



# Cambridge International AS & A Level

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## 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)

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### INSTRUCTIONS

- There are **forty** questions on this paper. Answer **all** questions.
- For each question there are four possible answers **A**, **B**, **C** and **D**. Choose the **one** you consider correct and record your choice in soft pencil on the multiple choice answer sheet.
- Follow the instructions on the multiple choice answer sheet.
- Write in soft pencil.
- Write your name, centre number and candidate number on the multiple choice answer sheet in the spaces provided unless this has been done for you.
- Do **not** use correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.

### INFORMATION

- The total mark for this paper is 40.
- Each correct answer will score one mark.
- Any rough working should be done on this question paper.
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.

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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,  $\text{PH}_3$ .

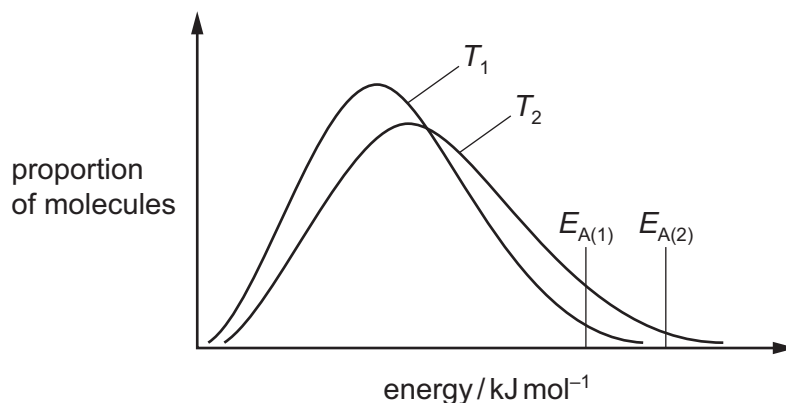
Which statements are correct?

- 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

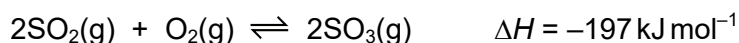
3 The diagram shows a Boltzmann distribution of molecular energies for a gaseous reaction at two different temperatures and two different activation energies.



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  $\text{SO}_2$  and 1.0 mol of  $\text{O}_2$  are placed in a closed container and heated to a constant temperature.

At this temperature, 0.8 mol of  $\text{SO}_3$  are present in the equilibrium mixture.

Which statement is correct?

- A** The equilibrium partial pressure of  $\text{SO}_2$  is greater than the equilibrium partial pressure of  $\text{O}_2$ .  
**B**  $K_p$  has units of  $\text{mol dm}^{-3}$ .  
**C** At a lower temperature, the equilibrium amount of  $\text{SO}_3$  is lower than 0.8 mol.  
**D** The mole fraction of  $\text{SO}_3$  is less than 0.8.

- 5 'Red lead' is a red pigment with the formula  $\text{Pb}_3\text{O}_4$ . 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 / $\text{kJ mol}^{-1}$ |
|----------------------------------|---------------------------------------------------------------|
| $\text{C}(\text{s})$             | -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**  $-240 \text{ kJ mol}^{-1}$     **B**  $-46 \text{ kJ mol}^{-1}$     **C**  $46 \text{ kJ mol}^{-1}$     **D**  $240 \text{ kJ mol}^{-1}$
- 7 Which row is correct?

|          | smallest bond angle  | →                    | largest bond angle   |
|----------|----------------------|----------------------|----------------------|
| <b>A</b> | $\text{H}_2\text{O}$ | $\text{NH}_3$        | $\text{BF}_3$        |
| <b>B</b> | $\text{BF}_3$        | $\text{NH}_3$        | $\text{H}_2\text{O}$ |
| <b>C</b> | $\text{NH}_3$        | $\text{H}_2\text{O}$ | $\text{BF}_3$        |
| <b>D</b> | $\text{H}_2\text{O}$ | $\text{BF}_3$        | $\text{NH}_3$        |

- 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 |
|----------|-------|------------|
| <b>A</b> | Fe    | 1 : 2      |
| <b>B</b> | Fe    | 1 : 3      |
| <b>C</b> | V     | 1 : 2      |
| <b>D</b> | V     | 1 : 3      |

- 9 Aqueous hydrogen peroxide,  $\text{H}_2\text{O}_2$ , decomposes into water and oxygen in the presence of a suitable catalyst.

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

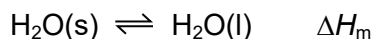
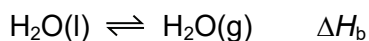
The volume of gas was measured at room conditions.

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  $\Delta H_b$  and  $\Delta H_m$  are both negative.
- 2  $\Delta H_b$  is greater than  $\Delta H_m$ .
- 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  $x$ ?

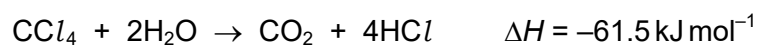
- A  $\frac{S-R}{18}$       B  $\frac{R-S}{18}$       C  $\frac{23.9(R-S)}{18(S-Q)}$       D  $\frac{23.9(S-R)}{18(S-Q)}$

- 12 A sample of an ideal gas occupies  $240 \text{ cm}^3$  at  $37^\circ\text{C}$  and  $100 \text{ kPa}$ .

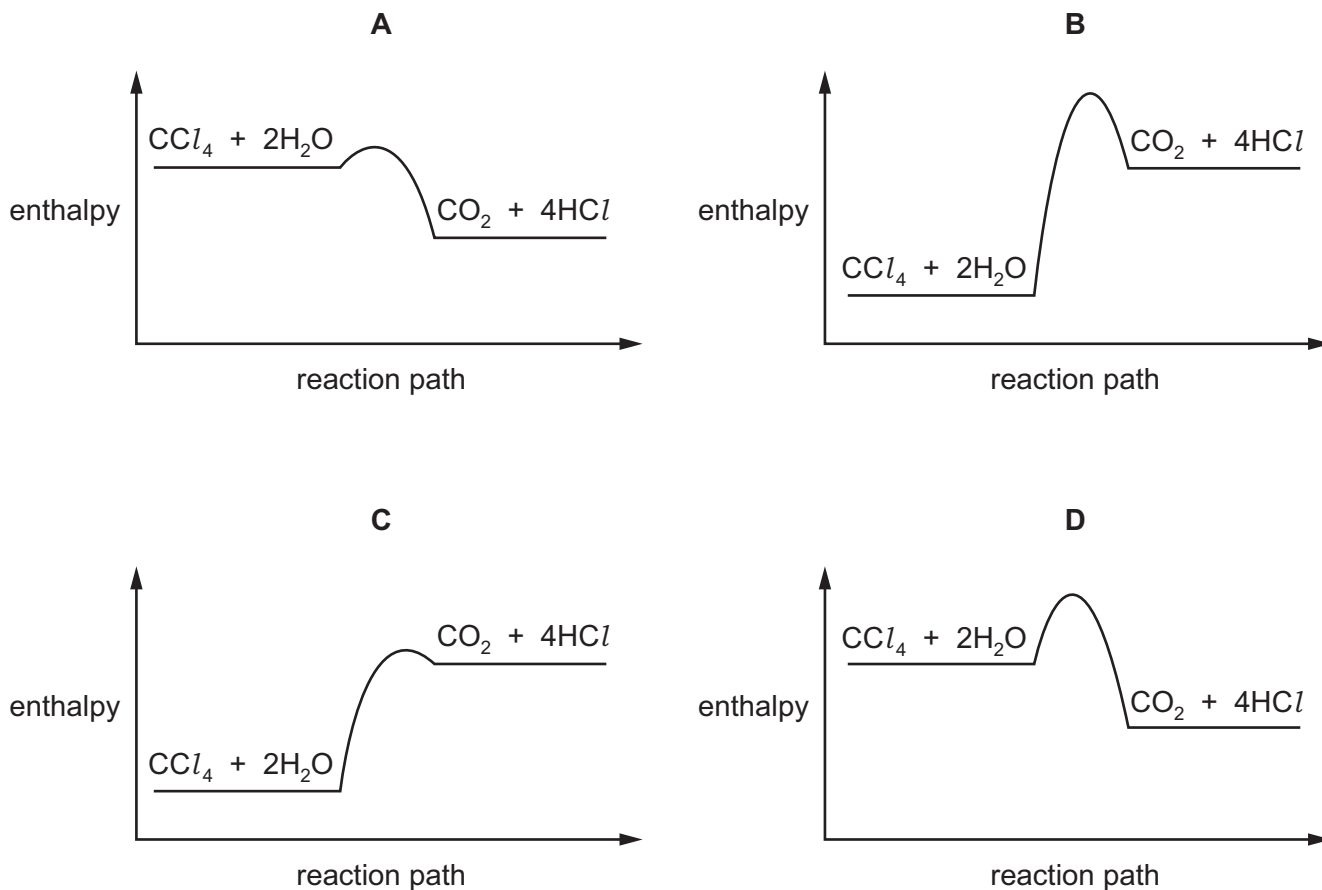
How many moles of gas are present in the sample?

- A  $9.32 \times 10^{-6}$       B  $9.32 \times 10^{-3}$       C 0.0781      D 78.1

- 13 Under certain conditions,  $\text{CCl}_4$  and  $\text{H}_2\text{O}$  react as shown. The activation energy for the reaction is  $+62 \text{ kJ mol}^{-1}$ .



Which enthalpy profile diagram best fits this reaction?

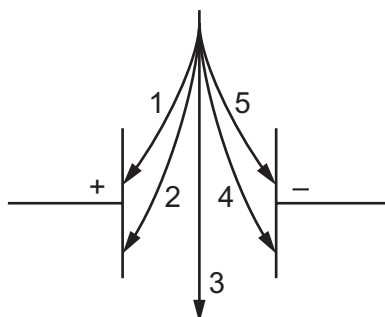


- 14** A helium ion contains two protons, two neutrons and one electron.

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

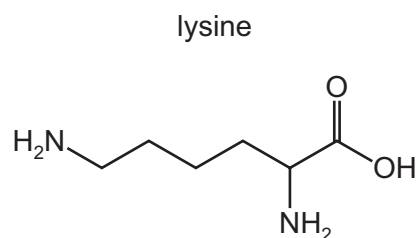
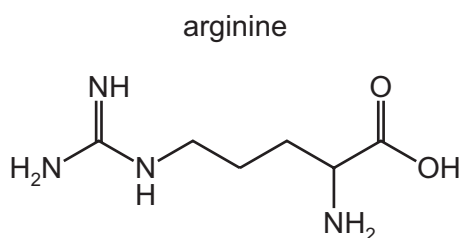
The particles are travelling at the same velocity.

Which arrow describes the path of each particle?



|          | helium ion | proton |
|----------|------------|--------|
| <b>A</b> | 1          | 2      |
| <b>B</b> | 2          | 1      |
| <b>C</b> | 4          | 5      |
| <b>D</b> | 5          | 4      |

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



Which row is correct?

|          | substance | empirical formula | $M_r$ |
|----------|-----------|-------------------|-------|
| <b>A</b> | arginine  | $C_3H_7N_2O$      | 174   |
| <b>B</b> | arginine  | $C_3H_8N_2O$      | 176   |
| <b>C</b> | lysine    | $C_3H_7NO$        | 144   |
| <b>D</b> | 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<br>colourless solution, R                    |
| fumes Q tested with moist blue litmus paper               | paper turns red                                              |
| solution R + a few drops of NaOH(aq)<br>+ excess NaOH(aq) | white precipitate<br>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 |
|----------|--------------------------------------|----------------------|
| <b>A</b> | +6 to +4                             | oxidising agent      |
| <b>B</b> | +6 to +4                             | reducing agent       |
| <b>C</b> | +4 to 0                              | oxidising agent      |
| <b>D</b> | +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**  $\text{MgCl}_2$       **B**  $\text{MgS}$       **C**  $\text{Na}_2\text{S}$       **D**  $\text{PCl}_3$

- 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  $\text{SO}_2$  to  $\text{SO}_3$
- 2 formation of dilute  $\text{H}_2\text{SO}_4$

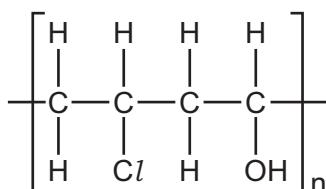
Which row identifies the atmospheric catalyst for step 1 and the reagent for step 2?

|          | catalyst      | reagent              |
|----------|---------------|----------------------|
| <b>A</b> | $\text{O}_2$  | $\text{H}_2\text{O}$ |
| <b>B</b> | $\text{O}_2$  | $\text{O}_2$         |
| <b>C</b> | $\text{NO}_2$ | $\text{H}_2\text{O}$ |
| <b>D</b> | $\text{NO}_2$ | $\text{O}_2$         |

**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?

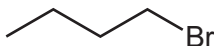
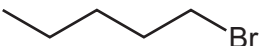
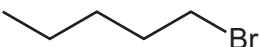
- A** 1 and 2
- B** 1 and 3
- C** 1 only
- D** 2 only

- 27 Methanoic acid,  $\text{HCO}_2\text{H}$ , 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  $\text{HCO}_2\text{H}$  and  $\text{CH}_3\text{CO}_2\text{H}$   
 B  $\text{HCO}_2\text{H}$  and  $\text{CH}_3\text{CO}_2\text{CH}_3$   
 C  $\text{HCO}_2\text{H}$  and  $\text{CH}_3\text{CH}_2\text{COCH}_3$   
 D  $\text{HCO}_2\text{H}$  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.  $\text{R}'$  and  $\text{R}''$  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

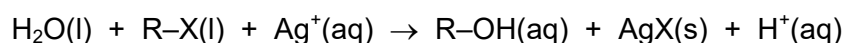
- 32** Four reagents are listed.

- 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  $1.0\text{ cm}^3$  of aqueous silver nitrate at  $60^\circ\text{C}$ . 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  $\text{LiAlH}_4$  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 |
|----------|-------------------|-------------------|
| <b>A</b> |                   |                   |
| <b>B</b> |                   |                   |
| <b>C</b> |                   |                   |
| <b>D</b> |                   |                   |

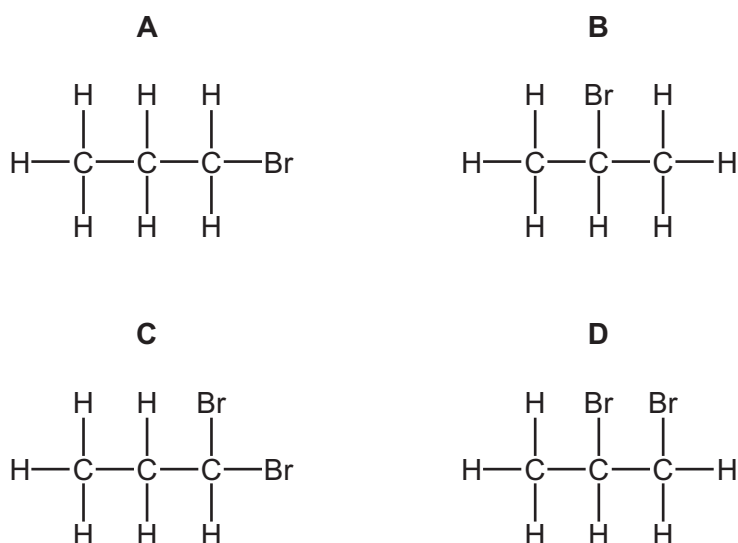
- 35 Samples of the gases  $\text{CH}_3\text{Cl}$  and  $\text{Cl}_2$  are mixed together and irradiated with ultraviolet light.

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

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

- 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)<br>$V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ 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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## 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 | gadolinum | 157.3 | 65 | Tb | terbium   | 158.9 | 66 | Dy | dysprosium  | 162.5 | 67 | Ho | holmium     | 164.9 | 68  | Er | erbium  | 168.9 | 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 | —     |