Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

2578092005

CHEMISTRY **9701/22**

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 **12** pages.

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

1 Hydrogen iodide, HI, is a colourless gas at room temperature.

(a) (i) Explain why HI has a higher boiling point than HC*l* and HBr.

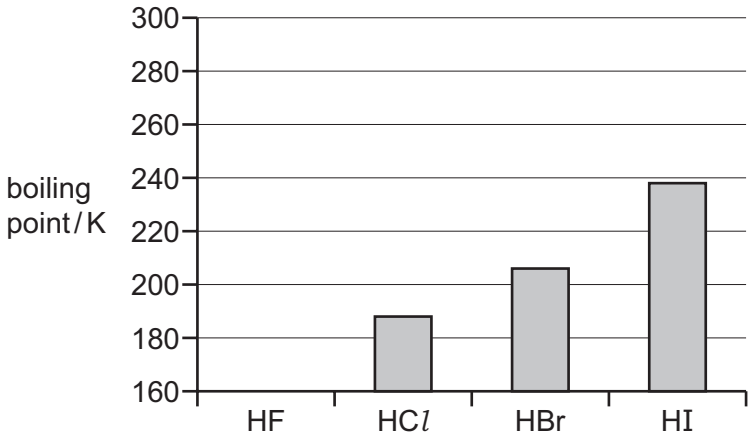
.....

.....

.....

..... [2]

(ii) The bar chart shows the boiling points of HC*l*, HBr and HI. The boiling point of HF is not shown.



Hydrogen bonds form between HF molecules.

Draw a bar on the bar chart to predict the boiling point of HF.

Explain your answer.

.....

..... [2]

(b) The standard enthalpy change of formation, $\Delta H_f^{\ominus}$, of HI(g) is +26.5 kJ mol^{-1}.

Define the term *standard enthalpy change of formation*.

.....

.....

..... [2]

(c) HI(g) can be formed by reacting $H_2(g)$ with $I_2(g)$. The reaction is reversible, and an equilibrium forms quickly at high temperatures.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

(i) Construct an expression for the equilibrium constant, K_p, for the reaction of $H_2(g)$ and $I_2(g)$ to form HI(g).

K_p =

[1]

(ii) The equilibrium partial pressures of the gases at 200 °C are as follows.

$$p_{H_2(g)} = 895\,Pa$$
$$p_{I_2(g)} = 895\,Pa$$
$$p_{HI(g)} = 4800\,Pa$$

Calculate K_p for this reaction.

K_p = ... [1]

(iii) State how the value of K_p would change, if at all, if the reaction were carried out at 100 °C rather than 200 °C.

Explain your answer.

.....

.....

.....

..... [2]

(d) HI reacts with oxygen to form iodine and water.

(i) Construct an equation for the reaction of HI with oxygen.

..... [1]

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

.....

.....

.....

..... [2]

(e) HI(g) can also be formed by the reaction of $I_2(g)$ with hydrazine, $N_2H_4(g)$.

$$2I_2(g) + N_2H_4(g) \rightarrow 4HI(g) + N_2(g)$$

State the change in pressure that would occur when 2 mol $I_2(g)$ fully reacts with 1 mol $N_2H_4(g)$ in a sealed container at constant temperature. Explain your answer.

.....

.....

.....

..... [2]

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(f) In the laboratory, HI(aq) can be formed in a two-step process.

step 1 $3I_2(s) + 2P(s) \rightarrow 2PI_3(s)$

step 2 $PI_3(s) + 3H_2O(l) \rightarrow H_3PO_3(aq) + 3HI(aq)$

(i) Draw a 'dot-and-cross' diagram of a PI_3 molecule.

[2]

(ii) Name the type of reaction in **step 2**.

..... [1]

(iii) $H_3PO_3(aq)$ and HI(aq) are both strong Brønsted–Lowry acids.

Give the meaning of the term *strong Brønsted–Lowry acid*.

.....

.....

..... [2]

(iv) Give the formula of the conjugate base of H_3PO_3.

..... [1]

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[Turn over

(g) HI(g) reacts with propene, $CH_3CH{=}CH_2$(g) to form a mixture of 1-iodopropane and 2-iodopropane.

(i) Identify which of 1-iodopropane and 2-iodopropane is the major product of this reaction.

Explain your answer.

.....

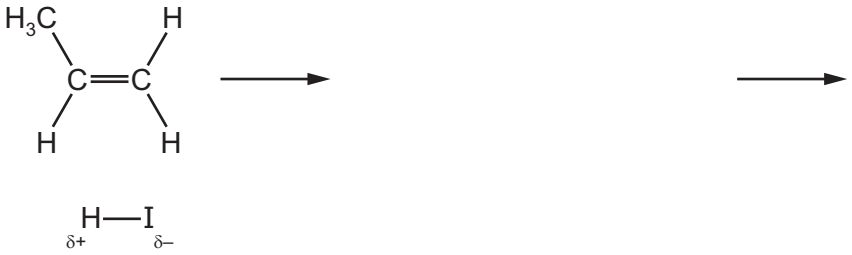
.....

.....

..... [2]

(ii) Complete the diagram to show the mechanism of the reaction between HI and $CH_3CH{=}CH_2$ that forms the major product identified in **(g)(i)**.

Include curly arrows, lone pairs of electrons and charges as necessary.



[3]

[Total: 26]

2 **(a)** Table 1 gives physical data for some of the Period 3 elements.

Table 1

atomic number, *Z*	11	12	13	14	15	16	17
bonding present in element	M						C
first ionisation energy / kJ mol^{-1}	494	736	577	786	1060	1000	1260
maximum oxidation number							+7
anionic radius / nm	–	–	–	0.271	0.212	0.184	0.181

(i) Complete the row in the table labelled 'bonding present in element'.

Use C = covalent, I = ionic, M = metallic, as appropriate. [1]

(ii) Explain the difference between the first ionisation energies of the elements with atomic numbers 11 and 17.

.....

.....

.....

.....

..... [2]

(iii) Explain the difference between the first ionisation energies of the elements with atomic numbers 15 and 16.

.....

.....

.....

.....

..... [2]

(iv) Complete the row in the table labelled 'maximum oxidation number'. [1]

(v) Explain the variation in anionic radius for the elements with atomic numbers 14 to 17.

.....

.....

.....

..... [2]

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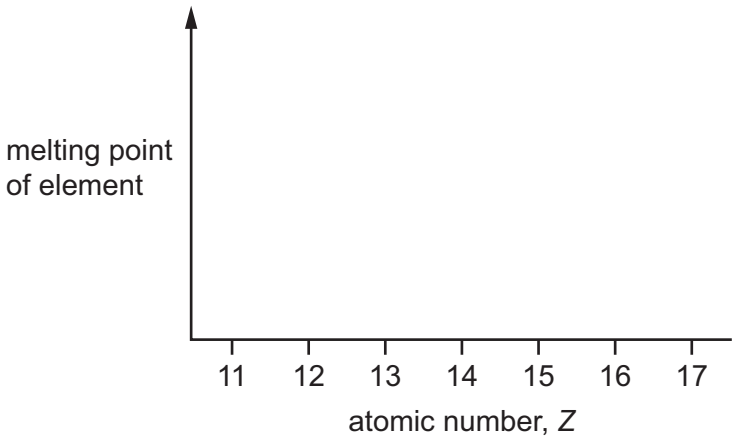
[Turn over

(b) Use the axes to sketch a graph that shows the trend in melting points of the elements with atomic numbers 11 to 17.



[2]

(c) Dmitri Mendeleev published the first Periodic Table in 1869.

Mendeleev used his knowledge of chemical periodicity to propose the properties of gallium, $_{31}$Ga, a Group 13 element.

Table 2 gives some chemical and physical data of elements in Group 13.

Table 2

element	density / g cm^{-3}	boiling point / K	cationic radius / nm
$_{5}$B	2.34	3930	0.020
$_{13}$A*l*		2470	0.050
$_{31}$Ga	5.91	2400	
$_{49}$In	7.30		0.081
$_{81}$T*l*	11.8	1460	0.095

Complete the table by predicting values for the missing data. [3]

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(d) Indium and aluminium are elements in Group 13 of the Periodic Table.

Indium has very similar chemical properties to aluminium.

- Indium reacts vigorously with hydrochloric acid to form a colourless gas and a salt in solution.
- Indium oxide, In_2O_3, is amphoteric.
- Gaseous indium bromide has the formula In_2Br_6. This molecule contains coordinate bonds.

(i) Identify the formula of the salt formed when indium reacts with hydrochloric acid.

..... [1]

(ii) Construct an equation for the reaction of In_2O_3 with excess aqueous NaOH.

..... [1]

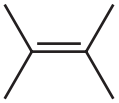
(iii) Draw a diagram that clearly shows the types of bond present in $In_2Br_6(g)$.

[2]

[Total: 17]

3 Compound **T** is an isomer of C_6H_{12}.

T



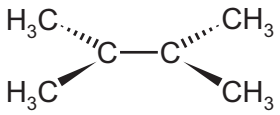
(a) Name **T**.

..... [1]

(b) Draw the skeletal formula of a structural isomer of **T** that shows *cis-trans* (geometrical) isomerism.

[1]

(c) Each carbon atom in **T** forms a sigma (σ) bond to at least one other carbon atom, as shown.

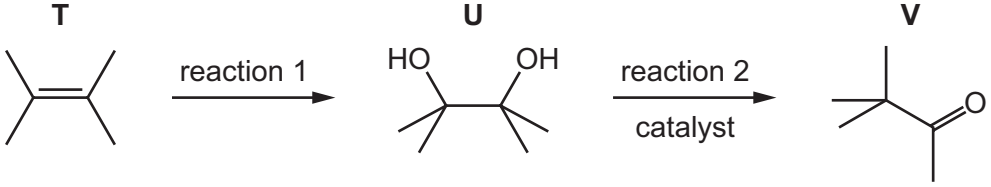


(i) On the diagram, draw the orbitals that represent the pi (π) bond that is also present in **T**. [1]

(ii) State the hybridisation of the two carbon atoms between which the pi (π) bond forms.

..... [1]

(d) A reaction scheme starting with **T** is shown. Reaction 2 occurs in the presence of a catalyst; knowledge of the mechanism for this reaction is not required.



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

..... [1]

(ii) State and explain how 2,4-dinitrophenylhydrazine (2,4-DNPH) can be used to detect the presence of **V** as a product of reaction 2.

.....

.....

..... [2]

(iii) The progress of reaction 2 can be monitored by infrared spectroscopy.

The absorption caused by O–H bonds is always present because water is used as a solvent.

Identify two absorptions, and the bonds responsible for these absorptions, whose appearance will change significantly during the reaction.

1 .....

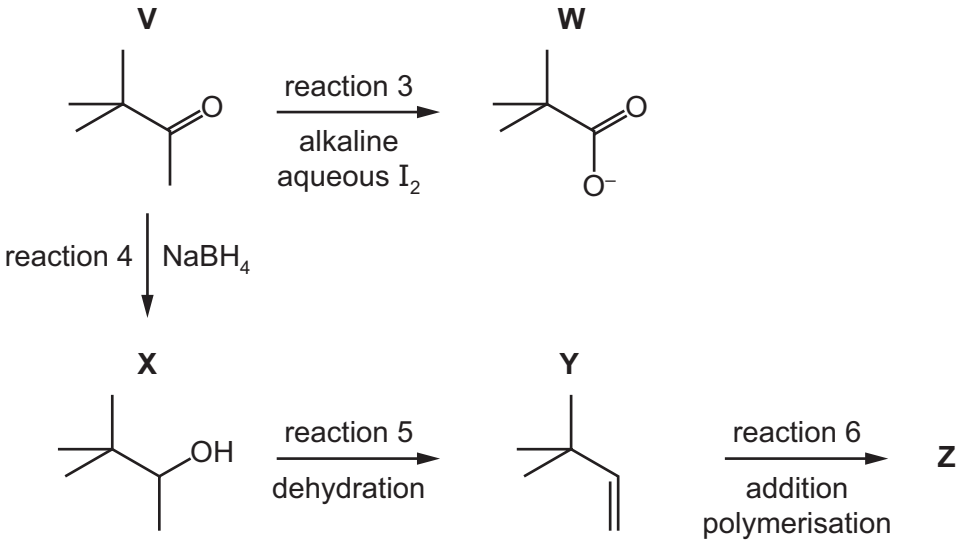
.....

2 .....

.....
[2]

(e) **V** is used in a wide range of organic reactions.

Some reactions of **V** are shown.



(i) **V** and **W** are colourless and soluble in water.

State what you would observe in reaction 3.

..... [1]

(ii) Reaction 3 is a redox reaction.

Identify which of the **reactants** is reduced in this reaction.

..... [1]

(iii) Construct an equation for reaction 4.

Use [H] in the equation to represent an atom of hydrogen from $NaBH_4$.

$C_6H_{12}O$ + ... [1]

(iv) **X** is a mixture of two optical isomers.

Draw the two optical isomers in the boxes provided.

[2]

(v) Both optical isomers of **X** can be dehydrated to form a single product, **Y**.
Give the reagent(s) and conditions required for reaction 5.

..... [1]

(vi) **Y** can form an addition polymer **Z**.

Draw one repeat unit of **Z**.

[1]

(vii) Reaction 6 does not proceed quickly at room temperature.

Suggest why this is the case.

.....

..... [1]

[Total: 17]

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