



UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education
Advanced Subsidiary Level and Advanced Level

CANDIDATE
NAME

--

CENTRE
NUMBER

--	--	--	--	--

CANDIDATE
NUMBER

--	--	--	--

CHEMISTRY

9701/21

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



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

For
Examiner's
Use

- 1 Elements and compounds which have small molecules usually exist as gases or liquids.

- (a) Chlorine, Cl_2 , is a gas at room temperature whereas bromine, Br_2 , is a liquid under the same conditions.

Explain these observations.

.....

 [2]

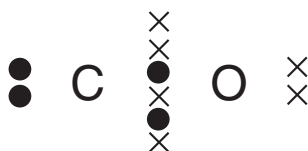
- (b) The gases nitrogen, N_2 , and carbon monoxide, CO , are isoelectronic, that is they have the same number of electrons in their molecules.

Suggest why N_2 has a lower boiling point than CO .

.....

 [2]

- (c) A 'dot-and-cross' diagram of a CO molecule is shown below. Only electrons from outer shells are represented.



In the table below, there are three copies of this structure.

On the structures, draw a circle round a pair of electrons that is associated with **each** of the following.

(i) a co-ordinate bond	(ii) a covalent bond	(iii) a lone pair
<pre> x x x x x x •• C •• O x •• •• </pre>	<pre> x x x x x x •• C •• O x •• •• </pre>	<pre> x x x x x x •• C •• O x •• •• </pre>

[3]

- (d) Hydrogen cyanide, HCN, is a gas which is also isoelectronic with N_2 and with CO. Each molecule contains a strong triple bond with the following bond energies.

For
Examiner's
Use

bond	bond energy / kJ mol^{-1}
$-\text{C}\equiv\text{N}$ in HCN	890
$\text{N}\equiv\text{N}$	994
$\text{C}\equiv\text{O}$	1078

Although each compound contains the same number of electrons and a strong triple bond in its molecule, CO and HCN are both very reactive whereas N_2 is not.

Suggest a reason for this.

.....
 [1]

- (e) HCN reacts with ethanal, CH_3CHO .

(i) Give the **displayed formula** of the organic product formed.

(ii) What type of reaction is this?

.....

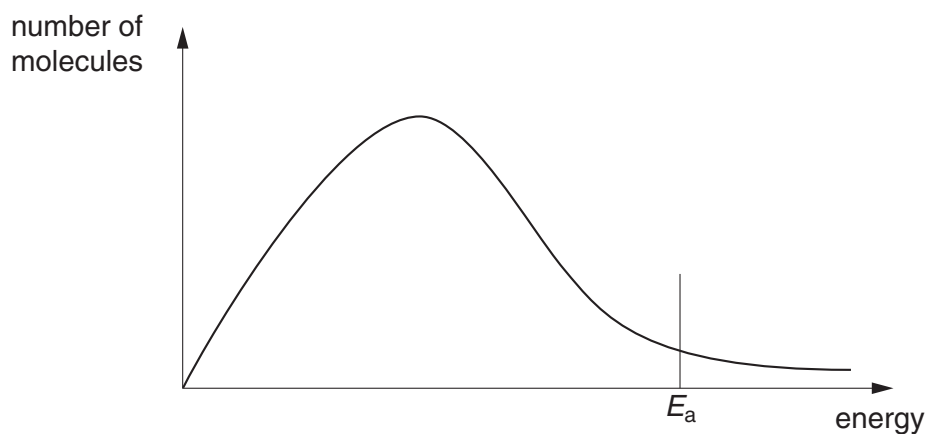
(iii) Draw the mechanism of this reaction. You should show all full and partial charges and represent the movement of electron pairs by curly arrows.

[5]

[Total: 13]

- 2 The diagram below shows, for a given temperature T , a Boltzmann distribution of the kinetic energy of the molecules of a mixture of two gases that will react together, such as nitrogen and hydrogen. The activation energy for the reaction, E_a , is marked.

For
Examiner's
Use



(a) On the graph above,

- draw a new distribution curve, **clearly labelled T'** , for the same mixture of gases at a higher temperature, T' ;
- mark clearly, as H**, the position of the activation energy of the reaction at the higher temperature, T' .

[3]

(b) Explain the meaning of the term *activation energy*.

.....

.....

.....

..... [2]

The reaction between nitrogen and hydrogen to produce ammonia in the Haber process is an example of a large-scale gaseous reaction that is catalysed.

For
Examiner's
Use

- (c) (i) State the catalyst used and give the operating temperature and pressure of the Haber process.

catalyst

temperature

pressure

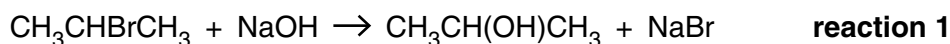
- (ii) On the energy axis of the graph opposite, mark the position, clearly labelled C, of the activation energy of the reaction when a catalyst is used.

- (iii) Use your answer to (ii) to explain how the use of a catalyst results in reactions occurring at a faster rate.

.....
.....
.....

[3]

- (d) Two reactions involving aqueous NaOH are given below.



In order for **reaction 1** to occur, the reagents must be heated together for some time. On the other hand, **reaction 2** is almost instantaneous at room temperature.

Suggest brief explanations why the rates of these two reactions are very different.

reaction 1

.....
.....

reaction 2

.....
.....

[4]

[Total: 12]

For
Examiner's
Use

For
Examiner's
Use

- For
Examiner's
Use

- For
Examiner's
Use

For
Examiner's
Use

- For
Examiner's
Use

For
Examiner's
Use

- For
Examiner's
Use

For
Examiner's
Use

- For
Examiner's
Use

For
Examiner's
Use

- For
Examiner's
Use

For
Examiner's
Use

For
Examiner's
Use

- (b) (i) Give the formula of the oxide of the most electronegative element.

.....

- (ii) Several of these elements form more than one acidic oxide.
Give the formulae of **two** such oxides formed by the **same** element.

..... and

[3]

The formulae and melting points of the fluorides of the elements in Period 3, Na to Cl, are given in the table.

formula of fluoride	NaF	MgF ₂	AlF ₃	SiF ₄	PF ₅	SF ₆	ClF ₅
m.p./K	1268	990	1017	183	189	223	170

- (c) (i) Suggest the formulae of **two** fluorides that could possibly be ionic.

.....

- (ii) What is the shape of the SF₆ molecule?

.....

- (iii) In the sequence of fluorides above, the oxidation number of the elements increases from NaF to SF₆ and then falls at ClF₅.
Attempts to make ClF₇ have failed but IF₇ has been prepared.
Suggest an explanation for the existence of IF₇ and for the non-existence of ClF₇.

.....

.....

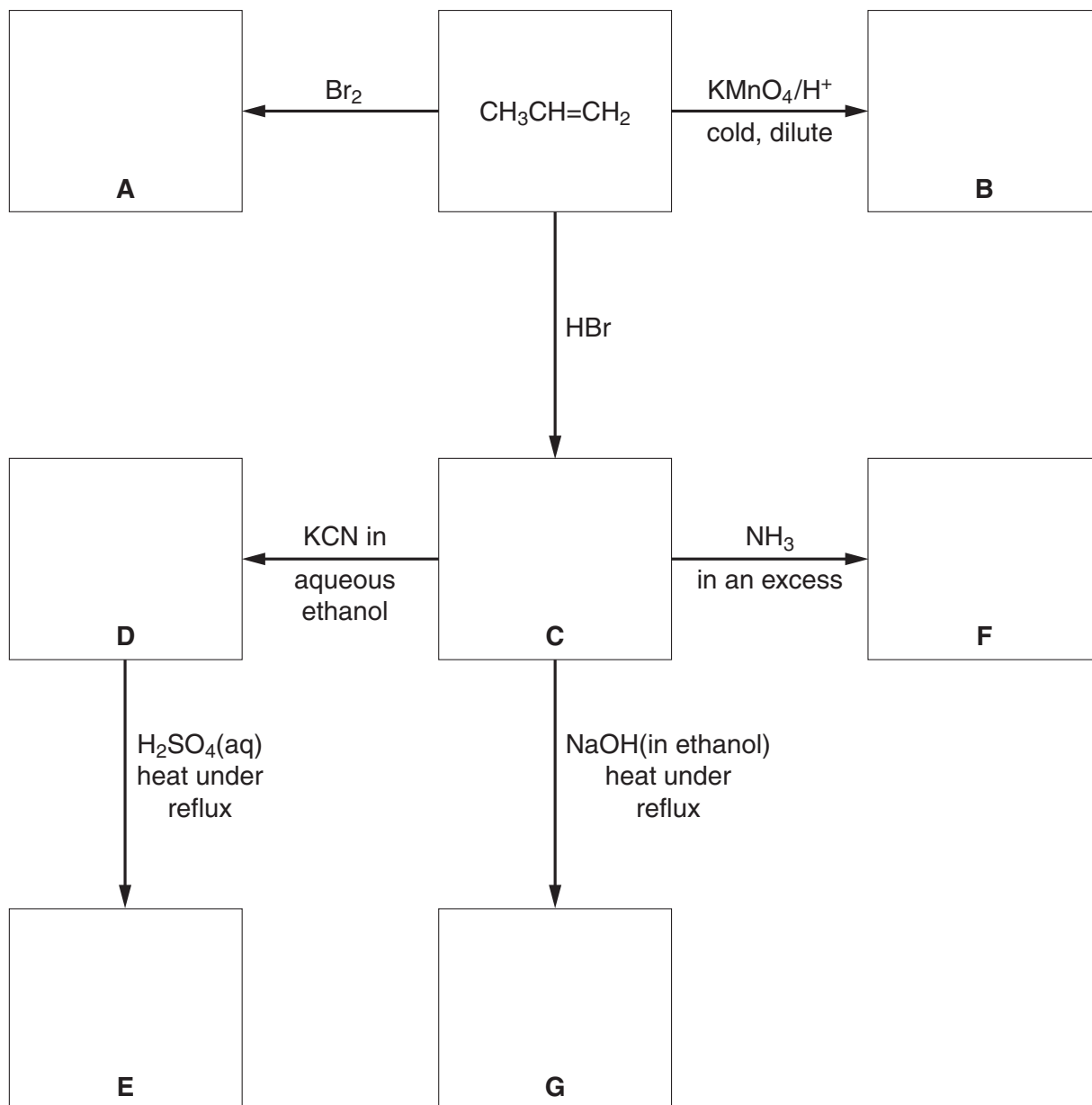
.....

[4]

[Total: 12]

- 4 (a) Complete the following reaction scheme which starts with propene. In **each empty** box, write the **structural formula** of the organic compound that would be formed.

For
Examiner's
Use



[7]

(b) Under suitable conditions, compound **E** will react with compound **B**.

*For
Examiner's
Use*

(i) What functional group is produced in this reaction?

.....

(ii) How is this reaction carried out in a school or college laboratory?

.....

.....

[3]

[Total: 10]

- 5 Isomerism occurs in many organic compounds. The two main forms of isomerism are structural isomerism and stereoisomerism. Many organic compounds that occur naturally have molecules that can show stereoisomerism, that is *cis-trans* or optical isomerism.

(a) (i) Explain what is meant by *structural isomerism*.

.....

.....

(ii) State **two** different features of molecules that can give rise to **stereoisomerism**.

.....

.....

[3]

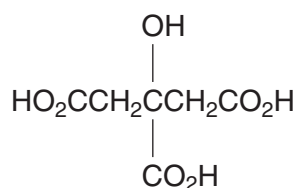
Unripe fruit often contains polycarboxylic acids, that is acids with more than one carboxylic acid group in their molecule.

One of these acids is commonly known as tartaric acid, $\text{HO}_2\text{CCH}(\text{OH})\text{CH}(\text{OH})\text{CO}_2\text{H}$.

(b) Give the structural formula of the organic compound produced when tartaric acid is reacted with an excess of NaHCO_3 .

[1]

Another acid present in unripe fruit is citric acid,



(c) Does citric acid show optical isomerism? Explain your answer.

.....

.....

.....

[1]

A third polycarboxylic acid present in unripe fruit is a colourless crystalline solid, **W**, which has the following composition by mass: C, 35.8%; H, 4.5%; O, 59.7%.

For
Examiner's
Use

(d) (i) Show by calculation that the empirical formula of **W** is $\text{C}_4\text{H}_6\text{O}_5$.

(ii) The M_r of **W** is 134. Use this value to determine the molecular formula of **W**.

[3]

A sample of **W** of mass 1.97 g was dissolved in water and the resulting solution titrated with 1.00 mol dm^{-3} NaOH. 29.4 cm^3 were required for complete neutralisation.

(e) (i) Use these data to deduce the number of carboxylic acid groups present in one molecule of **W**.

(ii) Suggest the displayed formula of **W**.

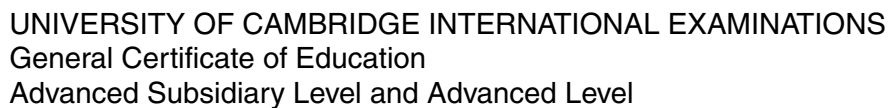
[5]

[Total: 13]

BLANK PAGE

Permission to reproduce items where third-party owned material protected by copyright is included has been sought and cleared where possible. Every reasonable effort has been made by the publisher (UCLES) to trace copyright holders, but if any items requiring clearance have unwittingly been included, the publisher will be pleased to make amends at the earliest possible opportunity.

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



--

--	--	--	--	--

--	--	--	--

9701/22

May/June 2010

1 hour 15 minutes

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.

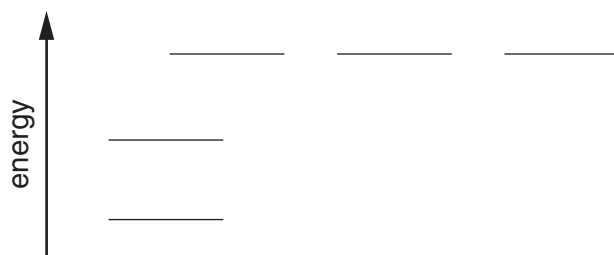
For
Examiner's
Use

- 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.

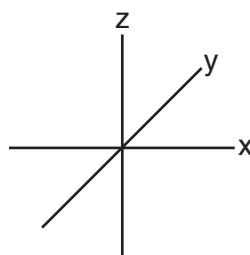
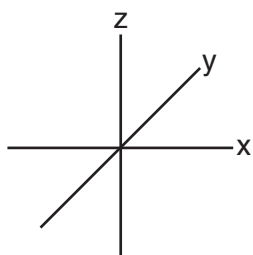
- (a) The diagram below represents the energy levels of the orbitals present in atoms of the second period (Li to Ne).

- (i) Label the energy levels to indicate the principal quantum number **and** the type of orbital at each energy level.



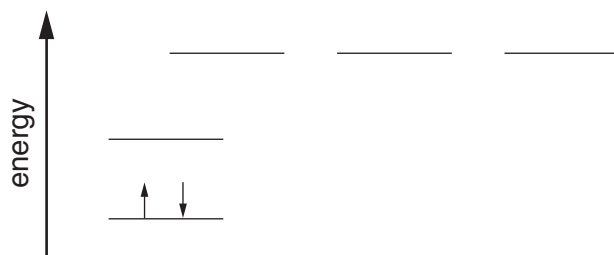
- (ii) On the axes below, draw a sketch diagram of **one** of each **different type (shape)** of orbital that is occupied by the electrons in a second-period element.

Label each type.

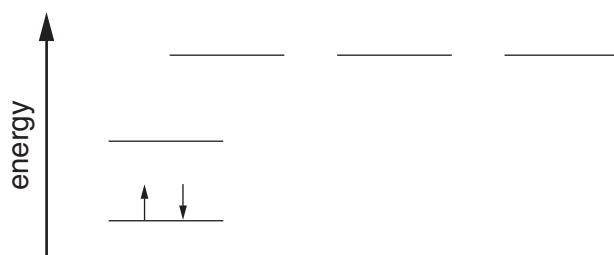


- (iii) Complete the electronic configurations of nitrogen atoms and oxygen atoms on the energy level diagrams below. Use arrows to represent electrons.

For
Examiner's
Use



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.

.....

.....

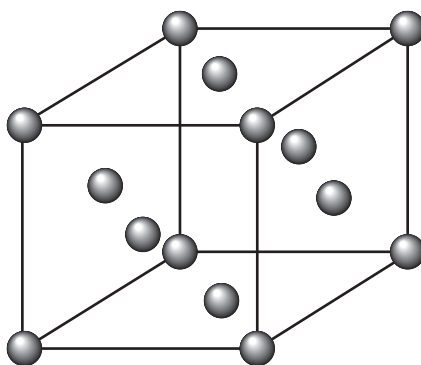
.....

[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.

For
Examiner's
Use



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 ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₄ O 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 Na₂O and SO₂ 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.

Na₂O

equation

pH

SO₂

equation

pH

- (ii) Construct a balanced equation for the reaction that occurs when a solution of Na₂O in water reacts with a solution of SO₂ 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%.

For
Examiner's
Use

(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 cm³ at 127 °C and $1.00 \times 10^5 \text{ N m}^{-2}$.

- (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 C₄H₈O₂.

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 ₂ CH(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.

.....

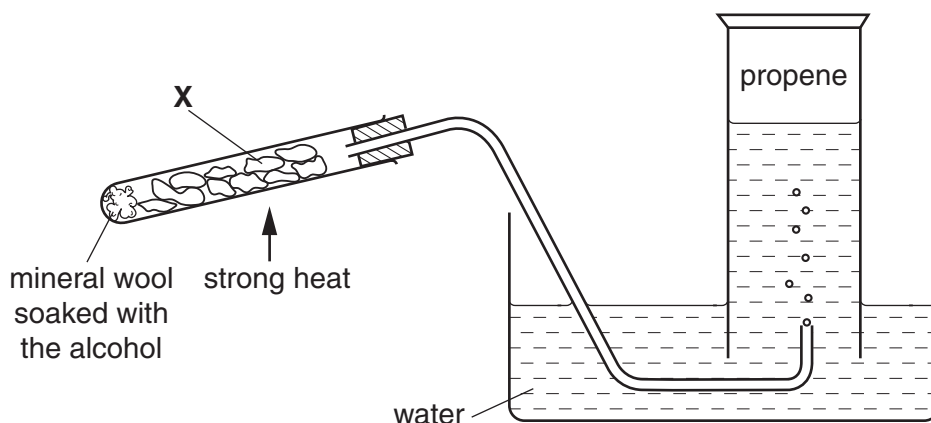
.....

[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]

(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.

.....

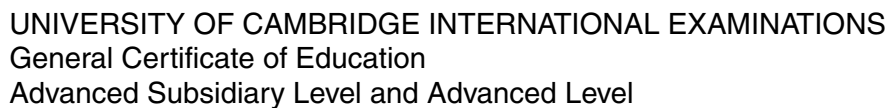
.....

[2]

[Total: 13]

Permission to reproduce items where third-party owned material protected by copyright is included has been sought and cleared where possible. Every reasonable effort has been made by the publisher (UCLES) to trace copyright holders, but if any items requiring clearance have unwittingly been included, the publisher will be pleased to make amends at the earliest possible opportunity.

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



--

--	--	--	--	--

--	--	--	--

9701/23

May/June 2010

1 hour 15 minutes

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 Hydrazine, N_2H_4 , can be used as a rocket fuel and is stored as a liquid. It reacts exothermically with oxygen to give only gaseous products.

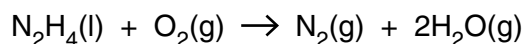
The enthalpy change of a reaction such as that between hydrazine and oxygen may be calculated by using standard enthalpy changes of formation.

- (a) Define the term *standard enthalpy change of formation*, $\Delta H_f^\ominus$.

.....

 [3]

- (b) Hydrazine reacts with oxygen according to the following equation.



- (i) Use the data in the table to calculate the standard enthalpy change of this reaction.

compound	$\Delta H_f^\ominus/\text{kJ mol}^{-1}$
$\text{N}_2\text{H}_4(\text{l})$	50.6
$\text{H}_2\text{O}(\text{g})$	-241.8

$$\Delta H^\ominus = \dots\dots\dots \text{kJ mol}^{-1}$$

- (ii) Although the above reaction is highly exothermic, hydrazine does not burn spontaneously in oxygen. Suggest a reason for this.

.....

- (iii) Suggest why using hydrazine as a rocket fuel could be regarded as being 'environmentally friendly'.

.....
.....

[4]

- (c) The bonding in hydrazine is similar to that in ammonia.

- (i) Showing outer-shell electrons only, draw a 'dot-and-cross' diagram of an ammonia molecule.

- (ii) Draw a diagram to show the three-dimensional shape of an ammonia molecule.

- (iii) Draw a diagram to show the shape of a hydrazine molecule.
Show clearly which atom is joined to which and show clearly the value of **one** bond angle.

[4]

- (d) Deduce the oxidation state of nitrogen in hydrazine.

.....

[1]

[Total: 12]

- 2 The alkali metals are a series of six elements in Group I of the Periodic Table. The first ionisation energy of these elements shows a marked trend as the Group is descended.

For
Examiner's
Use

(a) Define the term *first ionisation energy*.

.....
.....
..... [2]

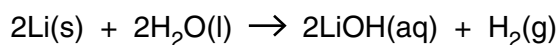
(b) (i) State and explain the trend in first ionisation energy as Group I is descended.

.....
.....
.....

(ii) Suggest how this trend helps to explain the increase in the reactivity of the elements as the Group is descended.

.....
..... [3]

(c) In a redox reaction, 0.83 g of lithium reacted with water to form 0.50 dm³ of aqueous lithium hydroxide.



(i) Calculate the amount, in moles, of lithium that reacted.

- (ii) Calculate the volume of hydrogen produced at room temperature and pressure.

For
Examiner's
Use

- (iii) Calculate the concentration, in mol dm^{-3} , of the LiOH(aq) formed.

[5]

- (d) When heated in chlorine, all of the alkali metals react to form the corresponding chloride.

Describe what you see when sodium is heated in chlorine and write a balanced equation for the reaction.

description

.....

.....

.....

equation

.....

[2]

[Total: 12]

																H																	He
Li		Be																B	C	N	O	F	Ne										
Na		Mg																Al	Si	P	S	Cl	Ar										
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr																

-

- ■ ■ ■ ■

- • • • •

- • • • •

- • • • •

-

..... and

9701/23/M/J/10

- (c) Use the elements in Period 3 (Na to Ar) in the section of the Periodic Table opposite to identify the oxide(s) referred to below.
In **each** case, give the formula of the oxide(s).

For
Examiner's
Use

- (i) an oxide which has no reaction with water

.....

- (ii) **two** acidic oxides formed by the same element

..... and

- (iii) an oxide which dissolves readily in water to give a strongly alkaline solution

.....

- (iv) an oxide which is amphoteric

.....

[5]

[Total: 12]

- 4 Organic reactions involve substances which may be
atoms, molecules, ions or free radicals.

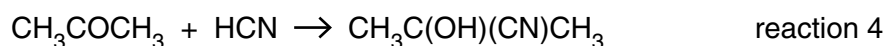
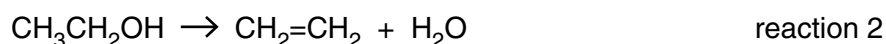
For
Examiner's
Use

We also apply the terms

electrophilic, nucleophilic, addition, elimination and substitution

to organic reactions.

Consider the following reactions.



- (a) Using the terms mentioned above, state as clearly as you can the nature of each of the following reactions.

reaction 1

reaction 2 [2]

- (b) By considering the four reactions above, suggest a formula for **each** of the following substances.

In **each** case, state which reaction you are considering.

- (i) **one** substance that is an addition product

reaction..... addition product

- (ii) **one** substance that is a leaving group

reaction..... leaving group

- (iii) **one** substance that behaves as an electrophile

reaction..... electrophile

[3]

(c) What is meant by the term *nucleophile*?

.....
..... [1]

(d) Reactions 3 and 4 involve nucleophiles.

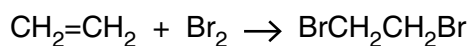
For **each** reaction, give the formula of the nucleophile.

reaction 3

reaction 4

[2]

(e) One characteristic reaction of ethene is its ability to decolourise bromine.



In this reaction, ethene behaves as a nucleophile.

Suggest an explanation for how ethene can behave in this way.

.....
..... [1]

[Total: 9]

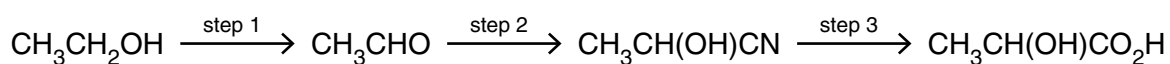
- 5 Lactic acid, 2-hydroxypropanoic acid, $\text{CH}_3\text{CH}(\text{OH})\text{CO}_2\text{H}$, occurs naturally in sour milk and in our muscles when we take hard exercise.
Lactic acid is chiral and shows stereoisomerism.

For
Examiner's
Use

- (a) Draw fully displayed structures of the two optical isomers of lactic acid.
Indicate with an asterisk (*) the chiral carbon atom in the lactic acid molecule.

[3]

- (b) Lactic acid may be synthesised from ethanol by the following route.



Give the reagent(s) and essential condition(s) for **each** step.

	reagent(s)	condition(s)
step 1		
step 2		
step 3		

[6]

During exercise, lactic acid is produced in our muscles from pyruvic acid, $\text{CH}_3\text{COCO}_2\text{H}$. This reaction occurs in the presence of the enzyme lactic acid dehydrogenase.

For
Examiner's
Use

(c) (i) What type of chemical compound is the enzyme lactic acid dehydrogenase?

.....

(ii) How would you detect a small quantity of pyruvic acid in a sample of lactic acid?

State the reagent(s) you would use and what would be seen in your test.

reagent(s)

observation

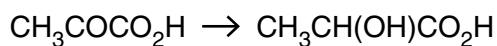
(iii) How would you detect a small quantity of lactic acid in a sample of pyruvic acid?

State the reagent(s) you would use and what would be seen in your test.

reagent(s)

observation

(iv) What chemical reagent would be used to convert pyruvic acid into lactic acid?



.....

[6]

[Total: 15]

BLANK PAGE

Permission to reproduce items where third-party owned material protected by copyright is included has been sought and cleared where possible. Every reasonable effort has been made by the publisher (UCLES) to trace copyright holders, but if any items requiring clearance have unwittingly been included, the publisher will be pleased to make amends at the earliest possible opportunity.

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