



# Cambridge International AS & A Level

## 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)

### 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.



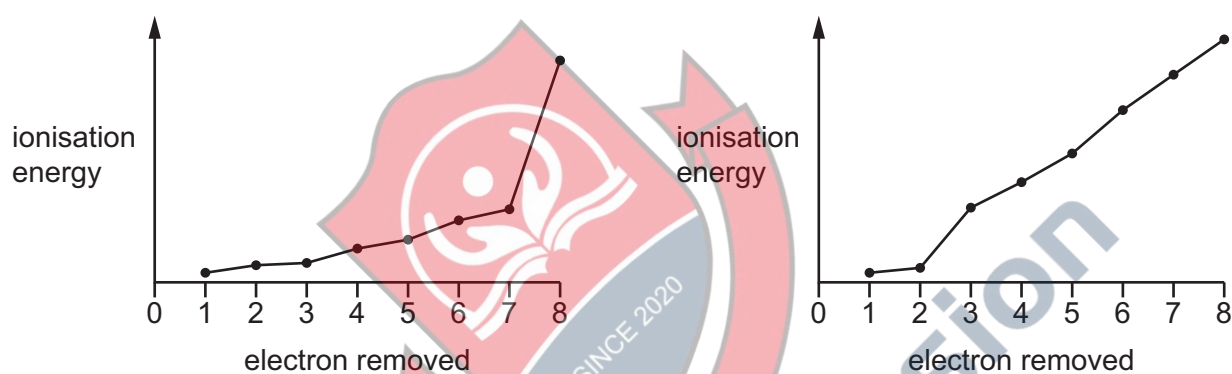
1 Which pair of formulae is correct?

- 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

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

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>

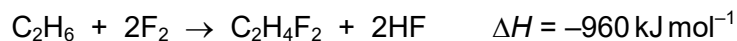
8 Consider the following four compounds.

- 1  $(\text{CH}_3)_3\text{CH}$
- 2  $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$
- 3  $\text{CH}_3\text{CH}_2\text{CH}_2\text{SH}$
- 4  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$

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

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



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

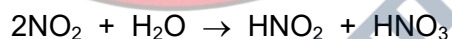
What is the bond energy of the C–F bond in 1,2-difluoroethane?

- 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**  $4\text{Na(s)} + \text{O}_2(\text{g}) \rightarrow 2\text{Na}_2\text{O(s)}$

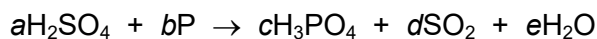
- 11 Nitrogen dioxide reacts with water.



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.

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



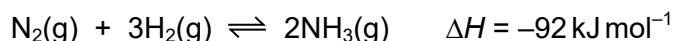
$a$ ,  $b$ ,  $c$ ,  $d$  and  $e$  are all whole numbers.

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

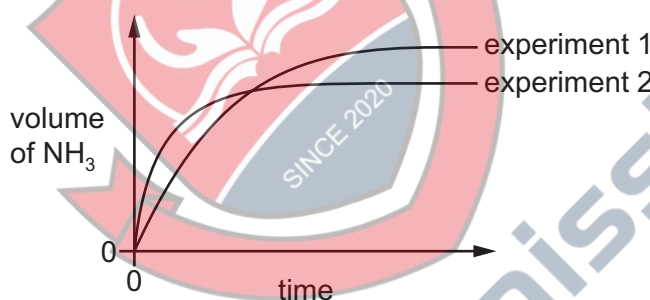
- 13 The volume of ammonia produced against time is measured in two experiments.



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.

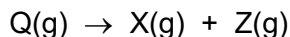
Experiment 2 is then performed. Experiment 2 differs from experiment 1 in **one** condition only.



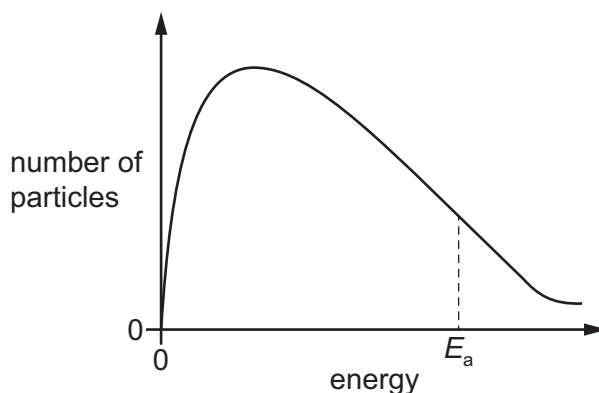
How does experiment 2 differ from experiment 1?

- 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  $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$

- 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  $\text{C}-\text{Br}$  bond to the C atom
- D the homolytic fission of the  $\text{C}-\text{Br}$  bond

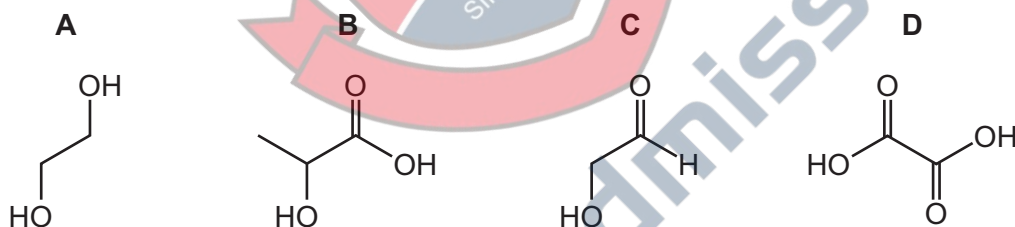
29 In which reaction is the organic compound oxidised?

- 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?

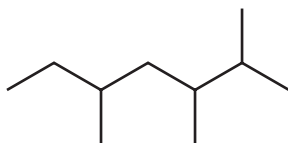


31 Which reaction will distinguish between propan-1-ol and propan-2-ol?

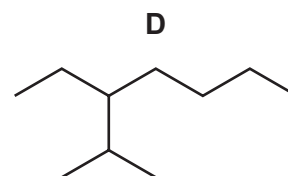
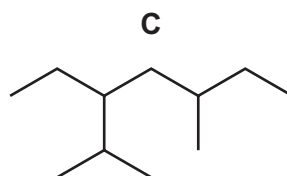
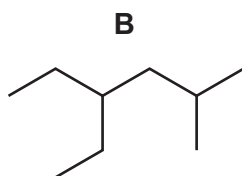
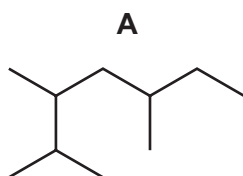
- A warming with acidified  $\text{KMnO}_4$
- B warming with acidified  $\text{K}_2\text{Cr}_2\text{O}_7$
- C dehydration, followed by reaction with  $\text{Br}_2(\text{aq})$
- D mild oxidation, followed by reaction with Fehling's reagent

32 Compound T has the skeletal formula shown.

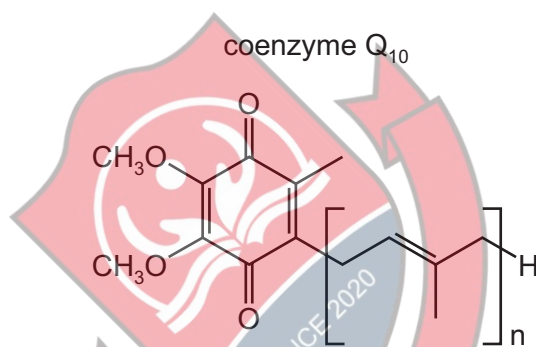
compound T



Which structure is a structural isomer of compound T?



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



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>

- 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.

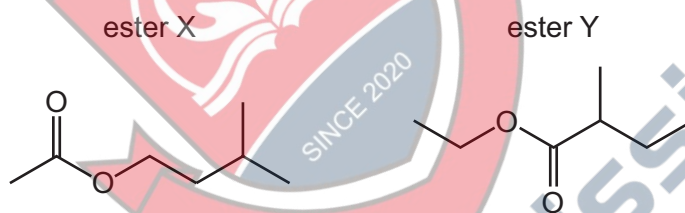
How many stereoisomers are there in the sample?

- 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.

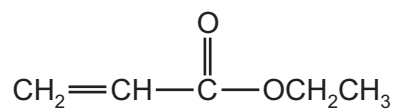


Which carboxylic acids are formed when these esters are hydrolysed by  $H_2SO_4(aq)$ ?

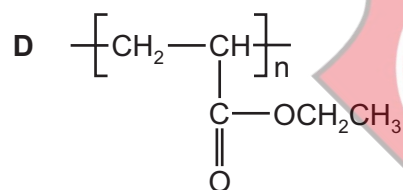
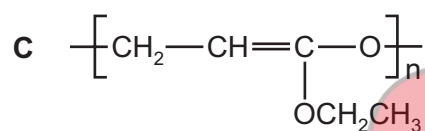
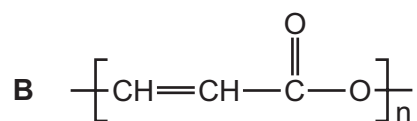
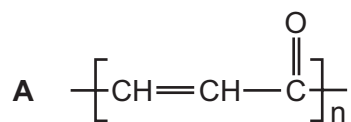
|   | ester X                | ester Y                |
|---|------------------------|------------------------|
| A | $CH_3COOH$             | $CH_3CH_2COOH$         |
| B | $CH_3COOH$             | $CH_3CH_2CH(CH_3)COOH$ |
| C | $CH_3CH(CH_3)CH_2COOH$ | $CH_3CH_2COOH$         |
| D | $CH_3CH(CH_3)CH_2COOH$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

- 39 An addition polymer is made from monomer Z.

monomer Z

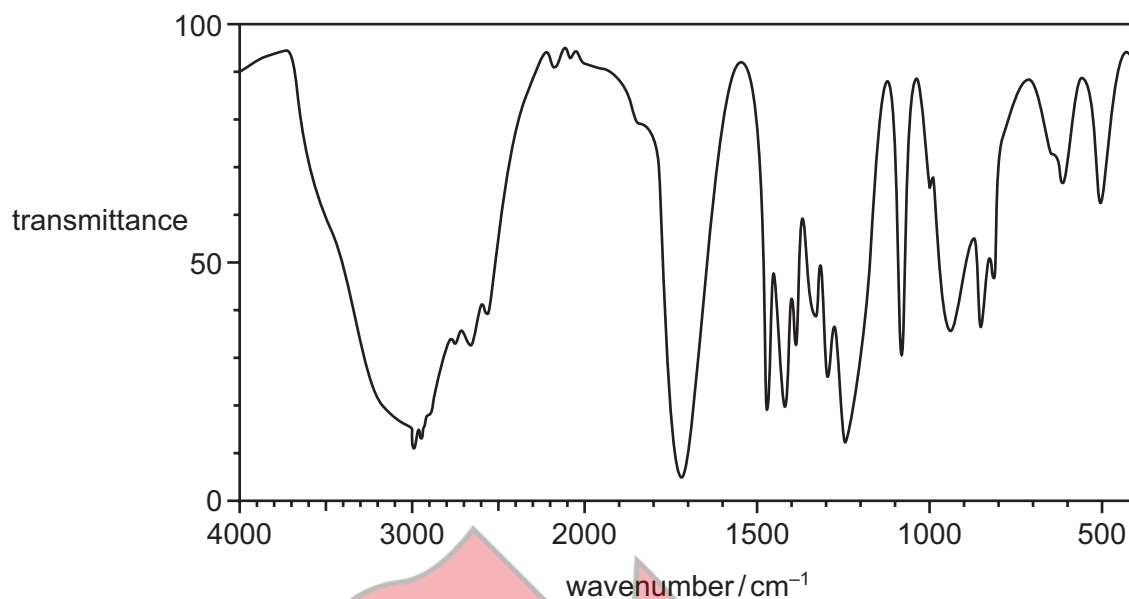


What is the structure of the polymer made from this monomer?



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 (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 | $c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ ( $4.18 \text{ J g}^{-1} \text{ K}^{-1}$ )                                                   |



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The Periodic Table of Elements

| Group                  |                         |                                                                              |                         |                       |                          |                         |                          |                        |                          |                        |                        |                         |                         |                         |                          |                         |                       |                        |                     |    |    |  |  |  |  |
|------------------------|-------------------------|------------------------------------------------------------------------------|-------------------------|-----------------------|--------------------------|-------------------------|--------------------------|------------------------|--------------------------|------------------------|------------------------|-------------------------|-------------------------|-------------------------|--------------------------|-------------------------|-----------------------|------------------------|---------------------|----|----|--|--|--|--|
| 1                      | 2                       |                                                                              |                         |                       |                          |                         |                          |                        |                          |                        |                        |                         |                         | 13                      | 14                       | 15                      | 16                    | 17                     | 18                  |    |    |  |  |  |  |
|                        |                         | <div>Key</div>                                                               |                         |                       |                          |                         |                          |                        |                          |                        |                        |                         |                         |                         |                          |                         |                       |                        |                     |    |    |  |  |  |  |
|                        |                         | <div>1<br/>H<br/>hydrogen<br/>1.0</div>                                      |                         |                       |                          |                         |                          |                        |                          |                        |                        |                         |                         |                         |                          |                         |                       |                        |                     |    |    |  |  |  |  |
|                        |                         | <div>atomic number<br/>atomic symbol<br/>name<br/>relative atomic mass</div> |                         |                       |                          |                         |                          |                        |                          |                        |                        |                         |                         |                         |                          |                         |                       |                        |                     |    |    |  |  |  |  |
| 3                      | 4                       |                                                                              |                         |                       |                          |                         |                          |                        |                          |                        |                        |                         |                         | 5                       | 6                        | 7                       | 8                     | 9                      | 10                  | 11 | 12 |  |  |  |  |
| Li<br>lithium<br>6.9   | Be<br>beryllium<br>9.0  |                                                                              |                         |                       |                          |                         |                          |                        |                          |                        |                        |                         |                         | B<br>boron<br>10.8      | C<br>carbon<br>12.0      |                         |                       |                        |                     |    |    |  |  |  |  |
| 11                     | 12                      |                                                                              |                         |                       |                          |                         |                          |                        |                          |                        |                        |                         |                         | 13                      | 14                       | 15                      | 16                    | 17                     | 18                  |    |    |  |  |  |  |
| Na<br>sodium<br>23.0   | Mg<br>magnesium<br>24.3 |                                                                              |                         |                       |                          |                         |                          |                        |                          |                        |                        |                         |                         | Al<br>aluminium<br>27.0 | Si<br>silicon<br>28.1    | P<br>phosphorus<br>31.0 | S<br>sulfur<br>32.1   | Cl<br>chlorine<br>35.5 | Ar<br>argon<br>39.9 |    |    |  |  |  |  |
| 19                     | 20                      | 21                                                                           | 22                      | 23                    | 24                       | 25                      | 26                       | 27                     | 28                       | 29                     | 30                     | 31                      | 32                      | 33                      | 34                       | 35                      | 36                    |                        |                     |    |    |  |  |  |  |
| K<br>potassium<br>39.1 | Ca<br>calcium<br>40.1   | Sc<br>scandium<br>45.0                                                       | Ti<br>titanium<br>47.9  | V<br>vanadium<br>50.9 | Cr<br>chromium<br>52.0   | Mn<br>manganese<br>54.9 | Fe<br>iron<br>55.8       | Co<br>cobalt<br>58.9   | Ni<br>nickel<br>58.7     | Cu<br>copper<br>63.5   | Zn<br>zinc<br>65.4     | Ga<br>gallium<br>69.7   | Ge<br>germanium<br>72.6 | As<br>arsenic<br>74.9   | Se<br>selenium<br>79.0   | Br<br>bromine<br>79.9   | Kr<br>krypton<br>83.8 |                        |                     |    |    |  |  |  |  |
| 37                     | 38                      | 39                                                                           | 40                      | 41                    | 42                       | 43                      | 44                       | 45                     | 46                       | 47                     | 48                     | 49                      | 50                      | 51                      | 52                       | 53                      | 54                    |                        |                     |    |    |  |  |  |  |
| Rb<br>rubidium<br>85.5 | Sr<br>strontium<br>87.6 | Y<br>yttrium<br>88.9                                                         | Zr<br>zirconium<br>91.2 | Nb<br>niobium<br>92.9 | Mo<br>molybdenum<br>95.9 | Tc<br>technetium<br>—   | Ru<br>ruthenium<br>101.1 | Rh<br>rhodium<br>102.9 | Pd<br>palladium<br>106.4 | Ag<br>silver<br>107.9  | Cd<br>cadmium<br>112.4 | In<br>indium<br>114.8   | Sn<br>tin<br>118.7      | Sb<br>antimony<br>121.8 | Te<br>tellurium<br>127.6 | I<br>iodine<br>126.9    | Xe<br>xenon<br>131.3  |                        |                     |    |    |  |  |  |  |
| 55                     | 56                      | 57–71                                                                        | 72                      | 73                    | 74                       | 75                      | 76                       | 77                     | 78                       | 79                     | 80                     | 81                      | 82                      | 83                      | 84                       | 85                      | 86                    |                        |                     |    |    |  |  |  |  |
| Cs<br>caesium<br>132.9 | Ba<br>barium<br>137.3   | lanthanoids                                                                  |                         |                       |                          |                         | Os<br>osmium<br>190.2    | Ir<br>iridium<br>192.2 | Pt<br>platinum<br>195.1  | Au<br>gold<br>197.0    | Hg<br>mercury<br>200.6 | Tl<br>thallium<br>204.4 | Pb<br>lead<br>207.2     | Bi<br>bismuth<br>209.0  | Po<br>polonium<br>—      | Rn<br>radon<br>—        |                       |                        |                     |    |    |  |  |  |  |
| 87                     | 88                      | 89–103                                                                       | 104                     | 105                   | 106                      | 107                     | 108                      | 109                    | 110                      | 111                    | 112                    | 113                     | 114                     | 115                     | 116                      | 117                     | 118                   |                        |                     |    |    |  |  |  |  |
| Fr<br>francium<br>—    | Ra<br>radium<br>—       | actinoids                                                                    |                         |                       |                          |                         | Hs<br>hassium<br>—       | Mt<br>meitnerium<br>—  | Ds<br>darmstadtium<br>—  | Rg<br>roentgenium<br>— | Cn<br>copernicium<br>— | Nh<br>nihonium<br>—     | Fl<br>flerovium<br>—    | Mc<br>moscovium<br>—    | Lv<br>livermorium<br>—   | Ts<br>tennessine<br>—   | Og<br>oganeson<br>—   |                        |                     |    |    |  |  |  |  |