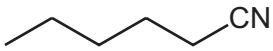
A



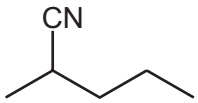
B



C



D



33 1-chlorobutane and 1-iodobutane both react with aqueous sodium hydroxide by a nucleophilic substitution mechanism.

Which reaction has the greatest rate under the same conditions and which mechanism is followed by this reaction?

	greatest rate	mechanism
A	1-chlorobutane	S_N1
B	1-chlorobutane	S_N2
C	1-iodobutane	S_N1
D	1-iodobutane	S_N2

34 Compound Y reacts with alkaline I_2(aq). When the products of this reaction are acidified, a dicarboxylic acid is produced. The formula of the dicarboxylic acid is HOOC–R–COOH where R consists of one or more CH_2 groups.

Which compound is Y?

A pentan-1,4-diol

B pentan-1,5-diol

C pentan-2,3-diol

D pentan-2,4-diol

[Turn over

35 Which alcohol gives only **one** possible oxidation product when warmed with dilute acidified potassium dichromate(VI)?

A butan-1-ol

B butan-2-ol

C 2-methylpropan-1-ol

D 2-methylpropan-2-ol

36 Which compound, on reaction with hydrogen cyanide, produces a compound with a chiral centre?

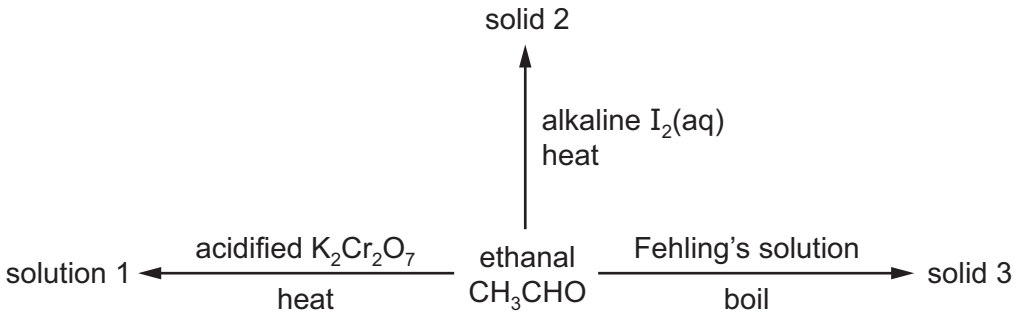
A CH_3CHO

B $CH_3CH_2COCH_2CH_3$

C $CH_3CO_2CH_3$

D HCHO

37 The diagram shows three reactions of ethanal. In each case, an excess of ethanal is used.



Observations are made after each of the three reactions.

What are the colours of solution 1 and solids 2 and 3?

	solution 1	solid 2	solid 3
A	green	yellow	silver mirror
B	green	yellow	red
C	orange	red	silver mirror
D	orange	red	red

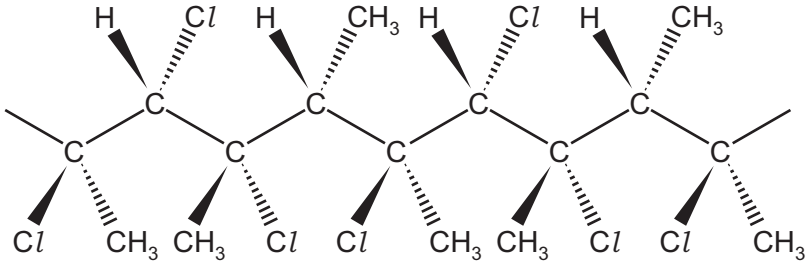
38 $(CH_3)_3CCN$ reacts to form alcohol Y via the reaction sequence shown.

$$(CH_3)_3CCN \xrightarrow[\text{reaction 1}]{H^+(aq)} X \xrightarrow[\text{reaction 2}]{LiAlH_4} \text{alcohol Y}$$

Which row names the molecule X and the class of alcohol Y?

	name of molecule X	class of alcohol Y
A	2,2-dimethylbutanoic acid	primary
B	3,3-dimethylbutanoic acid	tertiary
C	dimethylpropanoic acid	primary
D	dimethylpropanoic acid	tertiary

39 The diagram shows a section of an addition polymer. The polymer is made using two different monomers.



What are the names of the two monomers needed to make this polymer?

A 1,2-dichloropropene and 2-chlorobut-2-ene

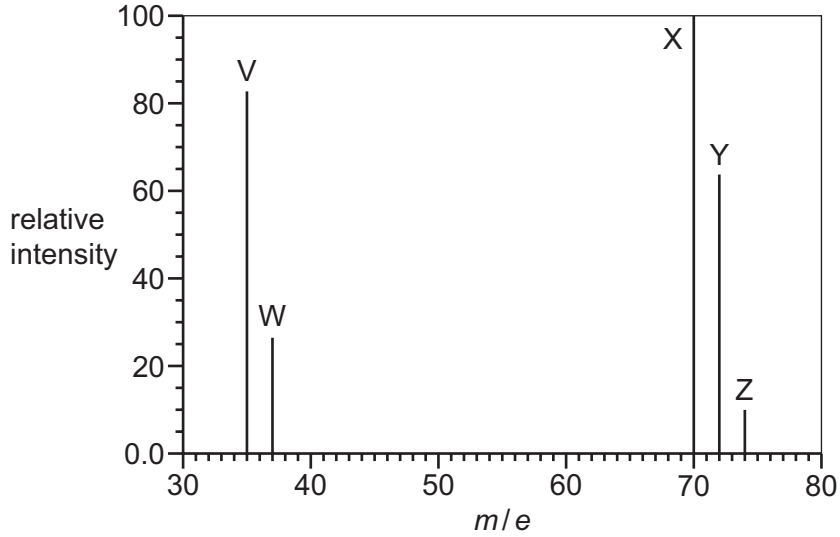
B 2,3-dichlorobut-2-ene and chloropropene

C 1,2-dichloropropene and chloroethene

D chloropropene and 2-chlorobut-2-ene

[Turn over

40 The diagram shows the mass spectrum of a sample of chlorine. Peaks V, W, X, Y and Z are labelled.



Which statements about this spectrum are correct?

1 The relative atomic mass of chlorine can be calculated from the abundances and m/e values of 2 of the 5 peaks.

2 37.0 g of the species responsible for peak Z contains 3.011×10^{23} molecules.

3 The relative molecular mass of chlorine can be calculated from the abundances and m/e values of peaks X, Y and Z.

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

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Important values, constants and standards

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

The Periodic Table of Elements

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

Key

atomic number
atomic symbol
name
relative atomic mass

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