Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER | | | | | |

CANDIDATE NUMBER | | | | |

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.

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]

(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, ΔH_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, ΔH_c, of $CS_2(l)$, in kJ mol^{-1}.

Show your working.

ΔH_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]

(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]

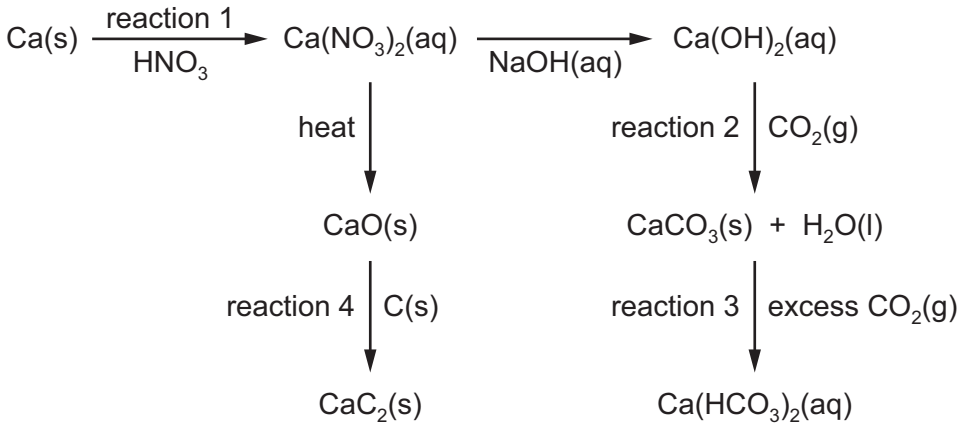
(iii) $SO_2(g)$ can be removed from the air by reacting it with NaOH(aq).

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]

(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.

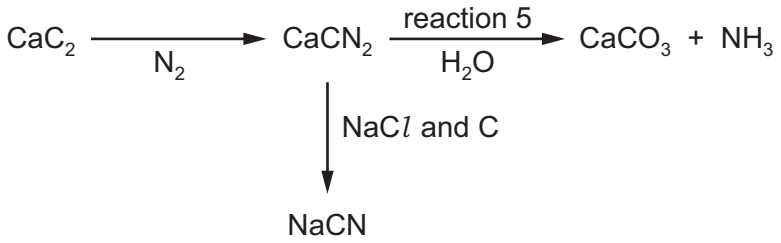
.....

..... [1]

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

[2]

(d) The flowchart shows some reactions of CaC_2.



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

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

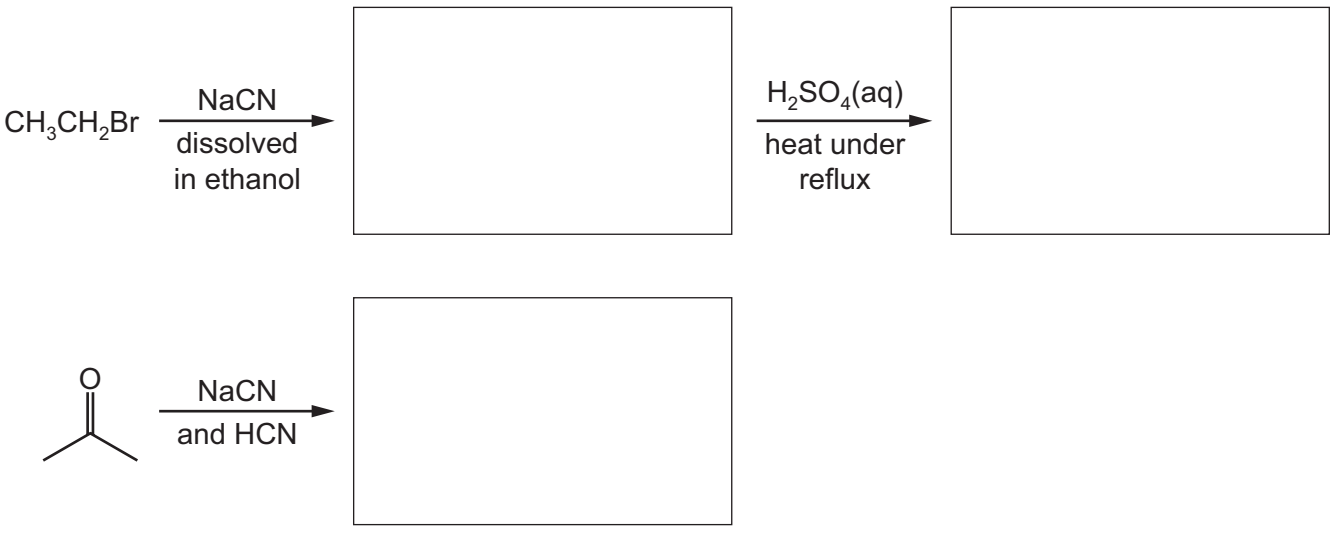
Calculate the minimum mass, in tonnes, of calcium cyanamide, $CaCN_2$, that is required to produce 1.50×10^6 tonnes of NH_3.

Show your working.

1 tonne = 1.00×10^6 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 .....

.....

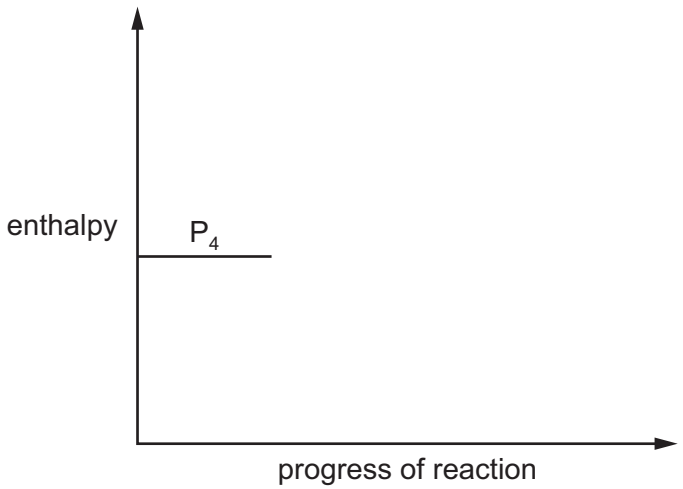
.....

[3]

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

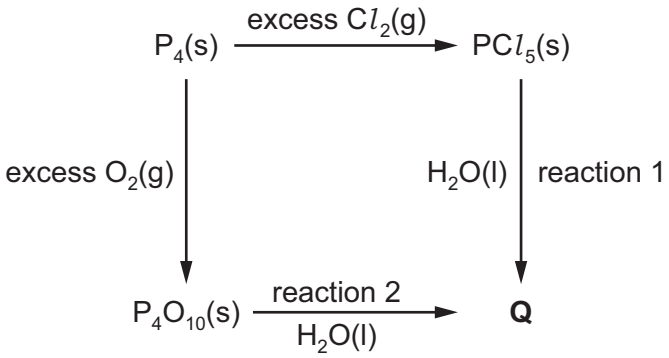
$$\underset{\text{white}}{\tfrac{1}{4}P_4(s)} \rightarrow \underset{\text{red}}{P(s)} \qquad \Delta H = -17.6\,\text{kJ mol}^{-1}$$

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.

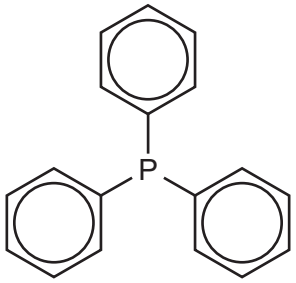
reaction 1 PCl_5 + ...H_2O → .....

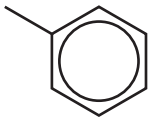
reaction 2 P_4O_{10} + ...H_2O → .....

[2]

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

triphenylphosphine

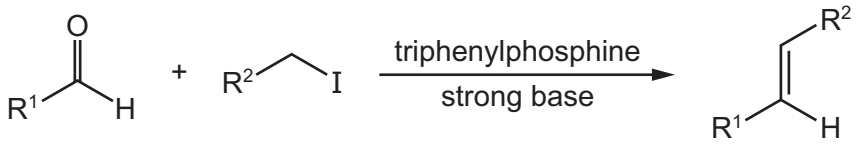


where  = $-C_6H_5$

(i) Give the empirical formula of triphenylphosphine.

..... [1]

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]

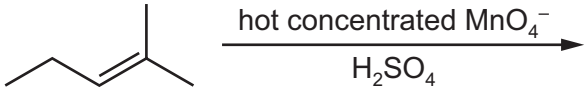
(iii) Draw the structures of **G** and **H** in the boxes provided.

G	**H**

[2]

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

J

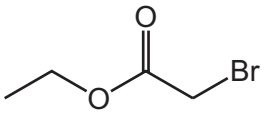


[2]

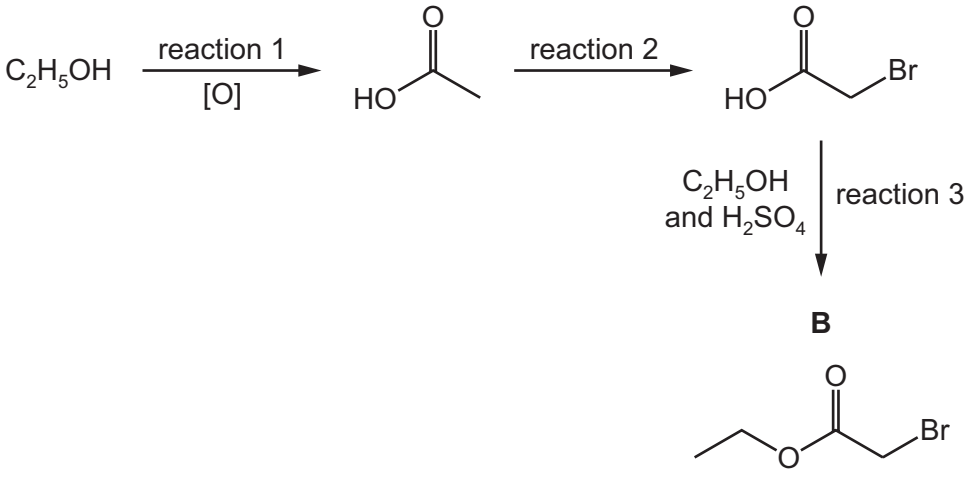
[Total: 14]

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.

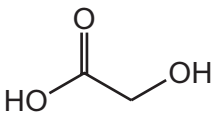
Explain why H_2SO_4 is described as *homogeneous*.

.....

..... [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.

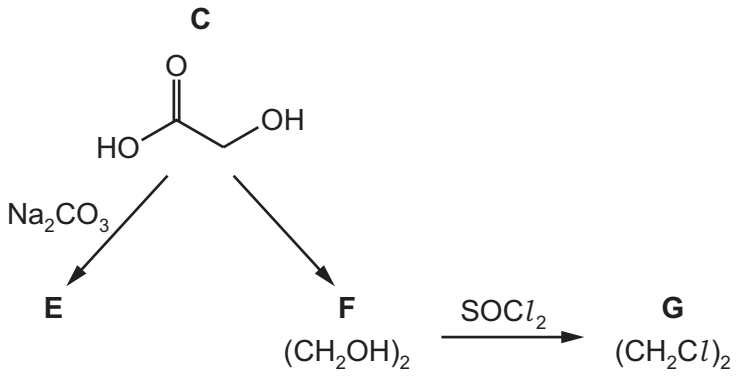
.....

.....

.....

..... [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]

BLANK PAGE

BLANK PAGE