Cambridge Assessment International Education

# Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER | | | | | |

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*7969751444*

**CHEMISTRY** **9701/21**

Paper 2 AS Level Structured Questions **October/November 2021**

**1 hour 15 minutes**

You must answer on the question paper.

You will need: Data booklet

**INSTRUCTIONS**

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working, use appropriate units and use an appropriate number of significant figures.

**INFORMATION**

- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **16** pages. Any blank pages are indicated.


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Answer **all** the questions in the spaces provided.

**1** Sulfides are compounds that contain sulfur but not oxygen.

**(a)** Carbon disulfide, $CS_2$, is a volatile liquid at room temperature and pressure.

**(i)** State the meaning of *volatile*.

..... [1]

**(ii)** Draw a 'dot-and-cross' diagram of the $CS_2$ molecule.

[2]

**(iii)** Suggest the bond angle in a molecule of $CS_2$.

..... [1]

**(iv)** $CS_2$ is a liquid under room conditions, while $CO_2$ is a gas.

Explain what causes the difference in the physical properties between $CS_2$ and $CO_2$.

.....

.....

..... [2]

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**(b)** The enthalpy change of combustion of $CS_2(l)$ is represented by the following equation.

$$CS_2(l) + 3O_2(g) \xrightarrow{\Delta H_c} CO_2(g) + 2SO_2(g)$$

**(i)** Define *enthalpy change of combustion*.

.....

.....

..... [2]

**(ii)** The table shows the enthalpy changes of formation of $CS_2(l)$, $CO_2(g)$ and $SO_2(g)$.

| compound | enthalpy change of formation, $\Delta H_f$ / kJ mol$^{-1}$ |
|---|---|
| $CS_2(l)$ | +89.7 |
| $CO_2(g)$ | –394 |
| $SO_2(g)$ | –297 |

Use the data in the table to calculate the enthalpy change of combustion, $\Delta H_c$, of $CS_2(l)$, in kJ mol$^{-1}$.

Show your working.

$\Delta H_c$ of $CS_2(l)$ = ..... kJ mol$^{-1}$
[2]

**(c)** Hydrogen sulfide gas, $H_2S(g)$, is slightly soluble in water. It acts as a weak acid in aqueous solution.

**(i)** State the meaning of *weak acid*.

.....

..... [1]

**(ii)** Give the formula of the conjugate base of $H_2S$.

..... [1]

**(iii)** $H_2S(aq)$ reacts slowly with oxygen dissolved in water. The reaction is represented by the following equation.

$$H_2S(aq) + \tfrac{1}{2}O_2(aq) \rightarrow H_2O(l) + S(s)$$

Explain, with reference to oxidation numbers, why this reaction is a redox reaction.

.....

.....

.....

..... [2]

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**(d)** The compound $As_2S_3$ is a common mineral.

When $As_2S_3$ is heated strongly in air, it forms a mixture of products, as shown.

$$2As_2S_3(s) + 9O_2(g) \rightarrow As_4O_6(s) + 6SO_2(g)$$

**(i)** A sample containing 0.198 g $As_2S_3$ is placed in 0.100 $dm^3$ of pure oxygen, an excess, in a reaction chamber connected to a gas syringe at room temperature.

The reactants are heated until no further change is observed. The products are then allowed to cool to room temperature.

Calculate the volume, in $dm^3$, of gas present at the end of the experiment.

The molar volume of gas is 24.0 $dm^3\,mol^{-1}$ under these conditions. Assume that the pressure is constant throughout the experiment.

Show your working.

volume of gas remaining = ..... $dm^3$
[4]

**(ii)** State the environmental consequences of releasing $SO_2(g)$ into the atmosphere.

..... [1]

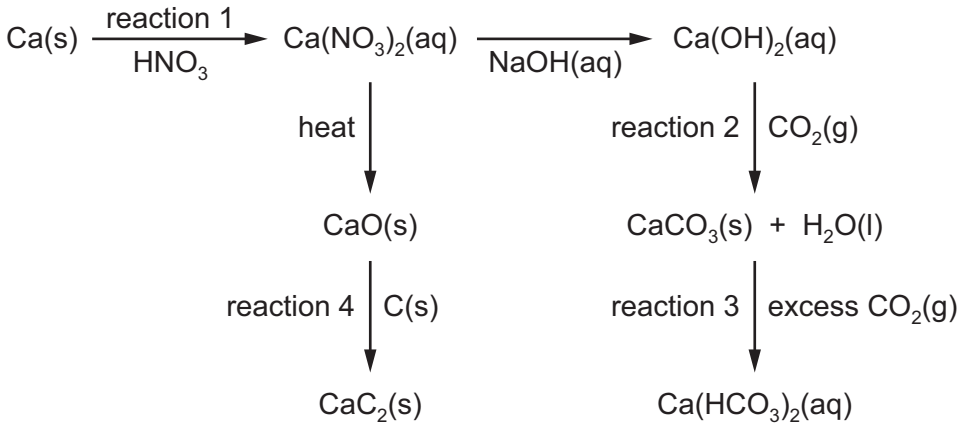
**(iii)** $SO_2(g)$ can be removed from the air by reacting it with NaOH(aq).

Construct an equation for the reaction of $SO_2(g)$ with NaOH(aq). Include state symbols.

..... [2]

[Total: 21]

**2** The reaction scheme shows some reactions of calcium.




**(a) (i)** Reaction 1 produces $Ca(NO_3)_2$ and one other product.

Identify the other product.

..... [1]

**(ii)** Construct an equation for the thermal decomposition of $Ca(NO_3)_2(s)$.

..... [1]

**(iii)** State the trend in the thermal stability of the Group 2 nitrates down the group.

..... [1]

**(iv)** In reaction 3, excess $CO_2$ is bubbled through water containing $CaCO_3$. A solution of $Ca(HCO_3)_2(aq)$ forms.

Construct an equation for reaction 3.

..... [1]

**(b)** Describe how $Ca(OH)_2$ is used in agriculture.

.....

..... [1]

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**(c)** In reaction 4, calcium carbide, $CaC_2$, is formed from CaO.

$CaC_2$ contains the $C_2^{2-}$ anion. Each carbon in $C_2^{2-}$ is sp hybridised.

**(i)** Describe how sp hybridised orbitals are formed.

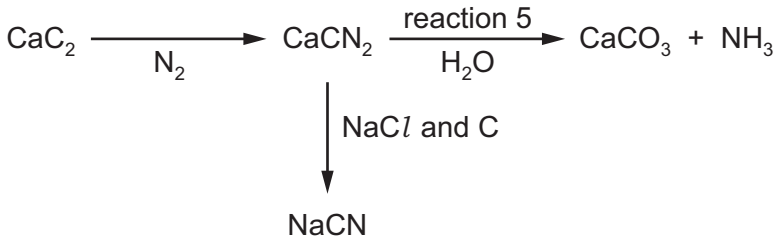
.....

..... [1]

**(ii)** Sketch a diagram to show how two sp hybrid orbitals can form a sigma ($\sigma$) bond.

[2]

**(d)** The flowchart shows some reactions of $CaC_2$.




**(i)** Reaction 5 can be used to prepare $NH_3$.

$$CaCN_2 + 3H_2O \rightarrow CaCO_3 + 2NH_3$$

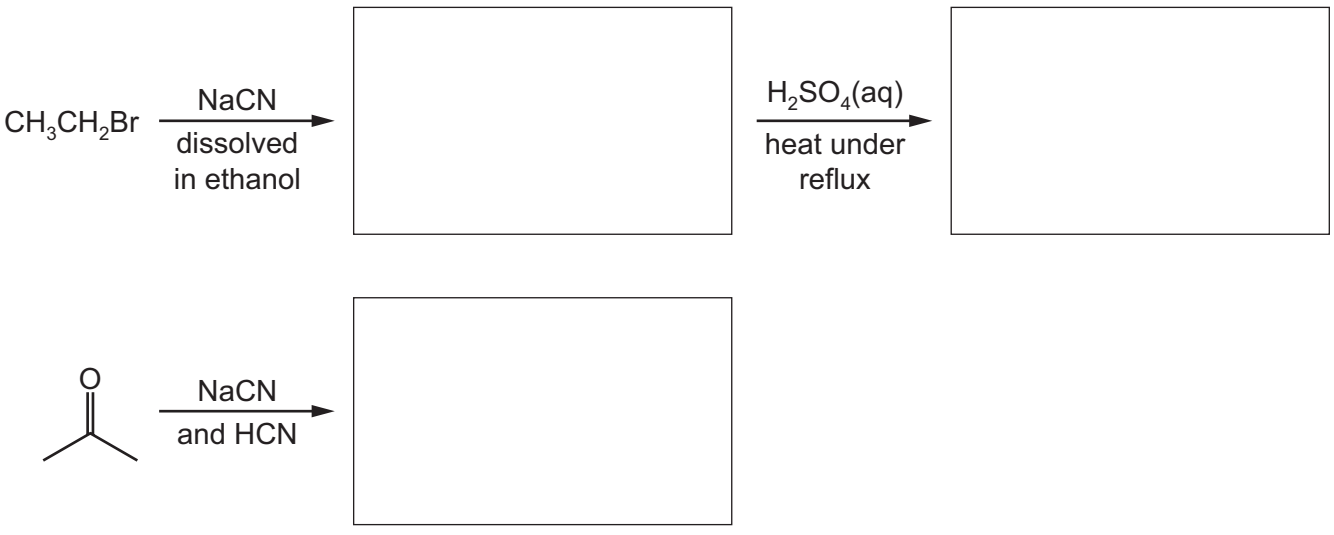
Calculate the minimum mass, in tonnes, of calcium cyanamide, $CaCN_2$, that is required to produce $1.50 \times 10^6$ tonnes of $NH_3$.

Show your working.

1 tonne = $1.00 \times 10^6$ g

minimum mass of $CaCN_2$ = ..... tonnes
[2]

**(ii)** Draw the structure of the organic products formed in the following reactions.




[3]

[Total: 13]

**3** Phosphorus is a reactive Period 3 element.

**(a)** Phosphorus has several allotropes. Details of two allotropes are given.

| allotrope of phosphorus | formula | melting point / °C |
|---|---|---|
| white | $P_4$ | 44 |
| red | P | 590 |

**(i)** White phosphorus and red phosphorus both have covalent bonding.

Suggest the types of structure shown by white phosphorus ($P_4$) and red phosphorus (P).

Explain why red phosphorus (P) has a higher melting point than white phosphorus ($P_4$).

structure of $P_4$ .....

structure of P .....

explanation .....

.....

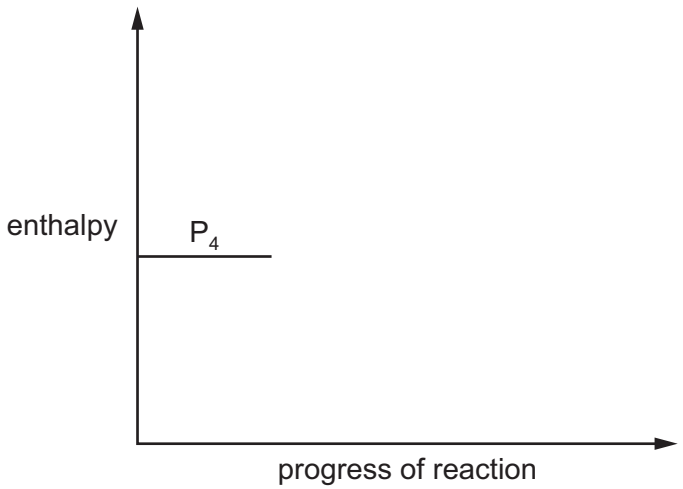
.....

[3]

**(ii)** Red phosphorus (P) forms when white phosphorus ($P_4$) is exposed to sunlight.

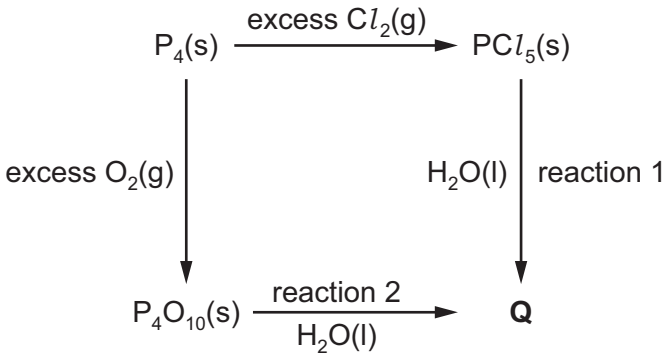
$$\underset{\text{white}}{\tfrac{1}{4}P_4(s)} \rightarrow \underset{\text{red}}{P(s)} \qquad \Delta H = -17.6\,\text{kJ mol}^{-1}$$

Use this information to draw a reaction pathway diagram to show the formation of red phosphorus (P) from white phosphorus ($P_4$).




[1]

**(b)** Some reactions of $P_4(s)$ are shown in the reaction scheme.




**(i)** State the oxidation number of phosphorus in $P_4O_{10}$.

..... [1]

**(ii)** Deduce the identity of **Q** and hence construct chemical equations for reactions 1 and 2.

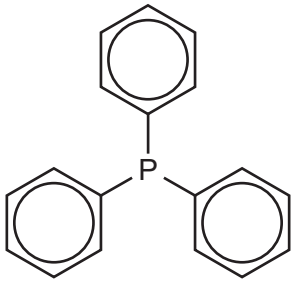
reaction 1 $PCl_5$ + .....$H_2O$ → .....

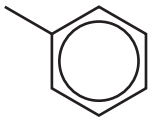
reaction 2 $P_4O_{10}$ + .....$H_2O$ → .....

[2]

**(c)** Triphenylphosphine is used in a type of reaction known as a *Wittig reaction*.

triphenylphosphine



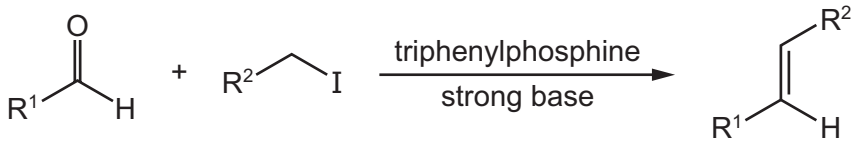

where  = $-C_6H_5$

**(i)** Give the empirical formula of triphenylphosphine.

..... [1]

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In a Wittig reaction, an aldehyde reacts with a halogenoalkane to form an alkene. The conversion is shown in the following unbalanced equation.




Compound **H** can be made from propanal, $C_2H_5CHO$. Stage 3 in the reaction scheme is a Wittig reaction.

stage 1 $C_2H_5CHO \xrightarrow{NaBH_4}$ **G**

stage 2 **G** $\xrightarrow{\text{red phosphorus and } I_2}$ $C_2H_5CH_2I$

stage 3 (Wittig reaction) $C_2H_5CH_2I + C_2H_5CHO \xrightarrow[\text{strong base}]{\text{triphenylphosphine}}$ **H**

**(ii)** State the types of reaction that occur in stages 1 and 2.

stage 1 .....

stage 2 .....

[2]

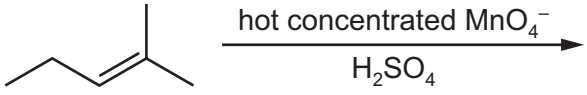
**(iii)** Draw the structures of **G** and **H** in the boxes provided.

| **G** | **H** |
|---|---|
| | |

[2]

**(d)** Identify the organic products formed when compound **J**, shown below, is heated with hot concentrated acidified manganate(VII) ions.

**J**

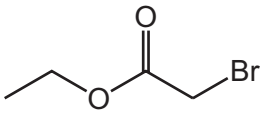



[2]

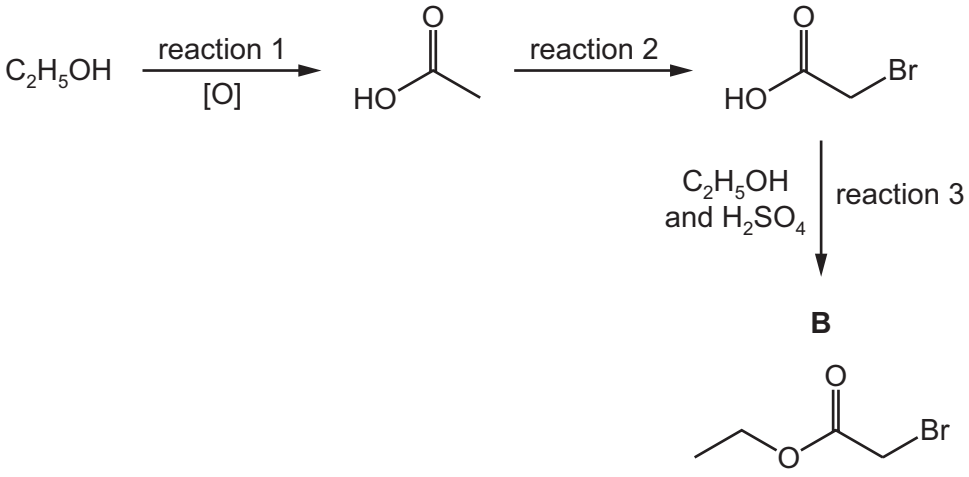
[Total: 14]

**4** Compound **B** is a liquid with a fruity smell.

**B**




The reaction scheme shows how **B** can be made from ethanol, $C_2H_5OH$.




**(a) (i)** Reaction 1 is an oxidation reaction.

Give the reagent(s) and conditions required for reaction 1.

reagent(s) .....

conditions .....

.....

[2]

**(ii)** Construct an equation to represent reaction 1.

Use [O] to represent an oxygen atom from the oxidising agent in this reaction.

..... [1]

**(iii)** Suggest the type of reaction that occurs in reaction 2.

..... [1]

**(iv)** $H_2SO_4$ acts as a homogeneous catalyst in reaction 3.

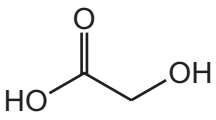
Explain why $H_2SO_4$ is described as *homogeneous*.

.....

..... [1]

**(b)** Reaction 2 needs to take place in the absence of water to prevent formation of compound **C**.

**C**




If **C** is present in the reaction mixture of reaction 3, a different compound, compound **D**, will also form. Compound **D** has two identical functional groups.

The infrared spectrum of **D** shows strong absorptions at 1100 $cm^{-1}$ and 1720 $cm^{-1}$, but no absorption due to O–H bonds.

Use the *Data Booklet* to identify the functional group present in **D**.

Explain your answer as fully as you can.

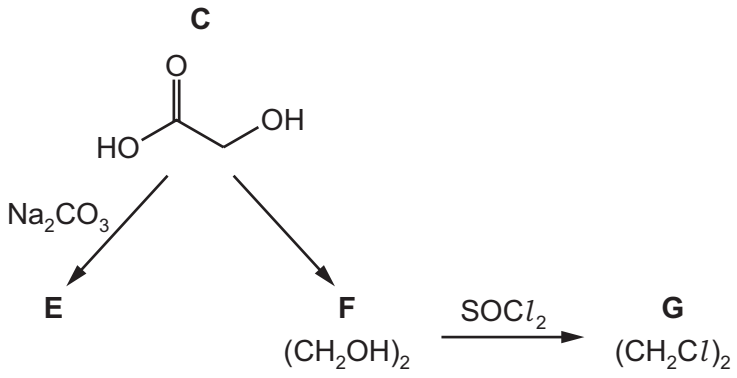
.....

.....

.....

..... [3]

**(c)** Some other reactions of **C** are shown.




**(i)** Draw the structure of **E**.

[1]

**(ii)** Suggest why $NaBH_4$ is not a suitable reagent to make **F**, $(CH_2OH)_2$, from **C**.
Explain your answer.

.....

..... [1]

**(iii)** Construct an equation for the reaction of $(CH_2OH)_2$ with $SOCl_2$ to form **G**, $(CH_2Cl)_2$.

..... [1]

**(d)** Explain why **C** is very soluble in water.

.....

.....

..... [1]

[Total: 12]

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