



CANDIDATE
NAME

--

CENTRE
NUMBER

--	--	--	--	--

CANDIDATE
NUMBER

--	--	--	--

9701/23

October/November 2021

1 hour 15 minutes

You must answer on the question paper.

You will need: Data booklet

- 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.

- 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 .

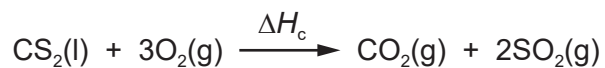
..... [1]

(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 $\text{CS}_2(\text{l})$ is represented by the following equation.



(i) Define *enthalpy change of combustion*.

.....

 [2]

(ii) The table shows the enthalpy changes of formation of $\text{CS}_2(\text{l})$, $\text{CO}_2(\text{g})$ and $\text{SO}_2(\text{g})$.

compound	enthalpy change of formation, $\Delta H_f / \text{kJ mol}^{-1}$
$\text{CS}_2(\text{l})$	+89.7
$\text{CO}_2(\text{g})$	-394
$\text{SO}_2(\text{g})$	-297

Use the data in the table to calculate the enthalpy change of combustion, ΔH_c , of $\text{CS}_2(\text{l})$, in kJ mol^{-1} .

Show your working.

ΔH_c of $\text{CS}_2(\text{l})$ = kJ mol^{-1}
 [2]

(c) Hydrogen sulfide gas, $\text{H}_2\text{S}(\text{g})$, is slightly soluble in water. It acts as a weak acid in aqueous solution.

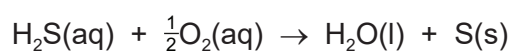
(i) State the meaning of *weak acid*.

.....
..... [1]

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

..... [1]

(iii) $\text{H}_2\text{S}(\text{aq})$ reacts slowly with oxygen dissolved in water. The reaction is represented by the following equation.

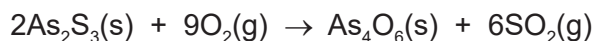


Explain, with reference to oxidation numbers, why this reaction is a redox reaction.

.....
.....
.....
..... [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.



- (i) A sample containing 0.198 g As_2S_3 is placed in 0.100 dm³ 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 dm³, of gas present at the end of the experiment.

The molar volume of gas is 24.0 dm³ mol⁻¹ under these conditions. Assume that the pressure is constant throughout the experiment.

Show your working.

volume of gas remaining = dm³
[4]

- (ii) State the environmental consequences of releasing $\text{SO}_2(\text{g})$ into the atmosphere.

..... [1]

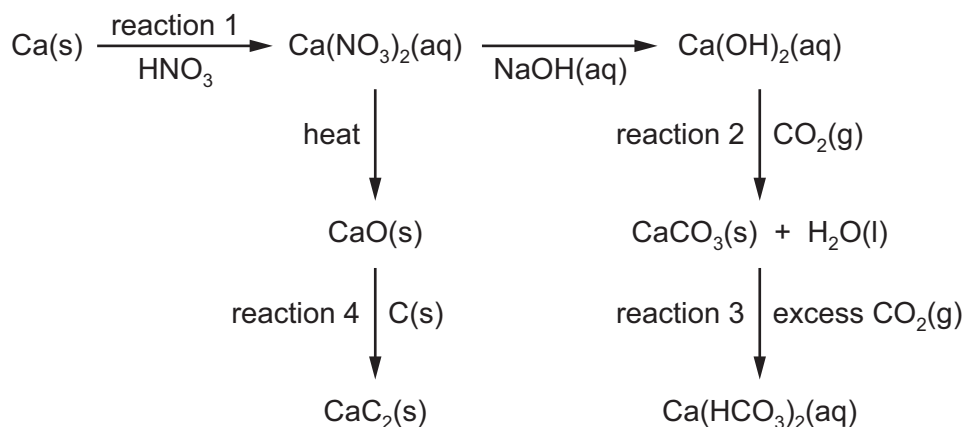
- (iii) $\text{SO}_2(\text{g})$ can be removed from the air by reacting it with $\text{NaOH}(\text{aq})$.

Construct an equation for the reaction of $\text{SO}_2(\text{g})$ with $\text{NaOH}(\text{aq})$. Include state symbols.

..... [2]

[Total: 21]

2 The reaction scheme shows some reactions of calcium.



(a) (i) Reaction 1 produces $\text{Ca(NO}_3)_2$ and one other product.

Identify the other product.

..... [1]

(ii) Construct an equation for the thermal decomposition of $\text{Ca(NO}_3)_2\text{(s)}$.

..... [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 $\text{Ca(HCO}_3)_2\text{(aq)}$ 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.

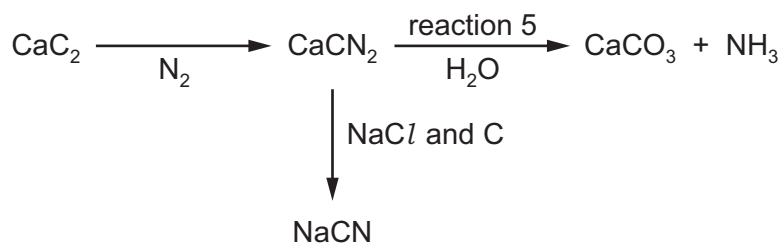
(i) Describe how sp hybridised orbitals are formed.

.....
..... [1]

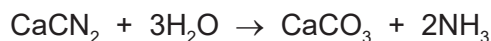
(ii) Sketch a diagram to show how two sp hybrid orbitals can form a sigma (σ) bond.

[2]

(d) The flowchart shows some reactions of CaC_2 .



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



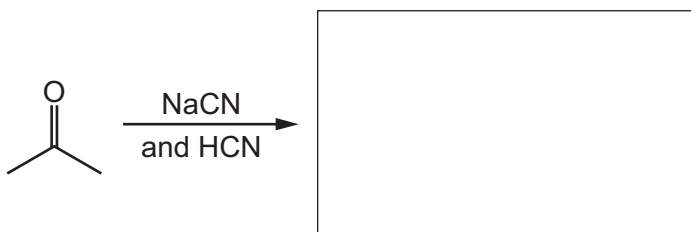
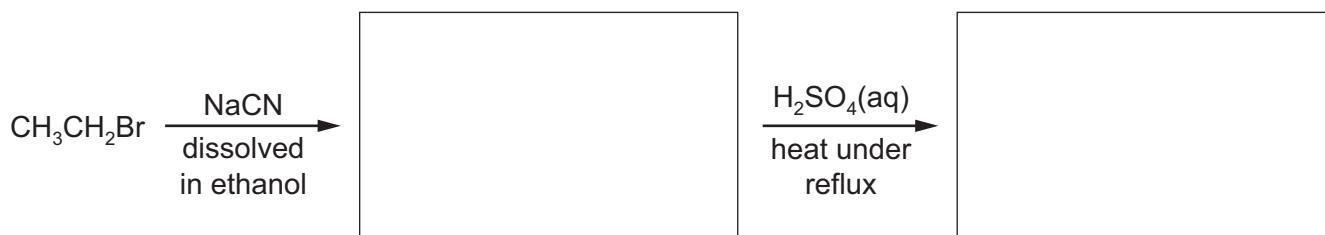
Calculate the minimum mass, in tonnes, of calcium cyanamide, CaCN_2 , that is required to produce 1.50×10^6 tonnes of NH_3 .

Show your working.

$$1 \text{ tonne} = 1.00 \times 10^6 \text{ g}$$

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 (P₄) and red phosphorus (P).

Explain why red phosphorus (P) has a higher melting point than white phosphorus (P₄).

structure of P₄

structure of P

explanation

.....

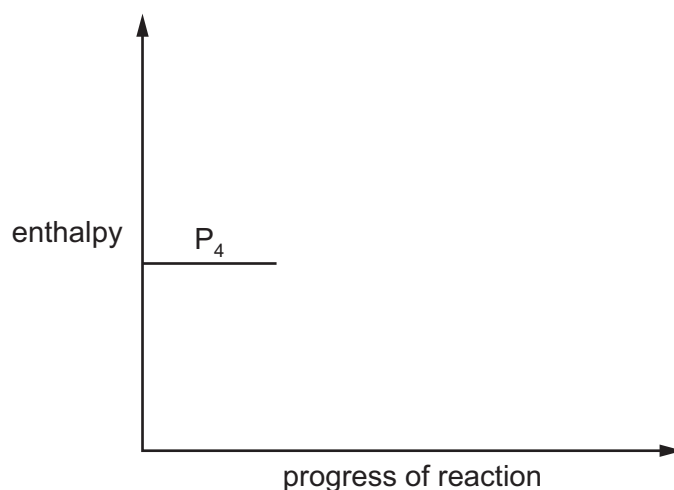
.....

[3]

(ii) Red phosphorus (P) forms when white phosphorus (P₄) is exposed to sunlight.

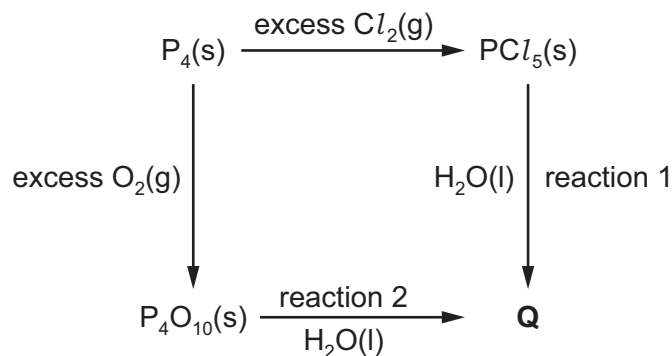


Use this information to draw a reaction pathway diagram to show the formation of red phosphorus (P) from white phosphorus (P₄).



[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.

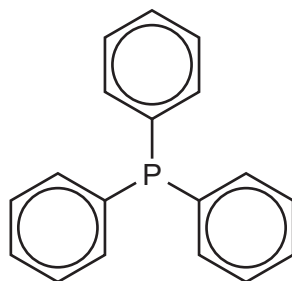
reaction 1 $PCl_5 + \dots H_2O \rightarrow \dots$

reaction 2 $P_4O_{10} + \dots H_2O \rightarrow \dots$

[2]

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

triphenylphosphine

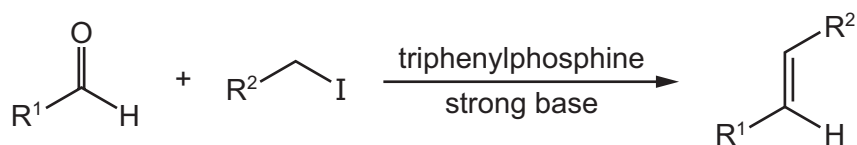


where = $-C_6H_5$

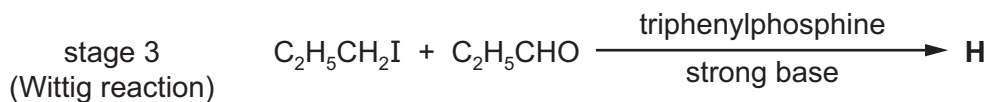
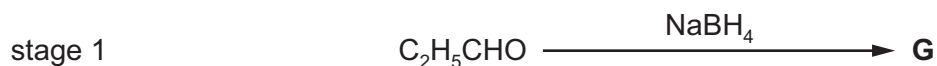
(i) Give the empirical formula of triphenylphosphine.

..... [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, $\text{C}_2\text{H}_5\text{CHO}$. Stage 3 in the reaction scheme is a Wittig reaction.



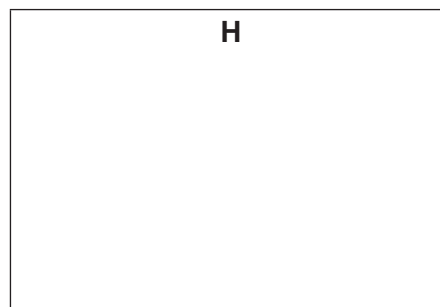
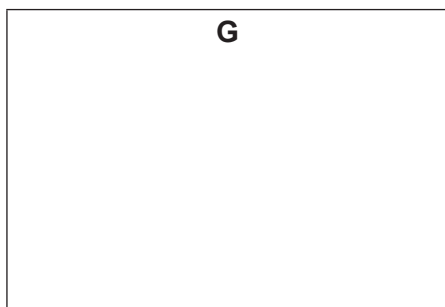
(ii) State the types of reaction that occur in stages 1 and 2.

stage 1

stage 2

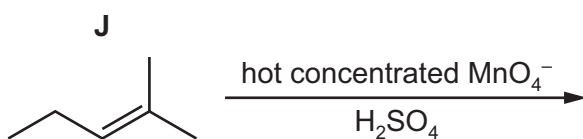
[2]

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



[2]

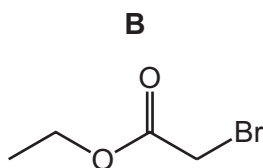
(d) Identify the organic products formed when compound **J**, shown below, is heated with hot concentrated acidified manganate(VII) ions.



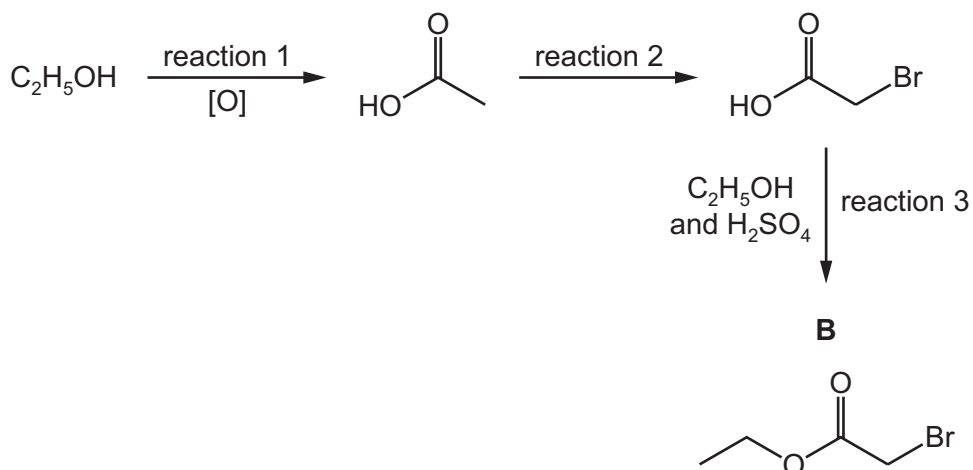
[2]

[Total: 14]

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



The reaction scheme shows how **B** can be made from ethanol, $\text{C}_2\text{H}_5\text{OH}$.



- (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]

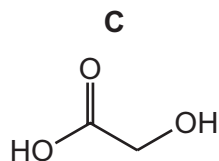
- (iv) H_2SO_4 acts as a homogeneous catalyst in reaction 3.

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**.



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.

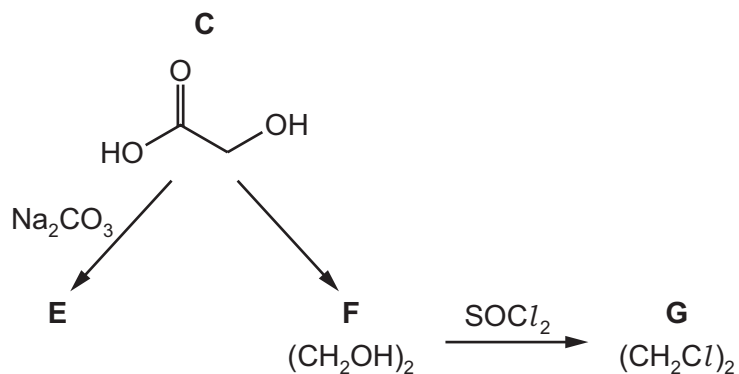
.....

.....

.....

..... [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**, $(\text{CH}_2\text{OH})_2$, from **C**. Explain your answer.

.....

..... [1]

(iii) Construct an equation for the reaction of $(\text{CH}_2\text{OH})_2$ with SOCl_2 to form **G**, $(\text{CH}_2\text{Cl})_2$.

..... [1]

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

.....

.....

..... [1]

[Total: 12]

BLANK PAGE

Permission to reproduce items where third-party owned material protected by copyright is included has been sought and cleared where possible. Every reasonable effort has been made by the publisher (UCLES) to trace copyright holders, but if any items requiring clearance have unwittingly been included, the publisher will be pleased to make amends at the earliest possible opportunity.

To avoid the issue of disclosure of answer-related information to candidates, all copyright acknowledgements are reproduced online in the Cambridge Assessment International Education Copyright Acknowledgements Booklet. This is produced for each series of examinations and is freely available to download at www.cambridgeinternational.org after the live examination series.

Cambridge Assessment International Education is part of the Cambridge Assessment Group. Cambridge Assessment is the brand name of the University of Cambridge Local Examinations Syndicate (UCLES), which itself is a department of the University of Cambridge.