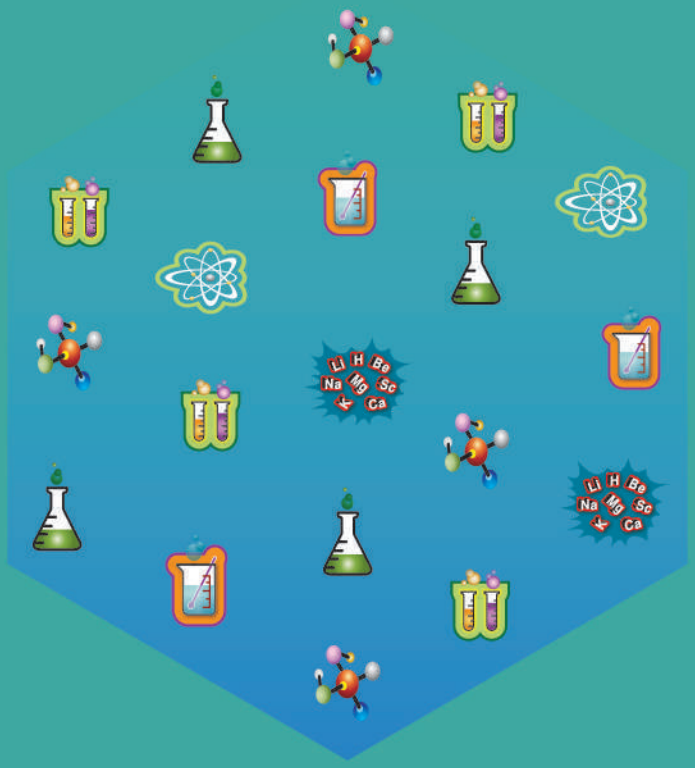
Cambridge International AS Level Chemistry

Question Papers

Paper #2



catadu.com

Non-traditional blended
learning institute.

CONTENTS

9701_s21_qp_22
9701_s20_qp_22
9701_s19_qp_22
9701_s18_qp_22
9701_s17_qp_22
9701_s16_qp_22
9701_s15_qp_22
9701_s14_qp_22
9701_s13_qp_22
9701_s12_qp_22
9701_s11_qp_22
9701_s10_qp_22

9701_w21_qp_22
9701_w20_qp_22
9701_w19_qp_22
9701_w18_qp_22
9701_w17_qp_22
9701_w16_qp_22
9701_w15_qp_22
9701_w14_qp_22
9701_w13_qp_22
9701_w12_qp_22
9701_w11_qp_22
9701_w10_qp_22

Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

6703041968

CHEMISTRY **9701/22**

Paper 2 AS Level Structured Questions **May/June 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. Any blank pages are indicated.

[Turn over

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

1 A Group 2 metal combines with bromine to form a crystalline solid, **M**Br_2.

Excess aqueous $AgNO_3$ is added to a solution of **M**Br_2 and a precipitate forms. The mixture is filtered. The precipitate is dried and the mass of the precipitate is recorded.

(a) State the formula and colour of the precipitate.

..... [2]

(b) Complete the equation to represent the reaction between **M**Br_2 and $AgNO_3$.

.....**M**Br_2 + ...$AgNO_3$ → ..... [1]

(c) A 0.250 g sample of pure **M**Br_2 contains 8.415×10^{-4} mol **M**Br_2.

Calculate the relative formula mass, M_r, of **M**Br_2. Use this to identify **M**.

Show your working.

M_r = ...

M = ...
[3]

(d) A sample of **M**Br_2 is dissolved in water. Chlorine gas is then bubbled into the solution.

(i) Describe the observations for this reaction.

.....

..... [1]

(ii) Name the type of reaction that occurs when **M**Br_2 reacts with chlorine gas.

..... [1]

(e) Compound **Y** is a pure **insoluble** solid which contains halide ions.

A single reagent is added directly to compound **Y** to determine the halide ion present.

Identify the reagent added. State the observation which would confirm that **Y** contains bromide ions.

reagent .....

observation .....
[2]

(f) Separate 1.0 g samples of three different magnesium salts are tested in order to identify the anion present in each sample.

(i) Explain how the action of heat is used to identify which sample is:

- $MgCO_3$
- $Mg(NO_3)_2$
- MgO.

.....

.....

.....

.....

..... [3]

(ii) Complete the electron configuration of the magnesium cation present in these salts.

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

(g) A sample of $MgCO_3(s)$ is distinguished from a sample of $Mg(OH)_2(s)$ by adding a small amount of each solid to $HCl(aq)$.

State **one** similarity and **one** difference in these two reactions.

similarity .....

.....

difference .....

.....
[2]

[Total: 16]

2 The strength of interaction between particles determines whether the substance is a solid, liquid or gas at room temperature.

(a) Lithium sulfide, Li_2S, is a crystalline solid with a melting point of 938 °C. It conducts electricity when it is molten.

(i) Give the formulae of the particles present in solid lithium sulfide.

..... [1]

(ii) Explain, in terms of the structure of the crystalline solid, why lithium sulfide has a high melting point.

.....

..... [2]

(b) Carbon monoxide, CO, is a gas at room temperature and pressure. It contains a coordinate bond.

(i) Explain what is meant by *coordinate bond*.

.....

..... [1]

(ii) Draw a 'dot-and-cross' diagram to show the arrangement of outer electrons in CO.

Show the electrons belonging to the C atom as ×.

Show the electrons belonging to the O atom as ●.

[2]

(c) Nitrogen, N_2, is also a gas at room temperature and pressure. Neither CO nor N_2 is an ideal gas.

(i) State two assumptions that are made about the behaviour of particles in an ideal gas.

1 .....

.....

2 .....

.....

[2]

(ii) Explain why N_2 does not behave as an ideal gas at very high pressures.

.....

.....

.....

..... [2]

(iii) Complete the table by naming **all** the types of intermolecular forces (van der Waals') in separate samples of $N_2(g)$ and CO(g).

	$N_2(g)$	CO(g)
number of electrons per molecule	14	14
presence of a dipole moment	✗	✓
boiling point/°C	–195.8	–191.5
intermolecular forces (van der Waals')		

[2]

(iv) Suggest why the bond in a molecule of CO contains a dipole moment.

..... [1]

[Total: 13]

[Turn over

3 A large excess of 2-bromo-2-methylpropane is added to 0.0010 mol of NaOH(aq), which contains a few drops of phenolphthalein indicator. A stopwatch is started as soon as the substances are mixed. The time taken for the pink colour to disappear is recorded.

The experiment is repeated at different temperatures, keeping all concentrations and volumes of reagents constant.

temperature / °C	time taken for pink colour to disappear / s
20	300
25	65
35	20

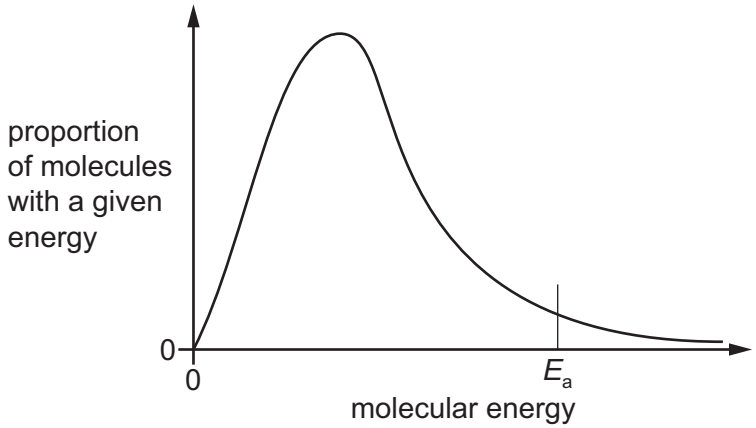
(a) Explain what is meant by the term *rate of reaction*.

.....

..... [1]

(b) The graph shows the energy distribution of molecules in a sample of 2-bromo-2-methylpropane at 25 °C.

E_a represents the activation energy for the reaction.



(i) Label the graph to show the proportion of 2-bromo-2-methylpropane molecules which have sufficient energy to react. [1]

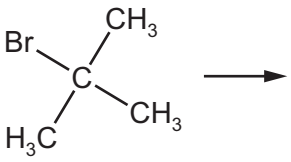
(ii) Use the same axes to sketch the distribution of energies of molecules in a sample of 2-bromo-2-methylpropane at 50 °C. [2]

(iii) State the effect of an increase in temperature on E_a for this reaction.

..... [1]

(c) (i) Draw the mechanism to show the reaction of 2-bromo-2-methylpropane with OH^-(aq). Show the intermediate formed in this reaction.

Include all charges, partial charges, lone pairs and curly arrows as appropriate.



[3]

(ii) Name the mechanism for this reaction.

..... [1]

(d) The original experiment is repeated at 25 °C with 2-chloro-2-methylpropane instead of 2-bromo-2-methylpropane. All other variables remain constant.

Predict the effect of using 2-chloro-2-methylpropane compared to 2-bromo-2-methylpropane on the time taken for the pink colour to disappear. Explain your answer.

.....

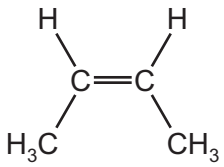
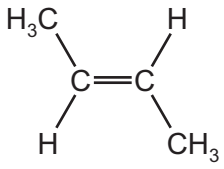
.....

..... [2]

[Total: 11]

4 **(a)** The table shows the structural formulae of four compounds, **A**, **B**, **C** and **D**, with molecular formula C_4H_8.

(i) Complete the table by giving the systematic name of **A**, **B**, **C** and **D**.

	structural formula	name
A	$CH_3CH_2CH{=}CH_2$	
B		
C		
D	$CH_2{=}C(CH_3)_2$	

[4]

(ii) Explain what is meant by *stereoisomerism*.

.....

..... [1]

(b) **W** is an alkene with formula C_4H_8. It reacts with HBr to form two possible carbocations, $CH_3C^+(H)(CH_2CH_3)$ and $H_2C^+CH_2CH_2CH_3$.

(i) Identify **W** as compound **A**, **B**, **C** or **D**.

..... [1]

(ii) Draw the skeletal formula of the major organic product formed when HBr reacts with **W**. Explain why this is the major organic product.

.....

.....

.....

[3]

(c) A sample of propan-1-ol reacts with concentrated sulfuric acid to form propene.

Identify the role of concentrated sulfuric acid in this reaction.

..... [1]

(d) Alcohol **Y** reacts completely when warmed with acidified $Cr_2O_7^{2-}$ to form **Z**.

Z is distilled from the reaction mixture as soon as it is made.

Tollens' reagent is added to a sample of **Z** and warmed. A silver mirror forms.

(i) Name the type of reaction that occurs when **Y** reacts to form **Z**.

..... [1]

(ii) Identify with a tick (✓) the functional group(s) present in **Z**.

functional group	present in **Z**
aldehyde	
ketone	
carboxylic acid	

[1]

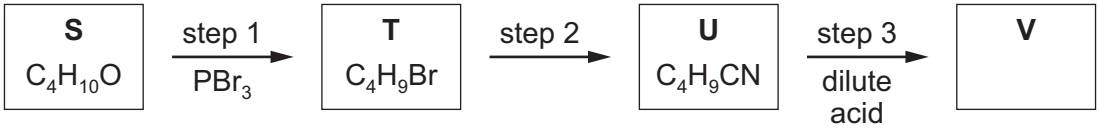
[Total: 12]

5 **S** is a secondary alcohol with molecular formula $C_4H_{10}O$.

(a) Draw the displayed formula of **S**.

[1]

(b) **S** is converted to **V** in a three-step reaction sequence.



In step 1, the secondary alcohol **S** reacts with PBr_3 to produce **T**, which has molecular formula C_4H_9Br.

(i) Give the systematic name of **T**.

..... [1]

(ii) Name the type of reaction that occurs in step 1.

..... [1]

(iii) State the reagent(s) and conditions for step 2.

.....

..... [2]

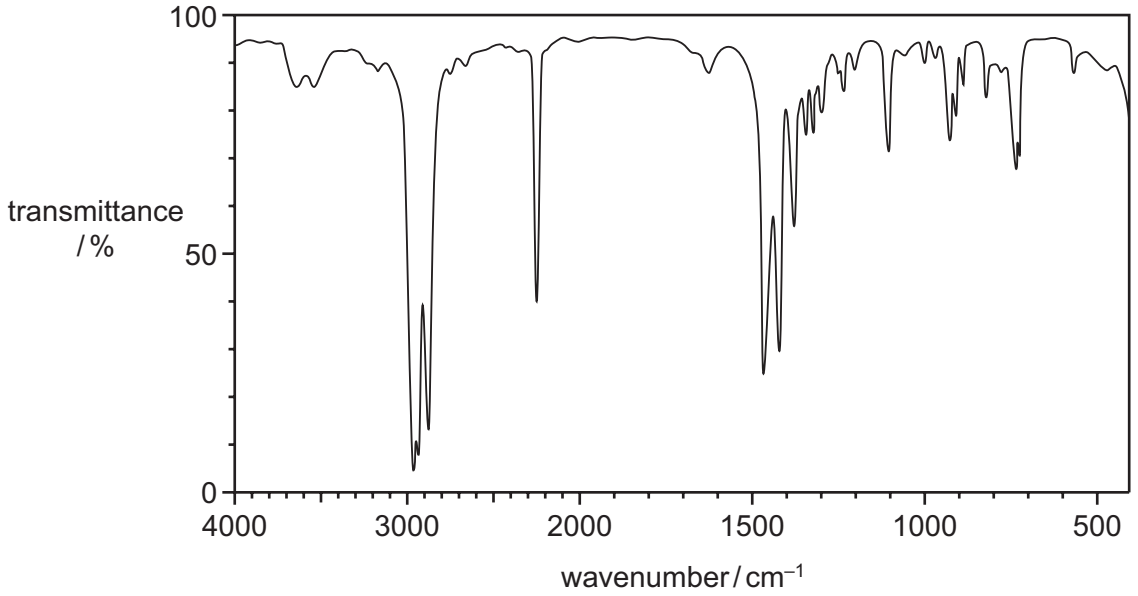
(iv) Step 3 involves heating C_4H_9CN with dilute acid to form **V**.

Complete the equation for this reaction.

$$.....C_4H_9CN + ...H^+ + ...H_2O \rightarrow .....$$ [2]

(v) An unlabelled sample contains either **S**, **T** or **U**.

The sample produces the infrared spectrum shown.



Explain how this spectrum confirms that the unknown sample contains **U**.

In your answer identify **one** relevant absorption in the infrared spectrum and the bond that corresponds to this absorption in the region above 1500 cm^{-1}.

.....

..... [1]

[Total: 8]

BLANK PAGE

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.

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.

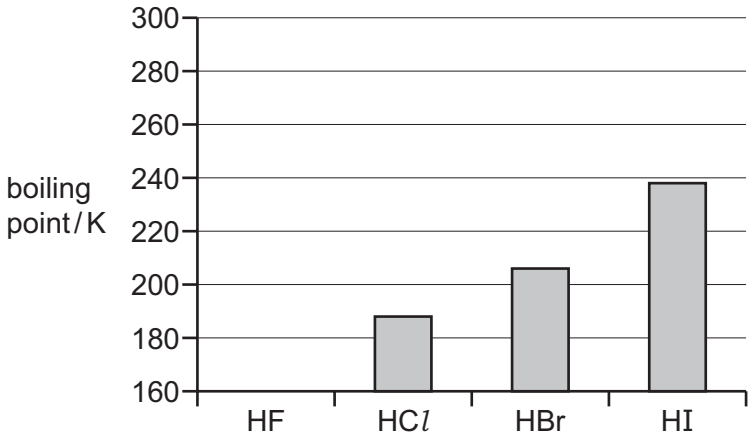
.....

.....

.....

..... [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]

(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]

[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.

.....

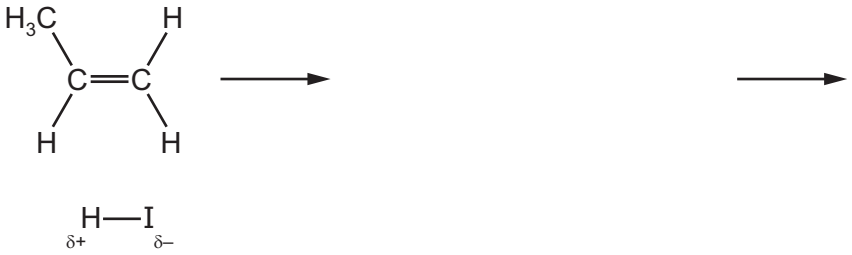
.....

.....

..... [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.

.....

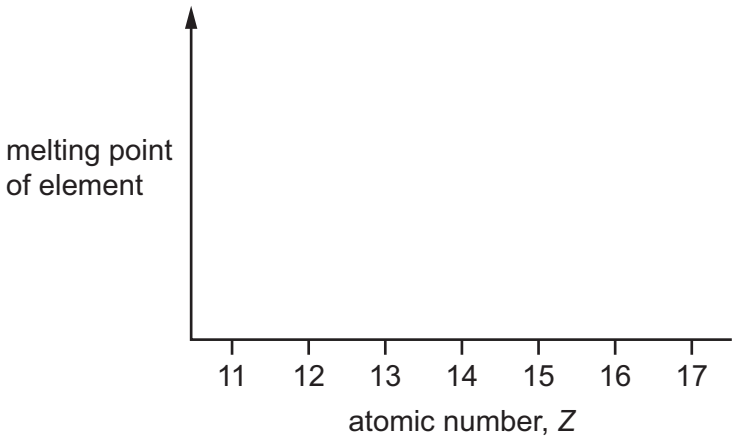
.....

.....

..... [2]

[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]

(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]

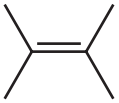
(iii) Draw a diagram that clearly shows the types of bond present in $In_2Br_6(g)$.

[2]

[Total: 17]

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

T



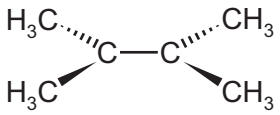
(a) Name **T**.

..... [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.

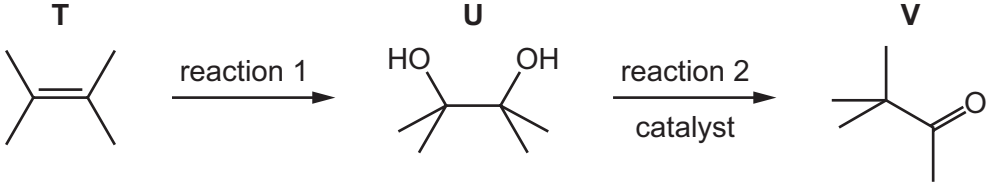


(i) On the diagram, draw the orbitals that represent the pi (π) bond that is also present in **T**. [1]

(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 .....

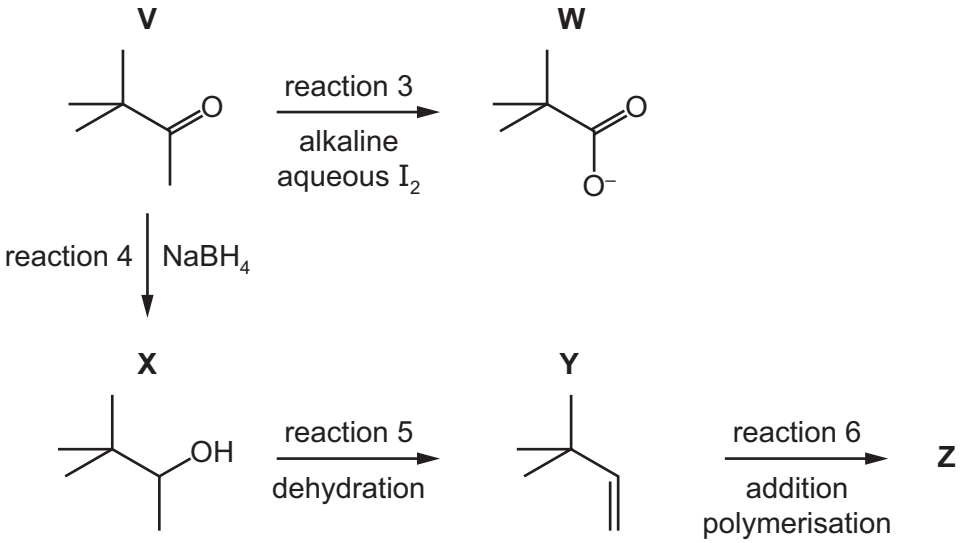
.....

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]

Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

2460007344

CHEMISTRY **9701/22**

Paper 2 AS Level Structured Questions **May/June 2020**

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

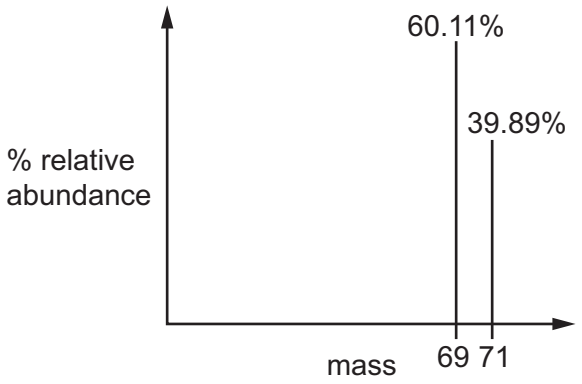
- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **12** pages. Blank pages are indicated.

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

1 Gallium is an element in Group 13.

A sample of gallium is analysed using a mass spectrometer. The mass spectrum produced is shown.



(a) Explain what is meant by the term *relative atomic mass*.

.....

..... [2]

(b) Calculate the relative atomic mass of gallium in this sample. Give your answer to 4 significant figures.

Show your working.

relative atomic mass = ... [2]

(c) Complete the table which describes a gaseous atom of gallium.

isotope	nucleon number	total number of electrons in **lowest** energy level	type of orbital which contains the electron in the **highest** energy level
^{71}Ga			

[3]

(d) When gallium is heated in excess chlorine, gallium trichloride, $GaCl_3$, is made.

Draw the shape of the gallium trichloride molecule and suggest the Cl–Ga–Cl bond angle.

shape of molecule

bond angle .....

[2]

(e) Gallium oxide, Ga_2O_3, and aluminium oxide react in the same way with HCl(aq) and with NaOH(aq).

(i) Suggest the equation for the reaction between Ga_2O_3 and HCl(aq).

..... [1]

(ii) Suggest an equation for the reaction between gallium oxide and NaOH(aq).

..... [2]

[Total: 12]

[Turn over

2 Nitric acid can be made in a 3-stage process.

Stage 1 Ammonia is oxidised by oxygen from the air, to form nitrogen monoxide and water. This reaction is carried out at 10–13 atmospheres pressure and 900 °C in the presence of a platinum catalyst.

Stage 2 Nitrogen monoxide reacts with more oxygen to form nitrogen dioxide.

$$2NO + O_2 \rightleftharpoons 2NO_2 \qquad \Delta H = -114\,kJ\,mol^{-1}$$

Stage 3 Nitrogen dioxide reacts with water to make nitric acid and nitrogen monoxide.

$$3NO_2 + H_2O \rightarrow 2HNO_3 + NO$$

(a) Write an equation to show the reaction occurring in stage 1.

..... [1]

(b) Draw a 'dot-and-cross' diagram to show the arrangement of outer electrons in a molecule of ammonia.

[1]

(c) (i) In the boxes, give the oxidation numbers of nitrogen in the nitrogen-containing species for the reaction in stage 3.

$$3NO_2 + H_2O \rightarrow 2HNO_3 + NO$$

[2]

(ii) Explain why the reaction in stage 3 is described as a disproportionation reaction. Include reference to transfer of electrons in your answer.

.....

.....

..... [2]

(d) The release of nitrogen monoxide into the atmosphere causes atmospheric pollution.

State and explain the effect of nitrogen monoxide gas in contact with moist air.

.....

..... [2]

(e) The nitric acid made in stage 3 can then be reacted with ammonia to form ammonium nitrate.

Stage 3 $3NO_2 + H_2O \rightarrow 2HNO_3 + NO$

$NH_3 + HNO_3 \rightarrow NH_4NO_3$

Calculate the volume of nitrogen dioxide, measured at room temperature and pressure, required to make 40 tonnes of ammonium nitrate.
[1 tonne = 1000 kg]

Show your working.

volume of nitrogen dioxide = ... [3]

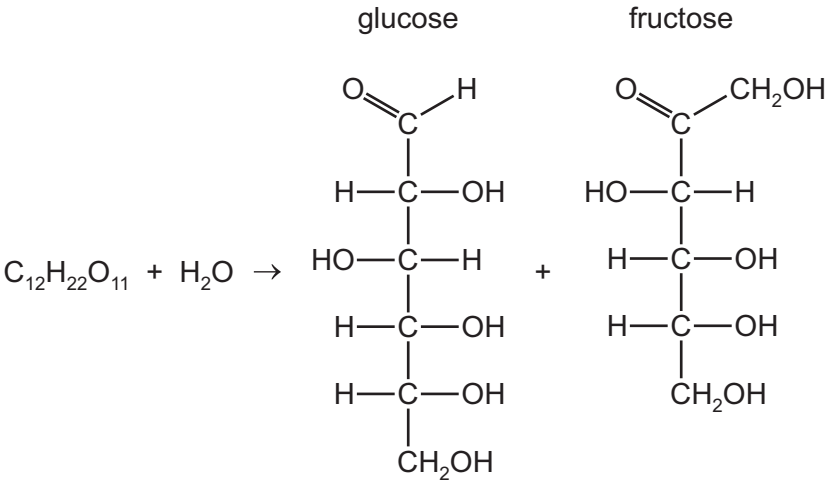
(f) State **one** use of ammonium nitrate.

..... [1]

[Total: 12]

[Turn over

3 Sucrose, $C_{12}H_{22}O_{11}$, reacts with water to form glucose and fructose in reaction **A**.



reaction **A**

(a) Suggest a name for this type of reaction.

..... [1]

(b) Explain in detail, why glucose and fructose are a pair of structural isomers. Your answer should refer specifically to these two molecules.

.....

.....

..... [2]

(c) Reaction **A** occurs faster in the presence of an enzyme. This is reaction **B**.

(i) The activation energy for reaction **B** is +29 kJ mol^{-1}.

Predict a value for the activation energy of reaction **A**.

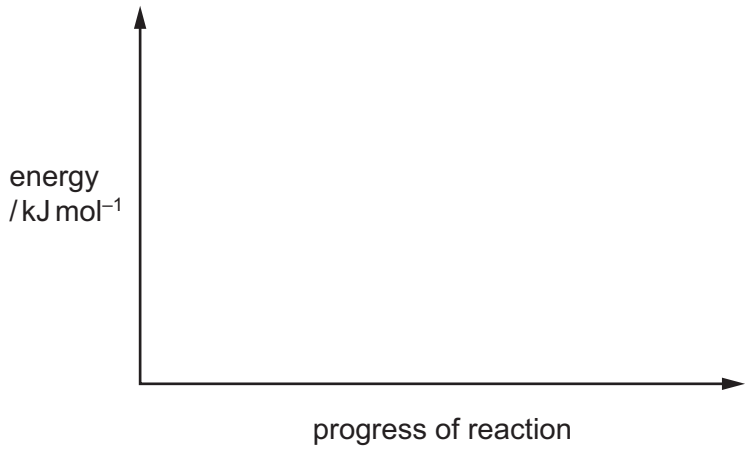
..... [1]

(ii) The enthalpy change for reaction **A** is –14 kJ mol^{-1}.

Predict a value for the enthalpy change for reaction **B**.

..... [1]

(iii) Sketch a labelled energy level diagram for reaction **B**. Use relevant values from **(c)(i)** and **(c)(ii)**.



[2]

(d) 1.00 g of sucrose, $C_{12}H_{22}O_{11}$, is completely combusted. The heat energy produced is used to increase the temperature of 250 g of water inside a calorimeter from 25.0 °C to 40.7 °C.

These data can be used to calculate the enthalpy change of combustion of sucrose.

(i) Explain what is meant by the term *enthalpy change of combustion of sucrose*.

.....

.....

..... [2]

(ii) Use the *Data Booklet* to calculate the enthalpy change, in kJ mol^{-1}, for the combustion of sucrose.
Assume that all of the heat energy produced is transferred to the water.

Show your working.

enthalpy change of combustion of sucrose = ... kJ mol^{-1}
[3]

[Total: 12]

[Turn over

4 **(a)** An unlabelled bottle contains a straight-chain halogenoalkane, **Q**. The molecular formula of **Q** is C_5H_{11}**X**, where **X** is a halogen; bromine, chlorine or iodine.

A test is carried out to identify the halogen present in **Q**.
A sample of **Q** is added to NaOH(aq) and warmed. Dilute nitric acid is then added followed by a few drops of aqueous silver nitrate. A cream precipitate is observed.

(i) Suggest the identity of **X**.

..... [1]

(ii) Write an ionic equation to describe the formation of the cream precipitate. Include state symbols.

..... [1]

(iii) Describe a further test which would confirm the identity of **X**.

test .....

expected result .....
[2]

(b) The reaction of **Q** with NaOH(aq) tends to proceed via an S_N2 mechanism.

(i) Suggest the structural formula of the straight-chain halogenoalkane **Q**.

[1]

(ii) Explain why the reaction tends to proceed via an S_N2 mechanism rather than an S_N1 mechanism.

.....

.....

..... [2]

(c) Two different halogenoalkanes, **P** and **R**, both with the molecular formula C_4H_9Cl, are separately dissolved in ethanol and heated under reflux with sodium hydroxide.

The major organic product of each of these reactions is methylpropene.

(i) Name the type of reaction occurring.

..... [1]

(ii) Write an equation, using molecular formulae, to represent the reaction occurring.

..... [1]

(iii) Draw the skeletal formula of methylpropene.

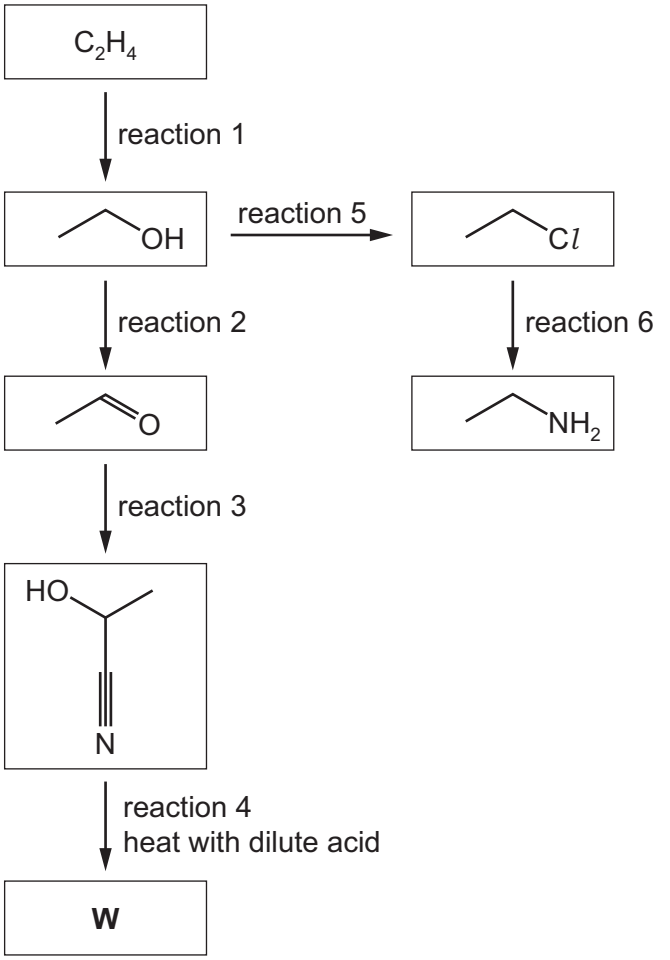
[1]

(iv) Give the names of **P** and **R**.

..... [2]

[Total: 12]

5 The reaction sequence shows how ethene, C_2H_4, can be converted into other organic molecules.



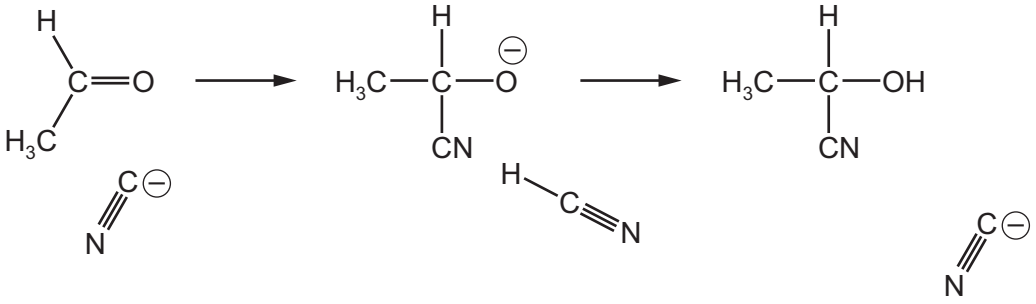
(a) Complete the table to give
- the name of the reaction mechanisms of reactions 1 and 6
- the reagents and conditions required for reactions 1, 2 and 6.

reaction	name of mechanism	**name** of reagents and conditions
1		
2		
6		

[6]

(b) In reaction 3 the organic molecule reacts with HCN and a KCN catalyst.

(i) Complete the diagram to show the mechanism of the reaction occurring.
Include all relevant dipoles, lone pairs and curly arrows in your answer.



[3]

(ii) Name the functional groups present in the product of reaction 3.

..... [2]

(c) Draw the structure of the organic molecule **W** formed in reaction 4.

[1]

[Total: 12]

BLANK PAGE

Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

1309098231

CHEMISTRY **9701/22**

Paper 2 AS Level Structured Questions **October/November 2020**

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

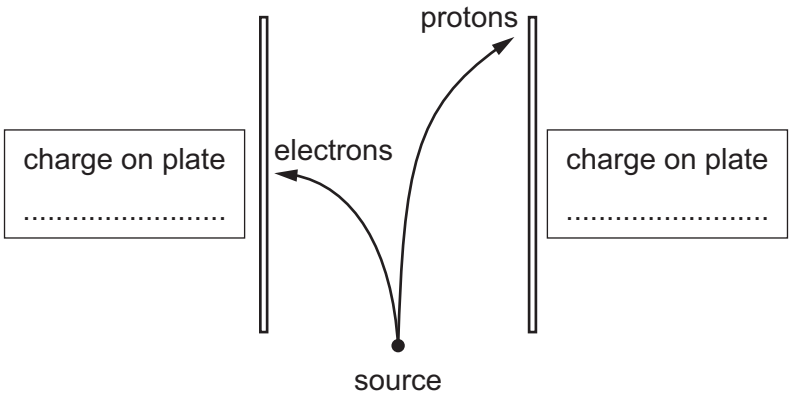
- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **16** pages. Blank pages are indicated.

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

1 Atoms contain the subatomic particles electrons, protons and neutrons. Protons and electrons were discovered by observations of their behaviours in electric fields.

(a) The diagram shows the behaviour of separate beams of electrons and protons in an electric field.



(i) Complete the diagram with the relative charge of each of the electrically charged plates. [1]

(ii) On the diagram, draw a line to show how a separate beam of neutrons from the same source behaves in the same electric field. [1]

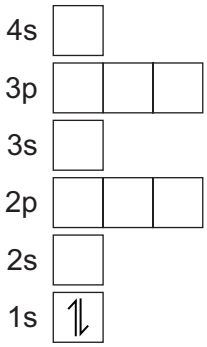
(b) Electrons in atoms up to $_{36}Kr$ are distributed in s, p and d orbitals.

(i) State the number of occupied orbitals in an isolated atom of $_{36}Kr$.

type of orbital	s	p	d
number of orbitals			

[3]

(ii) Complete the diagram to show the number and relative energies of the electrons in an isolated atom of $_{14}Si$.



[2]

(iii) The diagram shows a type of orbital.

State the total number of electrons that exist in all orbitals of this type in an atom of $_{9}F$.

..... [1]

(iv) The first ionisation energies of elements in the first row of the d block ($_{21}Sc$ to $_{29}Cu$) are very similar. For all these elements, it is a 4s electron that is lost during the first ionisation.

Suggest why the first ionisation energies of these elements are very similar.

.....

.....

.....

..... [3]

(c) *Hydron* is a general term used to represent the ions $^{1}_{1}H^{+}$, $^{2}_{1}H^{+}$ and $^{3}_{1}H^{+}$.

State, in terms of subatomic particles in the nucleus, what is the same about each of these ions and what is different.

same .....

different .....
[1]

[Total: 12]

2 The Period 3 elements, Na to S, all react with oxygen to form oxides.

(a) State the trend in acid/base behaviour of the oxides of the Period 3 elements, from Na to S.

.....

..... [1]

(b) State and explain the trend, from Na to S, in the maximum oxidation number of the Period 3 elements in their oxides.

.....

.....

..... [2]

(c) Sodium oxide and phosphorus(V) oxide both react with water.

Name the product of each reaction.

reaction	product
sodium oxide with water	
phosphorus(V) oxide with water	

[2]

(d) Explain why phosphorus(V) oxide has a low melting point of approximately 300 °C but magnesium oxide has a high melting point of approximately 2850 °C.

.....

.....

.....

.....

.....

..... [3]

(e) Aluminium oxide, Al_2O_3, reacts separately with both acids and alkalis.

(i) Write an equation for the reaction of aluminium oxide with excess aqueous hydrochloric acid.

..... [1]

(ii) Write an equation for the reaction of aluminium oxide with excess aqueous sodium hydroxide.

..... [1]

(f) Describe the lattice structure of silicon(IV) oxide.

Your answer should include reference to the arrangement of the silicon and oxygen atoms and the bonds between them.

.....

.....

.....

..... [2]

(g) Sodium oxide and silicon(IV) oxide react to form sodium silicate(IV), Na_2SiO_3.

Sodium oxide is obtained from the thermal decomposition of sodium carbonate.

Write equations for the following reactions:

(i) sodium oxide with silicon(IV) oxide

..... [1]

(ii) the thermal decomposition of sodium carbonate, forming sodium oxide and carbon dioxide.

..... [1]

[Total: 14]

[Turn over

3 PCl_5, PCl_3 and NCl_3 are halides of Group 15 elements.

(a) PCl_5 can be formed from the reaction of phosphorus with chlorine. PCl_5 has a melting point of 161 °C.

(i) Write an equation for the formation of PCl_5 from the reaction of phosphorus and chlorine.

..... [1]

(ii) State the type of structure and bonding shown by liquid PCl_5.

..... [1]

(b) A small amount of PCl_5 is added to excess water. The PCl_5 reacts vigorously to form a colourless solution.

(i) Give **one** other observation you would make when PCl_5 reacts with excess water.

..... [1]

(ii) Write the equation for the reaction of PCl_5 with excess water.

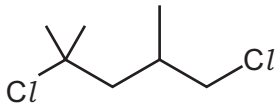
..... [1]

(iii) Estimate the pH of the resulting solution.

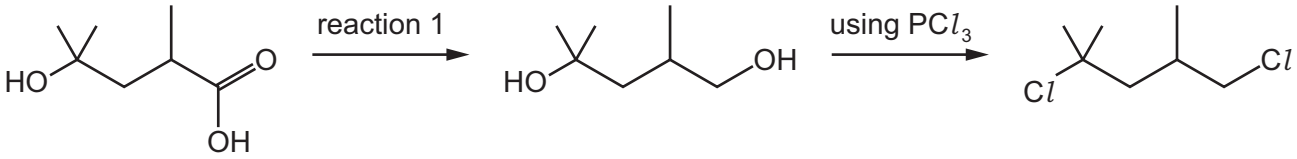
..... [1]

(c) PCl_3 is used to convert alcohols to chloroalkanes, such as compound **T**.

T



A possible synthesis of **T** is shown.



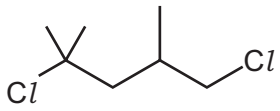
(i) Identify a reagent that could be used in reaction 1.

..... [1]

(ii) **T** exhibits optical isomerism.

Explain what is meant by the term *optical isomer* and circle any atom(s) in **T** that give rise to optical isomerism.

T



.....

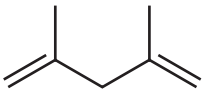
.....

.....

[2]

(iii) **T** is a **minor** product in the reaction of compound **S** with excess HC*l*.

S



Draw the structure of the **major** product of the reaction of **S** with excess HC*l*.

[1]

(d) NCl_3 is a yellow liquid that can be used to bleach flour.

(i) Predict the shape of the NCl_3 molecule and the C*l*–N–C*l* bond angle.

shape .....

bond angle .....
[2]

(ii) NCl_3 reacts with water to form HOC*l*, a weak Brønsted-Lowry acid.

Explain fully what is meant by the term *weak Brønsted-Lowry acid*.

.....

.....

..... [2]

(iii) NCl_3(l) decomposes according to the equation shown.

$$2NCl_3(l) \rightarrow N_2(g) + 3Cl_2(g)$$

A sealed container of volume 250 cm^3 contains an unreactive gas at a pressure of 1.00×10^5 Pa.

0.241 g of NCl_3(l) was injected into the sealed container.

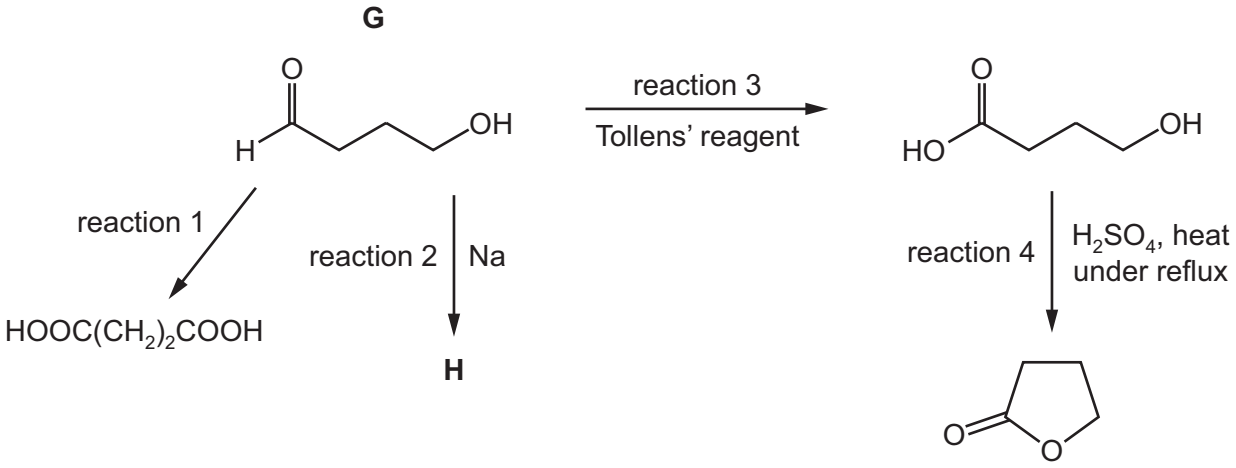
The sealed container was heated to make the NCl_3(l) decompose fully and then cooled to 20 °C.

Calculate the final **total** pressure inside the sealed container at 20 °C after the NCl_3(l) has fully decomposed.

final **total** pressure = ... Pa
[4]

[Total: 17]

4 Some reactions of compound **G** are shown.



(a) (i) State the type of reaction that occurs in reaction 1.

..... [1]

(ii) Suggest the reagent(s) and conditions required for reaction 1.

.....

..... [2]

(iii) Draw the structure of the organic product, **H**, from reaction 2.

[1]

(iv) State what you would observe in reaction 3.

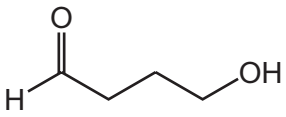
..... [1]

(v) Give the type of reaction shown by reaction 4.

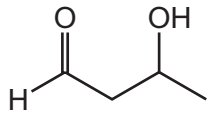
..... [1]

(b) **G** and **J** are structural isomers of each other.

G



J



(i) Name the type of structural isomerism shown by **G** and **J**.

..... [1]

(ii) Suggest **one** chemical test that can distinguish **G** from **J**. Give the result of the test with each compound.

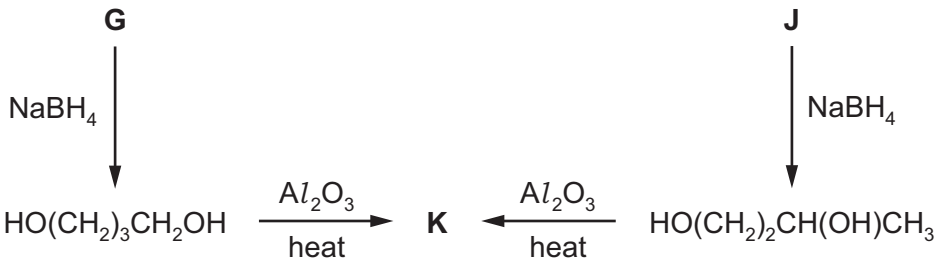
test .....

result with **G** .....

result with **J** .....

[2]

In the reaction schemes below, **G** and **J** are converted into organic compound **K**.



(iii) State the role of $NaBH_4$ in the reactions with **G** and **J**.

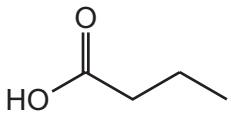
..... [1]

(iv) Identify the organic product **K**.

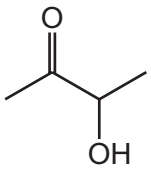
..... [1]

(c) **P** and **Q** have the same molecular formula as **G**.

P



Q



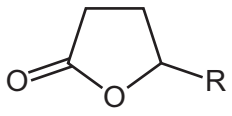
Complete the table with the expected observations for the reactions of **P** and **Q** with the named reagents.

reagent	result with **P**	result with **Q**
$Br_2(aq)$		
2,4-dinitrophenylhydrazine		
aqueous sodium carbonate		

[3]

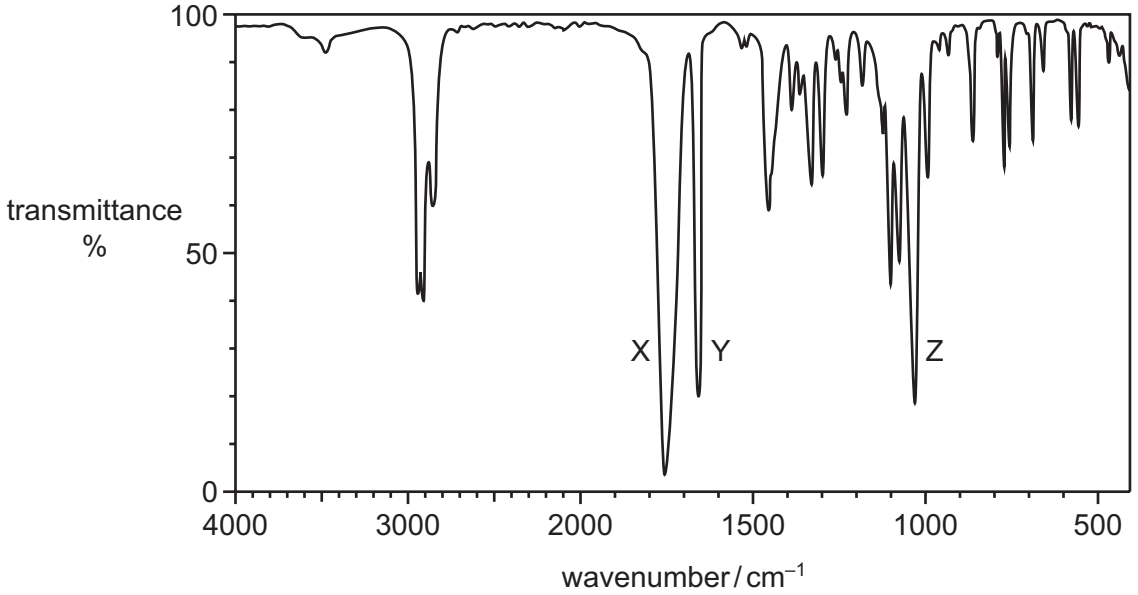
(d) The structure of compound **L** is shown. R represents a hydrocarbon chain.

L



A student was asked to deduce the full structure of **L**.

The student analysed **L** using infrared spectroscopy. The following spectrum was obtained.



(i) Identify the bonds responsible for the absorptions marked X and Z.

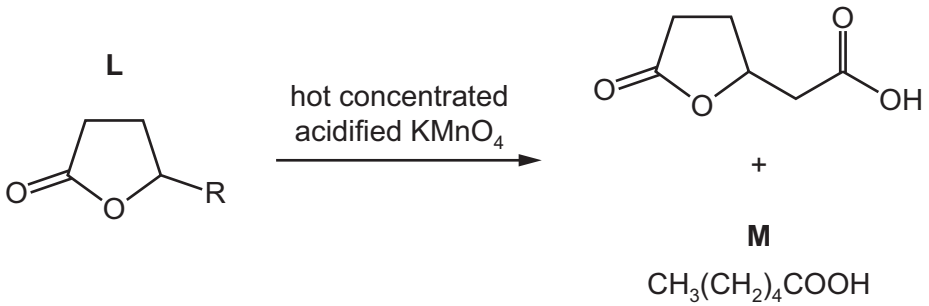
X .....

Z .....

[1]

Absorption Y shows that **L** has a C=C bond present in the R group.

The student decided to treat **L** with hot concentrated acidified potassium manganate(VII). The products of the reaction are shown.



(ii) Name **M**.

..... [1]

(iii) Use the information in **(d)** to deduce the molecular formula of **L**.

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

[Total: 17]

BLANK PAGE

BLANK PAGE

BLANK PAGE

Cambridge International AS & A Level

Cambridge Assessment International Education
Cambridge International Advanced Subsidiary and Advanced Level

CANDIDATE NAME	
CENTRE NUMBER	
CANDIDATE NUMBER	

3472908311

CHEMISTRY **9701/22**

Paper 2 AS Level Structured Questions **May/June 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 **10** printed pages and **2** blank pages.

Cambridge Assessment International Education

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

1 Methylpropane, $(CH_3)_2CHCH_3$, is an isomer of butane, $CH_3(CH_2)_2CH_3$.

(a) (i) Explain why methylpropane and butane are a pair of isomers.

.....

..... [2]

(ii) Identify the type of isomerism shown by methylpropane and butane.

..... [1]

(b) When a sample of butane is heated to 373 K, in the presence of a catalyst, and allowed to reach equilibrium the following reaction occurs.

$$CH_3(CH_2)_2CH_3(g) \rightleftharpoons (CH_3)_2CHCH_3(g) \qquad \Delta H = -8.0\,kJ\,mol^{-1}$$

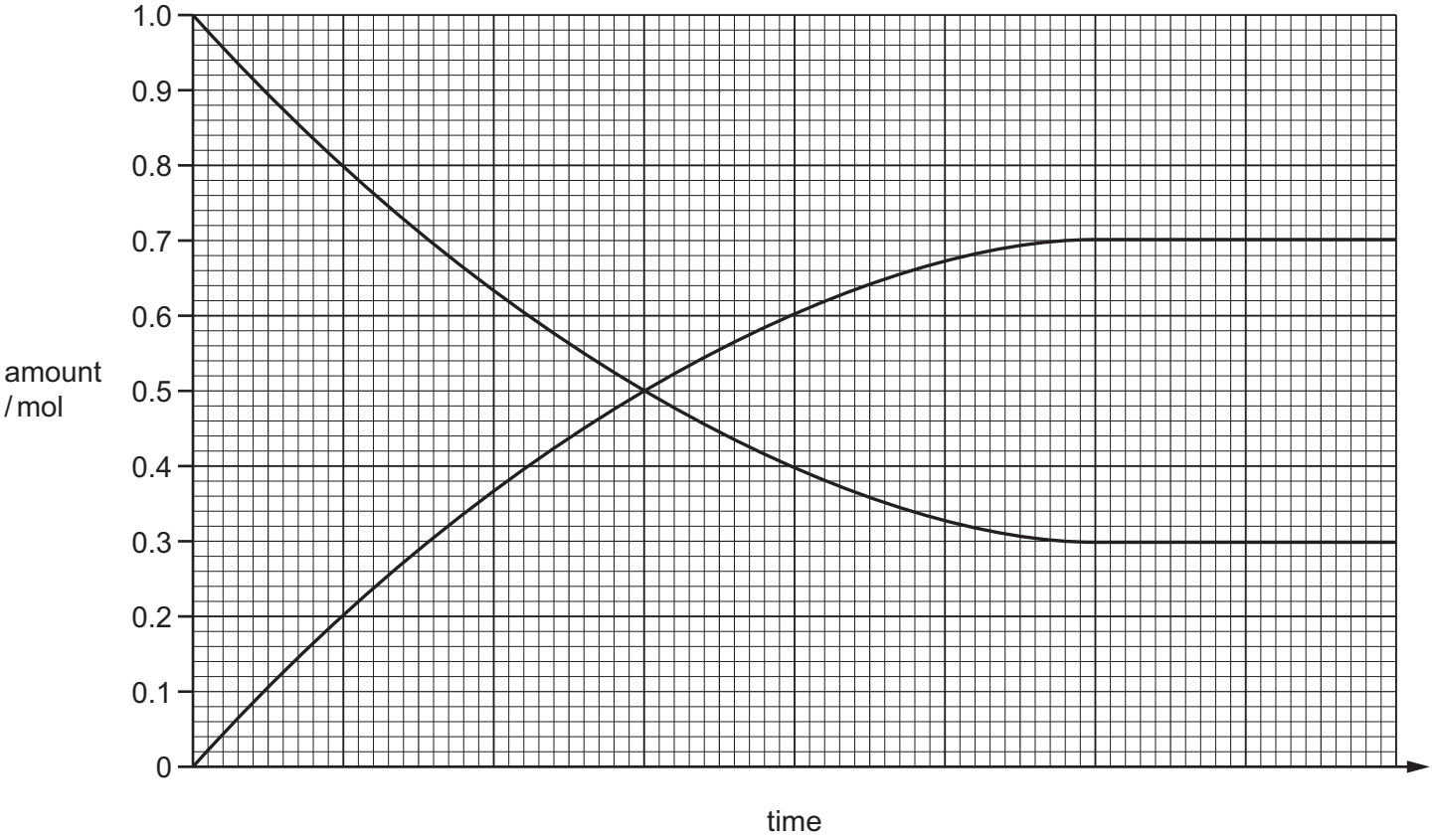
State and explain the effect on the composition of this equilibrium mixture when the temperature is increased to 473 K.

.....

.....

..... [2]

(c) 1 mole of butane gas was added to a 1 dm^3 closed system, at a constant temperature and pressure. The amount of butane and methylpropane was measured at regular time intervals.



(i) Label the graph with a *t* to show the time taken to reach dynamic equilibrium. [1]

(ii) Use the graph to find the concentration of butane and methylpropane in the mixture at equilibrium.

concentration of butane = ... mol dm^{-3}

concentration of methylpropane = ... mol dm^{-3}

[1]

(iii) Write an expression for K_c for this reaction.

[1]

(iv) Calculate a value for K_c and state its units.

K_c = ... units = ... [2]

[Total: 10]

[Turn over

2 Group 17 elements are commonly referred to as the halogens.

(a) State and explain the trend in volatility of chlorine, bromine and iodine down the group.

.....

.....

.....

..... [3]

Hydrogen gas reacts with the different halogens under different conditions.

(b) (i) State the conditions required for chlorine to react with hydrogen at room temperature.

..... [1]

(ii) On heating, iodine reacts with hydrogen in a reversible reaction.

Give the equation for this reaction. Include state symbols.

..... [2]

(c) Hydrogen chloride reacts with water.

$$HCl + H_2O \rightarrow H_3O^+ + Cl^-$$

(i) In this reaction, one of the reactants behaves as a Brønsted-Lowry acid.

What is meant by the term *Brønsted-Lowry acid*?

.....

..... [1]

(ii) Identify the reactant behaving as an acid and its conjugate base.

acid .....

conjugate base .....
[1]

(iii) Name the type of bond formed between H^+ and H_2O to make H_3O^+.

..... [1]

(iv) For H_3O^+, predict its shape and the H–O–H bond angle.

shape .....

bond angle .....
[2]

[Total: 11]

3 Period 3 elements react with chlorine gas, Cl_2(g), to form chlorides.

(a) The table shows the differences in observations which occur when two Period 3 chlorides are added to water.

Period 3 chloride	observations when added to water	pH of solution formed with water
NaCl	White solid disappears. Colourless solution made.	7
$SiCl_4$	Pale yellow solution forms. Bubbles form and the test-tube feels hot. White precipitate forms.	1–2

(i) Write an equation for the reaction occurring when $SiCl_4$ is added to cold water. Include state symbols.

..... [1]

(ii) Name the type of reaction occurring when $SiCl_4$ is added to water.
Ignore the exothermic/endothermic nature of the reaction.

..... [1]

(iii) Explain, in terms of bonding, why NaCl and $SiCl_4$ behave differently when added to water.

.....

.....

..... [2]

(iv) Explain, in terms of electronegativity, why the bonding in NaCl is different from the bonding in $SiCl_4$.

.....

.....

.....

..... [3]

[Turn over

(b) Cl_2(g) dissolves in cold water and reacts with it.

$$Cl_2 + H_2O \rightarrow HCl + HClO$$

(i) Identify the oxidation number of chlorine in each of the chlorine-containing species in this reaction.

chlorine-containing species	Cl_2	HCl	HClO
oxidation number of chlorine			

[2]

(ii) Name the type of reaction occurring.

..... [1]

(iii) Explain why chlorine is used in the purification of water.

.....

..... [1]

(c) A mixture of HCl and HClO is added to cold dilute NaOH. One of the products behaves as a bleach.

Suggest the equation for the reaction occurring.

..... [2]

[Total: 13]

4 There are many different types of aliphatic and aromatic hydrocarbons.

(a) Name a naturally occurring source of aliphatic and aromatic hydrocarbons and outline how different hydrocarbons are separated from this source.

name of source .....

outline of separation of hydrocarbons .....

.....

[2]

(b) When alkanes are heated to high temperatures, in the absence of air, the molecules can break into smaller molecules.

(i) Identify the type of reaction occurring.

..... [1]

(ii) Write an equation which describes the reaction occurring when heptane, C_7H_{16}, is heated in the absence of air, to form hexane, butane and ethene only.

..... [1]

(c) The equation for the complete combustion of ethene is shown.

$$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$$

Calculate the volume, in dm^3, of carbon dioxide formed in the complete combustion of 1.00 g of ethene at room temperature and pressure.

volume of CO_2 = ... dm^3 [3]

[Turn over

(d) The table compares the reactivity of alkanes and alkenes with chlorine.

	alkanes	alkenes
name of the type of reaction with chlorine	substitution	addition and substitution
name of the type of reacting species	free radical	electrophile and free radical

(i) During the first stage in the substitution reaction chlorine forms chlorine free radicals.

Explain what is meant by the term *free radical*.

..... [1]

(ii) Name and explain the type of bond breaking which occurs to form chlorine free radicals.

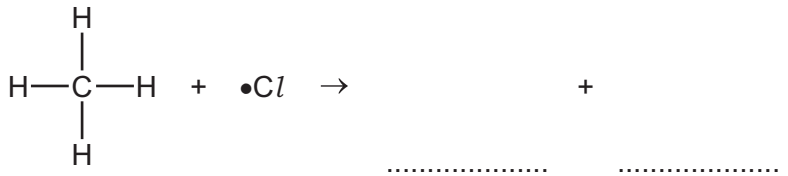
.....

..... [2]

(iii) Name the stage of the reaction mechanism which occurs when a methane molecule reacts with a chlorine free radical.

..... [1]

(iv) Complete the equation for the reaction which occurs when a methane molecule reacts with a chlorine free radical.



....

[1]

(v) Carbon atoms can form σ and π bonds within hydrocarbon molecules.

Explain the following statement with reference to σ and π bonds.

Alkenes react with electrophiles but alkanes do not.

.....

.....

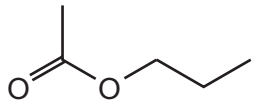
.....

..... [2]

[Total: 14]

5 Many naturally occurring esters are used as flavourings in food.

(a) The structure of ester **V** is shown.



V

(i) Name **V**.

..... [1]

V reacts with a reagent to form a salt of a carboxylic acid and an alcohol.

(ii) Identify a reagent that could be used in this reaction.

..... [1]

(iii) Draw the displayed formula of the alcohol made during this reaction.

[1]

(iv) State one other possible use for **V**, apart from as a food flavouring.

..... [1]

(b) Ester **W** is made up of 54.5% carbon, 9.1% hydrogen and 36.4% oxygen.

(i) Calculate the empirical formula of **W**.

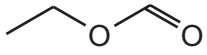
[3]

(ii) State what additional information is required to determine the molecular formula of **W**.

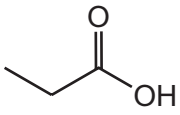
..... [1]

(c) Compounds **X**, **Y** and **Z** are shown. They all have the same molecular formula.

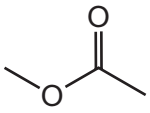
X



Y



Z



(i) Deduce the molecular formula of **X**, **Y** and **Z**.

..... [1]

(ii) In three experiments, sodium is added to separate samples of **X**, **Y** and **Z**.

Complete the table to show the observations for each of these three experiments. Ignore any temperature changes which may occur.

experiment	observations
Na + **X**	
Na + **Y**	
Na + **Z**	

[2]

(d) Sodium carbonate solution reacts with methanoic acid.

Write the equation for this reaction.

..... [1]

[Total: 12]

BLANK PAGE

BLANK PAGE

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

[Turn over

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.

.....

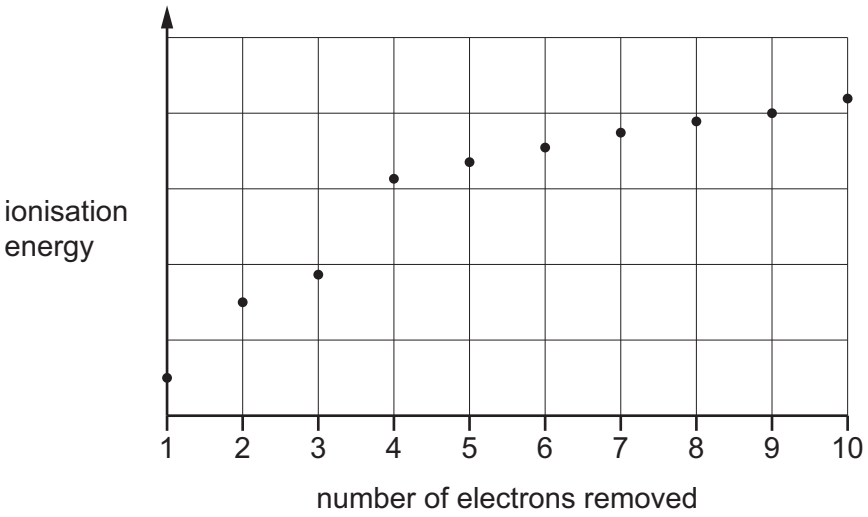
.....

.....

..... [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*.

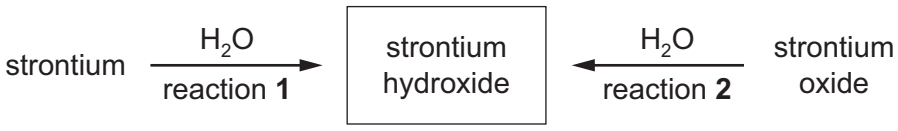
.....

..... [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.

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

(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.

.....

.....

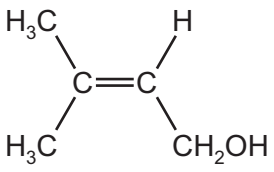
..... [2]

[Total: 13]

[Turn over

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

prenol

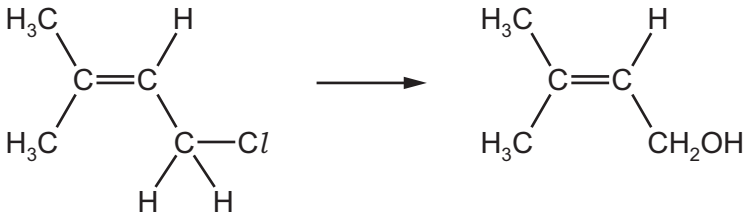


(a) Prenol can be formed by the reaction of **G** with NaOH(aq).

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]

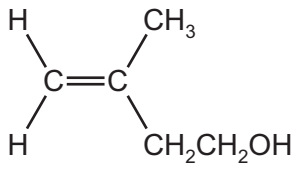
(ii) Prenol can be polymerised to form poly(prenol).

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

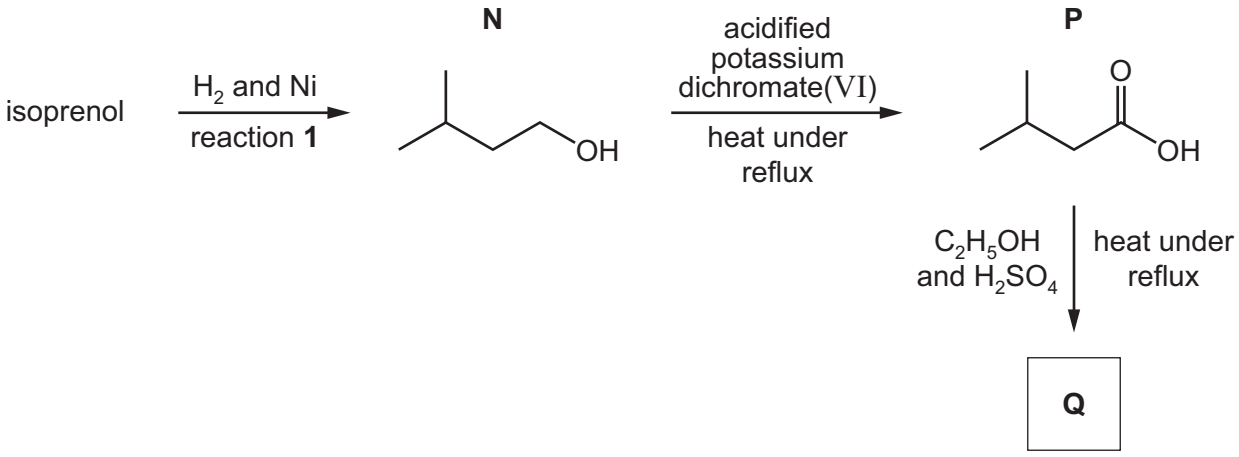
[1]

(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**.

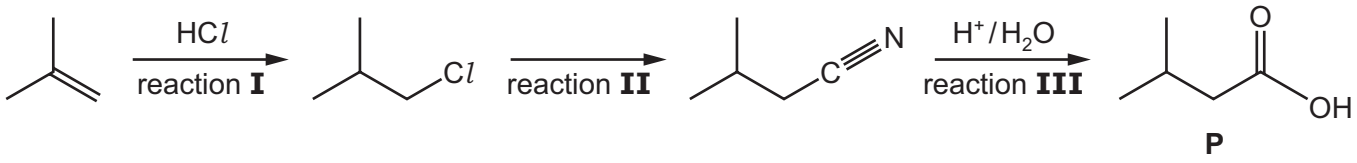
..... [1]

(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

Cambridge International AS & A Level

Cambridge International Examinations
Cambridge International Advanced Subsidiary and Advanced Level

CANDIDATE NAME									
CENTRE NUMBER						CANDIDATE NUMBER			

5604896066

CHEMISTRY **9701/22**

Paper 2 AS Level Structured Questions **May/June 2018**

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 **10** printed pages and **2** blank pages.

CAMBRIDGE International Examinations

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

1 Sodium and magnesium are the first two elements in the third period.

(a) Sodium and magnesium both react with cold water to produce the same type of product in solution. With sodium the solution is clear but with magnesium it appears cloudy.

(i) Write an equation for the reaction of magnesium with cold water.

..... [1]

(ii) Suggest why the solution is cloudy after the reaction of magnesium with cold water.

.....

..... [1]

(b) Group 2 elements, including magnesium, react with oxygen and with dilute acids. There are trends in both the physical and chemical properties of the elements and their compounds down the group. Reactivity generally increases from Mg to Ba.

(i) Explain why there is a general increase in reactivity from Mg to Ba.

.....

.....

..... [2]

(ii) Give **two** observations for the reaction of magnesium with oxygen. Write an equation for this reaction. Include state symbols.

.....

.....

equation .....
[3]

(iii) Write an equation for the reaction of magnesium with sulfuric acid.

..... [1]

(iv) Suggest why there is a general **decrease** in the melting points of the elements down Group 2.

.....

.....

.....

.....

..... [3]

[Total: 11]

2 Ammonium iron(II) sulfate, $(NH_4)_2Fe(SO_4)_2$, has a relative formula mass, M_r, of 284.

(a) Define the term *relative formula mass*.

.....

.....

.....

..... [2]

(b) One of the cations in ammonium iron(II) sulfate is the ammonium ion, NH_4^+.

(i) Draw a 'dot-and-cross' diagram of an ammonium ion. Show outer shell electrons only.

Use × to show electrons from nitrogen.
Use ● to show electrons from hydrogen.

[2]

(ii) Suggest the shape of an ammonium ion and predict the bond angle.

shape .....

bond angle .....
[2]

(c) In aqueous solution the ammonium ion acts as a weak Brønsted-Lowry acid.

(i) Explain the meaning of the term *weak Brønsted-Lowry acid*.

.....

.....

.....

..... [2]

(ii) Write an equation to show this behaviour of the ammonium ion in water. Include state symbols.

..... [2]

(d) Mohr's salt, $(NH_4)_2Fe(SO_4)_2 \cdot xH_2O$, is the hydrated form of ammonium iron(II) sulfate.

x represents the number of moles of water in 1 mole of the salt.

A student wanted to determine the value of x. 0.784 g of the hydrated salt was dissolved in water and this solution was acidified.

All of the solution was titrated with 0.0200 mol dm^{-3} potassium manganate(VII). 20.0 cm^3 of this potassium manganate(VII) solution was required for complete reaction with the Fe^{2+} ions.

(i) Use changes in oxidation numbers to balance the equation for the reaction taking place.

$MnO_4^-(aq)$ + ...$Fe^{2+}(aq)$ + ...$H^+(aq)$ → .....$Mn^{2+}(aq)$ + ...$Fe^{3+}(aq)$ + ...$H_2O(l)$ [1]

(ii) State the role of the Fe^{2+} ions in this reaction.

Explain your answer.

.....

..... [2]

(iii) Calculate the amount, in moles, of manganate(VII) ions that reacted.

amount = ... mol [1]

(iv) Calculate the amount, in moles, of Fe^{2+} ions in the sample of the salt.

amount = ... mol [1]

(v) Calculate the relative formula mass of $(NH_4)_2Fe(SO_4)_2 \cdot xH_2O$.

relative formula mass = ... [1]

(vi) Calculate the value of x.

x = ... [1]

[Total: 17]

3 Most vehicle fuels contain hydrocarbons obtained from crude oil.

(a) (i) State the name of the type of reaction that hydrocarbons undergo when being used as fuels.

..... [1]

(ii) Write an equation for the reaction of octane, C_8H_{18}, as a fuel, as in **(a)(i)**.

..... [2]

(b) The supply of material suitable for use as fuels directly from crude oil is **not** sufficient to meet demand. A process is carried out to make some of the larger hydrocarbon molecules more useful.

(i) Name this process.

..... [1]

As well as producing fuels, this process produces compounds suitable for use in the production of polymers. An example of such a compound is but-2-ene, $CH_3CH{=}CHCH_3$.

(ii) Draw the repeat unit of the polymer that is produced from but-2-ene.

[2]

(iii) Name the type of polymerisation that occurs during the production of the polymer in **(ii)**.

..... [1]

(c) Gases produced in internal combustion engines include carbon monoxide, oxides of nitrogen such as NO_2, and unburnt hydrocarbons.

These gases are removed from the exhaust before they can enter the atmosphere.

(i) State what is used to remove these gases from the exhaust.

..... [1]

(ii) Write **one** equation to show how both carbon monoxide, CO, and nitrogen dioxide, NO_2, are removed from the exhaust.

..... [1]

(iii) State the environmental consequence of allowing unburnt hydrocarbons to enter the atmosphere.

..... [1]

(d) Vehicle fuels are treated to remove sulfur. If sulfur is present in a fuel when it is burned, SO_2 is produced and may be released into the atmosphere where it can form acid rain.

(i) Acid rain can contribute to breathing difficulties.

Identify **two** other consequences of acid rain in the atmosphere.

.....

.....

.....

..... [2]

(ii) NO_2 is involved in the production of acid rain from SO_2.

Give **two** equations which describe how acid rain is formed by the action of NO_2 with SO_2.

.....

..... [2]

(iii) NO_2 is described as a catalyst during this process.

Explain, with the use of an appropriate equation, why NO_2 is described as a catalyst.

.....

..... [2]

[Total: 16]

[Turn over

4 **W** is $CH_3COCH_2CH_3$.

(a) The reaction between **W** and alkaline aqueous iodine produces a yellow precipitate.

(i) Give the name of the compound formed as a yellow precipitate in this reaction.

..... [1]

(ii) Give the name of **W**.

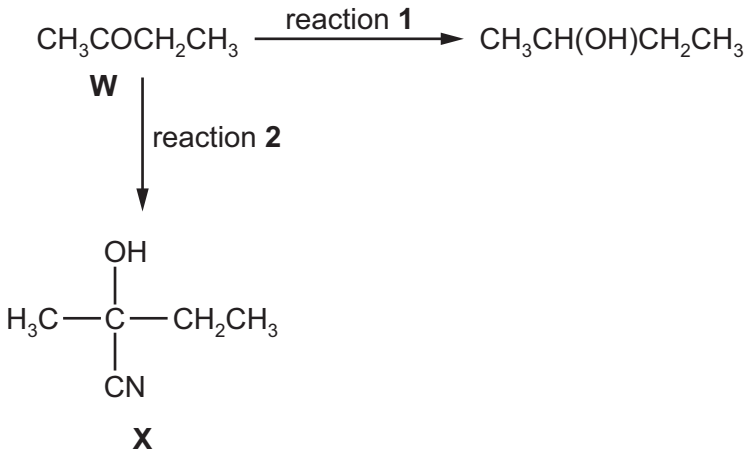
..... [1]

(b) There are two structural isomers of **W** that are also carbonyl compounds.

Draw the structures of these two isomers of **W**.

[2]

Two reactions of **W** are shown.



(c) **(i)** Identify the type of reaction occurring in reaction **1**.

..... [1]

(ii) Identify the reagent for reaction **1**.

..... [1]

(d) Reaction **2** is carried out by adding a mixture of HCN and NaCN to **W**.
The product, **X**, is formed as a mixture of two isomers.

(i) Complete the mechanism for this reaction.

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

W 

CN^- **X**

[4]

(ii) State the name of the type of isomerism shown by **X**.

..... [1]

(iii) Explain fully why **X** shows this type of isomerism.

.....

.....

.....

..... [2]

Question 4 continues on page 10.

(e) If **X** is treated with ammonia and the product hydrolysed, a compound, **Y**, is obtained that contains 51.3% C, 9.40% H, 12.0% N and 27.3% O by mass.

(i) Show that the empirical formula of **Y** is $C_5H_{11}NO_2$.

[2]

(ii) The empirical formula of **Y** is $C_5H_{11}NO_2$ and the M_r of **Y** is 117.

Deduce the molecular formula of **Y**. You **must** explain your reasoning.

molecular formula = ...

.....

.....

[1]

[Total: 16]

BLANK PAGE

BLANK PAGE

Cambridge International AS & A Level

Cambridge International Examinations
Cambridge International Advanced Subsidiary and Advanced Level

CANDIDATE NAME	
CENTRE NUMBER	
CANDIDATE NUMBER	

5824876239

CHEMISTRY **9701/22**

Paper 2 AS Level Structured Questions **October/November 2018**

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 International Examinations

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

1 The model of the nuclear atom was first proposed by Ernest Rutherford. He developed this model on the basis of results obtained from an experiment using gold metal foil.

(a) Complete the table with information for two of the particles in an atom of ^{197}Au.

particle	relative mass	relative charge	location within atom	total number in an atom of ^{197}Au
electron	0.0005	–1		79
neutron			nucleus	

[4]

(b) State the type of bonding in gold.

..... [1]

(c) A sample of gold found in the earth consists of only one isotope.

(i) Explain what is meant by the term *isotopes*.

.....

.....

..... [2]

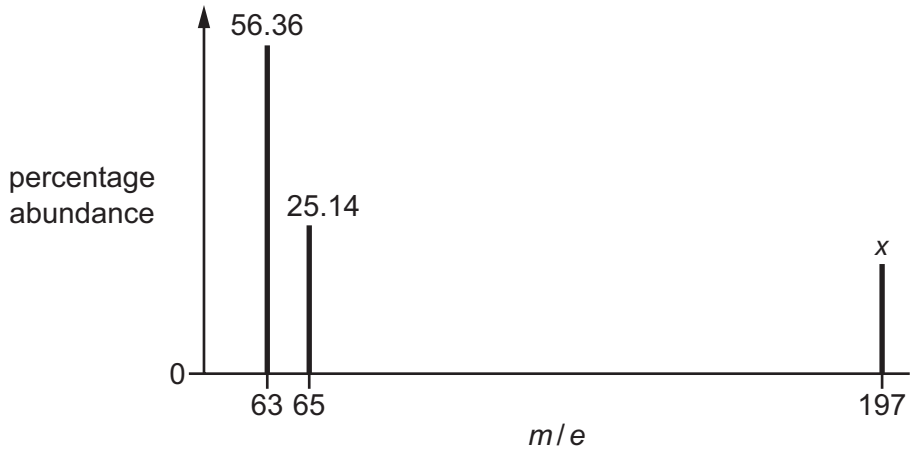
(ii) A different sample of gold contains more than one isotope.

Suggest why this different sample of gold has the same **chemical** properties as the sample found in the earth.

.....

..... [1]

(d) *Tumbaga* is an alloy of copper and gold. A sample of tumbaga was analysed. The mass spectrum of the sample is shown.



(i) Calculate the percentage abundance of gold, *x*, in the sample of tumbaga.

x = ... % [1]

(ii) Calculate the relative atomic mass, A_r, of the copper present in this sample.
Give your answer to **two** decimal places.

A_r (Cu) = ... [2]

[Total: 11]

2 The table gives some data for elements in the third period and some of their compounds.

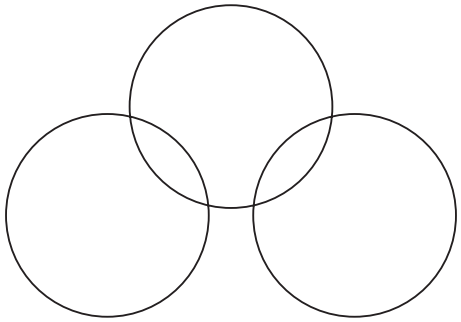
element	Na	Mg	Al	Si	P	S
type of bonding	metallic				covalent	covalent
formula of oxide					P_4O_{10}	SO_2
formula of chloride	NaCl	$MgCl_2$				SCl_2

(a) Complete the table to show the bonding in the elements, and the formulae of their oxides and chlorides. [3]

(b) SCl_2 is formed in the following reaction.

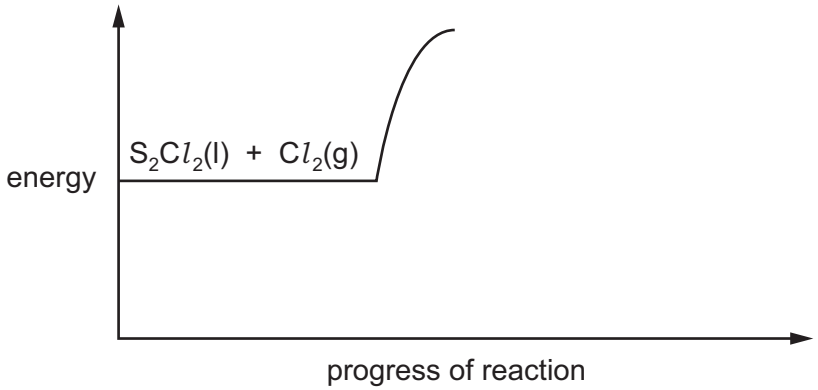
$$S_2Cl_2(l) + Cl_2(g) \rightleftharpoons 2SCl_2(l) \qquad \Delta H = -40.6\,kJ\,mol^{-1}$$

(i) Complete the 'dot-and-cross' diagram to show the bonding in a molecule of SCl_2. Show outer electrons only.



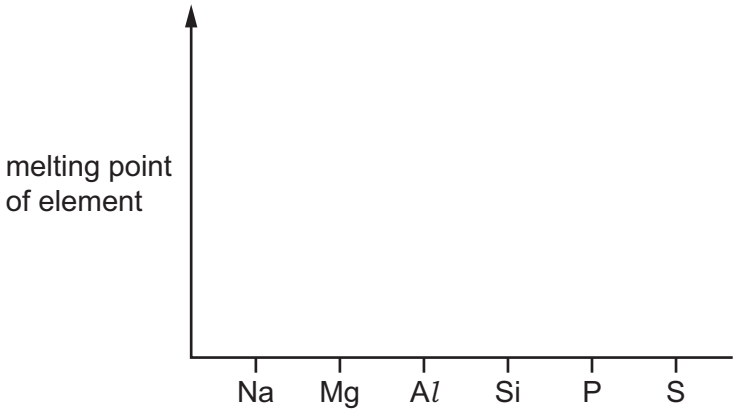
[1]

(ii) Complete and fully label the reaction pathway diagram for the reaction between S_2Cl_2 and Cl_2. Include labels for activation energy, E_a, and enthalpy change of the forward reaction, ΔH.



[2]

(c) (i) On the axes, sketch the trend in melting point of the elements Na to S.



[1]

(ii) Give three statements to explain your sketch.

1 .....

.....

2 .....

.....

3 .....

.....

[3]

(d) Write an equation for the reaction of P_4O_{10} with water.

..... [1]

(e) SO_2 can be released into the atmosphere when fossil fuels containing sulfur are burnt.

State and explain one environmental consequence of the release of SO_2 into the atmosphere.

.....

.....

.....

..... [2]

(f) The elements in the third period show a general increase in their first ionisation energies from left to right.

Identify **two** pairs of successive elements in the third period that do **not** agree with this statement.
For each pair, explain why the change in ionisation energy does **not** agree with this statement.

Use of the Data Booklet may help you to answer this question.

pair 1 .....

explanation .....

.....

.....

.....

.....

pair 2 .....

explanation .....

.....

.....

.....

.....

[4]

[Total: 17]

3 Trihalomethanes are organic molecules in which three of the hydrogen atoms of methane are replaced by halogen atoms, for example CHF_3.

(a) The equation shows a reaction to produce CHF_3.

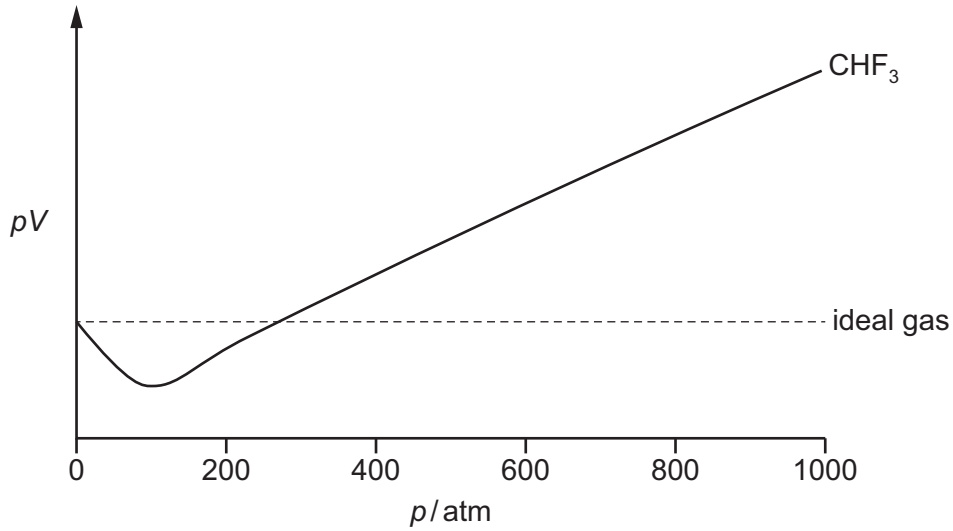
$$CHI_3(s) + 3AgF(s) \rightarrow CHF_3(g) + 3AgI(s)$$

Use the data to calculate the enthalpy change of reaction, ΔH_r, for this formation of CHF_3.

compound	enthalpy change of formation, ΔH_f / kJ mol^{-1}
$CHI_3(s)$	–182.1
$CHF_3(g)$	–692.9
AgF(s)	–204.6
AgI(s)	–61.8

enthalpy change of reaction, ΔH_r = ... kJ mol^{-1} [3]

(b) The graph shows the relationship between pV and p at a given temperature for CHF_3 and an ideal gas.



(i) CHF_3 is not an ideal gas.

State **three** basic assumptions that scientists make about the properties of ideal gases.

1 .....

2 .....

3 .....

[3]

(ii) Explain why CHF_3 deviates from the properties of an ideal gas at pressures greater than 300 atm.

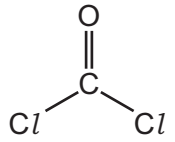
.....

.....

.....

..... [2]

(c) A different trihalomethane, $CHCl_3$, reacts with O_2 to produce carbonyl dichloride. HCl(g) is also released as a product of this reaction.

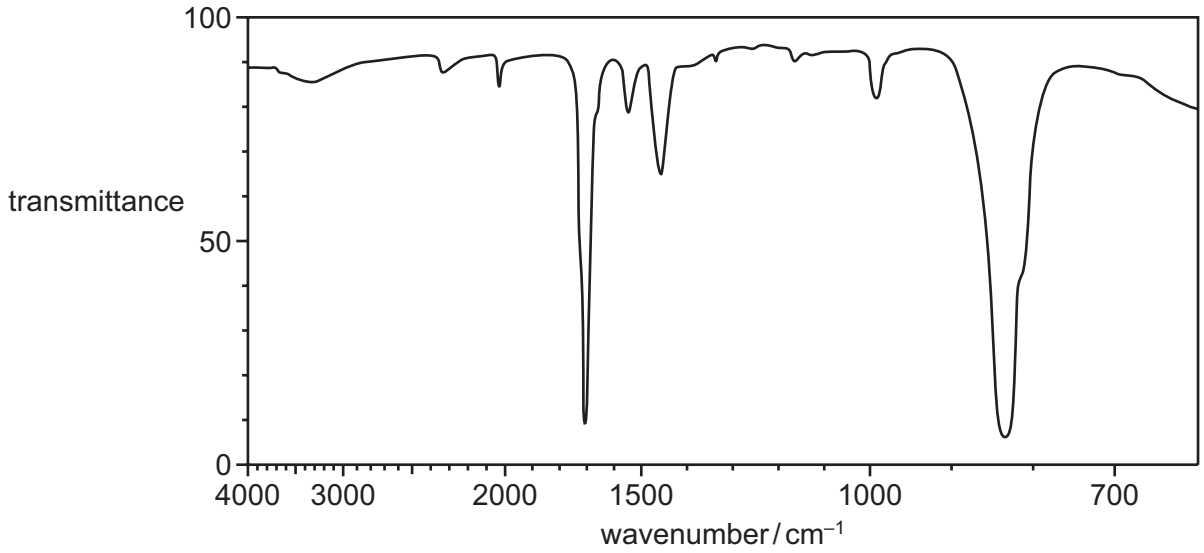


carbonyl dichloride

(i) Write an equation for this reaction of $CHCl_3$ with O_2.

..... [1]

(ii) The conversion of $CHCl_3$ to carbonyl dichloride can be monitored by infra-red spectroscopy. The infra-red spectrum of carbonyl dichloride is shown.



On the infra-red spectrum of carbonyl dichloride identify with an **X** the absorption that would **not** be present in an infra-red spectrum of $CHCl_3$.

Explain your answer.

.....

.....

[2]

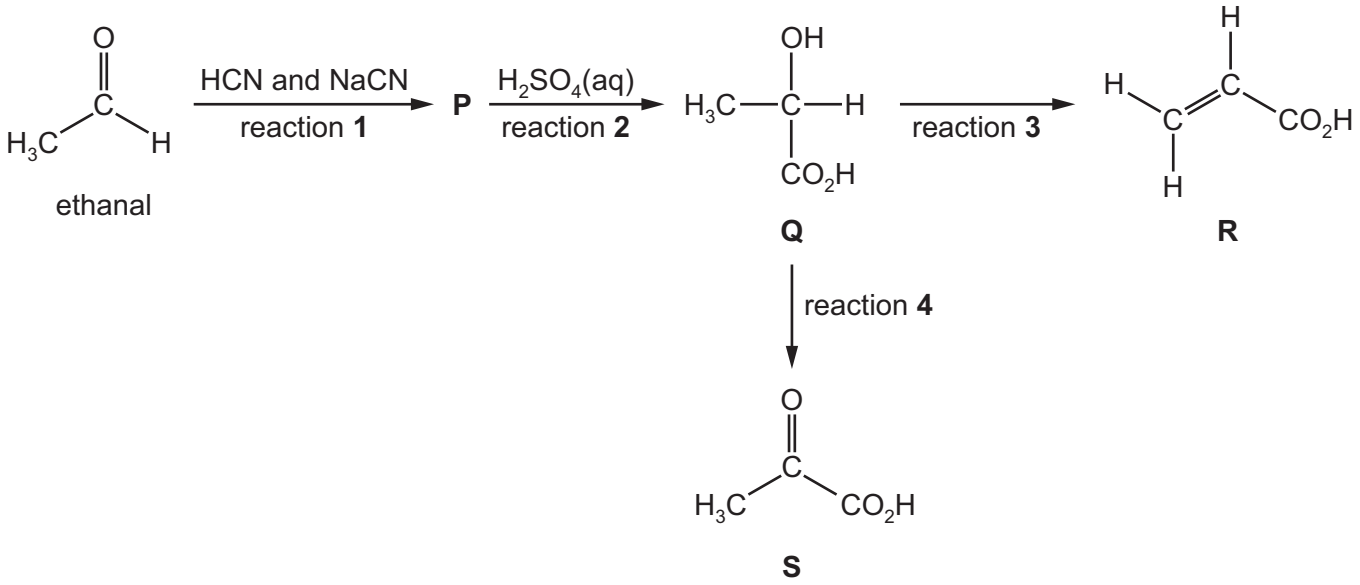
(iii) Suggest another difference between the infra-red spectra of $CHCl_3$ and carbonyl dichloride.

.....

..... [1]

[Total: 12]

4 The diagram shows a reaction sequence starting from ethanal.



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

[1]

(ii) Name the type of chemical reaction that occurs in reaction **3**.

..... [1]

(iii) Write an equation to represent reaction **4**.

Use [O] to represent the oxidising agent.

..... [1]

(iv) State the reagents and conditions for reaction **4**.

..... [1]

(b) Compound **Q** is formed as a mixture of two optical isomers.

(i) Explain what is meant by the term *optical isomers*.

.....

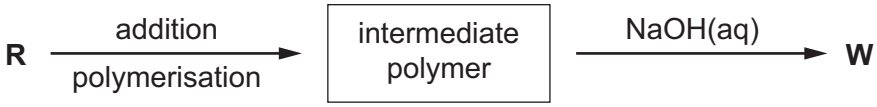
.....

..... [1]

(ii) Draw the **two** optical isomers of **Q**, showing clearly their three-dimensional structures.

[2]

(c) **R** can be used to make a polymer, **W**, in two steps.



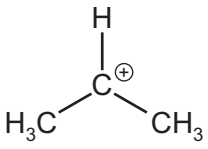
Draw one repeat unit of **W**.

[3]

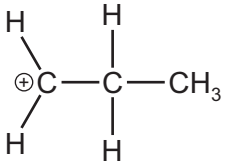
(d) Compound **Z**, $H_2C{=}CHCH_3$, is produced from **R**.

Z can be used in a two-step process to produce 2-aminopropane.

(i) In the first step, **Z** reacts with HBr to form two products. The structure of the product depends on which intermediate is formed, intermediate **I** or intermediate **II**.



intermediate **I**



intermediate **II**

Explain why intermediate **I** is more likely to form than intermediate **II**.

.....

.....

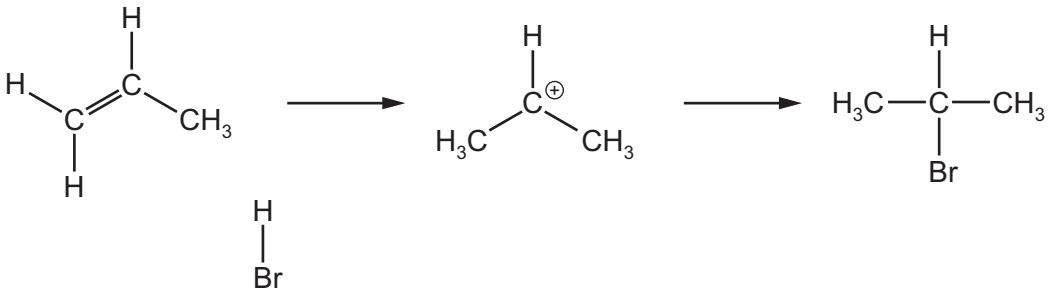
.....

..... [2]

(ii) When intermediate **I** forms, the product of the first step is **T**.

Complete the diagram to show the mechanism for the conversion of **Z** to **T**.
Include all relevant charges, partial charges, curly arrows and lone pairs.

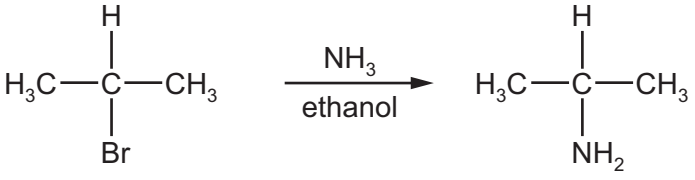
Z **T**



[3]

(iii) **T** can then be converted to 2-aminopropane.

T



2-aminopropane

Name the mechanism for this conversion.

..... [1]

(e) (i) Compound **S**, CH_3COCO_2H, can be reduced by $LiAlH_4$.

Complete the equation using structural formulae to represent this reaction.
Use [H] to represent the reducing agent.

CH_3COCO_2H + ... [2]

Other reducing agents containing Group 1 metal cations include $LiBH_4$, $NaBH_4$ and KBH_4.
The strength of the reducing agent depends on the size of its cation.

(ii) Give the electronic configuration of the Na^+ cation.

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

(iii) Suggest why ionic radius increases down Group 1.

.....

.....

..... [1]

[Total: 20]

BLANK PAGE

BLANK PAGE

BLANK PAGE

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.

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]

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]

[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.

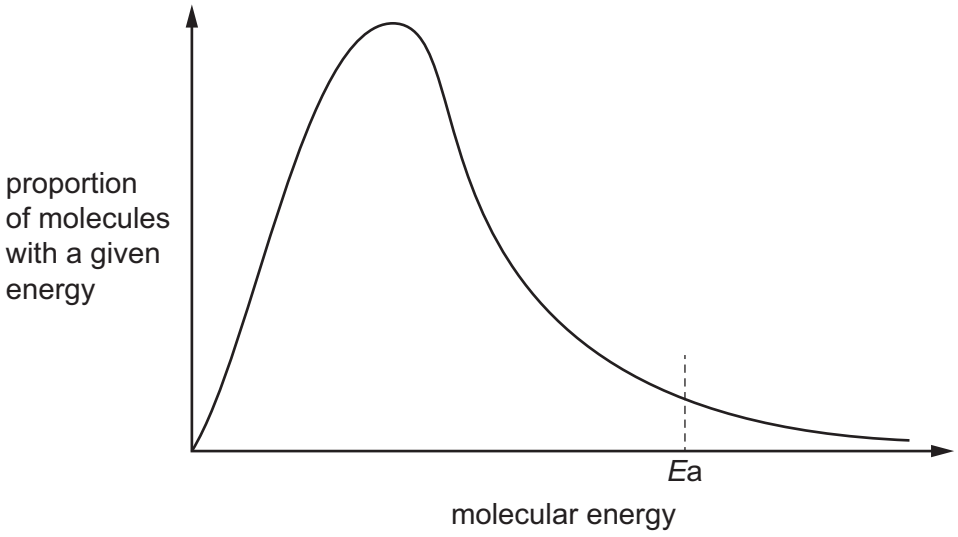
	bond energy / kJ mol^{-1}
H–Br	366
H–H	436
Br–Br	193

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

ΔH = ... 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]

[Turn over

(c) At temperatures above 1500 K, HCl will decompose.

A sample of 0.300 mol of HCl decomposed in a sealed container.

The resulting equilibrium mixture was found to contain 1.50×10^{-2} mol of Cl_2.

(i) Calculate the amounts, in mol, of H_2 and HCl present in the equilibrium mixture.

H_2 = ... mol

HCl = ... mol
[2]

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

mole fraction of HCl = ...

mole fraction of H_2 = ...

mole fraction of Cl_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
HCl	0.88
H_2	0.06
Cl_2	0.06

(i) Write the expression for the equilibrium constant, K_p, for the decomposition of HCl.

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

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]

(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 .....

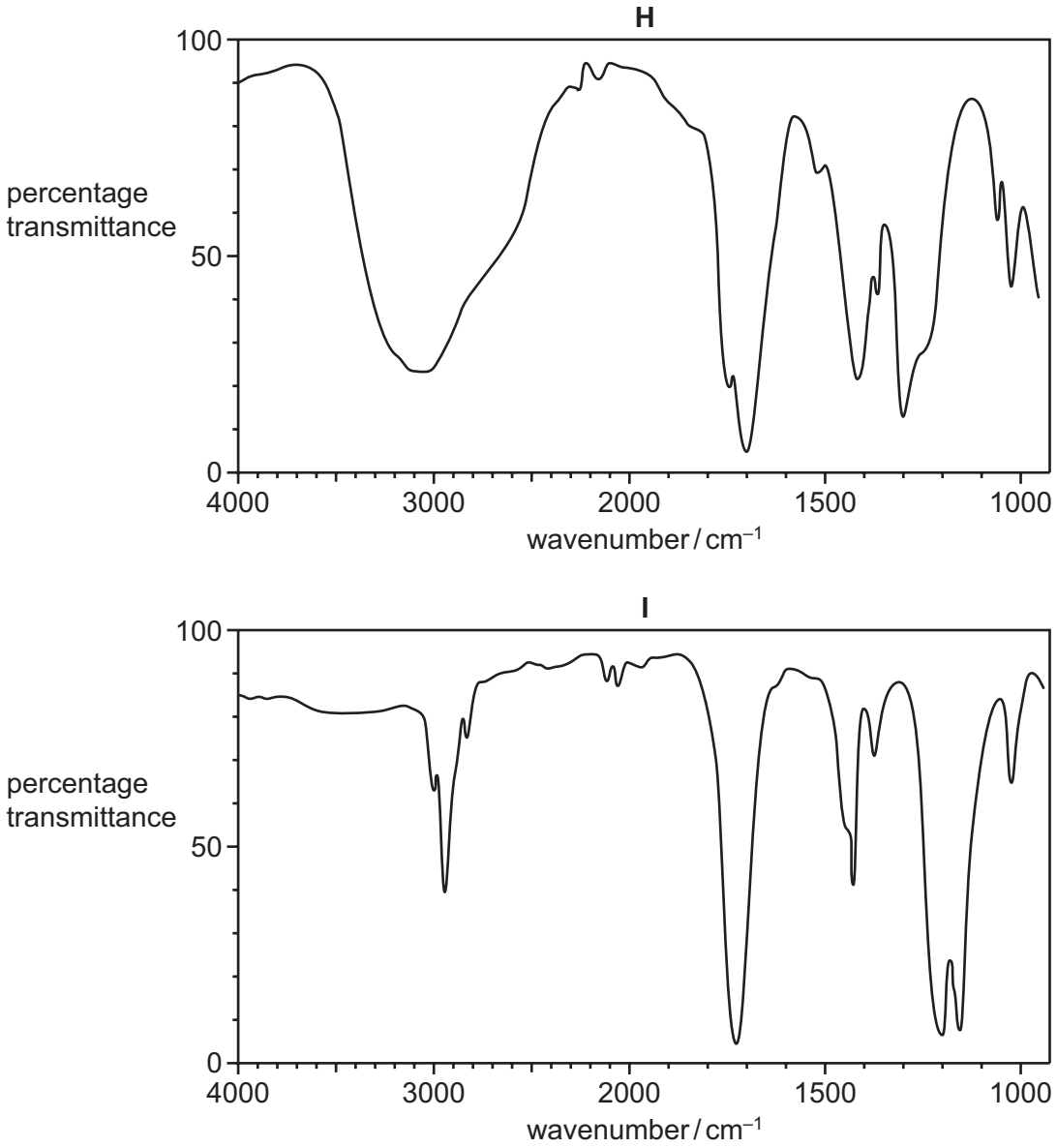
G .....
[2]

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

.....

..... [1]

(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]

BLANK PAGE

Cambridge International AS & A Level

Cambridge International Examinations
Cambridge International Advanced Subsidiary and Advanced Level

CANDIDATE NAME	
CENTRE NUMBER	
CANDIDATE NUMBER	

2865542814

CHEMISTRY **9701/22**

Paper 2 AS Level Structured Questions **October/November 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 **10** printed pages and **2** blank pages.

CAMBRIDGE International Examinations

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

1 The elements sodium to sulfur react with chlorine. The melting points of some of the chlorides formed are shown.

chloride	NaCl	$MgCl_2$	$AlCl_3$	$SiCl_4$	PCl_3	SCl_2
melting point / K	1074	987	463	203	161	195

(a) Predict the shapes of $AlCl_3$ and PCl_3.

Draw diagrams to show the shapes, name the shapes and state the bond angles.

$AlCl_3$	PCl_3
shape	shape .....
angle	angle .....

[4]

(b) (i) Explain, in terms of structure and bonding, why the melting point of $SiCl_4$ is much lower than that of NaCl.

.....

.....

.....

.....

..... [3]

(ii) Explain why the melting point of $SiCl_4$ is higher than that of PCl_3.

.....

.....

..... [2]

(iii) Draw the 'dot-and-cross' diagram of a molecule of $SiCl_4$.
Show outer electrons only.

[1]

[Total: 10]

2 At 450 K phosphorus(V) chloride, $PCl_5(g)$, decomposes to form phosphorus(III) chloride, $PCl_3(g)$, and chlorine, $Cl_2(g)$. A dynamic equilibrium is established as shown.

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g) \qquad \Delta H = +124\,kJ\,mol^{-1}$$

(a) The enthalpy change of formation of $PCl_3(g)$ under these conditions is given.

$$\Delta H_f\ PCl_3(g) = -320\,kJ\,mol^{-1}$$

Calculate the enthalpy change of formation of $PCl_5(g)$ under these conditions.

Include a sign with your answer.

enthalpy change = ... $kJ\,mol^{-1}$ [1]

(b) (i) State and explain the effect of increasing temperature on the rate of decomposition of $PCl_5(g)$.

.....

.....

..... [2]

(ii) State and explain the effect of increasing temperature on the percentage of $PCl_5(g)$ that decomposes.

.....

.....

..... [2]

(c) Explain the meaning of the term *dynamic equilibrium* and the conditions necessary for it to become established.

.....

.....

.....

..... [2]

(d) When 2.00 mol of $PCl_5(g)$ are decomposed at 450 K and 1.00×10^5 Pa the resulting equilibrium mixture contains 0.800 mol of $Cl_2(g)$.

(i) Calculate the partial pressure of phosphorus(V) chloride, $p PCl_5$, in this equilibrium mixture.

$p PCl_5$ = ... Pa [2]

(ii) Write the expression for the equilibrium constant, K_p, for the decomposition of $PCl_5(g)$.

K_p =

[1]

(iii) The partial pressures of $PCl_3(g)$ and of $Cl_2(g)$ in this equilibrium mixture are both 2.86×10^4 Pa.

Calculate the value of K_p and state its units.

K_p = ...

units = ...
[2]

[Total: 12]

[Turn over

3 The elements in Group 2 show trends in their properties that are typical of metals.
The elements in Group 17 show trends in their properties that are typical of non-metals.

(a) State and explain the trend in ionisation energy down Group 2.

.....

.....

..... [2]

(b) **(i)** State and explain the trend in melting point down Group 17.

.....

.....

..... [2]

(ii) The melting point decreases down Group 2.

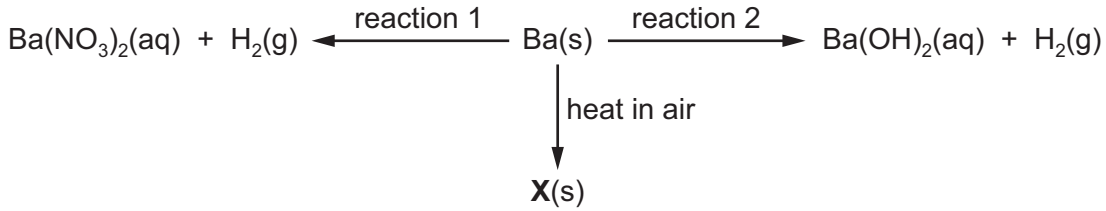
Explain this trend.

.....

.....

..... [2]

(c) Some reactions based on the Group 2 metal barium, Ba, are shown.



(i) State the reagent needed for each of reactions 1 and 2.

reaction 1 .....

reaction 2 .....
[2]

(ii) Name **X** and write an equation for its formation.

name .....

equation .....
[2]

(iii) The $Ba(NO_3)_2(aq)$, produced by reaction 1, is heated to dryness. The anhydrous solid is then heated strongly and decomposes. Barium oxide is produced, together with two other products.

Identify the **two** other products of this decomposition reaction and state what would be observed.

.....

..... [2]

(iv) State what would be observed when excess $MgSO_4(aq)$ is added to the $Ba(OH)_2(aq)$ produced in reaction 2. Explain your answer.

.....

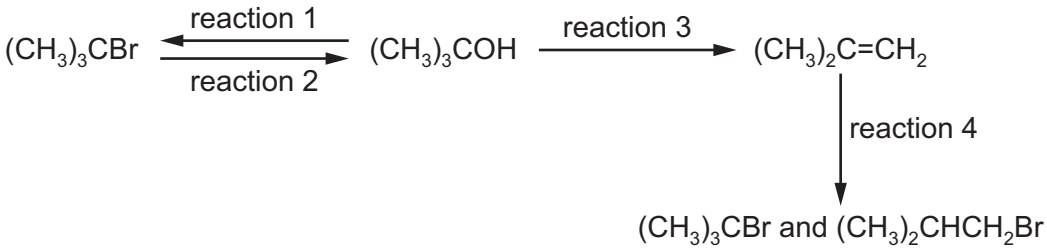
.....

.....

..... [3]

[Total: 15]

4 Some reactions are shown, based on methylpropan-2-ol, $(CH_3)_3COH$.



(a) For each of the reactions state the reagent(s), the particular conditions required, if any, and the type of reaction.

For the type of reaction choose from the list.
Each type may be used once, more than once or not at all.
Each reaction may be described by one or more than one type.

hydrolysis dehydration substitution

oxidation addition condensation

reaction	reagent(s) and conditions	type(s) of reaction
1		
2		
3		
4		

[5]

(b) Draw a diagram to show the S_N1 mechanism of reaction 2.
Include all necessary charges, dipoles, lone pairs and curly arrows.

[3]

(c) 1-bromobutane is a structural isomer of the product of reaction 1.

(i) Define the term *structural isomer* and name the three different types of structural isomerism.

definition .....

.....

.....

.....

types of structural isomerism

1 .....

2 .....

3 .....

[4]

(ii) 1-bromobutane is treated with the same reagents as in reaction 2. Butan-1-ol is formed.

Identify the mechanism of this reaction.
Explain why this reaction proceeds via a different mechanism from that of reaction 2.

mechanism .....

explanation .....

.....

.....

.....

.....

[3]

(d) The product of reaction 3, methylpropene, does **not** show stereoisomerism.

(i) Give **two** reasons why methylpropene does **not** show stereoisomerism.

.....

.....

..... [2]

[Turn over

(ii) Methylpropene can be polymerised to form a poly(alkene).

State the type of polymerisation and draw the repeat unit of the polymer formed from methylpropene.

type of polymerisation .....

repeat unit

[3]

(iii) State the difficulty associated with the disposal of poly(alkenes).

.....

..... [1]

(e) Name the two products of reaction 4.

name of $(CH_3)_3CBr$ .....

name of $(CH_3)_2CHCH_2Br$ .....

[2]

[Total: 23]

BLANK PAGE

BLANK PAGE

Cambridge International AS & A Level

Cambridge International Examinations
Cambridge International Advanced Subsidiary and Advanced Level

CANDIDATE NAME									
CENTRE NUMBER						CANDIDATE NUMBER			

6897491207

CHEMISTRY **9701/22**

Paper 2 AS Level Structured Questions **May/June 2016**

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.

CAMBRIDGE International Examinations

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

1 **(a)** Complete the table to show the composition and identity of some atoms and ions.

name of element	nucleon number	atomic number	number of protons	number of neutrons	number of electrons	overall charge
boron	10	5	.....	.....	.....	0
nitrogen	.....	.....	.....	8	10	.....
.....	208	82	82	.....	80	.....
.....	.....	.....	3	3	.....	+1

[4]

(b) The fifth to eighth ionisation energies of three elements in the third period of the Periodic Table are given. The symbols used for reference are **not** the actual symbols of the elements.

	ionisation energies, kJ mol^{-1}			
	fifth	sixth	seventh	eighth
X	7012	8496	27 107	31 671
Y	6542	9362	11 018	33 606
Z	7238	8781	11 996	13 842

(i) State and explain the group number of element **Y**.

group number .....

explanation .....

.....

[1]

(ii) State and explain the general trend in **first** ionisation energies across the third period.

.....

.....

..... [2]

(iii) Complete the electronic configuration of element **X**.

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

(c) A sample of oxygen exists as a mixture of three isotopes. Information about two of these isotopes is given in the table.

mass number	16	17
abundance	99.76%	0.04%

(i) Calculate the abundance of the third isotope.

abundance = ... % [1]

(ii) The relative atomic mass of this sample of oxygen is 16.0044.

Calculate the mass number of the third isotope. You **must** show your working.

mass number = ... [2]

[Total: 11]

[Turn over

2 The elements in Group 17, the halogens, and their compounds, show many similarities and trends in their properties. Some data are given for the elements fluorine to iodine.

element	bond energy / kJ mol^{-1}	standard enthalpy change of atomisation, $\Delta H_{at}^{\ominus}$ / kJ mol^{-1}	boiling point of element / K	boiling point of **hydrogen halide** / K
fluorine, F–F	158	79	85	293
chlorine, Cl–Cl	242	121	238	188
bromine, Br–Br	193	112	332	206
iodine, I–I	151	107	457	238

(a) (i) Explain the meaning of the term *standard enthalpy change of atomisation*.

.....

.....

..... [3]

(ii) For fluorine and chlorine, the enthalpy changes of atomisation are half the value of the bond energies.

For bromine and iodine, the enthalpy changes of atomisation are much more than half the value of the bond energies.

Suggest a reason for this difference.

.....

.....

..... [1]

(iii) The standard enthalpy of formation of iodine monochloride, ICl, is –24.0 kJ mol^{-1}.

Use this information and the bond energies of iodine and chlorine to calculate the I–Cl bond energy.

I–Cl bond energy = ... kJ mol^{-1} [2]

(b) (i) Explain the trend in the boiling points of the hydrogen halides, HC*l*, HBr and HI.

.....

.....

..... [2]

(ii) Suggest why the hydrogen halide HF does not follow the trend in boiling points shown by HC*l*, HBr and HI.

.....

.....

..... [2]

(c) In an experiment, two of the halogens are represented as $\mathbf{P}_2$ and $\mathbf{Q}_2$.

$\mathbf{P}_2$ combines with hydrogen on heating to form H**P**, which can be easily broken down into its elements. A solution of H**P** in water reacts with aqueous silver ions to form a yellow precipitate that is insoluble in dilute aqueous ammonia.

$\mathbf{Q}_2$ combines explosively with hydrogen in sunlight to form H**Q**, which is stable to heat. A solution of H**Q** in water reacts with aqueous silver ions to form a white precipitate that is soluble in dilute aqueous ammonia.

(i) Identify the halogens $\mathbf{P}_2$ and $\mathbf{Q}_2$.

$\mathbf{P}_2$ = ... $\mathbf{Q}_2$ = ...
[1]

(ii) H**P** readily decomposes into its elements when heated but H**Q** is stable to heat.
Explain this with reference to bond energies.

.....

.....

..... [2]

(iii) Write an equation for the thermal decomposition of H**P**.

..... [1]

[Turn over

(iv) Write ionic equations, including state symbols, for

1. the formation of the white precipitate on addition of aqueous silver ions to aqueous H**Q**,

.....

2. the subsequent dissolving of this precipitate in dilute aqueous ammonia.

.....

[2]

(d) Chlorine reacts directly with many elements to form chlorides. Three such compounds are $MgCl_2$, $AlCl_3$ and $SiCl_4$.

(i) State and explain the pattern shown by the formulae of these three chlorides.

.....

.....

..... [2]

(ii) Write equations to show the behaviour of each of these chlorides when added to water.

$MgCl_2$ .....

$AlCl_3$ .....

$SiCl_4$ .....

[3]

[Total: 21]

3 Acidified potassium dichromate(VI) can oxidise ethanedioic acid, $H_2C_2O_4$.
The relevant half-equations are shown.

$$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$$

$$H_2C_2O_4 \rightarrow 2CO_2 + 2H^+ + 2e^-$$

(a) State the overall equation for the reaction between acidified dichromate(VI) ions and ethanedioic acid.

..... [2]

(b) In an experiment a 0.242 g sample of hydrated ethanedioic acid, $H_2C_2O_4.\boldsymbol{x}H_2O$, was reacted with a 0.0200 mol dm^{-3} solution of acidified potassium dichromate(VI).

32.0 cm^3 of the acidified potassium dichromate(VI) solution was required for complete oxidation of the ethanedioic acid.

(i) Calculate the amount, in moles, of dichromate(VI) ions used to react with the sample of ethanedioic acid.

amount = ... mol [1]

(ii) Calculate the amount, in moles, of ethanedioic acid in the sample.

amount = ... mol [1]

(iii) Calculate the relative molecular mass, M_r, of the hydrated ethanedioic acid.

M_r = ... [1]

(iv) Calculate the value of $\boldsymbol{x}$ in $H_2C_2O_4.\boldsymbol{x}H_2O$.

$\boldsymbol{x}$ = ... [1]

[Total: 6]

[Turn over

4 This question is about molecules with molecular formula $C_4H_8O_2$.

(a) Give the structural formulae of the pair of **chain** isomers with the formula $C_4H_8O_2$ that are carboxylic acids.

[2]

(b) (i) Give the structural formulae of a pair of **positional** isomers with the formula $C_4H_8O_2$ that are esters.

[2]

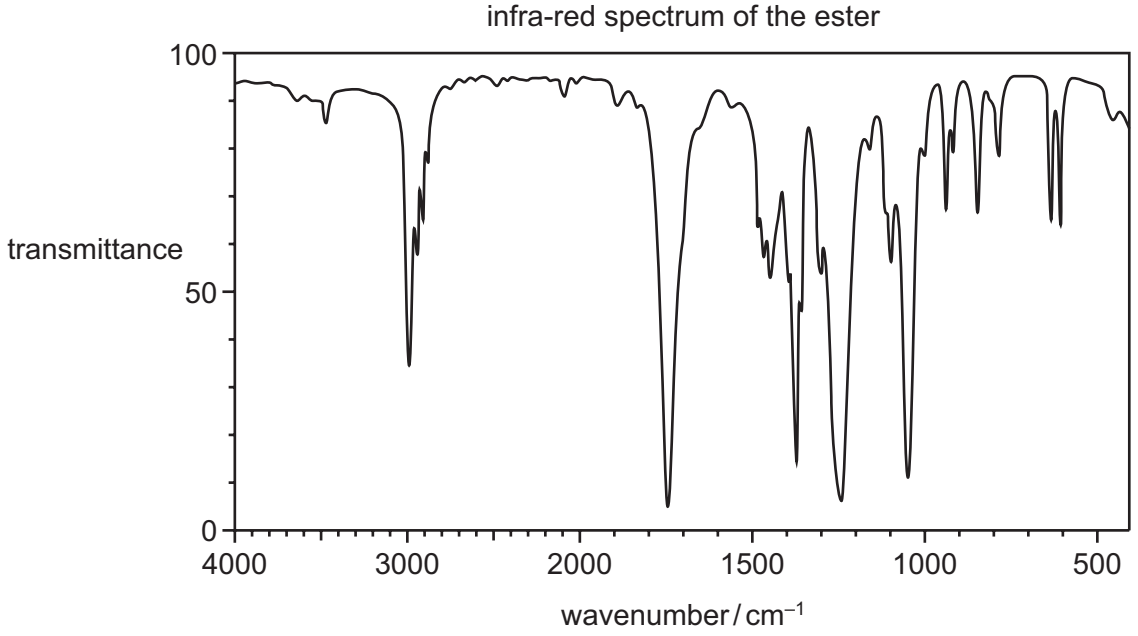
(ii) Give the reagents and conditions needed to produce one of your esters in **(i)**.

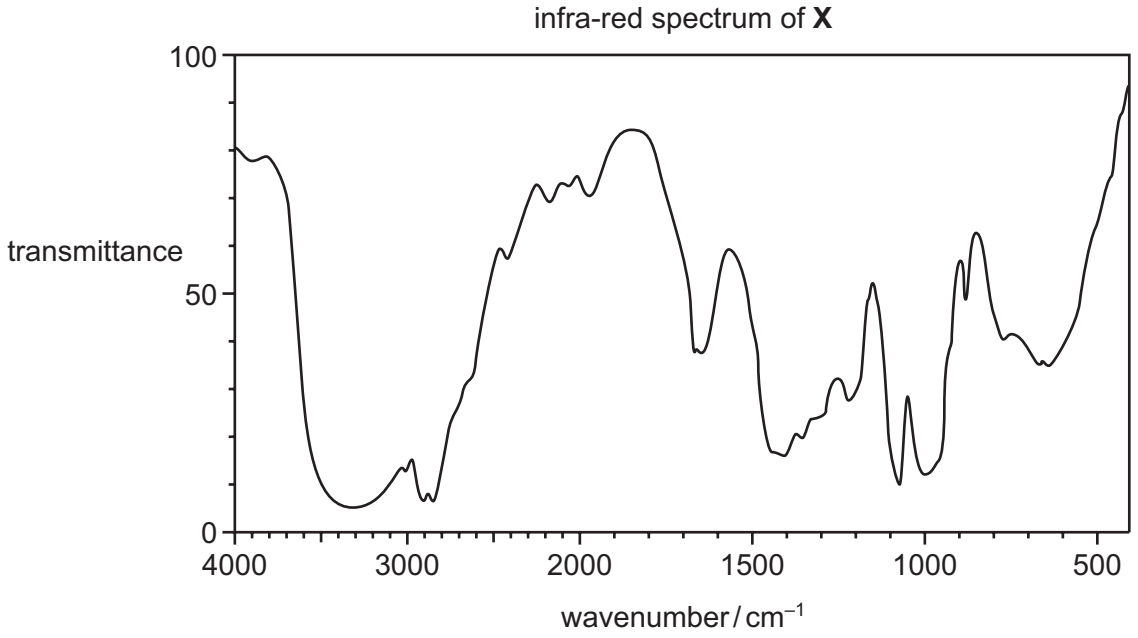
.....

..... [2]

(c) The infra-red spectra of one of the esters and of another isomer, **X**, are shown.

X decolourises bromine water and is not an ester or an acid.





Explain the differences between these two spectra, with particular reference to the peaks with wavenumbers above 1500 cm^{-1}.

.....

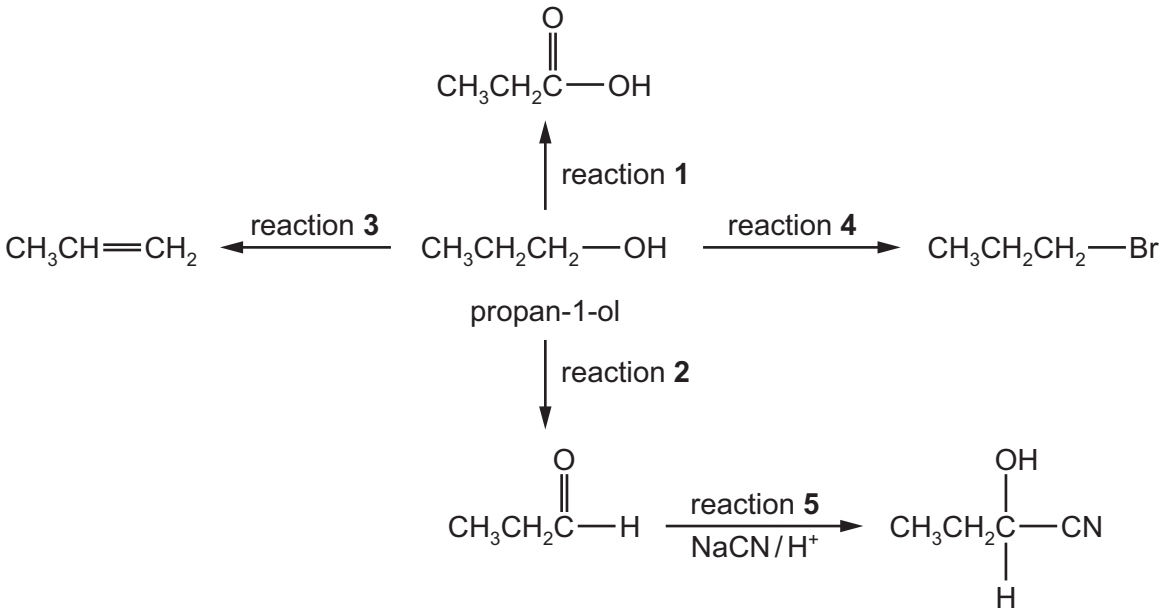
.....

.....

..... [3]

[Total: 9]

5 A reaction sequence based on propan-1-ol is shown.



(a) Reactions **1** and **2** can both be carried out using the same reagents.

(i) Identify suitable reagents for reactions **1** and **2**.

.....

..... [1]

(ii) State and explain how the reaction should be carried out to ensure that reaction **2** rather than reaction **1** occurs.

.....

.....

.....

..... [2]

(b) Identify the necessary reagents and conditions for each of reactions **3** and **4**.

reaction **3** .....

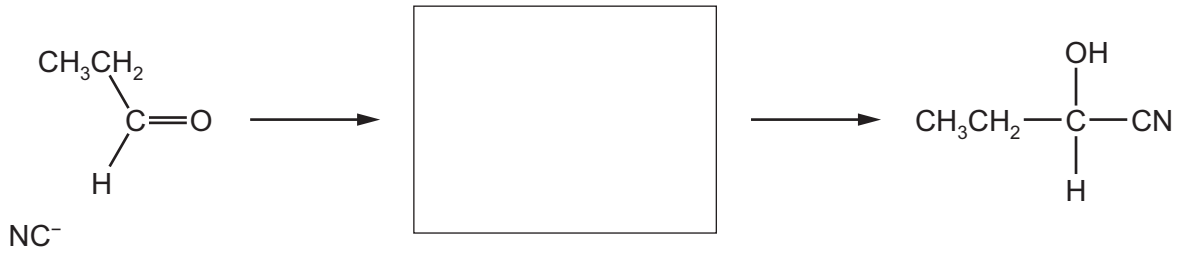
.....

reaction **4** .....

.....

[2]

(c) (i) Complete the reaction mechanism for reaction **5**. Include all relevant lone pairs, curly arrows, charges and partial charges.



[4]

The product of reaction **5** exhibits stereoisomerism.

(ii) Draw the two stereoisomers in the conventional way.

[2]

(iii) Suggest why a mixture of the two stereoisomers is formed by reaction **5**.

.....

.....

..... [2]

[Total: 13]

BLANK PAGE

Cambridge International AS & A Level

Cambridge International Examinations
Cambridge International Advanced Subsidiary and Advanced Level

CANDIDATE NAME	
CENTRE NUMBER	
CANDIDATE NUMBER	

8468970221

CHEMISTRY **9701/22**

Paper 2 AS Level Structured Questions **October/November 2016**

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 **10** printed pages and **2** blank pages.

CAMBRIDGE International Examinations

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

1 A 0.50 g sample of a Group 2 metal, **M**, was added to 40.0 cm^3 of 1.00 mol dm^{-3} hydrochloric acid (an excess).

equation 1 $\quad \mathbf{M}(s) + 2HCl(aq) \rightarrow \mathbf{M}Cl_2(aq) + H_2(g)$

(a) Calculate the amount, in moles, of hydrochloric acid present in 40.0 cm^3 of 1.00 mol dm^{-3} HCl.

amount = ... mol [1]

(b) When the reaction had finished, the resulting solution was made up to 100 cm^3 in a volumetric flask.

A 10.0 cm^3 sample of the solution from the volumetric flask required 15.0 cm^3 of 0.050 mol dm^{-3} sodium carbonate solution, Na_2CO_3, for complete neutralisation of the remaining hydrochloric acid.

(i) Write the equation for the complete reaction of sodium carbonate with hydrochloric acid.

..... [1]

(ii) Calculate the amount, in moles, of sodium carbonate needed to react with the hydrochloric acid in the 10.0 cm^3 sample from the volumetric flask.

amount = ... mol [1]

(iii) Calculate the amount, in moles, of hydrochloric acid in the 10.0 cm^3 sample.

amount = ... mol [1]

(iv) Calculate the total amount, in moles, of hydrochloric acid remaining after the reaction shown in equation 1.

amount = ... mol [1]

(v) Use your answers to **(a)** and **(b)(iv)** to calculate the amount, in moles, of hydrochloric acid that reacted with the 0.50 g sample of **M**.

amount = ... mol [1]

(vi) Use your answer to **(v)** and equation 1 to calculate the amount, in moles, of **M** in the 0.50 g sample.

amount = ... mol [1]

(vii) Calculate the relative atomic mass, A_r, of **M** and identify **M**.

A_r of **M** = ...

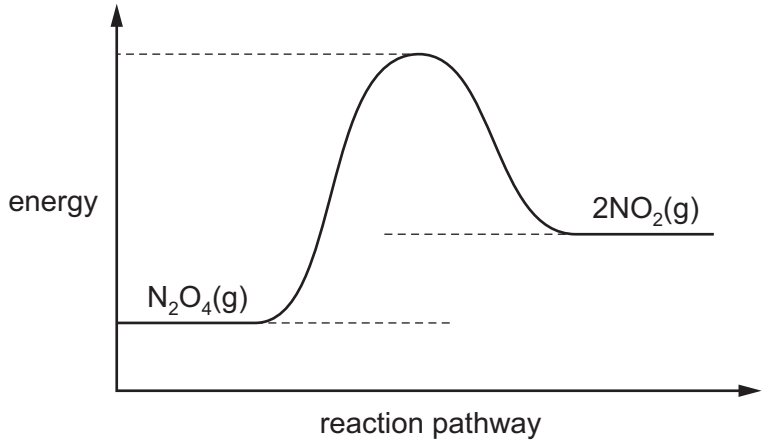
identity of **M** = ...
[2]

[Total: 9]

2 Dinitrogen tetraoxide, N_2O_4, and nitrogen dioxide, NO_2, exist in dynamic equilibrium with each other.

$$N_2O_4(g) \rightleftharpoons 2NO_2(g) \qquad \Delta H = +54\,kJ\,mol^{-1}$$

The energy profile for this reaction is shown.



(a) Add labelled arrows to the energy profile to indicate

- the enthalpy change of the reaction, ΔH,
- the activation energy of the forward reaction, E_a.

[2]

(b) 0.0500 mol of N_2O_4 was placed in a sealed vessel of volume 1.00 dm^3, at a temperature of 50 °C and a pressure of 1.68×10^5 Pa. The mass of the resulting equilibrium mixture was 4.606 g.

(i) Calculate the average molecular mass, M_r, of the resulting equilibrium mixture. Give your answer to **three** significant figures.

M_r = ... [2]

(ii) The number of moles of N_2O_4 that dissociated can be represented by n.

State, in terms of n, the amount, in moles, of NO_2 in the equilibrium mixture.

moles of NO_2 = ... [1]

The number of moles of N_2O_4 remaining at equilibrium is (0.05 – *n*).

(iii) State, in terms of *n*, the total amount, in moles, of gas in the equilibrium mixture.

[1]

(iv) State, in terms of *n*, the mole fraction of NO_2 in the equilibrium mixture.

[1]

In this equilibrium mixture, the mole fraction of NO_2 is 0.400.

(v) Use your answers to **(ii)** and **(iv)** to calculate the amount in moles of each gas in the equilibrium mixture. Give your answers to **three** significant figures.

amount of N_2O_4 = ... mol

amount of NO_2 = ... mol
[2]

(vi) Write the expression for the equilibrium constant, K_p, for this equilibrium.

K_p =

[1]

(vii) Use the total pressure of the mixture, 1.68×10^5 Pa, to calculate the value of the equilibrium constant, K_p, and give its units.

K_p = ...

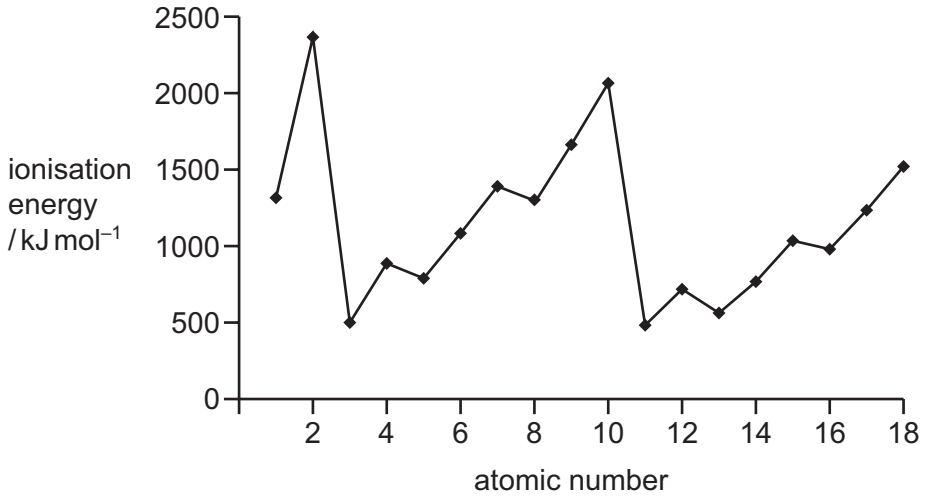
units = ...
[3]

[Total: 13]

[Turn over

3 The Periodic Table is arranged such that the properties of the elements show a number of trends.

(a) A plot of the first ionisation energies for the first 18 elements is shown.



(i) Explain why the values show a general increase from atomic number 11 to 18.

.....

.....

..... [2]

(ii) Explain the decreases in first ionisation energies between

- atomic numbers 12 and 13,

.....

.....

.....

- atomic numbers 15 and 16.

.....

.....

.....
[4]

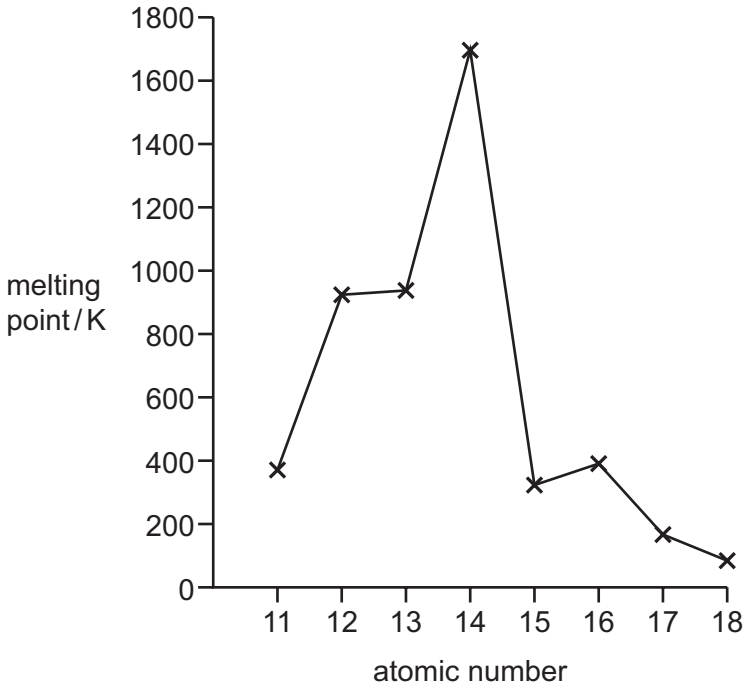
(iii) Suggest an explanation for the trend in the first ionisation energies of the elements with atomic numbers 2, 10 and 18.

.....

.....

..... [2]

(b) A plot of the melting points of the elements across the third period is shown.



(i) Explain the increase in melting point from atomic number 11 to 12.

.....

.....

..... [2]

(ii) Suggest a reason why the increase from atomic number 12 to 13 is much smaller than the increase from atomic number 11 to 12.

.....

..... [1]

(iii) State and explain the pattern of the melting points from atomic number 15 to 18.

.....

.....

.....

..... [3]

(iv) Explain why the element with atomic number 14 has a melting point so much higher than the rest of the elements in the third period.

.....

..... [1]

[Total: 15]

[Turn over

4 In each section of this question the structural formula of an organic compound is shown. For each compound answer the questions about it.

(a) $CH_3CH_2CHBrCH_3$

(i) Name this compound.

..... [1]

(ii) This compound shows stereoisomerism.

Draw the **two** stereoisomers in the conventional way.

[2]

(iii) Give the structures of **three** other structural isomers of C_4H_9Br.

[3]

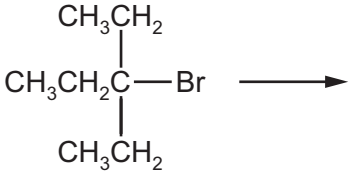
(b) $(C_2H_5)_3CBr$

(i) Name this compound.

..... [1]

(ii) $(C_2H_5)_3CBr$ reacts with aqueous OH^-.

Complete the mechanism for this reaction including all necessary curly arrows, charges, partial charges and lone pairs.



[3]

(iii) What *type of mechanism* occurs in **(ii)**?

..... [1]

(c) $CH_3CH_2CH_2CHBrCH_3$

(i) Give the reagents and conditions necessary for the conversion of this compound into a mixture of alkenes.

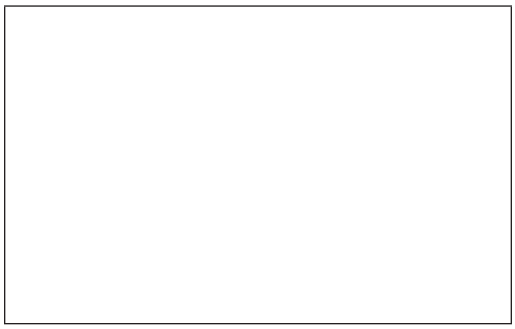
.....

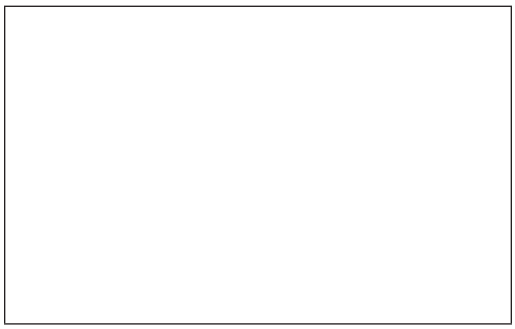
..... [2]

(ii) Give the name of the mechanism for the conversion in **(i)**.

..... [1]

(iii) Draw the skeletal formulae of the three alkenes produced by the conversion in **(i)**.





[3]

[Total: 17]

5 In each section of this question choose the answer or answers from the options listed.

(a) Six particles are listed.

$H\bullet$ H^+ $Cl\bullet$ Cl^- $\bullet CH_3$ $^+CH_3$

(i) Identify **two** particles produced during the reaction of methane and chlorine in the presence of UV light.

..... [1]

(ii) Identify the **two** particles produced by the heterolytic fission of a bond in chloromethane.

..... [1]

(b) Seven reaction types are listed.

addition substitution oxidation elimination

hydrolysis condensation reduction

(i) Name the type of reaction involved when Tollens' reagent is used to identify an aldehyde.

..... [1]

(ii) Name the type of reaction involved in the test for a carbonyl group using 2,4-DNPH.

..... [1]

(iii) Name the type of reaction involved in the reaction of a ketone with $NaBH_4$.

..... [1]

(iv) Name the type of reaction involved in the reaction of an aldehyde with HCN.

..... [1]

[Total: 6]

BLANK PAGE

BLANK PAGE

Cambridge International AS & A Level

Cambridge International Examinations
Cambridge International Advanced Subsidiary and Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

0728412024

CHEMISTRY **9701/22**

Paper 2 Structured Questions AS Core **May/June 2015**

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 **8** printed pages.

CAMBRIDGE International Examinations

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

1 **(a)** Chemists recognise that atoms are made of three types of particle.

Complete the following table with their names and properties.

name of particle	relative mass	relative charge
		+1
	1/1836	

[3]

(b) Most elements exist naturally as a mixture of isotopes, each with their own relative isotopic mass. The mass spectrum of an element reveals the abundances of these isotopes, which can be used to calculate the relative atomic mass of the element.

Magnesium has three stable isotopes. Information about two of these isotopes is given.

isotope	relative isotopic mass	percentage abundance
^{24}Mg	24.0	79.0
^{26}Mg	26.0	11.0

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

.....

.....

..... [2]

(ii) The relative atomic mass of magnesium is 24.3.

Calculate the percentage abundance and hence the relative isotopic mass of the third isotope of magnesium. Give your answer to **three** significant figures

percentage abundance = ...

isotopic mass = ...

[3]

(c) Magnesium can be produced by electrolysis of magnesium chloride in a molten mixture of salts.

(i) Give equations for the anode and cathode reactions during the electrolysis of molten magnesium chloride, $MgCl_2$.

anode .....

cathode .....
[2]

The electrolysis is carried out under an atmosphere of hydrogen chloride gas to convert any magnesium oxide impurity into magnesium chloride.

(ii) An investigation of the reaction between magnesium oxide and hydrogen chloride gas showed that an intermediate product was formed with the composition by mass Mg, 31.65%; O, 20.84%; H, 1.31% and C*l*, 46.20%.

Calculate the empirical formula of this intermediate compound.

empirical formula ..... [2]

(d) The acid/base behaviour of the oxides in the third period varies across the period.

(i) Describe this behaviour and explain it with reference to the structure and bonding of sodium oxide, Na_2O, aluminium oxide, Al_2O_3, and sulfur trioxide, SO_3.

.....

.....

..... [2]

(ii) Write equations for reactions of these three oxides with hydrochloric acid and/or sodium hydroxide as appropriate.

.....

.....

.....

..... [4]

[Total: 18]

[Turn over

2 Sulfuric acid is an important chemical with a variety of uses.

It is manufactured by the Contact process, the first stage of which involves the conversion of sulfur or a sulfide ore, such as galena, PbS, into sulfur dioxide, SO_2.

(a) (i) Write an equation for the reaction between galena and oxygen to form sulfur dioxide and lead(II) oxide.

..... [2]

(ii) Identify the oxidation number changes that take place during this reaction.

.....

..... [2]

(b) The second stage of the Contact process involves the production of sulfur trioxide, SO_3, from sulfur dioxide.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -197\,kJ\,mol^{-1}$$

(i) State the temperature usually chosen for this conversion and explain this in terms of reaction rates and Le Chatelier's principle.

temperature .....

explanation .....

.....

.....

..... [3]

(ii) State and explain the pressure conditions that would give the best rate and best yield of sulfur trioxide. Explain why these conditions are **not** actually used.

.....

.....

.....

.....

..... [3]

(c) In the third stage of the process the sulfur trioxide is dissolved in 98% sulfuric acid followed by carefully controlled addition of water.

(i) Explain why the sulfur trioxide is not dissolved directly in water to produce sulfuric acid.

.....

..... [1]

(ii) Write equations for the reaction of sulfur trioxide with sulfuric acid and for the subsequent reaction with water.

.....

..... [2]

(d) Explain why sulfur dioxide is used as an additive in some foods and wines.

.....

.....

..... [2]

(e) The sulfur dioxide content of wine is most commonly measured by the Ripper Method which involves titration with iodine in the presence of starch as an indicator.

$$SO_2(aq) + I_2(aq) + 2H_2O(l) \rightarrow 2I^-(aq) + SO_4^{2-}(aq) + 4H^+(aq)$$

A 50.0 cm^3 sample of wine required 12.35 cm^3 of 0.010 mol dm^{-3} $I_2(aq)$ for complete reaction with the SO_2.

(i) How many moles of SO_2 are present in 50.0 cm^3 of wine?

moles of SO_2 in 50.0 cm^3 = ... [1]

(ii) How many moles of SO_2 are present in 1 dm^3 of wine?

moles of SO_2 in 1 dm^3 = ... [1]

(iii) How many milligrams, mg, of SO_2 are present in 1 dm^3 of wine? Give your answer to **three** significant figures. (1 g = 1000 mg)

mass of SO_2 in 1 dm^3 = ... mg [1]

[Total: 18]

[Turn over

3 Ethane reacts with chlorine to form chloroethane.

$$C_2H_6(g) + Cl_2(g) \rightarrow C_2H_5Cl(g) + HCl(g)$$

(a) (i) Use bond energies from the *Data Booklet* to calculate the enthalpy change for this reaction. Include a sign in your answer.

enthalpy change = ... kJ mol^{-1} [3]

(ii) State the conditions needed for this reaction to occur.

..... [1]

(iii) Use a series of equations to describe the mechanism of this reaction including the names of each stage and an indication of how butane can be produced as a minor by-product.

.....

.....

.....

.....

.....

..... [5]

(b) Chloroethane can be converted back into ethane by a two-stage process via an intermediate compound, **X**.

$$C_2H_5Cl \xrightarrow{\text{reaction 1}} \mathbf{X} \xrightarrow{\text{reaction 2}} C_2H_6$$

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

..... [1]

(ii) Suggest the reagent and conditions needed for reaction 1.

..... [2]

(iii) Suggest the reagent and conditions needed for reaction 2.

..... [1]

[Total: 13]

4 There are seven structural isomers with the molecular formula $C_5H_{10}O$ that are carbonyl compounds. Four of these are aldehydes.

These four aldehydes, **A**, **B**, **C** and **D**, have the following properties.

- Aldehyde **A** has a straight chain while **B**, **C** and **D** are branched.
- Aldehyde **B** is the only one of the four isomers with a chiral centre and it exists as a pair of optical isomers.
- Aldehyde **C** has two methyl groups in its structure but **D** has three.

(a) (i) Give the structure of each of the four isomers.

A

B

C

D

[4]

(ii) Draw the three-dimensional structures of the two optical isomers of **B**.

[2]

(b) (i) Describe a chemical test that would allow you to distinguish between any of the four isomers **A** to **D** and any of the other three structural isomers of $C_5H_{10}O$, that are carbonyl compounds.

In your answer you should describe any necessary reagents and conditions as well as explaining what you would **see** in each case.

.....

.....

.....

.....

..... [3]

(ii) Describe a test that would give the same result with all seven carbonyl isomers of $C_5H_{10}O$.

.....

.....

..... [2]

[Total: 11]

Cambridge International AS & A Level

Cambridge International Examinations
Cambridge International Advanced Subsidiary and Advanced Level

CANDIDATE NAME	
CENTRE NUMBER	
CANDIDATE NUMBER	

6002972519

CHEMISTRY **9701/22**

Paper 2 Structured Questions AS Core **October/November 2015**

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 **10** printed pages and **2** blank pages.

CAMBRIDGE International Examinations

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

1 **(a)** Fill the gaps in the table for each of the given particles.

name of isotope	type of particle	charge	symbol	electron configuration
carbon-13				$1s^2 2s^2 2p^2$
		–1	$^{37}_{17}Cl^-$	
sulfur-34	atom	0		
iron-54	cation			$1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$

[5]

(b) One of the factors that determines the type of bonding present between the particles of a substance is the relative electronegativities of the bonded particles.

(i) Explain the meaning of the term *electronegativity*.

.....

.....

..... [2]

(ii) Name and describe the type of bonding you would expect to find between particles with equal electronegativities.

.....

.....

..... [2]

(iii) Name and describe the type of bonding you would expect to find between particles with very different electronegativities.

.....

.....

..... [2]

(c) The boiling points of some molecules with equal numbers of electrons are given.

substance	fluorine	argon	hydrogen chloride	methanol
formula	F_2	Ar	HCl	CH_3OH
boiling point / K	85	87	188	338

(i) Explain why the boiling points of fluorine and argon are so similar.

.....

.....

..... [2]

(ii) Explain why the boiling point of hydrogen chloride is higher than that of fluorine.

.....

.....

..... [2]

(iii) Explain why methanol has the highest boiling point of all these molecules.

.....

.....

..... [2]

[Total: 17]

[Turn over

2 Chemical reactions are accompanied by enthalpy changes.

(a) Explain the meaning of the term *standard enthalpy change* of reaction.

.....

.....

..... [2]

(b) The enthalpy change of hydration of anhydrous magnesium sulfate, ΔH_{hyd} $MgSO_4$, can be calculated by carrying out two separate experiments.

In the first experiment 45.00 g of water was weighed into a polystyrene cup and 3.01 g of $MgSO_4$ was added and stirred until it was completely dissolved. The temperature of the water rose from 23.4 °C to 34.7 °C.

(i) Calculate the amount of heat energy transferred to the water during this dissolving process.

You can assume that the specific heat capacity of the solution is the same as that of water, $4.18\,J\,g^{-1}\,K^{-1}$.

heat energy = ... J [1]

(ii) Calculate the amount, in moles, of $MgSO_4$ dissolved.

amount = ... mol [1]

(iii) Calculate the enthalpy change of solution, ΔH_{soln}, of $MgSO_4(s)$.

You must include a sign with your answer.

ΔH_{soln}, of $MgSO_4(s)$ = ... kJ mol^{-1} [1]

In the second experiment, the enthalpy change of solution for the hydrated salt, $MgSO_4.7H_2O(s)$, was calculated and found to be +9.60 kJ mol^{-1}.

(iv) Use the equation below for the hydration of anhydrous magnesium sulfate to construct a suitable, fully labelled energy cycle that will allow you to calculate the enthalpy change for this reaction, ΔH_{hyd} $MgSO_4$.

$$MgSO_4(s) + 7H_2O(l) \rightarrow MgSO_4.7H_2O(s)$$

[1]

(v) Calculate the enthalpy change for this reaction, ΔH_{hyd} $MgSO_4$. Include a sign in your answer.

ΔH_{hyd} $MgSO_4$ = ... kJ mol^{-1} [1]

[Total: 7]

[Turn over

3 The elements in Period 3, Na, Mg, A*l*, P and S, all react with oxygen when heated in air.

(a) (i) Give the formula of the oxide formed when each element is heated in air. One has been completed for you.

Na = ... Mg = ... A*l* = Al_2O_3

P = ... S = ...

[2]

(ii) Describe what you would **see** when sodium and sulfur are each heated separately in air and give an equation for each reaction.

Na .....

equation .....

S .....

equation .....

[4]

(b) The oxides show variations in their behaviour when added to water, acids and alkalis.

(i) Place the symbols of the elements in **(a)(i)** in the appropriate row of the table to indicate this behaviour.

acidic	
amphoteric	
basic	

[2]

(ii) State the bonding present in acidic and basic oxides.

acidic .....

basic .....

[2]

(iii) Write equations for the reaction of aluminium oxide with each of hydrochloric acid, HC*l*, and sodium hydroxide, NaOH.

with HC*l* .....

with NaOH .....

[2]

(c) Explain how the presence of an impurity in carbonaceous fuels can give rise to acid rain.

name of impurity .....

.....

..... [2]

[Total: 14]

BLANK PAGE

4 Halogenoalkanes are useful intermediates in the synthesis of a wide variety of compounds.

(a) 2-bromobutane reacts in two different ways with sodium hydroxide depending on the conditions.

When warmed with aqueous sodium hydroxide, 2-bromobutane produces an alcohol that exists as a pair of optical isomers.

(i) Give the name of the mechanism of the reaction between 2-bromobutane and aqueous sodium hydroxide.

..... [1]

(ii) Explain why the alcohol produced exists as a pair of optical isomers.

.....

..... [1]

(iii) Draw the three-dimensional structure of the two optical isomers of the alcohol produced in **(ii)**.

[2]

Heating 2-bromobutane with ethanolic sodium hydroxide produces a mixture of three alkenes, two of which are a pair of geometrical isomers.

(iv) Give the name of the mechanism of the reaction between 2-bromobutane and ethanolic sodium hydroxide.

..... [1]

(v) Draw and name the structures of the pair of geometrical isomers formed by reaction of 2-bromobutane with ethanolic sodium hydroxide.

name .....

name .....

[2]

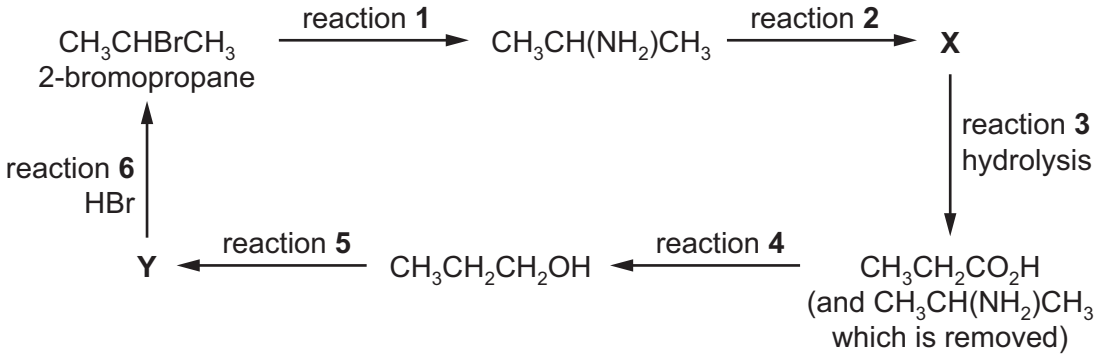
(vi) Name the third alkene produced by reaction of 2-bromobutane with ethanolic sodium hydroxide and explain why it does **not** show geometrical isomerism.

.....

.....

..... [2]

(b) Some reactions involving 2-bromopropane are shown.



(i) State the reagent needed for reaction **1**.

..... [1]

(ii) State the reagent needed for reaction **2**.

..... [1]

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

[1]

(iv) Name the type of reaction involved in reaction **4** and suggest a suitable reagent.

.....

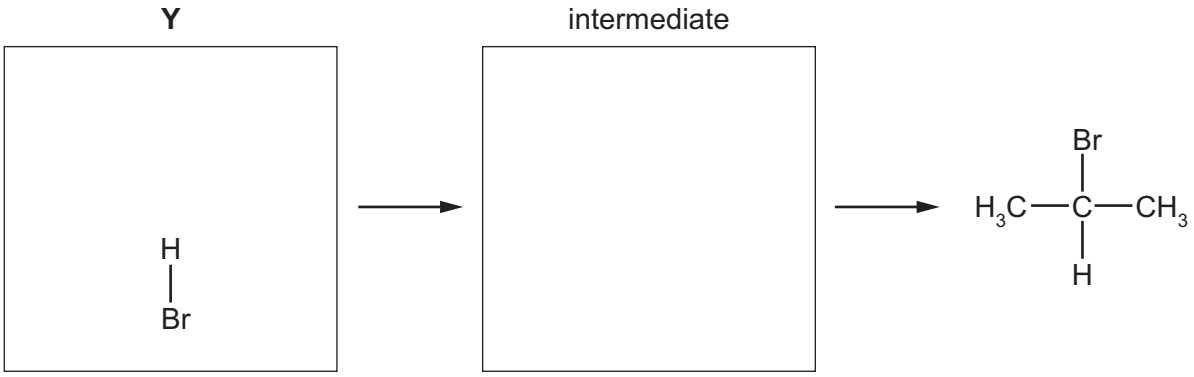
..... [2]

(v) State the name of a solid catalyst for reaction **5**.

..... [1]

(vi) Complete the mechanism for the production of 2-bromopropane from **Y** in reaction **6** shown below.

Include the structure of **Y** and any necessary lone pairs, curly arrows, charges and partial charges.



[4]

(vii) Give the name of the mechanism in **(vi)**.

..... [1]

(viii) 1-bromopropane is a minor product of reaction **6**.

Explain why 2-bromopropane is the major product of reaction **6**.

.....

.....

.....

..... [2]

[Total: 22]

BLANK PAGE

Cambridge International AS & A Level

Cambridge International Examinations
Cambridge International Advanced Subsidiary and Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

5132764907

CHEMISTRY **9701/22**

Paper 2 Structured Questions AS Core **May/June 2014**

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 **9** printed pages and **3** blank pages.

CAMBRIDGE International Examinations

www.onlineexamhelp.com

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

1 **(a)** Explain what is meant by the term *nucleon number*.

.....

..... [1]

(b) Bromine exists naturally as a mixture of two stable isotopes, ^{79}Br and ^{81}Br, with relative isotopic masses of 78.92 and 80.92 respectively.

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

.....

.....

..... [2]

(ii) Using the relative atomic mass of bromine, 79.90, calculate the relative isotopic abundances of ^{79}Br and ^{81}Br.

[3]

(c) Bromine reacts with the element **A** to form a compound with empirical formula **A**Br_3. The percentage composition by mass of **A**Br_3 is **A**, 4.31; Br, 95.69.

Calculate the relative atomic mass, A_r, of **A**.
Give your answer to **three** significant figures.

A_r of **A** = ... [3]

(d) The elements in Period 3 of the Periodic Table show different behaviours in their reactions with oxygen.

(i) Describe what you would **see** when separate samples of magnesium and sulfur are reacted with oxygen.

Write an equation for each reaction.

magnesium

.....

.....

sulfur

.....

.....

[4]

(ii) Write equations for the reactions of aluminium oxide, Al_2O_3, with

sodium hydroxide,

.....

hydrochloric acid.

.....

[2]

(e) Phosphorus reacts with chlorine to form PCl_5.

State the shape of and two different bond angles in a molecule of PCl_5.

shape of PCl_5 .....

bond angles in PCl_5 ....

[2]

[Total: 17]

[Turn over

2 A 6.30 g sample of hydrated ethanedioic acid, $H_2C_2O_4.xH_2O$, was dissolved in water and the solution made up to 250 cm^3.

A 25.0 cm^3 sample of this solution was acidified and titrated with 0.100 mol dm^{-3} potassium manganate(VII) solution. 20.0 cm^3 of this potassium manganate(VII) solution was required to react fully with the ethanedioate ions, $C_2O_4^{2-}$, present in the sample.

(a) The MnO_4^- ions in the potassium manganate(VII) *oxidise* the ethanedioate ions.

(i) Explain, in terms of electron transfer, the meaning of the term *oxidise* in the sentence above.

.....

..... [1]

(ii) Complete and balance the ionic equation for the reaction between the manganate(VII) ions and the ethanedioate ions.

$2MnO_4^-(aq) + 5C_2O_4^{2-}(aq) + ...H^+(aq) \rightarrow .....(aq) + 10CO_2(aq) + ...H_2O(l)$ [3]

(b) (i) Calculate the number of moles of manganate(VII) used in the titration.

[1]

(ii) Use the equation in **(a)(ii)** and your answer to **(b)(i)** to calculate the number of moles of $C_2O_4^{2-}$ present in the 25.0 cm^3 sample of solution used.

[1]

(iii) Calculate the number of moles of $H_2C_2O_4.xH_2O$ in 6.30 g of the compound.

[1]

(iv) Calculate the relative formula mass of $H_2C_2O_4.xH_2O$.

[1]

(v) The relative formula mass of anhydrous ethanedioic acid, $H_2C_2O_4$, is 90.

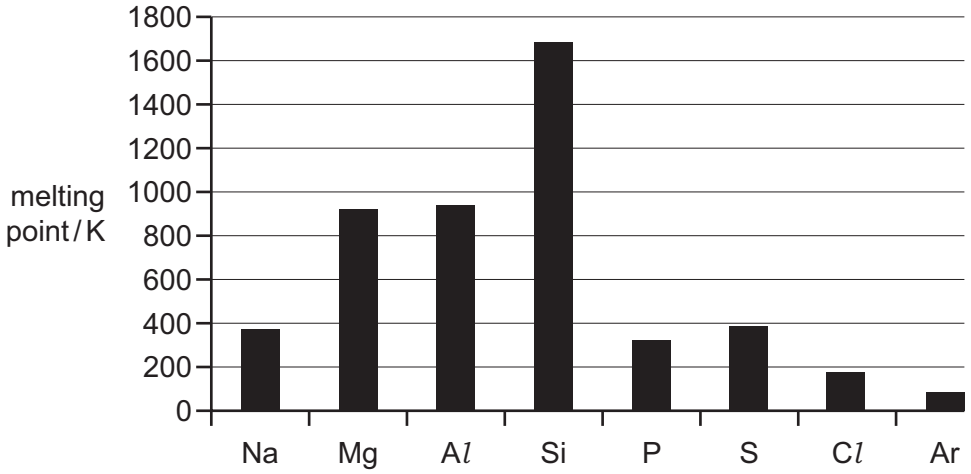
Calculate the value of x in $H_2C_2O_4.xH_2O$.

[1]

[Total: 9]

3 The elements in Period 3 of the Periodic Table show variations in their behaviour across the period.

(a) The bar chart below shows the variation of melting points of the elements across Period 3.



In each of the following parts of this question you should clearly identify the interactions involved and, where appropriate, explain their relative magnitudes.

(i) Explain the general increase in melting point from Na to A*l*.

.....

.....

.....

..... [3]

(ii) Explain the variation of melting points from P to Ar.

.....

.....

.....

.....

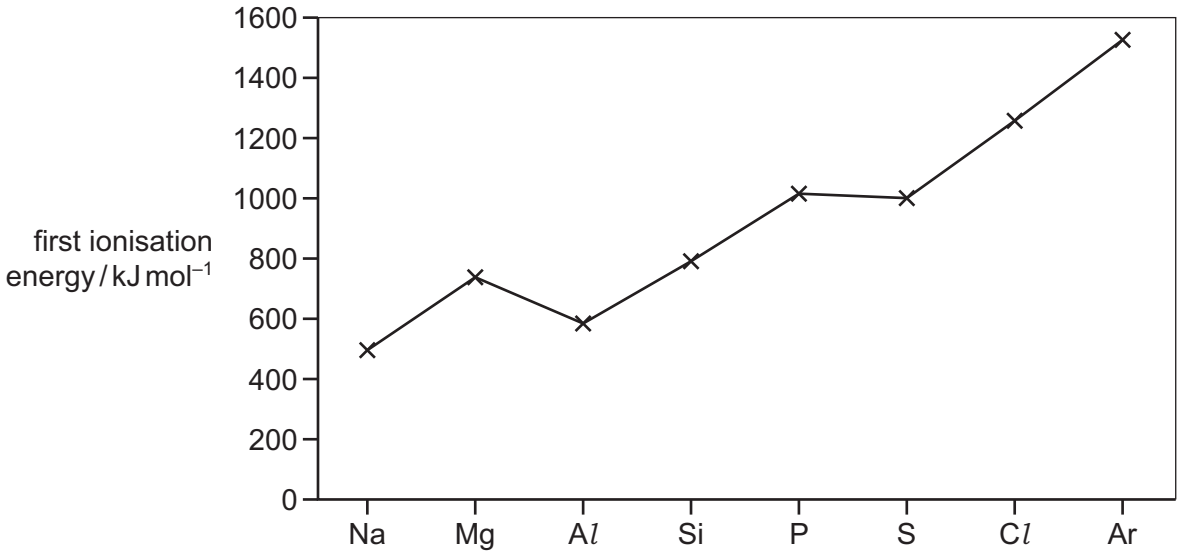
..... [3]

(iii) Explain why Si has a much higher melting point than any of the other elements in the period.

.....

..... [1]

(b) The graph below shows the variation of the first ionisation energies across Period 3.



(i) Explain why the first ionisation energy of Ar is greater than that of C*l*.

.....

..... [1]

(ii) Explain why the first ionisation energy of A*l* is less than that of Mg.

.....

..... [1]

(iii) Explain why the first ionisation energy of S is less than that of P.

.....

..... [1]

[Total: 10]

4 Crude oil is processed to give a wide variety of hydrocarbons.

(a) Give the names of one physical process and one chemical process carried out during the processing of crude oil.

physical process .....

chemical process .....
[2]

(b) Alkanes and alkenes can both be obtained from crude oil.

(i) Explain why alkanes are unreactive.

.....

..... [2]

(ii) State the bond angles in a molecule of

ethane, ...

ethene. .....
[1]

(iii) State the shape of each molecule in terms of the arrangement of the atoms bonded to each carbon atom.

ethane ..... ethene ..... [1]

(iv) Explain why these molecules have different shapes in terms of the carbon-carbon bonds present.

.....

..... [1]

(c) **(i)** Use a series of equations to describe the mechanism of the reaction of ethane with chlorine to form chloroethane. Name the steps in this reaction.

.....

.....

.....

.....

..... [5]

(ii) Write an equation to show how butane could be produced as a by-product of this reaction.

..... [1]

[Total: 13]

5 A hydrocarbon, **P**, with the formula C_6H_{12} readily decolourises bromine.

On reaction with hot, concentrated, acidified potassium manganate(VII) solution a single organic product, **Q**, is obtained.

Q gives an orange precipitate when reacted with 2,4-dinitrophenylhydrazine, 2,4-DNPH reagent, but has no reaction with Tollens' reagent.

(a) (i) Explain these observations.

.....

.....

.....

.....

.....

.....

.....

..... [4]

(ii) Draw the skeletal formula of **P** and give its name.

name of **P** .....
[2]

(iii) Draw the skeletal formula of **Q** and give its name.

name of **Q** .....
[2]

(b) There are several structural isomers of **P** that also decolourise bromine, but only four of these structural isomers exhibit geometrical (cis-trans) isomerism.

Give the structures of any **three** structural isomers of **P** that exhibit geometrical (cis-trans) isomerism.

[3]

[Total: 11]

BLANK PAGE

BLANK PAGE

BLANK PAGE

Cambridge International AS & A Level

Cambridge International Examinations
Cambridge International Advanced Subsidiary and Advanced Level

CANDIDATE NAME									
CENTRE NUMBER						CANDIDATE NUMBER			

0592941107

CHEMISTRY **9701/22**

Paper 2 Structured Questions AS Core **October/November 2014**

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 **10** printed pages and **2** blank pages.

CAMBRIDGE International Examinations

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

1 **(a)** Successive ionisation energies for the elements magnesium to barium are given in the table.

element	1st ionisation energy / kJ mol^{-1}	2nd ionisation energy / kJ mol^{-1}	3rd ionisation energy / kJ mol^{-1}
Mg	736	1450	7740
Ca	590	1150	4940
Sr	548	1060	4120
Ba	502	966	3390

(i) Explain why the first ionisation energies decrease down the group.

.....

.....

.....

..... [3]

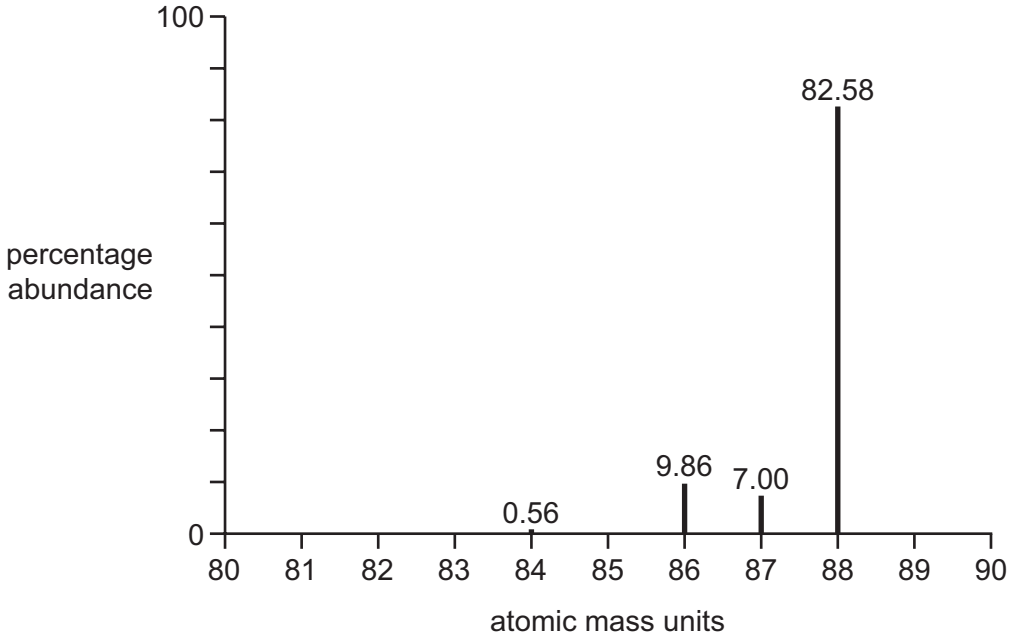
(ii) Explain why, for each element, there is a large increase between the 2nd and 3rd ionisation energies.

.....

.....

..... [2]

(b) A sample of strontium, atomic number 38, gave the mass spectrum shown. The percentage abundances are given above each peak.



(i) Complete the full electronic configuration of strontium.

$1s^2\ 2s^2\ 2p^6$ ..... [1]

(ii) Explain why there are four different peaks in the mass spectrum of strontium.

.....

..... [1]

(iii) Calculate the atomic mass, A_r, of this sample of strontium.
Give your answer to **three** significant figures.

A_r = ... [2]

(c) A compound of barium, **A**, is used in fireworks as an oxidising agent and to produce a green colour.

(i) Explain, in terms of electron transfer, what is meant by the term *oxidising agent*.

.....

..... [1]

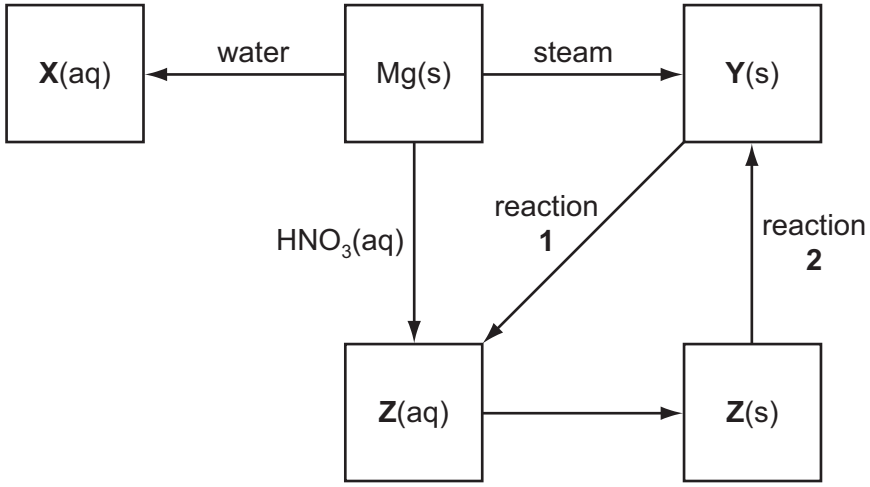
(ii) **A** has the following percentage composition by mass: Ba, 45.1; C*l*, 23.4; O, 31.5.

Calculate the empirical formula of **A**.

empirical formula of **A** ..... [3]

[Turn over

(d) Some reactions involving magnesium and its compounds are shown in the reaction scheme below.



(i) Give the **formulae** of the compounds **X**, **Y** and **Z**.

X .....

Y .....

Z .....

[3]

(ii) Name the reagent needed to convert **Y**(s) into **Z**(aq) in reaction **1** and write an equation for the reaction.

reagent .....

equation .....

[2]

(iii) How would you convert a sample of **Z**(s) into **Y**(s) in reaction **2**?

..... [1]

(iv) Give equations for the conversions of Mg into **X**, and **Z**(s) into **Y**.

Mg to **X** .....

Z to **Y** .....

[2]

[Total: 21]

Question 2 starts on the next page.

2 The Contact process for the manufacture of sulfuric acid was originally patented in the 19th century and is still in use today.

The key step in the overall process is the reversible conversion of sulfur dioxide to sulfur trioxide in the presence of a vanadium(V) oxide catalyst.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -196\,kJ\,mol^{-1}$$

(a) One way in which the sulfur dioxide for this reaction is produced is by heating the sulfide ore iron pyrites, FeS_2, in air. Iron(III) oxide is also produced. Write an equation for this reaction.

..... [2]

(b) The sulfur trioxide produced in the Contact process is reacted with 98% sulfuric acid. The resulting compound is **then** reacted with water to produce sulfuric acid.

(i) Explain why the sulfur trioxide is not first mixed directly with water.

.....

..... [1]

(ii) Write equations for the two steps involved in the conversion of sulfur trioxide into sulfuric acid.

.....

..... [2]

(c) (i) Sulfur dioxide and sulfur trioxide both contain only S=O double bonds.

Draw labelled diagrams to show the shapes of these two molecules.

SO_2 SO_3

[2]

(ii) For your diagrams in **(i)**, name the shapes and suggest the bond angles.

SO_2 shape ..... SO_3 shape .....

SO_2 bond angle ..... SO_3 bond angle .....

[2]

(d) The conversion of sulfur dioxide into sulfur trioxide is carried out at a temperature of 400 °C.

(i) With reference to Le Chatelier's Principle and reaction kinetics, state and explain one advantage and one disadvantage of using a higher temperature.

.....

.....

.....

.....

.....

..... [4]

(ii) State the expression for the equilibrium constant, K_p, for the formation of sulfur trioxide from sulfur dioxide.

K_p =

[1]

(iii) 2.00 moles of sulfur dioxide and 2.00 moles of oxygen were put in a flask and left to reach equilibrium.
At equilibrium, the pressure in the flask was 2.00×10^5 Pa and the mixture contained 1.80 moles of sulfur trioxide.

Calculate K_p. Include the units.

K_p = ...

units = ...
[5]

[Total: 19]

3 **P**, **Q** and **R** are structural isomers with the molecular formula C_4H_8.

All three compounds readily decolourise bromine in the dark.

P and **Q** do not exhibit stereoisomerism but **R** exists as a pair of geometrical (cis-trans) isomers.

All three compounds react with hot concentrated, acidified potassium manganate(VII) to produce a variety of products as shown in the table.

compound	products
P	CO_2 and **S** (C_3H_6O)
Q	CO_2 and $CH_3CH_2CO_2H$
R	CH_3CO_2H only

S reacts with 2,4-dinitrophenylhydrazine reagent, 2,4-DNPH, to form an orange crystalline product but does not react with Fehling's reagent.

(a) Give the structural formulae of **P**, **Q**, **R** and **S**.

P ..... **Q** .....

R ..... **S** .....
[4]

(b) **(i)** Explain what is meant by the term *stereoisomerism*.

.....

.....

..... [2]

(ii) Draw the **displayed** formulae of the geometrical isomers of **R** and name them both.

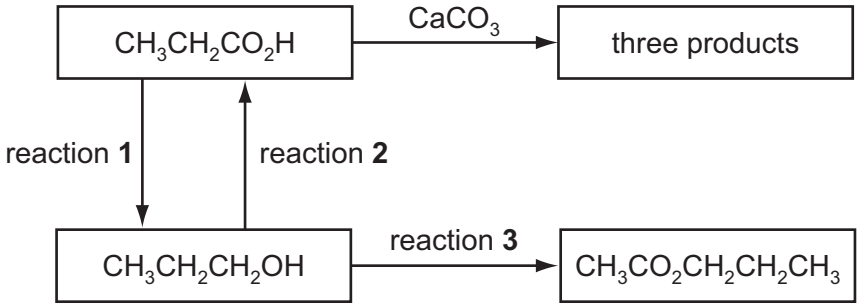
name ..... name ..... [2]

(c) State a reagent that could be used for the reduction of **S** and **name** the organic product of this reduction.

reagent ..... product ..... [2]

[Total: 10]

4 A series of reactions based on propanoic acid is shown.



(a) Write an equation for reaction **1**, using [H] to represent the reducing agent.

..... [2]

(b) (i) What type of reaction is reaction **2**?

..... [1]

(ii) Suggest a suitable reagent and conditions for reaction **2**.

..... [2]

(c) Write an equation for the reaction of propanoic acid with calcium carbonate, $CaCO_3$.

..... [2]

(d) (i) Suggest a suitable reagent and conditions for reaction **3**.

.....

..... [2]

(ii) Identify the **other** product of reaction **3**.

..... [1]

[Total: 10]

BLANK PAGE

BLANK PAGE

UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education
Advanced Subsidiary Level and Advanced Level

CANDIDATE NAME	
CENTRE NUMBER	
CANDIDATE NUMBER	

CHEMISTRY **9701/22**

Paper 2 Structured Questions AS Core **May/June 2013**

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 a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, 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.

For Examiner's Use	
1	
2	
3	
4	
5	
Total	

This document consists of **11** printed pages and **1** blank page.

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

For Examiner's Use

1 Ammonium sulfate is a fertiliser which is manufactured by the reaction between ammonia and sulfuric acid.

(a) Ammonia is described as a weak base and sulfuric acid as a strong acid.

By using an equation, explain clearly what is meant by the term *weak base*.

.....

.....

.....

.....

..... [3]

(b) Ammonia and sulfuric acid are both manufactured by processes which involve chemical equilibria.

(i) Sulfuric acid is produced from sulfur trioxide which is made by the Contact process.

State **three** important operating conditions for the Contact process for the manufacture of sulfur trioxide.

For **each** of your conditions, you should avoid the use of vague phrases such as 'high temperature'.

condition 1 .....

.....

condition 2 .....

.....

condition 3 .....

.....

(ii) How is the sulfur trioxide produced converted into sulfuric acid?

.....

.....
[4]

(c) Chloropropanols such as 1,3-dichloropropan-2-ol (1,3-DCP) are present in some foods.

$$Cl CH_2CH(OH)CH_2Cl$$

1,3-DCP

(i) What will be produced when 1,3-DCP is reacted separately with the following reagents under suitable conditions?
In each case give the **structural** formula.

concentrated sulfuric acid

an excess of ammonia

(ii) Describe as fully as you can what type of reaction occurs with ammonia.

.....

[4]

[Total: 11]

[Turn over

For Examiner's Use

2 Chile saltpetre is a mineral found in Chile and Peru, and which mainly consists of sodium nitrate, $NaNO_3$. The mineral is purified to concentrate the $NaNO_3$ which is used as a fertiliser and in some fireworks.

In order to find the purity of a sample of sodium nitrate, the compound is heated in NaOH(aq) with Devarda's alloy which contains aluminium. This reduces the sodium nitrate to ammonia which is boiled off and then dissolved in acid.

$$3NaNO_3(aq) + 8Al(s) + 5NaOH(aq) + 18H_2O(l) \rightarrow 3NH_3(g) + 8NaAl(OH)_4(aq)$$

The ammonia gas produced is dissolved in an excess of H_2SO_4 of known concentration.

$$2NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$$

The amount of unreacted H_2SO_4 is then determined by back-titration with NaOH of known concentration.

$$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$$

(a) A 1.64 g sample of impure $NaNO_3$ was reacted with an excess of Devarda's alloy.
The NH_3 produced was dissolved in 25.0 cm^3 of 1.00 mol dm^{-3} H_2SO_4.
When all of the NH_3 had dissolved, the resulting solution was titrated with NaOH(aq).
For neutralisation, 16.2 cm^3 of 2.00 mol dm^{-3} NaOH were required.

(i) Calculate the amount, in moles, of H_2SO_4 present in the 25.0 cm^3 of 1.00 mol dm^{-3} H_2SO_4.

(ii) Calculate the amount, in moles, of NaOH present in 16.2 cm^3 of 2.00 mol dm^{-3} NaOH.

(iii) Use your answer to **(ii)** to calculate the amount, in moles, of H_2SO_4 that reacted with 16.2 cm^3 of 2.00 mol dm^{-3} NaOH.

(iv) Use your answers to **(i)** and **(iii)** to calculate the amount, in moles, of H_2SO_4 that reacted with the NH_3.

For Examiner's Use

(v) Use your answer to **(iv)** to calculate the amount, in moles, of NH_3 that reacted with the H_2SO_4.

(vi) Use your answer to **(v)** to calculate the amount, in moles, of $NaNO_3$ that reacted with the Devarda's alloy.

(vii) Hence calculate the mass of $NaNO_3$ that reacted.

(viii) Use your answer to **(vii)** to calculate the percentage by mass of $NaNO_3$ present in the impure sample.
Write your answer to a suitable number of significant figures.

[9]

(b) The above reaction is an example of a redox reaction.
What are the oxidation numbers of nitrogen in $NaNO_3$ and in NH_3?

$NaNO_3$ ..... NH_3 ..... [1]

[Total: 10]

For Examiner's Use

3 This question refers to the elements in the section of the Periodic Table shown below.

		H						He
Li	Be		B	C	N	O	F	Ne
Na	Mg		Al	Si	P	S	Cl	Ar
K	Ca	..... transition elements	Ga	Ge	As	Se	Br	Kr

(a) From this list of elements, identify in **each** case **one** element that has the property described. Give the **symbol** of the element.

(i) An element that when placed in cold water sinks and reacts readily.

.....

(ii) An element whose molecules contain π bonding.

.....

(iii) An element that forms a gaseous toxic oxide.

.....

(iv) The element which has a giant molecular structure **and** forms an oxide which also has a giant molecular structure.

.....

(v) An element that forms a covalent chloride which dissolves in water to give a conducting solution.

.....

(vi) The element in Period 3 (Na to Ar) with the greatest electrical conductivity.

.....

[6]

For Examiner's Use

(b) Some of the elements in Period 3 (Na to Ar) burn with a coloured flame when heated in oxygen or chlorine.

(i) Give the symbol of **one** such element, the formula of the **oxide** formed, and state the flame colour that would be seen.

symbol of element .....

formula of oxide .....

flame colour .....

(ii) For the element you have used in **(i)**, give the formula of the chloride formed, and state the pH of the solution produced when this chloride is shaken with water.

formula of chloride .....

pH of solution .....

[4]

(c) Chlorine reacts with both bromine and iodine to form BrCl and ICl respectively. The melting points of chlorine and the two chlorides are shown in the table.

substance	Cl_2	BrCl	ICl
m.p./°C	–101	–66	24

(i) Showing outer electrons only draw a 'dot-and-cross' diagram of the bonding in ICl.

(ii) Suggest why the melting points increase from Cl_2 to ICl.

.....

.....

.....

(iii) Suggest which of these three molecules has the largest permanent dipole. Explain your answer.

.....

.....

.....

[5]

[Total: 15]

[Turn over

4 Crotyl alcohol, $CH_3CH=CHCH_2OH$, is a colourless liquid which is used as a solvent.

(a) In the boxes below, write the **structural formula** of the organic compound formed when crotyl alcohol is reacted separately with each reagent under suitable conditions.
If you think no reaction occurs, write 'NO REACTION' in the box.

A	Br_2 in an inert organic solvent	
B	PCl_5	
C	H_2 and Ni catalyst	
D	$NaBH_4$	
E	$K_2Cr_2O_7 / H^+$ heat under reflux	

[5]

(b) Draw the **displayed formula** of the organic compound formed when crotyl alcohol is reacted with cold, dilute acidified potassium manganate(VII).

[1]

(c) Draw the **skeletal formula** of the compound formed in reaction E.

[2]

For Examiner's Use

(d) Crotyl alcohol is obtained from crotonaldehyde, $CH_3CH=CHCHO$.

(i) Describe one test that would confirm the presence of a small amount of unreacted crotonaldehyde in the crotyl alcohol.
Give the name of the reagent used and state what you would see.

reagent .....

observation .....

(ii) What *type of reaction* is the conversion of crotonaldehyde into crotyl alcohol?

.....
[3]

(e) Compound **P**, another unsaturated compound, is found in some blue cheeses.
The percentage composition by mass of compound **P** is C: 73.7%; H: 12.3%; O: 14.0%.

Calculate the empirical formula of compound **P**.

[2]

[Total: 13]

For Examiner's Use

5 A student reacted together an alcohol and a carboxylic acid under appropriate conditions to produce an ester.
A sweet smelling organic liquid, **Q**, with the empirical formula C_2H_4O was produced.
The M_r of **Q** was found by experiment to be 87.5.

(a) What is the molecular formula of **Q**?

..... [1]

(b) In the boxes below, draw the structural formulae of **four** isomers with this formula that are esters.

W	**X**
Y	**Z**

[4]

A sample of **Q** was hydrolysed by heating with aqueous sulfuric acid.
The resulting mixture was heated under reflux with acidified potassium dichromate(VI) to give a **single** organic product, **R**.
The product, **R**, was collected and subjected to the following tests.

A sample of **R** gave no reaction with Tollens' reagent.

A second sample of **R** gave no reaction with 2,4-dinitrophenylhydrazine reagent.

A third sample of **R** gave an effervescence with sodium carbonate.

(c) (i) What does the result of the test with Tollens' reagent show about **R**?

.....

(ii) What does the result of the test with 2,4-dinitrophenylhydrazine reagent show about **R**?

.....

(iii) What functional group does the result of the test with sodium carbonate show to be present in **R**?

.....
[3]

(d) (i) What is the identity of the single organic compound, **R**?

.....

(ii) Which of your structures, **W**, **X**, **Y** or **Z**, represents the ester, **Q**?

.....
[2]

(e) Which, if any, of your esters, **W**, **X**, **Y** or **Z**, is chiral?

.....

..... [1]

[Total: 11]

BLANK PAGE

UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education
Advanced Subsidiary Level and Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

3576889954

CHEMISTRY **9701/22**

Paper 2 Structured Questions AS Core **October/November 2013**

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 a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, 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.

For Examiner's Use	
1	
2	
3	
4	
5	
Total	

This document consists of **9** printed pages and **3** blank pages.

UNIVERSITY of CAMBRIDGE International Examinations

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

For Examiner's Use

1 Valence Shell Electron Pair Repulsion theory (VSEPR) is a model of electron-pair repulsion (including lone pairs) that can be used to deduce the shapes of, and bond angles in, simple molecules.

(a) Complete the table below by using simple hydrogen-containing compounds. One example has been included.

number of bond pairs	number of lone pairs	shape of molecule	formula of a molecule with this shape
3	0	trigonal planar	BH_3
4	0		
3	1		
2	2		

[3]

(b) Tellurium, Te, proton number 52, is used in photovoltaic cells.

When fluorine gas is passed over tellurium at 150 °C, the colourless gas TeF_6 is formed.

(i) Draw a 'dot-and-cross' diagram of the TeF_6 molecule, showing outer electrons only.

(ii) What will be the shape of the TeF_6 molecule?

.....

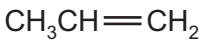
(iii) What is the F–Te–F bond angle in TeF_6?

.....

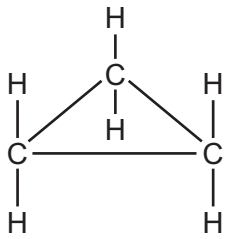
[3]

[Total: 6]

2 The molecular formula C_3H_6 represents the compounds propene and cyclopropane.



propene



cyclopropane

(a) What is the H–C–H bond angle at the terminal $=CH_2$ group in propene?

..... [1]

(b) Under suitable conditions, propene and cyclopropane each react with chlorine.

(i) With propene, 1,2-dichloropropane, $CH_3CHCl CH_2Cl$ is formed.

State fully what type of reaction this is.

..... [1]

(ii) When cyclopropane reacts with chlorine, three different compounds with the molecular formula $C_3H_4Cl_2$ can be formed.

Draw displayed structures of **each** of these three compounds.

[3]

[Total: 5]

For Examiner's Use

3 Chlorine gas is manufactured by the electrolysis of brine using a diaphragm cell.

(a) (i) Write half-equations, including state symbols, for the reactions occurring at **each** of the electrodes of a diaphragm cell.

anode .....

cathode .....

(ii) In the diaphragm cell, the anode is made of titanium and the cathode is made of steel.

Suggest why steel is never used for the anode.

.....

..... [3]

(b) Chlorine is very reactive and will form compounds by direct combination with many elements.

Describe what you would see when chlorine is passed over separate heated samples of sodium and phosphorus.
In **each** case write an equation for the reaction.

sodium

.....

.....

.....

phosphorus

.....

.....

..... [4]

(c) Chlorine reacts with aqueous sodium hydroxide in two different ways, depending on the conditions used. In each case, water, sodium chloride and one other chlorine-containing compound are formed.

For **each** condition below, give the formula of the **other** chlorine-containing compound and state the oxidation number of chlorine in it.

condition	formula of **other** chlorine-containing compound	oxidation number of chlorine in this compound
cold dilute NaOH(aq)		
hot concentrated NaOH(aq)		

[4]

(d) Magnesium chloride, $MgCl_2$, and silicon tetrachloride, $SiCl_4$, each dissolve in or react with water.

Suggest the approximate pH of the solution formed in **each** case.

$MgCl_2$ ..... $SiCl_4$ .....

Explain, with the aid of an equation, the difference between the two values.

.....

.....

.....

..... [5]

[Total: 16]

For Examiner's Use

4 Compound **R** is a weak diprotic (dibasic) acid which is very soluble in water.

(a) A solution of **R** was prepared which contained 1.25 g of **R** in 250 cm^3 of solution. When 25.0 cm^3 of this solution was titrated with 0.100 mol dm^{-3} NaOH, 21.6 cm^3 of the alkali were needed for complete reaction.

(i) Using the formula H_2X to represent **R**, construct a balanced equation for the reaction between H_2X and NaOH.

.....

(ii) Use the data above to calculate the amount, in moles, of OH^- ions used in the titration.

(iii) Use your answers to **(i)** and **(ii)** to calculate the amount, in moles, of **R** present in 25.0 cm^3 of solution.

(iv) Calculate the amount, in moles, of **R** present in 250 cm^3 of solution.

(v) Calculate M_r of **R**.

[5]

(b) Three possible structures for **R** are shown below.

S	**T**	**U**
$HO_2CCH{=}CHCO_2H$	$HO_2CCH(OH)CH_2CO_2H$	$HO_2CCH(OH)CH(OH)CO_2H$

(i) Calculate the M_r of each of these acids.

M_r of **S** = ... M_r of **T** = ... M_r of **U** = ...

(ii) Deduce which of the structures, **S**, **T** or **U**, correctly represents the structure of the acid, **R**.

R is represented by .....

[2]

It is possible to convert **S**, **T**, or **U** into one another.

(c) State the reagent(s) and essential conditions that would be used for the following conversions.

S into **T**

.....

S into **U**

.....

T into **S**

..... [5]

(d) Give the structural formula of the organic product formed in **each** of the following reactions.

T reacting with an excess of Na

U reacting with an excess of Na_2CO_3

[2]

(e) The acid **S** shows stereoisomerism. Draw structures to show this isomerism.
Label each isomer.

[2]

(f) When one of the isomers of **S** is heated at 110 °C in the absence of air, a cyclic compound **V**, with molecular formula $C_4H_2O_3$, is formed.
The other isomer of **S** does not react at this temperature.

Suggest the displayed formula of **V**.

[2]

[Total: 18]

For Examiner's Use

5 Propane, C_3H_8, and butane, C_4H_{10}, are components of Liquefied Petroleum Gas (LPG) which is widely used as a fuel for domestic cooking and heating.

(a) (i) To which class of compounds do these two hydrocarbons belong?

.....

(ii) Write a balanced equation for the complete combustion of butane.

.....
[2]

(b) When propane or butane is used in cooking, the saucepan may become covered by a solid black deposit.

(i) What is the chemical name for this black solid?

.....

(ii) Write a balanced equation for its formation from butane.

.....
[2]

(c) Propane and butane have different values of standard enthalpy change of combustion.

Define the term *standard enthalpy change of combustion*.

.....

.....

..... [2]

(d) A 125 cm^3 sample of propane gas, measured at 20 °C and 101 kPa, was completely burnt in air.
The heat produced raised the temperature of 200 g of water by 13.8 °C.
Assume no heat losses occurred during this experiment.

(i) Use the equation $pV = nRT$ to calculate the mass of propane used.

(ii) Use relevant data from the *Data Booklet* to calculate the amount of heat released in this experiment.

(iii) Use the data above and your answers to **(i)** and **(ii)** to calculate the energy produced by the burning of 1 mol of propane.

[5]

(e) The boiling points of methane, ethane, propane, and butane are given below.

compound	CH_4	CH_3CH_3	$CH_3CH_2CH_3$	$CH_3(CH_2)_2CH_3$
boiling point / K	112	185	231	273

(i) Suggest an explanation for the increase in boiling points from methane to butane.

.....

.....

.....

(ii) The isomer of butane, 2-methylpropane, $(CH_3)_3CH$, has a boiling point of 261 K. Suggest an explanation for the difference between this value and that for butane in the table above.

.....

.....

.....

[4]

[Total: 15]

BLANK PAGE

BLANK PAGE

BLANK PAGE

UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education
Advanced Subsidiary Level and Advanced Level

CANDIDATE NAME	
CENTRE NUMBER	
CANDIDATE NUMBER	

0950926149

CHEMISTRY **9701/22**

Paper 2 Structured Questions AS Core **May/June 2012**

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 a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.
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.

For Examiner's Use	
1	
2	
3	
4	
Total	

This document consists of **9** printed pages and **3** blank pages.

UNIVERSITY of CAMBRIDGE International Examinations

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

For Examiner's Use

1 The elements of the third period of the Periodic Table, sodium to sulfur, all form chlorides by direct combination.

(a) (i) Sulfur forms a number of chlorides which are liquid at room temperature.
Which other element of the third period forms a chloride which is liquid at room temperature?

.....

(ii) Name **one** element of the third period which burns in chlorine with a coloured flame.

.....

(iii) Aluminium chloride may be produced by passing a stream of chlorine over heated aluminium powder in a long hard-glass tube.
State **two** observations you could make during this reaction.

..... and .....

(iv) Write a balanced equation, with state symbols, for this reaction of aluminium with chlorine.

.....

(v) No chloride of argon has ever been produced.
Suggest a reason for this.

.....

.....
[7]

(b) When chlorides of the elements of the third period are added to water, some simply dissolve while others can be seen to react with the water.

(i) Complete the table below, stating how the chlorides of Na, A*l*, and Si behave when mixed with water. In the first column use only the terms 'dissolve' or 'react'.

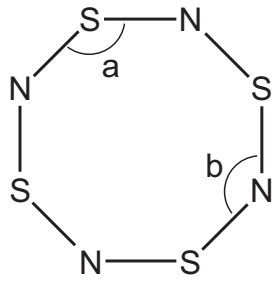
element	Does the chloride dissolve or react?	approximate pH of the resulting solution
Na		
A*l*		
Si		

(ii) What *type of reaction* takes place between a chloride and water?

.....

[7]

(c) Sulfur forms the compound S_4N_4 with nitrogen. The structure of S_4N_4 is shown below. Assume all bonds shown are single bonds.



(i) Determine the number of lone pairs of electrons around a nitrogen atom and a sulfur atom in S_4N_4.

nitrogen atom .....

sulfur atom .....

(ii) Which bond angle, a or b, in the S_4N_4 molecule will be smaller? Explain your answer.

.....

.....

[2]

[Total: 16]

2 Alcohols such as methanol, CH_3OH, are considered to be possible replacements for fossil fuels because they can be used in car engines.

(a) Define, with the aid of an equation which includes state symbols, the standard enthalpy change of combustion, $\Delta H_c^{\ominus}$, for methanol at 298 K.

equation .....

definition .....

.....

..... [3]

Methanol may be synthesised from carbon monoxide and hydrogen. Relevant $\Delta H_c^{\ominus}$ values for this reaction are given in the table below.

compound	$\Delta H_c^{\ominus}$ / kJ mol^{-1}
CO(g)	–283
H_2(g)	–286
CH_3OH(g)	–726

(b) Use these values to calculate $\Delta H_{reaction}^{\ominus}$ for the synthesis of methanol, using the following equation. Include a sign in your answer.

$$CO(g) + 2H_2(g) \rightarrow CH_3OH(g)$$

$\Delta H_{reaction}^{\ominus}$ = ...kJ mol^{-1}

[3]

(c) The operating conditions for this reaction are as follows.

pressure	200 atmospheres (2×10^7 Pa)
temperature	600 K
catalyst	oxides of Cr, Cu, and Zn

In the spaces below, explain how **each** of these conditions affects the **rate of formation** of methanol.

pressure

.....

.....

.....

temperature

.....

.....

.....

catalyst

.....

.....

.....

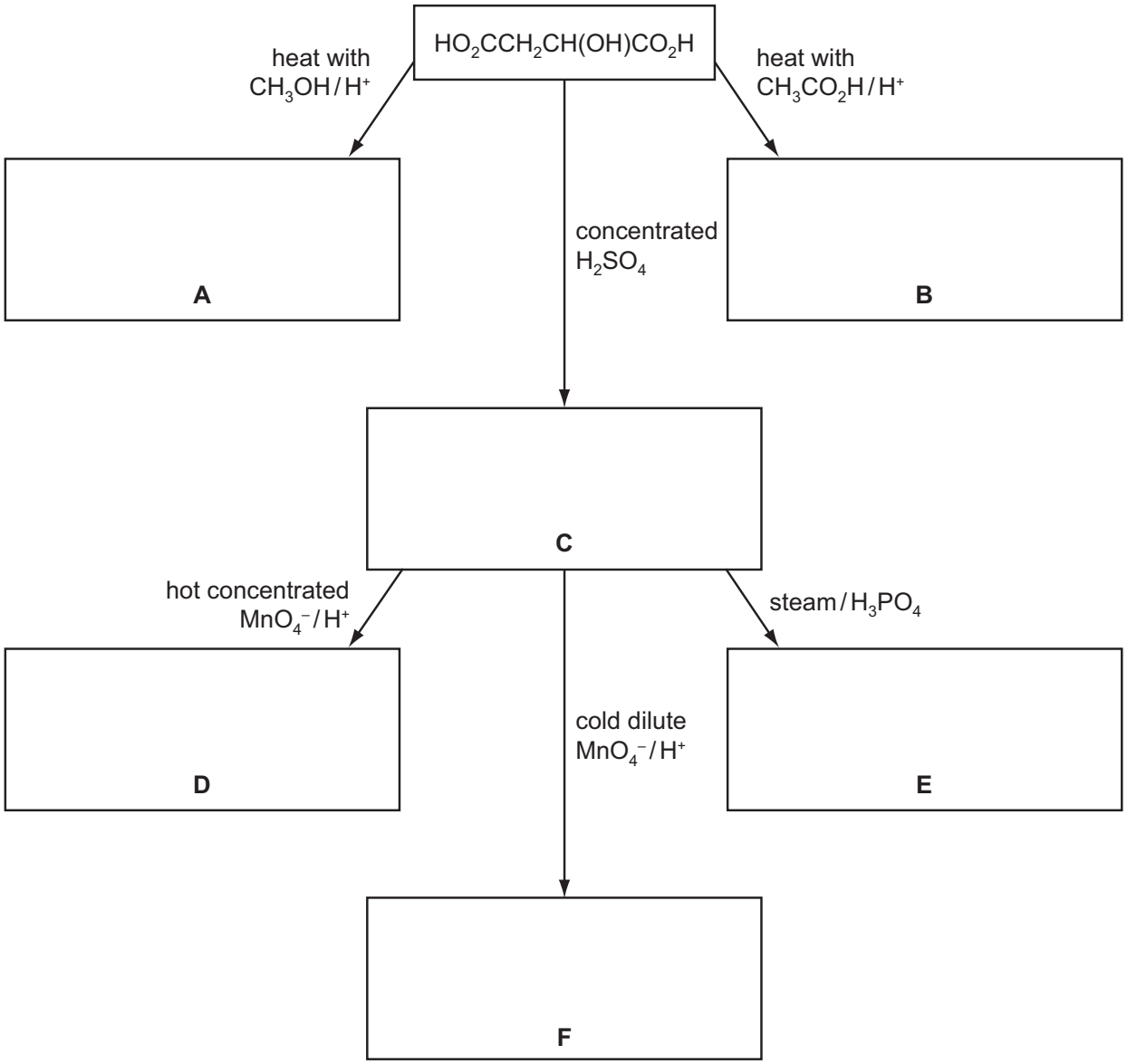
[6]

[Total: 12]

For Examiner's Use

3 Food additives are substances added to food to preserve the flavour or to improve its taste and appearance.
European Union legislation requires most additives used in foods to be labelled clearly in the list of ingredients, either by name or by an 'E number'. E296 is malic acid which occurs in unripe fruit.
Malic acid has the structural formula $HO_2CCH_2CH(OH)CO_2H$.

(a) Some reactions of malic acid are shown below.
In the boxes below, give the **structural** formulae of organic compounds **A** to **F**.



[6]

(b) What *type of reaction* is **each** of the following conversions?

malic acid into **C** .....

C into **D** .....

C into **E** ..... [3]

(c) Suggest **one** major commercial use of compounds such as **A** or **B**.

..... [1]

(d) **(i)** Malic acid is chiral.
Draw fully displayed formulae of the two optical isomers of malic acid.
Indicate with an asterisk (*) the chiral carbon atom.

(ii) Compound **C** also shows stereoisomerism.
Draw the skeletal formulae of **each** of the stereoisomers of **C**. Label **each** isomer.

[6]

(e) The food additive E330 is another organic compound which occurs naturally in fruit.
E330 has the following composition by mass: C, 37.5 %; H, 4.17 %; O, 58.3 %.
Calculate the empirical formula of E330.

[3]

[Total: 19]

4 Oxygen-containing organic compounds may contain a number of different functional groups including alcohol, aldehyde, carboxylic acid, ester or ketone functional groups. These functional groups may be identified by their reactions with specific reagents.

(a) On treating compounds containing each of these functional groups with the reagents below, only five reactions occur. Complete the table by placing a tick (✓) in each box where you believe a reaction will occur. You should place **no more** than five ticks in the table.

reagent	alcohol R_2CHOH	aldehyde RCHO	carboxylic acid RCO_2H	ester RCO_2R'	ketone RCOR'
$NaHCO_3$					
Na					
$Cr_2O_7^{2-}/H^+$					

[5]

Compound **G** has the empirical formula CH_2O and M_r of 90.

An aqueous solution of **G** is neutral. There is no reaction when **G** is treated with $NaHCO_3$.

When 0.30 g of pure **G** is reacted with an excess of Na, 80 cm^3 of H_2, measured at room temperature and pressure, is produced.

(b) (i) What functional group do these two reactions show to be present in **G**?

.....

(ii) Use the data to calculate the amount, in moles, of hydrogen **atoms** produced from 0.30 g of **G**.

(iii) Hence, show that each molecule of **G** contains **two** of the functional groups you have given in **(i)**.

[4]

(c) Treatment of **G** with 2,4-dinitrophenylhydrazine reagent produces an orange solid. When **G** is warmed with Fehling's reagent, no reaction occurs.

(i) What functional group do these reactions show to be present in **G**? Draw the displayed formula of this functional group.

(ii) Use your answers to **(b)(i)** and **(c)(i)** to deduce the structural formula of **G**.

[2]

(d) Compound **G** can be both oxidised and reduced.

(i) When **G** is heated under reflux with acidified $K_2Cr_2O_7$, compound **H** is formed. Give the structural formula of compound **H**.

(ii) When **G** is reacted with $NaBH_4$ under suitable conditions, compound **J** is formed. Give the structural formula of compound **J**.

[2]

[Total: 13]

BLANK PAGE

BLANK PAGE

BLANK PAGE

UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education
Advanced Subsidiary Level and Advanced Level

CANDIDATE NAME									
CENTRE NUMBER						CANDIDATE NUMBER			

CHEMISTRY **9701/22**

Paper 2 Structured Questions AS Core **October/November 2012**

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 a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.
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.

For Examiner's Use	
1	
2	
3	
4	
5	
Total	

This document consists of **11** printed pages and **1** blank page.

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

For Examiner's Use

1 Zinc is an essential trace element which is necessary for the healthy growth of animals and plants. Zinc deficiency in humans can be easily treated by using zinc salts as dietary supplements.

(a) One salt which is used as a dietary supplement is a hydrated zinc sulfate, $ZnSO_4.xH_2O$, which is a colourless crystalline solid.

Crystals of zinc sulfate may be prepared in a school or college laboratory by reacting dilute sulfuric acid with a suitable compound of zinc.

Give the formulae of **two** simple compounds of zinc that could **each** react with dilute sulfuric acid to produce zinc sulfate.

..... and ..... [2]

(b) A simple experiment to determine the value of x in the formula $ZnSO_4.xH_2O$ is to heat it carefully to drive off the water.

$$ZnSO_4.xH_2O(s) \rightarrow ZnSO_4(s) + xH_2O(g)$$

A student placed a sample of the hydrated zinc sulfate in a weighed boiling tube and reweighed it. He then heated the tube for a short time, cooled it and reweighed it when cool. This process was repeated four times. The final results are shown below.

mass of empty tube / g	mass of tube + hydrated salt / g	mass of tube + salt after fourth heating / g
74.25	77.97	76.34

(i) Why was the boiling tube heated, cooled and reweighed four times?

.....

.....

(ii) Calculate the amount, **in moles**, of the anhydrous salt produced.

(iii) Calculate the amount, **in moles**, of water driven off by heating.

For Examiner's Use

(iv) Use your results to **(ii)** and **(iii)** to calculate the value of x in $ZnSO_4.xH_2O$.

[7]

(c) For many people, an intake of approximately 15 mg per day of zinc will be sufficient to prevent deficiencies.

Zinc ethanoate crystals, $(CH_3CO_2)_2Zn.2H_2O$, may be used in this way.

(i) What mass of pure crystalline zinc ethanoate (M_r = 219.4) will need to be taken to obtain a dose of 15 mg of zinc?

(ii) If this dose is taken in solution as 5 cm^3 of aqueous zinc ethanoate, what would be the concentration of the solution used?
Give your answer in mol dm^{-3}.

[4]

[Total: 13]

[Turn over

For Examiner's Use

2 Each of the Group VII elements chlorine, bromine and iodine forms a hydride.

(a) (i) Outline how the relative thermal stabilities of these hydrides change from HC*l* to HI.

.....

.....

(ii) Explain the variation you have outlined in **(i)**.

.....

.....

.....

[3]

Hydrogen iodide can be made by heating together hydrogen gas and iodine vapour. The reaction is incomplete.

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

(b) Write an expression for K_c and state the units.

K_c = ... units ..... [2]

(c) For this equilibrium, the numerical value of the equilibrium constant K_c is 140 at 500 K and 59 at 650 K.

Use this information to state and explain the effect of the following changes on the equilibrium position.

(i) increasing the pressure applied to the equilibrium

.....

.....

(ii) decreasing the temperature of the equilibrium

.....

.....

[4]

For Examiner's Use

(d) A mixture of 0.02 mol of hydrogen and 0.02 mol of iodine was placed in a 1 dm^3 flask and allowed to come to equilibrium at 650 K.

Calculate the amount, in moles, of each substance present in the equilibrium mixture at 650 K.

	$H_2(g)$	+	$I_2(g)$	$\rightleftharpoons$	2HI(g)
initial moles	0.02		0.02		0

[4]

[Total: 13]

For Examiner's Use

3 Ammonia is an important industrial chemical which is manufactured on a large scale by using the Haber process.

(a) (i) Write a balanced equation, with state symbols, for the reaction occurring in the Haber process.

.....

(ii) Give **three** essential operating conditions that are used in the Haber process.

.....

.....

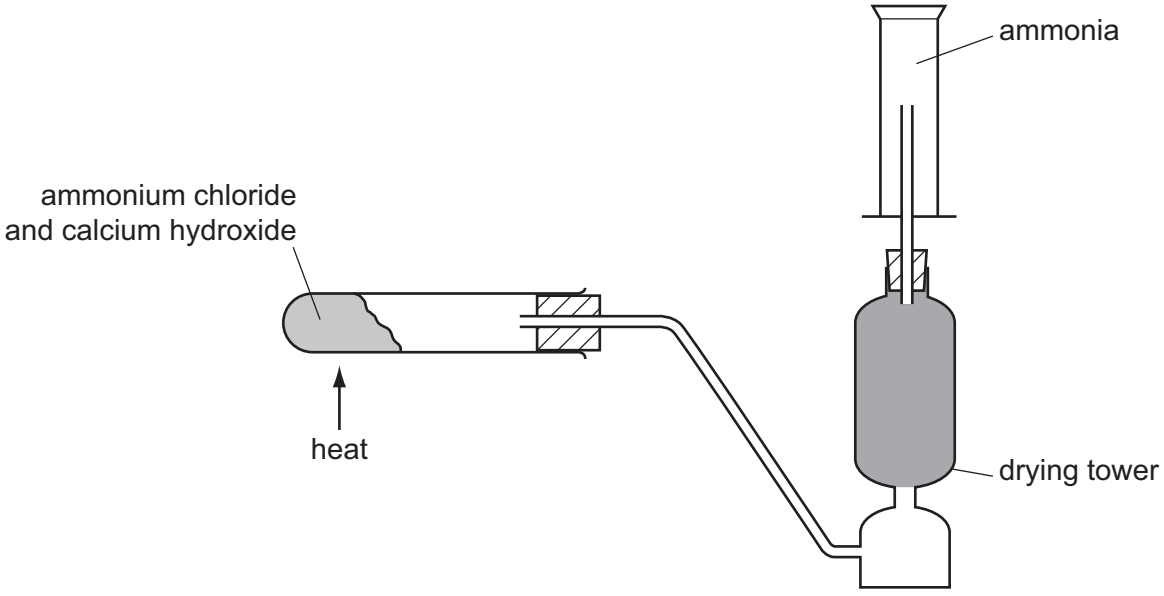
.....

(iii) State **one** large scale use of ammonia.

.....

[5]

(b) Ammonia may be prepared in a school or college laboratory by using the apparatus below.



The reaction involves the displacement of ammonia from one of its compounds.

(i) Give the formulae of the two reactants that are heated together to produce ammonia.

..... and .....

(ii) Construct a balanced equation for the reaction between your two reagents.

.....

For Examiner's Use

(iii) Common drying agents include calcium oxide, concentrated sulfuric acid and phosphorus(V) oxide.
Which **one** of these would be used in the drying tower in this experiment? Explain your answer.

.....

.....
[5]

(c) Ammonia is a weak base which forms salts containing the ammonium ion.

Describe, with the aid of an equation, the formation and structure of the ammonium ion. You should use displayed formulae in your answer.

[3]

[Total: 13]

[Turn over

For Examiner's Use

4 Many organic compounds, including alcohols, carbonyl compounds, carboxylic acids and esters, contain oxygen.

(a) The table below lists some oxygen-containing organic compounds and some common laboratory reagents.

(i) Complete the table as fully as you can.
If you think no reaction occurs, write 'no reaction' in the box for the structural formula(e).

reaction	organic compound	reagent	structural formula(e) of organic product(s)
A	$(CH_3)_3COH$	$Cr_2O_7^{2-}/H^+$ heat under reflux	
B	CH_3CH_2CHO	Fehling's reagent warm	
C	$HCO_2CH(CH_3)_2$	NaOH(aq) warm	
D	$CH_2{=}CHCHO$	$NaBH_4$	
E	$(CH_3)_3COH$	$NaBH_4$	
F	$CH_3CH_2COCH_3$	MnO_4^-/H^+ heat under reflux	

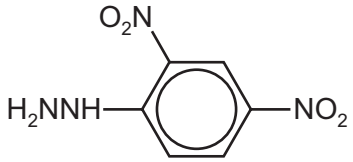
For Examiner's Use

(ii) During some of the reactions in **(i)** a colour change occurs.
Complete the table below for any such reactions, stating the letter of the reaction and what the colour change is.

reaction	colour at the beginning of the reaction	colour at the end of the reaction

[10]

(b) Some oxygen-containing compounds react with 2,4-dinitrophenylhydrazine.



2,4-dinitrophenylhydrazine

(i) Draw the structural formula of the organic compound formed when $HOCH_2CH_2CHO$ reacts with 2,4-dinitrophenylhydrazine reagent.

(ii) Suggest the colour of the organic product.

.....

[2]

[Total: 12]

For Examiner's Use

5 Compound **X** has the molecular formula $C_4H_8O_2$.

(a) (i) Treatment of **X** with sodium metal produces a colourless flammable gas.
What does this result tell you about the functional groups that could be present in **X**?

.....

.....

(ii) There is no reaction when **X** is treated with sodium hydrogencarbonate, $NaHCO_3$.
What does this result tell you about the functional groups that could be present in **X**?

.....

.....

(iii) When **X** is shaken with aqueous bromine the orange colour disappears.
What does this result tell you about the functional groups that could be present in **X**?

.....

.....
[3]

For Examiner's Use

(b) The molecule of **X** has the following features.

- The carbon chain is unbranched and the molecule is not cyclic.
- No oxygen atom is attached to any carbon atom which is involved in π bonding.
- No carbon atom has more than one oxygen atom joined to it.

There are five possible isomers of **X** which fit these data. Four of these isomers exist as two pairs of stereoisomers.

(i) Draw displayed formulae of **each** of these two pairs.

pair 1		
pair 2		

(ii) These four isomers of **X** show two types of stereoisomerism.

State which type of isomerism each pair shows.

pair 1 .....

pair 2 .....

[6]

[Total: 9]

BLANK PAGE

UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education
Advanced Subsidiary Level and Advanced Level

CANDIDATE NAME	
CENTRE NUMBER	
CANDIDATE NUMBER	

9992006701

CHEMISTRY **9701/22**

Paper 2 Structured Questions AS Core **May/June 2011**

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, Centre number and candidate number on all the work you hand in.
Write in dark blue or black pen.
You may use a pencil for any diagrams, graphs, or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE ON ANY BARCODES.

Answer **all** questions.
You may lose marks if you do not show your working or if you do not use appropriate units.
A Data Booklet is provided.

The number of marks is given in brackets [ ] at the end of each question or part question.
At the end of the examination, fasten all your work securely together.

For Examiner's Use	
1	
2	
3	
4	
5	
Total	

This document consists of **11** printed pages and **1** blank page.

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

For Examiner's Use

1 Ethanoic acid can be reacted with alcohols to form esters, an equilibrium mixture being formed.

$$CH_3CO_2H + ROH \rightleftharpoons CH_3CO_2R + H_2O$$

The reaction is usually carried out in the presence of an acid catalyst.

(a) Write an expression for the equilibrium constant, K_c, for this reaction, clearly stating the units.

K_c =

units ..... [2]

In an experiment to determine K_c a student placed together in a conical flask 0.10 mol of ethanoic acid, 0.10 mol of an alcohol ROH, and 0.005 mol of hydrogen chloride catalyst.
The flask was sealed and kept at 25 °C for seven days.
After this time, the student titrated all of the contents of the flask with 2.00 mol dm^{-3} NaOH using phenolphthalein indicator.
At the end-point, 22.5 cm^3 of NaOH had been used.

(b) (i) Calculate the amount, in moles, of NaOH used in the titration.

(ii) What amount, in moles, of this NaOH reacted with the hydrogen chloride?

(iii) Write a balanced equation for the reaction between ethanoic acid and NaOH.

(iv) Hence calculate the amount, in moles, of NaOH that reacted with the ethanoic acid.

[4]

(c) **(i)** Use your results from **(b)** to calculate the amount, in moles, of ethanoic acid present at equilibrium. Hence complete the table below.

	CH_3CO_2H	ROH	CH_3CO_2R	H_2O
initial amount/mol	0.10	0.10	0	0
equilibrium amount/mol				

(ii) Use your results to calculate a value for K_c for this reaction.

[3]

(d) Esters are hydrolysed by sodium hydroxide. During the titration, sodium hydroxide reacts with ethanoic acid and the hydrogen chloride, but not with the ester.

Suggest a reason for this.

.....

..... [1]

(e) What would be the effect, if any, on the amount of ester present if all of the water were removed from the flask and the flask kept for a further week at 25 °C?

Explain your answer.

.....

.....

..... [2]

[Total: 12]

[Turn over

2 Halogenoalkanes have been widely used as aerosol propellants, refrigerants and solvents for many years.

For Examiner's Use

Fluoroethane, CH_3CH_2F, has been used as a refrigerant. It may be made by reacting ethene with hydrogen fluoride.

You are to calculate a value for the C–F bond energy in fluoroethane.

(a) Use relevant bond energies from the *Data Booklet*, and the equation below to calculate a value for the bond energy of the C–F bond.

$$CH_2 = CH_2(g) \quad + \quad HF(g) \quad \longrightarrow \quad CH_3CH_2F(g) \qquad \Delta H^{\ominus} = -73\,kJ\,mol^{-1}$$

C–F bond energy = ... $kJ\,mol^{-1}$ [4]

(b) Another halogenoalkane which was used as a refrigerant, and also as an aerosol propellant, is dichlorodifluoromethane, CCl_2F_2.

State **two** reasons why compounds such as CH_3CH_2F and CCl_2F_2 have been used as aerosol propellants and refrigerants.

.....

..... [2]

CCl_2F_2 is one of many chlorofluorocarbon compounds responsible for damage to the ozone layer in the stratosphere.

For Examiner's Use

(c) By using relevant data from the *Data Booklet*, and your answer to **(a)** suggest why CCl_2F_2 is responsible for damage to the ozone layer in the stratosphere whereas CH_3CH_2F is not.

.....

.....

..... [2]

Both CH_3CH_2F and CCl_2F_2 are greenhouse gases.

The 'enhanced greenhouse effect' is of great concern to the international community.

(d) (i) What is meant by the term *enhanced greenhouse effect*?

.....

.....

.....

(ii) Water vapour is the most abundant greenhouse gas.

What is the second most abundant greenhouse gas?

..... [3]

A greenhouse gas which is present in very small amounts in the atmosphere is sulfur hexafluoride, SF_6, which is used in high voltage electrical switchgear.

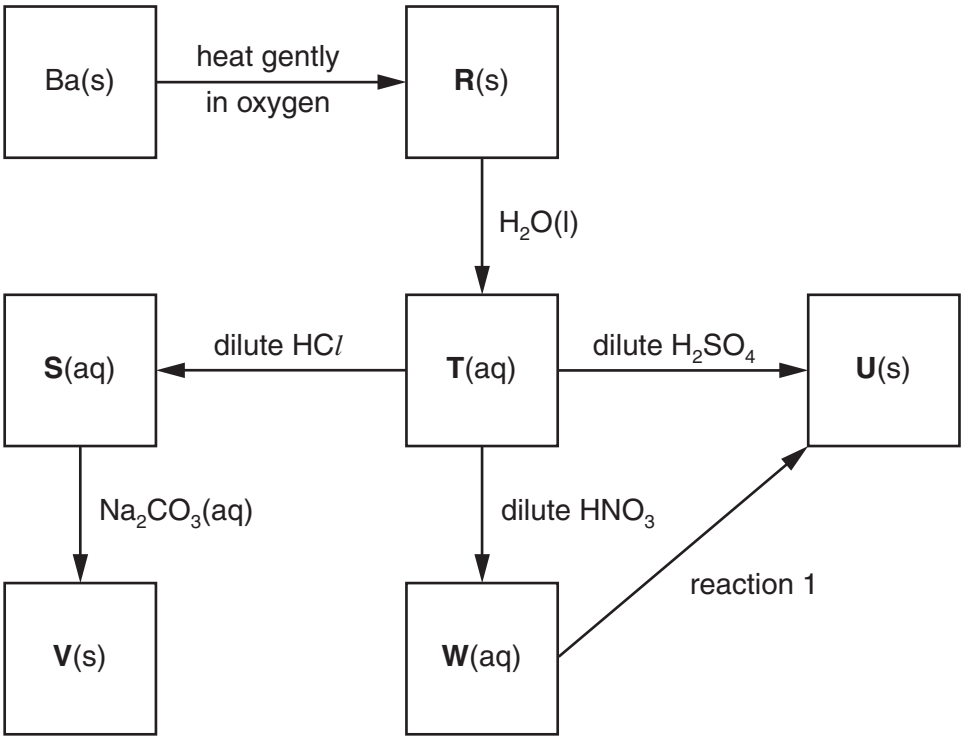
(e) What shape is the SF_6 molecule?

..... [1]

[Total: 12]

3 Barium, proton number 56, is a Group II element which occurs in nature as the carbonate or sulfate.
The element was first isolated by Sir Humphry Davy in 1808.
Some reactions of barium and its compounds are shown in the reaction scheme below.

For Examiner's Use



(a) State the formula of **each** of the barium compounds **R** to **W**.

R ..... **S** .....

T..... **U** .....

V ..... **W** ..... [6]

(b) **(i)** Write balanced equations for the following reactions.

compound **T** to compound **W**

.....

the roasting of **V** in air

.....

(ii) Suggest a gaseous reagent for the conversion of **T** into **V** and write a balanced equation for the reaction.

reagent .....

equation .....

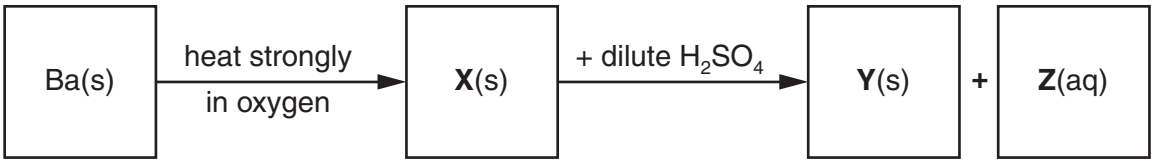
[4]

(c) Suggest the formula of an aqueous reagent, other than an acid, for reaction 1.

……..... [1]

When barium is heated strongly in oxygen, an oxide **X** is formed.
The oxide **X** contains 18.9% of oxygen by mass.

The oxide **X** reacts with dilute sulfuric acid in a 1:1 ratio.
Two products, one insoluble and one soluble, are formed.



(d) (i) Calculate the empirical formula of **X**.

(ii) Suggest the identity of the solid **Y**.

.....

(iii) Use your answers to **(i)** and **(ii)** to construct an equation for the reaction of **X** with H_2SO_4.

..... [4]

[Total: 15]

BLANK PAGE

4 Chlorine is manufactured by electrolysis from brine, concentrated aqueous sodium chloride.

For Examiner's Use

(a) (i) Describe, with the aid of a fully labelled diagram, the industrial electrolysis of brine in a diaphragm cell. State what each electrode is made of and show clearly the inlet for the brine and the outlets for the products.

(ii) Write a half-equation, with state symbols, for the reaction at **each** electrode.

anode .....

cathode .....

(iii) Name the chemical that is produced in solution in this electrolytic process.

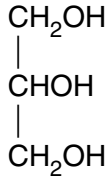
..... [7]

[Total: 7]

5 Although there are many different types of food eaten around the world, animal fats and/or vegetable oils are commonly used in cooking.

For Examiner's Use

Animal fats and vegetable oils are usually glyceryl esters, that is esters of glycerol, propane-1,2,3-triol.



Many animal fats contain esters of stearic acid, $CH_3(CH_2)_{16}CO_2H$.

Vegetable oils often contain esters of oleic acid, $CH_3(CH_2)_7CH{=}CH(CH_2)_7CO_2H$.

(a) Draw the structural formula of the glyceryl ester formed when one molecule of glycerol is completely esterified with stearic acid.

[1]

(b) What reagent(s) would you use, in a school or college laboratory, to obtain a small sample of oleic acid, $C_{17}H_{33}CO_2H$, from the glyceryl ester present in a vegetable oil?

..... [1]

Oleic acid is the *cis* isomer and elaidic acid the *trans* isomer of

$$CH_3(CH_2)_7CH{=}CH(CH_2)_7CO_2H.$$

(c) By using this formula, draw the structural formula of elaidic acid, clearly showing the stereochemistry.

[1]

Oleic and elaidic acids are examples of mono-unsaturated acids.
Many vegetable oils contain esters of polyunsaturated fatty acids. Such oils are often hydrogenated to form esters containing saturated or mono-unsaturated fatty acids.

For Examiner's Use

(d) (i) Suggest the meaning of the term *polyunsaturated fatty acid*.

.....

.....

(ii) What reagent and condition(s) are used for the hydrogenation of an unsaturated fatty acid?

reagent .....

condition(s) ..... [3]

In cooking, unsaturated fats are often oxidised to give aldehydes or ketones.

(e) (i) Give the structural formulae of the two aldehydes formed by the partial oxidation of the unsaturated fat below.
In the structure, *X*, represents the rest of the fat molecule.

$$CH_3(CH_2)_7CH{=}CH(CH_2)_7X$$

$$\downarrow$$

(ii) Name the reagent you would use to show that the product contained **either** an aldehyde **or** a ketone. What change would be seen?

reagent .....

observation .....

(iii) What reagent would you use to **confirm** the presence of an aldehyde?
What change would be seen?

reagent .....

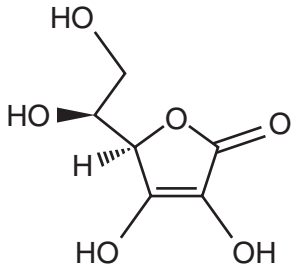
observation .....

[6]

Animal fats and vegetable oils can become rancid because of oxidation. The rancid fat or oil has an unpleasant smell and taste.

Antioxidants are used to prevent the spoilage of many foodstuffs by oxidation.

One antioxidant that is widely used is vitamin C, ascorbic acid.



ascorbic acid

(f) **(i)** How many chiral carbon atoms are present in one molecule of ascorbic acid? If none, write 'none'.

.....

(ii) The ascorbic acid molecule contains three functional groups.

Two of these are alcohol (primary and secondary) and alkene.

What is the name of the third functional group?

..... [2]

[Total: 14]

UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education Advanced Subsidiary Level and Advanced Level

CANDIDATE NAME									
CENTRE NUMBER						CANDIDATE NUMBER				

7726114870

CHEMISTRY **9701/22**

Paper 2 Structured Questions AS Core **October/November 2011**

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, Centre number and candidate number on all the work you hand in.
Write in dark blue or black pen.
You may use a pencil for any diagrams, graphs, or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE ON ANY BARCODES.

Answer **all** questions.
You may lose marks if you do not show your working or if you do not use appropriate units.
A Data Booklet is provided.

The number of marks is given in brackets [ ] at the end of each question or part question.
At the end of the examination, fasten all your work securely together.

For Examiner's Use	
1	
2	
3	
4	
5	
Total	

This document consists of **11** printed pages and **1** blank page.

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

For Examiner's Use

1 Compound **A** is an organic compound which contains carbon, hydrogen and oxygen.

When 0.240 g of the vapour of **A** is slowly passed over a large quantity of heated copper(II) oxide, CuO, the organic compound **A** is completely oxidised to carbon dioxide and water. Copper is the only other product of the reaction.

The products are collected and it is found that 0.352 g of CO_2 and 0.144 g of H_2O are formed.

(a) In this section, give your answers to <u>three</u> decimal places.

(i) Calculate the mass of carbon present in 0.352 g of CO_2.

Use this value to calculate the amount, in moles, of carbon atoms present in 0.240 g of **A**.

(ii) Calculate the mass of hydrogen present in 0.144 g of H_2O.

Use this value to calculate the amount, in moles, of hydrogen atoms present in 0.240 g of **A**.

(iii) Use your answers to calculate the mass of oxygen present in 0.240 g of **A**.

Use this value to calculate the amount, in moles, of oxygen atoms present in 0.240 g of **A**.

[6]

(b) Use your answers to **(a)** to calculate the empirical formula of **A**.

For Examiner's Use

[1]

(c) When a 0.148 g sample of **A** was vapourised at 60°C, the vapour occupied a volume of 67.7 cm^3 at a pressure of 101 kPa.

(i) Use the general gas equation $pV = nRT$ to calculate M_r of **A**.

M_r =.....

(ii) Hence calculate the molecular formula of **A**.

[3]

(d) Compound **A** is a liquid which does **not** react with 2,4-dinitrophenylhydrazine reagent or with aqueous bromine.

Suggest **two** structural formulae for **A**.

[2]

(e) Compound **A** contains only carbon, hydrogen and oxygen.

Explain how the information on the opposite page about the reaction of **A** with CuO confirms this statement.

.....

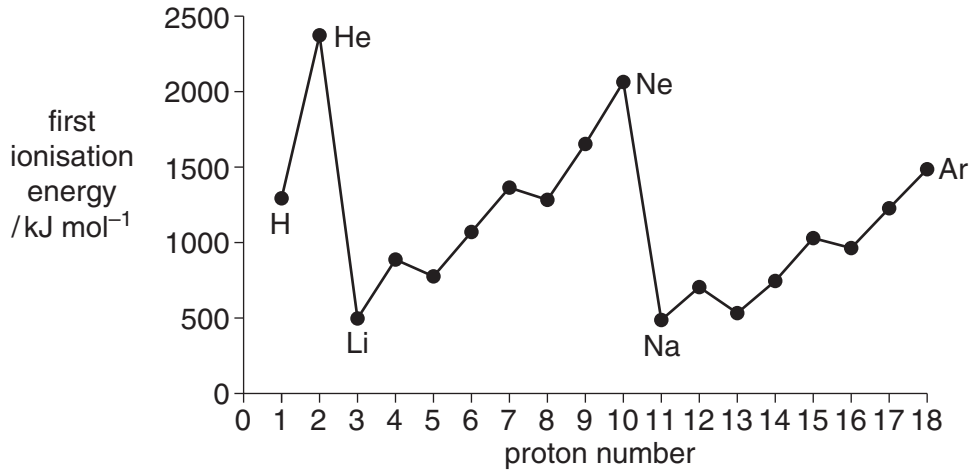
..... [1]

[Total: 13]

[Turn over

2 The Periodic Table we currently use is derived directly from that proposed in 1869 by Mendeleev who had noticed patterns in the physical and chemical properties of the elements he had studied.

The diagram below shows the first ionisation energies of the first 18 elements of the Periodic Table.



(a) Give the equation, including state symbols, for the first ionisation energy of sulfur.

..... [2]

(b) Explain why there is a **general** increase in first ionisation energies across the Period from sodium to argon.

.....

.....

.....

..... [3]

(c) **(i)** Explain why the first ionisation energy of magnesium is greater than that of aluminium.

.....

.....

.....

(ii) Explain why the first ionisation energy of phosphorus is greater than that of sulfur.

.....

.....

..... [4]

The table below refers to the elements of the third Period sodium to sulfur and is incomplete.

For Examiner's Use

element	Na	Mg	Al	Si	P	S
conductivity			high			
melting point			high			

(d) (i) Complete the 'conductivity' row by using **only** the words 'high', 'moderate' or 'low'.

(ii) Complete the 'melting point' row by using **only** the words 'high' or 'low'. [5]

When Mendeleev published his first Periodic Table, he left gaps for elements that had yet to be discovered. He also predicted some of the physical and chemical properties of these undiscovered elements.

For one element, **E**, he correctly predicted the following properties.

melting point of the element	high
melting point of the oxide	high
boiling point of the chloride	low

The element **E** was in the fourth Period and was one of the elements from gallium, proton number 31, to bromine, proton number 35.

(e) By considering the properties of the third Period elements aluminium to chlorine, suggest the identity of the fourth Period element **E**.

..... [1]

[Total: 15]

3 For some chemical reactions, such as the thermal decomposition of potassium hydrogencarbonate, $KHCO_3$, the enthalpy change of reaction cannot be measured directly.

In such cases, the use of Hess' Law enables the enthalpy change of reaction to be calculated from the enthalpy changes of other reactions.

(a) State Hess' Law.

.....

.....

..... [2]

In order to determine the enthalpy change for the thermal decomposition of potassium hydrogencarbonate, two separate experiments were carried out.

experiment 1

30.0 cm^3 of 2.00 mol dm^{-3} hydrochloric acid (an excess) was placed in a conical flask and the temperature recorded as 21.0 °C.
When 0.0200 mol of potassium carbonate, K_2CO_3, was added to the acid and the mixture stirred with a thermometer, the maximum temperature recorded was 26.2 °C.

(b) (i) Construct a balanced equation for this reaction.

.....

(ii) Calculate the quantity of heat produced in **experiment 1**, stating your units.
Use relevant data from the *Data Booklet* and assume that all solutions have the same specific heat capacity as water.

(iii) Use your answer to **(ii)** to calculate the enthalpy change per mole of K_2CO_3.
Give your answer in kJ mol^{-1} and include a sign in your answer.

(iv) Explain why the hydrochloric acid must be in an excess.

.....

..... [4]

experiment 2

For Examiner's Use

The experiment was repeated with 0.0200 mol of potassium hydrogencarbonate, $KHCO_3$.
All other conditions were the same.
In the second experiment, the temperature fell from 21.0 °C to 17.3 °C.

(c) (i) Construct a balanced equation for this reaction.

.....

(ii) Calculate the quantity of heat absorbed in **experiment 2**.

(iii) Use your answer to **(ii)** to calculate the enthalpy change per mole of $KHCO_3$.
Give your answer in kJ mol^{-1} and include a sign in your answer.

[3]

(d) When $KHCO_3$ is heated, it decomposes into K_2CO_3, CO_2 and H_2O.

$$2KHCO_3 \longrightarrow K_2CO_3 + CO_2 + H_2O$$

Use Hess' Law and your answers to **(b)(iii)** and **(c)(iii)** to calculate the enthalpy change for this reaction.
Give your answer in kJ mol^{-1} and include a sign in your answer.

[2]

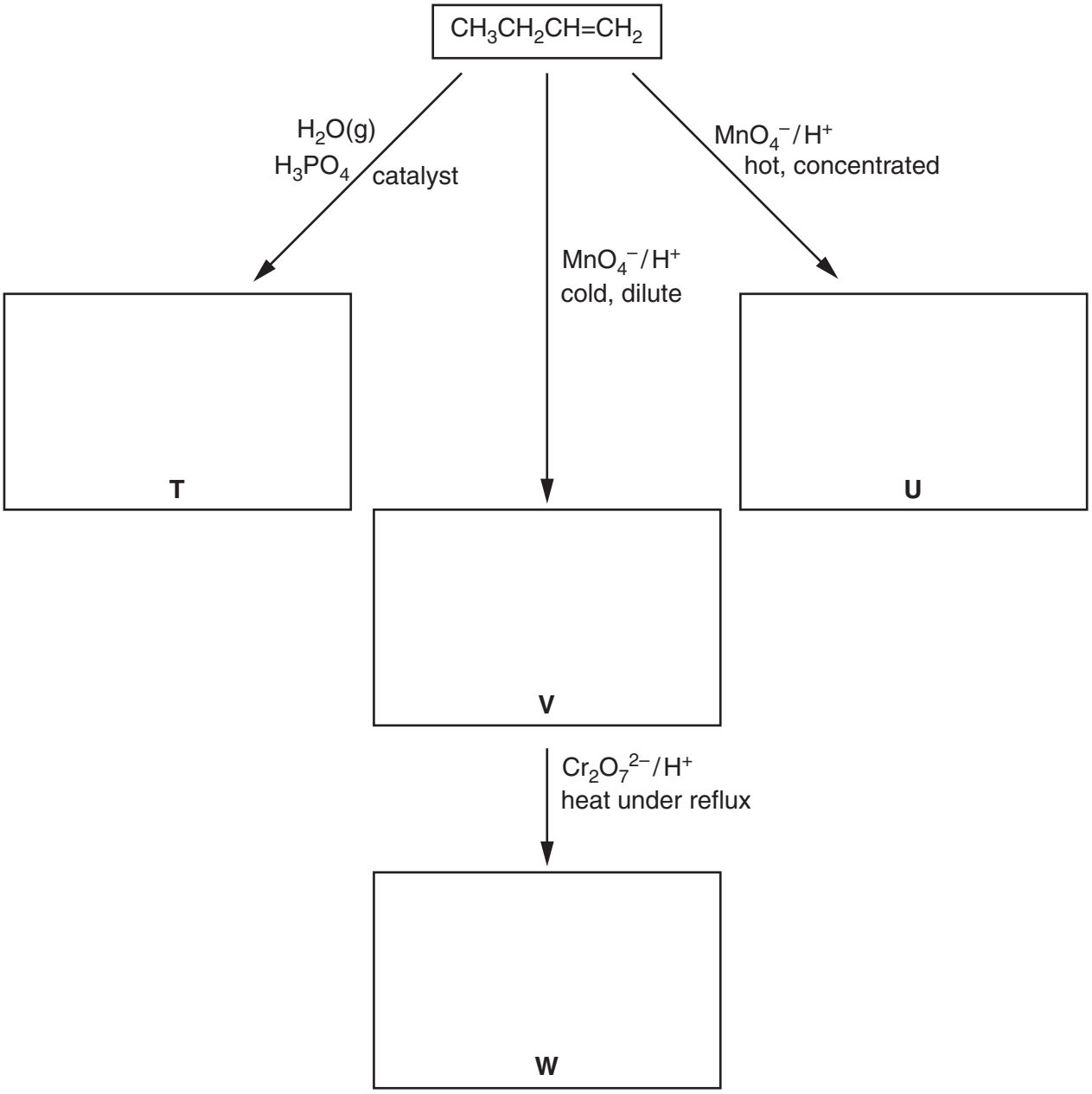
[Total: 11]

4 But-1-ene, $CH_3CH_2CH=CH_2$, is an important compound in the petrochemical industry.

For Examiner's Use

(a) Some reactions of but-1-ene are given below.

In **each** empty box, draw the structural formula of the organic compound formed.



[5]

(b) Compound **T** reacts with compound **U**.

Draw the **displayed** formula of the organic product of this reaction.

For Examiner's Use

[2]

[Total: 7]

5 Astronomers using modern telescopes of various types have found many molecules in the dust clouds in space. Many of these molecules are those of organic compounds and astronomers constantly look for evidence that amino acids such as aminoethanoic acid, $H_2NCH_2CO_2H$, are present.

One molecule that has been found in the dust clouds is hydroxyethanal, $HOCH_2CHO$.

(a) Hydroxyethanal contains two functional groups.

(i) Name, **as fully as you can**, each of the functional groups present in hydroxyethanal.

1 .....

2 .....

(ii) For **each** functional group, identify a reagent that will react with this group and **not** react with the other functional group present.
In each case, describe what would be observed when this reaction is carried out.

functional group 1 reagent .....

observation.....

functional group 2 reagent .....

observation..... [7]

(b) Give the **skeletal** formulae of the organic compounds formed when hydroxyethanal is reacted separately with the following.

(i) $NaBH_4$

(ii) $Cr_2O_7^{2-}/H^+$ under reflux conditions

[2]

In a school or college laboratory, it is possible to convert a sample of hydroxyethanal into aminoethanoic acid in a three-step process.

$$HOCH_2CHO \xrightarrow{\text{step 1}} \mathbf{X} \xrightarrow{\text{step 2}} \mathbf{Y} \xrightarrow{\text{step 3}} H_2NCH_2CO_2H$$

By considering the possible reactions of the functional groups present in hydroxyethanal, you are to deduce a possible route for this conversion.

(c) (i) In the boxes below, draw the structural formulae of your suggested intermediates **X** and **Y**.

X	**Y**

(ii) State the reagents for **each** of the three steps you have chosen.

step 1.....

step 2.....

step 3..... [5]

[Total: 14]

BLANK PAGE

UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education
Advanced Subsidiary Level and Advanced Level

CANDIDATE NAME	
CENTRE NUMBER	
CANDIDATE NUMBER	

3828945530

CHEMISTRY **9701/22**

Paper 2 Structured Questions AS Core **May/June 2010**

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, Centre number and candidate number on all the work you hand in.
Write in dark blue or black pen.
You may use a pencil for any diagrams, graphs, or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE ON ANY BARCODES.

Answer **all** questions.
You may lose marks if you do not show your working or if you do not use appropriate units.
A Data Booklet is provided.

The number of marks is given in brackets [ ] at the end of each question or part question.
At the end of the examination, fasten all your work securely together.

For Examiner's Use	
1	
2	
3	
4	
5	
Total	

This document consists of **12** printed pages.

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

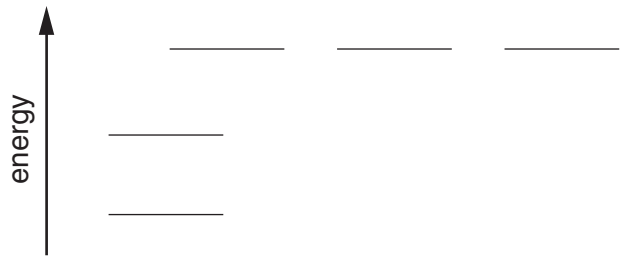
For Examiner's Use

1 In the 19th and 20th centuries, experimental results showed scientists that atoms consist of a positive, heavy nucleus which is surrounded by electrons.

Then in the 20th century, theoretical scientists explained how electrons are arranged in orbitals around atoms.

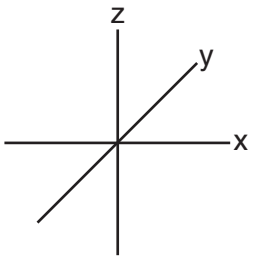
(a) The diagram below represents the energy levels of the orbitals present in atoms of the second period (Li to Ne).

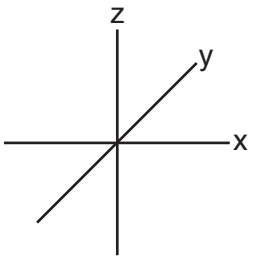
(i) Label the energy levels to indicate the principal quantum number **and** the type of orbital at each energy level.



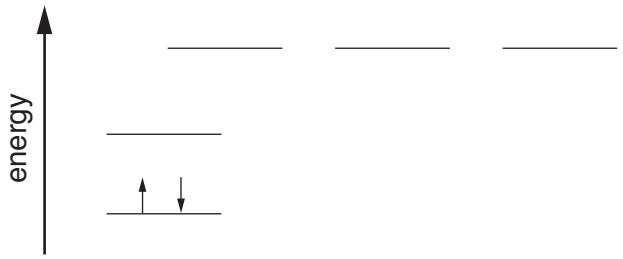
(ii) On the axes below, draw a sketch diagram of **one** of each **different type (shape)** of orbital that is occupied by the electrons in a second-period element.

Label each type.

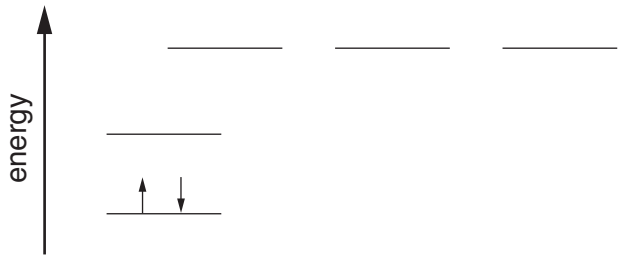




(iii) Complete the electronic configurations of nitrogen atoms and oxygen atoms on the energy level diagrams below.
Use arrows to represent electrons.



nitrogen



oxygen

[6]

(b) (i) Use the *Data Booklet* to state the value of the first ionisation energy of nitrogen and of oxygen.

N ..... kJ mol^{-1} O ..... kJ mol^{-1}

(ii) Explain, with reference to your answer to **(a)(iii)**, the relative values of these two ionisation energies.

.....

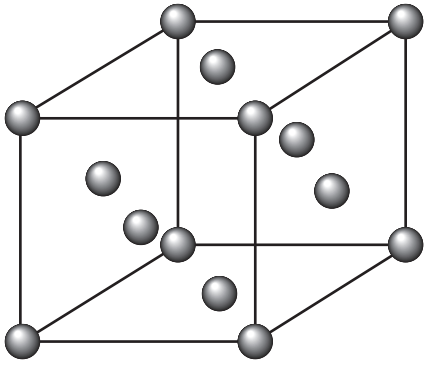
.....

.....

[3]

[Total: 9]

2 Copper, proton number 29, and argon, proton number 18, are elements which have different physical and chemical properties.
In the solid state, each element has the same face-centred cubic crystal structure which is shown below.



The particles present in such a crystal may be atoms, molecules, anions or cations. In the diagram above, the particles present are represented by ●.

(a) Which types of particle are present in the copper and argon crystals?
In each case, give their formula.

element	particle	formula
copper		
argon		

[2]

At room temperature, copper is a solid while argon is a gas.

(b) Explain these observations in terms of the forces present in **each** solid structure.

.....

.....

.....

.....

.....

..... [4]

Although copper is a relatively unreactive element, when it is heated to a high temperature in an excess of chlorine, copper(II) chloride is formed.

For Examiner's Use

When a mixture of argon and chlorine is heated to a high temperature, no reaction occurs.

(c) (i) How does chlorine behave in its reaction with copper?

.....

(ii) Suggest a reason for the lack of a reaction between argon and chlorine.

.....

..... [2]

The melting points of the noble gases neon to xenon are given below.

	Ne	Ar	Kr	Xe
melting point/K	25	84	116	161

(d) Explain why there is an increase in melting point from neon to xenon.

.....

.....

..... [2]

[Total: 10]

3 The table below gives data for some of the oxides of Period 3 elements.

For Examiner's Use

oxide	Na_2O	MgO	Al_2O_3	SiO_2	P_4O_6	SO_2
melting point/°C	1275	2827	2017	1607	24	–75
bonding						
structure						

(a) Complete the table by filling in

(i) the 'bonding' row by using **only** the words 'ionic' **or** 'covalent',

(ii) the 'structure' row by using **only** the words 'simple' **or** 'giant'.

[2]

(b) From the table of oxides above, suggest the formula of **one** oxide that is **completely** insoluble in water.

..... [1]

(c) Separate samples of Na_2O and SO_2 were added to water.

(i) For **each** oxide, write a balanced equation for its reaction with water and suggest a numerical value for the pH of the resulting solution.

Na_2O

equation .....

pH .....

SO_2

equation .....

pH .....

(ii) Construct a balanced equation for the reaction that occurs when a solution of Na_2O in water reacts with a solution of SO_2 in water.

.....

[5]

(d) Separate samples of the oxides MgO and SiO_2 are melted.
Each molten sample is then tested to see whether or not it conducts electricity.

For Examiner's Use

Suggest what would be the results in **each** case. Explain your answers.

MgO .....

.....

.....

SiO_2 .....

.....

.....

[4]

[Total: 12]

4 An organic compound, **E**, has the following composition by mass:
C, 48.7%; H, 8.1%; O, 43.2%.

(a) Calculate the empirical formula of **E**.

[2]

(b) When vaporised in a suitable apparatus, 0.130 g of **E** occupied a volume of 58.0 cm^3 at 127 °C and 1.00×10^5 $N m^{-2}$.

(i) Use the expression $pV = \frac{mRT}{M_r}$ to calculate M_r of **E**,

where m is the mass of **E**.

(ii) Hence calculate the molecular formula of **E**.

[4]

(c) Compound **F**, is an ester with the molecular formula $C_4H_8O_2$.

F is one of four isomers, **S**, **T**, **U**, and **V**, that are all esters.

In the boxes below, the structural formula of **S** is given.

Draw the structural formulae of the other **three** isomers of **F** that are esters.

$HCO_2CH(CH_3)_2$			
S	**T**	**U**	**V**

[3]

(d) When the ester **F** is hydrolysed, an alcohol **G** is produced.

(i) What reagent can be used to hydrolyse an ester to an alcohol?

.....

(ii) What other type of organic compound is produced at the same time?

.....

[2]

(e) On mild oxidation, the alcohol **G** gives a compound **H** which forms a silver mirror with Tollens' reagent.

(i) What functional group does the reaction with Tollens' reagent show to be present in compound **H**? Give the name of this group.

.....

(ii) What type of alcohol is **G**?

.....

(iii) What could be the structural formula of the alcohol **G**?

[3]

(f) **(i)** Which of the four isomers, **S**, **T**, **U**, or **V**, could **not** be **F**?

.....

(ii) Explain your answer.

.....

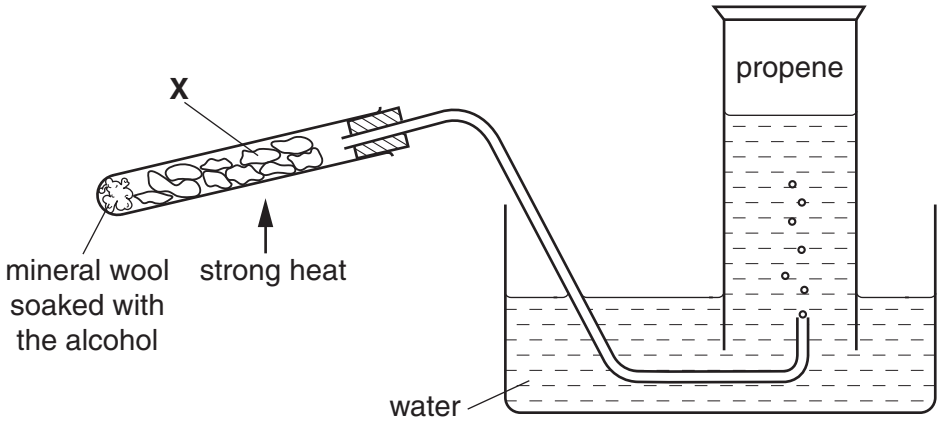
.....

[2]

[Total: 16]

5 Alkenes such as propene can be readily prepared from alcohols in a school or college laboratory by using the apparatus below.

For Examiner's Use



(a) (i) Give the **name** of an alcohol that can be used in this apparatus to prepare propene.

.....

(ii) Draw the **skeletal** formula of the alcohol you have named in **(i)**.

(iii) What type of reaction occurs in this case?

.....

[3]

(b) (i) During the reaction, the material **X** becomes black in colour.
Suggest the identity of the black substance and suggest how it is produced during the reaction.

.....

.....

.....

(ii) At the end of the experiment, when no more propene is being produced, the delivery tube is removed from the water before the apparatus is allowed to cool.

Suggest why this done.

.....

.....

.....

(iii) The material labelled **X** can be broken crockery, broken brick or pumice.

Give the chemical formula of a compound that is present in one of these materials.

.....

(iv) State another reagent that could be used to produce propene from an alcohol.

.....

[5]

(c) Give the structural formula of the organic product formed when propene reacts separately with **each** of the following substances.

(i) bromine

(ii) cold, dilute manganate(VII) ions

(iii) hot, concentrated manganate(VII) ions

[3]

For Examiner's Use

(d) Propene may be polymerised.

(i) What is the essential condition for such a polymerisation?

.....

(ii) The disposal of waste poly(propene) is very difficult.
Give **one** important reason for this.

.....

.....
[2]

[Total: 13]

UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education Advanced Subsidiary Level and Advanced Level

CANDIDATE NAME									
CENTRE NUMBER						CANDIDATE NUMBER				

5365795237

CHEMISTRY **9701/22**

Paper 2 Structured Questions AS Core **October/November 2010**

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, Centre number and candidate number on all the work you hand in.
Write in dark blue or black pen.
You may use a pencil for any diagrams, graphs, or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE ON ANY BARCODES.

Answer **all** questions.
You may lose marks if you do not show your working or if you do not use appropriate units.
A Data Booklet is provided.

The number of marks is given in brackets [ ] at the end of each question or part question.
At the end of the examination, fasten all your work securely together.

For Examiner's Use	
1	
2	
3	
4	
5	
Total	

This document consists of **10** printed pages and **2** blank pages.

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

For Examiner's Use

1 In 1814, Sir Humphrey Davy and Michael Faraday collected samples of a flammable gas, **A**, from the ground near Florence in Italy.
They analysed **A** which they found to be a hydrocarbon. Further experiments were then carried out to determine the molecular formula of **A**.

(a) What is meant by the term *molecular formula*?

.....

.....

.....[2]

Davy and Faraday deduced the formula of **A** by exploding it with an excess of oxygen and analysing the products of combustion.

(b) Complete and balance the following equation for the complete combustion of a hydrocarbon with the formula C_xH_y.

$$C_xH_y + \left(x + \frac{y}{4}\right)O_2 \rightarrow \text{.....} + \text{.....}$$

[2]

(c) When 10 cm^3 of **A** was mixed at room temperature with 50 cm^3 of oxygen (an excess) and exploded, 40 cm^3 of gas remained after cooling the apparatus to room temperature and pressure.
When this 40 cm^3 of gas was shaken with an excess of aqueous potassium hydroxide, KOH, 30 cm^3 of gas still remained.

(i) What is the identity of the 30 cm^3 of gas that remained at the end of the experiment?

.....

(ii) The combustion of **A** produced a gas that reacted with the KOH(aq).

What is the identity of this gas?

.....

(iii) What volume of the gas you have identified in **(ii)** was produced by the combustion of **A**?

.....cm^3

(iv) What volume of oxygen was used up in the combustion of **A**?

.....cm^3 [4]

(d) Use your equation in **(b)** and your results from **(c)(iii)** and **(c)(iv)** to calculate the molecular formula of **A**.
Show all of your working.

For Examiner's Use

[3]

[Total: 11]

2 Nitrogen makes up about 79% of the Earth's atmosphere. As a constituent element of proteins, it is present in living organisms.

For Examiner's Use

Atmospheric nitrogen is used in the Haber process for the manufacture of ammonia.

(a) Write an equation for the formation of ammonia in the Haber process.

.....[1]

(b) The Haber process is usually carried out at a high pressure of between 60 and 200 atmospheres (between 60×10^5 Pa and 200×10^5 Pa).
State **two further** important operating conditions that are used in the Haber process.
For **each** of your conditions, explain why it is used.

condition 1 .....

reason .....

condition 2 .....

reason .....[4]

(c) State **one** large-scale use for ammonia, other than in the production of nitrogenous fertilisers.

..... [1]

(d) The uncontrolled use of nitrogenous fertilisers can cause environmental damage to lakes and streams. This is known as 'eutrophication'.

What are the processes that occur when excessive amounts of nitrogenous fertilisers get into lakes and streams?

.....

.....

.....[2]

In many countries, new cars have to comply with regulations which are intended to reduce the pollutants coming from their internal combustion engines.

For Examiner's Use

Two pollutants that may be formed in an internal combustion engine are carbon monoxide, CO, and nitrogen monoxide, NO.

(e) (i) Outline how **each** of these pollutants may be formed in an internal combustion engine.

CO .....

.....

NO .....

.....

(ii) State the main hazard associated with **each** of these pollutants.

CO .....

NO ..... [4]

Pollutants such as CO and NO are removed from the exhaust gases of internal combustion engines by catalytic converters which are placed in the exhaust system of a car.

(f) (i) What metal is most commonly used as the catalyst in a catalytic converter?

.....

(ii) Construct **one** balanced equation for the reaction in which **both** CO **and** NO are removed from the exhaust gases by a catalytic converter.

.....[2]

[Total: 14]

3 Crude oil is a naturally occurring flammable liquid which consists of a complex mixture of hydrocarbons. In order to separate the hydrocarbons the crude oil is subjected to fractional distillation.

(a) Explain what is meant by the following terms.

(i) *hydrocarbon* .....

.....

(ii) *fractional distillation* .....

.....[2]

(b) Undecane, $C_{11}H_{24}$, is a long chain hydrocarbon which is present in crude oil.
Such long chain hydrocarbons are 'cracked' to produce alkanes and alkenes which have smaller molecules.

(i) Give the conditions for **two different** processes by which long chain molecules may be cracked.

process 1 .....

.....

process 2 .....

.....

(ii) Undecane, $C_{11}H_{24}$, can be cracked to form pentane, C_5H_{12}, and an alkene.
Construct a balanced equation for this reaction.

.....[3]

Pentane, C_5H_{12}, exhibits structural isomerism.

(c) **(i)** Draw the three structural isomers of pentane.

isomer **B**	isomer **C**	isomer **D**

(ii) The three isomers of pentane have different boiling points.

Which of your isomers has the highest boiling point?

isomer .....

Suggest an explanation for your answer.

.....

.....

.....[6]

The unsaturated hydrocarbon, **E**, is obtained by cracking hexane and is important in the chemical industry.

The standard enthalpy change of combustion of **E** is $-2059\,kJ\,mol^{-1}$.

(d) Define the term *standard enthalpy change of combustion*.

.....

.....[2]

When 0.47 g of **E** was completely burnt in air, the heat produced raised the temperature of 200 g of water by 27.5 °C. Assume no heat losses occurred during this experiment.

(e) (i) Use relevant data from the *Data Booklet* to calculate the amount of heat released in this experiment.

(ii) Use the data above and your answer to **(i)** to calculate the relative molecular mass, M_r, of **E**.

[4]

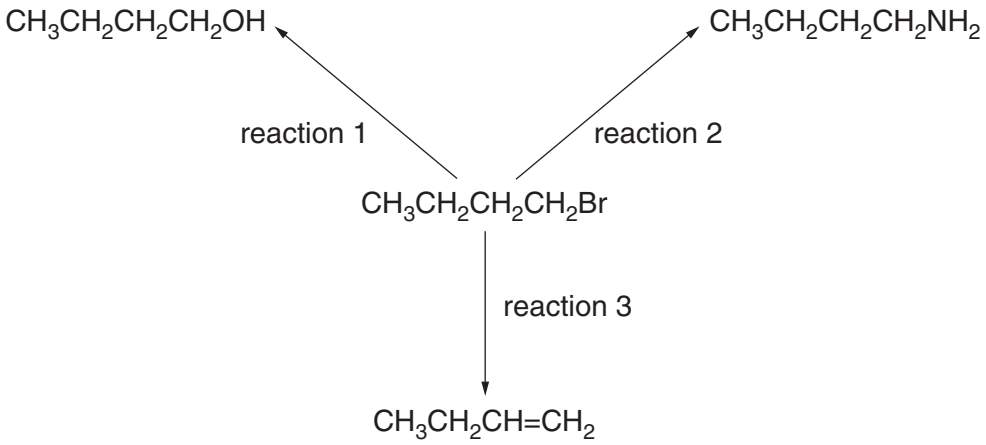
(f) Deduce the molecular formula of **E**.

[1]

[Total: 18]

4 Halogenoalkanes have many chemical uses, particularly as intermediates in organic reactions.

Three reactions of 1-bromobutane, $CH_3CH_2CH_2CH_2Br$, are shown below.



(a) For **each** reaction, state the reagent and solvent used.

reaction 1 reagent .....

solvent .....

reaction 2 reagent .....

solvent .....

reaction 3 reagent .....

solvent ..... [6]

(b) When 1-iodobutane, $CH_3CH_2CH_2CH_2I$, is reacted under the same conditions as those used in reaction 1, butan-1-ol is formed.

What difference, if any, would there be in the rate of this reaction compared to the reaction of 1-bromobutane?

Use appropriate data from the *Data Booklet* to explain your answer.

.....

.....

.....

.....[3]

Dichlorodifluoromethane, CCl_2F_2, is an example of a chlorofluorocarbon (CFC) that was formerly used as an aerosol propellant. In September 2007, at the Montreal summit, approximately 200 countries agreed to phase out the use of CFCs by 2020.

For Examiner's Use

(c) State two properties of CFCs that made them suitable as aerosol propellants.

1. .....

2. ..... [2]

(d) When CFCs are present in the upper atmosphere, homolytic fission takes place in the presence of ultraviolet light.

(i) What is meant by the term *homolytic fission*?

.....

.....

(ii) Suggest an equation for the homolytic fission of CCl_2F_2.

.....[2]

(e) The most common replacements for CFCs as aerosol propellants are hydrocarbons such as propane and butane.

Suggest **one** disadvantage of these compounds as aerosol propellants.

.....[1]

[Total: 14]

BLANK PAGE

5 The gaseous hydrogen halides HC*l*, HBr and HI, may be prepared by reacting the corresponding sodium salt with anhydrous phosphoric(V) acid, H_3PO_4.

When the sodium halide Na*X* was used, the following reaction occurred and a sample of gaseous H*X* was collected in a gas jar.

$$NaX + H_3PO_4 \longrightarrow NaH_2PO_4 + HX$$

A hot glass rod was placed in the sample of H*X* and immediately a red/orange colour was observed.

(a) What is the identity of Na*X*?

..... [1]

(b) What gas, other than H*X*, would be formed if concentrated sulfuric acid were used with Na*X* instead of phosphoric(V) acid?

..... [1]

(c) Suggest why phosphoric(V) acid rather than concentrated sulfuric acid is used to make samples of H*X* from the corresponding sodium salt.
Explain your answer.

.....

.....[1]

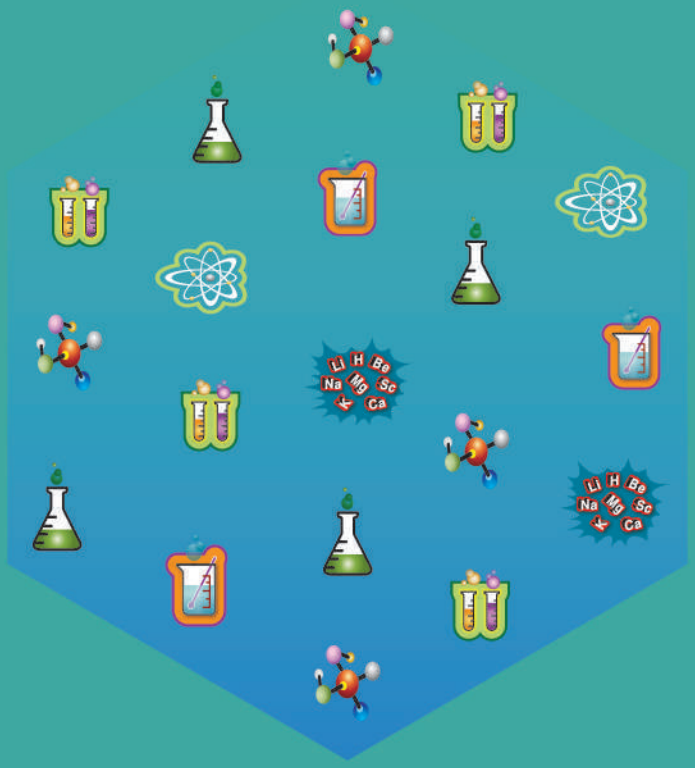
[Total: 3]

BLANK PAGE

Cambridge International AS Level Chemistry

Question Papers

Paper #2



catadu.com

Non-traditional blended
learning institute.