



# Cambridge International AS & A Level

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## CHEMISTRY

9701/13

Paper 1 Multiple Choice

October/November 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 **20** pages. Any blank pages are indicated.



- 1 In this question Q is used to represent a halogen atom.

Magnesium and calcium each form a compound with chlorine and a compound with bromine.

One of these compounds contains:

- the element in Group 2 with the higher first ionisation energy **and**
- the element in Group 17 with the higher Q–Q bond energy.

What is the formula of this compound?

- A**  $\text{MgCl}_2$       **B**  $\text{MgBr}_2$       **C**  $\text{CaCl}_2$       **D**  $\text{CaBr}_2$

- 2 Compound X contains two elements, Y and Z.

Element Y is in Period 2 of the Periodic Table. In one atom of element Y, the p sub-shell has all three orbitals occupied; only one of these three orbitals is fully occupied.

Element Z is in Period 3 of the Periodic Table. In one atom of element Z, the p sub-shell has only two orbitals occupied.

What is the formula of compound X?

- A**  $\text{CCl}_4$       **B**  $\text{SiCl}_4$       **C**  $\text{SiO}_2$       **D**  $\text{SO}_2$

- 3 Glauber's salt consists of crystals of hydrated sodium sulfate,  $\text{Na}_2\text{SO}_4 \cdot x\text{H}_2\text{O}$ , which can be used for the manufacture of detergents.

When a sample of Glauber's salt was heated, 1.91 g of water was removed leaving 1.51 g of anhydrous  $\text{Na}_2\text{SO}_4$ .

What is the value of x in  $\text{Na}_2\text{SO}_4 \cdot x\text{H}_2\text{O}$ ?

- A** 1      **B** 8.85      **C** 10      **D** 11.25

- 4 What contains the greatest number of the named particles?

- A**  $6.0 \text{ dm}^3$  of argon atoms at room conditions  
**B** 6.0 g of carbon dioxide molecules  
**C** 6.0 g of magnesium atoms  
**D** 6.0 g of water molecules

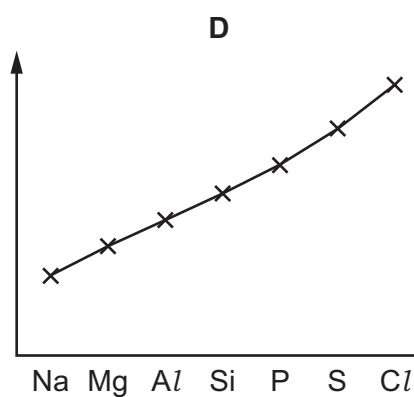
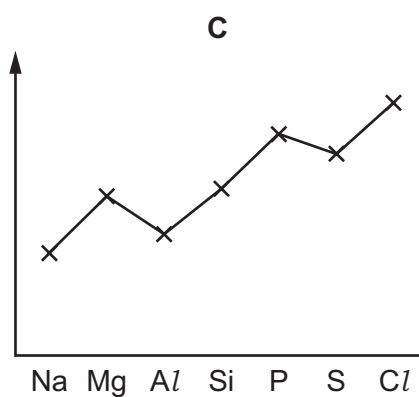
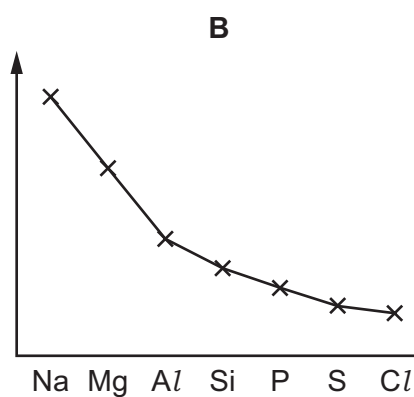
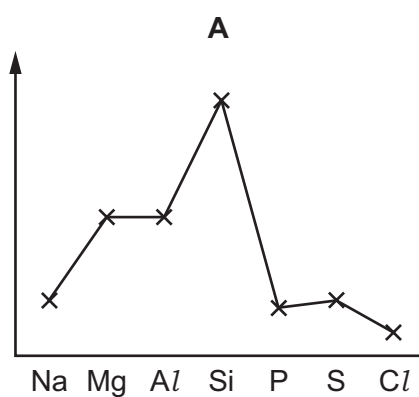
- 5 Phosphorus forms a compound with hydrogen called phosphine,  $\text{PH}_3$ . This compound can react with a hydrogen ion,  $\text{H}^+$ .

Which type of interaction occurs between  $\text{PH}_3$  and  $\text{H}^+$ ?

- A dative covalent bond
- B dipole–dipole forces
- C hydrogen bond
- D ionic bond

- 6 The graphs show trends in four physical properties of elements in Period 3, excluding argon.

Which graph has electronegativity on the  $y$ -axis?



- 7 The element tin exists in two forms, grey tin and white tin.

Some properties of grey tin and white tin are shown.

|                         | grey tin                | white tin                |
|-------------------------|-------------------------|--------------------------|
| boiling point/K         | 2543                    | 2533                     |
| electrical conductivity | none in solid or liquid | good in solid and liquid |
| malleability            | brittle                 | malleable                |

Which structural change might take place when grey tin changes to white tin?

- A** giant covalent to giant ionic  
**B** giant covalent to giant metallic  
**C** giant ionic to giant covalent  
**D** giant ionic to giant metallic
- 8 Which solid has a simple molecular lattice?
- A** calcium fluoride  
**B** nickel  
**C** silicon(IV) oxide  
**D** sulfur

- 9 The standard enthalpy change of combustion of carbon is  $-394 \text{ kJ mol}^{-1}$ .

The standard enthalpy change of combustion of hydrogen is  $-286 \text{ kJ mol}^{-1}$ .

The standard enthalpy change of formation of butane is  $-129 \text{ kJ mol}^{-1}$ .

What is the standard enthalpy change of combustion of butane?

- A**  $-551 \text{ kJ mol}^{-1}$   
**B**  $-2877 \text{ kJ mol}^{-1}$   
**C**  $-3135 \text{ kJ mol}^{-1}$   
**D**  $-4307 \text{ kJ mol}^{-1}$

10 Three processes are described.

- 1  $\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l})$
- 2  $\text{CH}_4(\text{g}) + 2\text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l})$
- 3  $\text{NH}_3(\text{g}) \rightarrow \text{NH}_3(\text{l})$

Which statement is correct?

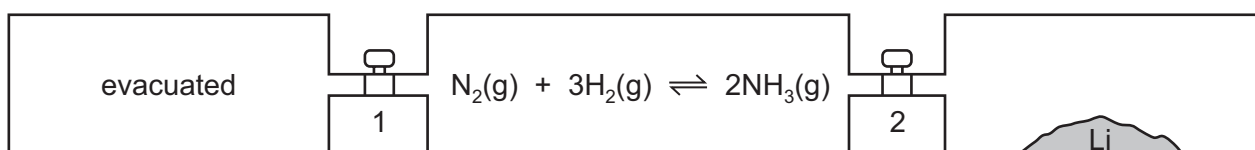
- A** None of the processes have a positive enthalpy change.
- B** Only process 1 has a positive enthalpy change.
- C** Only process 2 has a positive enthalpy change.
- D** Only process 3 has a positive enthalpy change.
- 11 In alkaline solution,  $\text{MnO}_4^-$  ions oxidise  $\text{SO}_3^{2-}$  ions to  $\text{SO}_4^{2-}$  ions. The  $\text{MnO}_4^-$  ions are reduced to  $\text{MnO}_2$ .

What is the ratio of the two ions in the balanced chemical equation for this reaction?

|          | $\text{MnO}_4^-$ | $\text{SO}_3^{2-}$ |
|----------|------------------|--------------------|
| <b>A</b> | 2                | 3                  |
| <b>B</b> | 3                | 2                  |
| <b>C</b> | 4                | 7                  |
| <b>D</b> | 7                | 4                  |

12 Lithium reacts with nitrogen at room temperature to form solid  $\text{Li}_3\text{N}$ .

Three vessels of equal volume are connected by taps 1 and 2 as shown.



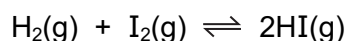
At the start, taps 1 and 2 are closed, the left-hand vessel is evacuated, the middle vessel has the indicated reaction at equilibrium and the right-hand vessel contains lithium only.

Which action would allow the equilibrium mixture to contain the **most** ammonia?

- A** Keep both taps 1 and 2 closed.
- B** Open both taps 1 and 2.
- C** Open tap 1 only.
- D** Open tap 2 only.

- 13 When 0.20 mol of hydrogen gas and 0.15 mol of iodine gas are heated at 723 K until equilibrium is established, the equilibrium mixture contains 0.26 mol of hydrogen iodide.

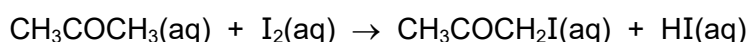
The equation for the reaction is as follows.



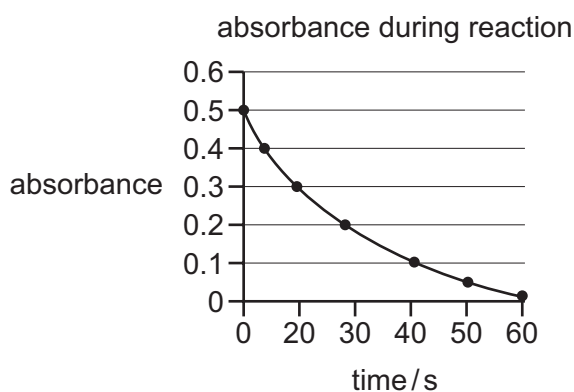
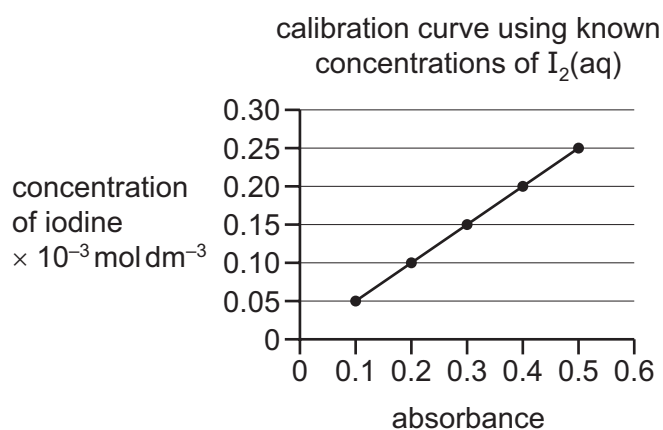
What is the correct expression for the equilibrium constant  $K_c$ ?

- A  $\frac{2 \times 0.26}{0.20 \times 0.15}$     B  $\frac{(2 \times 0.26)^2}{0.20 \times 0.15}$     C  $\frac{(0.26)^2}{0.07 \times 0.02}$     D  $\frac{(0.26)^2}{0.13 \times 0.13}$

- 14 In acidic conditions, iodine reacts with propanone in a substitution reaction.



The kinetics of the reaction are investigated using a colorimeter. As the  $\text{I}_2$  reacts, the yellow/brown colour of the  $\text{I}_2(\text{aq})$  fades to colourless, changing the absorbance of the solution. Known concentrations of  $\text{I}_2(\text{aq})$  are used to prepare a calibration curve graph and the absorbance is then measured as the reaction proceeds.

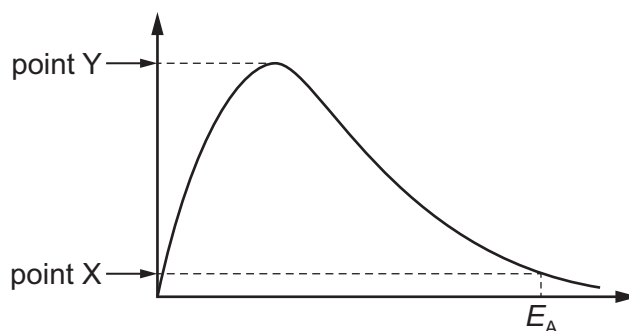


What is the rate of reaction at 20 s?

- A  $5 \times 10^{-6} \text{ mol dm}^{-3} \text{ s}^{-1}$   
 B  $1 \times 10^{-5} \text{ mol dm}^{-3} \text{ s}^{-1}$   
 C  $5 \times 10^{-3} \text{ mol dm}^{-3} \text{ s}^{-1}$   
 D  $1 \times 10^{-2} \text{ mol dm}^{-3} \text{ s}^{-1}$

15 The diagram shows a Boltzmann distribution curve.

The axes are not labelled.



Points X and Y are points on the vertical axis.

What is represented by both points X and Y?

|          | point X                                                        | point Y                                                  |
|----------|----------------------------------------------------------------|----------------------------------------------------------|
| <b>A</b> | number of molecules with energy equal to $E_A$                 | largest number of molecules with the same energy         |
| <b>B</b> | number of molecules with energy equal to or greater than $E_A$ | largest number of molecules with the same energy         |
| <b>C</b> | number of molecules with energy equal to $E_A$                 | the amount of energy of the greatest number of molecules |
| <b>D</b> | number of molecules with energy equal to or greater than $E_A$ | the amount of energy of the greatest number of molecules |

16 What are the acid–base nature and structure of  $\text{SO}_2$ ?

|          | acid–base nature | structure              |
|----------|------------------|------------------------|
| <b>A</b> | acidic           | giant covalent lattice |
| <b>B</b> | acidic           | simple molecular       |
| <b>C</b> | basic            | giant covalent lattice |
| <b>D</b> | basic            | simple molecular       |

- 17** Elements X and Y are in Period 3 of the Periodic Table. Element X is either phosphorus or sulfur. Element Y is either sodium or magnesium.

Element X forms an oxide that reacts with water to give a solution containing the aqueous anion  $\text{XO}_4^{2-}$ .

One mole of element Y reacts with one mole of chlorine molecules. At the end of the reaction, all of the element Y and all of the chlorine molecules have been used up.

What are elements X and Y?

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

- 18** Q is a semi-conductor. The chloride of Q reacts with water to form white fumes and an acidic solution.

Which Period 3 element is Q?

- A** magnesium  
**B** aluminium  
**C** silicon  
**D** phosphorus

- 19** V and W are two compounds. Each one contains a different Group 2 element.

A sample of each solid is added to water, shaken, and the pH of the resulting solution is measured.

| compound | V    | W   |
|----------|------|-----|
| pH       | 13.6 | 9.4 |

Which row could identify V and W?

|          | V                 | W                 |
|----------|-------------------|-------------------|
| <b>A</b> | $\text{BaSO}_4$   | $\text{MgSO}_4$   |
| <b>B</b> | $\text{MgSO}_4$   | $\text{BaSO}_4$   |
| <b>C</b> | $\text{Ba(OH)}_2$ | $\text{Mg(OH)}_2$ |
| <b>D</b> | $\text{Mg(OH)}_2$ | $\text{Ba(OH)}_2$ |

- 20 Compound L decomposes on heating. One of the products is gas M.

M reacts with unburned hydrocarbons to form peroxyacetyl nitrate, PAN.

What could be the formula of L?

- A**  $\text{CaNO}_3$       **B**  $\text{Ca}(\text{NO}_3)_2$       **C**  $\text{MgCO}_3$       **D**  $\text{Mg}(\text{CO}_3)_2$

- 21 In reaction 1, concentrated sulfuric acid is added to potassium chloride and the fumes produced are bubbled into aqueous potassium iodide solution.

In reaction 2, potassium chloride is dissolved in aqueous ammonia and this is then added to aqueous silver nitrate.

What are the observations for reactions 1 and 2?

|          | observation for reaction 1 | observation for reaction 2 |
|----------|----------------------------|----------------------------|
| <b>A</b> | brown solution             | colourless solution        |
| <b>B</b> | brown solution             | white precipitate          |
| <b>C</b> | colourless solution        | colourless solution        |
| <b>D</b> | colourless solution        | white precipitate          |

- 22 The table refers to the hydrogen halides.

Which row is correct?

|          | oxidation                                | thermal stability        |
|----------|------------------------------------------|--------------------------|
| <b>A</b> | easier to oxidise down the group         | increases down the group |
| <b>B</b> | more difficult to oxidise down the group | increases down the group |
| <b>C</b> | easier to oxidise down the group         | decreases down the group |
| <b>D</b> | more difficult to oxidise down the group | decreases down the group |

- 23 7.5 g of nitrogen monoxide reacts with 7.0 g of carbon monoxide on the surface of the catalytic converter in the exhaust system of a car.

What is the total volume of the product gases measured at room conditions?

- A**  $3.0 \text{ dm}^3$       **B**  $6.0 \text{ dm}^3$       **C**  $9.0 \text{ dm}^3$       **D**  $12.0 \text{ dm}^3$

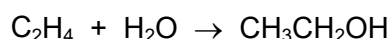
**24** Three statements about ammonia molecules and ammonium ions are given.

- 1 In aqueous solution, ammonia molecules form coordinate bonds with hydroxide ions.
- 2 Ammonium ions are Brønsted–Lowry acids.
- 3 The H–N–H bond angle is larger in the ammonium ion than in the ammonia molecule.

Which statements are correct?

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

**25** Ethene reacts with steam in the presence of sulfuric acid.



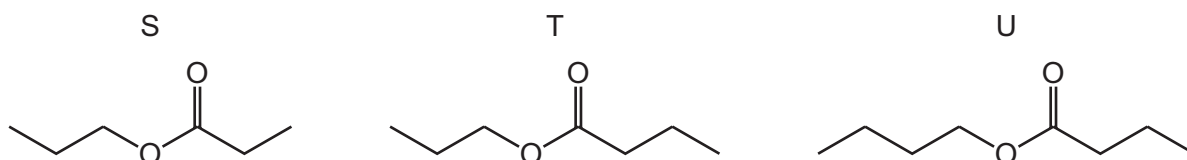
Which type of reaction is this?

- A** acid–base  
**B** addition  
**C** hydrolysis  
**D** substitution

**26** Compound Z has the molecular formula  $\text{C}_4\text{H}_8\text{O}_2$ .

Compound Z reacts with propan-1-ol in the presence of concentrated  $\text{H}_2\text{SO}_4$ .

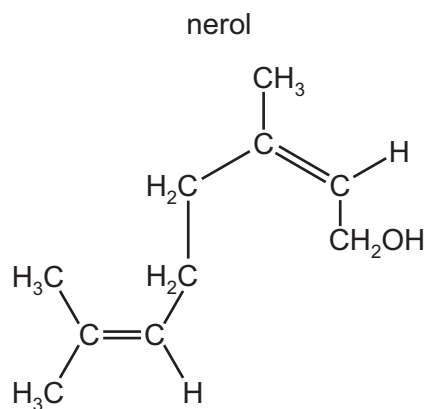
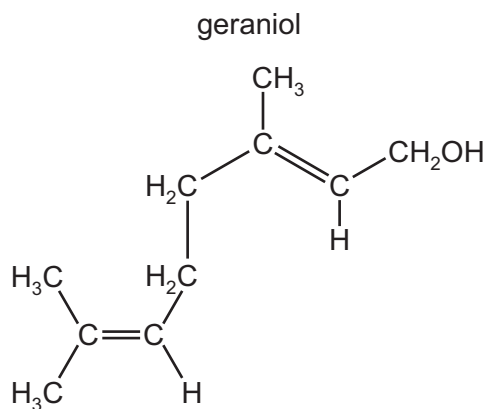
The diagram shows the skeletal formulae of three compounds, S, T and U.



What are the possible skeletal formulae of the products of the reaction between compound Z and propan-1-ol?

- A** S and T    **B** U only    **C** S and U    **D** T only

27 Geraniol and nerol are isomers of each other.



Which type of isomerism is shown here?

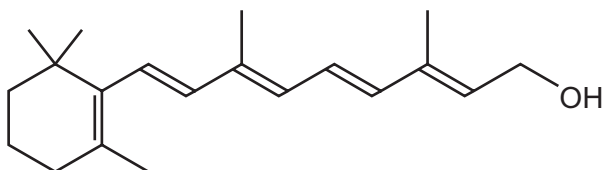
- A chain
- B geometrical (cis / trans)
- C optical
- D positional

28 Which compound has the greatest number of stereoisomers?

- A 2-methylhex-2-ene
- B 3-methylhex-2-ene
- C 4-methylhex-2-ene
- D 5-methylhex-2-ene

29 Vitamin A contains retinol.

retinol



Under appropriate conditions, acidified  $\text{KMnO}_4(\text{aq})$  can be used to break  $\text{C}=\text{C}$  bonds.

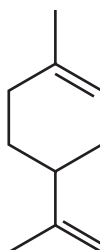
After these bonds have been broken, further oxidation of the fragments may occur.

Under which conditions is the acidified  $\text{KMnO}_4(\text{aq})$  used and what do the final oxidation products include?

|          | conditions        | final oxidation products       |
|----------|-------------------|--------------------------------|
| <b>A</b> | cold, dilute      | aldehydes and carboxylic acids |
| <b>B</b> | cold, dilute      | ketones and carboxylic acids   |
| <b>C</b> | hot, concentrated | aldehydes and carboxylic acids |
| <b>D</b> | hot, concentrated | ketones and carboxylic acids   |

30 The structure of limonene is shown.

limonene



What are the number of moles of carbon dioxide and water produced when a sample of limonene is completely combusted in oxygen?

|          | number of moles of carbon dioxide | number of moles of water |
|----------|-----------------------------------|--------------------------|
| <b>A</b> | 4                                 | 3                        |
| <b>B</b> | 5                                 | 4                        |
| <b>C</b> | 5                                 | 8                        |
| <b>D</b> | 9                                 | 7                        |

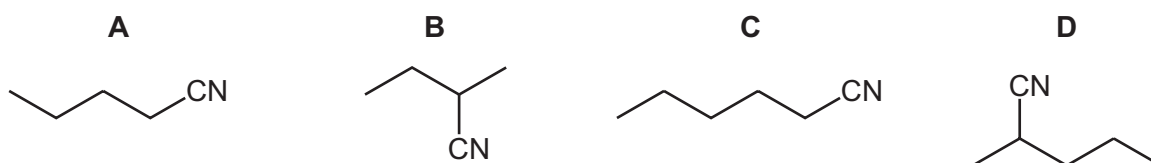
- 31 The reaction of chlorine with methane is carried out in the presence of light.

What is the function of the light?

- A to break the C–H bonds in methane
- B to break the chlorine molecules into atoms
- C to break the chlorine molecules into ions
- D to heat the mixture

- 32 When X is added to NaOH(aq) and heated under reflux, pentan-2-ol is made.

Which organic product is made when X is heated with a solution of KCN dissolved in ethanol?



- 33 1-chlorobutane and 1-iodobutane both react with aqueous sodium hydroxide by a nucleophilic substitution mechanism.

Which reaction has the greatest rate under the same conditions and which mechanism is followed by this reaction?

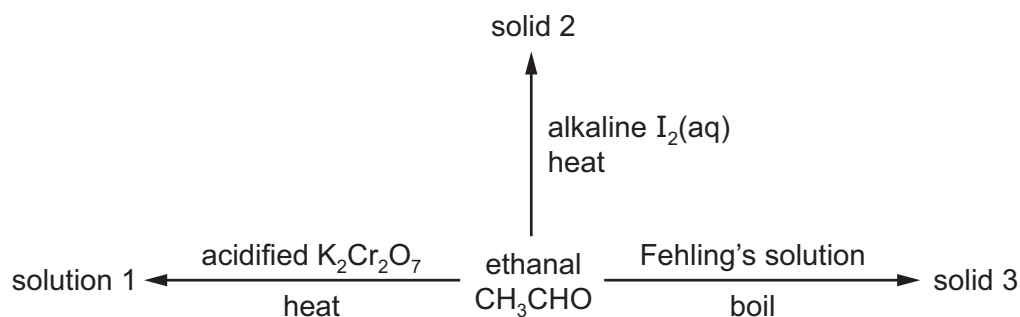
|          | greatest rate  | mechanism        |
|----------|----------------|------------------|
| <b>A</b> | 1-chlorobutane | S <sub>N</sub> 1 |
| <b>B</b> | 1-chlorobutane | S <sub>N</sub> 2 |
| <b>C</b> | 1-iodobutane   | S <sub>N</sub> 1 |
| <b>D</b> | 1-iodobutane   | S <sub>N</sub> 2 |

- 34 Compound Y reacts with alkaline I<sub>2</sub>(aq). When the products of this reaction are acidified, a dicarboxylic acid is produced. The formula of the dicarboxylic acid is HOOC–R–COOH where R consists of one or more CH<sub>2</sub> groups.

Which compound is Y?

- A pentan-1,4-diol
- B pentan-1,5-diol
- C pentan-2,3-diol
- D pentan-2,4-diol

- 35 Which alcohol gives only **one** possible oxidation product when warmed with dilute acidified potassium dichromate(VI)?
- A butan-1-ol  
 B butan-2-ol  
 C 2-methylpropan-1-ol  
 D 2-methylpropan-2-ol
- 36 Which compound, on reaction with hydrogen cyanide, produces a compound with a chiral centre?
- A  $\text{CH}_3\text{CHO}$   
 B  $\text{CH}_3\text{CH}_2\text{COCH}_2\text{CH}_3$   
 C  $\text{CH}_3\text{CO}_2\text{CH}_3$   
 D  $\text{HCHO}$
- 37 The diagram shows three reactions of ethanal. In each case, an excess of ethanal is used.

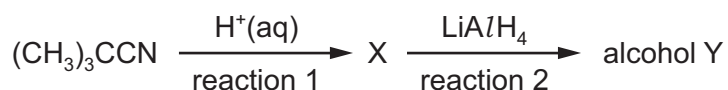


Observations are made after each of the three reactions.

What are the colours of solution 1 and solids 2 and 3?

|          | solution 1 | solid 2 | solid 3       |
|----------|------------|---------|---------------|
| <b>A</b> | green      | yellow  | silver mirror |
| <b>B</b> | green      | yellow  | red           |
| <b>C</b> | orange     | red     | silver mirror |
| <b>D</b> | orange     | red     | red           |

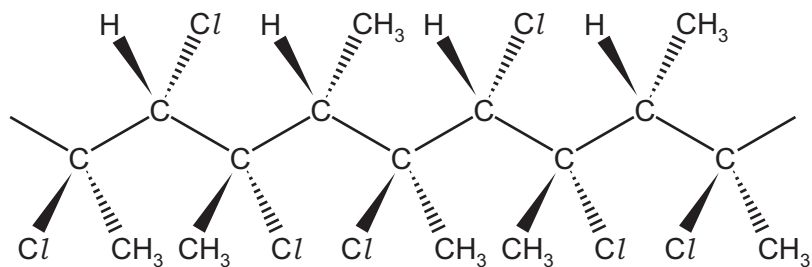
- 38  $(\text{CH}_3)_3\text{CCN}$  reacts to form alcohol Y via the reaction sequence shown.



Which row names the molecule X and the class of alcohol Y?

|          | name of molecule X        | class of alcohol Y |
|----------|---------------------------|--------------------|
| <b>A</b> | 2,2-dimethylbutanoic acid | primary            |
| <b>B</b> | 3,3-dimethylbutanoic acid | tertiary           |
| <b>C</b> | dimethylpropanoic acid    | primary            |
| <b>D</b> | dimethylpropanoic acid    | tertiary           |

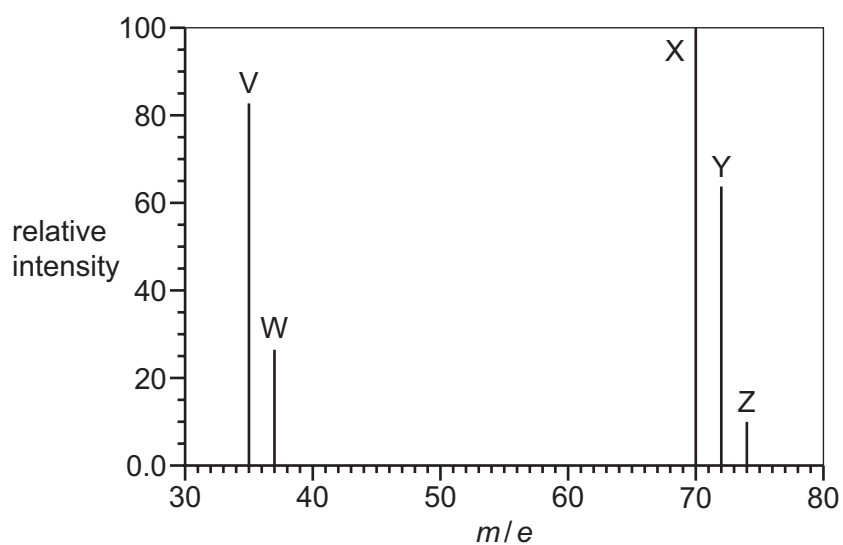
- 39 The diagram shows a section of an addition polymer. The polymer is made using two different monomers.



What are the names of the two monomers needed to make this polymer?

- A** 1,2-dichloropropene and 2-chlorobut-2-ene  
**B** 2,3-dichlorobut-2-ene and chloropropene  
**C** 1,2-dichloropropene and chloroethene  
**D** chloropropene and 2-chlorobut-2-ene

- 40 The diagram shows the mass spectrum of a sample of chlorine. Peaks V, W, X, Y and Z are labelled.



Which statements about this spectrum are correct?

- 1 The relative atomic mass of chlorine can be calculated from the abundances and  $m/e$  values of 2 of the 5 peaks.
- 2 37.0 g of the species responsible for peak Z contains  $3.011 \times 10^{23}$  molecules.
- 3 The relative molecular mass of chlorine can be calculated from the abundances and  $m/e$  values of peaks X, Y and Z.

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

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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> )                                                    |

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The Periodic Table of Elements

| Group                        |                               |                                                                |                               |                                 |                                |                               |                                |                              |                                |                                |                               |                               |                               |                               |                                |                               |                              |                               |                             |                               |                           |                              |                           |  |  |
|------------------------------|-------------------------------|----------------------------------------------------------------|-------------------------------|---------------------------------|--------------------------------|-------------------------------|--------------------------------|------------------------------|--------------------------------|--------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|--------------------------------|-------------------------------|------------------------------|-------------------------------|-----------------------------|-------------------------------|---------------------------|------------------------------|---------------------------|--|--|
| 1                            | 2                             | Key                                                            |                               |                                 |                                |                               |                                |                              |                                |                                |                               | 13                            | 14                            | 15                            | 16                             | 17                            | 18                           |                               |                             |                               |                           |                              |                           |  |  |
|                              |                               | atomic number<br>atomic symbol<br>name<br>relative atomic mass |                               |                                 |                                |                               |                                |                              |                                |                                |                               |                               |                               | 1<br>H<br>hydrogen<br>1.0     |                                |                               |                              |                               |                             |                               |                           |                              |                           |  |  |
| 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>oganesson<br>—   |                             |                               |                           |                              |                           |  |  |
|                              |                               |                                                                |                               |                                 |                                |                               |                                |                              |                                |                                |                               |                               |                               |                               |                                |                               |                              |                               |                             |                               |                           |                              |                           |  |  |
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