Cambridge International AS & A Level

**Cambridge International Examinations**
Cambridge International Advanced Subsidiary and Advanced Level

| | |
|---|---|
| CANDIDATE NAME | |
| CENTRE NUMBER | |
| CANDIDATE NUMBER | |

*8530346621*

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

Paper 2 AS Level Structured Questions **May/June 2017**

**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 **11** printed pages and **1** blank page.


© UCLES 2017

CAMBRIDGE International Examinations

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

**1** The composition of atoms and ions can be determined from knowledge of atomic number, nucleon number and charge.

**(a)** Complete the table.

| atomic number | nucleon number | number of electrons | number of protons | number of neutrons | symbol |
|---|---|---|---|---|---|
| 3 | | 2 | | | $^{6}_{3}Li^{+}$ |
| | | 23 | 26 | 32 | |

[2]

**(b)** Boron occurs naturally as a mixture of two stable isotopes, $^{10}B$ and $^{11}B$. The relative isotopic masses and percentage abundances are shown.

| isotope | relative isotopic mass | abundance / % |
|---|---|---|
| $^{10}B$ | 10.0129 | 19.78 |
| $^{11}B$ | to be calculated | 80.22 |

**(i)** Define the term *relative isotopic mass*.

.....

..... [2]

**(ii)** Calculate the relative isotopic mass of $^{11}B$.

Give your answer to **six** significant figures. Show your working.

[2]

[Total: 6]

© UCLES 2017

**2** Nitrogen gas, $N_2$, is very unreactive.

**(a)** Explain why nitrogen gas is so unreactive.

.....

.....

..... [2]

**(b)** Despite the low reactivity of $N_2$, oxides of nitrogen occur in the atmosphere through both natural and man-made processes.

**(i)** Explain why oxides of nitrogen can be produced by internal combustion engines.

.....

.....

..... [2]

**(ii)** State and explain, using a suitable equation, how oxides of nitrogen produced by internal combustion engines can be prevented from reaching the atmosphere.

.....

..... [2]

**(iii)** State the role of nitrogen dioxide, $NO_2$, in the formation of acid rain by oxides of sulfur. Write suitable equations to explain this role.

role .....

equation 1 .....

equation 2 .....

[3]

**(iv)** Suggest an equation to show how $NO_2$ can contribute **directly** to acid rain.

..... [1]

**(c)** Explain how the uncontrolled use of nitrate fertilisers on land can lead to a severe reduction in water quality in rivers.

.....

.....

.....

..... [3]

[Total: 13]

© UCLES 2017



**[Turn over**

**3** The hydrogen halides, HC*l*, HBr and HI, can undergo thermal decomposition.
In a sealed container an equilibrium is established according to the equation shown.

$$2HX(g) \rightleftharpoons H_2(g) + X_2(g) \qquad \text{(where X = C}l\text{, Br or I)}$$

**(a)** Some bond energies are shown in the table.

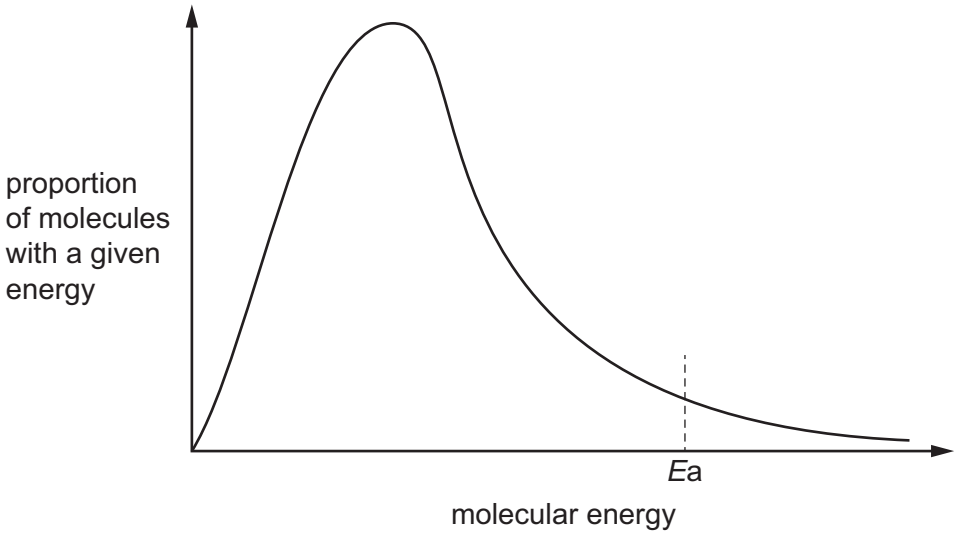
| | bond energy / kJ mol$^{-1}$ |
|---|---|
| H–Br | 366 |
| H–H | 436 |
| Br–Br | 193 |

Use these data to calculate a value for the enthalpy change, $\Delta H$, for the thermal decomposition of hydrogen bromide, HBr, according to the equation shown.

$\Delta H$ = ..... kJ mol$^{-1}$ [1]

**(b)** At a temperature of 700 K a sample of HBr is approximately 10% decomposed. Changing the temperature affects both the rate of decomposition of HBr and the percentage that decomposes.

The Boltzmann distribution for a sample of HBr at 700 K is shown. *E*a represents the activation energy for the reaction.




**(i)** Using the same axes, sketch a second curve to indicate the Boltzmann distribution at a higher temperature. [2]

**(ii)** With reference to the curves, state and explain the effect of increasing temperature on the **rate** of decomposition of HBr.

.....

.....

.....

..... [3]

**(iii)** The decomposition of HBr is endothermic.

State the effect of increasing temperature on the **percentage** of HBr that decomposes. Use Le Chatelier's principle to explain your answer.

.....

.....

.....

..... [3]

**(iv)** At 700 K HBr is approximately 10% decomposed but hydrogen iodide, HI, is approximately 20% decomposed.

Explain this difference with reference to bond strengths and the factors that affect them.

.....

.....

.....

..... [3]

© UCLES 2017

**[Turn over**

**(c)** At temperatures above 1500 K, HC$l$ will decompose.

A sample of 0.300 mol of HC$l$ decomposed in a sealed container.

The resulting equilibrium mixture was found to contain $1.50 \times 10^{-2}$ mol of C$l_2$.

**(i)** Calculate the amounts, in mol, of $H_2$ and HC$l$ present in the equilibrium mixture.

$H_2$ = ..... mol

HC$l$ = ..... mol
[2]

**(ii)** Calculate the mole fraction of each gas in the equilibrium mixture.

mole fraction of HC$l$ = .....

mole fraction of $H_2$ = .....

mole fraction of C$l_2$ = .....
[1]

**(d)** In another experiment under different conditions, an equilibrium mixture was produced with mole fractions for each species as shown.

| species | mole fraction |
|---|---|
| HC$l$ | 0.88 |
| $H_2$ | 0.06 |
| C$l_2$ | 0.06 |

**(i)** Write the expression for the equilibrium constant, $K_p$, for the decomposition of HC$l$.

$$2HCl(g) \rightleftharpoons H_2(g) + Cl_2(g)$$

$K_p$ =

[1]

**(ii)** Explain why the total pressure of the system does **not** need to be known for $K_p$ to be calculated for this experiment.

.....

..... [1]

**(iii)** Calculate the value of $K_p$ for this experiment.

$K_p$ = ..... [1]

[Total: 18]

**4** **(a)** The hydrocarbons **A**, $C_4H_{10}$, and **B**, $C_4H_8$, are both unbranched.

**A** does **not** decolourise bromine.

**B** decolourises bromine and shows geometrical isomerism.

**(i)** Draw the skeletal formula of **A**.

**A**

[1]

**(ii)** The hydrocarbon **A**, $C_4H_{10}$, has a branched isomer.

Suggest why unbranched **A** has a higher boiling point than its branched isomer.

.....

.....

.....

.....

..... [2]

**(iii)** Give the structural formula of **B**.

..... [1]

**(iv)** Explain why **B** shows geometrical isomerism.

.....

.....

.....

..... [2]

© UCLES 2017

**(v)** Draw the mechanism of the reaction of **B** with bromine, $Br_2$.
Include all necessary charges, dipoles, lone pairs and curly arrows.

[4]

**(vi)** Explain the origin of the dipole on $Br_2$ in this mechanism.

.....

.....

..... [1]

**(b)** The alcohols **C** and **D** are isomers of each other with molecular formula $C_4H_{10}O$. Both isomers are branched.

When **C** is heated under reflux with acidified potassium dichromate(VI) no colour change is observed.

When **D** is heated under reflux with acidified potassium dichromate(VI) the colour of the mixture changes from orange to green and **E**, $C_4H_8O_2$, is produced.

**E** reacts with aqueous sodium carbonate to form carbon dioxide gas.

**(i)** Identify **C**, **D** and **E**.

| **C** | **D** | **E** |
|---|---|---|
| | | |

[3]

**(ii)** Write the equation for the reaction between **E** and aqueous sodium carbonate.

..... [1]

**(c)** The isomers **F** and **G**, $C_5H_{10}O$, both form an orange precipitate when reacted with 2,4-DNPH.

**F** is unbranched and reacts with alkaline aqueous iodine to produce a yellow precipitate.

**G** does not react with alkaline aqueous iodine. It contains a chiral centre and produces a silver mirror when warmed with Tollens' reagent.

**(i)** Name the yellow precipitate produced by the reaction between **F** and alkaline aqueous iodine.

..... [1]

**(ii)** Give the structural formula of **F** and of **G**.

**F** .....

**G** .....
[2]

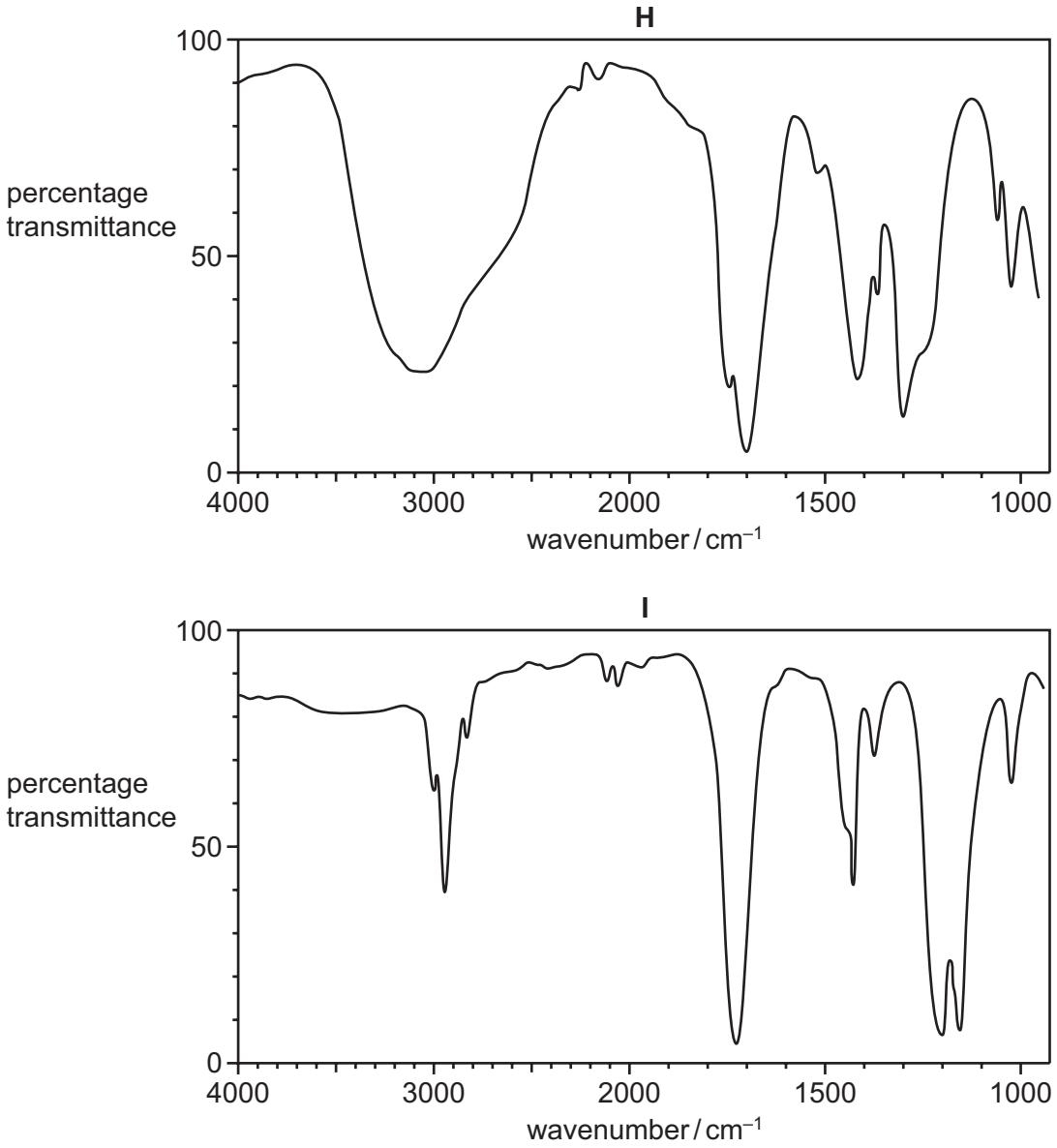
**(iii)** Explain the meaning of the term *chiral centre*.

.....

..... [1]

© UCLES 2017

**(d)** **H** and **I** are isomers with molecular formula $C_2H_4O_2$. The infra-red spectra of isomers **H** and **I** are shown.




**(i)** Identify the bonds responsible for the principal peaks above 1500 $cm^{-1}$ in each spectrum.

spectrum of **H** .....

.....

spectrum of **I** .....

.....

[2]

**(ii)** Name **H** and **I**.

**H** .....

**I** .....

[2]

[Total: 23]

© UCLES 2017

**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 International Examinations Copyright Acknowledgements Booklet. This is produced for each series of examinations and is freely available to download at www.cie.org.uk after the live examination series.

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