Cambridge International AS & A Level

Cambridge International Examinations
Cambridge International Advanced Subsidiary and Advanced Level

CANDIDATE NAME									
CENTRE NUMBER						CANDIDATE NUMBER			

* 9 4 4 7 6 2 0 8 9 5 *

CHEMISTRY **9701/22**

Paper 2 AS Level Structured Questions **February/March 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 **15** printed pages and **1** blank page.

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[Turn over

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

1 **(a)** The table shows information about some of the elements in the third period.

element	Na	Mg	A*l*	P	S	C*l*
atomic radius / nm	0.186	0.160	0.143	0.110	0.104	0.099
radius of most common ion / nm	0.095	0.065	0.050	0.212	0.184	0.181
maximum oxidation number of the element in its compounds	+1					+7

(i) Complete the table to show the maximum oxidation number of each element in its compounds. [1]

(ii) Explain why the atomic radius of elements in the third period decreases from Na to C*l*.

.....

.....

.....

.....

..... [3]

(iii) The radius of the most common ion of Mg is much smaller than the radius of the most common ion of S.

Identify both ions and explain the difference in their radii.

.....

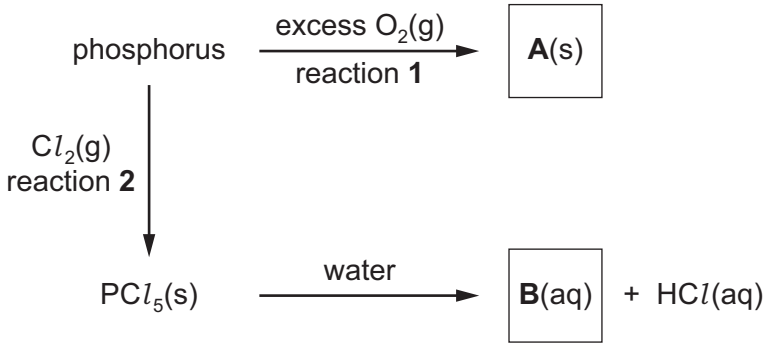
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..... [2]

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(b) Phosphorus is a non-metal in the third period. It reacts vigorously with excess oxygen but slowly with chlorine.

Some reactions of phosphorus are shown.



(i) Write an equation to represent reaction **1**, the formation of compound **A**.

..... [1]

(ii) Give **two** observations you could make in reaction **2**.

1. .....

2. .....

[2]

(iii) Name compound **B**.

..... [1]

(c) Cerium is a lanthanoid metal that shows similar chemical reactions to some elements in the third period. Most of cerium's compounds contain Ce^{3+} or Ce^{4+} ions.

(i) Cerium shows the same structure and bonding as a typical metal.

Draw a labelled diagram to show the structure and bonding in cerium.

[2]

(ii) Cerium(IV) oxide, CeO_2, is a ceramic.

Suggest **two** physical properties of cerium(IV) oxide.

1. .....

2. .....

[2]

(iii) A naturally occurring sample of cerium contains only **four** isotopes. Data for **three** of the isotopes are shown in the table.

isotope	^{136}Ce	^{138}Ce	^{140}Ce	^{142}Ce
relative isotopic mass	135.907	137.906	139.905	to be calculated
percentage abundance	0.185	0.251	88.450	to be calculated

The A_r of the sample is 140.116.

Use these data to calculate the **relative isotopic mass** of the fourth isotope in this sample of cerium.

Give your answer to **three** decimal places.

relative isotopic mass = ... [3]

[Total: 17]

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[Turn over

2 Hydrogen halides are compounds formed when halogens (Group 17 elements) react with hydrogen. The bond polarity of the hydrogen halides decreases from HF to HI.

Some relevant data are shown in the table.

hydrogen halide	HF	HC*l*	HBr	HI
boiling point / °C	19	–85	–67	–35
H–X bond energy / kJ mol^{-1}	562	431	366	299

(a) (i) Explain the meaning of the term *bond polarity*.

.....

.....

..... [1]

(ii) Suggest why the boiling point of HF is **much** higher than the boiling points of the other hydrogen halides.

.....

.....

.....

.....

..... [2]

(iii) Describe and explain the relative thermal stabilities of the hydrogen halides.

.....

.....

.....

.....

.....

..... [3]

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(b) The equation for the preparation of hydrogen chloride using concentrated sulfuric acid is shown.

$$H_2SO_4 + NaCl \rightarrow NaHSO_4 + HCl$$

(i) Use the Brønsted-Lowry theory of acids and bases to identify the base and its conjugate acid in this reaction. Explain your answer.

Brønsted-Lowry base (base-I) = ...

conjugate acid (acid-II) = ...

.....

.....

.....
[2]

(ii) Explain why the reaction of concentrated sulfuric acid and sodium iodide is **not** suitable for the preparation of hydrogen iodide.

.....

.....

.....

..... [2]

(c) Hydrogen chloride undergoes a reversible reaction with oxygen.

$$4HCl(g) + O_2(g) \rightleftharpoons 2Cl_2(g) + 2H_2O(g)$$

The reaction is carried out at 400 °C in the presence of a copper(II) chloride catalyst.

(i) Use the data in the table to calculate the overall enthalpy change of reaction.

compound	enthalpy change of formation / kJ mol^{-1}
$HCl(g)$	–92
$H_2O(g)$	–242

enthalpy change of reaction = ... kJ mol^{-1} [2]

(ii) State the **type** of catalyst used in this reaction. Explain how a catalyst is able to increase the rate of a chemical reaction.

.....

.....

.....

..... [2]

(iii) The reaction exists in dynamic equilibrium.

The reaction was repeated at 1000 °C and the same pressure.

State and explain the effect on the composition of the equilibrium mixture of the change in temperature.

.....

.....

.....

..... [2]

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(iv) When 1.60 mol of HCl are mixed in a sealed container with 0.500 mol of O_2 at 400 °C, 0.600 mol of Cl_2 and 0.600 mol of H_2O are formed.

The total pressure inside the container is 1.50×10^5 Pa.

- Calculate the amounts, in mol, of HCl and O_2 in the equilibrium mixture.

HCl = ... mol

O_2 = ... mol

- Calculate the mole fraction of Cl_2 and hence the partial pressure of Cl_2 in the equilibrium mixture.

mole fraction of Cl_2 = ...

p_{Cl_2} = ... Pa
[3]

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[Turn over

(v) In a separate experiment, an equilibrium reaction mixture was found to contain the four gases at the partial pressures shown in the table.

gas	HCl	O_2	Cl_2	H_2O
partial pressure / Pa	4.8×10^4	3.0×10^4	3.6×10^4	3.6×10^4

$$K_p = \frac{(p_{Cl_2})^2 \times (p_{H_2O})^2}{(p_{HCl})^4 \times p_{O_2}}$$

Use this information and the expression given for K_p to calculate a value for K_p. State the units of K_p.

K_p = ...

units = ...
[2]

(vi) The reaction is repeated without a catalyst.

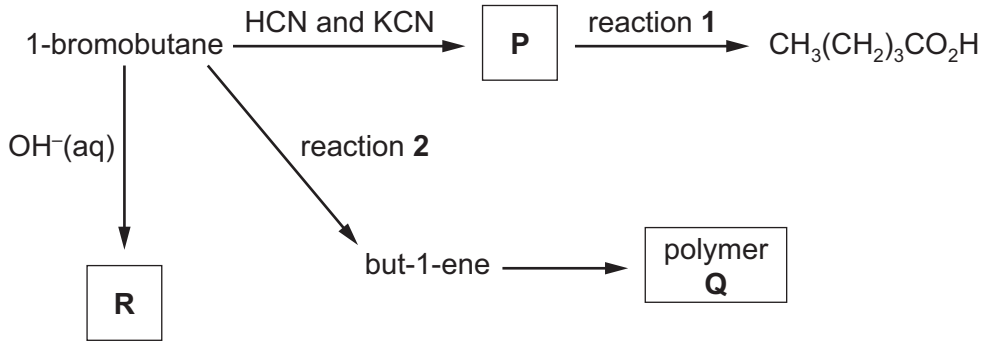
State the effect of this on K_p.

..... [1]

[Total: 22]

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3 **(a)** A series of reactions starting from 1-bromobutane is shown.



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

[1]

(ii) Identify the reagent(s) and conditions for reactions **1** and **2**.

reaction **1** .....

reaction **2** .....

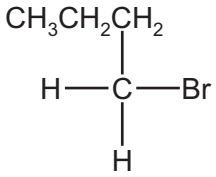
[2]

(iii) Draw the structure of the repeat unit of polymer **Q**.

[2]

(b) Complete the reaction scheme to show the mechanism of the reaction of 1-bromobutane with OH^-(aq) to produce **R**.

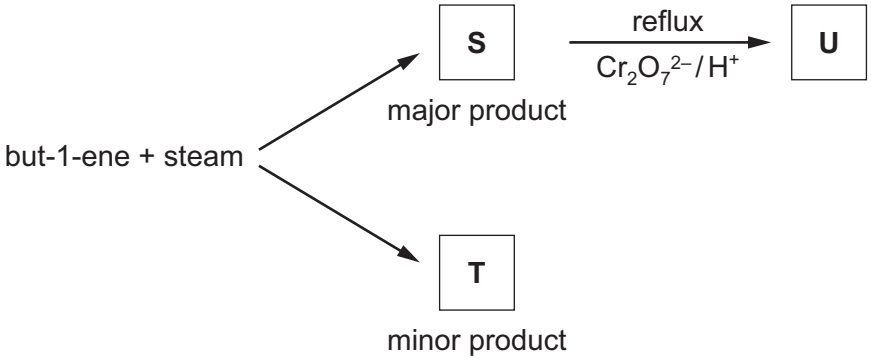
Include all necessary charges, dipoles, lone pairs and curly arrows and the structure of **R**.



^-OH

[3]

(c) But-1-ene reacts with steam as shown to form a mixture of two structural isomers, **S** and **T**.



S can be oxidised with acidified potassium dichromate(VI) to form compound **U**.
S and **U** both react with alkaline aqueous iodine.

(i) Identify the *type of reaction* that occurs when but-1-ene reacts with steam.

..... [1]

(ii) State what can be deduced about the structure of **S** from its reaction with alkaline aqueous iodine.

..... [1]

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(iii) Explain why **S** is the major product of the reaction of but-1-ene with steam.

.....

.....

.....

.....

..... [2]

(iv) Draw the **skeletal** formulae of **S**, **T** and **U**.

S

T

U

[3]

(v) Write an equation to represent the oxidation of **S** to **U** by acidified potassium dichromate(VI).

You should use [O] to represent the oxidising agent.

..... [1]

(d) $CH_3(CH_2)_3CO_2H$ is a colourless liquid with an unpleasant odour.

It reacts with methanol in the presence of an acid catalyst to produce an organic product **V**, which has a pleasant fruity smell.

(i) Name **V**.

..... [1]

(ii) A student analysed $CH_3(CH_2)_3CO_2H$, methanol and **V** using infra-red spectroscopy. The spectra were returned to the student without labels.

Identify which of the infra-red spectra, X, Y or Z, corresponds to **V**.

compound	$CH_3(CH_2)_3CO_2H$	methanol	**V**
spectrum			

Explain your answer with reference to relevant features of the **three** spectra in the region above 1500 cm^{-1}.

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.....

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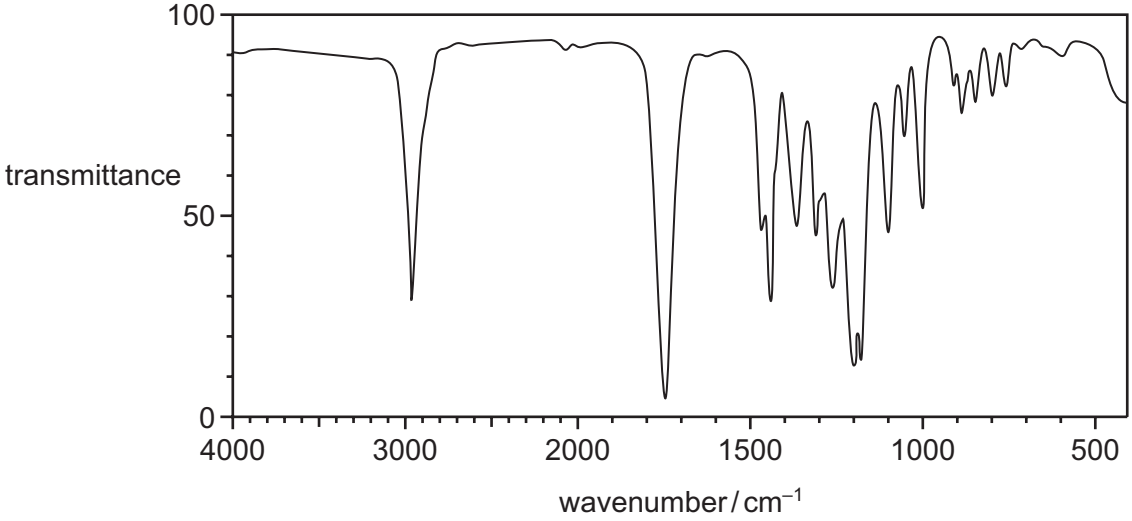
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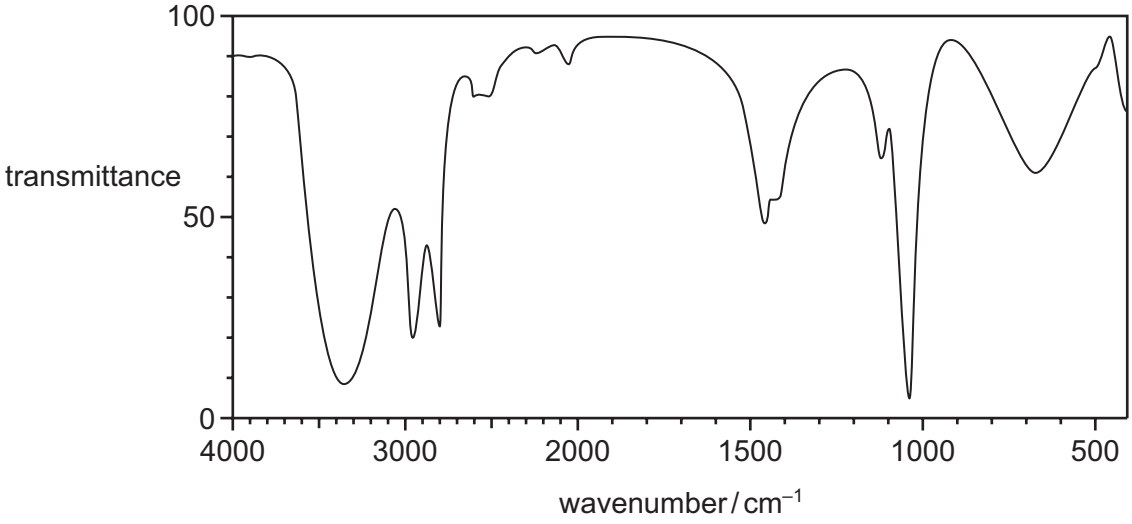
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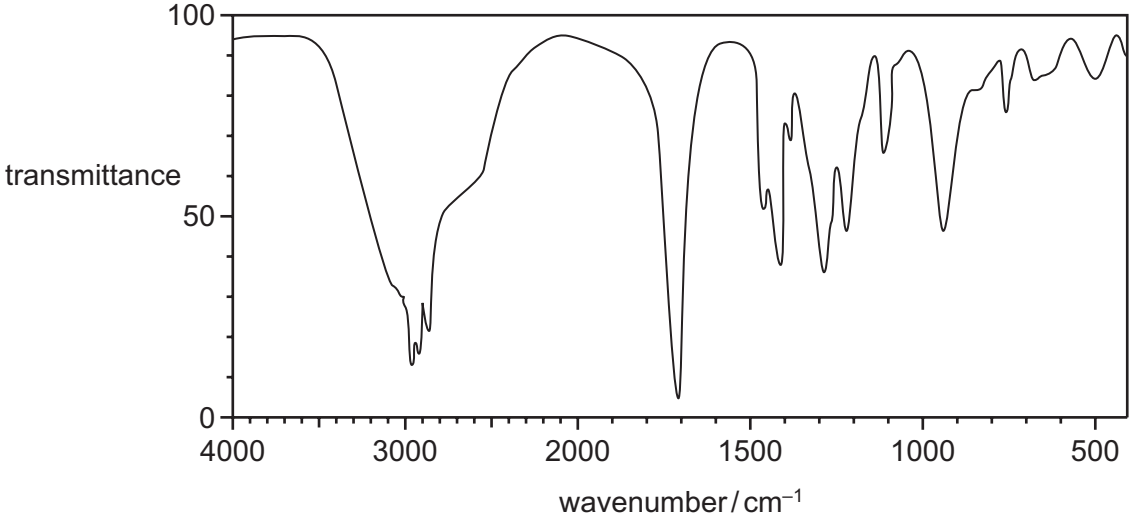
infra-red spectrum X



infra-red spectrum Y



infra-red spectrum Z



[Total: 21]

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