



# Cambridge International AS & A Level

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## CHEMISTRY

9701/12

Paper 1 Multiple Choice

February/March 2023

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 **20** pages. Any blank pages are indicated.

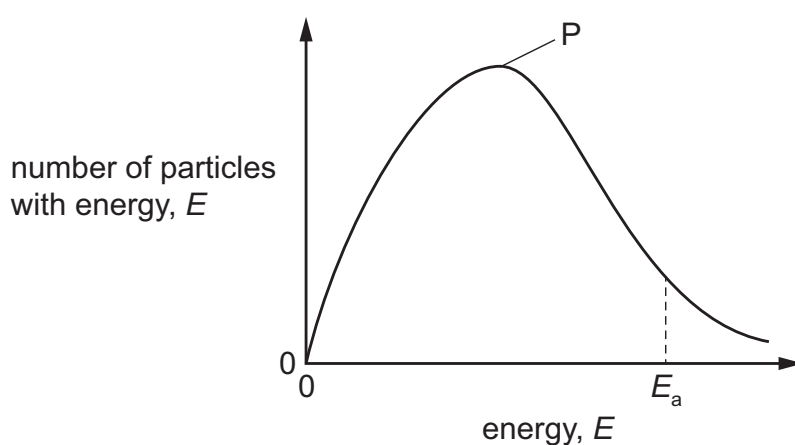


- 1 Four equations representing reactions of nitrogen or one of its compounds are given.

Which equation represents a disproportionation reaction?

- A**  $2\text{HNO}_3 + \text{CaCO}_3 \rightarrow \text{Ca}(\text{NO}_3)_2 + \text{CO}_2 + \text{H}_2\text{O}$   
**B**  $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$   
**C**  $\text{NH}_4\text{Cl} + \text{NaOH} \rightarrow \text{NH}_3 + \text{NaCl} + \text{H}_2\text{O}$   
**D**  $2\text{NO}_2 + \text{H}_2\text{O} \rightarrow \text{HNO}_3 + \text{HNO}_2$

- 2 The diagram shows the Boltzmann distribution for one mole of a gas. The gas takes part in a reaction with an activation energy,  $E_a$ .



Which statement correctly describes the effect of an increase in temperature?

- A** Peak P will be higher and fewer molecules will have energy  $> E_a$ .  
**B** Peak P will be higher and more molecules will have energy  $> E_a$ .  
**C** Peak P will be lower and fewer molecules will have energy  $> E_a$ .  
**D** Peak P will be lower and more molecules will have energy  $> E_a$ .

- 3 A student carries out four experiments to investigate the rate of reaction between 3.0 g of calcium carbonate and hydrochloric acid.



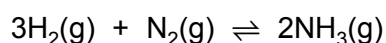
|              |                                                                                      |
|--------------|--------------------------------------------------------------------------------------|
| experiment 1 | $\text{CaCO}_3$ powder + $2.0 \text{ mol dm}^{-3}$ HCl at $35^\circ\text{C}$         |
| experiment 2 | $\text{CaCO}_3$ powder + $2.0 \text{ mol dm}^{-3}$ HCl at $35^\circ\text{C}$         |
| experiment 3 | large chips of $\text{CaCO}_3$ + $1.0 \text{ mol dm}^{-3}$ HCl at room temperature   |
| experiment 4 | large chips of $\text{CaCO}_3$ + $1.0 \text{ mol dm}^{-3}$ HCl at $35^\circ\text{C}$ |

The student collects the  $\text{CO}_2(\text{g})$  and times how long it takes to produce the same volume of gas for each experiment.

What could be the correct times for the four experiments?

|          | experiment 1<br>/s | experiment 2<br>/s | experiment 3<br>/s | experiment 4<br>/s |
|----------|--------------------|--------------------|--------------------|--------------------|
| <b>A</b> | 5                  | 10                 | 30                 | 95                 |
| <b>B</b> | 5                  | 10                 | 95                 | 30                 |
| <b>C</b> | 5                  | 30                 | 95                 | 10                 |
| <b>D</b> | 95                 | 30                 | 10                 | 5                  |

- 4 The table shows the partial pressures in an equilibrium mixture formed by the Haber process.

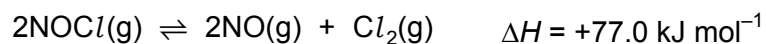


| substance | partial pressure / kPa |
|-----------|------------------------|
| nitrogen  | 7000                   |
| hydrogen  | 8000                   |
| ammonia   | 4000                   |

What is the numerical value of the equilibrium constant,  $K_p$ , for this reaction?

- A**  $4.46 \times 10^{-9}$     **B**  $4.76 \times 10^{-5}$     **C**  $7.14 \times 10^{-5}$     **D**  $2.24 \times 10^8$

- 5 A reversible reaction is shown.

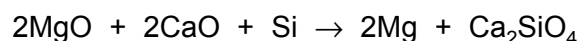


Which change in conditions will move the position of equilibrium to the right and increase the value of the equilibrium constant?

- A** a decrease in pressure  
**B** a decrease in temperature  
**C** an increase in pressure  
**D** an increase in temperature
- 6 The ore psilomelane may be considered to have the general formula  $\text{Ba}(\text{Mn}^{x+})(\text{Mn}^{y+})_8\text{O}_{16}(\text{OH})_4$ .  
 In this general formula,  $x+$  and  $y+$  are the two different oxidation states of manganese in psilomelane.  
 What could be the values of  $x$  and  $y$ ?

|          | $x$ | $y$ |
|----------|-----|-----|
| <b>A</b> | 2   | 4   |
| <b>B</b> | 6   | 4   |
| <b>C</b> | 6   | 3   |
| <b>D</b> | 7   | 3   |

- 7 Silicon reacts with a mixture of calcium oxide and magnesium oxide at  $1200^\circ\text{C}$ .



Which statement about this reaction is correct?

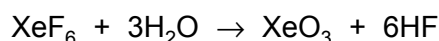
- A** Calcium is reduced and silicon is neither oxidised nor reduced.  
**B** Magnesium is reduced and calcium is neither oxidised nor reduced.  
**C** Magnesium is reduced and silicon is neither oxidised nor reduced.  
**D** Silicon is reduced and calcium is neither oxidised nor reduced.
- 8 In which species is there a lone pair of electrons?

- A**  $\text{CH}_3$                       **B**  $\text{CH}_3^+$                       **C**  $\text{CH}_3^-$                       **D**  $\text{CH}_4$

- 9 Under which conditions will nitrogen behave most like an ideal gas?

|          | temperature | pressure |
|----------|-------------|----------|
| <b>A</b> | low         | high     |
| <b>B</b> | high        | low      |
| <b>C</b> | low         | low      |
| <b>D</b> | high        | high     |

- 10 The equation for a chemical reaction is shown. All substances are in their standard states.



Which statement describes the standard enthalpy change of reaction for this reaction?

- A** the enthalpy change when a total of one mole of products is produced  
**B** the enthalpy change when a total of one mole of reactants is reacted  
**C** the enthalpy change when one mole of water reacts  
**D** the enthalpy change when six moles of hydrogen fluoride are produced
- 11 Molten aluminium chloride has a simple molecular structure. Each molecule consists of two aluminium atoms and six chlorine atoms.

Which statement is correct?

- A** All the chlorine atoms in 1 g of molten aluminium chloride have the same mass.  
**B** One mole of molten aluminium chloride contains  $6.02 \times 10^{23}$  aluminium atoms.  
**C** One mole of molten aluminium chloride contains  $3.61 \times 10^{24}$  chlorine atoms.  
**D** The empirical formula of molten aluminium chloride is  $\text{Al}_2\text{Cl}_6$ .
- 12 Which atom contains four times as many neutrons as the  ${}^7_3\text{Li}$  atom?

- A**  ${}^{40}_{20}\text{Ca}$       **B**  ${}^{24}_{12}\text{Mg}$       **C**  ${}^{31}_{15}\text{P}$       **D**  ${}^{26}_{14}\text{Si}$

- 13 Which statement about the first ionisation energies of magnesium and neon is correct?

- A** Magnesium has the greater numerical value and both are endothermic.  
**B** Magnesium has the greater numerical value and both are exothermic.  
**C** Neon has the greater numerical value and both are endothermic.  
**D** Neon has the greater numerical value and both are exothermic.

- 14 In a sample of pure water, what is the maximum number of hydrogen bonds that one molecule of water can be involved in?

A 1                      B 2                      C 3                      D 4

- 15 Hydrated cobalt(II) sulfate loses water when heated to give anhydrous cobalt(II) sulfate. All the water of crystallisation is lost to the atmosphere as steam.

When 3.10 g of hydrated cobalt(II) sulfate,  $\text{CoSO}_4 \cdot x\text{H}_2\text{O}$ , is heated to constant mass the **loss** in mass is 1.39 g.

What is the value of  $x$ , to the nearest whole number?

A 4                      B 6                      C 7                      D 11

- 16 The table shows bond energies for some diatomic molecules. Deuterium, D, is an isotope of hydrogen.

| bond  | energy<br>/ $\text{kJ mol}^{-1}$ |
|-------|----------------------------------|
| F–F   | 158                              |
| Cl–Cl | 242                              |
| Br–Br | 193                              |
| I–I   | 151                              |
| H–H   | 436                              |
| D–D   | 442                              |

Which statements are correct?

- 1 Diatomic molecules have exact values for their bond energies, which are always positive.
- 2 The trend in Group 7 bond energies can be explained by the variation in instantaneous dipole–induced dipole (id–id) forces.
- 3 A value for the enthalpy change for the reaction between deuterium and chlorine can be calculated using these data alone.

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

17 Two procedures are described.

- 1 Sulfur is burned in an excess of oxygen and then NO is added to the product mixture.
- 2 Sulfur is burned in an excess of oxygen and then NO<sub>2</sub> is added to the product mixture.

Which procedures will produce some sulfur trioxide, SO<sub>3</sub>?

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

18 Powder P is a mixture containing two of AgCl, AgBr or AgI.

P is shaken with dilute aqueous ammonia. A yellow solid, Q, remains.

The mixture is filtered and Q is washed and dried. The filtrate is collected and treated with aqueous nitric acid to produce a white precipitate, R, which is filtered off, washed and dried.

Q and R are warmed separately with concentrated sulfuric acid, H<sub>2</sub>SO<sub>4</sub>.

Which observations are made?

|          | Q + concentrated H <sub>2</sub> SO <sub>4</sub> | R + concentrated H <sub>2</sub> SO <sub>4</sub> |
|----------|-------------------------------------------------|-------------------------------------------------|
| <b>A</b> | violet fumes                                    | orange fumes                                    |
| <b>B</b> | violet fumes                                    | steamy fumes                                    |
| <b>C</b> | steamy fumes                                    | violet fumes                                    |
| <b>D</b> | orange fumes                                    | steamy fumes                                    |

19 Two Period 3 elements, X and Y, burn separately in oxygen to form solid oxides.

The oxide of X is insoluble in water.

The oxide of Y dissolves in water to form a solution which dissolves the oxide of X.

What could X and Y be?

|          | X         | Y          |
|----------|-----------|------------|
| <b>A</b> | aluminium | sodium     |
| <b>B</b> | magnesium | sodium     |
| <b>C</b> | silicon   | phosphorus |
| <b>D</b> | silicon   | sulfur     |

20 Which row describes the structure and bonding of  $\text{SiO}_2$  and  $\text{SiCl}_4$ ?

|          | $\text{SiO}_2$ |          | $\text{SiCl}_4$ |          |
|----------|----------------|----------|-----------------|----------|
|          | structure      | bonding  | structure       | bonding  |
| <b>A</b> | giant          | covalent | giant           | covalent |
| <b>B</b> | giant          | covalent | simple          | covalent |
| <b>C</b> | giant          | ionic    | giant           | covalent |
| <b>D</b> | giant          | ionic    | simple          | covalent |

21 A sample containing 0.010 mol of anhydrous calcium nitrate is heated strongly until it fully decomposes.

All the gas produced is collected and its volume measured at room conditions.

What is the volume of gas produced?

- A** 120 cm<sup>3</sup>      **B** 600 cm<sup>3</sup>      **C** 720 cm<sup>3</sup>      **D** 840 cm<sup>3</sup>

22 V and Z are both elements in Period 3 of the Periodic Table. Each element forms one stable ion that does not contain another element.

The atomic radius of each element and the ionic radius of the ion described above is shown.

| element | atomic radius<br>/ nm | ionic radius<br>/ nm |
|---------|-----------------------|----------------------|
| V       | 0.186                 | 0.095                |
| Z       | 0.099                 | 0.181                |

Which statement is correct?

- A** Ions of V and Z have the same number of full electron shells.  
**B** Ions of Z are positively charged.  
**C** Z has a greater electronegativity than V.  
**D** V has more outer electrons than Z.

- 23 In Group 2 of the Periodic Table, the properties of the elements and their compounds show regular change down the group.

Which property shows a **decrease** from magnesium to barium?

- A the decomposition temperature of the carbonates
- B the decomposition temperature of the nitrates
- C the solubility of the hydroxides
- D the solubility of the sulfates

- 24 Four properties of beryllium, Be, or a beryllium compound are listed.

Which property is different from the property of magnesium or the equivalent magnesium compound?

- A Be reacts with  $O_2$  when heated in air; Mg does not.
- B Be reacts with aqueous  $H_2SO_4$  to form a metal sulfate and  $H_2$ ; Mg does not.
- C  $Be(NO_3)_2$  decomposes on heating to form a metal oxide,  $NO_2$  and  $O_2$ ;  $Mg(NO_3)_2$  does not.
- D  $BeCl_2$  reacts with water to form fumes of  $HCl$ ;  $MgCl_2$  does not.

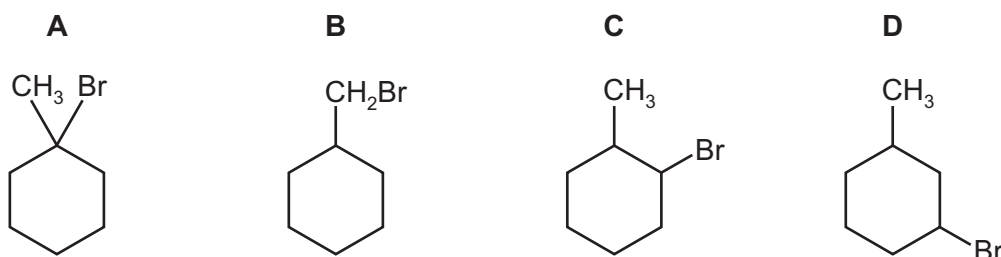
- 25 Which two formulae correctly represent a pair of structural isomers?

- A  $CH_3CH(CH_3)COOH$  and  $(CH_3)_2CHCOOH$
- B  $CH_3CH(COOH)CH_3$  and  $(CH_3)_2CHCOOH$
- C  $CH_3CHCOOH$  and  $CH_3CH_2CH_2COOH$
- D  $CH_3CH_2CH_2COOH$  and  $(CH_3)_2CHCOOH$

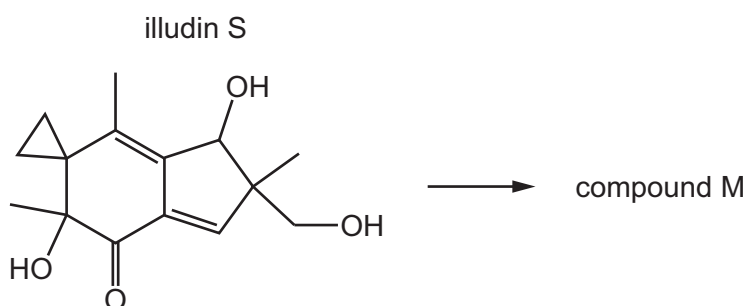
- 26 Which reagents and conditions would result in the formation of butanenitrile,  $CH_3CH_2CH_2CN$ ?

- A 1-bromobutane heated under pressure with ammonia in ethanol
- B 1-bromopropane heated with potassium cyanide in ethanol
- C propanal heated with hydrogen cyanide in the presence of potassium cyanide
- D propanone heated with hydrogen cyanide in the presence of potassium cyanide

- 27** Compound X,  $C_7H_{13}Br$ , reacts with hot alcoholic NaOH to produce two compounds, Y and Z. On reaction with  $Br_2$ , Y gives a product,  $C_7H_{12}Br_2$ , which exists as a mixture of four optical isomers. On reaction with  $Br_2$ , Z gives a product,  $C_7H_{12}Br_2$ , which is non-chiral. What could X be?



- 28** When illudin S is heated under reflux with an excess of acidified potassium dichromate(VI), compound M is formed.



What is the molecular formula of compound M?

- A**  $C_{15}H_{16}O_4$       **B**  $C_{15}H_{16}O_5$       **C**  $C_{15}H_{18}O_4$       **D**  $C_{15}H_{18}O_5$
- 29** Cyclohexene,  $C_6H_{10}$ , is a hydrocarbon with a six-membered ring of carbon atoms.

It has several structural isomers that are straight-chain alkenes. The number of double bonds in each of these molecules is P.

What is the shape of the cyclohexene molecule and what is the value of P?

|          | shape      | P |
|----------|------------|---|
| <b>A</b> | planar     | 1 |
| <b>B</b> | planar     | 2 |
| <b>C</b> | non-planar | 1 |
| <b>D</b> | non-planar | 2 |

- 30** Exhaust gases from an internal combustion engine are made less harmful by passing them through a catalytic converter. A number of reactions take place in the catalytic converter. Two such reactions are described in the table.

Which row is correct?

|          | the type of reaction that removes carbon monoxide | the type of reaction that removes unburned hydrocarbons |
|----------|---------------------------------------------------|---------------------------------------------------------|
| <b>A</b> | oxidation                                         | oxidation                                               |
| <b>B</b> | oxidation                                         | reduction                                               |
| <b>C</b> | reduction                                         | reduction                                               |
| <b>D</b> | reduction                                         | oxidation                                               |

- 31** Which compound reacts most rapidly with aqueous silver nitrate by an  $S_N1$  mechanism?

- A** 1-chloromethylpropane
- B** 2-chloromethylpropane
- C** 1-iodomethylpropane
- D** 2-iodomethylpropane

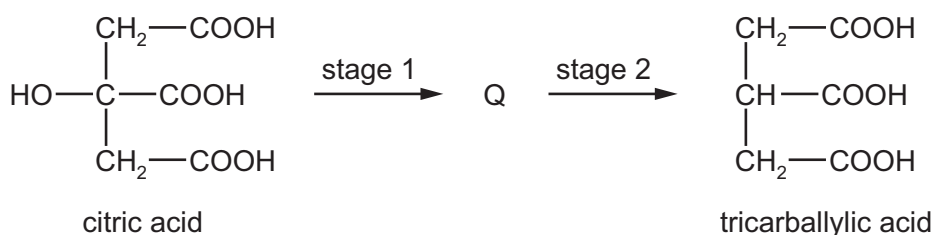
- 32** Tartaric acid,  $\text{HOOCCH(OH)CH(OH)COOH}$ , is found in many plants.

A sample of tartaric acid reacts with an excess of  $\text{LiAlH}_4$  to form the organic product J.

What happens when  $\text{NaOH(aq)}$  is added to separate samples of tartaric acid and J?

- A** Both tartaric acid and J react.
- B** Only tartaric acid reacts.
- C** Only J reacts.
- D** Neither tartaric acid nor J react.

- 33 Citric acid can be converted into tricarballic acid in two stages. An intermediate, Q, is formed.



Which reagents are needed for each stage?

|          | stage 1                              | stage 2                            |
|----------|--------------------------------------|------------------------------------|
| <b>A</b> | concentrated $\text{H}_2\text{SO}_4$ | $\text{H}_2(\text{g})$ and Ni      |
| <b>B</b> | concentrated $\text{H}_2\text{SO}_4$ | $\text{LiAlH}_4$                   |
| <b>C</b> | $\text{LiAlH}_4$                     | $\text{H}_2\text{SO}_4(\text{aq})$ |
| <b>D</b> | $\text{NaOH}(\text{aq})$             | $\text{H}_2(\text{g})$ and Ni      |

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

P has molecular formula  $\text{C}_5\text{H}_{10}\text{O}$ .

P produces an orange precipitate with 2,4-dinitrophenylhydrazine (2,4-DNPH reagent).

How many isomeric structures does P have?

- A** 5                      **B** 6                      **C** 7                      **D** 8

- 35 Two isomeric alcohols, W and X, have molecular formula  $\text{C}_4\text{H}_9\text{OH}$ .

W is oxidised to carbonyl compound Y which gives a red precipitate with Fehling's solution.

X is oxidised to carbonyl compound Z which does **not** give a red precipitate with Fehling's solution.

Which of W and X gives a yellow precipitate with alkaline  $\text{I}_2(\text{aq})$ ?

- A** insufficient data is given to answer this question  
**B** W only  
**C** X only  
**D** neither W nor X

- 36 The ester ethyl butanoate can be hydrolysed using an excess of dilute sodium hydroxide solution.

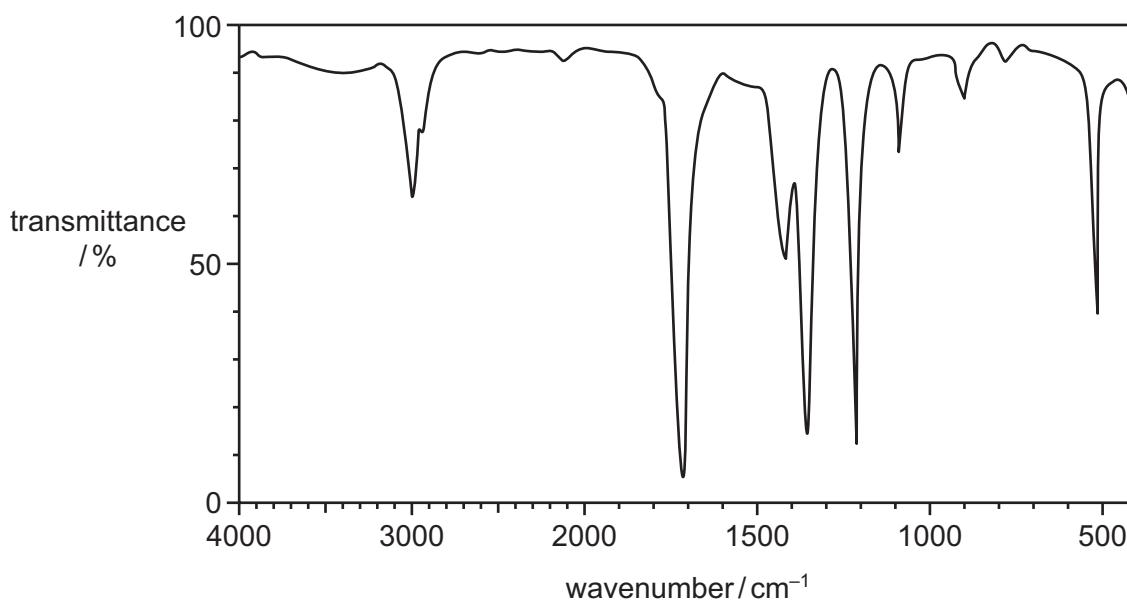
Which substance is a product of this reaction?

- A  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CO}_2\text{Na}$   
B  $\text{CH}_3\text{CO}_2\text{Na}$   
C  $\text{CH}_3\text{CH}_2\text{ONa}$   
D  $\text{H}_2\text{O}$
- 37 An aqueous solution contains 4.00 g of a carboxylic acid, Q. When this solution reacts with an excess of magnesium,  $380\text{ cm}^3$  of gas is produced, measured at s.t.p.

What is the relative formula mass of Q?

- A 59                      B 118                      C 126                      D 236

38 The infrared spectrum of an organic compound is shown.

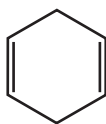


| bond | functional groups containing the bond | characteristic infrared absorption range<br>(in wavenumbers)/cm <sup>-1</sup> |
|------|---------------------------------------|-------------------------------------------------------------------------------|
| C–O  | hydroxy, ester                        | 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                                | 2850–3100                                                                     |
| N–H  | amine, amide                          | 3300–3500                                                                     |
| O–H  | carboxyl<br>hydroxy                   | 2500–3000<br>3200–3650                                                        |

Which compound could give this spectrum?

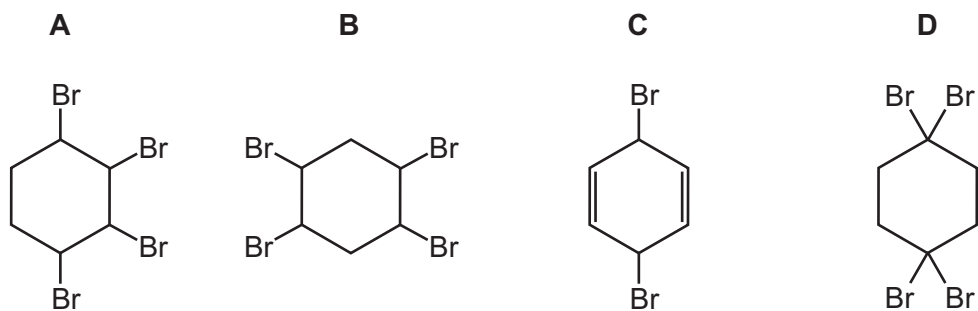
- A  $\text{CH}_3\text{CH}_2\text{CO}_2\text{H}$
- B  $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$
- C  $\text{CH}_3\text{COCH}_3$
- D  $\text{CH}_3\text{COCH}_2\text{OH}$

- 39 Cyclohexa-1,4-diene is treated with a solution of bromine in tetrachloromethane in the dark.



cyclohexa-1,4-diene

Which product is formed?



- 40 2-methylbut-2-ene is reacted with hot, concentrated, acidified potassium manganate(VII) solution.

What are the products of this reaction?

- A** ethanal and propanone  
**B** ethanoic acid and propanone  
**C** ethanoic acid and propan-2-ol  
**D** ethanol and propan-2-ol

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**Important values, constants and standards**

|                                 |                                                                                                                                           |
|---------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| molar gas constant              | $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$                                                                                              |
| Faraday constant                | $F = 9.65 \times 10^4 \text{ C mol}^{-1}$                                                                                                 |
| Avogadro constant               | $L = 6.022 \times 10^{23} \text{ mol}^{-1}$                                                                                               |
| electronic charge               | $e = -1.60 \times 10^{-19} \text{ C}$                                                                                                     |
| molar volume of gas             | $V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K)<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> )                                                    |

The Periodic Table of Elements

| Group                        |                               |                                                                |                               |                                 |                                |                               |                                |                              |                                |                                |                               |                               |                               |                               |                                |                               |                              |                               |                             |                               |                           |                              |                           |
|------------------------------|-------------------------------|----------------------------------------------------------------|-------------------------------|---------------------------------|--------------------------------|-------------------------------|--------------------------------|------------------------------|--------------------------------|--------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|--------------------------------|-------------------------------|------------------------------|-------------------------------|-----------------------------|-------------------------------|---------------------------|------------------------------|---------------------------|
| 1                            | 2                             | Key                                                            |                               |                                 |                                |                               |                                |                              |                                |                                |                               |                               |                               | 13                            | 14                             | 15                            | 16                           | 17                            | 18                          |                               |                           |                              |                           |
|                              |                               | 1<br>H<br>hydrogen<br>1.0                                      |                               |                                 |                                |                               |                                |                              |                                |                                |                               |                               |                               |                               |                                |                               |                              |                               |                             |                               |                           |                              |                           |
|                              |                               | atomic number<br>atomic symbol<br>name<br>relative atomic mass |                               |                                 |                                |                               |                                |                              |                                |                                |                               |                               |                               |                               |                                |                               |                              |                               |                             |                               |                           |                              |                           |
| 3<br>Li<br>lithium<br>6.9    | 4<br>Be<br>beryllium<br>9.0   |                                                                |                               |                                 |                                |                               |                                |                              |                                |                                |                               |                               |                               |                               |                                |                               |                              | 5<br>B<br>boron<br>10.8       | 6<br>C<br>carbon<br>12.0    | 7<br>N<br>nitrogen<br>14.0    | 8<br>O<br>oxygen<br>16.0  | 9<br>F<br>fluorine<br>19.0   | 10<br>Ne<br>neon<br>20.2  |
| 11<br>Na<br>sodium<br>23.0   | 12<br>Mg<br>magnesium<br>24.3 |                                                                |                               |                                 |                                |                               |                                |                              |                                |                                |                               |                               |                               |                               |                                |                               |                              | 13<br>Al<br>aluminium<br>27.0 | 14<br>Si<br>silicon<br>28.1 | 15<br>P<br>phosphorus<br>31.0 | 16<br>S<br>sulfur<br>32.1 | 17<br>Cl<br>chlorine<br>35.5 | 18<br>Ar<br>argon<br>39.9 |
| 19<br>K<br>potassium<br>39.1 | 20<br>Ca<br>calcium<br>40.1   | 21<br>Sc<br>scandium<br>45.0                                   | 22<br>Ti<br>titanium<br>47.9  | 23<br>V<br>vanadium<br>50.9     | 24<br>Cr<br>chromium<br>52.0   | 25<br>Mn<br>manganese<br>54.9 | 26<br>Fe<br>iron<br>55.8       | 27<br>Co<br>cobalt<br>58.9   | 28<br>Ni<br>nickel<br>58.7     | 29<br>Cu<br>copper<br>63.5     | 30<br>Zn<br>zinc<br>65.4      | 31<br>Ga<br>gallium<br>69.7   | 32<br>Ge<br>germanium<br>72.6 | 33<br>As<br>arsenic<br>74.9   | 34<br>Se<br>selenium<br>79.0   | 35<br>Br<br>bromine<br>79.9   | 36<br>Kr<br>krypton<br>83.8  |                               |                             |                               |                           |                              |                           |
| 37<br>Rb<br>rubidium<br>85.5 | 38<br>Sr<br>strontium<br>87.6 | 39<br>Y<br>yttrium<br>88.9                                     | 40<br>Zr<br>zirconium<br>91.2 | 41<br>Nb<br>niobium<br>92.9     | 42<br>Mo<br>molybdenum<br>95.9 | 43<br>Tc<br>technetium<br>—   | 44<br>Ru<br>ruthenium<br>101.1 | 45<br>Rh<br>rhodium<br>102.9 | 46<br>Pd<br>palladium<br>106.4 | 47<br>Ag<br>silver<br>107.9    | 48<br>Cd<br>cadmium<br>112.4  | 49<br>In<br>indium<br>114.8   | 50<br>Sn<br>tin<br>118.7      | 51<br>Sb<br>antimony<br>121.8 | 52<br>Te<br>tellurium<br>127.6 | 53<br>I<br>iodine<br>126.9    | 54<br>Xe<br>xenon<br>131.3   |                               |                             |                               |                           |                              |                           |
| 55<br>Cs<br>caesium<br>132.9 | 56<br>Ba<br>barium<br>137.3   | 57–71<br>lanthanoids                                           |                               | 72<br>Hf<br>hafnium<br>178.5    | 73<br>Ta<br>tantalum<br>180.9  | 74<br>W<br>tungsten<br>183.8  | 75<br>Re<br>rhenium<br>186.2   | 76<br>Os<br>osmium<br>190.2  | 77<br>Ir<br>iridium<br>192.2   | 78<br>Pt<br>platinum<br>195.1  | 79<br>Au<br>gold<br>197.0     | 80<br>Hg<br>mercury<br>200.6  | 81<br>Tl<br>thallium<br>204.4 | 82<br>Pb<br>lead<br>207.2     | 83<br>Bi<br>bismuth<br>209.0   | 84<br>Po<br>polonium<br>—     | 85<br>At<br>astatine<br>—    | 86<br>Rn<br>radon<br>—        |                             |                               |                           |                              |                           |
| 87<br>Fr<br>francium<br>—    | 88<br>Ra<br>radium<br>—       | 89–103<br>actinoids                                            |                               | 104<br>Rf<br>rutherfordium<br>— | 105<br>Db<br>dubnium<br>—      | 106<br>Sg<br>seaborgium<br>—  | 107<br>Bh<br>bohrium<br>—      | 108<br>Hs<br>hassium<br>—    | 109<br>Mt<br>meitnerium<br>—   | 110<br>Ds<br>darmstadtium<br>— | 111<br>Rg<br>roentgenium<br>— | 112<br>Cn<br>copernicium<br>— | 113<br>Nh<br>nihonium<br>—    | 114<br>Fl<br>flerovium<br>—   | 115<br>Mc<br>moscovium<br>—    | 116<br>Lv<br>livermorium<br>— | 117<br>Ts<br>tennessine<br>— | 118<br>Og<br>oganeson<br>—    |                             |                               |                           |                              |                           |