



# Cambridge International AS & A Level

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**CHEMISTRY****9701/12**

Paper 1 Multiple Choice

**May/June 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)

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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.

## 2

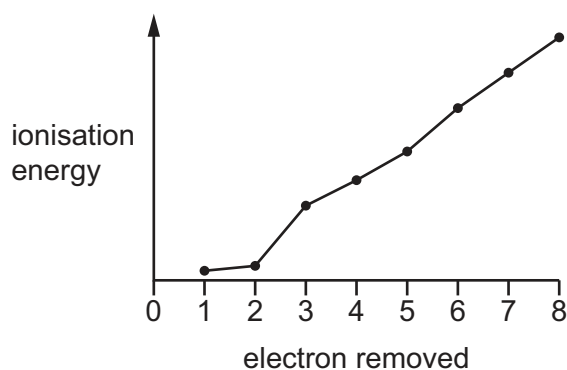
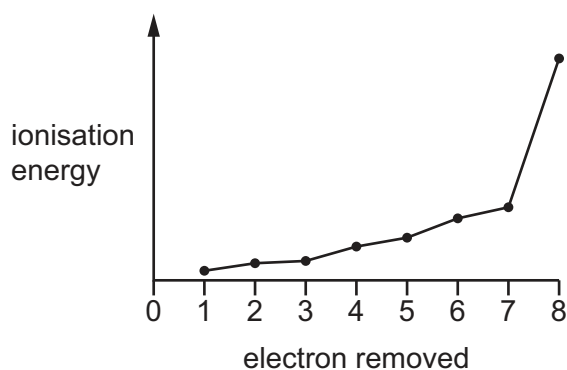
1 Which pair of formulae is correct?

- A  $\text{Ag}_2\text{CO}_3$  and  $(\text{NH}_4)_3\text{NO}_3$   
 B  $\text{K}_2\text{HCO}_3$  and  $\text{Zn}_3(\text{PO}_4)_2$   
 C  $\text{AgHCO}_3$  and  $\text{K}_3\text{PO}_4$   
 D  $\text{ZnCO}_3$  and  $(\text{NH}_4)_2\text{PO}_4$

2 How many molecules are present in 62 g of solid white phosphorus,  $\text{P}_4$ ?

- A  $L$                       B  $2L$                       C  $\frac{L}{2}$                       D  $\frac{L}{4}$

3 The first eight successive ionisation energies for two elements of Period 3 of the Periodic Table are shown in the graphs.



What is the formula of the ionic compound formed from these elements?

- A  $\text{MgCl}_2$                       B  $\text{CaBr}_2$                       C  $\text{Na}_2\text{S}$                       D  $\text{K}_2\text{Se}$

4 In which pairs are **both** species free radicals?

- 1  $\text{Cl}$  and  $\text{O}$   
 2  $\text{Cl}^-$  and  $\text{O}^{2-}$   
 3  $\text{Cl}$  and  $\text{O}^-$   
 4  $\text{Cl}^+$  and  $\text{O}^{2+}$

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

## 3

5 Which shape is correctly predicted by VSEPR theory?

|          | number of bonded electron pairs | number of lone pairs | shape           |
|----------|---------------------------------|----------------------|-----------------|
| <b>A</b> | 2                               | 2                    | linear          |
| <b>B</b> | 2                               | 2                    | tetrahedral     |
| <b>C</b> | 3                               | 1                    | pyramidal       |
| <b>D</b> | 3                               | 1                    | trigonal planar |

6 In which species does the underlined atom have an incomplete outer shell?

- A**  $\underline{\text{B}}\text{F}_3$       **B**  $\underline{\text{C}}\text{H}_3^-$       **C**  $\text{F}_2\underline{\text{O}}$       **D**  $\text{H}_3\underline{\text{O}}^+$

7 In this question it should be assumed that nitrogen behaves as an ideal gas under the conditions stated.

Which volume is occupied by 1.00 g of nitrogen at 50.0 °C and at a pressure of 120 kPa?

- A** 0.124 dm<sup>3</sup>      **B** 0.799 dm<sup>3</sup>      **C** 1.60 dm<sup>3</sup>      **D** 22.4 dm<sup>3</sup>

8 Consider the following four compounds.

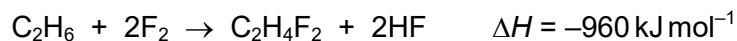
- 1 (CH<sub>3</sub>)<sub>3</sub>CH
- 2 CH<sub>3</sub>CH<sub>2</sub>CH<sub>2</sub>OH
- 3 CH<sub>3</sub>CH<sub>2</sub>CH<sub>2</sub>SH
- 4 CH<sub>3</sub>CH<sub>2</sub>CH<sub>2</sub>CH<sub>3</sub>

What is the order of increasing boiling point of the compounds (lowest first)?

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

## 4

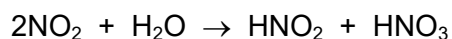
- 9 Ethane can react with fluorine to produce 1,2-difluoroethane,  $\text{C}_2\text{H}_4\text{F}_2$ .



| bond | energy<br>/ $\text{kJ mol}^{-1}$ |
|------|----------------------------------|
| C–H  | 410                              |
| C–C  | 350                              |
| F–F  | 158                              |
| H–F  | 562                              |

What is the bond energy of the C–F bond in 1,2-difluoroethane?

- A**  $407 \text{ kJ mol}^{-1}$     **B**  $474 \text{ kJ mol}^{-1}$     **C**  $486 \text{ kJ mol}^{-1}$     **D**  $972 \text{ kJ mol}^{-1}$
- 10 Which equation has an enthalpy change equal to the standard enthalpy of formation of sodium oxide?
- A**  $\text{Na(s)} + \frac{1}{4} \text{O}_2(\text{g}) \rightarrow \frac{1}{2} \text{Na}_2\text{O(s)}$
- B**  $\text{Na(s)} + \text{O}_2(\text{g}) \rightarrow \text{Na}_2\text{O(s)}$
- C**  $2\text{Na(s)} + \frac{1}{2} \text{O}_2(\text{g}) \rightarrow \text{Na}_2\text{O(s)}$
- D**  $4\text{Na(s)} + \text{O}_2(\text{g}) \rightarrow 2\text{Na}_2\text{O(s)}$
- 11 Nitrogen dioxide reacts with water.

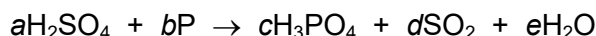


Which statement about this reaction is correct?

- A** Both products are formed because oxygen atoms gain electrons.
- B** Nitrogen atoms undergo disproportionation.
- C** The oxidation number of hydrogen is increased.
- D** Water acts as an oxidising agent.

5

- 12 Phosphorus reacts with concentrated sulfuric acid to produce phosphoric acid, sulfur dioxide and water.



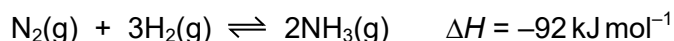
$a$ ,  $b$ ,  $c$ ,  $d$  and  $e$  are all whole numbers.

The equation can be balanced by using oxidation numbers.

What is the value of the sum  $a + b + c + d + e$ ?

- A 10                      B 14                      C 15                      D 16

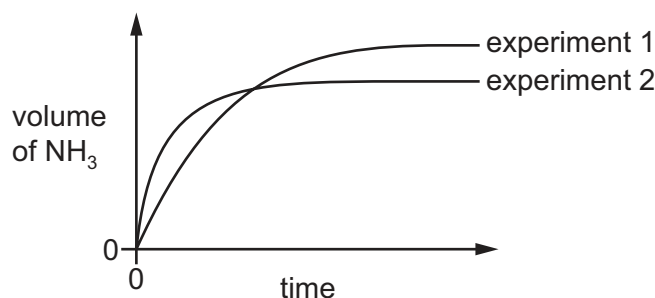
- 13 The volume of ammonia produced against time is measured in two experiments.



In experiment 1, 3 mol of  $\text{H}_2(\text{g})$  and 1 mol of  $\text{N}_2(\text{g})$  react together at  $45^\circ\text{C}$  and a pressure of 200 atm.

A graph showing the volume of ammonia produced against time is plotted.

Experiment 2 is then performed. Experiment 2 differs from experiment 1 in **one** condition only.

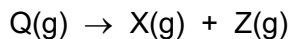


How does experiment 2 differ from experiment 1?

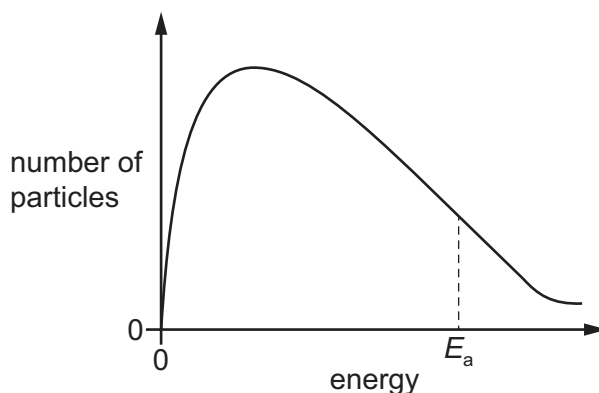
- A An iron catalyst is present in experiment 2.  
B 2 mol of helium gas is present in the reaction mixture in experiment 2.  
C A pressure of 250 atm is used in experiment 2.  
D A temperature of  $600^\circ\text{C}$  is used in experiment 2.
- 14 Which reaction has an equilibrium constant,  $K_p$ , that has no units?
- A  $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g})$   
B  $3\text{H}_2(\text{g}) + \text{N}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$   
C  $2\text{NO}_2(\text{g}) \rightleftharpoons \text{N}_2\text{O}_4(\text{g})$   
D  $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$

6

15 Gas Q decomposes slowly at room temperature.



The Boltzmann distribution curve for gas Q at room temperature is shown.



Which change occurs when a catalyst is added to gas Q?

- A The peak of the curve moves to the right on the diagram.
- B The number of particles with enough energy to decompose increases.
- C The kinetic energy of the unreacted particles increases.
- D The value of  $E_a$  decreases, moving the vertical dotted line to the right on the diagram.

16 Which statement is correct?

- A Aluminium chloride has a giant ionic lattice of  $\text{Al}^{3+}$  and  $\text{Cl}^-$  ions.
- B Sodium chloride dissolves in water, forming hydrogen chloride and sodium hydroxide.
- C The strong covalent bonds in silicon chloride prevent it from reacting with water.
- D When phosphorus(V) chloride is added to water, the resulting solution conducts electricity.

17 A mixture of calcium carbonate, calcium nitrate, strontium carbonate and strontium nitrate is thermally decomposed. The decomposition reaction of each substance goes to completion. Each substance is anhydrous.

How many different products are formed?

- A 4                      B 5                      C 7                      D 8

- 18 W is a solid that reacts with water to produce an alkaline solution.

The addition of two drops of dilute  $\text{H}_2\text{SO}_4$  to this alkaline solution produces a white precipitate.

What could be the identity of solid W?

- A magnesium hydroxide
  - B magnesium oxide
  - C barium oxide
  - D phosphorus oxide
- 19 Chlorine gas is reacted with cold aqueous sodium hydroxide.

Which statement is correct for this reaction?

- A Chlorine is both oxidised and reduced.
  - B Chlorine is neither oxidised nor reduced.
  - C Chlorine is oxidised but not reduced.
  - D Chlorine is reduced but not oxidised.
- 20 Sodium is added to water to form solution Y. The pH of solution Y is measured.

When powdered substance X is added to solution Y, the pH falls.

Which **two** compounds could each be substance X?

- A  $\text{MgCl}_2$  and  $\text{Al}(\text{OH})_3$
- B  $\text{MgCl}_2$  and  $\text{K}_2\text{O}$
- C  $\text{NaCl}$  and  $\text{Al}(\text{OH})_3$
- D  $\text{NaCl}$  and  $\text{K}_2\text{O}$

- 21** The table shows statements about some of the properties of halogens and their compounds and explanations for these properties.

Which row shows a correct statement about the property and a correct explanation for the statement?

|          | statement                                                                                            | explanation                                                   |
|----------|------------------------------------------------------------------------------------------------------|---------------------------------------------------------------|
| <b>A</b> | iodine is a solid at room temperature                                                                | the I–I bond strength is high                                 |
| <b>B</b> | the decomposition of hydrogen iodide is more endothermic than the decomposition of hydrogen chloride | chlorine is more reactive than iodine                         |
| <b>C</b> | when chlorine is bubbled into aqueous potassium iodide, a purple solution is seen                    | chlorine is a stronger oxidising agent than iodine            |
| <b>D</b> | when concentrated sulfuric acid is added to solid potassium iodide, a purple vapour is seen          | iodide ions are being oxidised to iodine by the sulfuric acid |

- 22** Which statement describes a property of an ammonium ion?

- A** An aqueous ammonium ion is a weak Brønsted–Lowry base.
- B** Aqueous ammonium sulfate reacts with dilute hydrochloric acid to make ammonia gas.
- C** An ammonium ion has a pyramidal shape with an H–N–H bond angle of 107°.
- D** The four N–H covalent bonds in an ammonium ion are identical to each other.

- 23** Catalytic converters are fitted in the exhaust systems of many cars.

Gas X:

- causes acid rain if it is released into the air
- is removed from car exhaust fumes by a catalytic converter.

What is gas X?

- A** carbon dioxide
- B** carbon monoxide
- C** hydrocarbon vapour
- D** nitrogen dioxide

**24** In the general formula of which class of compound is the ratio of hydrogen atoms to carbon atoms the highest?

- A** alcohols
- B** aldehydes
- C** carboxylic acids
- D** halogenoalkanes

**25** Which statement is correct?

- A** Adding sodium oxide to water gives a lower pH solution than adding silicon oxide to water.
- B** The oxidation state of sodium in its chloride is higher than the oxidation state of silicon in its chloride.
- C** The atomic radius of sodium is larger than that of silicon.
- D** The melting point of the chloride of sodium is lower than the melting point of the chloride of silicon.

**26** Z is a gaseous hydrocarbon which has a density of  $3.50 \times 10^{-3} \text{ g cm}^{-3}$  under room conditions.

Z reacts with an excess of hot concentrated acidified  $\text{KMnO}_4$ . Only **one** type of carboxylic acid is formed in this reaction.

What is Z?

- A** but-2-ene
- B** 2,3-dimethylbut-2-ene
- C** hex-2-ene
- D** hex-3-ene

**27** Compound X can be oxidised to compound Y.

Compound Y gives a yellow precipitate with alkaline  $\text{I}_2(\text{aq})$ .

What is compound X?

- A** butan-1-ol
- B** butan-2-ol
- C** methylpropan-1-ol
- D** methylpropan-2-ol

28 Aqueous NaOH reacts with 1-bromopropane to give propan-1-ol.

What should be included in a diagram of the first step in the mechanism?

- A a curly arrow from a lone pair on the  $\text{OH}^-$  ion to the  $\text{C}^{\delta+}$  atom of 1-bromopropane
- B a curly arrow from the  $\text{C}^{\delta+}$  atom of 1-bromopropane to the  $\text{OH}^-$  ion
- C a curly arrow from the C–Br bond to the C atom
- D the homolytic fission of the C–Br bond

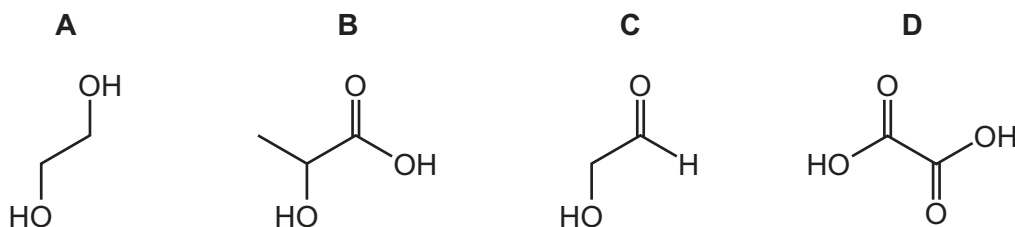
29 In which reaction is the organic compound oxidised?

- A  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CHO} + \text{Tollens' reagent}$
- B  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CHO} + \text{LiAlH}_4$
- C  $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH} + \text{concentrated H}_3\text{PO}_4$
- D  $\text{CH}_3\text{CO}_2\text{C}_2\text{H}_5 + \text{dilute H}_2\text{SO}_4$

30 1 mole of each of the following four compounds is reacted separately with:

- an excess of sodium
- an excess of sodium carbonate.

Which compound produces the same volume of gas with each of the **two** reagents?



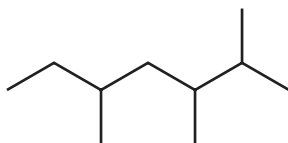
31 Which reaction will distinguish between propan-1-ol and propan-2-ol?

- A warming with acidified  $\text{KMnO}_4$
- B warming with acidified  $\text{K}_2\text{Cr}_2\text{O}_7$
- C dehydration, followed by reaction with  $\text{Br}_2(\text{aq})$
- D mild oxidation, followed by reaction with Fehling's reagent

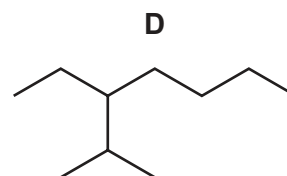
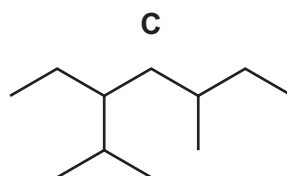
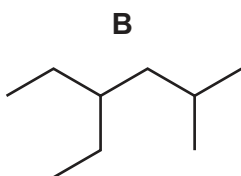
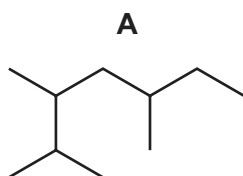
11

32 Compound T has the skeletal formula shown.

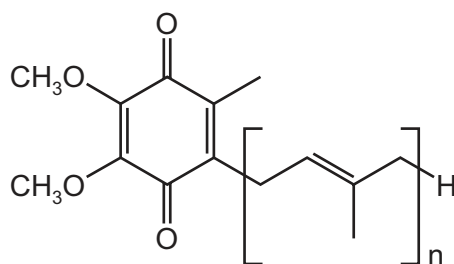
compound T



Which structure is a structural isomer of compound T?



33 The diagram shows a simplified structure of coenzyme Q<sub>10</sub>.

coenzyme Q<sub>10</sub>

Which row describes the structure of coenzyme Q<sub>10</sub> correctly?

|          | the coenzyme is | number of $\pi$ bonds in one molecule |
|----------|-----------------|---------------------------------------|
| <b>A</b> | an aldehyde     | $n + 2$                               |
| <b>B</b> | an aldehyde     | $n + 4$                               |
| <b>C</b> | a ketone        | $n + 2$                               |
| <b>D</b> | a ketone        | $n + 4$                               |

34 The molecule of limonene, C<sub>10</sub>H<sub>16</sub>, contains a 6-membered ring. This is the only cyclic component in its structure.

Which volume of hydrogen, at room conditions, is required to react completely with the C=C double bonds in **one** mole of limonene?

- A** 12 dm<sup>3</sup>      **B** 24 dm<sup>3</sup>      **C** 48 dm<sup>3</sup>      **D** 72 dm<sup>3</sup>

## 12

35 1-bromopropane reacts with hot ethanolic NaOH.

What is the molecular formula of the product in this reaction?

- A  $C_3H_6$                       B  $C_3H_8$                       C  $C_3H_7O$                       D  $C_3H_8O$

36 A sample of pent-2-en-4-ol,  $C_5H_{10}O$ , contains all the possible stereoisomers of this compound.

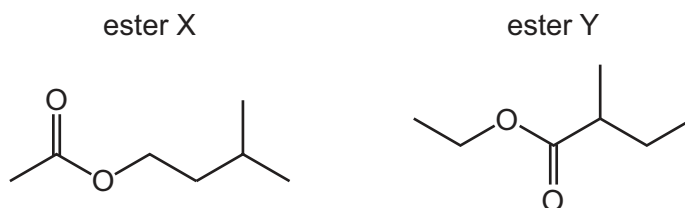
How many stereoisomers are there in the sample?

- A 2                                  B 3                                  C 4                                  D 5

37 Which pair of reagents reacts to form a product with a chiral carbon atom?

- A  $CH_3CH=CH_2 + HBr$   
 B  $(CH_3)_2C=O + NaBH_4$   
 C  $CH_3CH_2CHO + HCN$   
 D  $CH_3COOH + CH_3CH_2OH$

38 The diagrams show the structures of two esters, X and Y, that are formed in ripening apples.



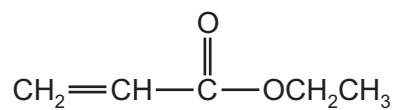
Which carboxylic acids are formed when these esters are hydrolysed by  $H_2SO_4(aq)$ ?

|   | ester X                | ester Y                |
|---|------------------------|------------------------|
| A | $CH_3COOH$             | $CH_3CH_2COOH$         |
| B | $CH_3COOH$             | $CH_3CH_2CH(CH_3)COOH$ |
| C | $CH_3CH(CH_3)CH_2COOH$ | $CH_3CH_2COOH$         |
| D | $CH_3CH(CH_3)CH_2COOH$ | $CH_3CH_2CH(CH_3)COOH$ |

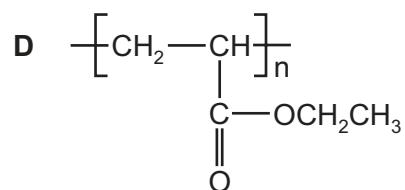
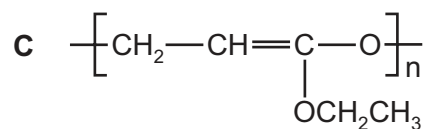
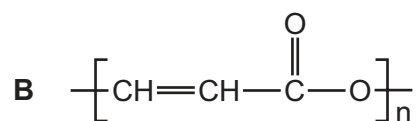
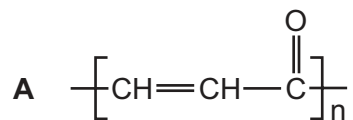
13

39 An addition polymer is made from monomer Z.

monomer Z

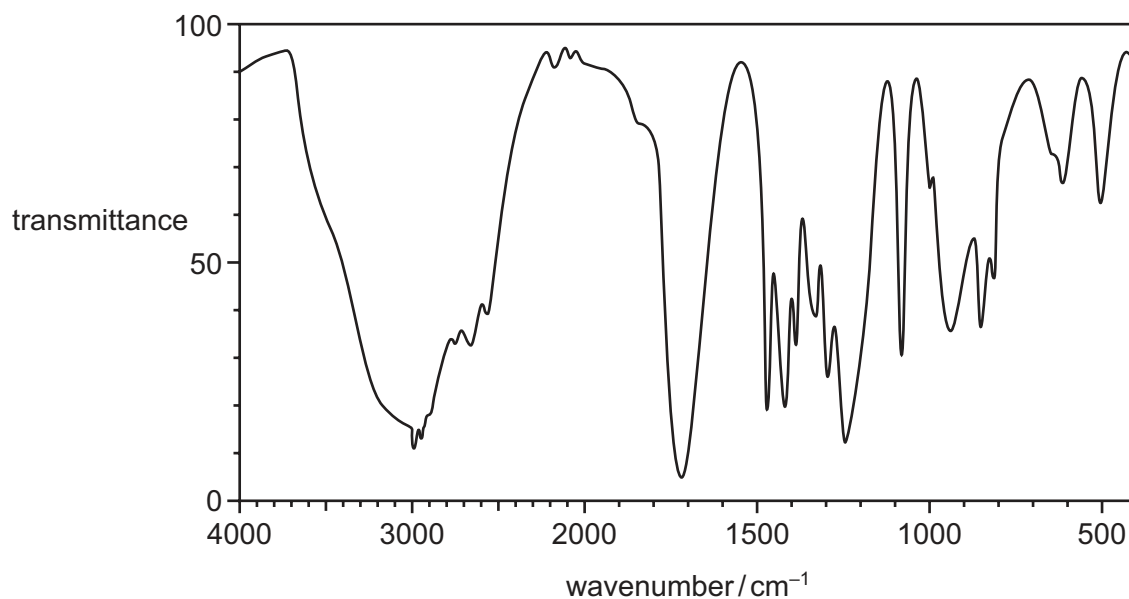


What is the structure of the polymer made from this monomer?



40 Compound X reacts with acidified  $\text{K}_2\text{Cr}_2\text{O}_7$  to form compound Y.

The infrared spectrum of compound Y is shown.



| bond | functional groups containing the bond | characteristic infrared absorption range<br>(in wavenumbers) / $\text{cm}^{-1}$ |
|------|---------------------------------------|---------------------------------------------------------------------------------|
| C–O  | hydroxy, ester                        | 1040–1300                                                                       |
| C=C  | aromatic compound, alkene             | 1500–1680                                                                       |
| C=O  | amide<br>carbonyl, carboxyl<br>ester  | 1640–1690<br>1670–1740<br>1710–1750                                             |
| C≡N  | nitrile                               | 2200–2250                                                                       |
| C–H  | alkane                                | 2850–2950                                                                       |
| N–H  | amine, amide                          | 3300–3500                                                                       |
| O–H  | carboxyl<br>hydroxy                   | 2500–3000<br>3200–3600                                                          |

What is the identity of compound X?

- A propan-1-ol
- B propan-2-ol
- C propanone
- D propanoic acid

**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 J g <sup>-1</sup> K <sup>-1</sup> )                                                    |

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| Group                    |                          |                                                                |  |  |  |  |    |    |    |    |    |    |  |
|--------------------------|--------------------------|----------------------------------------------------------------|--|--|--|--|----|----|----|----|----|----|--|
| 1                        | 2                        | Key                                                            |  |  |  |  | 13 | 14 | 15 | 16 | 17 | 18 |  |
|                          |                          | <div>1<br/>H<br/>hydrogen<br/>1.0</div>                        |  |  |  |  |    |    |    |    |    |    |  |
| 3                        | 4                        | atomic number<br>atomic symbol<br>name<br>relative atomic mass |  |  |  |  |    |    |    |    |    |    |  |
| Li<br>lithium<br>6.9     | Be<br>beryllium<br>9.0   |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 11                       | 12                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| Na<br>sodium<br>23.0     | Mg<br>magnesium<br>24.3  |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 19                       | 20                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| K<br>potassium<br>39.1   | Ca<br>calcium<br>40.1    |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 37                       | 38                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| Rb<br>rubidium<br>85.5   | Sr<br>strontium<br>87.6  |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 55                       | 56                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| Cs<br>caesium<br>132.9   | Ba<br>barium<br>137.3    |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 87                       | 88                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| Fr<br>francium<br>—      | Ra<br>radium<br>—        |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 21                       | 22                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| Sc<br>scandium<br>45.0   | Ti<br>titanium<br>47.9   |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 39                       | 40                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| Y<br>yttrium<br>88.9     | Zr<br>zirconium<br>91.2  |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 57–71                    | 72                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| lanthanoids              | Hf<br>hafnium<br>178.5   |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 73                       | 74                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| Ta<br>tantalum<br>180.9  | W<br>tungsten<br>183.8   |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 75                       | 76                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| Re<br>rhenium<br>186.2   | Os<br>osmium<br>190.2    |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 77                       | 78                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| Ir<br>iridium<br>192.2   | Pt<br>platinum<br>195.1  |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 79                       | 80                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| Au<br>gold<br>197.0      | Hg<br>mercury<br>200.6   |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 81                       | 82                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| Tl<br>thallium<br>204.4  | Pb<br>lead<br>207.2      |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 83                       | 84                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| Bi<br>bismuth<br>209.0   | Po<br>polonium<br>—      |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 85                       | 86                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| I<br>iodine<br>126.9     | At<br>astatine<br>—      |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 51                       | 52                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| Sb<br>antimony<br>121.8  | Te<br>tellurium<br>127.6 |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 53                       | 54                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 55                       | 56                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| In<br>indium<br>114.8    | Sn<br>tin<br>118.7       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 49                       | 50                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| Cd<br>cadmium<br>112.4   | Cu<br>copper<br>63.5     |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 47                       | 48                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| Ag<br>silver<br>107.9    | Ni<br>nickel<br>58.7     |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 46                       | 45                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| Pd<br>palladium<br>106.4 | Co<br>cobalt<br>58.9     |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 28                       | 27                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 29                       | 26                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 30                       | 25                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| Zn<br>zinc<br>65.4       | Mn<br>manganese<br>54.9  |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 31                       | 32                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| Ga<br>gallium<br>69.7    | Cr<br>chromium<br>52.0   |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 33                       | 34                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| As<br>arsenic<br>74.9    | V<br>vanadium<br>50.9    |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 35                       | 36                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| Br<br>bromine<br>79.9    | Ti<br>titanium<br>47.9   |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 37                       | 38                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| Se<br>selenium<br>79.0   | Zr<br>zirconium<br>91.2  |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 39                       | 40                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 41                       | 42                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| Ge<br>germanium<br>72.6  | Mo<br>molybdenum<br>95.9 |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 43                       | 44                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 45                       | 46                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 47                       | 48                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 49                       | 50                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 51                       | 52                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 53                       | 54                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 55                       | 56                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 57                       | 58                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 59                       | 60                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 61                       | 62                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 63                       | 64                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 65                       | 66                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 67                       | 68                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 69                       | 70                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 71                       | 72                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 73                       | 74                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 75                       | 76                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 77                       | 78                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 79                       | 80                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 81                       | 82                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 83                       | 84                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 85                       | 86                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 87                       | 88                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 89                       | 90                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 91                       | 92                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 93                       | 94                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 95                       | 96                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 97                       | 98                       |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 99                       | 100                      |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 101                      | 102                      |                                                                |  |  |  |  |    |    |    |    |    |    |  |
| 103                      |                          |                                                                |  |  |  |  |    |    |    |    |    |    |  |

## actinoids

|    |    |           |       |    |    |         |       |    |    |              |       |    |    |           |       |    |    |            |   |    |    |           |       |    |    |           |       |    |    |            |       |    |    |           |       |    |    |             |       |    |    |             |       |     |    |         |       |     |    |             |       |     |    |           |       |     |    |            |       |
|----|----|-----------|-------|----|----|---------|-------|----|----|--------------|-------|----|----|-----------|-------|----|----|------------|---|----|----|-----------|-------|----|----|-----------|-------|----|----|------------|-------|----|----|-----------|-------|----|----|-------------|-------|----|----|-------------|-------|-----|----|---------|-------|-----|----|-------------|-------|-----|----|-----------|-------|-----|----|------------|-------|
| 57 | La | lanthanum | 138.9 | 58 | Ce | cerium  | 140.1 | 59 | Pr | praseodymium | 140.9 | 60 | Nd | neodymium | 144.4 | 61 | Pm | promethium | — | 62 | Sm | samarium  | 150.4 | 63 | Eu | euporium  | 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  | 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 | —     |