Cambridge International AS & A Level

Cambridge Assessment International Education
Cambridge International Advanced Subsidiary and Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

6417226760

CHEMISTRY **9701/22**

Paper 2 AS Level Structured Questions **February/March 2019**

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 **14** printed pages and **2** blank pages.

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

1 Nitrogen, N_2, is the most abundant gas in the Earth's atmosphere and is very unreactive.

(a) State why N_2 is very unreactive.

..... [1]

(b) Magnesium and lithium both form nitrides with N_2. These compounds both contain the N^{3-} ion.

(i) Write an equation for the reaction of magnesium with N_2 to form magnesium nitride.

..... [1]

(ii) Solid lithium nitride, Li_3N, reacts with water according to the following equation.

$$Li_3N(s) + 3H_2O(l) \rightarrow 3LiOH(aq) + NH_3(aq)$$

State **one** observation you would make during this reaction.

..... [1]

(c) (i) State the industrial importance of ammonia.

..... [1]

(ii) One method of producing NH_3 is by heating ammonium chloride, NH_4Cl, with CaO.

$$2NH_4Cl + CaO \rightarrow 2NH_3 + CaCl_2 + H_2O$$

Explain why the reaction of NH_4Cl with CaO produces ammonia.

.....

.....

..... [2]

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(d) Three oxides of nitrogen, NO, NO_2 and N_2O, can be formed under different conditions.

(i) Complete the table to give the oxidation numbers of nitrogen in NO and NO_2.

compound	NO	NO_2
oxidation number of N		

[1]

(ii) NO_2 can be formed by different chemical reactions.

Write equations for the formation of NO_2 by:

- the reaction of N_2 with O_2

.....

- the thermal decomposition of magnesium nitrate.

.....

[2]

(iii) Molecules of N_2O can be formed by the reaction between N_2 and O_2. The bond between the N and O atoms (N→O) is a co-ordinate (dative covalent) bond.

$$2N_2(g) + O_2(g) \rightarrow 2N{\equiv}N{\rightarrow}O(g)$$

The enthalpy change of reaction for this reaction is $+82\,kJ\,mol^{-1}$.

Calculate the bond enthalpy, in $kJ\,mol^{-1}$, of the N→O bond.

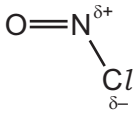
Use relevant data from the *Data Booklet* to answer this question.

bond enthalpy of the N→O bond = ... $kJ\,mol^{-1}$

[2]

(e) Nitrosyl chloride, NOCl, is a reactive gas that is sometimes formed when NO reacts with Cl_2.

nitrosyl chloride



NOCl is a strong electrophile and readily undergoes an addition reaction with alkenes.

Complete the diagram to show the mechanism of the electrophilic addition reaction of NOCl with ethene.

Include all necessary charges, lone pairs and curly arrows, and the structure of the organic intermediate.



[2]

[Total: 13]

2 The elements in Group 17 of the Periodic Table are called the halogens. They form stable compounds with both metals and non-metals.

The table gives some data about F_2, HC*l* and CaF_2.

	F_2	HC*l*	CaF_2
boiling point / K	85	188	2773
relative formula mass	38.0	36.5	78.1

(a) (i) State what is meant by the term *relative formula mass*.

.....

.....

..... [2]

(ii) F_2 and HC*l* are both covalent molecules.

Suggest why the boiling point of HC*l* is higher than that of F_2.

.....

.....

..... [2]

(iii) Explain why CaF_2 has a very high boiling point.

.....

..... [1]

(iv) CaF_2(aq) can be made by the reaction of calcium carbonate with hydrofluoric acid, HF(aq).

Write an equation for this reaction. Include state symbols.

..... [2]

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[Turn over

(b) (i) Complete the electronic configuration of a chloride ion.

$1s^2$ ..... [1]

(ii) When Cl_2 is passed over hot iron, $FeCl_3$ is formed.

However, when $I_2(g)$ is passed over hot iron, the following reaction occurs.

$$Fe(s) + I_2(g) \rightarrow FeI_2(s)$$

State what you would observe during the reaction between Fe and I_2. Explain why $FeI_2(s)$ is formed rather than $FeI_3(s)$.

observation .....

.....

explanation .....

.....

.....

[2]

(iii) FeI_2 is soluble in water.

A student carries out a chemical test to confirm that a solution of FeI_2 contains aqueous iodide ions, $I^-(aq)$. The student adds a single reagent and a precipitate forms.

Identify the reagent the student uses. State the colour of the precipitate that forms.

reagent .....

colour of precipitate .....

[2]

(iv) Compounds containing I^- are often contaminated by bromide ions, Br^-.

Identify a further reagent that the student could use to show that the precipitate formed in **(iii)** contained iodide ions.

..... [1]

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(c) HOF is the only known molecule that contains only the elements hydrogen, oxygen and fluorine.

(i) Draw a 'dot-and-cross' diagram to represent the bonding in a molecule of HOF.

Show the outer shell electrons only.

[2]

(ii) HOF can be made by the reaction of F_2 with ice at –40 °C. The reaction is similar to the reaction of Cl_2 with cold water.

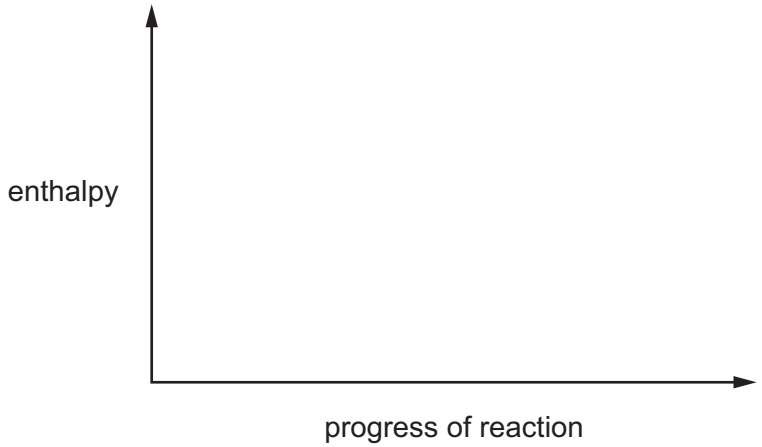
Suggest an equation for the reaction of F_2 with ice.

..... [1]

(iii) HOF is an unstable compound and decomposes to form HF and O_2.

$$HOF \rightarrow HF + \tfrac{1}{2}O_2 \qquad \Delta H = -139\,kJ\,mol^{-1}$$

Draw a fully labelled reaction pathway diagram on the axes provided to show the decomposition of HOF into HF and O_2.



[2]

(iv) Pure HF is a colourless liquid at 273 K. The liquid contains HF molecules that have strong hydrogen bonds between them.

Draw a fully labelled diagram to suggest how a hydrogen bond can form between two HF molecules.

[3]

(d) Interhalogen compounds, such as BrC*l* or IF_5, contain two or more different halogen atoms that are covalently bonded.

D is an interhalogen compound that contains only chlorine and fluorine.

At 0 °C and 101 325 Pa, 1 dm^3 of **D** has a mass of 4.13 g.

(i) Use the general gas equation to calculate the relative molecular mass, M_r, of **D**.

M_r = ...
[3]

(ii) Use your answer to **(i)** to determine the molecular formula of **D**.

If you were unable to calculate the M_r in **(i)**, assume that the M_r is 130.5. This is **not** the correct value.

molecular formula of **D** = ...
[1]

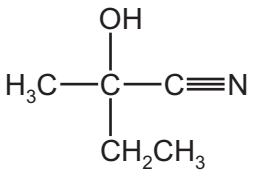
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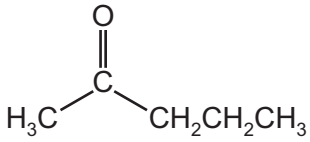
Question 3 starts on the next page.

3 **P**, **Q** and **R** all contain five carbon atoms.

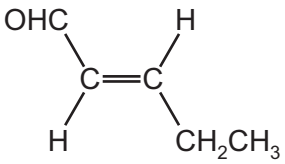
P



Q



R



A student carries out several tests to distinguish between **P**, **Q** and **R**.

(a) Complete the table, identifying any observations for the reaction of each reagent with **P**, **Q** and **R**.

If no reaction occurs, write 'no reaction'.

reagent	observations with		
	P	**Q**	**R**
Na(s)			
2,4-DNPH	no reaction		
acidified $K_2Cr_2O_7$(aq)	no reaction		

[3]

(b) **Q** is reduced by $NaBH_4$.

Write an equation for the reaction of **Q** with $NaBH_4$.

In your answer, use [H] to represent $NaBH_4$.

$C_5H_{10}O$ + ... [1]

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(c) **R** exists as a pair of stereoisomers.

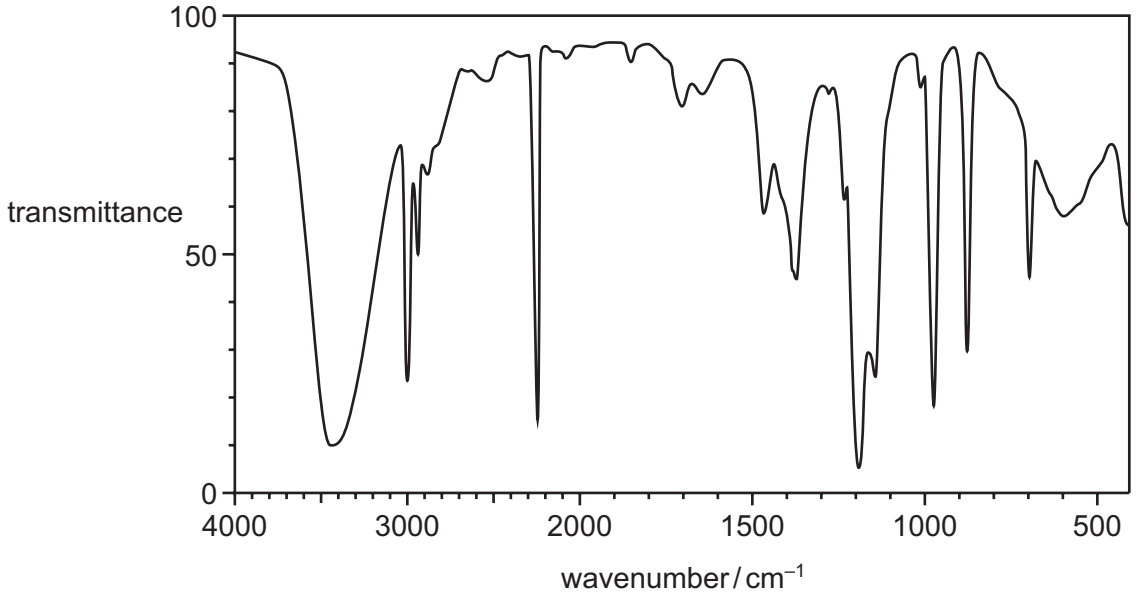
Identify the type of stereoisomerism shown by **R** and draw the structure of the other stereoisomer.

type of stereoisomerism .....

stereoisomer of **R**

[2]

(d) The infra-red spectrum shown corresponds to one of **P**, **Q** or **R**.



Deduce which of the compounds, **P**, **Q** or **R**, produces this spectrum. Explain your reasoning.

In your answer, identify any relevant absorptions in the infra-red spectrum and the bonds that correspond to these absorptions in the region **above** 1500 cm^{-1}.

compound .....

explanation .....

.....

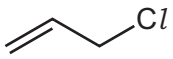
.....

[3]

[Total: 9]

4 Allyl chloride is an important chemical used in the manufacture of plastics, pharmaceuticals and pesticides.

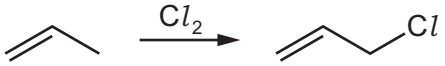
allyl chloride



(a) Give the systematic name of allyl chloride.

..... [1]

(b) Allyl chloride can be produced by many different methods. The most common method is chlorination of propene which proceeds via a free-radical substitution mechanism.



(i) The initiation step in this reaction is the formation of chlorine radicals ($Cl^{\bullet}$) from Cl_2 molecules.

State the conditions required to initiate this reaction.

..... [1]

(ii) The propenyl radical, $CH_2{=}CHCH_2^{\bullet}$, is formed in the first propagation step of the reaction.

Write an equation to show the formation of $CH_2{=}CHCH_2^{\bullet}$ in this propagation step.

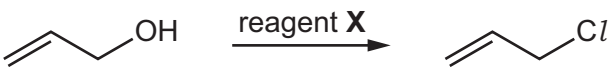
..... [1]

(iii) Explain why the free-radical substitution reaction gives a low yield of allyl chloride.

.....

..... [1]

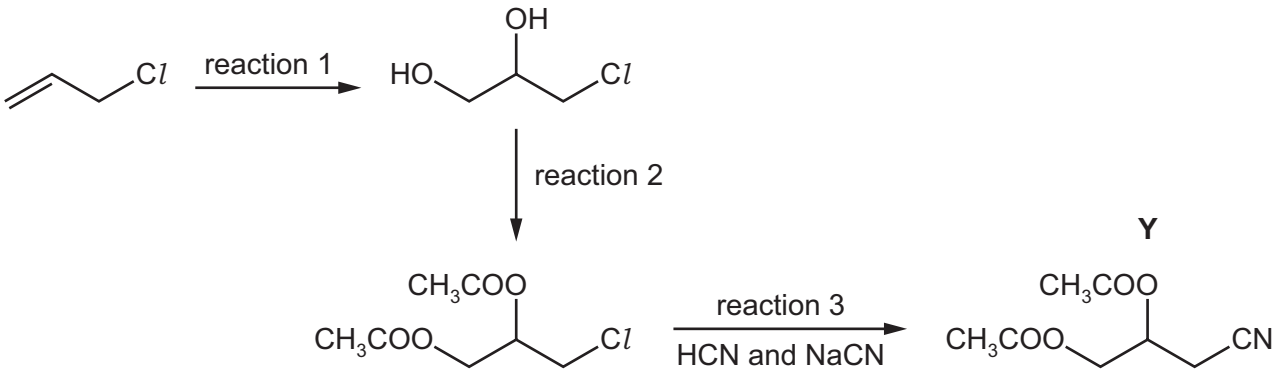
(iv) Allyl chloride can also be formed by the following substitution reaction.



Suggest the identity of reagent **X**.

..... [1]

(c) A series of reactions starting from allyl chloride is shown.



(i) Suggest a reagent that can be used in reaction 1.

..... [1]

(ii) In reaction 2, the organic product of reaction 1 is mixed with concentrated H_2SO_4 and an organic acid, and then heated under reflux.

State the role of the concentrated H_2SO_4. Identify the organic acid used.

role of the concentrated H_2SO_4 .....

identity of the organic acid .....
[2]

(iii) State the name of the mechanism that occurs in reaction 3.

..... [1]

(iv) The organic product of reaction 3 is **Y**.

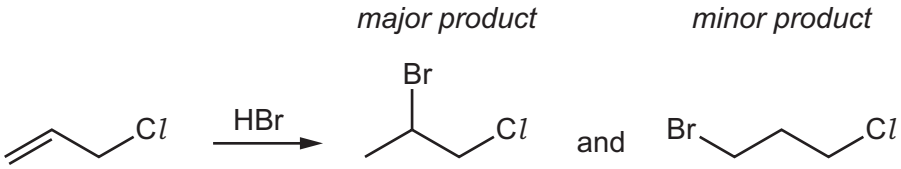
Y can be hydrolysed using excess aqueous H_2SO_4 to form **Z**.

The molecular formula of **Z** is $C_4H_8O_4$.

Draw the structure of **Z**.

[2]

(d) 2-bromo-1-chloropropane, $CH_3CHBrCH_2Cl$, is the major product of the reaction of allyl chloride with HBr.



Explain why 2-bromo-1-chloropropane is the major product of this reaction.

.....

.....

.....

..... [2]

[Total: 13]

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