Cambridge International AS & A Level

**Cambridge Assessment International Education**
Cambridge International Advanced Subsidiary and Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

*8474817039*

**CHEMISTRY** **9701/22**

Paper 2 AS Level Structured Questions **October/November 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 **13** printed pages and **3** blank pages.




Cambridge Assessment International Education

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

**1** In the Periodic Table, the p block contains elements whose outer electrons are found in the p subshell.

**(a)** Elements in the p block show a general increase in first ionisation energy as the atomic number increases.

**(i)** Draw the shape of a p orbital.

[1]

**(ii)** Write an equation to show the first ionisation energy of silicon.

..... [1]

**(iii)** Explain why there is a general increase in first ionisation energies of the elements across Period 3.

.....

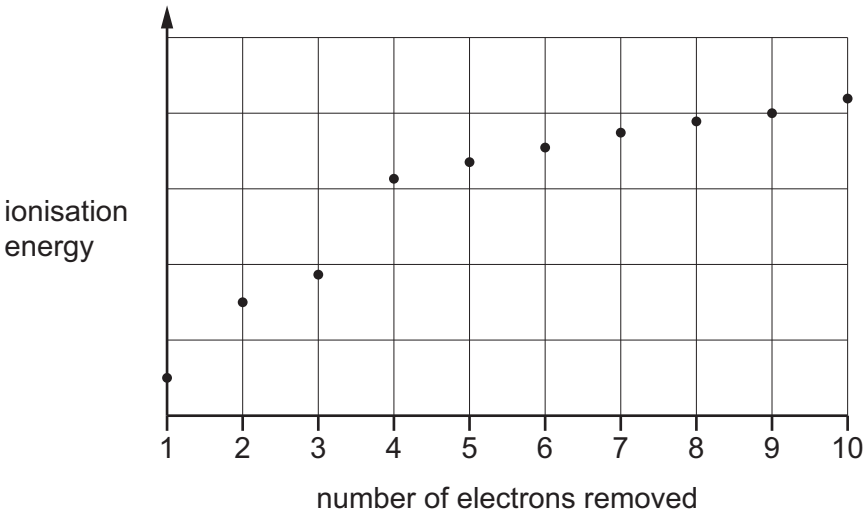
.....

.....

..... [2]

**(iv)** Element **A** is in the p block.

The graph shows the successive ionisation energies for the removal of the first ten electrons of **A**.




State and explain the group of the Periodic Table that element **A** belongs to.

group number .....

explanation .....

.....

.....

[2]

**(b)** Silicon is found in many compounds in the Earth's crust. Silicon has only three naturally occurring isotopes, $^{28}Si$, $^{29}Si$ and $^{30}Si$.

**(i)** The table shows data for $^{28}Si$, $^{29}Si$ and $^{30}Si$.

| | $^{28}Si$ | $^{29}Si$ | $^{30}Si$ |
|---|---|---|---|
| relative isotopic mass | 28.0 | 29.0 | 30.0 |

A sample of silicon contains 92.2% $^{28}Si$. The total percentage abundance of $^{29}Si$ and $^{30}Si$ in the sample is 7.8%.

The relative atomic mass, $A_r$, of silicon in the sample is 28.09.

Calculate the percentage abundance of $^{30}Si$.

Give your answer to **one** decimal place.

percentage abundance of $^{30}Si$ = ..... %
[3]

**(ii)** Silicon reacts with nitrogen gas to form $Si_3N_4$.

$Si_3N_4$ is a solid with a melting point of 1900 °C. It is insoluble in water and does not conduct electricity when molten.

Suggest the type of bonding in **and** structure of $Si_3N_4$. Explain your answer.

.....

.....

.....

.....

..... [3]

**(c)** Sulfur-containing compounds, such as $C_2H_5SH$, are found in fossil fuels, and produce $SO_2$ when they are burned.

**(i)** Write the equation to show the complete combustion of $C_2H_5SH$.

..... [1]

**(ii)** State why the presence of $SO_2$ in the atmosphere has environmental consequences. Describe **one** of the consequences on the environment.

.....

.....

..... [2]

**(d)** $SO_2$ can react with ozone, $O_3$, to form $SO_3$ in two different reactions.

**(i)** In one reaction, $SO_2$ reacts with $O_3$ until a dynamic equilibrium is established.

$$SO_2(g) + O_3(g) \rightleftharpoons SO_3(g) + O_2(g)$$

State and explain the effect of an increase in pressure on the composition of the equilibrium mixture.

.....

.....

..... [2]

**(ii)** In the other reaction, a different equilibrium is established at 300 K as shown.

$$3SO_2(g) + O_3(g) \rightleftharpoons 3SO_3(g) \qquad \Delta H = +462.3\,kJ\,mol^{-1}$$

Suggest a temperature needed to increase the yield of $SO_3$ at equilibrium.

Explain your answer.

.....

.....

..... [2]

[Total: 19]



**[Turn over**

**2** Oxygen is the most abundant element in the Earth's crust. It reacts with other elements to form stable compounds, ions and molecules.

**(a)** Complete the table to give the formulae and acid/base behaviour of some of the oxides of the Period 3 elements.

| element | sodium | aluminium | silicon | phosphorus | sulfur |
|---|---|---|---|---|---|
| formula of oxide | $Na_2O$ | | | | $SO_3$ |
| acid/base behaviour | | amphoteric | | | |

[2]

**(b)** Group 2 elements form stable hydroxides, with general formula $M(OH)_2$, where M is the Group 2 element.

**(i)** Beryllium hydroxide, $Be(OH)_2$, is an amphoteric compound that shows similar chemical reactions to aluminium oxide.

State the meaning of the term *amphoteric*.

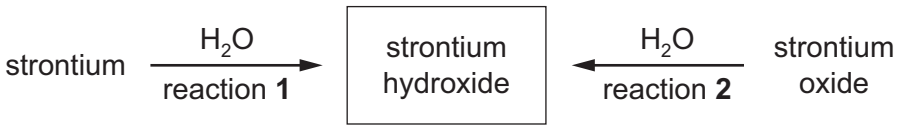
.....

..... [1]

**(ii)** Write an **ionic** equation for the reaction of magnesium hydroxide, $Mg(OH)_2$, with hydrochloric acid.

..... [1]

**(iii)** Two methods of preparing strontium hydroxide are shown.




State **one** difference between the observations you would make for reaction **1** and reaction **2**.

.....

.....

..... [1]

**(iv)** State how the solubility of the Group 2 hydroxides changes down the group.

..... [1]

**(c)** Sodium peroxide, $Na_2O_2$, reacts with $CO_2$.

$$Na_2O_2(s) + CO_2(g) \rightarrow Na_2CO_3(s) + \tfrac{1}{2}O_2(g)$$

The partial pressure of $CO_2(g)$ in a 0.500 $dm^3$ sample of air is 5.37 kPa at 20 °C.

**(i)** Calculate the amount, in moles, of $CO_2(g)$ present in the sample of air at 20 °C.

amount of $CO_2(g)$ = ..... mol [2]

**(ii)** Calculate the mass of $Na_2O_2(s)$ that would react fully with the amount of $CO_2(g)$ calculated in **(i)**.

mass of $Na_2O_2(s)$ = ..... g [1]

**(iii)** The peroxide ion, $O_2^{2-}$, has a single covalent bond between the two oxygen atoms. Each oxygen atom carries a negative charge.

Draw a 'dot-and-cross' diagram for the peroxide ion. Show outer electrons only.

[2]

[Total: 11]

**3** A series of reactions for phosphorus and its compounds is shown.

$$P \xrightarrow[\text{reaction } \mathbf{1}]{\text{excess } Cl_2} PCl_5 \xrightarrow[\text{reaction } \mathbf{2}]{H_2O} H_3PO_4 \xrightarrow[\text{reaction } \mathbf{3}]{NH_3} (NH_4^+)(H_2PO_4^-)$$

**(a) (i)** State what you would observe in reaction **1**.

.....

..... [1]

**(ii)** State the type of reaction that occurs in reaction **2**.

..... [1]

**(iii)** $H_3PO_4$ can be produced by direct reaction of phosphorus with nitric acid.

$$P + 5HNO_3 \rightarrow H_2O + 5NO_2 + H_3PO_4$$

Use oxidation numbers to show that this reaction is a redox reaction.

.....

.....

..... [2]

**(b)** Reaction **3** is a neutralisation reaction in which $NH_3$ acts as a base.

**(i)** Explain how $NH_3$ acts as a base in reaction **3**.

.....

..... [1]

**(ii)** Draw the three-dimensional shape of the ammonium ion, $NH_4^+$. Give the bond angle.

bond angle = ..... ° [1]

**(iii)** State the industrial importance of compounds such as $(NH_4^+)(H_2PO_4^-)$.

..... [1]

**(c)** $PCl_5$ can be used to convert alcohols to halogenoalkanes.

**(i)** Write an equation for the reaction of $C_2H_5OH$ with $PCl_5$ to form $C_2H_5Cl$.

..... [1]

**(ii)** State the type of reaction in **(i)**.

..... [1]

**(iii)** Halogenoalkanes can also be prepared by reacting alcohols with hydrogen halides, such as HCl and HI.

- HCl is prepared using NaCl and concentrated $H_2SO_4$.
- HI is prepared by reacting NaI with concentrated $H_3PO_4$.

Suggest why HI is **not** prepared by the reaction of NaI with concentrated $H_2SO_4$.

.....

.....

..... [2]

**(iv)** The rate of the hydrolysis reaction of halogenoalkanes with NaOH(aq) is dependent on the halogen that is bonded to carbon.

State and explain the order of reactivity when NaOH(aq) reacts separately with $C_2H_5Cl$, $C_2H_5Br$ and $C_2H_5I$.

.....

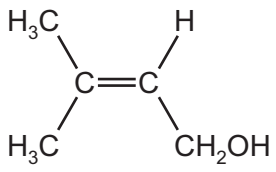
.....

..... [2]

[Total: 13]

**4** Prenol is a naturally occurring organic molecule found in many fruits. It contains both an alkene and an alcohol functional group.

prenol

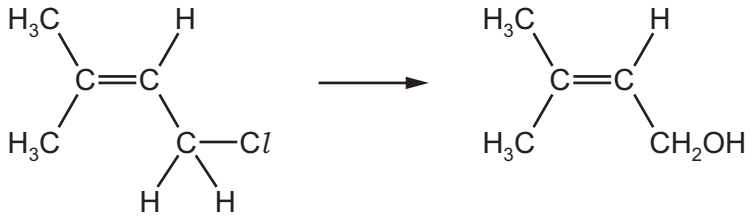


**(a)** Prenol can be formed by the reaction of **G** with NaOH(aq).

Complete the diagram to show the mechanism of the reaction between **G** and NaOH(aq) to form prenol.

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

**G** prenol



[2]

**(b)** Prenol reacts with steam to form a mixture of three isomers, **J**, **K** and **L**, of molecular formula $C_5H_{12}O_2$.

**(i)** When **J** is heated with excess acidified potassium dichromate(VI) it forms an organic product which shows no reaction with 2,4-DNPH.

Draw the structure of **J**.

[1]

**K** and **L** are stereoisomers with molecular formula $C_5H_{12}O_2$.

**K** and **L** both react when heated with excess acidified potassium dichromate(VI) to form **M**, $C_5H_8O_3$.

**M** forms an orange precipitate on reaction with 2,4-DNPH.

**(ii)** Give the structural formula of **K** and **L**.

..... [1]

**(iii)** Name the type of stereoisomerism shown by **K** and **L**.

..... [1]

**(iv)** Give the balanced equation to represent the reaction of **K**, $C_5H_{12}O_2$, with acidified potassium dichromate(VI) to form **M**, $C_5H_8O_3$.

Use [O] to represent an atom of oxygen provided by the oxidising agent.

..... [1]

**(c) (i)** Prenol contains an alkene functional group.

Describe a chemical test to confirm the presence of an alkene functional group. Give the result of the test.

.....

..... [1]

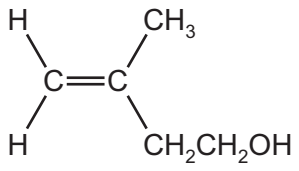
**(ii)** Prenol can be polymerised to form poly(prenol).

Draw **one** repeat unit of poly(prenol).

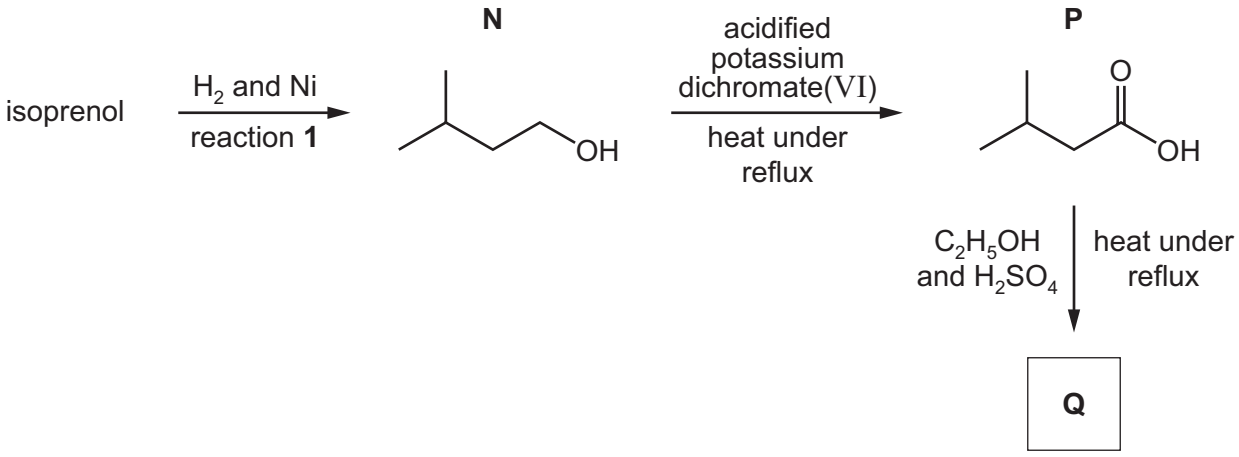
[1]

**(d)** Isoprenol is a structural isomer of prenol.

isoprenol




The series of reactions shows how isoprenol can be used to form **Q**, a sweet-smelling liquid.




**(i)** Give the name of **N**.

..... [1]

**(ii)** Isoprenol is a liquid.

Ni acts as a catalyst for reaction **1**.

Identify the type of catalysis shown by Ni in reaction **1**.

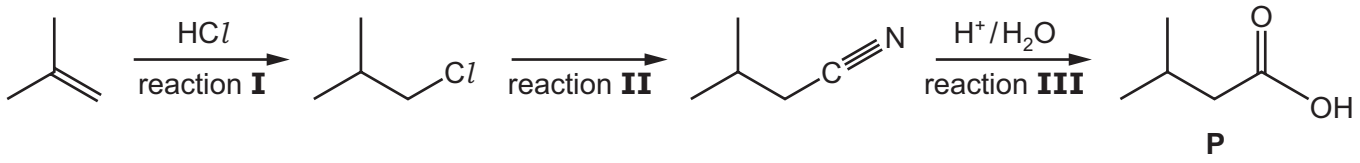
..... [1]

**(iii)** Draw the **skeletal** formula of **Q** and suggest one commercial use of **Q**.

**Q**

commercial use .....
[2]

**(e)** **P** can be produced as shown.




**P**

**(i)** The progress of reaction **I** can be monitored using infra-red spectroscopy.

One absorption that can be used to monitor the progress of this reaction is that of C–Cl at 730 $cm^{-1}$.

Identify another absorption that can be used to monitor the progress of this reaction. In your answer, you should refer to the specific bond and its corresponding absorption range in wavenumbers.

.....

..... [1]

**(ii)** State the reagent(s) needed for reaction **II**.

..... [1]

**(iii)** Name the type of reaction that occurs in reaction **III**.

..... [1]

**(iv)** The yield of reaction **I** is very low.

Explain why.

.....

.....

..... [2]

[Total: 17]

**BLANK PAGE**

**BLANK PAGE**

**BLANK PAGE**