

CANDIDATE
NAME

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CENTRE
NUMBER

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CANDIDATE
NUMBER

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CHEMISTRY

9701/21

Paper 2 AS Level Structured Questions

October/November 2018

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.

Write in dark blue or black pen.

You may use an HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.

You may lose marks if you do not show your working or if you do not use appropriate units.

A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [] at the end of each question or part question.

This document consists of **12** printed pages.



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

- 1 Iron pyrite, FeS_2 , has a yellow colour that makes it look like gold metal. The compound contains the ions Fe^{2+} and S_2^{2-} .

(a) (i) Give the full electronic configuration of Fe^{2+} .

1s² [1]

(ii) Calculate the oxidation number of sulfur in the S_2^{2-} ion.
Assume that each sulfur atom in the ion has the same oxidation number.

oxidation number of sulfur in the S_2^{2-} ion = ... [1]

(b) Describe the metallic bonding in gold.

.....

 [2]

(c) Iron pyrite is often called *fool's gold* because of its appearance. Impure samples of iron pyrite often contain a small amount of gold.

The gold can be obtained from impure iron pyrite. The impure iron pyrite is roasted in oxygen, to produce iron(III) oxide and sulfur dioxide. Gold does not react with oxygen.

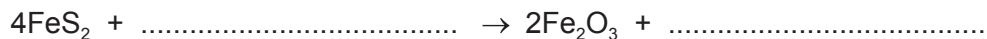
(i) The sulfur dioxide produced during roasting would cause environmental consequences if released into the atmosphere.

State and explain **one** of these environmental consequences.

.....

 [2]

- (ii) Complete the equation to show the roasting of iron pyrite in oxygen.



[2]

- (iii) A sample of impure iron pyrite was roasted in oxygen. The composition of the mixture of solid products is shown.

solid product	mass/g
Fe_2O_3	33.18
Au	0.37

Calculate the mass of FeS_2 present in the sample of impure iron pyrite.
Assume that all the FeS_2 was converted to Fe_2O_3 during the roasting process.

(M_r : FeS_2 , 120.0; Fe_2O_3 , 159.6)

mass of FeS_2 = ... g [2]

- (iv) Use your answer to (iii) to calculate the percentage by mass of gold in this sample of impure iron pyrite. Assume that gold is the only impurity in this sample of impure iron pyrite.

Give your answer to **two** significant figures.

(If you were unable to calculate an answer to (iii), use 55.00 g as the mass of FeS_2 in this calculation. This is **not** the correct answer.)

percentage by mass of gold = ... % [1]

[Total: 11]

2 (a) Nitrogen, N_2 , is an inert gas that makes up 78% of the Earth's atmosphere.

(i) Explain why nitrogen is inert.

.....
.....
..... [2]

(ii) Draw a 'dot-and-cross' diagram of a nitrogen molecule. Show outer electrons only.

[1]

(b) Nitrogen, N_2 , and oxygen, O_2 , react together in the air during lightning strikes to form nitrogen monoxide, NO.

(i) Explain why the reaction of N_2 and O_2 occurs during lightning strikes.

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

(ii) Write two equations to suggest how the NO formed reacts further to create nitric acid, HNO_3 .

1
2 [2]

- (c) Nitrate fertilisers are used to provide nitrogen for plant growth. Uncontrolled use of these can cause a reduction in animal and plant life in natural water supplies.

Explain how uncontrolled use of nitrate fertilisers can cause this problem.

.....

.....

.....

..... [3]

- (d) Some soils have compounds such as ammonium nitrate, calcium carbonate and calcium hydroxide added to them.

- (i) Suggest why calcium hydroxide is added to some soils.

..... [1]

- (ii) When calcium hydroxide reacts with compounds containing the ammonium ion, NH_4^+ , a gas is produced.

State the identity of this gas and explain why the reaction occurs.

gas

explanation

.....

.....

[2]

- (iii) Another fertiliser, calcium ammonium nitrate, is formed when solid calcium carbonate is added to a mixture of aqueous ammonium nitrate and dilute nitric acid.

Suggest what would be **observed** in this reaction.

.....

.....

..... [2]

- (iv) Calcium nitrate decomposes at a higher temperature than calcium ammonium nitrate.

Write an equation for the thermal decomposition of calcium nitrate.

..... [1]

[Total: 15]

- 3 Trihalomethanes are organic molecules in which three of the hydrogen atoms of methane are replaced by halogen atoms, for example CHCl_3 .

(a) CHCl_3 is a colourless liquid with a high vapour pressure.

(i) Explain what is meant by *high vapour pressure*.

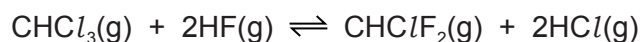
.....

.....

.....

..... [2]

(ii) An important reaction of $\text{CHCl}_3(\text{g})$ is the manufacture of $\text{CHClF}_2(\text{g})$, using the following reversible reaction.



Use the data to calculate the enthalpy change of reaction, ΔH_r , for the formation of $\text{CHClF}_2(\text{g})$ as shown in the equation.

compound	enthalpy change of formation, $\Delta H_f^\circ / \text{kJ mol}^{-1}$
$\text{CHCl}_3(\text{g})$	-103.2
$\text{CHClF}_2(\text{g})$	-482.2
$\text{HF}(\text{g})$	-273.3
$\text{HCl}(\text{g})$	-92.3

enthalpy change of reaction, $\Delta H_r = \dots\dots\dots \text{kJ mol}^{-1}$ [3]

- (iii) The reaction in (ii) is carried out using a heterogeneous catalyst.

Explain fully the meaning of the terms *heterogeneous* and *catalyst*.

heterogeneous

.....

.....

catalyst

.....

.....

.....

[3]

- (b) CHClF_2 was used as an alternative to chlorofluorocarbons (CFCs). CHClF_2 should no longer be used because it was found to contribute to the *enhanced greenhouse effect*.

- (i) Give the meaning of the term *enhanced greenhouse effect*.

.....

..... [1]

- (ii) Explain how $\text{CHClF}_2(\text{g})$ may contribute to this effect.

.....

.....

..... [2]

- (iii) Suggest another environmental problem associated with the use of CHClF_2 .

..... [1]

(c) CHClF_2 is also used to produce the monomer tetrafluoroethene, C_2F_4 .

This monomer can be used to produce poly(tetrafluoroethene), PTFE.

(i) State the type of polymerisation that occurs during the production of PTFE.

..... [1]

(ii) Draw the repeat unit of PTFE.

[1]

(iii) Suggest why PTFE is used as a coating for cooking pans.

.....

 [1]

(iv) Waste disposal can cause litter problems.

State two **other** difficulties associated with the disposal of PTFE.

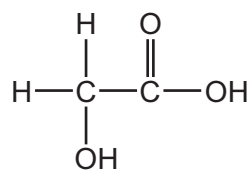
1

 2
 [2]

[Total: 17]

Question 4 starts on the next page.

4 The structure of glycolic acid is shown.



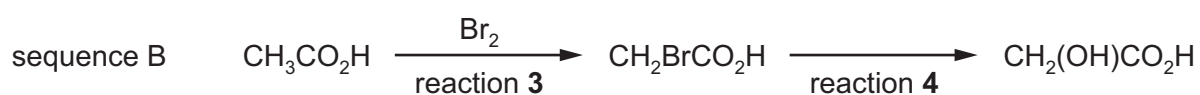
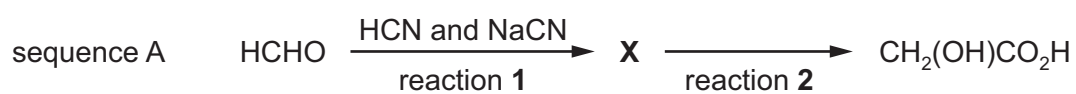
glycolic acid

(a) Complete the table to show what you would **observe** when an aqueous solution of glycolic acid is added separately to each of the reagents. If a reaction occurs, state the functional group of glycolic acid that is responsible for the reaction.

reagent	observation with glycolic acid	does a reaction occur? ✓/✗	functional group
$\text{Na}_2\text{CO}_3(\text{aq})$			
2,4-DNPH			
acidified $\text{Cr}_2\text{O}_7^{2-}$			

[4]

(b) Two reaction sequences to make glycolic acid are shown.



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

[1]

(ii) Name the reagent for reaction 2.

..... [1]

(iii) Name the mechanism of reaction 3.

..... [1]

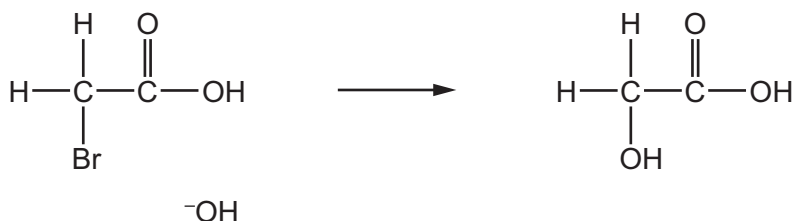
(iv) Suggest the essential condition for reaction 3.

..... [1]

(v) Reaction 4 occurs via an S_N2 mechanism.

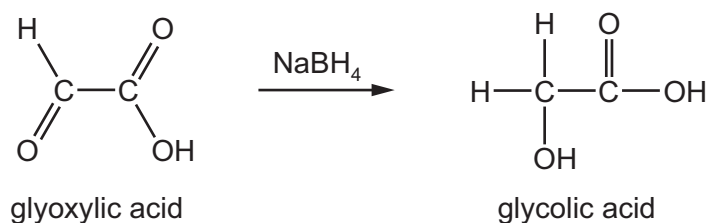
Complete the diagram for the mechanism for reaction 4.

Include all relevant charges, partial charges, curly arrows and lone pairs.



[2]

(c) Glycolic acid can also be made by reacting glyoxylic acid with NaBH_4 .



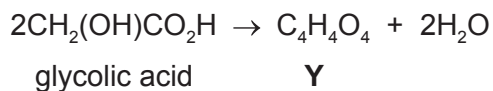
(i) State the role of NaBH_4 in this reaction.

..... [1]

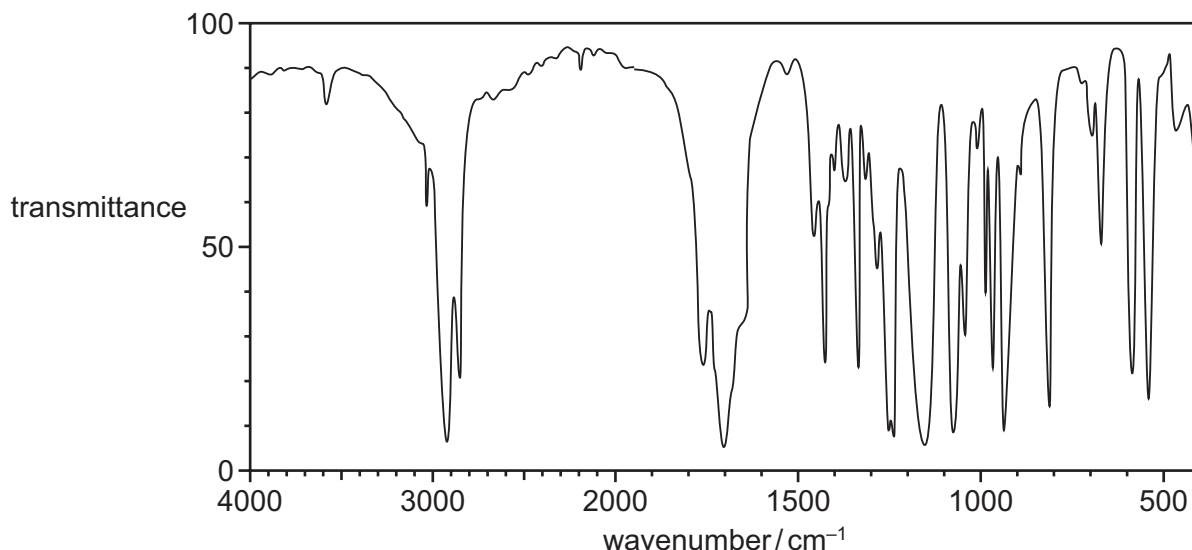
(ii) Write an equation for this reaction using molecular formulae.
Use [H] to represent NaBH_4 .

..... [2]

- (d) When glycolic acid is heated in the presence of a sulfuric acid catalyst, a new compound, **Y**, $C_4H_4O_4$, is formed.
The equation for the reaction is given.



- (i) The infra-red spectrum of **Y** is shown.



State how this spectrum differs from an infra-red spectrum of glycolic acid. Explain your answer with particular reference to the peaks within the range $1500-4000\text{ cm}^{-1}$.

.....

 [2]

- (ii) Suggest a structure for **Y**.

[2]

[Total: 17]

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- 1 The model of the nuclear atom was first proposed by Ernest Rutherford. He developed this model on the basis of results obtained from an experiment using gold metal foil.

(a) Complete the table with information for two of the particles in an atom of ^{197}Au .

particle	relative mass	relative charge	location within atom	total number in an atom of ^{197}Au
electron	0.0005	-1		79
neutron			nucleus	

[4]

(b) State the type of bonding in gold.

..... [1]

(c) A sample of gold found in the earth consists of only one isotope.

(i) Explain what is meant by the term *isotopes*.

.....

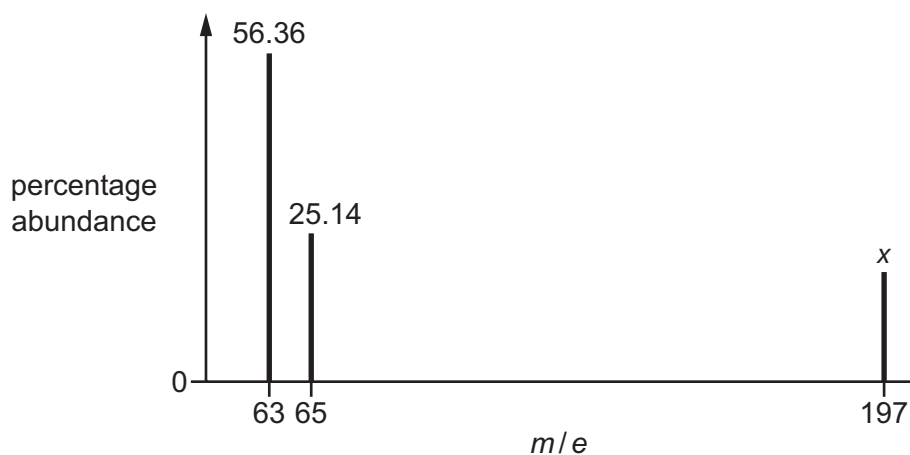
 [2]

(ii) A different sample of gold contains more than one isotope.

Suggest why this different sample of gold has the same **chemical** properties as the sample found in the earth.

.....
 [1]

- (d) *Tumbaga* is an alloy of copper and gold. A sample of tumbaga was analysed. The mass spectrum of the sample is shown.



- (i) Calculate the percentage abundance of gold, x , in the sample of tumbaga.

$x = \dots\dots\dots\%$ [1]

- (ii) Calculate the relative atomic mass, A_r , of the copper present in this sample. Give your answer to **two** decimal places.

$A_r(\text{Cu}) = \dots\dots\dots$ [2]

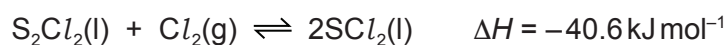
[Total: 11]

2 The table gives some data for elements in the third period and some of their compounds.

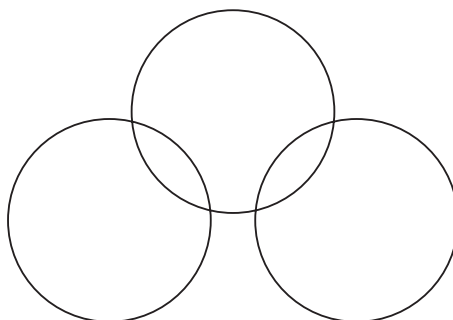
element	Na	Mg	Al	Si	P	S
type of bonding	metallic				covalent	covalent
formula of oxide					P ₄ O ₁₀	SO ₂
formula of chloride	NaCl	MgCl ₂				SCl ₂

(a) Complete the table to show the bonding in the elements, and the formulae of their oxides and chlorides. [3]

(b) SCl₂ is formed in the following reaction.

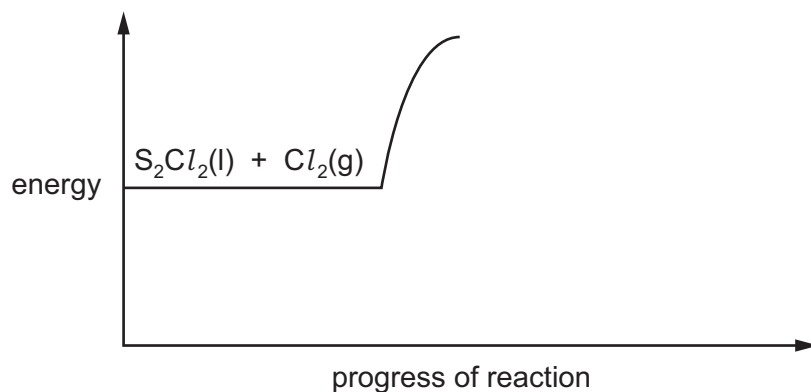


(i) Complete the 'dot-and-cross' diagram to show the bonding in a molecule of SCl₂. Show outer electrons only.



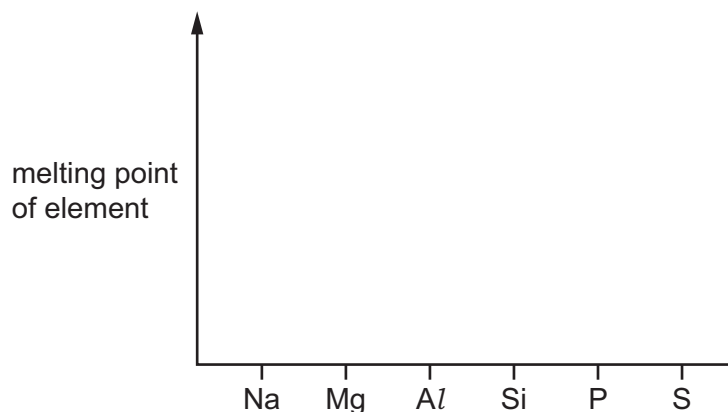
[1]

(ii) Complete and fully label the reaction pathway diagram for the reaction between S₂Cl₂ and Cl₂. Include labels for activation energy, E_a , and enthalpy change of the forward reaction, ΔH .



[2]

- (c) (i) On the axes, sketch the trend in melting point of the elements Na to S.



[1]

- (ii) Give three statements to explain your sketch.

- 1
-
- 2
-
- 3
-

[3]

- (d) Write an equation for the reaction of P_4O_{10} with water.

..... [1]

- (e) SO_2 can be released into the atmosphere when fossil fuels containing sulfur are burnt.

State and explain one environmental consequence of the release of SO_2 into the atmosphere.

.....

.....

.....

..... [2]

- (f) The elements in the third period show a general increase in their first ionisation energies from left to right.

Identify **two** pairs of successive elements in the third period that do **not** agree with this statement.

For each pair, explain why the change in ionisation energy does **not** agree with this statement.

Use of the Data Booklet may help you to answer this question.

pair 1

explanation

.....

.....

.....

.....

pair 2

explanation

.....

.....

.....

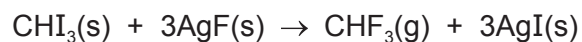
.....

[4]

[Total: 17]

- 3 Trihalomethanes are organic molecules in which three of the hydrogen atoms of methane are replaced by halogen atoms, for example CHF_3 .

(a) The equation shows a reaction to produce CHF_3 .

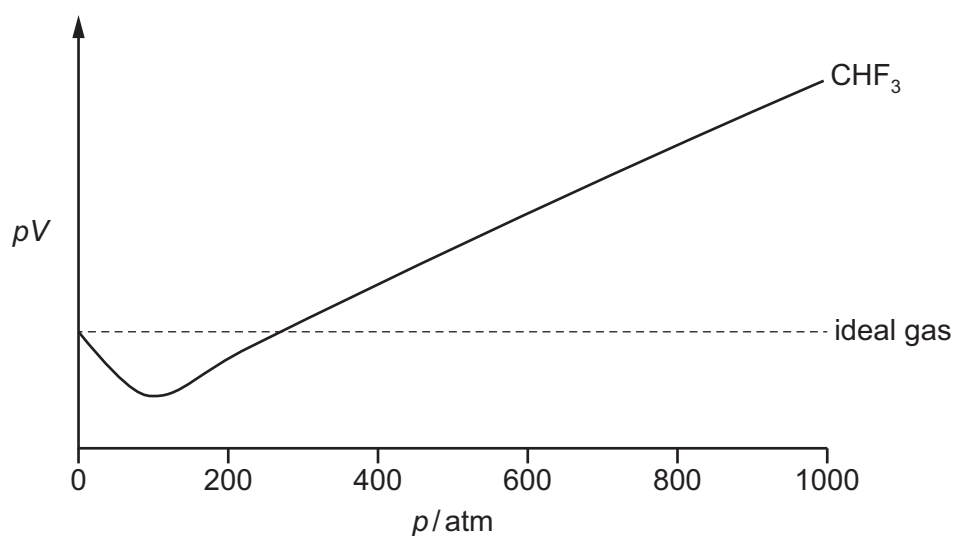


Use the data to calculate the enthalpy change of reaction, ΔH_r , for this formation of CHF_3 .

compound	enthalpy change of formation, $\Delta H_f / \text{kJ mol}^{-1}$
$\text{CHI}_3(\text{s})$	-182.1
$\text{CHF}_3(\text{g})$	-692.9
$\text{AgF}(\text{s})$	-204.6
$\text{AgI}(\text{s})$	-61.8

enthalpy change of reaction, $\Delta H_r = \dots\dots\dots \text{kJ mol}^{-1}$ [3]

- (b) The graph shows the relationship between pV and p at a given temperature for CHF_3 and an ideal gas.



- (i) CHF_3 is not an ideal gas.

State **three** basic assumptions that scientists make about the properties of ideal gases.

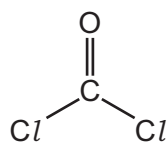
- 1
- 2
- 3

[3]

- (ii) Explain why CHF_3 deviates from the properties of an ideal gas at pressures greater than 300 atm.

-
-
-
- [2]

- (c) A different trihalomethane, CHCl_3 , reacts with O_2 to produce carbonyl dichloride. HCl(g) is also released as a product of this reaction.

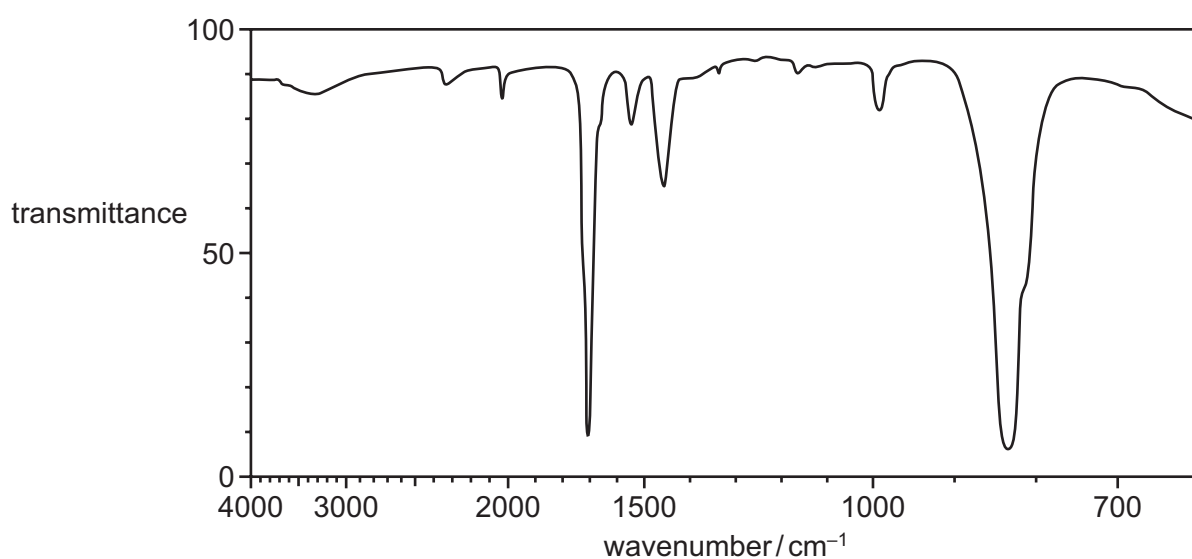


carbonyl dichloride

- (i) Write an equation for this reaction of CHCl_3 with O_2 .

..... [1]

- (ii) The conversion of CHCl_3 to carbonyl dichloride can be monitored by infra-red spectroscopy. The infra-red spectrum of carbonyl dichloride is shown.



On the infra-red spectrum of carbonyl dichloride identify with an **X** the absorption that would **not** be present in an infra-red spectrum of CHCl_3 .

Explain your answer.

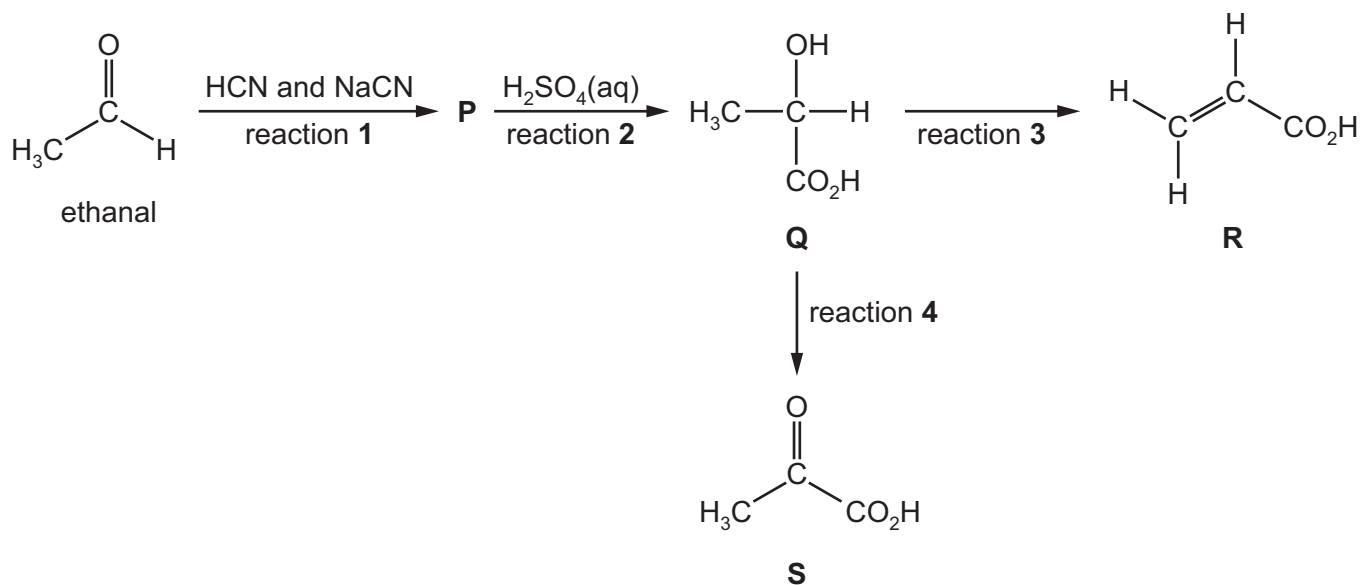
.....
 [2]

- (iii) Suggest another difference between the infra-red spectra of CHCl_3 and carbonyl dichloride.

.....
 [1]

[Total: 12]

4 The diagram shows a reaction sequence starting from ethanal.



(a) (i) Draw the **displayed** formula of **P**.

[1]

(ii) Name the type of chemical reaction that occurs in reaction 3.

[1]

(iii) Write an equation to represent reaction 4.

Use [O] to represent the oxidising agent.

[1]

(iv) State the reagents and conditions for reaction 4.

[1]

(b) Compound **Q** is formed as a mixture of two optical isomers.

(i) Explain what is meant by the term *optical isomers*.

.....

.....

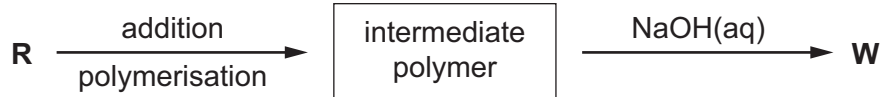
..... [1]

(ii) Draw the **two** optical isomers of **Q**, showing clearly their three-dimensional structures.



[2]

(c) **R** can be used to make a polymer, **W**, in two steps.



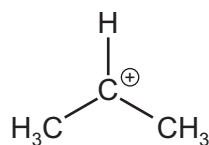
Draw one repeat unit of **W**.

[3]

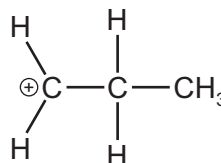
(d) Compound **Z**, $\text{H}_2\text{C}=\text{CHCH}_3$, is produced from **R**.

Z can be used in a two-step process to produce 2-aminopropane.

- (i) In the first step, **Z** reacts with HBr to form two products. The structure of the product depends on which intermediate is formed, intermediate **I** or intermediate **II**.



intermediate **I**



intermediate **II**

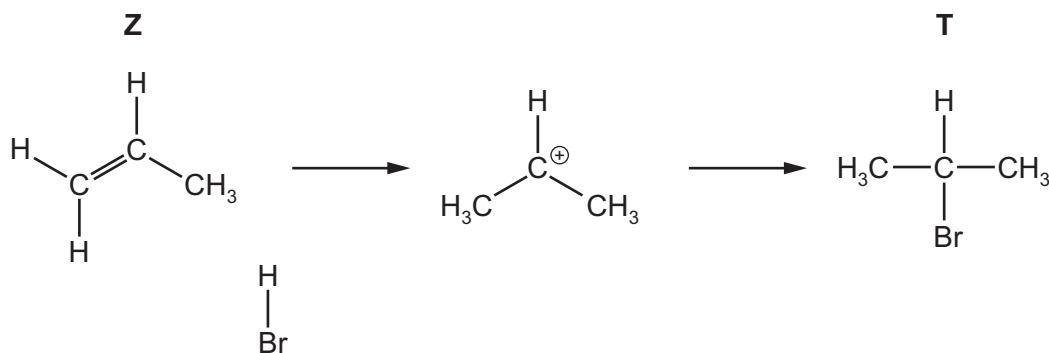
Explain why intermediate **I** is more likely to form than intermediate **II**.

.....

 [2]

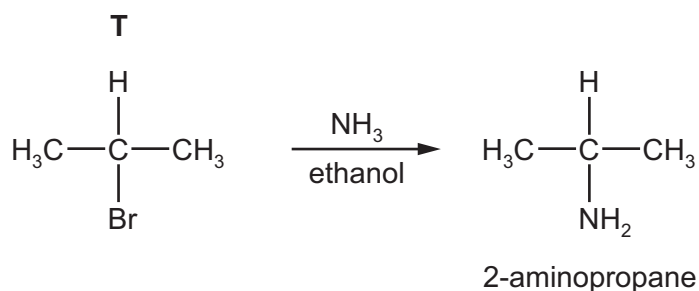
- (ii) When intermediate **I** forms, the product of the first step is **T**.

Complete the diagram to show the mechanism for the conversion of **Z** to **T**.
 Include all relevant charges, partial charges, curly arrows and lone pairs.



[3]

- (iii) **T** can then be converted to 2-aminopropane.

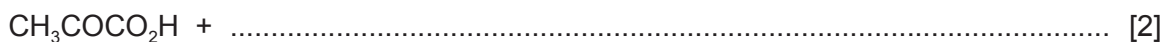


Name the mechanism for this conversion.

..... [1]

- (e) (i) Compound **S**, $\text{CH}_3\text{COCO}_2\text{H}$, can be reduced by LiAlH_4 .

Complete the equation using structural formulae to represent this reaction.
Use [H] to represent the reducing agent.



Other reducing agents containing Group 1 metal cations include LiBH_4 , NaBH_4 and KBH_4 .
The strength of the reducing agent depends on the size of its cation.

- (ii) Give the electronic configuration of the Na^+ cation.

$1s^2 \dots\dots\dots$ [1]

- (iii) Suggest why ionic radius increases down Group 1.

$\dots\dots\dots$
 $\dots\dots\dots$
 $\dots\dots\dots$ [1]

[Total: 20]

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- 1 Iron pyrite, FeS_2 , has a yellow colour that makes it look like gold metal. The compound contains the ions Fe^{2+} and S_2^{2-} .

(a) (i) Give the full electronic configuration of Fe^{2+} .

1s² [1]

- (ii) Calculate the oxidation number of sulfur in the S_2^{2-} ion.
Assume that each sulfur atom in the ion has the same oxidation number.

oxidation number of sulfur in the S_2^{2-} ion = ... [1]

(b) Describe the metallic bonding in gold.

.....

 [2]

- (c) Iron pyrite is often called *fool's gold* because of its appearance. Impure samples of iron pyrite often contain a small amount of gold.

The gold can be obtained from impure iron pyrite. The impure iron pyrite is roasted in oxygen, to produce iron(III) oxide and sulfur dioxide. Gold does not react with oxygen.

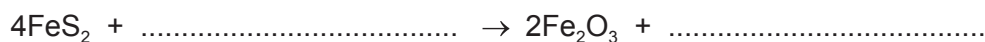
- (i) The sulfur dioxide produced during roasting would cause environmental consequences if released into the atmosphere.

State and explain **one** of these environmental consequences.

.....

 [2]

- (ii) Complete the equation to show the roasting of iron pyrite in oxygen.



[2]

- (iii) A sample of impure iron pyrite was roasted in oxygen. The composition of the mixture of solid products is shown.

solid product	mass/g
Fe_2O_3	33.18
Au	0.37

Calculate the mass of FeS_2 present in the sample of impure iron pyrite.
Assume that all the FeS_2 was converted to Fe_2O_3 during the roasting process.

(M_r : FeS_2 , 120.0; Fe_2O_3 , 159.6)

mass of FeS_2 = ... g [2]

- (iv) Use your answer to (iii) to calculate the percentage by mass of gold in this sample of impure iron pyrite. Assume that gold is the only impurity in this sample of impure iron pyrite.

Give your answer to **two** significant figures.

(If you were unable to calculate an answer to (iii), use 55.00 g as the mass of FeS_2 in this calculation. This is **not** the correct answer.)

percentage by mass of gold = ... % [1]

[Total: 11]

2 (a) Nitrogen, N_2 , is an inert gas that makes up 78% of the Earth's atmosphere.

(i) Explain why nitrogen is inert.

.....
.....
..... [2]

(ii) Draw a 'dot-and-cross' diagram of a nitrogen molecule. Show outer electrons only.

[1]

(b) Nitrogen, N_2 , and oxygen, O_2 , react together in the air during lightning strikes to form nitrogen monoxide, NO.

(i) Explain why the reaction of N_2 and O_2 occurs during lightning strikes.

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

(ii) Write two equations to suggest how the NO formed reacts further to create nitric acid, HNO_3 .

1

2 [2]

- (c) Nitrate fertilisers are used to provide nitrogen for plant growth. Uncontrolled use of these can cause a reduction in animal and plant life in natural water supplies.

Explain how uncontrolled use of nitrate fertilisers can cause this problem.

.....

.....

.....

..... [3]

- (d) Some soils have compounds such as ammonium nitrate, calcium carbonate and calcium hydroxide added to them.

- (i) Suggest why calcium hydroxide is added to some soils.

..... [1]

- (ii) When calcium hydroxide reacts with compounds containing the ammonium ion, NH_4^+ , a gas is produced.

State the identity of this gas and explain why the reaction occurs.

gas

explanation

.....

.....

[2]

- (iii) Another fertiliser, calcium ammonium nitrate, is formed when solid calcium carbonate is added to a mixture of aqueous ammonium nitrate and dilute nitric acid.

Suggest what would be **observed** in this reaction.

.....

.....

..... [2]

- (iv) Calcium nitrate decomposes at a higher temperature than calcium ammonium nitrate.

Write an equation for the thermal decomposition of calcium nitrate.

..... [1]

[Total: 15]

- 3 Trihalomethanes are organic molecules in which three of the hydrogen atoms of methane are replaced by halogen atoms, for example CHCl_3 .

(a) CHCl_3 is a colourless liquid with a high vapour pressure.

(i) Explain what is meant by *high vapour pressure*.

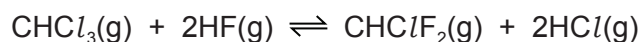
.....

.....

.....

..... [2]

(ii) An important reaction of $\text{CHCl}_3(\text{g})$ is the manufacture of $\text{CHClF}_2(\text{g})$, using the following reversible reaction.



Use the data to calculate the enthalpy change of reaction, ΔH_r , for the formation of $\text{CHClF}_2(\text{g})$ as shown in the equation.

compound	enthalpy change of formation, $\Delta H_f^\circ / \text{kJ mol}^{-1}$
$\text{CHCl}_3(\text{g})$	-103.2
$\text{CHClF}_2(\text{g})$	-482.2
$\text{HF}(\text{g})$	-273.3
$\text{HCl}(\text{g})$	-92.3

enthalpy change of reaction, $\Delta H_r = \dots\dots\dots \text{kJ mol}^{-1}$ [3]

- (iii) The reaction in (ii) is carried out using a heterogeneous catalyst.

Explain fully the meaning of the terms *heterogeneous* and *catalyst*.

heterogeneous

.....

.....

catalyst

.....

.....

.....

[3]

- (b) CHClF_2 was used as an alternative to chlorofluorocarbons (CFCs). CHClF_2 should no longer be used because it was found to contribute to the *enhanced greenhouse effect*.

- (i) Give the meaning of the term *enhanced greenhouse effect*.

.....

..... [1]

- (ii) Explain how $\text{CHClF}_2(\text{g})$ may contribute to this effect.

.....

.....

..... [2]

- (iii) Suggest another environmental problem associated with the use of CHClF_2 .

..... [1]

- (c) CHClF_2 is also used to produce the monomer tetrafluoroethene, C_2F_4 .

This monomer can be used to produce poly(tetrafluoroethene), PTFE.

- (i) State the type of polymerisation that occurs during the production of PTFE.

..... [1]

- (ii) Draw the repeat unit of PTFE.

[1]

- (iii) Suggest why PTFE is used as a coating for cooking pans.

.....

 [1]

- (iv) Waste disposal can cause litter problems.

State two **other** difficulties associated with the disposal of PTFE.

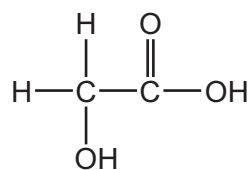
1

 2
 [2]

[Total: 17]

Question 4 starts on the next page.

4 The structure of glycolic acid is shown.



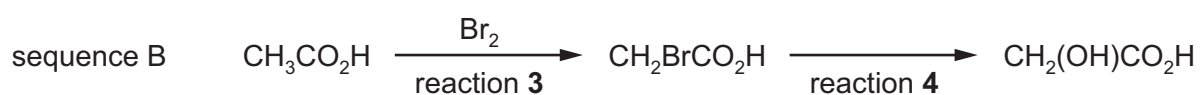
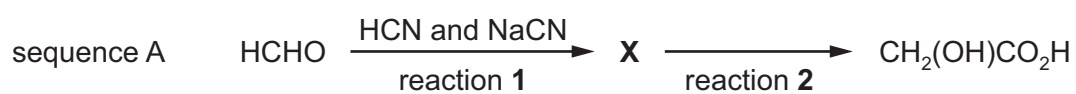
glycolic acid

(a) Complete the table to show what you would **observe** when an aqueous solution of glycolic acid is added separately to each of the reagents. If a reaction occurs, state the functional group of glycolic acid that is responsible for the reaction.

reagent	observation with glycolic acid	does a reaction occur? ✓/✗	functional group
$\text{Na}_2\text{CO}_3(\text{aq})$			
2,4-DNPH			
acidified $\text{Cr}_2\text{O}_7^{2-}$			

[4]

(b) Two reaction sequences to make glycolic acid are shown.



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

[1]

(ii) Name the reagent for reaction 2.

..... [1]

(iii) Name the mechanism of reaction 3.

..... [1]

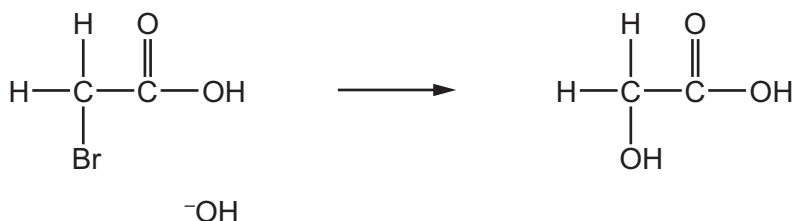
(iv) Suggest the essential condition for reaction 3.

..... [1]

(v) Reaction 4 occurs via an S_N2 mechanism.

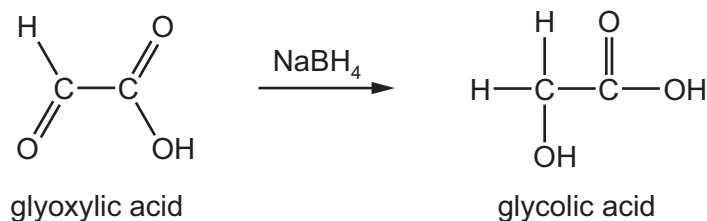
Complete the diagram for the mechanism for reaction 4.

Include all relevant charges, partial charges, curly arrows and lone pairs.



[2]

(c) Glycolic acid can also be made by reacting glyoxylic acid with $NaBH_4$.



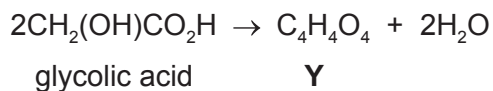
(i) State the role of $NaBH_4$ in this reaction.

..... [1]

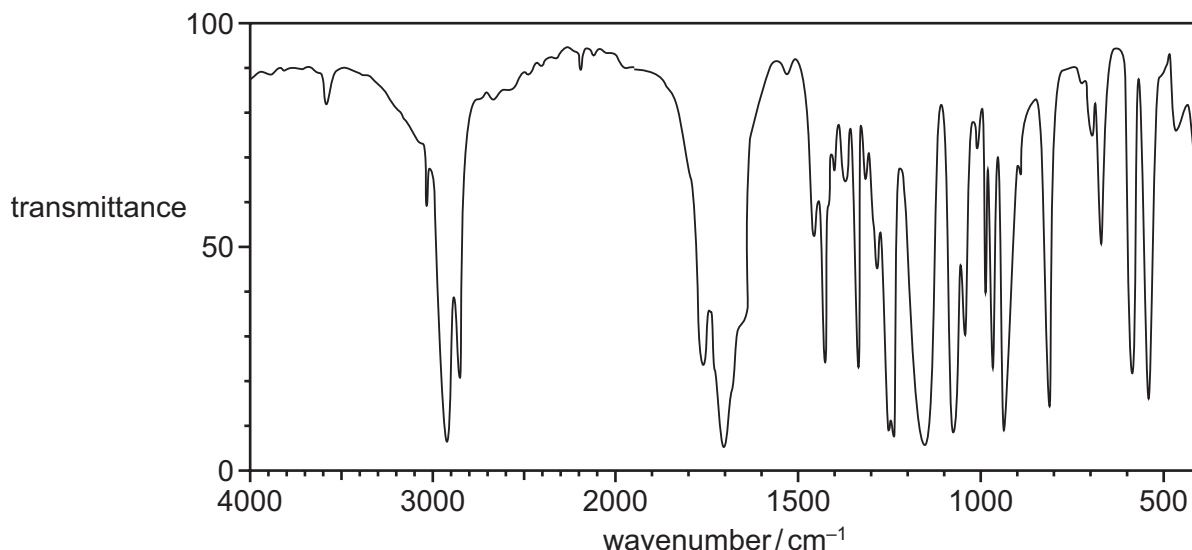
(ii) Write an equation for this reaction using molecular formulae.
Use [H] to represent $NaBH_4$.

..... [2]

- (d) When glycolic acid is heated in the presence of a sulfuric acid catalyst, a new compound, **Y**, $C_4H_4O_4$, is formed.
The equation for the reaction is given.



- (i) The infra-red spectrum of **Y** is shown.



State how this spectrum differs from an infra-red spectrum of glycolic acid. Explain your answer with particular reference to the peaks within the range $1500-4000\text{ cm}^{-1}$.

.....

 [2]

- (ii) Suggest a structure for **Y**.

[2]

[Total: 17]

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