



# Cambridge International AS & A Level

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## CHEMISTRY

9701/11

Paper 1 Multiple Choice

October/November 2022

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. Any blank pages are indicated.



- 1 Which sample contains the same number of the named species as the number of molecules in 35.5 g of chlorine?
- A atoms in 16 g of sulfur  
B atoms in 23 g of sodium  
C ions in 74.5 g of potassium chloride  
D molecules in 88 g of carbon dioxide
- 2 Mixture R consists of one mole of  $\text{C}_3\text{H}_6$  and one mole of  $\text{C}_4\text{H}_6$ .  
What is the minimum number of moles of oxygen molecules needed for complete combustion of mixture R?
- A 6.5                      B 7                      C 10                      D 20
- 3 Which statement about the electrons in a ground state carbon atom is correct?
- A Electrons are present in four different energy levels.  
B There are more electrons in p orbitals than there are in s orbitals.  
C The occupied orbital of highest energy is spherical.  
D The occupied orbital of lowest energy is spherical.
- 4 For the element sulfur, which pair of ionisation energies has the largest difference between them?
- A third and fourth ionisation energies  
B fourth and fifth ionisation energies  
C fifth and sixth ionisation energies  
D sixth and seventh ionisation energies
- 5 How many  $\sigma$  bonds are present in one  $\text{H}-\text{C}\equiv\text{C}-\text{C}(\text{CH}_3)=\text{CH}(\text{CH}_3)$  molecule?
- A 5                      B 11                      C 13                      D 16
- 6 Which molecule has an equal number of bonding electrons and lone-pair electrons?
- A  $\text{BH}_3$                       B  $\text{CO}_2$                       C  $\text{F}_2\text{O}$                       D  $\text{SO}_2$

- 7 The table shows properties of four solids held together by different types of bonding.

Which row correctly describes the properties of a solid with a giant covalent structure?

|          | melting point | solubility in polar solvents |
|----------|---------------|------------------------------|
| <b>A</b> | high          | insoluble                    |
| <b>B</b> | high          | soluble                      |
| <b>C</b> | low           | insoluble                    |
| <b>D</b> | low           | soluble                      |

- 8 The carbonate of an s-block element is reacted with an excess of hydrochloric acid.

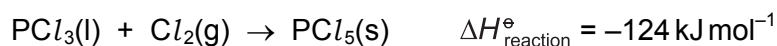
0.833 g of the carbonate releases 200 cm<sup>3</sup> of gas, measured under room conditions.

What is the identity of the metal carbonate?

- A** Na<sub>2</sub>CO<sub>3</sub>      **B** K<sub>2</sub>CO<sub>3</sub>      **C** MgCO<sub>3</sub>      **D** CaCO<sub>3</sub>

- 9 The enthalpy changes of formation,  $\Delta H_f^\ominus$ , of both PCl<sub>3</sub> and PCl<sub>5</sub> are exothermic.

PCl<sub>3</sub> reacts with chlorine.



Which pair of statements is correct?

|          | statement 1                                                                                     | statement 2                                                                                                                     |
|----------|-------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|
| <b>A</b> | $\Delta H_{\text{reaction}}^\ominus$ is less negative than $\Delta H_f^\ominus(\text{PCl}_5)$ . | The Cl <sub>2</sub> bond energy is needed in calculating $\Delta H_{\text{reaction}}^\ominus$ from enthalpies of formation.     |
| <b>B</b> | $\Delta H_{\text{reaction}}^\ominus$ is more negative than $\Delta H_f^\ominus(\text{PCl}_5)$ . | The Cl <sub>2</sub> bond energy is needed in calculating $\Delta H_{\text{reaction}}^\ominus$ from enthalpies of formation.     |
| <b>C</b> | $\Delta H_{\text{reaction}}^\ominus$ is less negative than $\Delta H_f^\ominus(\text{PCl}_5)$ . | The Cl <sub>2</sub> bond energy is not needed in calculating $\Delta H_{\text{reaction}}^\ominus$ from enthalpies of formation. |
| <b>D</b> | $\Delta H_{\text{reaction}}^\ominus$ is more negative than $\Delta H_f^\ominus(\text{PCl}_5)$ . | The Cl <sub>2</sub> bond energy is not needed in calculating $\Delta H_{\text{reaction}}^\ominus$ from enthalpies of formation. |

- 10** A student mixes  $25.0\text{ cm}^3$  of  $0.350\text{ mol dm}^{-3}$  sodium hydroxide solution with  $25.0\text{ cm}^3$  of  $0.350\text{ mol dm}^{-3}$  hydrochloric acid. The temperature increases by  $2.5^\circ\text{C}$ . No heat is lost to the surroundings.

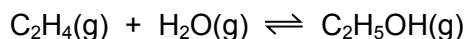
The final mixture has a specific heat capacity of  $4.2\text{ J cm}^{-3}\text{ K}^{-1}$ .

What is the molar enthalpy change for the reaction?

- A**  $-150\text{ kJ mol}^{-1}$   
**B**  $-60\text{ kJ mol}^{-1}$   
**C**  $-30\text{ kJ mol}^{-1}$   
**D**  $-0.15\text{ kJ mol}^{-1}$
- 11** Ammonium ions are converted into nitrate ions by bacteria.
- What is the change in the oxidation number of nitrogen?
- A**  $-6$                       **B**  $+6$                       **C**  $+8$                       **D**  $+9$
- 12** Sodium dichromate(VI),  $\text{Na}_2\text{Cr}_2\text{O}_7$ , reacts with hydrogen peroxide,  $\text{H}_2\text{O}_2$ , producing  $\text{Cr}^{3+}$  ions, water and oxygen.
- What is the correctly balanced ionic equation for this reaction?
- A**  $\text{Cr}_2\text{O}_7^{2-} + 2\text{H}^+ + \text{H}_2\text{O}_2 \rightarrow 2\text{Cr}^{3+} + 2\text{H}_2\text{O} + 4\text{O}_2$   
**B**  $\text{Cr}_2\text{O}_7^{2-} + 8\text{H}^+ + 3\text{H}_2\text{O}_2 \rightarrow 2\text{Cr}^{3+} + 7\text{H}_2\text{O} + 3\text{O}_2$   
**C**  $\text{Cr}_2\text{O}_7^{2-} + 8\text{H}^+ + 6\text{H}_2\text{O}_2 \rightarrow 2\text{Cr}^{3+} + 10\text{H}_2\text{O} + 6\text{O}_2$   
**D**  $\text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ + 3\text{H}_2\text{O}_2 \rightarrow 2\text{Cr}^{3+} + 7\text{H}_2\text{O} + 3\text{O}_2$
- 13** In which equilibrium reaction is the position of equilibrium moved to the right-hand side by increasing the temperature and also by decreasing the pressure?

- A**  $\text{H}_2(\text{g}) + \text{CO}_2(\text{g}) \rightleftharpoons \text{H}_2\text{O}(\text{g}) + \text{CO}(\text{g}) \quad \Delta H = 40\text{ kJ mol}^{-1}$   
**B**  $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g}) \quad \Delta H = 58\text{ kJ mol}^{-1}$   
**C**  $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g}) \quad \Delta H = -197\text{ kJ mol}^{-1}$   
**D**  $2\text{HI}(\text{g}) \rightleftharpoons \text{H}_2(\text{g}) + \text{I}_2(\text{g}) \quad \Delta H = -10\text{ kJ mol}^{-1}$

- 14 Ethanol is produced industrially by reacting ethene and steam.



$K_p$  has a value of  $1.8 \times 10^{-5}$  and the partial pressures of the reactants at equilibrium are shown.

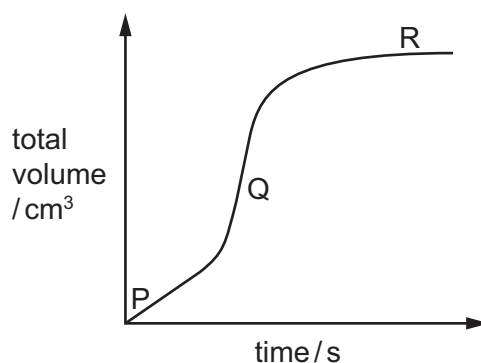
| reactant | partial pressure / kPa |
|----------|------------------------|
| ethene   | $4.8 \times 10^3$      |
| steam    | $2.8 \times 10^3$      |

Which row is correct?

|          | partial pressure of ethanol at equilibrium / kPa | units of $K_p$    |
|----------|--------------------------------------------------|-------------------|
| <b>A</b> | $2.42 \times 10^2$                               | $\text{kPa}^{-1}$ |
| <b>B</b> | $2.42 \times 10^2$                               | kPa               |
| <b>C</b> | $7.47 \times 10^{11}$                            | $\text{kPa}^{-1}$ |
| <b>D</b> | $7.47 \times 10^{11}$                            | kPa               |

- 15 A large excess of magnesium ribbon is added to dilute hydrochloric acid and the volume of hydrogen gas produced is measured as the reaction proceeds. The reaction is exothermic.

The results are shown.

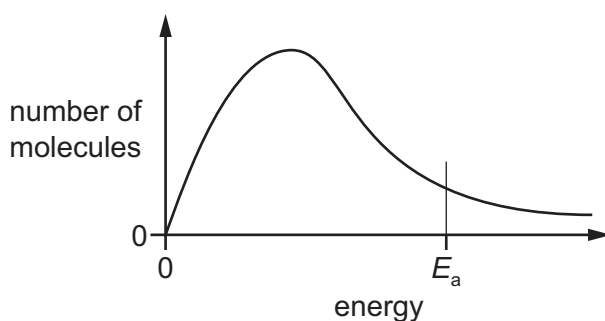


Which row explains the changes in the rate of reaction between points P and Q and between points Q and R?

|          | between points P and Q                 | between points Q and R            |
|----------|----------------------------------------|-----------------------------------|
| <b>A</b> | the reaction temperature is increasing | the acid concentration is falling |
| <b>B</b> | the reaction temperature is increasing | the magnesium has been used up    |
| <b>C</b> | magnesium's surface area is decreasing | the acid concentration is falling |
| <b>D</b> | magnesium's surface area is decreasing | the magnesium has been used up    |

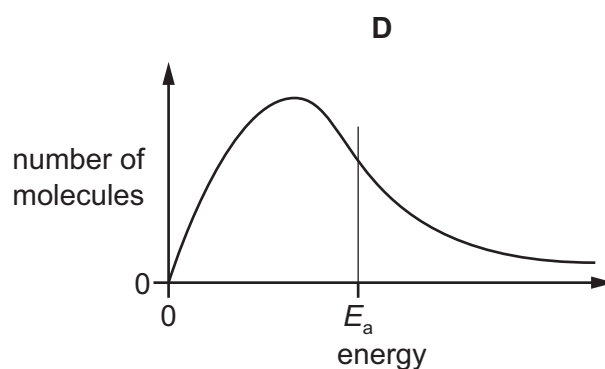
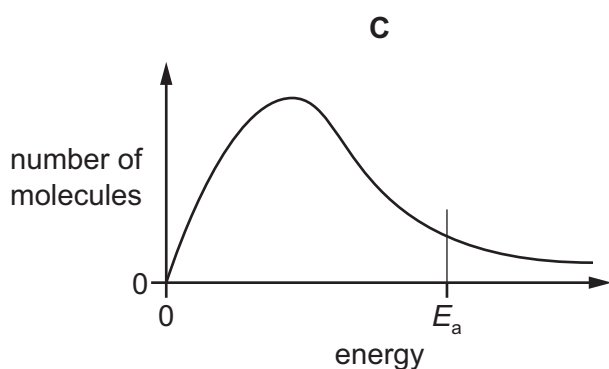
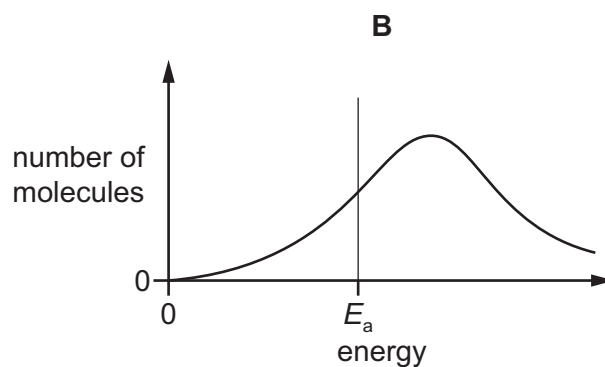
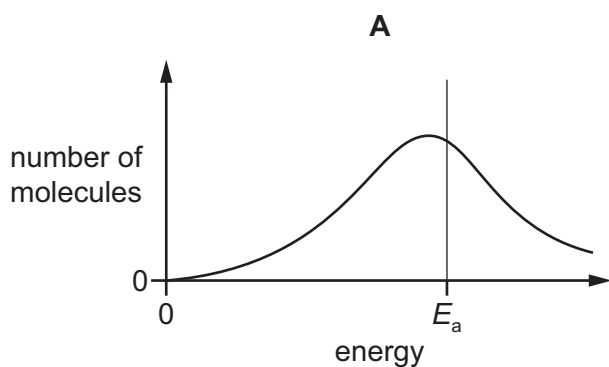
**16** Measurements are made to determine the activation energy,  $E_a$ , of a reaction.

The diagram shows  $E_a$  on the Boltzmann distribution at temperature  $T_1$ .



Measurements are then made at a higher temperature,  $T_2$ .

Which diagram correctly shows the Boltzmann distribution and  $E_a$  at  $T_2$ ?



17 The electrical conductivities of two compounds, Y and Z, are shown.

|                                                                      | for Y | for Z            |
|----------------------------------------------------------------------|-------|------------------|
| conductivity of the compound in the liquid state                     | good  | does not conduct |
| conductivity of the mixture obtained by adding the compound to water | good  | good             |

What are compounds Y and Z?

|          | Y         | Z         |
|----------|-----------|-----------|
| <b>A</b> | $Al_2O_3$ | $SiCl_4$  |
| <b>B</b> | $NaCl$    | $Al_2O_3$ |
| <b>C</b> | $NaCl$    | $SiCl_4$  |
| <b>D</b> | $SiCl_4$  | $Al_2O_3$ |

18 Which row describes the relative sizes of the ionic radii of  $Na^+$ ,  $Mg^{2+}$  and  $S^{2-}$ ?

|          | smallest  | →         | largest   |
|----------|-----------|-----------|-----------|
| <b>A</b> | $Na^+$    | $Mg^{2+}$ | $S^{2-}$  |
| <b>B</b> | $Mg^{2+}$ | $Na^+$    | $S^{2-}$  |
| <b>C</b> | $S^{2-}$  | $Na^+$    | $Mg^{2+}$ |
| <b>D</b> | $S^{2-}$  | $Mg^{2+}$ | $Na^+$    |

19 The oxides  $BaO$ ,  $CaO$ ,  $MgO$  and  $SrO$  all produce alkaline solutions when added to water.

Which oxide produces the saturated solution with the highest pH?

**A**  $BaO$                       **B**  $CaO$                       **C**  $MgO$                       **D**  $SrO$

20 Which row is correct?

|          | the temperature needed to decompose Group 2 metal nitrates | the solubility of Group 2 sulfates |
|----------|------------------------------------------------------------|------------------------------------|
| <b>A</b> | decreases down the group                                   | decreases down the group           |
| <b>B</b> | decreases down the group                                   | increases down the group           |
| <b>C</b> | increases down the group                                   | increases down the group           |
| <b>D</b> | increases down the group                                   | decreases down the group           |

21 Which statement about Group 17 elements and compounds is correct?

- A Sodium chloride produces chlorine when reacted with concentrated sulfuric acid.
- B Sodium chloride produces chlorine when reacted with bromine.
- C Sodium bromide produces bromine when reacted with concentrated sulfuric acid.
- D Sodium bromide produces bromine when reacted with iodine in aqueous potassium iodide.

22 Chlorine is bubbled through 100 cm<sup>3</sup> of hot 4.0 mol dm<sup>-3</sup> sodium hydroxide until the reaction is complete.



Which row is correct?

|   | $x$ | $[\text{Na}^+](\text{aq})$ after reaction / mol dm <sup>-3</sup> |
|---|-----|------------------------------------------------------------------|
| A | 3   | 4.0                                                              |
| B | 3   | less than 4.0                                                    |
| C | 6   | 4.0                                                              |
| D | 6   | less than 4.0                                                    |

23 Which statement about ammonia or the ammonium ion is correct?

- A Ammonia gas is produced when an aqueous solution containing the ammonium ion is reacted with a strong acid.
- B Silver iodide is soluble in a concentrated aqueous solution of ammonia.
- C The ammonium ion has the same number of electrons as a methane molecule.
- D The square planar ammonium ion contains a dative covalent bond.

24 Sulfur dioxide can be catalytically oxidised by an oxide of nitrogen in the atmosphere.

Which reaction shows how the catalyst is reformed?

- A  $\text{N}_2 + 2\text{O}_2 \rightleftharpoons 2\text{NO}_2$
- B  $4\text{NH}_3 + 5\text{O}_2 \rightarrow 4\text{NO} + 6\text{H}_2\text{O}$
- C  $\text{N}_2 + \text{O}_2 \rightarrow 2\text{NO}$
- D  $\text{NO} + \frac{1}{2}\text{O}_2 \rightarrow \text{NO}_2$

- 25 Separate 1.0 g samples of  $\text{Na}_2\text{O}$ ,  $\text{MgO}$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{SiO}_2$ ,  $\text{NaCl}$ ,  $\text{MgCl}_2$ ,  $\text{Al}_2\text{Cl}_6$  and  $\text{SiCl}_4$  are added to separate beakers containing water and stirred.

The number of beakers containing a white solid is Q.

An excess of  $\text{NaOH(aq)}$  is then added to each beaker and stirred.

The number of beakers now containing a white solid is R.

Which row is correct?

|          | Q | R |
|----------|---|---|
| <b>A</b> | 3 | 2 |
| <b>B</b> | 3 | 3 |
| <b>C</b> | 4 | 3 |
| <b>D</b> | 4 | 4 |

- 26 Which pair of alcohols are isomers of each other?

- A** butan-1-ol and 2,2-dimethylpropan-1-ol  
**B** butan-2-ol and 2-methylpropan-2-ol  
**C** pentan-1-ol and 2-methylpropan-2-ol  
**D** propan-2-ol and 2-methylpropan-2-ol

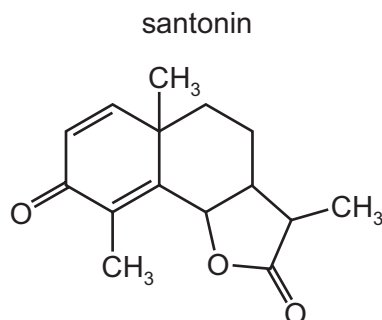
- 27 How many chiral carbon atoms are there in one molecule of 2,2,4,5-tetramethylhexan-3-ol?

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

- 28 Which pair of reagents react together in a redox reaction?

- A**  $\text{CH}_3\text{CHCH}_2 + \text{Br}_2$   
**B**  $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH} + \text{concentrated H}_3\text{PO}_4$   
**C**  $\text{CH}_3\text{COCH}_3 + \text{HCN}$   
**D**  $\text{HCO}_2\text{C}_2\text{H}_5 + \text{dilute H}_2\text{SO}_4$

29 The structure of santonin is shown.



Santonin is first treated with warm dilute  $\text{H}_2\text{SO}_4$ . The product of this reaction is treated with cold dilute acidified  $\text{KMnO}_4$ . A final product, Q, is obtained.

How many atoms of hydrogen in each molecule of product Q will react with sodium metal?

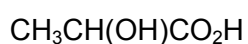
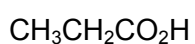
- A** 2                      **B** 4                      **C** 5                      **D** 6

30 Compound R can be formed from 1-bromopropane using a nucleophilic substitution reaction followed by an oxidation reaction.

What is the identity of R?

- A** propanoic acid  
**B** propanone  
**C** propylamine  
**D** propyl ethanoate

31 Three colourless liquids with the following formulae are contained in separate unlabelled bottles.

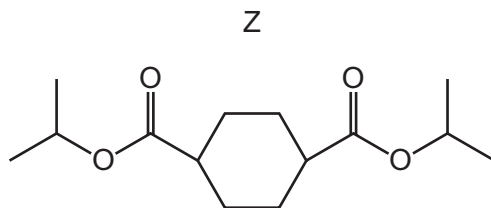


Which two tests, carried out on separate samples of each liquid, will successfully identify each liquid?

|          | test 1                    | test 2           |
|----------|---------------------------|------------------|
| <b>A</b> | $\text{NaHCO}_3$          | 2,4-DNPH reagent |
| <b>B</b> | $\text{NaHCO}_3$          | Tollens' reagent |
| <b>C</b> | warm acidified dichromate | 2,4-DNPH reagent |
| <b>D</b> | warm acidified dichromate | Tollens' reagent |

- 32 An alcohol, X, reacts with a dicarboxylic acid, Y, to form a double ester, Z.

The diagram shows the structure of the ester.



Which row about the reactants forming ester Z is correct?

|          | the class of alcohol X | the shape of the ring in Y |
|----------|------------------------|----------------------------|
| <b>A</b> | secondary              | non-planar                 |
| <b>B</b> | secondary              | planar                     |
| <b>C</b> | tertiary               | non-planar                 |
| <b>D</b> | tertiary               | planar                     |

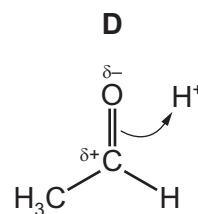
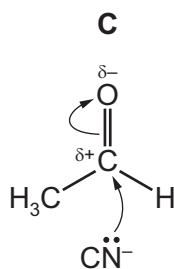
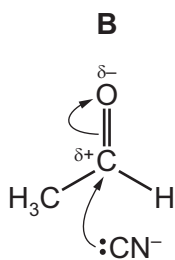
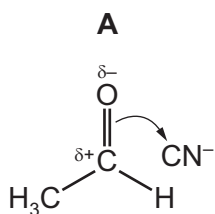
- 33 W reacts with alkaline  $I_2(aq)$  to form a yellow precipitate and  $CH_3CH_2CO_2^-$  ions.

Which row identifies W and the yellow precipitate?

|          | identity of W | identity of yellow precipitate |
|----------|---------------|--------------------------------|
| <b>A</b> | butanone      | $CHI_3$                        |
| <b>B</b> | butanone      | $CH_3I$                        |
| <b>C</b> | propanone     | $CHI_3$                        |
| <b>D</b> | propanone     | $CH_3I$                        |

- 34 Ethanal reacts with hydrogen cyanide in the presence of KCN to produce a hydroxynitrile.

What is the first step in the mechanism of this reaction?

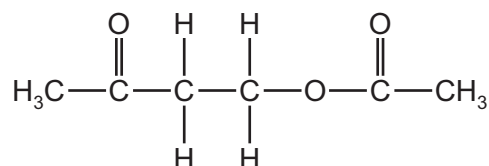


- 35 Structural isomerism and stereoisomerism should be considered when answering this question.

How many isomeric compounds with molecular formula  $C_5H_6O_4$  contain two  $-CO_2H$  groups and one  $C=C$  double bond?

- A 5                      B 6                      C 7                      D 8

- 36 Compound X reacts with ethanoic acid in the presence of an  $H^+$  catalyst to produce the compound shown.



What is the molecular formula of compound X?

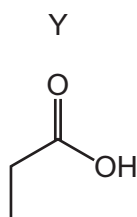
- A  $C_2H_4O$               B  $C_2H_6O_2$               C  $C_4H_8O$               D  $C_4H_8O_2$

- 37 2-bromopropane reacts with hot ethanolic sodium hydroxide.

Which substance is the major product of this reaction?

- A propan-1-ol  
B propan-2-ol  
C 2-hydroxypropene  
D propene

- 38 Which compounds can be used to make Y in a single-step reaction?

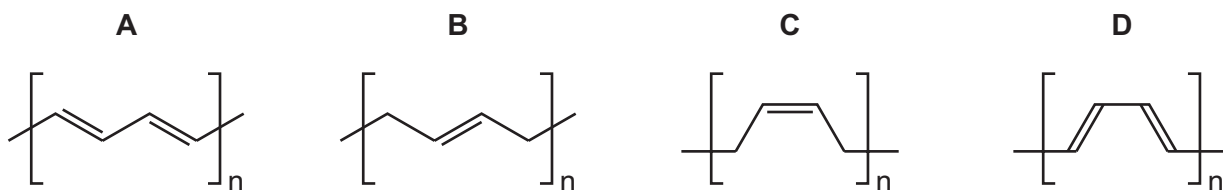


- 1 propanenitrile
- 2 ethanenitrile
- 3 propyl ethanoate
- 4 ethyl propanoate

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

- 39 The monomer buta-1,3-diene can undergo addition polymerisation in various ways. Two of the polymers that can be made are called *cis*-poly(buta-1,3-diene) and *trans*-poly(buta-1,3-diene). In these names *cis* and *trans* have their usual meanings.

What is the structure of the repeat unit of *cis*-poly(buta-1,3-diene)?



- 40 In the mass spectrum of a compound, Z, the relative abundances of the M and M+1 peaks are in the ratio 13 : 1.

What is compound Z?

- A** butyl butanoate
- B** hexan-3-one
- C** 2,2,3-trimethylhexane
- D** 3,3-dimethylpentan-1-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> )                                                    |

16

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