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

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

8522443878

CHEMISTRY **9701/02**

Paper 2 AS Structured Questions **May/June 2008**

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 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.
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.

DO NOT WRITE IN THE GREY AREAS BETWEEN THE PAGES.

For Examiner's Use	
1	
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3	
4	
5	
Total	

This document consists of **10** printed pages and **2** blank pages.

SP (SLM/CGW) T58865/2

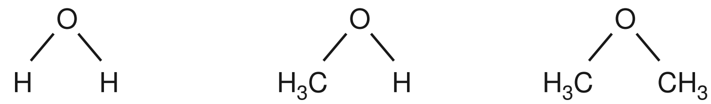
UNIVERSITY of CAMBRIDGE International Examinations

[Turn over

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

For Examiner's Use

1 The structural formulae of water, methanol and methoxymethane, CH_3OCH_3, are given below.



(a) (i) How many lone pairs of electrons are there around the oxygen atom in methoxymethane?

....

(ii) Suggest the size of the C–O–C bond angle in methoxymethane.

.... [2]

The physical properties of a covalent compound, such as its melting point, boiling point, vapour pressure, or solubility, are related to the strength of attractive forces between the molecules of that compound.

These relatively weak attractive forces are called intermolecular forces. They differ in their strength and include the following.

A interactions involving permanent dipoles

B interactions involving temporary or induced dipoles

C hydrogen bonds

(b) By using the letters **A**, **B**, or **C**, state the **strongest** intermolecular force present in **each** of the following compounds.
For each compound, write the answer on the dotted line.

ethanal	CH_3CHO	....
ethanol	CH_3CH_2OH	....
methoxymethane	CH_3OCH_3	....
2-methylpropane	$(CH_3)_2CHCH_3$	....

[4]

For Examiner's Use

(c) Methanol and water are completely soluble in each other.

(i) Which intermolecular force exists between methanol molecules and water molecules that makes these two liquids soluble in each other?

....

(ii) Draw a diagram that clearly shows this intermolecular force. Your diagram should show any lone pairs or dipoles present on either molecule that you consider to be important.

[4]

(d) When equal volumes of ethoxyethane, $C_2H_5OC_2H_5$, and water are mixed, shaken, and then allowed to stand, two layers are formed.

Suggest why ethoxyethane does not fully dissolve in water. Explain your answer.

....

....

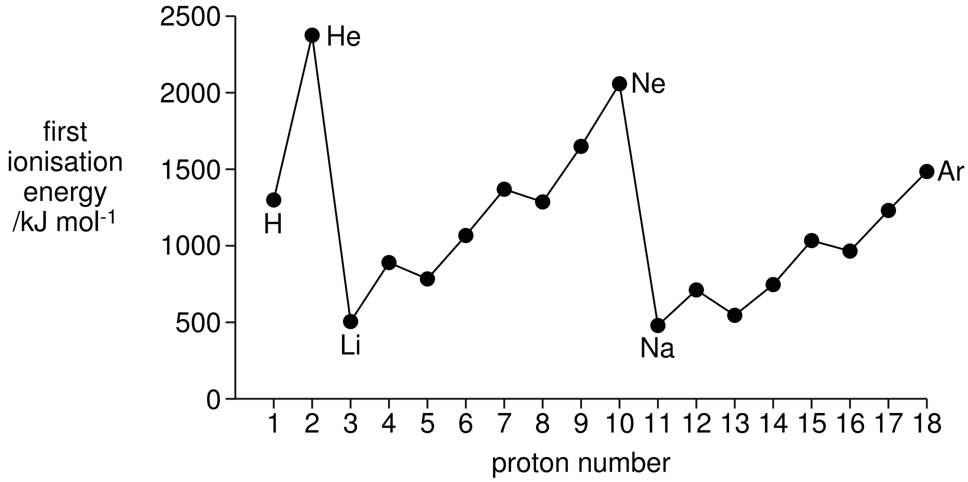
....

....[2]

[Total: 12]

2 The Periodic Table we currently use is derived directly from that proposed by Mendeleev in 1869 after he had noticed patterns in the 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 as we know it today.



(a) Give the equation, including state symbols, for the first ionisation energy of fluorine.

....[2]

(b) Explain why there is a general increase in first ionisation energies from sodium to argon.

....

....

....

....[3]

(c) **(i)** Explain why the first ionisation energy of aluminium is less than that of magnesium.

....

....

....

For Examiner's Use

(ii) Explain why the first ionisation energy of sulphur is less than that of phosphorus.

....

....

....
[4]

The table below refers to the elements sodium to sulphur and is incomplete.

element	Na	Mg	A*l*	Si	P	S
melting point		high				
conductivity		high				

(d) **(i)** Complete the 'melting point' row by using **only** the words 'high' **or** 'low'.

(ii) Complete the 'conductivity' row by using **only** the words 'high', 'moderate' **or** 'low'.
[5]

(e) When Mendeleev published his Periodic Table, the elements helium, neon and argon were not included.

Suggest a reason for this.

....

....[1]

[Total: 15]

3 When hydrocarbons such as petrol or paraffin wax are burned in an excess of air in a laboratory, carbon dioxide and water are the only products.
When petrol is burned in a car engine, nitrogen monoxide, NO, is also formed.

For Examiner's Use

(a) Explain how NO is formed in an internal combustion engine but not formed when a small sample of petrol is burnt in an evaporating basin.

....

....

....[2]

The engines of modern motor cars have exhaust systems which are fitted with catalytic converters in order to reduce atmospheric pollution from substances such as NO.

(b) (i) State **three more** pollutants, other than CO_2 and H_2O, that are present in the exhaust gases of a car engine.

.... and .... and ....

(ii) What is the active material present in the catalytic converter?

....

(iii) Write **one** balanced equation to show how NO is removed from the exhaust gases of a car engine by a catalytic converter.

....
[4]

NO is also formed when nitrosyl chloride, $NOCl$, dissociates according to the following equation.

$$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$$

Different amounts of the three gases were placed in a closed container and allowed to come to equilibrium at 230 °C. The experiment was repeated at 465 °C.

The equilibrium concentrations of the three gases at each temperature are given in the table below.

	concentration / mol dm^{-3}		
temperature / °C	$NOCl$	NO	Cl_2
230	2.33×10^{-3}	1.46×10^{-3}	1.15×10^{-2}
465	3.68×10^{-4}	7.63×10^{-3}	2.14×10^{-4}

For Examiner's Use

(c) **(i)** Write the expression for the equilibrium constant, K_c, for this reaction. Give the units.

(ii) Calculate the value of K_c at each of the temperatures given.

230 °C

465 °C

(iii) Is the forward reaction endothermic or exothermic? Explain your answer.

....

....
[5]

(d) The temperature of the equilibrium was then altered so that the equilibrium concentrations of $NOCl$ and NO were the same as each other.

What will be the effect on the equilibrium concentration of $NOCl$ when the following changes are carried out on this new equilibrium? In each case, explain your answer.

(i) The pressure of the system is halved at constant temperature.

....

....

(ii) A mixture of $NOCl$(g) and NO(g) containing equal numbers of moles of each gas is introduced into the container at constant temperature.

....

....
[4]

[Total: 15]

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For Examiner's Use

4 Two types of isomerism found in organic compounds are structural isomerism and *cis-trans* isomerism.

(a) Draw displayed formulae for

(i) **two** structural isomers of $C_2H_4Br_2$,

D	**E**

(ii) the *cis-* and the *trans-* isomers of $C_2H_2Br_2$.

cis	*trans*

[4]

(b) **(i)** The *cis-* isomer of $C_2H_2Br_2$ can be converted into **one** of the structural isomers of $C_2H_4Br_2$. State the reagent(s) and conditions you would use to do this.

....

....

(ii) Which of your structural isomers, **D** or **E**, would be formed? Explain your answer.

isomer formed is ....

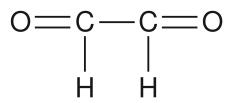
reason ....

[3]

[Total: 7]

For Examiner's Use

5 Ethanedial (glyoxal) is used in the production of fabrics which have permanent creases.



ethanedial

Ethanedial undergoes many of the reactions of aldehydes.

(a) Ethanedial reacts with Tollens' reagent.

(i) What would you see if you carried out this reaction?

....

(ii) What is the structural formula of the organic compound formed?

[2]

(b) Ethanedial reacts with hydrogen cyanide, HCN, to give compound **F**.

(i) What is the structural formula of **F**?

(ii) What type of reaction is this?

....

(iii) What is the structural formula of the compound formed when **F** is heated with an aqueous mineral acid such as dilute sulphuric acid?

[3]

For Examiner's Use

(c) Ethanedial can be oxidised and reduced.

(i) What is the structural formula of the organic compound formed when ethanedial is heated under reflux with an excess of acidified potassium dichromate(VI)?

(ii) What is the structural formula of the compound formed when ethanedial is reduced?

(iii) What reagent would be used for this reduction?

....

[3]

(d) When ethanedial is reacted with NaOH and the product treated with a mineral acid such as dilute sulphuric acid, the following reaction sequence takes place.

I $CHOCHO + NaOH \rightarrow HOCH_2CO_2Na$

II $HOCH_2CO_2Na + H^+ \rightarrow HOCH_2CO_2H + Na^+$

What type of reaction is the overall change?

.... [1]

(e) An isomer of ethanedial exists which reacts with sodium metal to give hydrogen.

Suggest the displayed formula of this isomer.

[2]

[Total: 11]

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS

GCE Advanced Subsidiary Level and GCE Advanced Level

MARK SCHEME for the May/June 2008 question paper

9701 CHEMISTRY

9701/02 Paper 2 (AS Structured Questions), maximum raw mark 60

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began.

All Examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes must be read in conjunction with the question papers and the report on the examination.

- CIE will not enter into discussions or correspondence in connection with these mark schemes.

CIE is publishing the mark schemes for the May/June 2008 question papers for most IGCSE, GCE Advanced Level and Advanced Subsidiary Level syllabuses and some Ordinary Level syllabuses.

1 **(a)** **(i)** 2 (1)

(ii) between 104° and 105° (1) [2]

(b)

ethanal	CH_3CHO	**A** (1)
ethanol	CH_3CH_2OH	**C** (1)
methoxymethane	CH_3OCH_3	**A** (1)
2-methylpropane	$(CH_3)_2CHCH_3$	**B** (1) [4]

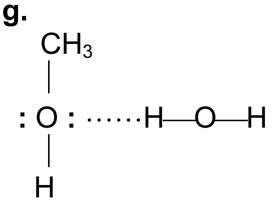
(c) **(i)** hydrogen bonds (1)

(ii) correct dipole on an -O—H bond (1)

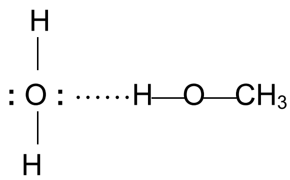
hydrogen bond shown between the lone pair of an O and a H atom in an –OH group (1)

lone pair on O atom of CH_3OH **or** H_2O clearly shown **in the hydrogen bond** (1)

e.g.



or



[4]

(d) hydrogen bonds exist between H_2O molecules (1)

hydrogen bonds cannot form between $C_2H_5OC_2H_5$ molecules (1) [2]

[Total: 12]

2 **(a)** $F(g) \rightarrow F^+(g) + e$

correct equation (1)

correct state symbols (1) [2]

(b) from Na to Ar, electrons

are added to the same shell/have same shielding (1)

are subject to increasing nuclear charge/proton number (1)

are closer to the nucleus **or** atom gets smaller (1) [3]

(c) **(i)** **A*l* and Mg**

in A*l* outermost electron is in 3p rather than 3s (1)

3p electron is at higher energy
or is further away/is more shielded from nucleus (1)

(ii) **P and S**

for P 3p sub-shell is singly filled
and for S one 3p orbital has paired electrons (1)

paired electrons repel (1) [4]

(d) **(i)** and **(ii)**

element	Na	Mg	A*l*	Si	P	S
melting point	low	------	high	high	low	low
conductivity	high	------	high	moderate	low	low
	(1)		(1)	(1)	(1)	(1)

one mark for each correct column [5]

(e) because they had not been discovered (1) [1]

[Total: 15]

3 **(a)** high temperature (and/or pressure) provide enough energy (1)

to break N≡N bond
or to provide E_a for N_2/O_2 reaction (1) [2]

(b) **(i)** **two** from C, CO, hydrocarbon, SO_2, H_2S, NO_2/NO_x (1 + 1)

not CO_2, H_2, H_2O, SO_3, NO

(ii) Pt **or** Pd **or** Pt/Rh **or** Pt/Pd/Rh (1)

(iii) $2NO + 2CO \rightarrow 2CO_2 + N_2$
or $2NO + C \rightarrow CO_2 + N_2$ (1) [4]

(c) **(i)** $K_c \quad \frac{[NO]^2[Cl_2]}{[NOCl]^2}$ (1)

units are mol dm ^{3} (1)

(ii) at 230 °C $\quad K_c \quad \frac{(1.46\times10^{\ 3})^2\times1.15\times10^{\ 2}}{(2.33\times10^{\ 3})^2}$

$= 4.5 \times 10^{\ 3}$ mol dm ^{3} (1)

at 465 °C $\quad K_c \quad \frac{(7.63\times10^{\ 3})^2\times2.14\times10^{\ 4}}{(3.68\times10^{\ 4})^2}$

$= 9.2 \times 10^{\ 2}$ mol dm ^{3} (1)

allow ecf on answer to part **(i)**

(iii) endothermic **because** K_c increases with temperature
mark is for explanation
allow ecf on answer to part **(ii)** (1) [5]

(d) **(i)** equilibrium moves to RHS (1)

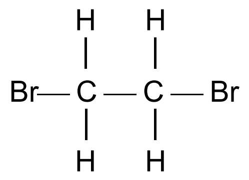
more moles on RHS (1)

(ii) no change to equilibrium position (1)

[NOC*l*] and [NO] change by same amount (1) [4]

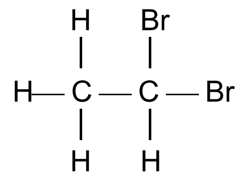
[Total: 15]

4 (a) (i)



D

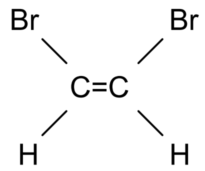
(1)



E

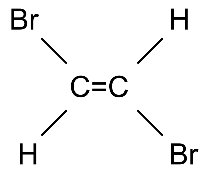
(1)

(ii)



cis

(1)



trans

(1)

[4]

(b) (i) hydrogen (1)

nickel catalyst – allow platinum or palladium (1)

(ii) isomer formed **must** be 1,2-dibromoethane (**D** above)

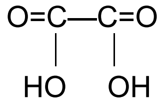
because

cis isomer has one Br atom on **each** carbon atom (1)

mark is for the reason but wrong isomer is penalised [3]

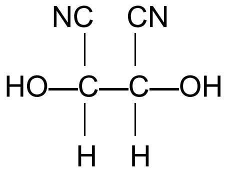
[Total: 7]

5 **(a)** **(i)** silver or black ppt. (1)

(ii)  **or** HO_2CCO_2H (1)

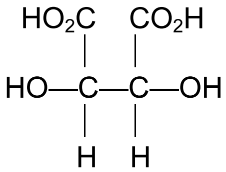
allow anion

[2]

(b) **(i)**  **or** NCCH(OH)CH(OH)CN (1)

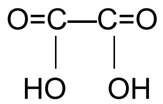
allow NCCH(OH)CHO

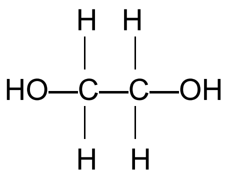
(ii) nucleophilic addition (1)

(iii)  **or** $HO_2CCH(OH)CH(OH)CO_2H$ (1)

allow $HO_2CCH(OH)CHO$ (ecf)

[3]

(c) **(i)**  **or** HO_2CCO_2H (1)

(ii)  **or** HOH_2CCH_2OH (1)

allow HOH_2CCHO

(iii) $NaBH_4$ **or** $LiAlH_4$ **or** H_2/Ni (1) [3]

(d) **both** oxidation **and** reduction **allow** disproportionation (1) [1]

(e) HO—C≡C—OH – candidate's compound must be $C_2H_2O_2$

-OH present (1)

C≡C present (1) [2]

[Total: 11]

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

CANDIDATE NAME

CENTRE NUMBER | CANDIDATE NUMBER

2045742995

CHEMISTRY **9701/02**

Paper 2 Structured Questions AS Core **October/November 2008**

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

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UNIVERSITY of CAMBRIDGE International Examinations

[Turn over

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

For Examiner's Use

1 Most submarines travel under water using electrical power from batteries. The German engineer Helmut Walter designed a diesel engine that could be used to propel a submarine beneath the surface of the sea. Instead of taking air from above the surface of the sea, Walter's engine used hydrogen peroxide, H_2O_2, to provide oxygen for a conventional diesel engine.

Hydrogen peroxide may be catalytically decomposed to give water and oxygen.

(a) **(i)** What is meant by the term *catalyst*?

....

....

(ii) Construct a balanced equation for the decomposition of H_2O_2.

.... [3]

Diesel fuel may be considered to consist of the hydrocarbon $C_{15}H_{32}$ which reacts completely with oxygen according to the following equation.

$$C_{15}H_{32} + 23O_2 \rightarrow 15CO_2 + 16H_2O$$

(b) **(i)** To which homologous series does $C_{15}H_{32}$ belong?

....

(ii) Use the equation above and your answer to **(a)(ii)** to calculate the amount, in moles, of H_2O_2, that will provide sufficient oxygen for the complete oxidation of one mole of $C_{15}H_{32}$.

amount of H_2O_2 = ... mol

[3]

A submarine equipped with a Walter engine used 212 tonnes of diesel fuel during an underwater voyage. The submarine also carried concentrated aqueous H_2O_2.
[1 tonne = 10^6 g]

For Examiner's Use

(c) **(i)** Calculate the amount, in moles, of diesel fuel used during the underwater voyage.

amount of diesel fuel = ... mol

(ii) Use your answers to **(b)(ii)** and **(c)(i)** to calculate the mass, in tonnes, of hydrogen peroxide used during the underwater voyage.

mass of H_2O_2 = ... tonnes
[4]

(d) The exhaust products of the Walter engine were passed into the sea.

What would happen to them?

.... [1]

[Total: 11]

2 Ketene, C_2H_2O, is a member of a class of unsaturated organic compounds that is widely used in pharmaceutical research for the synthesis of organic compounds.

For Examiner's Use

$CH_2{=}C{=}O$

ketene

(a) (i) Suggest values for the H-C-H and C=C=O bond angles in ketene.

H-C-H …………………………………… C=C=O ……………………………………

(ii) By considering the structure of the molecule, suggest why the name *ketene* is used.

....

.... [3]

(b) Ketene burns completely in air to form carbon dioxide and water.

(i) Write a balanced equation for this reaction.

....

(ii) Use your equation to calculate the volume of CO_2, in dm^3, measured at room temperature and pressure, which will be formed when 3.5 g of ketene are burned in an excess of air.

Give your answer to **two** significant figures.

volume of CO_2 = ... dm^3 [4]

For Examiner's Use

(c) **(i)** Define the term *standard enthalpy change of formation.*

....

....

....

(ii) Use the data below to calculate the standard enthalpy change of formation of ketene.

	$\Delta H^\ominus$/kJ mol^{-1}
standard enthalpy change of formation of CO_2	–395
standard enthalpy change of combustion of H_2	–286
standard enthalpy change of combustion of $CH_2{=}C{=}O$	–1028

[6]

(d) Ketene can be converted directly into ethanoic acid, CH_3CO_2H, by reaction with a compound **A**.

Suggest the identity of **A**.

.... [1]

[Total: 14]

For Examiner's Use

3 Chlorine gas is manufactured by the electrolysis of brine using a diaphragm cell.

(a) Write half-equations, including state symbols, for the reactions occurring at each of the electrodes of a diaphragm cell.

anode ....

cathode .... [2]

(b) 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.

....

.... [1]

(c) One important product made in the diaphragm cell is formed in aqueous solution.

(i) What substance is produced in aqueous solution in the diaphragm cell?

....

(ii) Explain, with the aid of appropriate half-equation(s), how this compound is formed by electrolysis.

....

....

.... [3]

(d) 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]

(e) Magnesium chloride, $MgCl_2$, and silicon tetrachloride, $SiCl_4$, each dissolve in or react with water.

For Examiner's Use

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: 15]

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4 Organic chemistry is the chemistry of carbon compounds. The types of organic reactions that you have studied are listed below.

addition	elimination	hydrolysis
oxidation	reduction	substitution

Addition and substitution reactions are further described as follows.

electrophilic	nucleophilic	free radical

Complete the table below.

Fill in the central column by using **only** the types of reaction given in the lists above. Use **both** lists when appropriate.

In the right hand column give the name(s) or formula(e) of the reagent(s) you would use to carry out the reaction given.

organic reaction	type of reaction	reagent(s)
$CH_3CHO \rightarrow CH_3CH(OH)CN$		
$CH_3CH_2CH_2CH_3 \rightarrow CH_3CH_2CHBrCH_3$		
$CH_3CH(OH)CH_3 \rightarrow CH_3CH{=}CH_2$		
$CH_3CH{=}CH_2 \rightarrow CH_3CH(OH)CH_2OH$		

[Total: 10]

5 An organic ester, **B**, has the empirical formula C_2H_4O. An experiment by a student in a college gave a value of 87.5 for M_r of **B**.

For Examiner's Use

(a) What is the molecular formula of **B**?

.... [1]

(b) In the boxes below, draw the structural formulae of **four** isomers of **B** that are esters.

W	**X**
Y	**Z**

[4]

The student hydrolysed his sample of **B** by heating with aqueous mineral acid and then separating the alcohol, **C**, that was formed. He heated the alcohol **C** under reflux with acidified dichromate(VI) ions and collected the product **D**.

For Examiner's Use

A sample of **D** gave an orange precipitate with 2,4-dinitrophenylhydrazine reagent. A second sample of **D** gave no reaction with Tollens' reagent.

(c) **(i)** What group does the reaction with 2,4-dinitrophenylhydrazine reagent show to be present in **D**?

....

(ii) What does the result of the test with Tollens' reagent show about **D**?

....

(iii) What is the structural formula of the alcohol **C**?

(iv) Which of your esters, **W**, **X**, **Y**, or **Z** has the same structure as that of the ester **B**?

.... [4]

(d) Which, if any of your esters, **W**, **X**, **Y**, or **Z** is chiral? Explain your answer.

....

.... [1]

[Total: 10]

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS

GCE Advanced Subsidiary Level and GCE Advanced Level

MARK SCHEME for the October/November 2008 question paper

9701 CHEMISTRY

9701/02 Paper 2 (Theory 1), maximum raw mark 60

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began.

All Examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes must be read in conjunction with the question papers and the report on the examination.

- CIE will not enter into discussions or correspondence in connection with these mark schemes.

CIE is publishing the mark schemes for the October/November 2008 question papers for most IGCSE, GCE Advanced Level and Advanced Subsidiary Level syllabuses and some Ordinary Level syllabuses.

1 **(a)** **(i)** substance that speeds up a chemical reaction (1)
by lowering E_a
or by providing an alternative reaction pathway
or without being used up in the process (1)

(ii) $2H_2O_2 \rightarrow 2H_2O + O_2$ (1) [3]

(b) **(i)** alkanes **or** paraffins (1)

(ii) $2H_2O_2 : O_2$ and $C_{15}H_{32} : 23O_2$ (1)
whence $C_{15}H_{32} : 46H_2O_2$ (1)
allow e.c.f. on **(a)(ii)** [3]

(c) **(i)** $C_{15}H_{32} = 212$ (1)
$n(C_{15}H_{32}) = \dfrac{212 \times 10^6}{212} = 1 \times 10^6$ mol
allow e.c.f. on wrong M_r of $C_{15}H_{32}$ (1)

(ii) $n(H_2O_2)$ required $= 46 \times 10^6$ mol (1)
mass of $H_2O_2 = 34 \times 46 \times 10^6$ g $= 1564$ tonnes
final answer must be in tonnes (1)
allow e.c.f. on **(b)(ii)** and **(c)(i)** [4]

(d) they would dissolve (1) [1]

[Total: 11]

2 **(a)** **(i)** H–C–H 117 to 120^o (1)
C=C=O 180^o (1)

(ii) molecule contains **both** ketone **and** alkene (1) [3]

(b) **(i)** $C_2H_2O + 2O_2 \rightarrow 2CO_2 + H_2O$ (1)

(ii) from eqn., 42 g $C_2H_2O \rightarrow 48$ dm^3 of CO_2 (1)
whence 3.5 g $C_2H_2O \rightarrow \dfrac{48 \times 3.5}{42}$ dm^3 of CO_2 (1)
$= 4.0$ dm^3 of CO_2 (1)

or $n(C_2H_2O) = \dfrac{42}{3.5} = 0.0833$ (1)
$n(CO_2) = 2 \times 0.083 = 0.0166$ (1)
vol. of $CO_2 = 0.0166 \times 24 = 4.0$ dm^3 (1)
allow e.c.f. on wrong eqn. in **(b)(i)**
penalise significant figure error [4]

(c) **(i)** enthalpy change when
1 mol of a compound is formed (1)
from its elements (1)
in their standard states under standard conditions (1)

(ii) $C + O_2 \rightarrow CO_2$ $-395\ kJ\ mol^{1}$
$H_2 + ½O_2 \rightarrow H_2O$ $-286\ kJ\ mol^{1}$
$C_2H_2O + 2O_2 \rightarrow 2CO_2 + H_2O$ $-1028\ kJ\ mol^{1}$
$2C + H_2 + ½O_2 \rightarrow C_2H_2O\ \Delta H = 2(-395) + (-286) - (-1028)$
$= -48\ kJ\ mol^{1}$
correct cycle (1) use of 2 for C/CO_2 (1) answer (1) [6]

(d) H_2O/water/steam (1) [1]

[Total: 14]

3 **(a)** anode $Cl\ (aq) \rightarrow ½\ Cl_2(g) + e$ (1)
cathode $H^+(aq) + e \rightarrow ½H_2(g)$
or $2H_2O(l) + 2e \rightarrow H_2(g) + 2OH\ (aq)$ (1)
correct state symbols (1) [2]

(b) because the iron in steel will react with chlorine (1) [1]

(c) **(i)** sodium hydroxide/NaOH (1)
$2H_2O + 2e \rightarrow H_2 + 2OH$
or $2H^+ + 2e \rightarrow H_2$ (1)
leaving OH in solution as NaOH (1) [3]

(d) **Na** burns with a yellow flame/forms a white solid (1)
$2Na + Cl_2 \rightarrow 2NaCl$ (1)
P burns with a white flame/forms a colourless liquid (PCl_3) **or** a white solid (PCl_5) (1)
$P + 1½Cl_2 \rightarrow PCl_3$ **or** $P_4 + 6Cl_2 \rightarrow 4PCl_3$
or $P + 2½Cl_2 \rightarrow PCl_5$ **or** $P_4 + 10Cl_2 \rightarrow 4PCl_5$ (1) [4]

(e) $MgCl_2$ 6 to 7 (1)
$SiCl_4$ 0 to 3 (1)
$MgCl_2$ dissolves without reaction (1)
$SiCl_4$ reacts with water/hydrolyses (1)
$SiCl_4 + 2H_2O \rightarrow SiO_2 + 4HCl$ **or**
$SiCl_4 + 4H_2O \rightarrow Si(OH)_4 + 4HCl$ **or**
$SiCl_4 + 4H_2O \rightarrow SiO_2.2H_2O + 4HCl$ (1) [5]

[Total: 15 max]

4

organic reaction	type of reaction	reagent(s)
$CH_3CHO \rightarrow$ $CH_3CH(OH)CN$	nucleophilic (1) addition (1)	HCN **or** HCN and CN (1)
$CH_3CH_2CH_2CH_3 \rightarrow$ $CH_3CH_2CHBrCH_3$	free radical (1) substitution (1)	Br_2 **or** Br_2 in an organic solvent **not** $Br_2(aq)$ (1)
$CH_3CH(OH)CH_3 \rightarrow$ $CH_3CH{=}CH_2$	elimination (1)	conc. H_2SO_4 (1)
$CH_3CH{=}CH_2 \rightarrow$ $CH_3CH(OH)CH_2OH$	addition **or** oxidation (1)	$KMnO_4/MnO_4$ (1)

[10]

[Total: 10]

5 **(a)** $C_4H_8O_2$ (1) [1]

(b)

$HCO_2CH(CH_3)_2$	$HCO_2CH_2CH_2CH_3$	$CH_3CO_2CH_2CH_3$ **or** $CH_3CO_2C_2H_5$	$CH_3CH_2CO_2CH_3$ **or** $C_2H_5CO_2CH_3$
W	**X**	**Y**	**Z**

each correct structure is worth (1) [4]

(c) **(i)** presence of >C=O group/carbonyl group (1)

(ii) –CHO group/aldehyde group is absent
or ketone is present (1)

(iii) alcohol **C** is $(CH_3)_2CHOH$
allow e.c.f. on **(c)(i)** and**(ii)** (1)

(iv) correct identification of candidate's ester
(**W** in this case)

allow e.c.f. on **(c)(iii)** (1) [4]

(d) none
no chiral centres are present in any of the four esters
allow e.c.f. on candidate's compounds in **(a)** (1) [1]

[Total: 10]

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

CANDIDATE NAME	

CENTRE NUMBER			CANDIDATE NUMBER	

2744384496

CHEMISTRY **9701/21**

Paper 2 Structured Questions AS Core **October/November 2009**

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.

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UNIVERSITY of CAMBRIDGE International Examinations

[Turn over

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

For Examiner's Use

1 Magnesium, Mg, and radium, Ra, are elements in Group II of the Periodic Table.

Magnesium has three isotopes.

(a) Explain the meaning of the term *isotope.*

....

....

.... [2]

A sample of magnesium has the following isotopic composition by mass.

isotope mass	24	25	26
% by mass	78.60	10.11	11.29

(b) Calculate the relative atomic mass, A_r, of magnesium to **four** significant figures.

A_r = ………………
[2]

Radium, proton number 88, and uranium, proton number 92, are radioactive elements.

For Examiner's Use

The isotope ^{226}Ra is produced by the radioactive decay of the uranium isotope ^{238}U.

(c) Complete the table below to show the atomic structures of the isotopes ^{226}Ra and ^{238}U.

	number of		
isotopes	protons	neutrons	electrons
^{226}Ra			
^{238}U			

[3]

(d) Radium, like other Group II elements, forms a number of ionic compounds.

(i) What is the formula of the radium cation?

………………

(ii) Use the *Data Booklet* to suggest a value for the energy required to form one mole of the gaseous radium cation you have given in **(i)** from one mole of gaseous radium atoms. Explain your answer.

....

....

.... [3]

[Total: 10]

For Examiner's Use

2 Radium was discovered in the ore pitchblende by Marie and Pierre Curie in 1898, and the metal was first isolated by them in 1910.

The metal was obtained by first reacting the radium present in the pitchblende to form insoluble radium sulfate which was converted into aqueous radium bromide. This solution was then electrolysed using a mercury cathode and a carbon anode.

(a) Radium has chemical reactions that are typical of Group II metals and forms ionic compounds.

(i) What is the characteristic feature of the electronic configurations of all Group II metals?

....

(ii) Radium sulfate is extremely insoluble. From your knowledge of the simple salts of Group II metals, suggest another very insoluble radium salt.

....

[2]

(b) During their electrolysis of aqueous radium bromide, the Curies obtained radium at the cathode and bromine at the anode.

Write half-equations for the two electrode reactions that take place during this electrolysis.

anode ....

cathode .... [2]

(c) **(i)** Describe what you would see when magnesium reacts with

cold water, ...

....

steam. ....

....

(ii) Write an equation for the reaction with steam.

....

[5]

For Examiner's Use

(d) Radium reacts vigorously when added to water.

(i) Write an equation, with state symbols, for this reaction.

....

(ii) State **two** observations that could be made during this reaction.

....

....

(iii) Suggest the approximate pH of the resulting solution.

………………

(iv) Will the reaction be more or less vigorous than the reaction of barium with water?

Explain your answer.

....

....

[6]

[Total: 15]

For Examiner's Use

3 Alkanes such as methane, CH_4, undergo few chemical reactions. Methane will, however, react with chlorine but not with iodine.

Relevant standard enthalpy changes of formation for the reaction of methane with chlorine to form chloromethane, CH_3Cl, are given below.

	$\Delta H_f^{\ominus}$/kJ mol^{-1}
CH_4	–75
CH_3Cl	–82
HCl	–92

(a) **(i)** Use the data to calculate $\Delta H^{\ominus}_{reaction}$ for the formation of CH_3Cl.

$$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$$

(ii) The corresponding reaction with iodine does **not** take place.

Use bond energy data from the *Data Booklet* to calculate a 'theoretical value' for $\Delta H_{reaction}$ for the following equation.

$$CH_4 + I_2 \rightarrow CH_3I + HI$$

(iii) Suggest why this reaction does **not** in fact occur.

....

....
[5]

(b) (i) By using equations, describe the mechanism of the reaction between chlorine and methane to form chloromethane, CH_3Cl.

Identify, by name, the separate steps of the overall reaction.

....

....

....

....

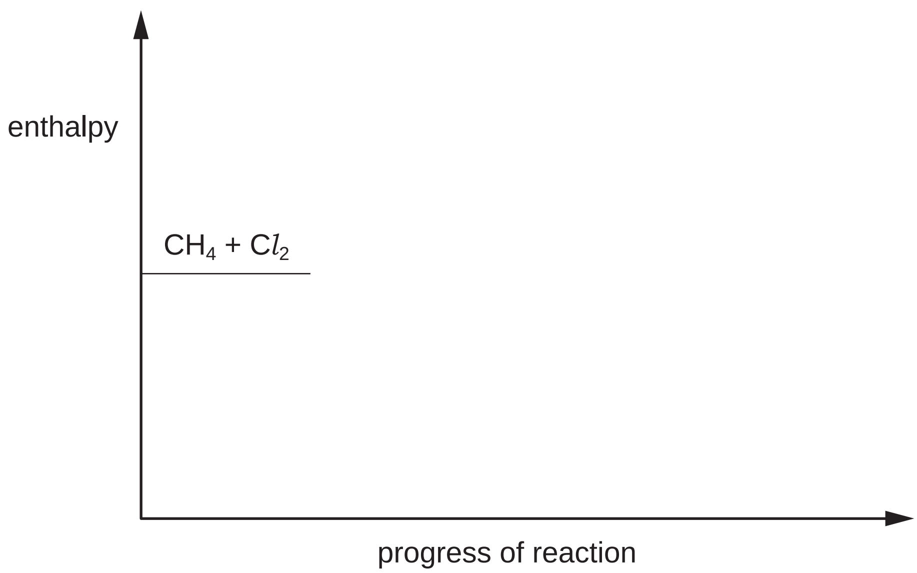
....

....

(ii) What is the intermediate organic species in this reaction?

.... [7]

(c) The energy of activation for the formation of CH_3Cl is 16 kJ mol^{-1}.
Use this figure and your answer to **(a)(i)** to complete the reaction pathway diagram below showing the formation of CH_3Cl from CH_4 and Cl_2.
Show clearly the intermediate organic species and the final products.
Indicate on your sketch the relevant enthalpy changes and their values.



[4]

[Total: 16]

For Examiner's Use

4 The structural formulae of six different compounds, **A – F**, are given below.
Each compound contains four carbon atoms in its molecule.

$CH_3CH{=}CHCH_3$	$CH_3CH_2COCH_3$	$CH_2{=}CHCH_2CH_3$
A	**B**	**C**
$CH_3CH_2CH(OH)CH_3$	$HOCH_2CH_2CH_2CH_2OH$	$CH_3CH_2OCH_2CH_3$
D	**E**	**F**

(a) **(i)** What is the empirical formula of compound **E**? ………………

(ii) Draw the skeletal formula of compound **D**.

(iii) Structural formulae do not show all of the isomers that may exist for a given molecular formula. Which **two** compounds **each** show **different** types of isomerism and what type of isomerism does each compound show? Identify each compound by its letter.

compound	type of isomerism

[4]

Compound **D** may be converted into compound **C**.

(b) **(i)** What type of reaction is this?

………………………………………

(ii) What reagent would you use for this reaction?

………………………………………

(iii) What is formed when compound **E** undergoes the same reaction using an excess of the same reagent?

……………………………………… [3]

Compound **A** may be converted into compound **B** in a two-stage reaction.

For Examiner's Use

$$CH_3CH{=}CHCH_3 \xrightarrow{\text{stage I}} \text{intermediate} \xrightarrow{\text{stage II}} CH_3CH_2COCH_3$$

(c) **(i)** What is the structural formula of the intermediate compound formed in this sequence?

(ii) Outline how stage I may be carried out to give this intermediate compound.

....

....

....

(iii) What reagent would be used for stage II?

…………………………………………… [4]

(d) Compounds **D** and **F** are isomers.

What type of isomerism do they show?

…………………………………………… [1]

[Total: 12]

For Examiner's Use

5 Three organic compounds, **G**, **H**, and **J**, each have the empirical formula CH_2O.
The numbers of carbon atoms in their molecules are shown in the table.

compound	number of C atoms
G	1
H	2
J	3

In **H** and in **J**, the carbon atoms are bonded directly to one another.

G gives a silver mirror when treated with Tollens' reagent.

H and **J** each give a brisk effervescence with $Na_2CO_3(aq)$.

(a) Identify **G**.

.... [1]

(b) **(i)** What functional group is common to both **H** and **J**?

....

(ii) Identify **H**.

....

(iii) Identify **J**.

.... [3]

(c) When **J** is heated under reflux with acidified $K_2Cr_2O_7$, the product, **K**, gives a red-orange precipitate with 2,4-dinitrophenylhydrazine reagent.

Draw the structural formula of **K**, the compound formed from **J**.

[1]

For Examiner's Use

(d) When **J** is warmed with concentrated sulfuric acid, a cyclic compound, **L**, is formed. **L** has the molecular formula $C_6H_8O_4$.

(i) Suggest a displayed formula for **L**.

(ii) What type of reaction occurs when **L** is formed from **J**?

……………………………………… [2]

[Total: 7]

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS

GCE Advanced Subsidiary Level and GCE Advanced Level

MARK SCHEME for the October/November 2009 question paper

for the guidance of teachers

9701 CHEMISTRY

9701/21 Paper 21 (AS Structured Questions), maximum raw mark 60

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1 **(a)** same proton number/atomic number (1)
different mass number/nucleon number (1) [2]

(b) A_r $\dfrac{(24 \times 78.60) + (25 \times 10.11) + (26 \times 11.29)}{100}$ (1)

$\dfrac{1886.4 + 252.75 + 293.54}{100}$ $\dfrac{2432.69}{100}$

which gives A_r = 24.33 (1)
penalise (–1) for misuse of significant figures [2]

(c)

isotopes	number of		
	protons	neutrons	electrons
^{226}Ra	88	138	88
^{238}U	92	146	92

allow **one mark** for each correct column (3 × 1)
if there are no correct columns,
allow **maximum one mark** for a correct row [3]

(d) **(i)** Ra^{2+} (1)

(ii) less than (502 + 966)
allow answers in the range 1000–1400 kJ mol ^{1} (1)

ionisation energies decrease down the Group
or must be less than IE for Ba $\rightarrow$ Ba^{2+}
or size of atom increases down Group/
electrons are further away from nucleus
or there is increased shielding down Group (1)

allow ecf on answer to **(i)** [3]

[Total: 10]

2	**(a)**	**(i)**	configuration ends in s^2 **or** there are two electrons in outermost/valence shell	(1)	
		(ii)	$RaCO_3$/radium carbonate	(1)	[2]
	(b)		anode $Br^- \rightarrow \frac{1}{2}Br_2 + e$	(1)	
			cathode $Ra^{2+} + 2e \rightarrow Ra$	(1)	[2]
	(c)	**(i)**	**water** slow reaction gas bubbles gas is colourless	any 2 (2)	
			steam Mg glows vigorous reaction white solid formed	any 2 (2)	
		(ii)	$Mg + H_2O \rightarrow MgO + H_2$	(1)	[5]
	(d)	**(i)**	$Ra(s) + 2H_2O(l) \rightarrow Ra(OH)_2(aq) + H_2(g)$	eqn. (1) s.s. (1)	
		(ii)	radium dissolves/disappears gas evolved gas is colourless heat evolved	any 2 (2)	
		(iii)	10–14	(1)	
		(iv)	more – **no mark for this alone** **because** reactivity of metals increases down the Group **or** electrons are further from nucleus **or** IE is lower **or** Ra is a stronger reducing agent	(1)	[6]

[Total: 15]

3 (a) (i)

	CH_4	+	Cl_2	→	CH_3Cl	+	HCl	
$\Delta H_f^\ominus$	–75		0		–82		–92	(1)

$\Delta H^\ominus_{reaction}$ = –82 + (–92) – (–75)
= –99 kJ mol–1 (1)

(ii)

	CH_4	+	I_2	→	CH_3I	+	HI	
broken	C–H		I–I	made	C–I		H–I	
	410		151		240		299	(1)

$\Delta H^\ominus_{reaction}$ = –240 + (–299) + 410 + 151
= +22 kJ mol–1 (1)

(iii) activation energy is too great (1) [5]

(b) (i) initiation (1)
Cl_2 + uvl → 2Cl (1)
propagation (1)

CH_4 + Cl → CH_3 + HCl
CH_3 + Cl_2 → CH_3Cl + Cl both needed (1)

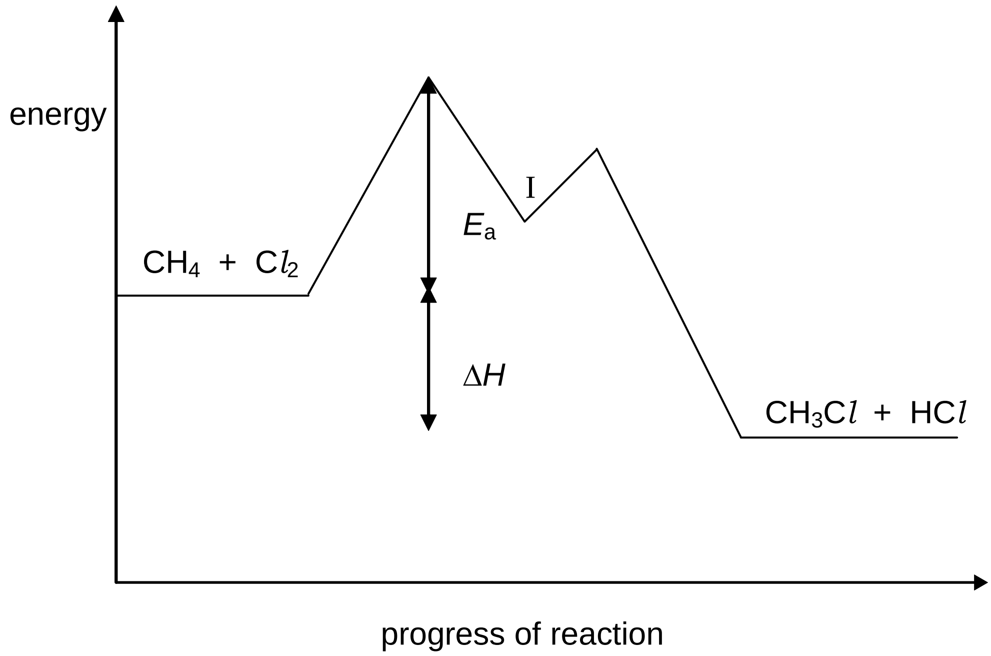
termination (1)

CH_3 + CH_3 → C_2H_6 **or**
CH_3 + Cl → CH_3Cl **or**

Cl + Cl → Cl_2 (1)

(ii) CH_3/methyl radical (1) [7]

(c)

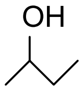


correct placement of 16 kJ (1)
correct placement of –99 kJ (allow ecf on wrong calculation in **(a) (i)**) (1)
intermediate clearly shown at I (1)
correct 'double peak' shape (1)
second peak lower than first (1) [5]

[Total: max 16]

4 **(a)** **(i)** C_2H_5O (1)

(ii)



(1)

(iii)

compound	type of isomerism
A	*cis-trans* **or** geometrical
D	optical

allow one mark if **both A and D** are correctly identified
but in **both** cases, the type of isomerism is incorrect

(1 + 1) [4]

(b) **(i)** dehydration/elimination (1)

(ii) conc. H_2SO_4/P_4O_{10}/Al_2O_3/pumice etc. (1)

(iii) CH_2=CHCH=CH_2/butadiene/buta-1,3-diene (1) [3]

(c) **(i)** $CH_3CH_2CH(OH)CH_3$ (1)

(ii) steam with H_3PO_4 catalyst **or**
conc. H_2SO_4 then water (1 + 1)

(iii) $Cr_2O_7^{2}$ /H^+ (1) [4]

(d) functional group isomerism
or structural isomerism
not positional isomerism (1) [1]

[Total: 12]

5 **(a)** **G** is HCHO/methanal (1) [1]

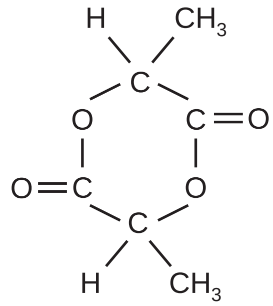
(b) **(i)** carboxylic acid/carboxyl/–CO_2H
not acid (1)

(ii) **H** is CH_3CO_2H/ethanoic acid (1)

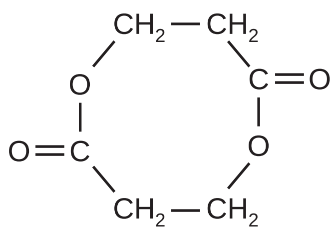
(iii) **J** is $CH_3CH(OH)CO_2H$/2-hydroxypropanoic acid
allow $HOCH_2CH_2CO_2H$/3-hydroxypropanoic acid (1) [3]

(c) **K** is CH_3COCO_2H (1) [1]

(d) **(i)** **L** is



allow as ecf on $HOCH_2CH_2CO_2H$/3-hydroxypropanoic acid



(1)

(ii) esterification
allow elimination/dehydration/condensation (1) [2]

[Total: 7]

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

CANDIDATE NAME	

CENTRE NUMBER		CANDIDATE NUMBER	

6547572065

CHEMISTRY **9701/22**

Paper 2 Structured Questions AS Core **October/November 2009**

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

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Answer **all** questions.
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For Examiner's Use	
1	
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Total	

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DC (SHW 00422 3/09) 11743/2

UNIVERSITY *of* CAMBRIDGE International Examinations

[Turn over

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

For Examiner's Use

1 The elements carbon and silicon are both in Group IV of the Periodic Table.
Carbon is the second most abundant element by mass in the human body and silicon is the second most common element in the Earth's crust.

Carbon and silicon each form an oxide of general formula XO_2.
At room temperature, CO_2 is a gas while SiO_2 is a solid with a high melting point.

(a) Briefly explain, in terms of the chemical bonds and intermolecular forces present in **each** compound, why CO_2 is a gas and SiO_2 is a solid at room temperature.

....

....

....

.... [3]

(b) Draw a simple diagram to show the structure of SiO_2. Your diagram should contain at least **two** silicon atoms **and** show clearly how many bonds each atom forms.

[2]

CO_2 does not behave as an ideal gas.

For Examiner's Use

(c) **(i)** State the basic assumptions of the kinetic theory as applied to an ideal gas.

....

....

....

....

....

....

(ii) Suggest **one** reason why CO_2 does not behave as an ideal gas.

....

[5]

Carbon exists in a number of forms, one of which is a conductor of electricity and one of which is a non-conductor of electricity. Silicon is the main component of most semi-conductors.

(d) Graphite is the form of carbon that is a conductor of electricity. Give a simple explanation for this property.

....

.... [1]

When carbon and silicon(IV) oxide are heated together at about 2000 °C, silicon carbide, SiC, is formed. Silicon carbide is a hard material which is widely used as an abrasive and in ceramics.

(e) **(i)** Construct an equation for the reaction of carbon and silicon(IV) oxide.

....

(ii) SiC has a similar structure to one of the common forms of carbon.
Which form is this? Give a reason for your answer.

form ....

reason ....

[2]

[Total: 13]

2 The elements of the third period of the Periodic Table form chlorides of general formula ECl_x where E represents the element. These chlorides show a variation in oxidation number from sodium to sulfur.

For Examiner's Use

(a) (i) Use the information given to complete the table below.

formula of chloride	$NaCl$	$MgCl_2$	$AlCl_3$	$SiCl_4$	PCl_3	SCl_2
oxidation number of element in the chloride						

(ii) By considering the electron configurations of the elements, explain the variation in oxidation number in the chlorides from Na to Al and from Si to S.

Na to Al ....

....

Si to S ....

....

[5]

Sodium hydride, NaH, is a colourless crystalline solid which melts at 800 °C and has the same crystal structure as sodium chloride which has a melting point of 808 °C. When molten sodium chloride is electrolysed using graphite electrodes, a shiny deposit, **D**, forms on the cathode and a greenish-yellow gas is evolved from the anode. When molten sodium hydride is electrolysed, under suitable conditions using graphite electrodes, the same shiny deposit **D** is formed on the cathode and a colourless gas, **G**, is evolved from the anode.

(b) (i) Describe with the aid of a diagram the bonding in a sodium chloride crystal.

(ii) Suggest the type of bonding that is present in sodium hydride.

....

(iii) What is the oxidation number of hydrogen in sodium hydride?

....

For Examiner's Use

(iv) Draw a 'dot-and-cross' diagram for sodium hydride. Show outer electrons only.

(v) The metals magnesium and aluminium form hydrides with formulae MgH_2 and AlH_3. The non-metals phosphorus and sulfur form hydrides with formulae PH_3 and H_2S.
By considering their positions in the Periodic Table, suggest oxidation numbers for these four elements in their hydrides.

compound	MgH_2	AlH_3	PH_3	H_2S
oxidation number of element in the hydride				

[8]

At room temperature, the chlorides of sodium, magnesium and aluminium are all solids which dissolve in water.
The hydrides of sodium, magnesium and aluminium are also solids which react with water with the rapid evolution of the **same** colourless gas **G** in each case.

(c) (i) What is the pH of the solutions formed when separate samples of sodium chloride, magnesium chloride, and aluminium chloride are dissolved in water?

chloride	sodium	magnesium	aluminium
pH			

(ii) Suggest an equation for the reaction between sodium hydride and water.

....

(iii) Suggest a value for the pH of the solution formed in **(ii)**.

....

[4]

At room temperature, the chlorides of silicon, phosphorus and sulfur are all low melting point solids or low boiling point liquids that can be seen to react with water.

(d) (i) Suggest what type of bonding is present in sulfur dichloride, SCl_2.

....

(ii) Write a balanced equation for the reaction between the chloride of silicon, $SiCl_4$, and water.

.... [2]

[Total: 19]

For Examiner's Use

3 One method of making 1-bromobutane in the laboratory is described below.

Stage 1	Place	35 g of powdered sodium bromide, 30 cm^3 of water, and 25 cm^3 (20 g) of butan-1-ol, in a 250 cm^3 two necked flask fitted with a tap funnel and reflux condenser.
Stage 2		Concentrated sulfuric acid (25 cm^3) is then placed in the tap funnel and added drop by drop to the reagents in the flask, keeping the contents well shaken and cooled occasionally in an ice-water bath.

(a) The overall reaction may be considered to take place in two stages. In the first stage the inorganic reagents react together to form HBr. In the second stage, the organic reagent reacts with the HBr that is formed in the first stage.

Write an equation for **each** of these stages.

stage I ....

stage II .... [2]

(b) In this preparation, by using the amounts given above, **one** of the reagents, sodium bromide or butan-1-ol, will be present in an excess.

Use your equations in **(a)** and the data above to determine, by calculation, which reagent is in an excess.

[2]

(c) In a laboratory preparation of 1-bromobutane, when 15.4 g of butan-1-ol was used, 22.5 g of 1-bromobutane was obtained after purification.

Calculate the yield of 1-bromobutane as a percentage of the theoretical maximum yield.

[2]

(d) When the concentrated sulfuric acid is added to the reaction mixture (stage 2), unless the temperature is controlled carefully, the acid may react with either of the original reactants (sodium bromide or butan-1-ol) to give at least two by-products, one of which is inorganic and the other organic.

For Examiner's Use

What inorganic and organic by-products may be formed?

In **each** case, identify **one** by-product and state the role of the concentrated sulfuric acid in the formation of this by-product.

inorganic by-product ....

role of conc. H_2SO_4 ....

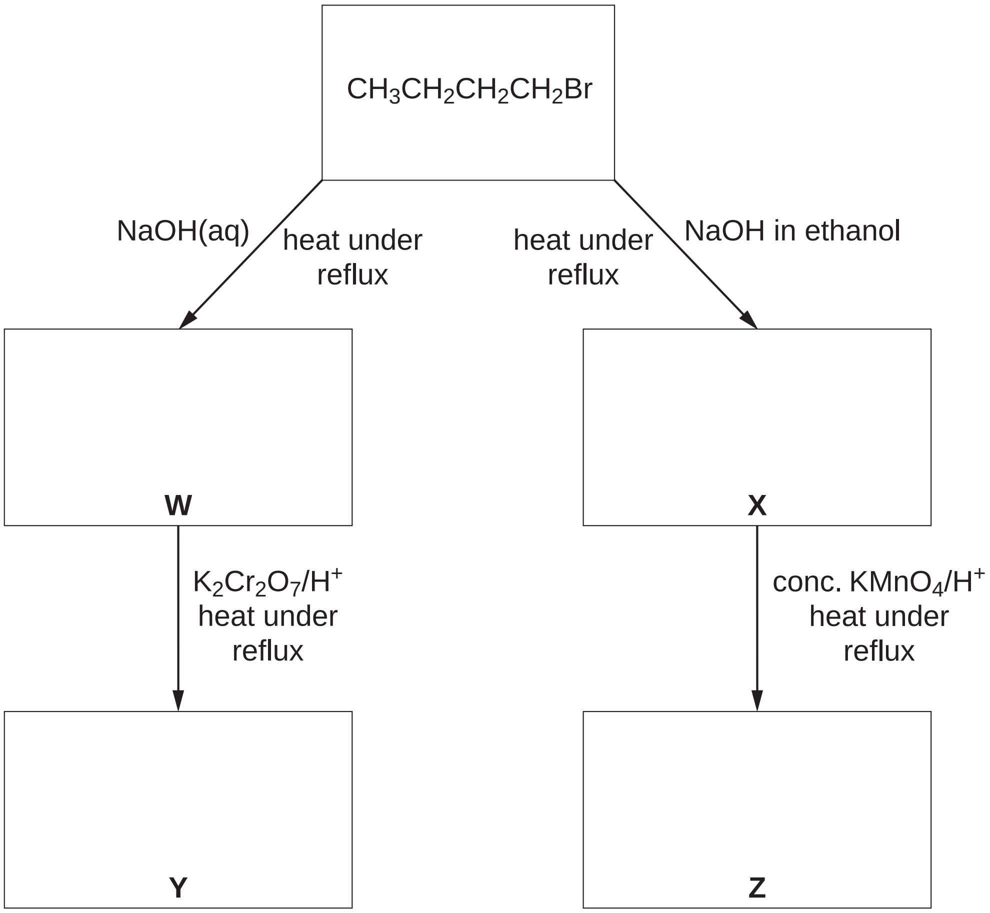
organic by-product ....

role of conc. H_2SO_4 .... [4]

[Total: 10]

For Examiner's Use

4 **(a)** Complete the following reaction scheme which starts with 1-bromobutane.
In **each empty** box, write the **structural formula** of the organic compound that would be formed.



[4]

For Examiner's Use

(b) One of the compounds **W**, **X**, **Y** or **Z** can be polymerised.

(i) Identify this compound by its letter.

....

(ii) Draw a section of the polymer chain formed by this compound.

Show **two** repeat units.

[2]

[Total: 6]

5 The fermentation of starch or molasses using the bacterium *Clostridium acetobutylicum*, produces a mixture of propanone and butan-1-ol.

For Examiner's Use

(a) Give the reagent(s) and state what would be observed when **one** test is carried out to confirm the presence of propanone in a mixture of propanone and butan-1-ol.

reagent(s) ....

observation .... [2]

(b) What will be observed when a small piece of sodium metal is dropped into a dry sample of butan-1-ol? Write an equation for the reaction that takes place.

observation ....

equation .... [2]

The molecular formula $C_5H_{12}O$ represents a number of alcohols.
Three alcohols with molecular formula $C_5H_{12}O$ are straight chain pentanols.

(c) Draw the following formulae.

(i) the **structural** formula of pentan-1-ol

(ii) the **displayed** formula of pentan-2-ol

(iii) the **skeletal** formula of pentan-3-ol

[3]

When one of the three pentanols in **(c)** is dehydrated, alkenes with **two** different structural formulae are formed.

(d) Identify this alcohol and give the structural formula of **each** alkene.

name of alcohol ....

alkene 1	alkene 2

[3]

A number of alcohols with molecular formula $C_5H_{12}O$ are branched chain compounds and may be considered as derivatives of butanol or propanol with alkyl side chains.

(e) **(i)** Draw the structural formula of the **derivative of propanol** that has the molecular formula $C_5H_{12}O$.

(ii) Draw the structural formula of the organic compound that will be present when the derivative of propanol you have given in **(i)** is heated under reflux with acidified potassium dichromate(VI).

[2]

[Total: 12]

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS

GCE Advanced Subsidiary Level and GCE Advanced Level

MARK SCHEME for the October/November 2009 question paper

for the guidance of teachers

9701 CHEMISTRY

9701/22 Paper 22 (AS Structured Questions), maximum raw mark 60

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

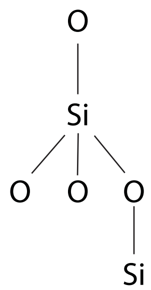
Mark schemes must be read in conjunction with the question papers and the report on the examination.

- CIE will not enter into discussions or correspondence in connection with these mark schemes.

CIE is publishing the mark schemes for the October/November 2009 question papers for most IGCSE, GCE Advanced Level and Advanced Subsidiary Level syllabuses and some Ordinary Level syllabuses.

1 **(a)** CO_2 is simple molecular/simple covalent/has discrete molecules (1)
CO_2 has induced dipole – induced dipole interactions/
van der Waals' forces/weak intermolecular forces (1)
SiO_2 is giant molecular/giant covalent/macromolecular (1)
SiO_2 has strong covalent bonds (1)
[any 3]

(b) minimum is 4-valent Si-O (1)
and at least one Si-O-Si (1)
i.e.



[2]

(c) **(i)** for an ideal gas, **any four** from the following
the molecules behave as rigid spheres (1)
there are no/negligible intermolecular forces
between the molecules (1)
collisions between the molecules are perfectly elastic (1)
the molecules have no/negligible volume (1)
the molecules move in random motion (1)
the molecules move in straight lines (1)
the kinetic energy of the molecules is
directly proportional to the temperature (1)
the pressure exerted by the gas is due to the collisions
between the gas molecules and the walls of the container (1)
not an ideal gas obeys $pV = nRT$
(max 4)

(ii) there are intermolecular forces between CO_2 molecules/
CO_2 molecules have volume (1) [5]

(d) graphite has delocalised electrons (1) [1]

(e) **(i)** $SiO_2 + 2C \rightarrow SiC + CO_2$ **or**
$SiO_2 + 3C \rightarrow SiC + 2CO$ (1)

(ii) diamond **because** SiC is hard (1) [2]

[Total: 13]

2 (a) (i)

formula of chloride	$NaCl$	$MgCl_2$	$AlCl_3$	$SiCl_4$	PCl_3	SCl_2
oxidation number of element in the chloride	+1	+2	+3	+4	+3	+2

correct oxidation nos. for $NaCl$ to SCl_2 (1)

(ii) **Na to A*l***
loss of outer/valence electrons (1)
to give configuration of Ne/to complete octet (1)
Si to S
gain or sharing of outer electrons (1)
to give configuration of Ar/to complete octet (1) [5]

(b) (i) giant lattice (may be in diagram) (1)
with strong ionic bonding (1)

(ii) ionic (1)

(iii) –1 (1)

(iv)

. . **+** **–**
: Na : ˣ. H
. .

correct numbers of electrons (1)
correct charges (1)

(v)

compound	MgH_2	AlH_3	PH_3	H_2S
oxidation number of element in the hydride	+2	+3	–3	–2

correct oxidation nos. for MgH_2 **and** AlH_3 (1)
correct oxidation nos. for PH_3 **and** H_2S (1) [8]

(c) (i)

chloride	sodium	magnesium	aluminium
pH	7	6.5–6.9	1–4
	(no mark)	(1)	(1)

(ii) $NaH + H_2O \rightarrow NaOH + H_2$ (1)

(iii) 10–14 (1) [4]

(d) **(i)** covalent (1)

(ii) $SiCl_4 + 4H_2O \rightarrow Si(OH)_4 + 4HCl$ **or**
$SiCl_4 + 4H_2O \rightarrow SiO_2.2H_2O + 4HCl$ **or**
$SiCl_4 + 2H_2O \rightarrow SiO_2 + 4HCl$ (1) [2]

[Total: 19]

3 **(a)** stage I $NaBr + H_2SO_4 \rightarrow NaHSO_4 + HBr$
allow $2NaBr + H_2SO_4 \rightarrow Na_2SO_4 + 2HBr$ (1)
stage II $C_4H_9OH + HBr \rightarrow C_4H_9Br + H_2O$ (1) [2]

(b) $n(\text{NaBr}) = n(\text{HBr}) = \dfrac{35}{103} = 0.34$ (1)

$n(C_4H_9OH) = \dfrac{20}{74} = 0.27$ (1)

NaBr/HBr is in an excess – **no mark just for this answer** [2]

(c) **method 1, using mass**

$C_4H_9OH \equiv C_4H_9Br$

if yield is 100%,

74 g $C_4H_9OH \rightarrow$ 137 g C_4H_9Br

15.4 g C_4H_9OH would produce $\dfrac{137 \times 15.4}{74}$ = 28.5 g C_4H_9Br (1)

% yield = $\dfrac{22.5 \times 100}{28.5} = 78.9$ (1)

or methods using moles

method 2

$n(C_4H_9OH) = \dfrac{15.4}{74} = 0.208$

for 100% yield $n(C_4H_9Br)$ would be 0.208 × 137 = 28.5g (1)

% yield = $\dfrac{22.5 \times 100}{28.5} = 78.9$ (1)

method 3

$n(C_4H_9OH) = \dfrac{15.4}{74} = 0.208$ mol

for 100% yield $n(C_4H_9Br)$ would be 0.208 mol

actual $n(C_4H_9Br) = \dfrac{22.5}{137} = 0.164$ mol (1)

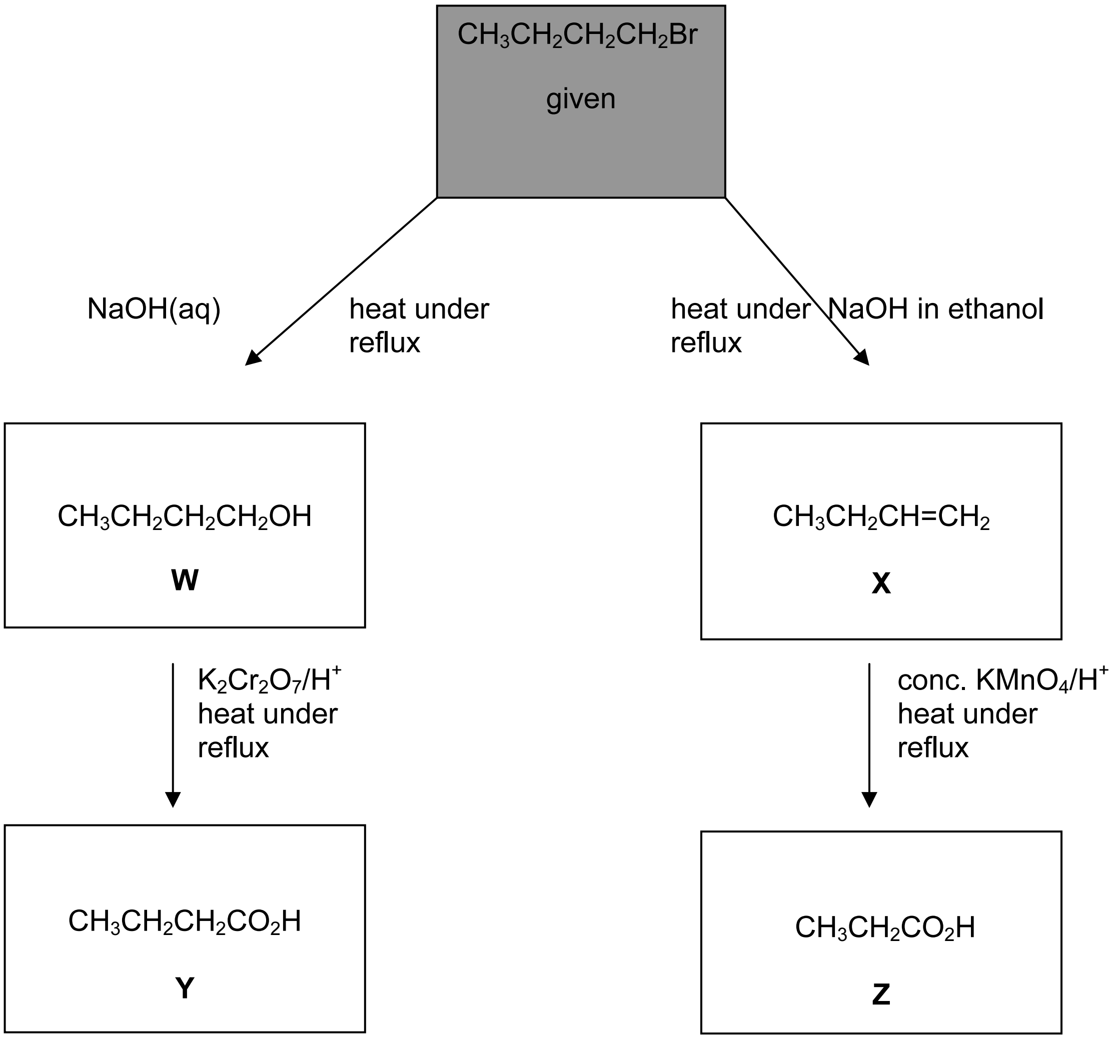
% yield = $\dfrac{0.164 \times 100}{0.208} = 78.8$ (1) [2]

(d) **inorganic by-product**
Br_2/bromine **or** sulfur dioxide/SO_2 (1)
conc. H_2SO_4 behaves as an oxidising agent (1)

organic by-product
but-1-ene/$CH_3CH_2CH=CH_2$
allow butane and $C_4H_9OC_4H_9$ (1)
conc. H_2SO_4 behaves as a dehydrating agent (1) [4]

[Total: 10]

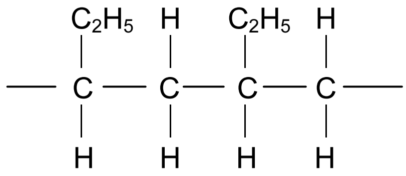
4 (a)



(4 × 1) [4]

(b) (i) X
allow ecf on any alkene above (1)

(ii)



allow ecf on any alkene above (1) [2]

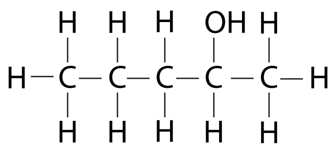
[Total: 6]

5 (a) 2,4-dinitrophenylhydrazine **or** aqueous alkaline iodine (1)
yellow-orange-red ppt. yellow ppt. (1) [2]

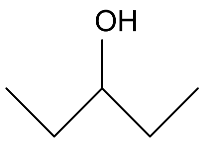
(b) colourless gas evolved **or** Na dissolves (1)
$C_4H_9OH + Na \rightarrow C_4H_9ONa + \frac{1}{2}H_2$ (1) [2]

(c) (i) $CH_3CH_2CH_2CH_2CH_2OH$ (1)

(ii)



(iii)



(1) [3]

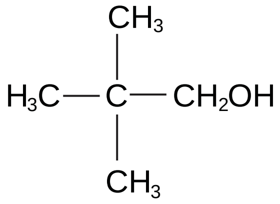
(d) (i) pentan-2-ol (1)

(ii)

$CH_3CH_2CH{=}CHCH_3$ product 1	$CH_3CH_2CH_2CH{=}CH_2$ product 2

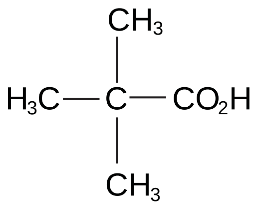
(1 + 1) [3]

(e) (i)



or $CH_3C(CH_3)_2CH_2OH$ (1)

(ii)



or $CH_3C(CH_3)_2CO_2H$

allow ecf on **(e)(i)** (1) [2]

[Total: 12]

Location Entry Codes

As part of CIE's continual commitment to maintaining best practice in assessment, CIE uses different variants of some question papers for our most popular assessments with large and widespread candidature. The question papers are closely related and the relationships between them have been thoroughly established using our assessment expertise. All versions of the paper give assessment of equal standard.

The content assessed by the examination papers and the type of questions is unchanged.

This change means that for this component there are now two variant Question Papers, Mark Schemes and Principal Examiner's Reports where previously there was only one. For any individual country, it is intended that only one variant is used. This document contains both variants which will give all Centres access to even more past examination material than is usually the case.

The diagram shows the relationship between the Question Papers, Mark Schemes and Principal Examiners' Reports that are available.

Question Paper	**Mark Scheme**	**Principal Examiner's Report**
Introduction	Introduction	Introduction
First variant Question Paper	First variant Mark Scheme	First variant Principal Examiner's Report
Second variant Question Paper	Second variant Mark Scheme	Second variant Principal Examiner's Report

Who can I contact for further information on these changes?
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- First variant Question Paper / Mark Scheme / Principal Examiner's Report

or

- Second variant Question Paper / Mark Scheme / Principal Examiner's Report

as appropriate.

First Variant Question Paper

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

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

1998330602

CHEMISTRY **9701/21**

Paper 2 Structured Questions AS Core **May/June 2009**

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 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.

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.

DO NOT WRITE IN THE GREY AREAS BETWEEN THE PAGES.

For Examiner's Use	
1	
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Total	

This document consists of **11** printed pages and **1** blank page.

SJF4799/DT T65099/2

UNIVERSITY of CAMBRIDGE International Examinations

[Turn over

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

For Examiner's Use

1 Copper and titanium are each used with aluminium to make alloys which are light, strong and resistant to corrosion.

Aluminium, A*l*, is in the third period of the Periodic Table; copper and titanium are both transition elements.

(a) Complete the electronic configuration of aluminium and of titanium, proton number 22.

A*l*	$1s^2$
Ti	$1s^2$

[1]

Aluminium reacts with chlorine.

(b) **(i)** Outline how, starting from aluminium powder, this reaction could be carried out in a school or college laboratory to give a small sample of aluminium chloride. A diagram is not necessary.

....

....

....

(ii) Describe what you would see during this reaction.

....

....

(iii) At low temperatures, aluminium chloride vapour has the formula Al_2Cl_6.
Draw a 'dot-and-cross' diagram to show the bonding in Al_2Cl_6.
Show outer electrons only.
Represent the aluminium electrons by ●.
Represent the chlorine electrons by ***x***.

[6]

Copper forms two chlorides, $CuCl$ and $CuCl_2$.

For Examiner's Use

(c) When copper is reacted directly with chlorine, only $CuCl_2$ is formed.
Suggest an explanation for this observation.

....

.... [1]

Titanium also reacts with chlorine.

(d) When an excess of chlorine was reacted with 0.72 g of titanium, 2.85 g of a chloride **A** was formed.

(i) Calculate the amount, in moles, of titanium used.

(ii) Calculate the amount, in moles, of chlorine atoms that reacted.

(iii) Hence, determine the empirical formula of **A**.

(iv) Construct a balanced equation for the reaction between titanium and chlorine.

....

[4]

(e) At room temperature, the chloride of titanium, **A**, is a liquid which does not conduct electricity.

What does this information suggest about the bonding and structure in **A**?

....

....

.... [2]

[Total: 14]

2 Magnesium will react on heating with chlorine, or oxygen, or nitrogen to give the chloride, or oxide, or nitride respectively. Each of these compounds is ionic and in them magnesium has the same +2 oxidation state.

For Examiner's Use

(a) **(i)** Write an equation, with state symbols, for the **second** ionisation energy of magnesium.

....

(ii) Use the *Data Booklet* to calculate the enthalpy change that occurs when one mole of gaseous magnesium ions, Mg^{2+}, is formed from one mole of gaseous magnesium atoms.

Include a sign in your answer.

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

(b) Separate samples of magnesium chloride and magnesium oxide are shaken with water. In **each** case, describe what you would see when this is done, and state the approximate pH of the water after the solid has been shaken with it.

(i) magnesium chloride

observation ....

approximate pH of the water …………………

(ii) magnesium oxide

observation ....

approximate pH of the water …………………

[4]

(c) Magnesium burns in nitrogen to give magnesium nitride, a yellow solid which has the formula Mg_3N_2.

For Examiner's Use

Magnesium nitride reacts with water to give ammonia and magnesium hydroxide.

(i) Construct an equation for the reaction of magnesium nitride with water.

....

(ii) Does a redox reaction occur when magnesium nitride reacts with water?

Use the oxidation numbers of nitrogen to explain your answer.

....

....

....

....

[4]

[Total: 11]

For Examiner's Use

3 Concern over the ever-increasing use of fossil fuels has led to many suggestions for alternative sources of energy. One of these, suggested by Professor George Olah, winner of a Nobel Prize in chemistry, is to use methanol, CH_3OH, which can be obtained in a number of different ways.

Methanol could be used instead of petrol in a conventional internal combustion engine or used to produce electricity in a fuel cell.

(a) Construct a balanced equation for the **complete** combustion of methanol.

.... [1]

When hydrocarbon fuels are completely burned in an internal combustion engine, several toxic pollutants may be formed.

(b) State **two toxic** pollutants that can be produced after **complete** combustion of a hydrocarbon fuel in an internal combustion engine.

....

.... [2]

Methanol may be manufactured catalytically from *synthesis gas*, a mixture of CO, CO_2 and H_2. The CO is reacted with H_2 to form methanol, CH_3OH.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = -91\ \text{kJ mol}^{-1}$$

(c) From your understanding of Le Chatelier's principle, state **two** conditions that could be used in order to produce a high yield of methanol.

In **each** case, explain why the yield would increase.

condition 1 ....

explanation ....

....

condition 2 ....

explanation ....

.... [4]

Carbon monoxide, which can be used to make methanol, may be formed by reacting carbon dioxide with hydrogen.

For Examiner's Use

$$CO_2(g) + H_2(g) \rightleftharpoons CO(g) + H_2O(g) \qquad K_c = 1.44 \text{ at } 1200\,K$$

(d) **(i)** It has been suggested that, on a large scale, this reaction could be helpful to the environment.

Explain, with reasons, why this would be the case.

....

....

(ii) A mixture containing 0.50 mol of CO_2, 0.50 mol of H_2, 0.20 mol of CO and 0.20 mol of H_2O was placed in a 1.0 dm^3 flask and allowed to come to equilibrium at 1200 K.

Calculate the amount, in moles, of each substance present in the equilibrium mixture at 1200 K.

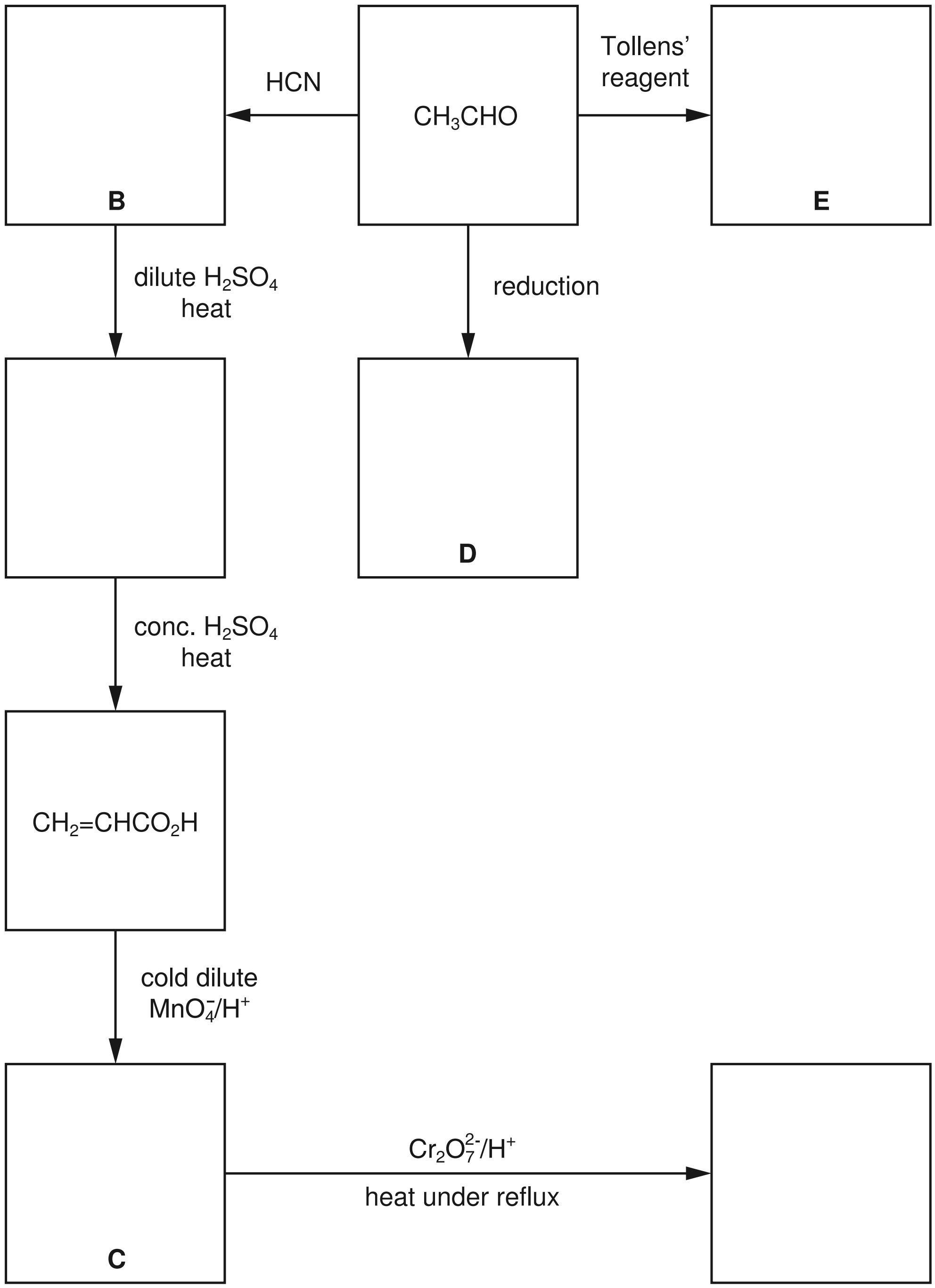
	CO_2	+	H_2	$\rightleftharpoons$	CO	+	H_2O
initial moles	0.50		0.50		0.20		0.20

[6]

[Total: 13]

4 **(a)** Complete the following reaction scheme which starts with ethanal.

In **each empty** box, write the **structural formula** of the organic compound that would be formed.



[6]

For Examiner's Use

For Examiner's Use

(b) Write the structural formula for the organic compound formed when, under suitable conditions,

(i) compound **C** reacts with compound **D**,

(ii) compound **C** reacts with compound **E**.

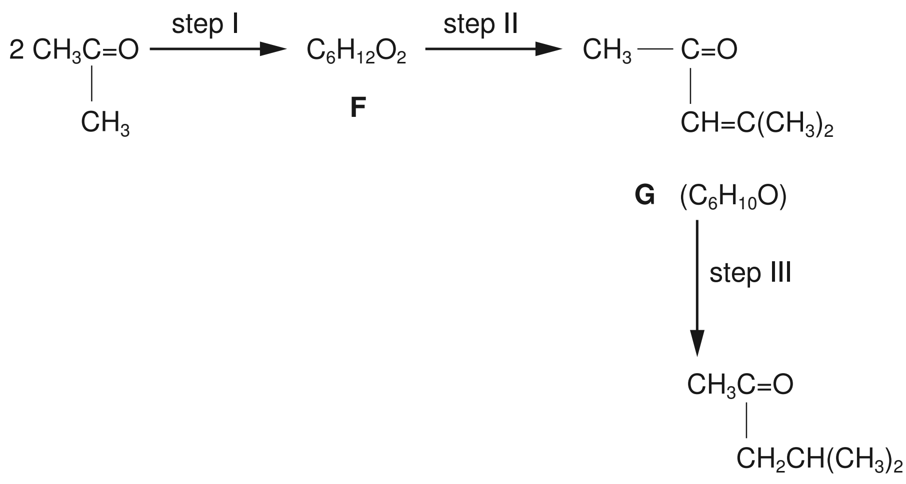
[2]

(c) Compound **B** is chiral. Draw displayed formulae of the two optical isomers of compound **B**, indicating with an asterisk (*) the chiral carbon atom.

[3]

[Total: 11]

5 Propanone, CH_3COCH_3, an important industrial solvent, can be converted into another industrially important solvent, MIBK, by the following sequence.



MIBK

(a) When **F** is formed in step **I** no other compound is produced.
Suggest a structural formula for **F**, which contains one –OH group.

[1]

(b) Compound **G** has two functional groups.

Name **one** functional group present in **G** and show how you would identify it. Put your answers in the table.

functional group in **G**	reagent used in test	what would be seen

[3]

(c) **G** is formed from **F** in step II.
Use your answers to **(a)** and **(b)** to suggest

(i) what type of reaction occurs in step II,

....

(ii) a reagent for step II.

.... [2]

For Examiner's Use

For Examiner's Use

(d) The production of MIBK from **G** in step **III** involves the hydrogenation of the >C=C< group and is carried out catalytically. A mixture of compounds is formed because the >C=O group is also reduced.

What reagent(s) and solvent are normally used in a laboratory to reduce a >C=O group without reducing a >C=C< group present in the same molecule?

reagent(s) ....

solvent .... [2]

G has a number of structural isomers.

(e) Draw the displayed formulae of a pair of structural isomers of **G** which contain the $CH_3CO–$ group and which exhibit *cis-trans* isomerism.

Label each structure *cis* or *trans* and give your reasoning.

[3]

[Total: 11]

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Second Variant Question Paper

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 2009**

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 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.

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.

DO NOT WRITE IN THE GREY AREAS BETWEEN THE PAGES.

For Examiner's Use	
1	
2	
3	
4	
5	
Total	

This document consists of **11** printed pages and **1** blank page.

SP (CW) V04258/2

UNIVERSITY of CAMBRIDGE International Examinations

[Turn over

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

For Examiner's Use

1 Copper and titanium are each used with aluminium to make alloys which are light, strong and resistant to corrosion.

Aluminium, Al, is in the third period of the Periodic Table; copper and titanium are both transition elements.

(a) Complete the electronic configuration of aluminium and of titanium, proton number 22.

Al	$1s^2$
Ti	$1s^2$

[1]

Aluminium reacts with chlorine.

(b) (i) Outline how, starting from aluminium powder, this reaction could be carried out in a school or college laboratory to give a small sample of aluminium chloride. A diagram is not necessary.

....

....

....

(ii) Describe what you would see during this reaction.

....

....

(iii) At low temperatures, aluminium chloride vapour has the formula Al_2Cl_6.
Draw a 'dot-and-cross' diagram to show the bonding in Al_2Cl_6.
Show outer electrons only.
Represent the aluminium electrons by ●.
Represent the chlorine electrons by ***x***.

[6]

Copper forms two chlorides, $CuCl$ and $CuCl_2$.

For Examiner's Use

(c) When copper is reacted directly with chlorine, only $CuCl_2$ is formed.
Suggest an explanation for this observation.

....

.... [1]

Titanium also reacts with chlorine.

(d) When an excess of chlorine was reacted with 0.72 g of titanium, 2.85 g of a chloride **A** was formed.

(i) Calculate the amount, in moles, of titanium used.

(ii) Calculate the amount, in moles, of chlorine atoms that reacted.

(iii) Hence, determine the empirical formula of **A**.

(iv) Construct a balanced equation for the reaction between titanium and chlorine.

....

[4]

(e) At room temperature, the chloride of titanium, **A**, is a liquid which does not conduct electricity.

What does this information suggest about the bonding and structure in **A**?

....

....

.... [2]

[Total: 14]

2 Phosphorus is a very reactive non-metallic element which readily forms ionic compounds with metals such as calcium and covalent compounds with non-metals such as chlorine and oxygen.

(a) **(i)** Write an equation, with state symbols, for the **second** ionisation energy of calcium.

....

(ii) Use the *Data Booklet* to calculate the enthalpy change that occurs when one mole of gaseous calcium ions, Ca^{2+}, is formed from one mole of gaseous calcium atoms.
Include a sign in your answer.

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

(b) Separate small samples of phosphorus(V) chloride and phosphorus(V) oxide are shaken with water. In **each** case, describe what you would see when this is done, and state the approximate pH of the water after the solid has been shaken with it.

(i) phosphorus(V) chloride

observation ....

approximate pH of the water ....

(ii) phosphorus(V) oxide

observation ....

approximate pH of the water .... [4]

(c) When phosphorus is heated with an excess of sulfur in an inert atmosphere, a pale yellow solid, with formula P_4S_{10} is formed.
P_4S_{10} reacts with water to give phosphoric acid, H_3PO_4, and hydrogen sulfide, H_2S.

For Examiner's Use

(i) Complete the equation for the reaction of P_4S_{10} with water.

$$P_4S_{10} + 16H_2O \rightarrow$$

(ii) Does a redox reaction occur when P_4S_{10} reacts with water?
Use the oxidation numbers of phosphorus to explain your answer.

....

....

....

.... [4]

[Total: 11]

3 Concern over the ever-increasing use of fossil fuels has led to many suggestions for alternative sources of energy. One of these, suggested by Professor George Olah, winner of a Nobel Prize in chemistry, is to use methanol, CH_3OH, which can be obtained in a number of different ways.

Methanol could be used instead of petrol in a conventional internal combustion engine or used to produce electricity in a fuel cell.

(a) Construct a balanced equation for the **complete** combustion of methanol.

.... [1]

When hydrocarbon fuels are completely burned in an internal combustion engine, several toxic pollutants may be formed.

(b) State **two toxic** pollutants that can be produced after **complete** combustion of a hydrocarbon fuel in an internal combustion engine.

....

.... [2]

Methanol may be manufactured catalytically from *synthesis gas*, a mixture of CO, CO_2 and H_2. The CO is reacted with H_2 to form methanol, CH_3OH.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = -91 \text{ kJ mol}^{-1}$$

(c) From your understanding of Le Chatelier's principle, state **two** conditions that could be used in order to produce a high yield of methanol.

In **each** case, explain why the yield would increase.

condition 1 ....

explanation ....

....

condition 2 ....

explanation ....

.... [4]

Carbon monoxide, which can be used to make methanol, may be formed by reacting carbon dioxide with hydrogen.

For Examiner's Use

$$CO_2(g) + H_2(g) \rightleftharpoons CO(g) + H_2O(g) \qquad K_c = 1.44 \text{ at } 1200\text{ K}$$

(d) **(i)** It has been suggested that, on a large scale, this reaction could be helpful to the environment.

Explain, with reasons, why this would be the case.

....

....

(ii) A mixture containing 0.50 mol of CO_2, 0.50 mol of H_2, 0.20 mol of CO and 0.20 mol of H_2O was placed in a 1.0 dm^3 flask and allowed to come to equilibrium at 1200 K.

Calculate the amount, in moles, of each substance present in the equilibrium mixture at 1200 K.

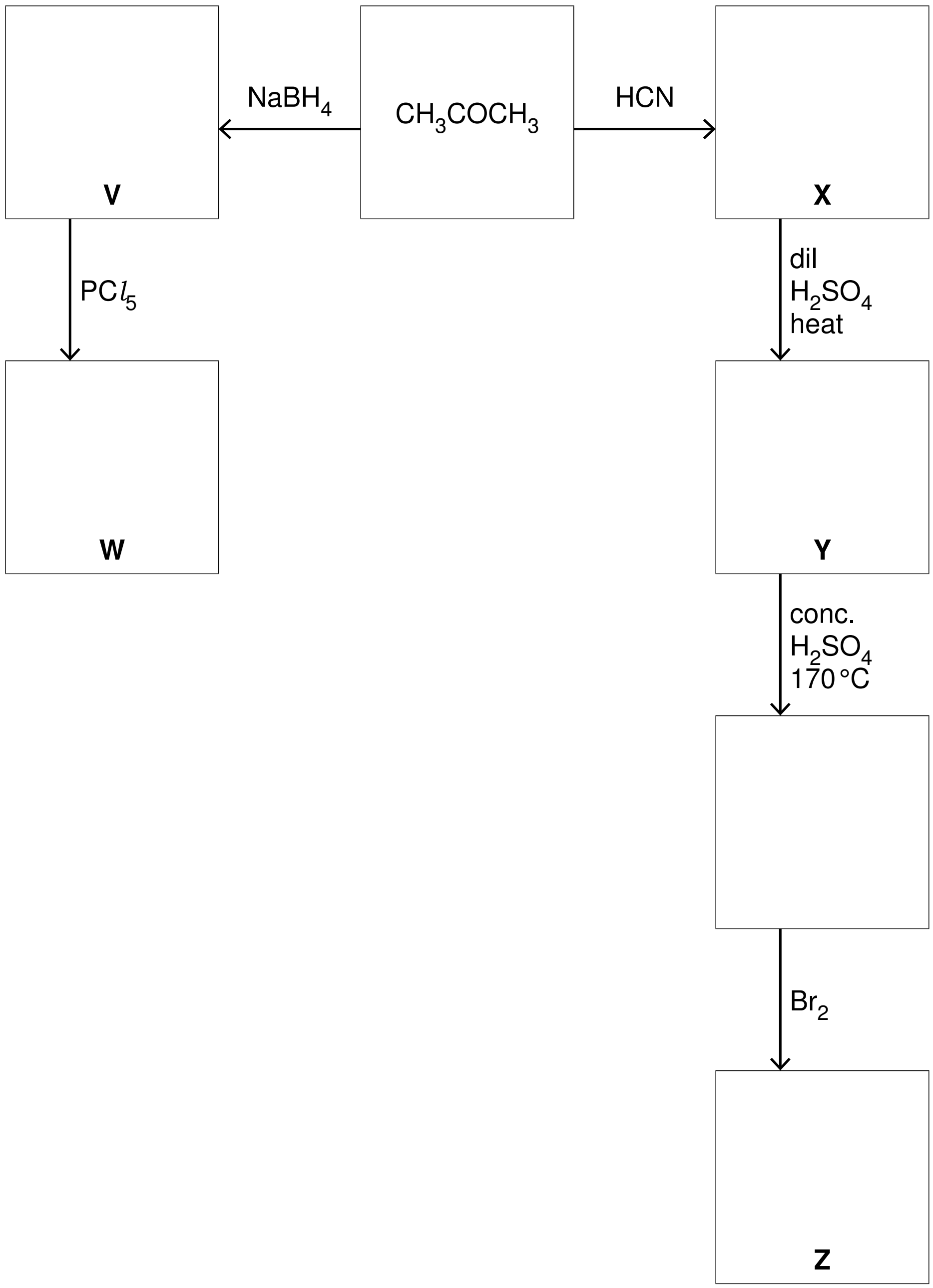
	CO_2	+	H_2	$\rightleftharpoons$	CO	+	H_2O
initial moles	0.50		0.50		0.20		0.20

[6]

[Total: 13]

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

For Examiner's Use



[6]

For Examiner's Use

(b) One of the compounds **V**, **W**, **X**, **Y** or **Z** is chiral.

(i) Identify this compound by its letter.

....

(ii) Draw displayed formulae of the two optical isomers of this compound.
Indicate with an asterisk (*) the chiral carbon atom.

[3]

(c) Write the structural formula for the organic compound formed when, under suitable conditions,

(i) compound **Y** reacts with compound **V**,

(ii) compound **Y** reacts with compound **Z**.

[2]

[Total: 11]

5 Ethanal, CH_3CHO, can be converted into compound **U** by the following sequence.

For Examiner's Use

$$2\ CH_3CHO \xrightarrow{\text{step I}} \underset{\mathbf{T}}{C_4H_8O_2} \xrightarrow{\text{step II}} \underset{\mathbf{U},\ C_4H_6O}{CH_3CH{=}CHCHO}$$

(a) When **T** is formed in step I, no other compound is produced.

Suggest a structural formula for **T** which contains one –OH group in its molecule.

[1]

(b) Compound **U** has two functional groups.

You are to name **one** functional group present in **U** and show how you would identify it. Put your answers in the table.

functional group in **U**	reagent used in test	what would be seen

[3]

(c) **U** is formed from **T** in step II.
Use your answers to **(a)** and **(b)** to suggest

(i) what type of reaction occurs in step II,

....

(ii) a reagent for step II.

.... [2]

(d) Compound **U** can be converted into $CH_3CH{=}CHCH_2OH$.

What reagent(s) and solvent are normally used in a laboratory to reduce a >C=O group without reducing a >C=C< group present in the same molecule?

reagent(s) ....

solvent .... [2]

U has three structural isomers.

(e) Draw the displayed formulae of **two** structural isomers of **U** that each contain the same functional groups as **U**.

[2]

(f) When a mixture of ethanal and propanal is reacted under the same conditions as in step I above, a similar reaction occurs with the formation of compound **S**, $C_5H_{10}O_2$.

$CH_3CHO + CH_3CH_2CHO \rightarrow C_5H_{10}O_2$

Suggest a structural formula for **S**.

[1]

[Total: 11]

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Location Entry Codes

UNIVERSITY *of* CAMBRIDGE
International Examinations

As part of CIE's continual commitment to maintaining best practice in assessment, CIE has begun to use different variants of some question papers for our most popular assessments with extremely large and widespread candidature, The question papers are closely related and the relationships between them have been thoroughly established using our assessment expertise. All versions of the paper give assessment of equal standard.

The content assessed by the examination papers and the type of questions are unchanged.

This change means that for this component there are now two variant Question Papers, Mark Schemes and Principal Examiner's Reports where previously there was only one. For any individual country, it is intended that only one variant is used. This document contains both variants which will give all Centres access to even more past examination material than is usually the case.

The diagram shows the relationship between the Question Papers, Mark Schemes and Principal Examiner's Reports.

Question Paper	**Mark Scheme**	**Principal Examiner's Report**
Introduction	Introduction	Introduction
First variant Question Paper	First variant Mark Scheme	First variant Principal Examiner's Report
Second variant Question Paper	Second variant Mark Scheme	Second variant Principal Examiner's Report

Who can I contact for further information on these changes?
Please direct any questions about this to CIE's Customer Services team at: international@cie.org.uk

UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS

GCE Advanced Subsidiary Level and GCE Advanced Level

MARK SCHEME for the May/June 2009 question paper

for the guidance of teachers

9701 CHEMISTRY

9701/21 Paper 2 (AS Structured Questions), maximum raw mark 60

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

Mark schemes must be read in conjunction with the question papers and the report on the examination.

- CIE will not enter into discussions or correspondence in connection with these mark schemes.

CIE is publishing the mark schemes for the May/June 2009 question papers for most IGCSE, GCE Advanced Level and Advanced Subsidiary Level syllabuses and some Ordinary Level syllabuses.

1 **(a)** A*l* $1s^2\ 2s^2 2p^6\ 3s^2 3p^1$ (1)

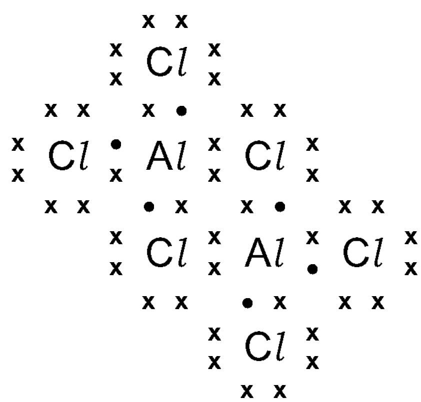
Ti $1s^2\ 2s^2 2p^6\ 3s^2\ 3p^6\ 3d^2\ 4s^2$ **or**

$1s^2\ 2s^2 2p^6\ 3s^2\ 3p^6\ 4s^2 3d^2$ penalise any error (1) [2]

(b) **(i)** pass chlorine gas (1)
over heated aluminium (1)

(ii) aluminium glows (1)
white/yellow solid formed (1)
chlorine colour disappears/fades (1) (any 2)

(iii)



correct numbers of electrons, i.e.

3 • per A*l* atom **and 7x** per C*l* atom

i.e. 6 • and 42 **x** in total (1)

dative bond C*l* to A*l* clearly shown by $^{x}{}_{x}$ (1) [6]

(c) chlorine is a strong/powerful oxidising agent (1) [1]

(d) **(i)** $n(Ti) = \frac{0.72}{47.9} = 0.015$ (1)

(ii) $n(Cl) = \frac{(2.85 - 0.72)}{35.5} = 0.06$ (1)

(iii) 0.015 : 0.06 = 1:4
empirical formula of **A** is $TiCl_4$
Allow ecf on answers to **(i)** and/or **(ii)**. (1)

(iv) $Ti + 2Cl_2 \rightarrow TiCl_4$ (1)
Allow ecf on answers to **(iii)**. [4]

(e) covalent/not ionic (1)
simple molecular **or**
mention of weak intermolecular forces **or**
weak van der Waals's forces between molecules (1) [2]

[Total: 14 max]

2 **(a)** **(i)** $Mg^{+}(g) \rightarrow Mg^{2+}(g) + e$ eqn. (1)
state symbols (1)

(ii) 736 + 1450 = +2186 kJ mol ^{1} (1) [3]

(b) **(i)** dissolves (1)
6 – 7 (1)

(ii) does not dissolve/slightly soluble (1)
8 – 11 (1) [4]

(c) **(i)** $Mg_3N_2 + 6H_2O \rightarrow 3Mg(OH)_2 + 2NH_3$ (1)

(ii) Mg_3N_2 N is –3 (1)
NH_3 N is –3 (1)

No **because**
there is no change in the oxidation no. of N (1) [4]
e.c.f on **(c)(i)** and values of oxidation numbers

[Total: 11]

3 (a) $2CH_3OH + 3O_2 \rightarrow 2CO_2 + 4H_2O$ (1) [1]

(b) SO_2 (1)

NO_x / NO_2 / NO – **not** N_2O (1)
Pb compounds – **not** Pb (1) (any 2)

If more than two answers are given any wrong ones will be penalised. [2]

(c) low temperature (1)
because forward reaction is exothermic (1)

high pressure (1)
because forward reaction goes to fewer molecules (1)
or shows a reduction in volume

increase [CO] **or** $[H_2]$
or remove CH_3OH (1)

correct explanation in terms of the effect of the change
on the position of equilibrium or on the rate of reaction (1)
(any two pairs) [4]

(d) (i) removes CO_2 (1)
which causes greenhouse effect/global warming (1)

(ii)

	CO_2	+	H_2	$\rightleftharpoons$	CO	+	H_2O	
initial moles	0.50		0.50		0.20		0.20	
equil. moles	(0.50-x)		(0.50-x)		(0.20+x)		(0.20+x)	(1)
equil. concn.	$\frac{(0.50-x)}{1}$		$\frac{(0.50-x)}{1}$		$\frac{(0.20+x)}{1}$		$\frac{(0.20+x)}{1}$	

$$K_c = \frac{[CO][H_2O]}{[CO_2][H_2]} \quad (1)$$

$$K_c = \frac{(0.20+x)^2}{(0.50-x)^2} = 1.44 \quad (1)$$

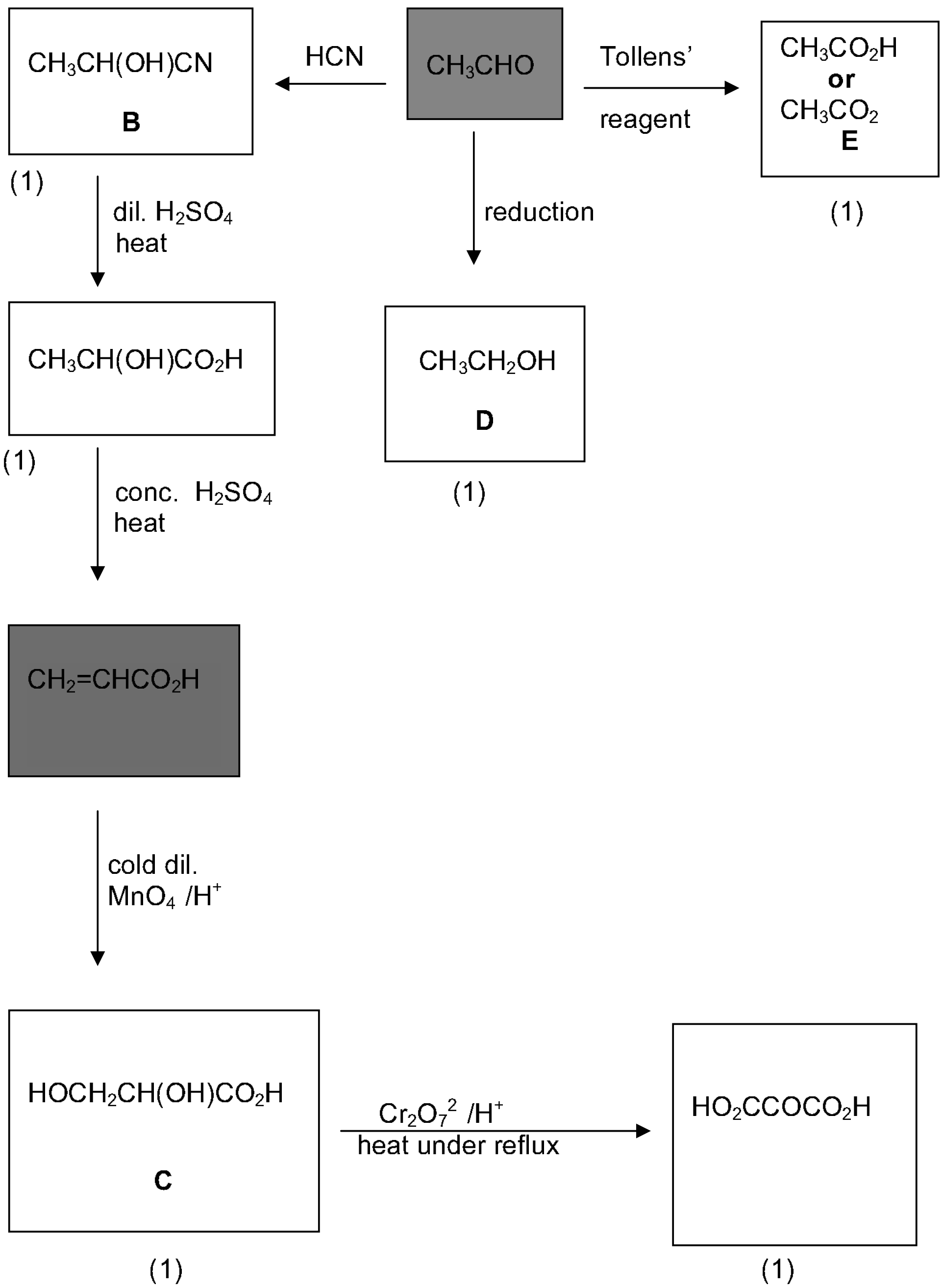
gives x = 0.18 (1)

at equilibrium,
$n(CO_2) = n(H_2) = 0.32$ **and**
$n(CO) = n(H_2O) = 0.38$ (1)

Allow ecf on wrong values of x that are less than 0.5. [7]

[Total: 13 max]

4 (a)



one mark for each correct structure [6]

(b) **C** + **D**

$HOCH_2CH(OH)CO_2C_2H_5$ as minimum or

$$\begin{array}{l} \quad\quad H \\ \quad\quad | \\ HOCH_2CCO_2C_2H_5 \\ \quad\quad | \\ \quad\quad OH \end{array}$$

(1)

Allow e.c.f on candidate's **C** and/or **D**.

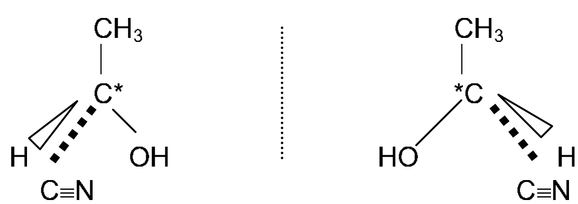
C + **E**

$$\begin{array}{l} CH_2OCOCH_3 \\ | \\ CHOCOCH_3 \\ | \\ CO_2H \end{array}$$

Allow either monoester. (1) [2]

Allow e.c.f on candidate's **C** and/or **E**.

(c)



correct chiral carbon atom indicated (1)
one structure drawn fully displayed with C≡N (1)
mirror object/mirror image pair correctly drawn in 3D (1) [3]

[Total: 11]

5 **(a)** $CH_3COCH_2C(OH)(CH_3)_2$ **or** (by addition of one molecule of $(CH_3)_2CO$ across the >C=O bond of another)

$$\begin{array}{l} CH_3COCH_2C(CH_3)_2 \\ \quad\quad\quad\quad\quad | \\ \quad\quad\quad\quad\quad OH \end{array}$$

$$\begin{array}{l} CH_3COCHCH(CH_3)_2 \\ \quad\quad\quad | \\ \quad\quad\quad OH \end{array}$$

(by working backwards from **G** and adding one molecule of H_2O across the C=C bond)

(1) [1]

(b)

functional group in **G**	reagent used in test	what would be seen
alkene .... **or** carbonyl	Br_2 **or** $KMnO_4$(aq) .... **or** 2,4-dinitro-phenylhydrazine/ Brady's reagent	decolourised .... **or** yellow/orange/red colour or ppt.
(1)	(1)	(1)

[3]

(c) **(i)** dehydration/elimination (1)

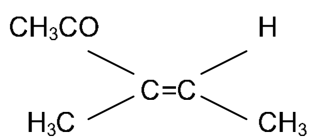
(ii) Al_2O_3 / P_4O_{10} / conc. H_2SO_4/ conc.H_3PO_4 (1) [2]

(d) $NaBH_4$ **or** $LiAlH_4$ (1)

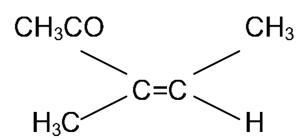
in water **or** methanol/ethanol **or** mixture of alcohol and water **or** in **dry** ether (1) [2]

not ether
Solvent mark is only awarded if reagent is correct.

(e)



*cis**

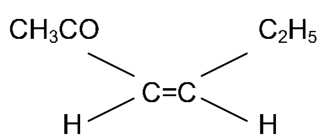


*trans***

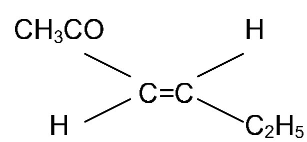
* allow this to be called Z

** allow this to be called E

or



*cis**

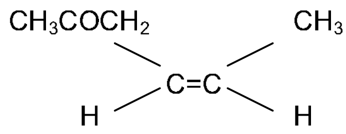


*trans***

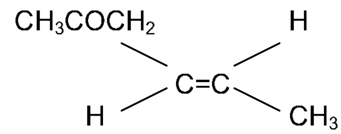
* allow this to be called Z

** allow this to be called E

or



cis or Z



trans or E

two structures	(1)	
correct *cis* and *trans*	(1)	
explanation	(1)	[3]

For *cis* and *trans* answers, the explanation should be in terms of the methyl groups (first pair of isomers) or hydrogen atoms (second and third pairs of isomers) being on the same or opposite sides relative to the C=C bond.

For E/Z answers, the explanation will need to involve the relative sizes of the CH_3C- group and the CH_3- group. This really only affects the first pair of isomers.

[Total: 11]

UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS

GCE Advanced Subsidiary Level and GCE Advanced Level

MARK SCHEME for the May/June 2009 question paper

for the guidance of teachers

9701 CHEMISTRY

9701/22 Paper 22 (AS Structured Questions), maximum raw mark 60

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International Examinations

1 **(a)** A*l* $1s^2\ 2s^2 2p^6\ 3s^2 3p^1$ (1)

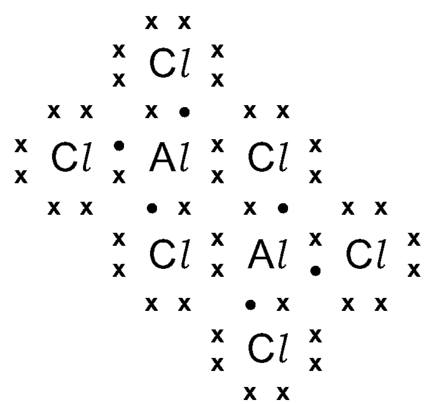
Ti $1s^2\ 2s^2 2p^6\ 3s^2\ 3p^6\ 3d^2\ 4s^2$ **or**

$1s^2\ 2s^2 2p^6\ 3s^2\ 3p^6\ 4s^2 3d^2$ penalise any error (1) [2]

(b) **(i)** pass chlorine gas (1)
over heated aluminium (1)

(ii) aluminium glows (1)
white/yellow solid formed (1)
chlorine colour disappears/fades (1) (any 2)

(iii)



correct numbers of electrons, i.e.

3 • per A*l* atom **and 7x** per C*l* atom

i.e. 6 • and 42 **x** in total (1)

dative bond C*l* to A*l* clearly shown by $^{x}_{x}$ (1) [6]

(c) chlorine is a strong/powerful oxidising agent (1) [1]

(d) **(i)** $n(Ti) = \frac{0.72}{47.9} = 0.015$ (1)

(ii) $n(Cl) = \frac{(2.85 \quad 0.72)}{35.5} = 0.06$ (1)

(iii) 0.015 : 0.06 = 1:4
empirical formula of **A** is $TiCl_4$
Allow ecf on answers to **(i)** and/or **(ii)**. (1)

(iv) $Ti + 2Cl_2 \rightarrow TiCl_4$ (1)
Allow ecf on answers to **(iii)**. [4]

(e) covalent/not ionic (1)

simple molecular **or**
mention of weak intermolecular forces **or**
weak van der Waals's forces between molecules (1) [2]

[Total: 14 max]

2 **(a)** **(i)** $Ca^{+}(g) \rightarrow Ca^{2+}(g) + e$ equation (1)
state symbols (1)

(ii) 590 + 1150 = +1740 kJ mol ^{1} (1) [3]

(b) **(i)** dissolves/vigorous reaction/
white or steamy fumes of HCl (1)
0 – 4 (1)

(ii) dissolves/vigorous reaction (1)
0 – 4 (1) [4]

(c) **(i)** $P_4S_{10} + 16H_2O \rightarrow 4H_3PO_4 + 10H_2S$ (1)

(ii) P_4S_{10} P is +5 (1)
H_3PO_4 P is +5 (1)

No **because**
there is no change in the oxidation no. of P (1)
ecf on answer to **(c)(i)**
and on calculated oxidation numbers [4]

[Total: 11]

3 **(a)** $2CH_3OH + 3O_2 \rightarrow 2CO_2 + 4H_2O$ (1) [1]

(b) SO_2 (1)

NO_x / NO_2 / NO – **not** N_2O (1)

Pb compounds – **not** Pb (1) (any 2)

if more than two answers are given any wrong ones will be penalised [2]

(c) low temperature (1)
because forward reaction is exothermic (1)

high pressure (1)
because forward reaction goes to fewer molecules (1)
or shows a reduction in volume

increase [CO] **or** [H_2]
or remove CH_3OH (1)
correct explanation in terms of the effect of the change
on the position of equilibrium or on the rate of reaction (1)

(any two pairs) [4]

(d) **(i)** removes CO_2 (1)
which causes greenhouse effect/global warming (1)

(ii) $CO_2 + H_2 \rightleftharpoons CO + H_2O$

	CO_2	H_2	CO	H_2O	
initial moles	0.50	0.50	0.20	0.20	
equil. moles	(0.50-x)	(0.50-x)	(0.20+x)	(0.20+x)	(1)
equil. concn.	$\frac{(0.50-x)}{1}$	$\frac{(0.50-x)}{1}$	$\frac{(0.20+x)}{1}$	$\frac{(0.20+x)}{1}$	

$K_c = \frac{[CO][H_2O]}{[CO_2][H_2]}$ (1)

$K_c = \frac{(0.20+x)^2}{(0.50-x)^2} = 1.44$ (1)

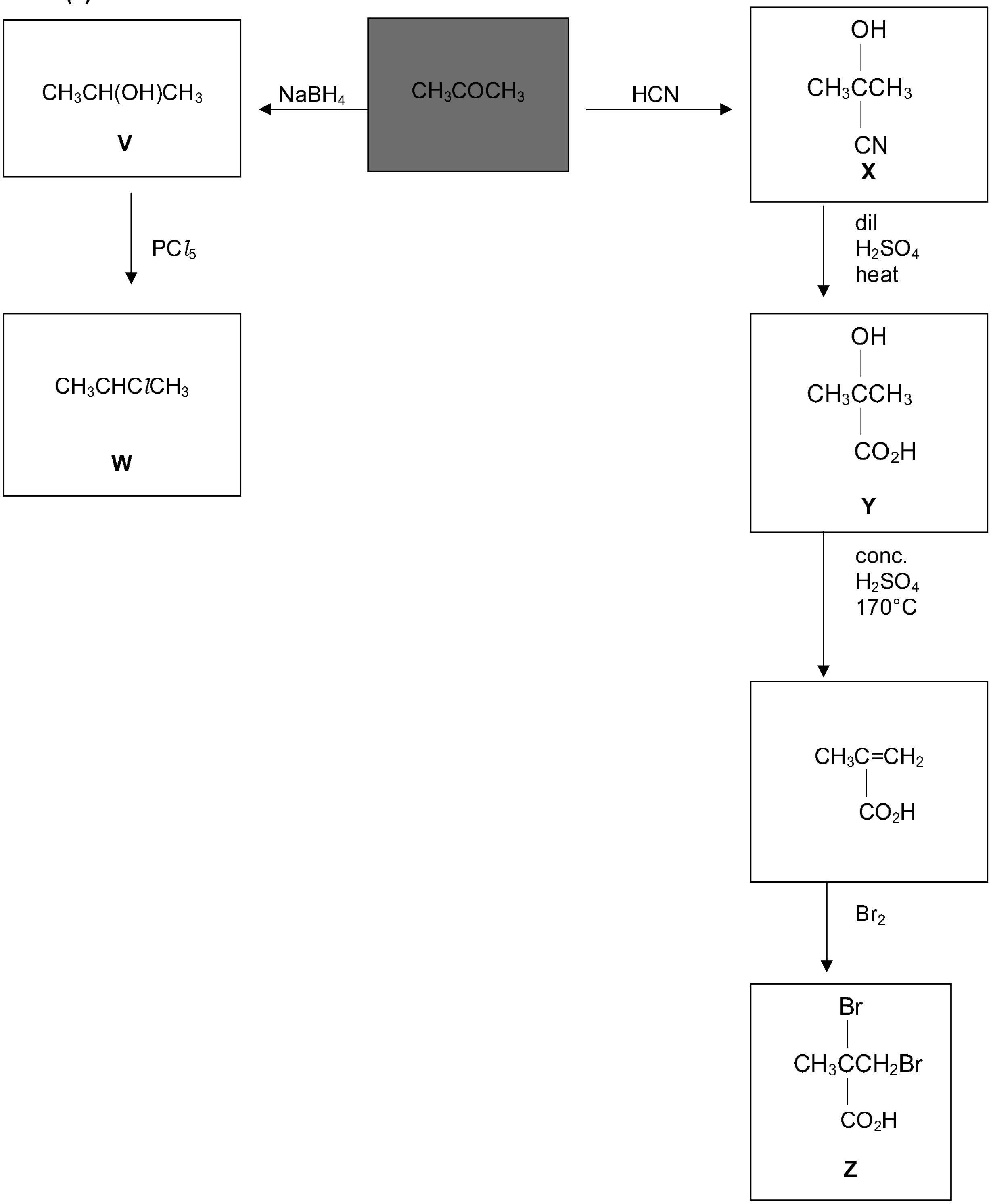
gives x = 0.18 (1)

at equilibrium,
$n(CO_2) = n(H_2) = 0.32$ **and**
$n(CO) = n(H_2O) = 0.38$ (1)

Allow ecf on wrong values of x that are less than 0.5. [7]

[Total: 13 max]

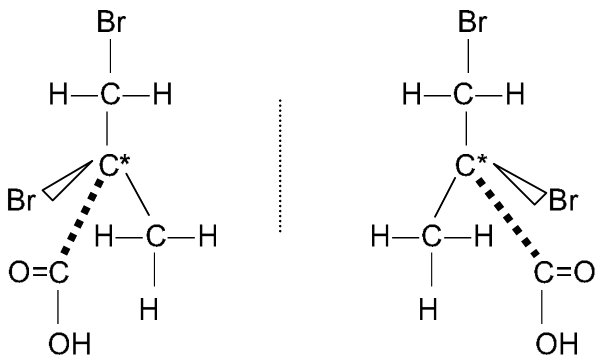
4 (a)



(each correct structure gets 1 mark) [6]

(b) (i) Z
allow ecf on candidate's **Z**
or other **chiral** compound (1)

(ii)



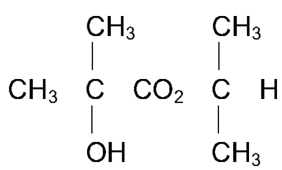
chiral centre clearly shown by * (1)

one structure drawn fully displayed

especially $–CO_2H$ group (1)

mirror object/mirror image pair correctly drawn in 3D (1) [4]

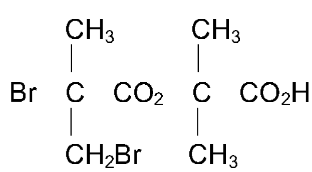
(c) (i) Y + V



or $(CH_3)_2C(OH)CO_2CH(CH_3)_2$

allow ecf on **candidate's Y** and/or **V** (1)

(ii) Y + Z



or $CH_3C(CH_2Br)BrCO_2C(CH_3)_2CO_2H$

allow ecf on **candidate's Y** and/or **Z** (1) [2]

[Total: 11 max]

5 **(a)** $CH_3CH(OH)CH_2CHO$ (by addition of one molecule of CH_3CHO across the >C=O bond of another)

or

$CH_3CH_2CH(OH)CHO$ (by working backwards from **U** and adding one molecule of H_2O across the C=C bond 'the other way') (1) [1]

(b)

functional group in **U**	reagent used in test	what would be seen
alkene	Br_2 **or** $KMnO_4$(aq)	decolourised
....	....	....
or carbonyl not ketone	**or** 2,4-dinitro-phenylhydrazine/ Brady's reagent	**or** yellow/orange/red colour or ppt.
....	....	....
or aldehyde	**or** Tollens' reagent	**or** silver ppt./mirror black colour
	or Fehling's solution	**or** brick red ppt.
(1)	(1)	(1)

[3]

(c) **(i)** dehydration/elimination (1)

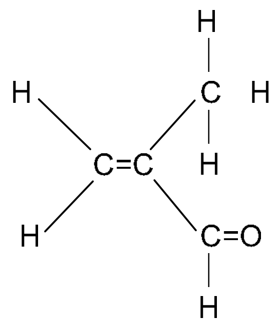
(ii) Al_2O_3/P_4O_{10}/conc. H_2SO_4/conc. H_3PO_4 (1) [2]

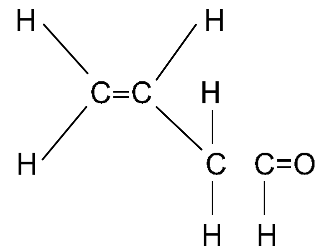
(d) $NaBH_4$ **or** $LiAlH_4$ (1)

in water **or** methanol **or** ethanol **or** mixture of water and alcohol **or** in **dry** ether (1)

not ether
Solvent mark is only to be awarded if reagent is correct. [2]

5 (e)





two structures (1) + (1) [2]

$CH_3CH_2CH(OH)CH_2CHO$

or

$CH_3CH(OH)CH(CH_3)CHO$

allow

$CH_3CH(OH)CH_2CH_2CHO$ (1) [1]

[Total: 11]

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

CANDIDATE NAME	

CENTRE NUMBER		CANDIDATE NUMBER	

1565076543

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.

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International Examinations

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.

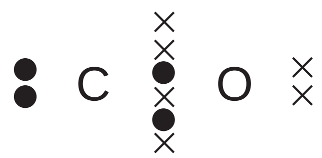
Suggest why N_2 has a lower boiling point than CO.

....

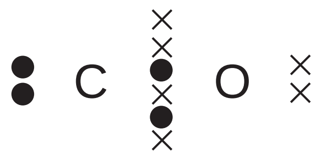
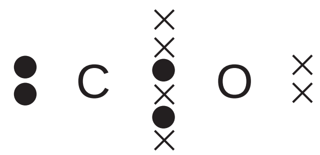
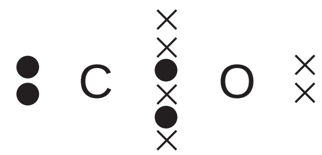
....

.... [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
		

[3]

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(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.

bond	bond energy / kJ mol^{-1}
−C≡N in HCN	890
N≡N	994
C≡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?

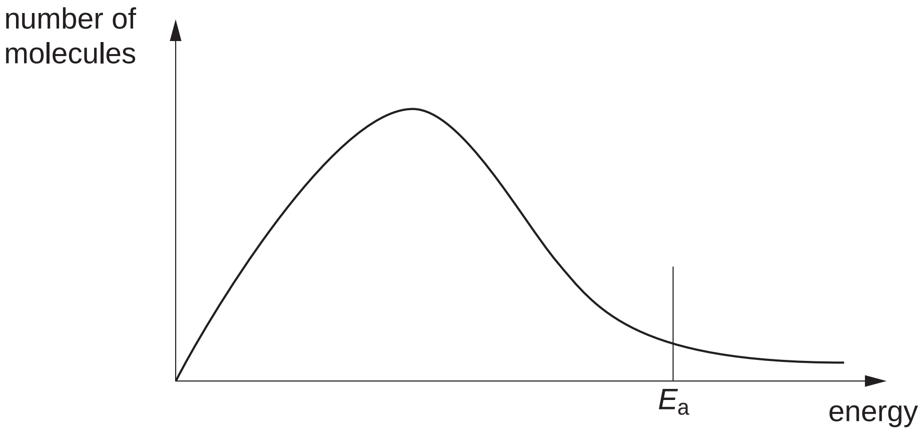
....

(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.



(a) On the graph above,

(i) draw a new distribution curve, **clearly labelled T′**, for the same mixture of gases at a higher temperature, **T′**;

(ii) **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.

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(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.

$CH_3CHBrCH_3 + NaOH \rightarrow CH_3CH(OH)CH_3 + NaBr$ **reaction 1**

$HCl + NaOH \rightarrow NaCl + H_2O$ **reaction 2**

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]

3 This question refers to the elements shown in the portion of the Periodic Table given below.

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

(a) From this table, identify in **each** case **one** element that has the property described. Give the **symbol** of the element in each case.

(i) The element that has a molecule which contains exactly eight atoms.

....

(ii) The element that forms the largest cation.

....

(iii) An element that floats on water and reacts with it.

....

(iv) An element that reacts with water to give a solution that can behave as an oxidising agent.

....

(v) An element whose nitrate gives a brown gas on thermal decomposition.

....

[5]

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(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 C*l*, 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 SF_6 molecule?

....

(iii) In the sequence of fluorides above, the oxidation number of the elements increases from NaF to SF_6 and then falls at ClF_5.
Attempts to make ClF_7 have failed but IF_7 has been prepared.
Suggest an explanation for the existence of IF_7 and for the non-existence of ClF_7.

....

....

....

[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.

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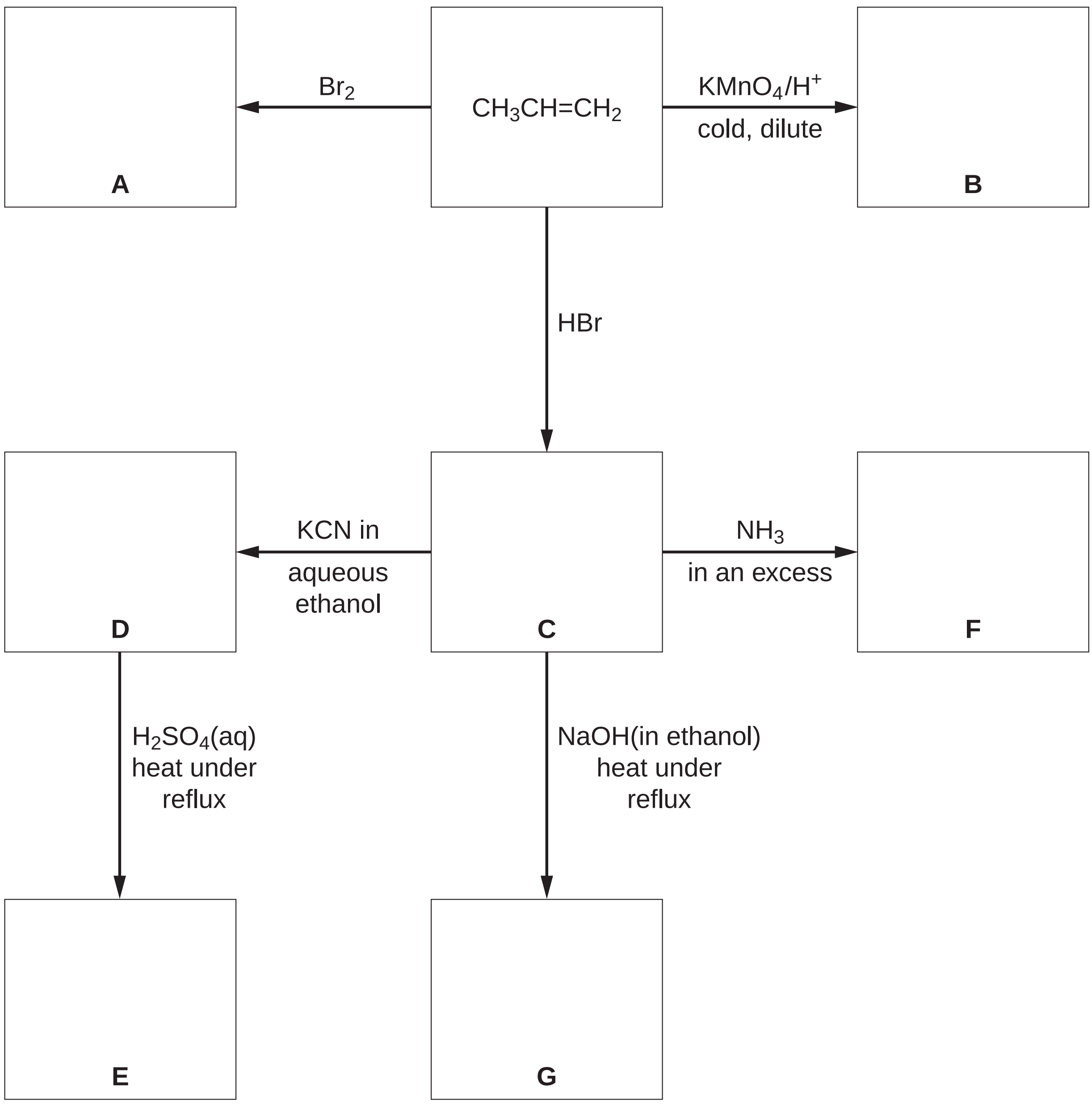


[7]

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

(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]

For Examiner's Use

For Examiner's Use

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]

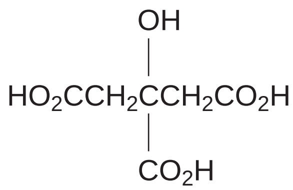
Unripe fruit often contains polycarboxylic acids, that is acids with more than one carboxylic acid group in their molecule.

One of these acids is commonly known as tartaric acid, $HO_2CCH(OH)CH(OH)CO_2H$.

(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%.

(d) (i) Show by calculation that the empirical formula of **W** is $C_4H_6O_5$.

(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]

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS

GCE Advanced Subsidiary Level and GCE Advanced Level

MARK SCHEME for the May/June 2010 question paper

for the guidance of teachers

9701 CHEMISTRY

9701/21 Paper 2 (AS Structured Questions), maximum raw mark 60

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

Mark schemes must be read in conjunction with the question papers and the report on the examination.

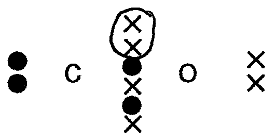
- CIE will not enter into discussions or correspondence in connection with these mark schemes.

CIE is publishing the mark schemes for the May/June 2010 question papers for most IGCSE, GCE Advanced Level and Advanced Subsidiary Level syllabuses and some Ordinary Level syllabuses.

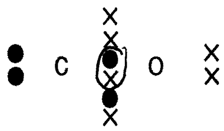
1 **(a)** fewer electrons in Cl_2 than in Br_2 (1)
smaller van der Waals' forces in Cl_2 **or** stronger van der Waals' forces in Br_2 (1) [2]

(b) CO has a permanent dipole **or** N_2 does not (1)
permanent dipole-permanent dipole interactions are stronger than those from induced dipoles (1) [2]

(c) **(i)** a co-ordinate bond (1)



(ii) a covalent bond (1)



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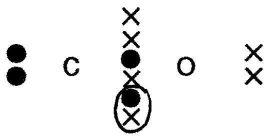
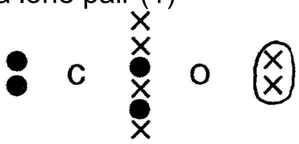


(iii) a lone pair (1)



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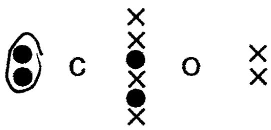
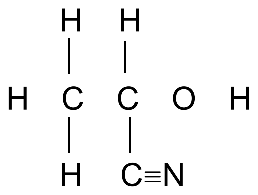


penalise any groups of 3 or 4 electrons that are circled [3]

(d) CO and HCN both have a dipole **or** N_2 does not have a dipole (1) [1]

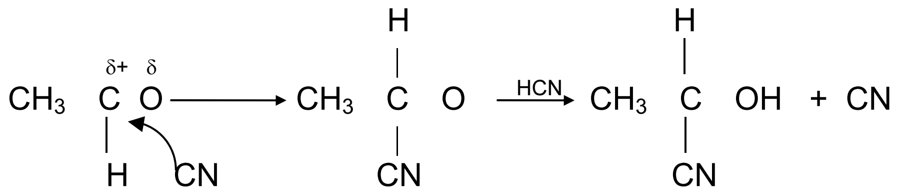
(e) **(i)**



C≡N must be shown (1)

(ii) nucleophilic addition (1)

(iii)



C=O dipole correctly shown **or** correct curly arrow on C=O (1)
attack on $C^{\delta+}$ by C of CN (1)
correct intermediate (1)
CN regenerated (1) [5 max]

[Total: 13]

2 **(a)** **(i)** new graph has **lower** maximum (1)
maximum is **to the right of** previous maximum (1)

(ii) **H** is at E_a (1) [3]

(b) the minimum amount of energy molecules must have **or** energy required (1)
in order for the reaction to take place (1) [2]

(c) **(i)** iron **or** iron oxide (1)
100 to 500 atm **and** 400–550°C
units necessary – allow other correct values and units (1)

(ii) **C** is placed to the left of **H** (1)

(iii) more molecules now have energy $>E_a$ (1) [4]

(d) **reaction 1**
has greater E_a (1)
because energy is needed to break covalent bonds (1)
reaction 2
has lower E_a
or actual reaction is $H^+ + OH \rightarrow H_2O$
or reaction involves ions (1)
opposite charges attract (1) [4]

[Total: max 12]

3 **(a)** Accept only symbols.

(i) S or S_8 (1)

(ii) K or K^+ (1)

(iii) Na – allow K or Li (1)

(iv) C*l* **or** Br **or** F (1)

(v) Mg **or** Ca **or** Li
allow Ni, Cu, or Zn (1) [5]

(b) Accept only formulae.

(i) F_2O (1)

(ii) SO_2 **and** SO_3
or P_2O_3/P_4O_6 **and** P_2O_5/P_4O_{10}
or any two from N_2O_3, NO_2/N_2O_4, N_2O_5
or any two from Cl_2O, ClO_2, ClO_3, Cl_2O_7 (1+1) [3]

(c) **(i)** NaF, MgF_2, AlF_3 – any two (1)

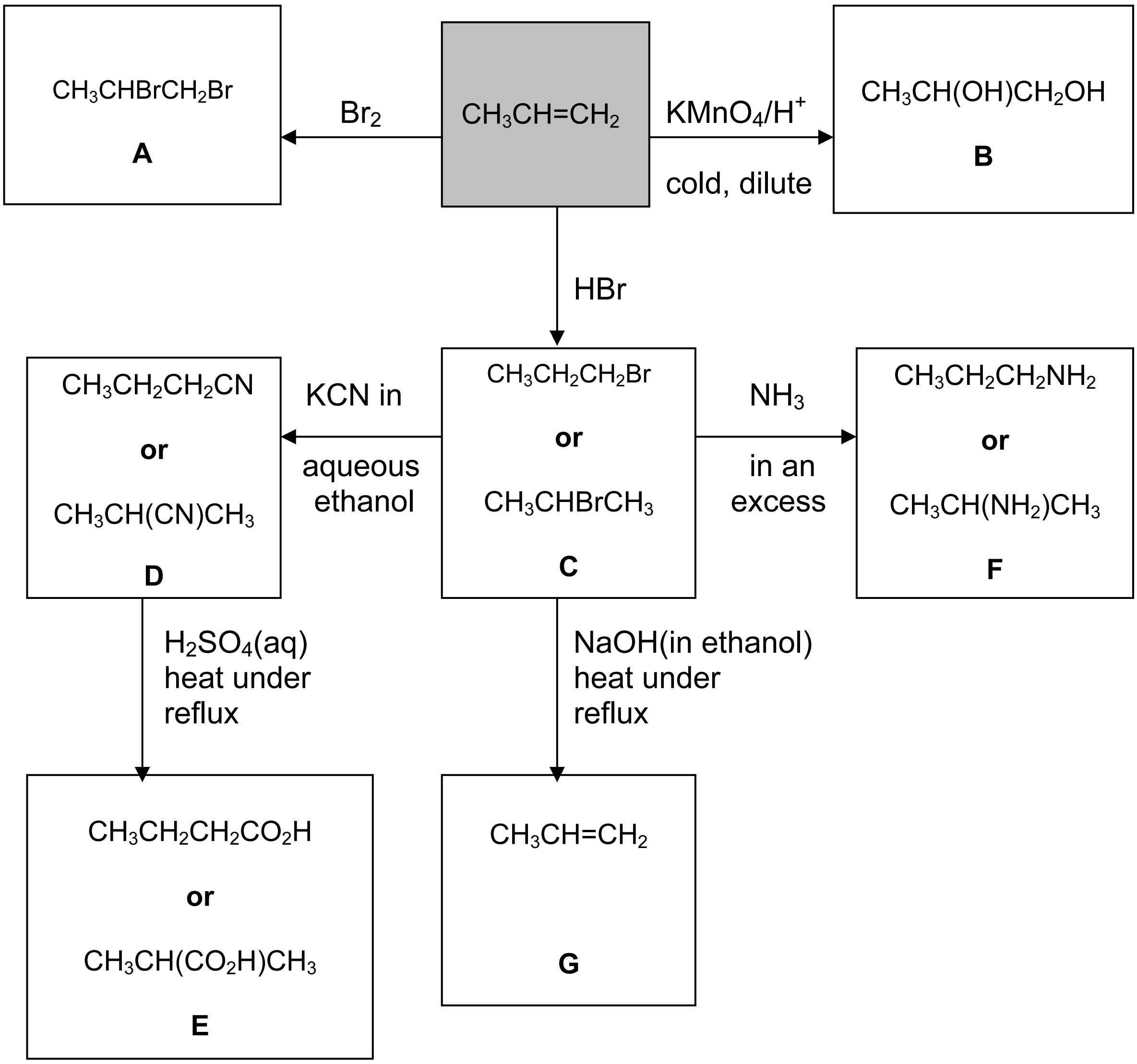
(ii) octahedral (1)

(iii) I atom is larger than C*l* atom (1)

(iv) cannot pack 7 F atoms around C*l* atom
or can pack 7 F atoms around I atom (1) [4]

[Total: 12]

4 (a)



give 1 for each correct structure (7 × 1) [7]

(b) **(i)** ester (1)

(ii) heat under reflux (1)
trace of conc. H_2SO_4 **or** presence of HCl (g) (1) [3]

[Total: 10]

5 **(a)** **(i)** same molecular formula
but different structural formula/structure (1)

(ii) asymmetric C atom/chiral centre present (1)
>C=C< bond present (1) [3]

(b) $NaO_2CCH(OH)CH(OH)CO_2Na$ (1) [1]

(c) no **because** there is no chiral carbon atom present (1) [1]

(d) **(i)** C : H : O = $\frac{35.8}{12} : \frac{4.5}{1} : \frac{59.7}{16}$ this mark is for correct use of A_r values (1)
C : H : O = 2.98 : 4.5 : 3.73
C : H : O = 1 : 1.5 : 1.25 this mark is for evidence of correct calculation (1)
gives empirical formula of **W** is $C_4H_6O_5$

(ii) $C_4H_6O_5$ = 12 × 4 + 1 × 6 + 16 × 5 = 134
molecular formula of **W** is $C_4H_6O_5$ (1) [3]

(e) **(i)** $n(\text{OH}\ ) = \dfrac{29.4 \times 100}{1000} = 0.0294$ (1)

$n(\mathbf{W}) = \dfrac{1.97}{134} = 0.0147$ (1)

no. of $–CO_2H$ groups present

in one molecule of **W** $= \dfrac{0.0294}{0.0147} = 2$ (1)

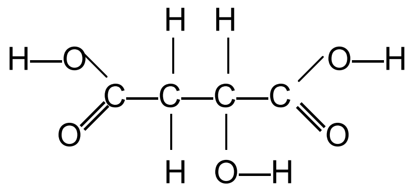
or $n(\text{OH}\ ) = \dfrac{29.4 \times 1.00}{1000} = 0.0294$ (1)

1.97 g **W** $\equiv$ 0.0294 mol NaOH

134 g **W** $\equiv \dfrac{0.0294 \times 134}{1.97} = 1.999 \approx 2$ mol NaOH (1)

no. of $–CO_2H$ groups present in 1 molecule of **W** = 2 (1) [3]

(ii)



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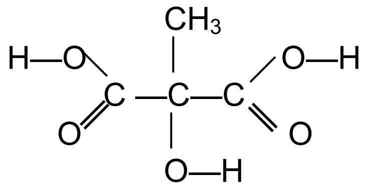

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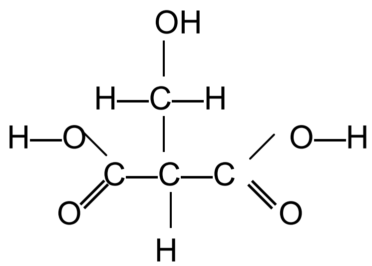

one correct structure (1)
correctly displayed (1)
allow any **correct** ether [2]

[Total: 13]

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

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER					

5242495758

CHEMISTRY **9701/21**

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.
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Total	

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UNIVERSITY *of* CAMBRIDGE International Examinations

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]

For Examiner's Use

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]

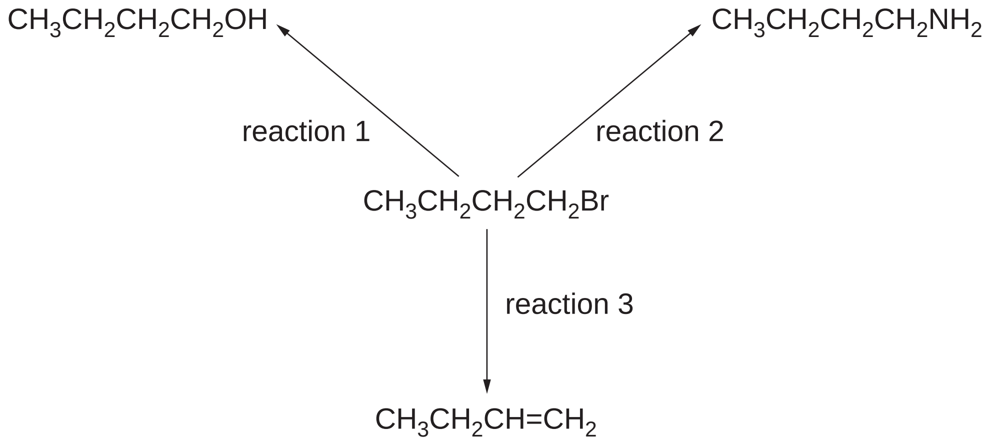
[Total: 18]

For Examiner's Use

4 Halogenoalkanes have many chemical uses, particularly as intermediates in organic reactions.

For Examiner's Use

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]

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For Examiner's Use

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.

$$NaX + H_3PO_4 \rightarrow NaH_2PO_4 + HX$$

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]

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS

GCE Advanced Subsidiary Level and GCE Advanced Level

MARK SCHEME for the October/November 2010 question paper for the guidance of teachers

9701 CHEMISTRY

9701/21 Paper 2 (AS Structured Questions), maximum raw mark 60

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

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1 **(a)** the actual number of atoms of each element present (1)

in one molecule of a compound (1) [2]

(b) $C_xH_y + \left(x + \frac{y}{4}\right)O_2 \longrightarrow xCO_2 + \frac{y}{2}H_2O$

xCO_2 (1)

$\frac{y}{2}H_2O$ (1) [2]

(c) **(i)** oxygen/O_2 (1)

(ii) carbon dioxide/CO_2 (1)

(iii) 10 cm^3 (1)

(iv) 20 cm^3 (1) [4]

(d) $C_xH_y + \left(x + \frac{y}{4}\right)O_2 \longrightarrow xCO_2 + \frac{y}{2}H_2O$

10 cm^3 20 cm^3 10 cm^3

1 mol of C_xH_y gives 1 mol of CO_2

whence $x = 1$ (1)

1 mol of C_xH_y reacts with 2 mol of O_2

whence $\left(x + \frac{y}{4}\right) = 2$

and $y = 4$ (1)

molecular formula is CH_4 (1) [3]

[Total: 11]

2 **(a)** $N_2 + 3H_2 \rightleftharpoons 2NH_3$ (1) [1]

(b) temperature between 300 and 550°C (1)

correct explanation of effect of temperature on
rate of formation of NH_3 **or** on position of equilibrium (1)

catalyst of iron **or** iron oxide (1)

to speed up reaction **or** to reduce E_a (1) [4]

(c) manufacture of HNO_3
or explosives
or nylon
or as a cleaning agent
or as a refrigerant (1) [1]

(d) fertiliser in rivers causes excessive growth of aquatic plants/algae (1)

when plants and algae die O_2 is used up/fish or aquatic life die (1) [2]

(e) **(i)** CO by incomplete combustion of the hydrocarbon fuel (1)

NO by reaction between N_2 and O_2 in the engine (1)

(ii) CO toxic/effect on haemoglobin (1)

NO toxic/formation of acid rain (1) [4]

(f) **(i)** platinum/Pt – allow palladium/Pd **or** rhodium/Rh (1)

(ii) $2CO + 2NO \rightarrow 2CO_2 + N_2$ (1) [2]

[Total: 14]

3 (a) (i) a compound which contains **only** carbon and hydrogen (1)

(ii) separation of compounds by their boiling points (1) [2]

(b) (i) high temperature **and** high pressure (1)

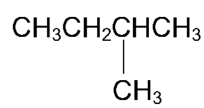
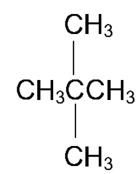
high temperature **and** catalyst (1)

(ii) $C_{11}H_{24} \rightarrow C_5H_{12} + C_6H_{12}$ **or**

$C_{11}H_{24} \rightarrow C_5H_{12} + 2C_3H_6$ **or**

$C_{11}H_{24} \rightarrow C_5H_{12} + 3C_2H_4$ (1) [3]

(c) (i)

$CH_3CH_2CH_2CH_2CH_3$		
isomer **B**	isomer **C**	isomer **D**
(1)	(1)	(1)

(ii) the straight chain isomer (isomer **B** above) (1)

it has the greatest van der Waals' forces (1)

because unbranched molecules have greater area of contact/
can pack more closely together (1) [6]

(d) enthalpy change when 1 mol of a substance (1)

is burnt in an excess of oxygen/air under standard conditions
or is completely combusted under standard conditions (1) [2]

(e) **(i)** heat released = m c δT = 200 x 4.18 x 27.5 (1)

= 22990 J = 23.0 kJ (1)

(ii) 23.0 kJ produced from 0.47 g of **E**

2059 kJ produced from $\dfrac{0.47 \times 2059}{23.0}$ g of **E** (1)

= 42.08 g of **E** (1)

allow ecf in **(i)** or **(ii)** on candidate's expressions [4]

(f) C_3H_6 = 42

E is C_3H_6

for ecf, **E** must be unsaturated and be no larger than C_5 (1) [1]

[Total: 18]

4 **(a)**

reaction 1	reagent	NaOH/KOH (1)
	solvent	H_2O/water/aqueous (1)
reaction 2	reagent	NH_3/ammonia (1)
	solvent	ethanol/C_2H_5OH/alcohol (1)
reaction 3	reagent	NaOH/KOH (1)
	solvent	ethanol/C_2H_5OH/alcohol (1)

[6]

(b) with $CH_3CH_2CH_2CH_2I$ rate would be faster (1)

C-I bond is weaker than C-Br bond (1)

C-I bond energy is 240 kJ mol ^{1}, C-Br bond energy is 280 kJ mol ^{1}
data **must** be quoted for this mark (1) [3]

(c) non-toxic non-flammable

volatile/low bp unreactive (any 2) [2]

(d) **(i)** when a covalent bond breaks the two electrons in the bond are shared between the two atoms (1)

(ii) $CCl_2F_2 \rightarrow CClF_2 + Cl$ (as minimum)

allow $CCl_2F + F$ (1) [2]

(e) they are flammable (1) [1]

[Total: 14]

5 **(a)** NaBr/sodium bromide [1]

(b) Br_2/bromine or SO_2/sulfur dioxide [1]

(c) concentrated sulfuric acid is an oxidising agent
or
phosphoric(V) acid is **not** an oxidising agent [1]

[Total: 3]

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.

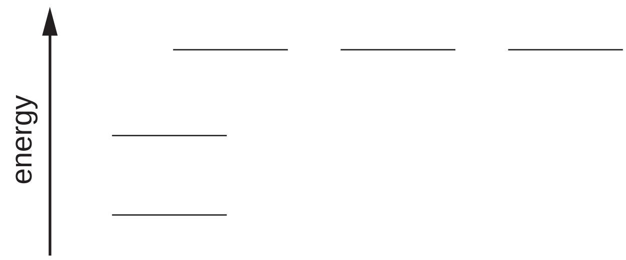
Answer **all** the questions in the spaces provided.

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.

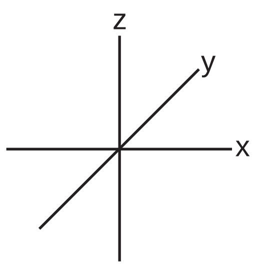
(a) The diagram below represents the energy levels of the orbitals present in atoms of the second period (Li to Ne).

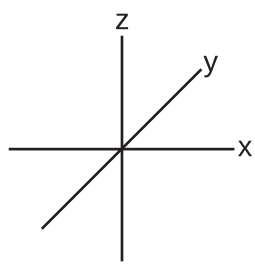
(i) Label the energy levels to indicate the principal quantum number **and** the type of orbital at each energy level.



(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.

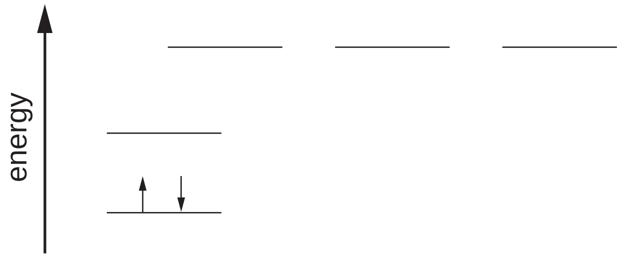
Label each type.



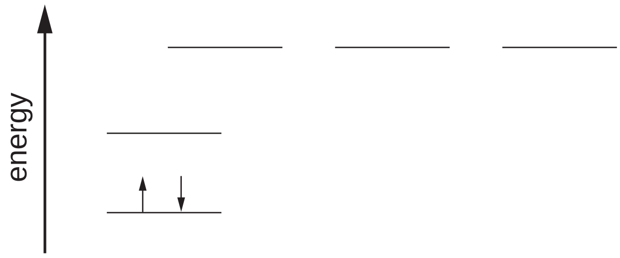


For Examiner's Use

(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.

....

....

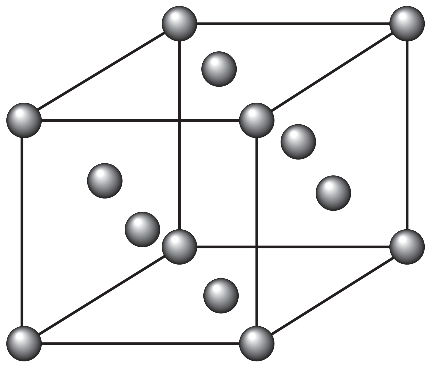
....

[3]

[Total: 9]

For Examiner's Use

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]

For Examiner's Use

3 The table below gives data for some of the oxides of Period 3 elements.

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]

For Examiner's Use

(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.

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]

For Examiner's Use

(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.

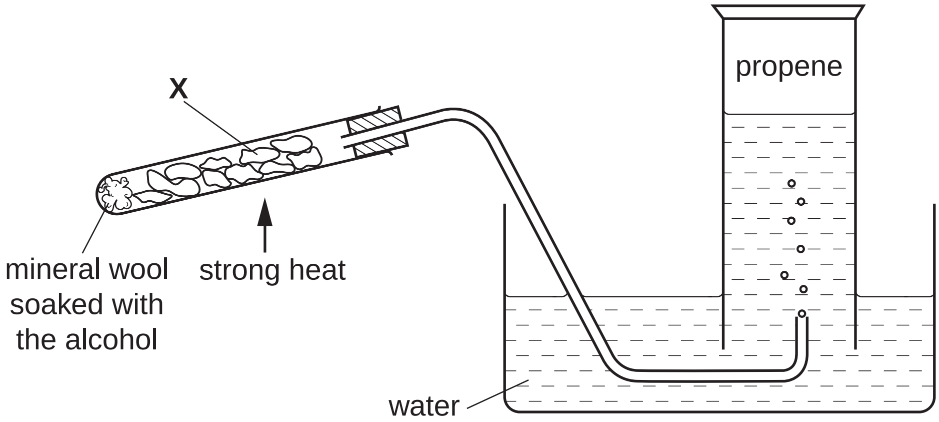
....

....

[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.



(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.

....

....

....

For Examiner's Use

(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]

UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS

GCE Advanced Subsidiary Level and GCE Advanced Level

MARK SCHEME for the May/June 2010 question paper

for the guidance of teachers

9701 CHEMISTRY

9701/22 Paper 2 (AS Structured Questions), maximum raw mark 60

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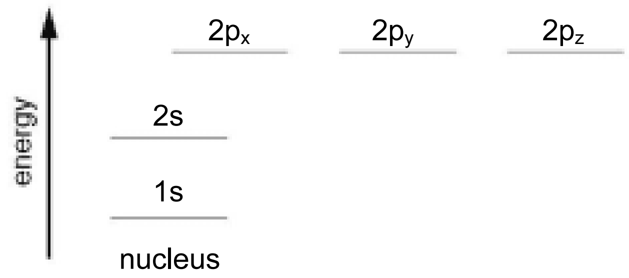
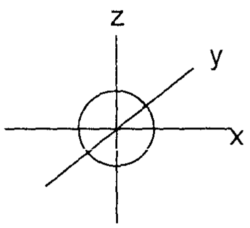
1 (a) (i)



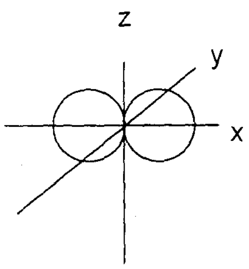
correct 1s and 2s (1)

correct $2p_x$, $2p_y$ and $2p_z$ (1)

(ii)



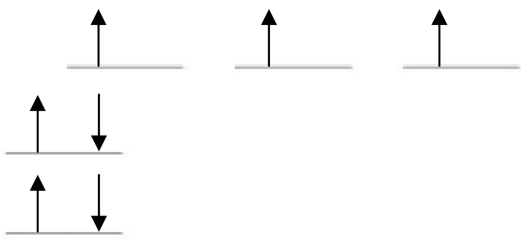
spherical s orbital (1)



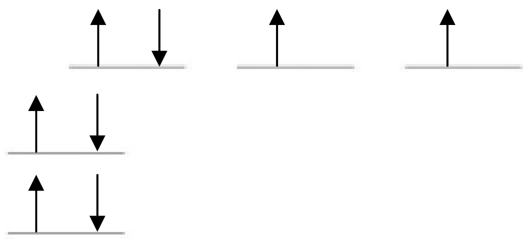
double lobed p orbital along one axis (1)

both orbitals correctly labelled (1)

(iii)



nitrogen



oxygen

both correct (1) [6]

(b) (i) N 1400 kJ mol^{1} O 1310 kJ mol^{1} **both** (1)

(ii) N is all singly filled 2p orbitals **or** O has one filled/paired 2p orbital (1)
these paired 2p electrons in the O atom repel one another (1) [3]

[Total: 9]

2 (a)

element	particle	formula
copper	cation	Cu^{2+} allow Cu^{+}
argon	atom **or** molecule	Ar

one mark for each correct row **or** column (2 × 1) [2]

(b) **Cu** cations held in 'sea' of delocalised electrons (1)
by strong metallic bonds (1)
Ar van der Waals' forces between molecules (1)
which are weak (1) [4]

(c) (i) oxidising agent **or** electron acceptor (1)
Ar has very high first I.E
or E_a for reaction is very high
or Ar has full valency shell/complete octet (1) [2]

(d) from Ne to Xe more electrons in atom (1)
hence more induced dipoles/van der Waals' forces (1) [2]

[Total: 10]

3 **(a)**

oxide	Na_2O	MgO	Al_2O_3	SiO_2	P_4O_6	SO_2
bonding	ionic	ionic	ionic/covalent	covalent	covalent	covalent
structure	giant	giant	giant	giant	simple	simple

(i) fully correct 'bonding' row (1)

(ii) fully correct 'structure' row (1) [2]

(b) Al_2O_3 **or** SiO_2 (1) [1]

(c) **(i)** **Na_2O** $Na_2O + H_2O \rightarrow 2NaOH$ (1)
pH 10–14 (1)
SO_2 $SO_2 + H_2O \rightarrow H_2SO_3$ (1)
pH 2–5 (1)

(ii) $NaOH + H_2SO_3 \rightarrow NaHSO_3 + H_2O$
or $2NaOH + H_2SO_3 \rightarrow Na_2SO_3 + 2H_2O$ (1) [5]

(d) MgO(l) conducts (1)
MgO(l) contains free/mobile ions (1)
SiO_2(l) does not conduct (1)
SiO_2(l) has no free ions (1) [4]

[Total: 12]

4 **(a)** C : H : O $= \frac{48.7}{12} : \frac{8.1}{1} : \frac{43.2}{16}$ (1)

= 4.06 : 8.1 : 2.70
= 1.5 : 3 : 1
= 3 : 6 : 2

empirical formula is $C_3H_6O_2$ (1) [2]

(b) **(i)** $M_r = \frac{mRT}{pV} \quad \frac{0.13 \times 8.31 \times 400}{1.00 \times 10^5 \times 58.0 \times 10^{-6}}$ (1)

= 74.5 (1)

(ii) $C_3H_6O_2$ = 36 + 6 + 32 = 74 (1)
$n(C_3H_6O_2)$ = 74.5
hence molecular formula of **E** is $C_3H_6O_2$ (1) [4]

(c) structures of **F** are

$HCO_2CH(CH_3)_2$	$HCO_2CH_2CH_2CH_3$	$CH_3CO_2CH_2CH_3$	$CH_3CH_2CO_2CH_3$
S	**T**	**U**	**V**

each correct structure is worth one mark (3 × 1) [3]

(d) **(i)** H_2SO_4/HCl/mineral acid **or** NaOH/KOH (1)

(ii) carboxylic acid **not** 'acid' (1) [2]

(e) **(i)** aldehyde (1)

(ii) must be a primary alcohol (1)

(iii) CH_3OH **or** CH_3CH_2OH **or** $CH_3CH_2CH_2OH$ (1) [3]

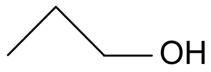
(f) **(i)** **S** (1)

(ii) only **S** is **not** the ester of a primary alcohol
or only **S** is the ester of a secondary alcohol (1) [2]

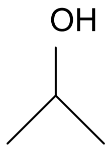
[Total: 16]

5 **(a)** **(i)** propan-1-ol **or** propan-2-ol (1)

(ii)



or



(1)

(iii) dehydration **or** elimination (1) [3]

(b) **(i)** carbon (1)
by decomposition/cracking of the alcohol (1)

(ii) to avoid 'sucking back' of water into the hot tube (1)

(iii) SiO_2 (1)

(iv) conc. H_2SO_4 **or** P_4O_{10} **or** Al_2O_3 **or** H_3PO_4 (1) [5]

(c) **(i)** $CH_3CHBrCH_2Br$ (1)

(ii) $CH_3CH(OH)CH_2OH$ (1)

(iii) CH_3CO_2H (1) [3]

(d) **(i)** (very) high pressure **or** Ziegler-Natta catalyst (1)

(ii) does not biodegrade **or** gives harmful combustion products (1) [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.

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1	
2	
3	
4	
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Total	

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DC (CW/KN) 34037

UNIVERSITY *of* CAMBRIDGE International Examinations

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

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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.

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.

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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]

For Examiner's Use

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**

For Examiner's Use

(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]

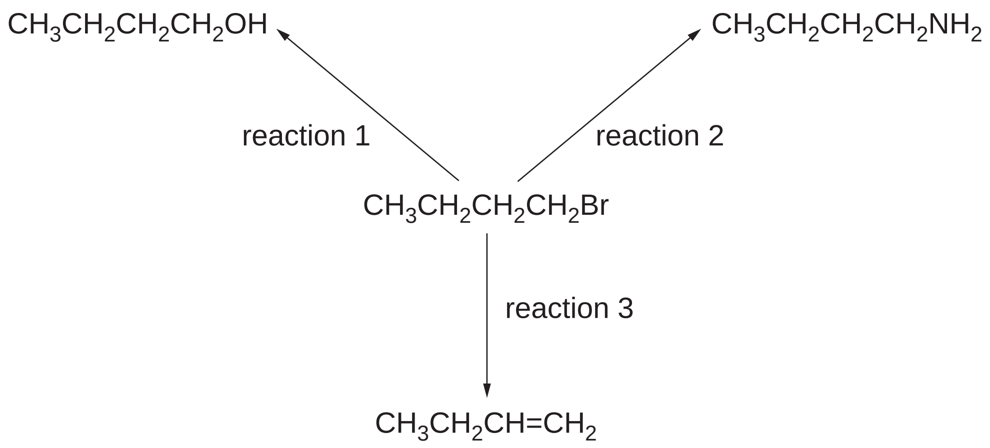
(f) Deduce the molecular formula of **E**.

[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.

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(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]

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5 The gaseous hydrogen halides HCl, 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.

$$NaX + H_3PO_4 \rightarrow NaH_2PO_4 + HX$$

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]

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS

GCE Advanced Subsidiary Level and GCE Advanced Level

MARK SCHEME for the October/November 2010 question paper for the guidance of teachers

9701 CHEMISTRY

9701/22 Paper 2 (AS Structured Questions), maximum raw mark 60

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

Mark schemes must be read in conjunction with the question papers and the report on the examination.

- CIE will not enter into discussions or correspondence in connection with these mark schemes.

CIE is publishing the mark schemes for the October/November 2010 question papers for most IGCSE, GCE Advanced Level and Advanced Subsidiary Level syllabuses and some Ordinary Level syllabuses.

1 **(a)** the actual number of atoms of each element present (1)

in one molecule of a compound (1) [2]

(b) $C_xH_y + \left(x + \frac{y}{4}\right)O_2 \longrightarrow xCO_2 + \frac{y}{2}H_2O$

xCO_2 (1)

$\frac{y}{2}H_2O$ (1) [2]

(c) **(i)** oxygen/O_2 (1)

(ii) carbon dioxide/CO_2 (1)

(iii) 10 cm^3 (1)

(iv) 20 cm^3 (1) [4]

(d) $C_xH_y + \left(x + \frac{y}{4}\right)O_2 \longrightarrow xCO_2 + \frac{y}{2}H_2O$

10 cm^3 20 cm^3 10 cm^3

1 mol of C_xH_y gives 1 mol of CO_2

whence $x = 1$ (1)

1 mol of C_xH_y reacts with 2 mol of O_2

whence $\left(x + \frac{y}{4}\right) = 2$

and $y = 4$ (1)

molecular formula is CH_4 (1) [3]

[Total: 11]

2 **(a)** $N_2 + 3H_2 \rightleftharpoons 2NH_3$ (1) [1]

(b) temperature between 300 and 550°C (1)

correct explanation of effect of temperature on
rate of formation of NH_3 **or** on position of equilibrium (1)

catalyst of iron **or** iron oxide (1)

to speed up reaction **or** to reduce E_a (1) [4]

(c) manufacture of HNO_3
or explosives
or nylon
or as a cleaning agent
or as a refrigerant (1) [1]

(d) fertiliser in rivers causes excessive growth of aquatic plants/algae (1)

when plants and algae die O_2 is used up/fish or aquatic life die (1) [2]

(e) **(i)** CO by incomplete combustion of the hydrocarbon fuel (1)

NO by reaction between N_2 and O_2 in the engine (1)

(ii) CO toxic/effect on haemoglobin (1)

NO toxic/formation of acid rain (1) [4]

(f) **(i)** platinum/Pt – allow palladium/Pd **or** rhodium/Rh (1)

(ii) $2CO + 2NO \rightarrow 2CO_2 + N_2$ (1) [2]

[Total: 14]

3 **(a)** **(i)** a compound which contains **only** carbon and hydrogen (1)

(ii) separation of compounds by their boiling points (1) [2]

(b) **(i)** high temperature **and** high pressure (1)

high temperature **and** catalyst (1)

(ii) $C_{11}H_{24} \rightarrow C_5H_{12} + C_6H_{12}$ **or**

$C_{11}H_{24} \rightarrow C_5H_{12} + 2C_3H_6$ **or**

$C_{11}H_{24} \rightarrow C_5H_{12} + 3C_2H_4$ (1) [3]

(c) **(i)**

$CH_3CH_2CH_2CH_2CH_3$	$CH_3CH_2CHCH_3$ | CH_3	CH_3 | CH_3CCH_3 | CH_3
isomer **B**	isomer **C**	isomer **D**
(1)	(1)	(1)

(ii) the straight chain isomer (isomer **B** above) (1)

it has the greatest van der Waals' forces (1)

because unbranched molecules have greater area of contact/
can pack more closely together (1) [6]

(d) enthalpy change when 1 mol of a substance (1)

is burnt in an excess of oxygen/air under standard conditions
or is completely combusted under standard conditions (1) [2]

(e) **(i)** heat released = m c δT = 200 x 4.18 x 27.5 (1)

= 22990 J = 23.0 kJ (1)

(ii) 23.0 kJ produced from 0.47 g of **E**

2059 kJ produced from $\frac{0.47 \times 2059}{23.0}$ g of **E** (1)

= 42.08 g of **E** (1)

allow ecf in **(i)** or **(ii)** on candidate's expressions [4]

(f) C_3H_6 = 42

E is C_3H_6

for ecf, **E** must be unsaturated and be no larger than C_5 (1) [1]

[Total: 18]

4 **(a)**

reaction 1	reagent	NaOH/KOH (1)
	solvent	H_2O/water/aqueous (1)
reaction 2	reagent	NH_3/ammonia (1)
	solvent	ethanol/C_2H_5OH/alcohol (1)
reaction 3	reagent	NaOH/KOH (1)
	solvent	ethanol/C_2H_5OH/alcohol (1)

[6]

(b) with $CH_3CH_2CH_2CH_2I$ rate would be faster (1)

C-I bond is weaker than C-Br bond (1)

C-I bond energy is 240 kJ mol ^{1}, C-Br bond energy is 280 kJ mol ^{1}
data **must** be quoted for this mark (1) [3]

(c) non-toxic non-flammable

volatile/low bp unreactive (any 2) [2]

(d) **(i)** when a covalent bond breaks the two electrons in the bond are shared between the two atoms (1)

(ii) $CCl_2F_2 \rightarrow CClF_2 + Cl$ (as minimum)

allow $CCl_2F + F$ (1) [2]

(e) they are flammable (1) [1]

[Total: 14]

5 **(a)** NaBr/sodium bromide [1]

(b) Br_2/bromine or SO_2/sulfur dioxide [1]

(c) concentrated sulfuric acid is an oxidising agent
or
phosphoric(V) acid is **not** an oxidising agent [1]

[Total: 3]

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

CANDIDATE NAME	

CENTRE NUMBER		CANDIDATE NUMBER	

7524377035

CHEMISTRY **9701/23**

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.
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[Turn over

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

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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.

$$N_2H_4(l) \ + \ O_2(g) \longrightarrow N_2(g) \ + \ 2H_2O(g)$$

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

compound	$\Delta H_f^{\ominus}$/kJ mol^{-1}
$N_2H_4(l)$	50.6
$H_2O(g)$	–241.8

$\Delta H^{\ominus}$ = ... 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 dm^3 of aqueous lithium hydroxide.

$$2Li(s) + 2H_2O(l) \rightarrow 2LiOH(aq) + H_2(g)$$

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

For Examiner's Use

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

(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]

[Turn over

For Examiner's Use

3 This question refers to the elements shown in the section of the Periodic Table below.

							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

(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 sinks in cold water and reacts readily with it

....

(ii) an element that forms an oxide that is a reducing agent

....

(iii) the element that has the largest first ionisation energy

....

(iv) the metal in Period 3 (Na to Ar) that has the smallest cation

....

(v) the element which has a giant molecular structure **and** forms an oxide which also has a giant molecular structure

....

(vi) the element in Period 3 (Na to Ar) with the greatest electrical conductivity

....

[6]

(b) From the section of the Periodic Table above, identify **two** elements whose hydrides form hydrogen bonds between their molecules.

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

For Examiner's Use

(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).

(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]

For Examiner's Use

4 Organic reactions involve substances which may be

atoms, *molecules*, *ions* or *free radicals*.

We also apply the terms

electrophilic, *nucleophilic*, *addition*, *elimination* and *substitution*

to organic reactions.

Consider the following reactions.

$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$ reaction 1

$CH_3CH_2OH \rightarrow CH_2{=}CH_2 + H_2O$ reaction 2

$CH_3I + OH^- \rightarrow CH_3OH + I^-$ reaction 3

$CH_3COCH_3 + HCN \rightarrow CH_3C(OH)(CN)CH_3$ reaction 4

(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]

For Examiner's Use

(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.

$$CH_2{=}CH_2 + Br_2 \rightarrow BrCH_2CH_2Br$$

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, $CH_3CH(OH)CO_2H$, occurs naturally in sour milk and in our muscles when we take hard exercise.
Lactic acid is chiral and shows stereoisomerism.

(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.

$$CH_3CH_2OH \xrightarrow{\text{step 1}} CH_3CHO \xrightarrow{\text{step 2}} CH_3CH(OH)CN \xrightarrow{\text{step 3}} CH_3CH(OH)CO_2H$$

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

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

[6]

For Examiner's Use

During exercise, lactic acid is produced in our muscles from pyruvic acid, CH_3COCO_2H. This reaction occurs in the presence of the enzyme lactic acid dehydrogenase.

(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?

$$CH_3COCO_2H \rightarrow CH_3CH(OH)CO_2H$$

....

[6]

[Total: 15]

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS

GCE Advanced Subsidiary Level and GCE Advanced Level

MARK SCHEME for the May/June 2010 question paper

for the guidance of teachers

9701 CHEMISTRY

9701/23 Paper 2 (AS Structured Questions), maximum raw mark 60

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

Mark schemes must be read in conjunction with the question papers and the report on the examination.

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1 **(a)** enthalpy change when 1 mol of a compound is formed (1)
from its elements (1)
in their standard states under standard conditions (1) [3]

(b) **(i)** $N_2H_4(l) + O_2(g) \rightarrow N_2(g) + 2H_2O(g)$

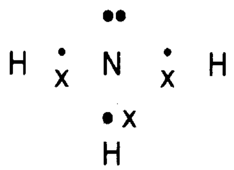
ΔH_f^o/kJ mol^{1} +50.6 –241.8

$\Delta H^o_{reaction}$ = 2(–241.8) – (+50.6) (1)
= –534.2 kJ mol^{1} (1)

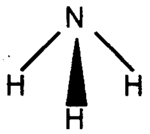
(ii) E_a is too high (1)

(iii) products are H_2O and N_2 which are harmless/non toxic
or are already present in the atmosphere (1) [4]

(c) **(i)** 'dot-and-cross' diagram (1)

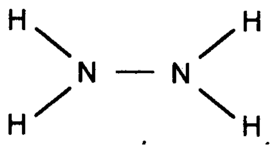


(ii)



(1)

(iii) minimum is



allow bond angle around N atom between 109° and 104° (1) [4]

(d) –2 (1) [1]

[Total: 12]

2 **(a)** the energy required to remove one electron from each atom (1)
in one mole of gaseous atoms (1)
or
the enthalpy change in kJ mol^{1} for (1)
$M(g) \rightarrow M^{+}(g) + e$ (1) [2]

(b) **(i)** first ionisation energy decreases down Group 1 (1)
outermost electron is further from nucleus
or has greater shielding (1)

(ii) outermost electron experiences less attraction
or formation of M^{+} cation becomes easier down Group 1 (1) [3]

(c) **(i)** $n(Li) = \dfrac{0.83}{6.9} = 0.12$ (1)

(ii) 2 mol Li $\rightarrow$ 1 mol H_2
0.12 mol Li $\rightarrow \dfrac{1 \times 0.12}{2} = 0.06$ mol H_2 (1)
volume of H_2 = 0.06 × 24.0 = 1.44dm^{3} (1)

(iii) 2 mol Li $\rightarrow$ 2 mol LiOH
0.12 mol Li $\rightarrow$ 0.12 mol LiOH in 0.50 dm^{3} (1)
$[LiOH] = \dfrac{0.12 \times 1}{0.50} = 0.24$ mol dm^{3} (1) [5]

(d) sodium burns with a yellow flame
or white solid formed
or colour of chlorine disappears (1)

$2Na + Cl_2 \rightarrow 2NaCl$ (1) [2]

[Total: 12]

3 **(a)** **(i)** Ca (1)

(ii) S **or** C [allow H (H_2O_2) or N (NO, NO_2)] (1)

(iii) He (1)

(iv) A*l* (1)

(v) Si **or** Ge (1)

(vi) A*l* (1) [6]

(b) any **two** from N **or** O **or** F (1) [1]

(c) **(i)** Al_2O_3 **or** SiO_2 (1)

(ii) SO_2 **or** P_2O_3/P_4O_6 (1)
and and
SO_3 **or** P_2O_5/P_4O_{10} (1)

(iii) Na_2O (1)

(iv) Al_2O_3 (1) [5]

[Total: 12]

4 **(a)** **reaction 1** free radical substitution (1)

reaction 2 elimination (1) [2]

(b) **(i)** in reaction 4 $CH_3C(OH)(CN)CH_3$ (1)

(ii) in reaction 3 I (1)

(iii) in reaction 3 CH_3I
or in reaction 4 CH_3COCH_3 (1) [3]

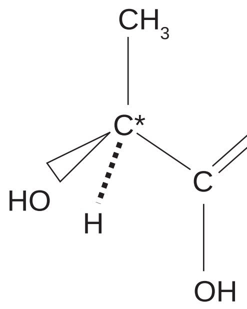
(c) a species which has a lone pair of electrons
or which reacts with an electron deficient (δ+) centre in a molecule (1) [1]

(d) in reaction 3 OH (1)
in reaction 4 CN (1) [2]

(e) π bonding is electron rich (1) [1]

[Total: 9]

5 (a)



[3]

(b)

	reagent(s)	condition(s)
step 1	$Cr_2O_7^{2}$ / H^+ (1)	distil off aldehyde (1)
step 2	HCN in presence of CN **or** KCN + dil H_2SO_4 (1)	room temperature (1)
step 3	aqueous mineral acid/ /H_2SO_4/HCl **not** HNO_3 (1)	heat under reflux (1)

in **each** case, the reagent must be correct before the condition mark is awarded [6]

(c) (i) a protein (1)

(ii) 2,4-dinitrophenylhydrazine/Brady's reagent (1)
yellow-orange-red ppt. (1)

(iii) acidified $K_2Cr_2O_7$ **or** Lucas test **or** CH_3CO_2H/H^+ (1)
colour changes **or** cloudiness **or** fruity smell
from orange to green (1)

(iv) $LiAlH_4/NaBH_4$
or H_2/Ni etc. (1) [6]

[Total: 15]

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

CANDIDATE NAME	

CENTRE NUMBER		CANDIDATE NUMBER	

0955802702

CHEMISTRY **9701/23**

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 The element magnesium, Mg, proton number 12, is a metal which is used in many alloys which are strong and light.

Magnesium has several naturally occurring isotopes.

(a) What is meant by the term *isotope*?

....

....

.... [2]

(b) Complete the table below for two of the isotopes of magnesium.

isotope	number of protons	number of neutrons	number of electrons
^{24}Mg			
^{26}Mg			

[2]

A sample of magnesium had the following isotopic composition:
^{24}Mg, 78.60%; ^{25}Mg, 10.11%; ^{26}Mg, 11.29%.

(c) Calculate the relative atomic mass, A_r, of magnesium in the sample.
Express your answer to an appropriate number of significant figures.

[2]

For Examiner's Use

Antimony, Sb, proton number 51, is another element which is used in alloys.

Magnesium and antimony each react when heated separately in chlorine.

(d) Construct a balanced equation for the reaction between magnesium and chlorine.

.... [1]

When a 2.45 g sample of antimony was heated in chlorine under suitable conditions, 4.57 g of a chloride **A** were formed.

(e) **(i)** Calculate the amount, in moles, of antimony atoms that reacted.

(ii) Calculate the amount, in moles, of chlorine atoms that reacted.

(iii) Use your answers to **(i)** and **(ii)** to determine the empirical formula of **A**.

(iv) The empirical and molecular formulae of **A** are the same.

Construct a balanced equation for the reaction between antimony and chlorine.

.... [5]

(f) The chloride **A** melts at 73.4 °C while magnesium chloride melts at 714 °C.

(i) What type of bonding is present in magnesium chloride?

....

(ii) Suggest what type of bonding is present in **A**.

.... [2]

[Total: 14]

For Examiner's Use

2 Sulfur and its compounds are found in volcanoes, in organic matter and in minerals.
Sulfuric acid, an important industrial chemical, is manufactured from sulfur by the Contact process.
The Contact process may be considered to be a three-stage process in which sulfur is converted into sulfuric acid. Each stage consists of a single chemical reaction.

(a) Write a balanced equation for **each** of these reactions **in the correct sequence**.
Where appropriate, use $\rightleftharpoons$ to indicate that the reaction is an equilibrium.

first reaction ....

second reaction ....

third reaction .... [4]

(b) Give **three** different operating conditions that are used in the **second** stage.

condition 1 ....

condition 2 ....

condition 3 .... [3]

(c) State **one** large scale use of sulfuric acid.

.... [1]

(d) Most of the sulfur that is used in the Contact process is recovered from sulfur compounds present in crude oil and natural gas by using the Claus process.

(i) In this process, about one third of the hydrogen sulfide, H_2S, present in the oil or gas, is converted into sulfur dioxide, SO_2.

Balance the equation for this reaction.

$$.....H_2S \quad + ...O_2 \rightarrow .....SO_2 \quad + ...H_2O$$

(ii) The SO_2 formed is then reacted catalytically with the remaining H_2S, producing sulfur and water.

For Examiner's Use

$$2H_2S + SO_2 \rightarrow 3S + 2H_2O$$

What are the oxidation numbers of each of the sulfur-containing substances in this reaction?

H_2S......... SO_2 .... S ....

Which substance is reduced? Explain your answer.

substance ....

explanation ....[3]

The sulfur present in crude oil is removed in order to prevent the formation of sulfur dioxide when fuels such as petrol (gasoline) or diesel fuel are burned in internal combustion engines.
Other substances that may be present in the exhaust gases of motor vehicles include CO, CO_2, NO/NO_2, and unburnt hydrocarbons.

The emission of sulfur dioxide can produce 'acid rain'.

(e) **(i)** Outline, with the aid of equations, how acid rain is formed from the exhaust gases of motor vehicles.

....

....

....

....

(ii) State **one** environmental effect of acid rain.

....[4]

(f) Sulfur dioxide is used to preserve dried fruits and vegetables.

What chemical property of SO_2 enables it to be used as a food preservative?

....[1]

[Total: 16]

For Examiner's Use

3 Astronomers using modern spectroscopic techniques of various types have found evidence of many molecules, ions and free radicals in the dust clouds in Space. Many of the species concerned have also been produced in laboratories on Earth.

Two such species are the dicarbon monoxide molecule, C_2O, and the amino free radical, NH_2.

(a) **(i)** Dicarbon monoxide can be produced in a laboratory and analysis of it shows that the sequence of atoms in this molecule is carbon-carbon-oxygen and there are no unpaired electrons, but one of the atoms is only surrounded by six electrons.

Draw a 'dot-and-cross' diagram of C_2O and suggest the shape of the molecule.

shape ....

(ii) What is meant by the term *free radical*?

....

....

(iii) Explain why NH_2 is described as a 'free radical'.

....

....[5]

Two derivatives of ethene which have been detected in dust clouds in Space are acrylonitrile (2-propenenitrile), CH_2=CHCN, and vinyl alcohol (ethenol), CH_2=CHOH.

(b) Like ethene, acrylonitrile can be polymerised. The resulting polymer can be used to make carbon fibres.

(i) Draw the structural formula of the polymer made from acrylonitrile, showing **two** repeat units.

(ii) What type of polymerisation is this reaction?

....[2]

Vinyl alcohol cannot be polymerised in the same way as acrylonitrile because it will readily isomerise into another common organic compound, **Z**.

For Examiner's Use

(c) **(i)** Suggest the structural formula of the organic compound **Z**.

(ii) Suggest the structural formula of another isomer of vinyl alcohol which has a cyclic (ring) structure.

[2]

Acrolein (2-propenal), CH_2=CHCHO, has also been found in Space.

(d) Give the structural formulae of the organic compounds formed when acrolein is reacted separately with **each** of the following reagents.

reagent	product
Br_2 in an inert solvent	
NaCN + dilute H_2SO_4	
Tollens' reagent	
$NaBH_4$	

[4]

[Total: 13]

For Examiner's Use

4 Although few halogenoalkanes exist naturally, such compounds are important as intermediates in organic reactions and as solvents.

The bromoalkane **B** has the following composition by mass: C, 29.3%; H, 5.7%; Br, 65.0%. The relative molecular mass of **B** is 123.

(a) Calculate the molecular formula of **B**.

[3]

Halogenoalkanes such as bromoethane, C_2H_5Br, have two different reactions with sodium hydroxide, NaOH, depending on the conditions used.

(b) **(i)** When hot aqueous NaOH is used, the C_2H_5Br is hydrolysed to ethanol, C_2H_5OH.

Describe the mechanism of this reaction. In your answer, show any relevant charges, dipoles, lone pairs of electrons and movement of electron pairs by curly arrows.

For Examiner's Use

(ii) What will be formed when C_2H_5Br is reacted with NaOH under different conditions?

....

(iii) What are the conditions used?

....

(iv) What type of reaction is this?

....[7]

When 1,4-dichlorobutane, $ClCH_2CH_2CH_2CH_2Cl$, is reacted with NaOH, two different reactions can occur, depending on the conditions used.

(c) **(i)** Draw the **displayed** formula of the product formed when 1,4-dichlorobutane is reacted with hot aqueous NaOH as in **(b)(i)**.

(ii) Draw the **skeletal** formula of the product formed when 1,4-dichlorobutane is reacted with NaOH in the way you have described in **(b)(ii)** and **(b)(iii)**.

[2]

[Total: 12]

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For Examiner's Use

5 A student placed separate small samples of 1-chlorobutane, 1-bromobutane and, 1-iodobutane, in three separate test-tubes. To each test-tube, 1 cm^3 of ethanol was added, followed by 1 cm^3 of aqueous silver nitrate, $AgNO_3$. The tubes were then carefully shaken, placed in a test-tube rack and observed for 30 minutes.

A precipitate was formed in each test-tube but **not** at the same time; the fastest taking about two minutes to become opaque and the slowest about 20 minutes.

(a) What is the identity of the precipitate formed when 1-chlorobutane is used?

.... [1]

(b) What will be the colour of this precipitate?

.... [1]

(c) Which of the three halogenoalkanes will produce a precipitate in about two minutes?

.... [1]

(d) Use appropriate data from the *Data Booklet* to explain why this reaction takes place most quickly of the three.

....

....

.... [2]

[Total: 5]

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS

GCE Advanced Subsidiary Level and GCE Advanced Level

MARK SCHEME for the October/November 2010 question paper for the guidance of teachers

9701 CHEMISTRY

9701/23 Paper 2 (AS Structured Questions), maximum raw mark 60

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1 **(a)** atoms of the same element / with same proton (atomic) number / same number of protons (1)
different numbers of neutrons / nucleon number / mass number (1) [2]

(b)

isotope	**no. of protons**	**no. of neutrons**	**no. of electrons**
^{24}Mg	12	12	12
^{26}Mg	12	14	12

each correct row (1) [2]

(c) $A_r = \dfrac{24 \times 78.60 + 25 \times 10.11 + 26 \times 11.29}{100}$ (1)

$= \dfrac{1886.40 + 252.75 + 293.54}{100}$

gives 24.33 to 4 sig fig (same as data in question)

do not credit wrong number of sig figs **or** incorrect rounding up/down (1) [2]

(d) $Mg + Cl_2 \rightarrow MgCl_2$ (1) [1]

(e) **(i)** $n(Sb) = \dfrac{2.45}{122} = 0.020$ (1)

(ii) mass of Cl in **A** = 4.57 – 2.45 = 2.12 g (1)

$n(Cl) = \dfrac{4.57 \quad 2.45}{35.5} = \dfrac{2.12}{35.5} = 0.06$

allow ecf as appropriate (1)

(iii) $Sb : Cl = 0.02 : 0.06 = 1:3$
empirical formula of **A** is $SbCl_3$ (1)

(iv) $2Sb + 3Cl_2 \rightarrow 2SbCl_3$ (1) [5]

(f) **(i)** ionic (1)

(ii) covalent (1)
not van der Waals' forces [2]

[Total: 14]

2 **(a)** 1 $S + O_2 \rightarrow SO_2$ (1)

2 $2SO_2 + O_2 \rightleftharpoons 2SO_3$ equation (1)
equilibrium sign (1)

3 $SO_3 + H_2O \rightarrow H_2SO_4$ **or**
$SO_3 + H_2SO_4 \rightarrow H_2S_2O_7$ (1) [4]

(b) condition 1 400 – 600 °C (650 – 900K) (1)
condition 2 1–10 atm/just above atmospheric pressure
allow equivalent pressure units (1)
condition 3 vanadium pentoxide/vanadium(V) oxide/V_2O_5 (1) [3]

(c) fertilisers/phosphates/ammonium sulfate **or**
lead/acid batteries **or** paints/pigments **or** dyestuffs **or**
steel pickling **or** metal treatment **or** detergents **or** explosives (1) [1]

(d) **(i)** $2H_2S + 3O_2 \rightarrow 2SO_2 + 2H_2O$ (1)

(ii) H_2S –2 SO_2 +4 S 0 **all three** (1)
SO_2 **because** the oxidation number of S is reduced (1) [3]

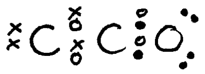
(e) **(i)** $2NO + O_2 \rightarrow 2NO_2$ (1)
$SO_2 + NO_2 \rightarrow SO_3 + NO$ (1)
$SO_3 + H_2O \rightarrow H_2SO_4$
final product must be H_2SO_4 (1)

(ii) corrosion of buildings **or**
dissolving of Al^{3+} ions from soil **or**
pollution of rivers/killing aquatic life **or**
making soil acidic/killing trees/corrosion of metals (1) [4]

(f) it is a reducing agent/inhibits oxidation (1) [1]

[Total: 16]

3 **(a)** **(i)** order of atoms **must** be C-C-O



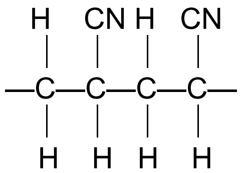
(1)

linear (1)

(ii) a molecule or atom with an unpaired electron **or**
a species formed by the homolytic fission of a covalent bond (1)

(iii) molecule has 2 bond pairs and one lone pair (1)
and one unpaired electron (1)
these may be shown in a diagram [5]

(b) **(i)**

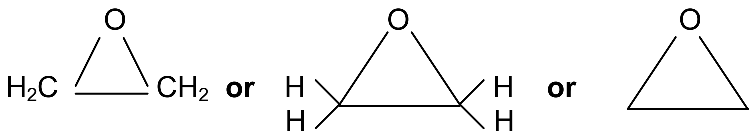


allow the structural formula —$CH_2CH(CN)CH_2CH(CN)$— (1)

(ii) addition (1) [2]

(c) **(i)** CH_3CHO (1)

(ii)



(1) [2]

(d)

reagent	product
Br_2 in an inert solvent	$BrCH_2CHBrCHO$
NaCN + dil. H_2SO_4	CH_2=CHCH(OH)CN allow CH_2=CHCH(OH)CO_2H
Tollens' reagent	CH_2=$CHCO_2$H **or** CH_2=$CHCO_2$
$NaBH_4$	CH_2=$CHCH_2$OH

(4 × 1) [4]

[Total: 13]

4 **(a)** C : H : Br $= \dfrac{29.3}{12} : \dfrac{5.7}{1} : \dfrac{65.0}{79.9}$ (1)
$= 2.44 : 5.7 : 0.81$
$= 3 : 7 : 1$ (1)
$C_3H_7Br = (3 \times 12) + (7 \times 1) + 79.9 = 122.9$
use of 122.9 or 123 to prove
molecular formula must be C_3H_7Br (1) [3]

(b) **(i)** mechanism must be S_N2

dipole on C-Br bond **or**
central C atom shown with δ+ (1)

attack on C atom by lone pair of OH
not from negative charge (1)

transition state formed **with** negative charge shown (1)

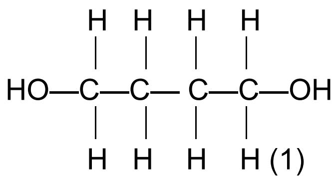
Br leaves/NaBr formed (1)

(ii) C_2H_4/ethane (1)

(iii) ethanol/C_2H_5OH (1)

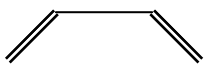
(iv) elimination (1) [7]

(c) **(i)**



(1)

(ii) **must** be skeletal



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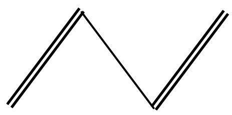


(1) [2]

[Total: 12]

5 **(a)** AgC*l*/silver chloride (1) [1]

(b) white (1) [1]

(c) 1-iodobutane (1) [1]

(d) C-I bond is weaker/longer than the other C-halogen bonds (1)

C-I bond energy is 240 kJ mol ^{1}
or covalent radius of I is 0.133 nm (1) [2]

[Total: 5]

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

CANDIDATE NAME	

CENTRE NUMBER		CANDIDATE NUMBER	

4044868560

CHEMISTRY **9701/21**

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.

UNIVERSITY *of* CAMBRIDGE International Examinations
[Turn over

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

For Examiner's Use

1 Some intercontinental jet airliners use kerosene as fuel. The formula of kerosene may be taken as $C_{14}H_{30}$.

(a) To which homologous series of compounds does kerosene belong?

.... [1]

(b) When kerosene burns in an excess of air, carbon dioxide and water form.
Balance the following equation for the complete combustion of kerosene.

$$......C_{14}H_{30}(l) \ + \ ......O_2(g) \rightarrow \ ......CO_2(g) \ + \ ......H_2O(g)$$ [1]

(c) In this section, give your answers to <u>one</u> decimal place.

The flight path from Beijing to Paris is approximately 8195 km.
A typical intercontinental jet airliner burns 10.8 kg of kerosene for each kilometre covered.

(i) Calculate the mass, in tonnes, of $C_{14}H_{30}$ burnt on a flight from Beijing to Paris.
[1 tonne = 1 000 kg]

(ii) Use your equation in **(b)** to calculate the mass, in tonnes, of CO_2 produced during this flight.

[4]

For Examiner's Use

Bicycles may be carried on commercial airliners. When carried on airliners, bicycles are placed in the luggage hold. This is a part of the aircraft which, in flight, will have different temperatures and air pressures from those at sea level.

This question concerns the change in pressure in an inflated bicycle tyre from when it is at sea level to when it is in the hold of an airliner in flight.

(d) At sea level and a temperature of 20 °C an inflated bicycle tyre contains 710 cm^3 of air at an internal pressure of 6×10^5 Pa.

Use the general gas equation $PV = nRT$ to calculate the amount, in moles, of air in the tyre at sea level.

[2]

The same bicycle, with its tyres inflated at sea level as described in **(d)** above, is placed in the luggage hold of an airliner. At a height of 10 000 m, the temperature in the luggage hold is 5 °C and the air pressure is 2.8×10^4 Pa.

(e) Assuming the volume of the tyre does not change, use your answer to **(d)** to calculate the pressure inside the tyre at a height of 10 000 m.

[2]

[Total: 10]

2 Crude oil contains a mixture of hydrocarbons together with other organic compounds which may contain nitrogen, oxygen or sulfur in their molecules.

For Examiner's Use

At an oil refinery, after the fractional distillation of crude oil, a number of other processes may be used including 'cracking', 'isomerisation', and 'reforming'.

(a) **(i)** What is meant by the term '*cracking*' and why is it carried out?

....

....

....

....

(ii) Outline briefly how the cracking of hydrocarbons would be carried out.

....

....

(iii) Construct a balanced equation for the formation of heptane, C_7H_{16}, by cracking tetradecane, $C_{14}H_{30}$.

....

[4]

One of the sulfur-containing compounds present in crude oil is ethanethiol, C_2H_5SH, the sulfur-containing equivalent of ethanol. Ethanethiol is toxic and is regarded as one of the smelliest compounds in existence.

(b) The boiling point of ethanol, C_2H_5OH, is higher than that of C_2H_5SH.
Suggest a reason for this difference.

....

.... [1]

When ethanethiol is burned in an excess of air, three oxides of different elements are formed.

For Examiner's Use

(c) **(i)** Construct a balanced equation for this reaction.

....

(ii) **Two** of the oxides formed cause serious environmental damage.

For **each** of these oxides, identify the type of pollution caused and describe one consequence of this pollution.

....

....

....

....

....
[6]

(d) A small amount of ethanethiol is added to liquefied gases such as butane that are widely used in portable cooking stoves.

Suggest a reason for this.

.... [1]

Sulfur-containing compounds are removed from oil products at the refinery. The sulfur is recovered and converted into SO_2, which is then used in the Contact process.

(e) State the main operating details of the formation of SO_3 in the Contact process.

....

....

....

....

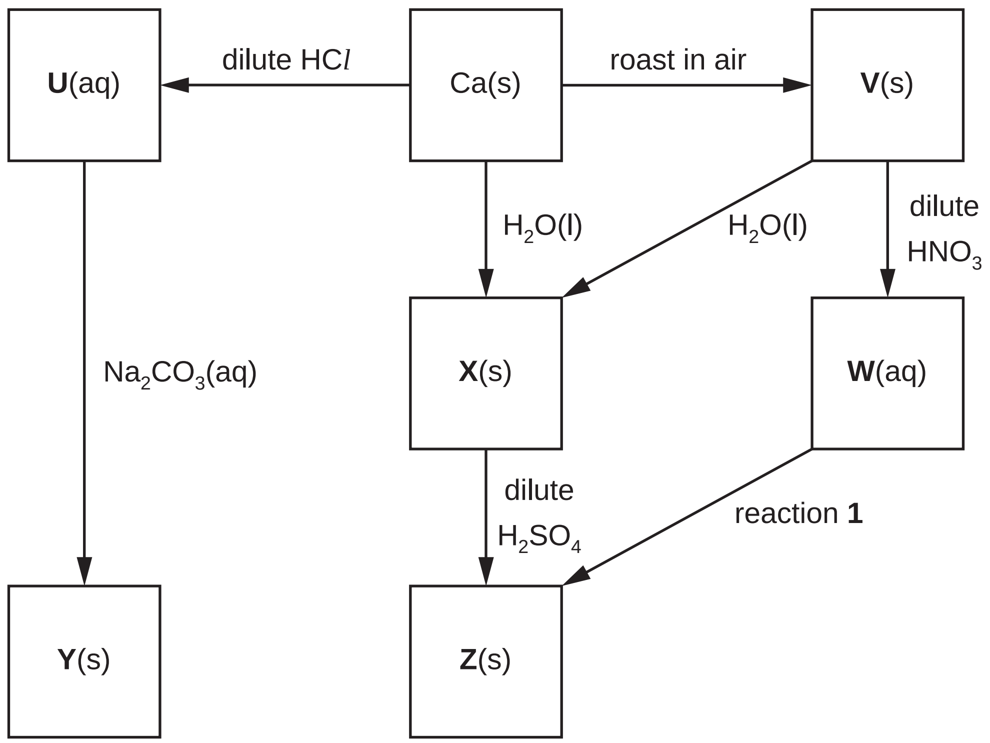
.... [3]

[Total: 15]

[Turn over

3 Calcium is the fifth most common element in the Earth's crust.
Calcium compounds occur in bones and teeth and also in many minerals.

Some reactions of calcium and its compounds are shown in the reaction scheme below.



(a) State the formula of **each** of the calcium compounds **U** to **Y**.

U ....

V ....

W ....

X ....

Y .... [5]

(b) Compound **Y** may be converted into compound **V**.
Outline how this reaction would be carried out in a school or college laboratory using a small sample of **Y**.

....

.... [1]

For Examiner's Use

(c) (i) Construct balanced equations for the following reactions.

calcium to compound **U**

....

compound **V** to compound **W**

....

compound **U** to compound **Y**

....

(ii) Construct a balanced equation for the effect of heat on solid compound **W**.

....
[4]

(d) Suggest the formula of an aqueous reagent, other than an acid, for reaction **1**.

.... [1]

(e) What would be observed when **each** of the following reactions is carried out in a test-tube?

the formation of **X** from Ca(s)

....

the formation of **X** from **V**

....
[2]

[Total: 13]

4 Ketones are widely used as solvents and as intermediates in the chemical industry.

Ketones contain the reactive keto group, $\gt C=O$.

(a) Propanone, CH_3COCH_3, undergoes a reaction with hydrogen cyanide, HCN.

(i) What type of reaction is this?

....

(ii) What reagents are used?

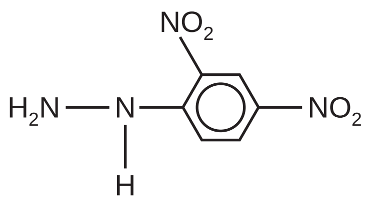
....

(iii) Draw a diagram to show the dipole present in the propanone molecule.

[3]

For Examiner's Use

(b) Propanone reacts with 2,4-dinitrophenylhydrazine reagent.

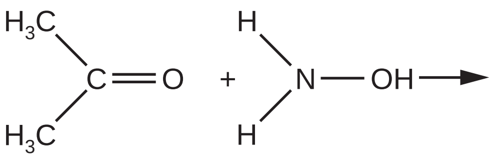


2,4-dinitrophenylhydrazine

(i) Construct a balanced equation for the reaction between propanone and 2,4-dinitrophenylhydrazine.

(ii) A similar type of reaction occurs between propanone and hydroxylamine, NH_2OH.

Draw the displayed formula of the organic product of this reaction.



[3]

[Total: 6]

For Examiner's Use

5 The gas ethyne, C_2H_2, more commonly known as acetylene, is manufactured for use in the synthesis of organic compounds. It is also used, in combination with oxygen, in 'oxy-acetylene' torches for the cutting and welding of metals.

Industrially, ethyne is made from calcium carbide, CaC_2, or by cracking liquid hydrocarbons.

(a) When calcium carbide is reacted with water, ethyne and calcium hydroxide are formed.

Construct a balanced equation for this reaction.

.... [1]

Ethyne can also be obtained from ethene by using the following sequence of reactions.

$$CH_2CH_2 \xrightarrow{\text{step 1}} ClCH_2CH_2Cl \xrightarrow{\text{step 2}} HC\equiv CH$$

(b) **(i)** What types of reaction are step 1 and step 2?

step 1 ....

step 2 ....

(ii) Suggest what reagent and conditions would be used in a laboratory in step 2.

reagent ....

conditions .... [5]

When ethyne is passed into water at 60 °C, in the presence of a little H_2SO_4 and Hg^{2+} ions, a pungent, colourless organic liquid, **Q**, with M_r of 44 is obtained. This is step 3.

When **Q** is warmed with Tollens' reagent in a test-tube, a silver mirror is formed.
On acidification, the solution remaining in the test-tube is found to contain the organic compound **R** which has M_r of 60. This is step 4.

(c) **(i)** Give the structural formulae of **Q** and **R**.

$$HC\equiv CH \xrightarrow{\text{step 3}} \boxed{\quad \mathbf{Q} \quad} \xrightarrow{\text{step 4}} \boxed{\quad \mathbf{R} \quad}$$

(ii) What type of reaction is step 3 and step 4?

step 3 ....

step 4 .... [4]

For Examiner's Use

(d) The standard enthalpy change of combustion of C_2H_2, $\Delta H^{\ominus}_{c}$, is –1300 kJ mol^{-1} at 298 K.

Values of relevant standard enthalpy changes of formation, $\Delta H^{\ominus}_{f}$, measured at 298 K, are given in the table.

substance	$\Delta H^{\ominus}_{f}$ / kJ mol^{-1}
CO_2(g)	–394
H_2O(l)	–286

(i) Write balanced equations, with state symbols, that represent

the standard enthalpy change of combustion, $\Delta H^{\ominus}_{c}$, of C_2H_2, and

....

the standard enthalpy change of formation, $\Delta H^{\ominus}_{f}$, of C_2H_2.

....

(ii) Use the data above and your answer to **(i)** to calculate the standard enthalpy change of formation, $\Delta H^{\ominus}_{f}$, of C_2H_2.
Show clearly whether the standard enthalpy change of formation of C_2H_2 has a positive or negative value.

[6]

[Total: 16]

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS

GCE Advanced Subsidiary Level and GCE Advanced Level

MARK SCHEME for the May/June 2011 question paper

for the guidance of teachers

9701 CHEMISTRY

9701/21 Paper 2 (AS Structured Questions), maximum raw mark 60

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

Mark schemes must be read in conjunction with the question papers and the report on the examination.

- Cambridge will not enter into discussions or correspondence in connection with these mark schemes.

Cambridge is publishing the mark schemes for the May/June 2011 question papers for most IGCSE, GCE Advanced Level and Advanced Subsidiary Level syllabuses and some Ordinary Level syllabuses.

1 **(a)** alkanes/paraffins
not hydrocarbon (1) [1]

(b) $\mathbf{2}\ C_{14}H_{30} + \mathbf{43}\ O_2 \rightarrow \mathbf{28}\ CO_2 + \mathbf{30}\ H_2O$ **or**

$C_{14}H_{30} + {}^{\mathbf{43}}/_{\mathbf{2}}O_2 \rightarrow \mathbf{14}\ CO_2 + \mathbf{15}\ H_2O$ (1) [1]

(c) **(i)** **mass of $C_{14}H_{30}$ burnt**

$\dfrac{8195 \times 10.8}{1000} = 88.506 = 88.5$ t (1)

(ii) **mass of CO_2 produced**

M_r of $C_{14}H_{30} = (14 \times 12 + 30 \times 1) = 198$ (1)

2×198 t of $C_{14}H_{30} \rightarrow 28 \times 44$ t of CO_2

88.5 t of $C_{14}H_{30} \rightarrow \dfrac{28 \times 44 \times 88.5}{2 \times 198}$ (1)

$= 275.3$ t of CO_2 (1)

allow 275.4 t if candidate has used 88.506
allow ecf on wrong value for M_r of $C_{14}H_{30}$ [4]

(d) $n = \dfrac{PV}{RT} = \dfrac{6 \times 10^5 \times 710 \times 10^{6}}{8.31 \times 293}$ (1)

$= 0.175$ (1) [2]

(e) $P = \dfrac{nRT}{V} = \dfrac{0.175 \times 8.31 \times 278}{710 \times 10^{6}}$ (1)

$= 569410.5634$ Pa $= 5.7 \times 10^5$ (1)

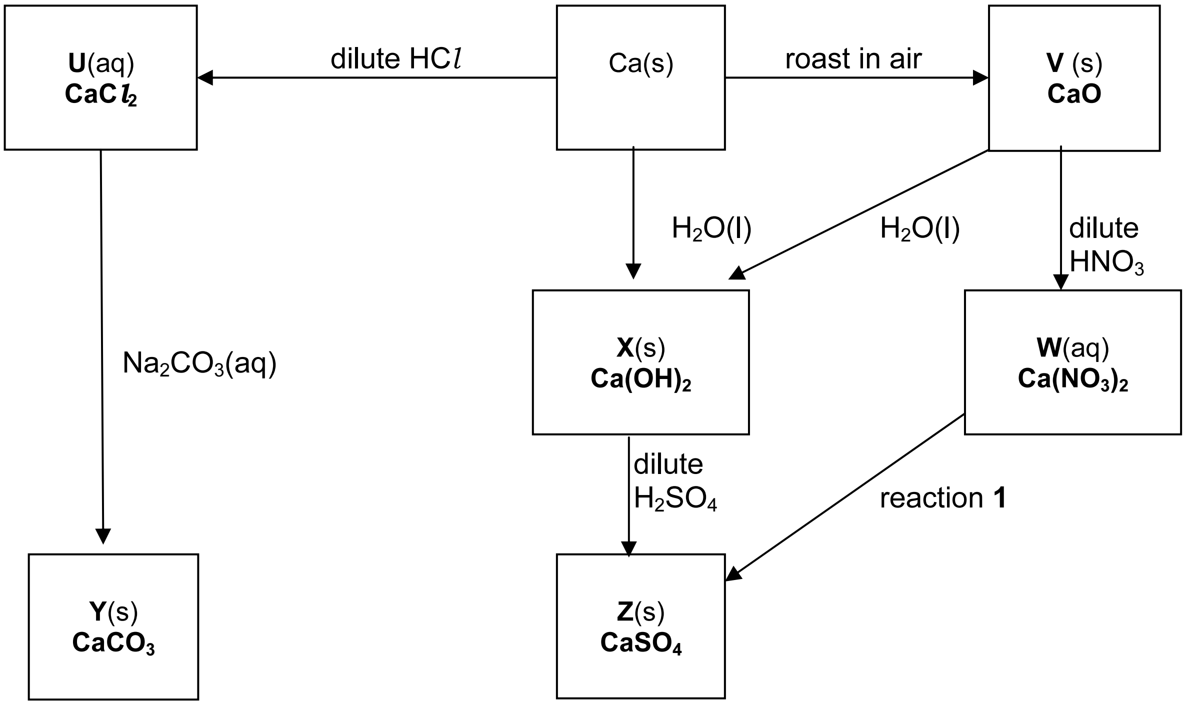
allow ecf on **(d)** [2]

[Total: 10]

2	(a)	(i)	break large hydrocarbons into smaller hydrocarbons **or** break down large hydrocarbons	(1)	
			smaller hydrocarbons are more useful **or** smaller hydrocarbons are more in demand	(1)	
		(ii)	using high temperatures/thermal cracking **or** using catalysts/catalytic cracking	(1)	
		(iii)	$C_{14}H_{30} \rightarrow C_7H_{16} + C_7H_{14}$ **or** $C_{14}H_{30} \rightarrow C_7H_{16} + C_2H_4 + C_5H_{10}$ **or** $C_{14}H_{30} \rightarrow C_7H_{16} + C_3H_6 + C_4H_8$ **or** $C_{14}H_{30} \rightarrow C_7H_{16} + 2C_2H_4 + C_3H_6$	(1)	
			do not allow any equation with H_2		[4]
	(b)		ethanol has hydrogen bonding, ethanethiol does not	(1)	[1]
	(c)	(i)	$C_2H_5SH + \mathbf{{}^9/_2}\,O_2 \rightarrow \mathbf{2}CO_2 + SO_2 + \mathbf{3}H_2O$ **or** $\mathbf{2}C_2H_5SH + \mathbf{9}O_2 \rightarrow \mathbf{4}CO_2 + \mathbf{2}SO_2 + \mathbf{6}H_2O$ correct products correct equation which is balanced	(1) (1)	
		(ii)	**for CO_2** enhanced greenhouse effect global warming	(1) (1)	
			for SO_2 formation of acid rain damage to stonework of buildings/ dissolving of aluminium ions into rivers/ damage to watercourses or forests/ aquatic life destroyed/ corrosion of metals	(1) (1)	[6]
	(d)		help detect leaks of gas	(1)	[1]
	(e)		temperature of 450°C pressure of 1 – 2 atm V_2O_5/vanadium(V) oxide/vanadium pentoxide catalyst	(1) (1) (1)	[3]

[Total: 15]

3



(a)	**U**	$CaCl_2$	(1)	
	V	CaO	(1)	
	W	$Ca(NO_3)_2$	(1)	
	X	$Ca(OH)_2$	(1)	
	Y	$CaCO_3$	(1)	[5]

(b) heat strongly in a test-tube or a boiling tube
do not allow 'heat gently' or 'reflux' (1) [1]

(c) **(i)** Ca to **U**
$Ca + 2HCl \rightarrow CaCl_2 + H_2$ (1)

V to **W**
$CaO + 2HNO_3 \rightarrow Ca(NO_3)_2 + H_2O$ (1)

U to **Y**
$CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 + 2NaCl$ (1)

(ii) $2Ca(NO_3)_2 \rightarrow 2CaO + 4NO_2 + O_2$ (1) [4]

(d) Na_2SO_4(aq)/K_2SO_4(aq) **or** formula of any **soluble** sulfate (1) [1]

(e) **(i)** Ca to **X**
colourless gas formed/fizzing/effervescence/bubbles **or**
Ca dissolves **or**
white precipitate/suspension formed (1)

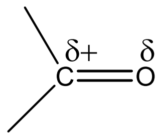
(ii) strongly exothermic/vigorous reaction **or**
steam formed/steamy fumes **or**
surface crumbles (1)
do not allow white ppt. [2]

[Total: 13]

4 **(a)** **(i)** nucleophilic addition (1)
both words are necessary

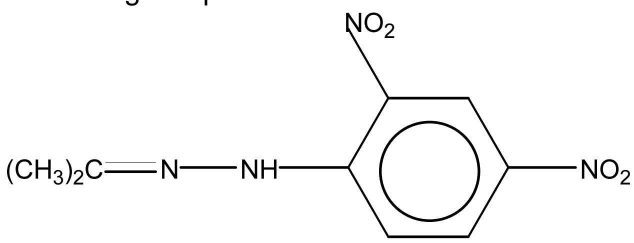
(ii) NaCN and H_2SO_4 **or**
HCN plus CN
do not allow HCN on its own (1)

(iii) correct δ+ **and** δ-, i.e.



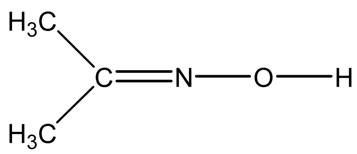
(1) [3]

(b) **(i)** correct organic product



C=N bond must be clearly shown (1)
H_2O formed/ equation balanced (1) [2]

(ii)



(1) [1]

[Total: 6]

5 **(a)** $CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2$ (1) [1]

(b) **(i)** step 1 electrophilic (1)
addition (1)
step 2 elimination **or** dehydrohalogenation (1)

(ii) reagent NaOH/KOH/OH (1)
conditions in alcohol/ethanol (1)
only allow conditions mark if reagent is correct [5]

(c) **(i)** **Q** is CH_3CHO (as minimum) (1)
R is CH_3CO_2H (as minimum) (1)

(ii) step 3 is addition (1)
step 4 is oxidation/redox (1) [4]

(d) **(i)** **combustion**
$C_2H_2(g) + {}^{\mathbf{5}}/_{\mathbf{2}}O_2(g) \rightarrow \mathbf{2}CO_2(g) + H_2O(l)$ **or**
equation must be for the combustion of one mole of C_2H_2
H_2O must be shown as liquid (1)
correct state symbols in this equation (1)

formation
$2C(s) + H_2(g) \rightarrow C_2H_2(g)$
no mark for state symbols here (1)

(ii) let **Z** be $\Delta H^{\ominus}_{f}$ of C_2H_2

	C_2H_2 +	${}^{5}/_{2}O_2$ →	$2CO_2$ +	H_2O
$\Delta H^{\ominus}_{f}$	**Z**	0	2(-394)	-286

$\Delta H^{\ominus}_{c}$ = -1300 = 2(-394) + (-286) – **Z** (1)

whence **Z** = 2(-394) + (-286) – (-1300)

= **+**226 kJ mol^{1}
value (1)
sign (1)
allow ecf on wrong equation [6]

[Total: 16]

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

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

1499884392

CHEMISTRY **9701/21**

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.
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UNIVERSITY *of* CAMBRIDGE International Examinations

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

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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]

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(b) Use your answers to **(a)** to calculate the empirical formula of **A**.

[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.

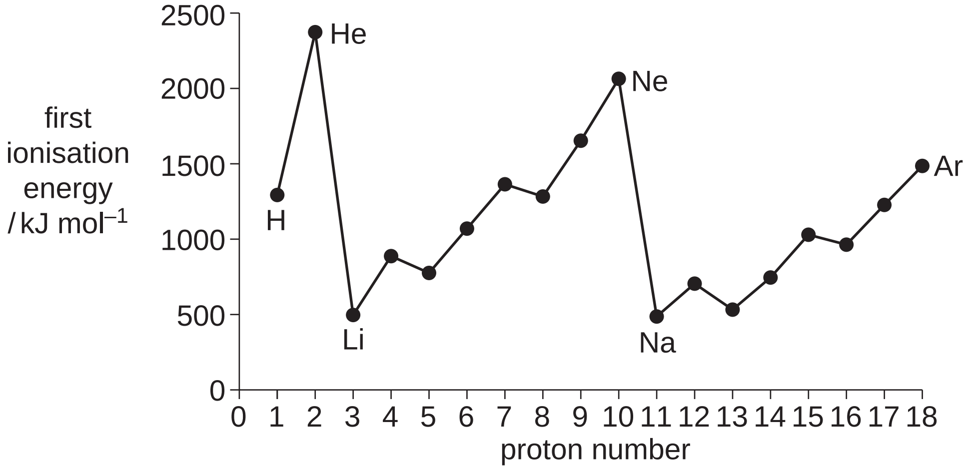
....

.... [1]

[Total: 13]

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.

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]

For Examiner's Use

experiment 2

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.

$$2KHCO_3 \rightarrow K_2CO_3 + CO_2 + H_2O$$

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]

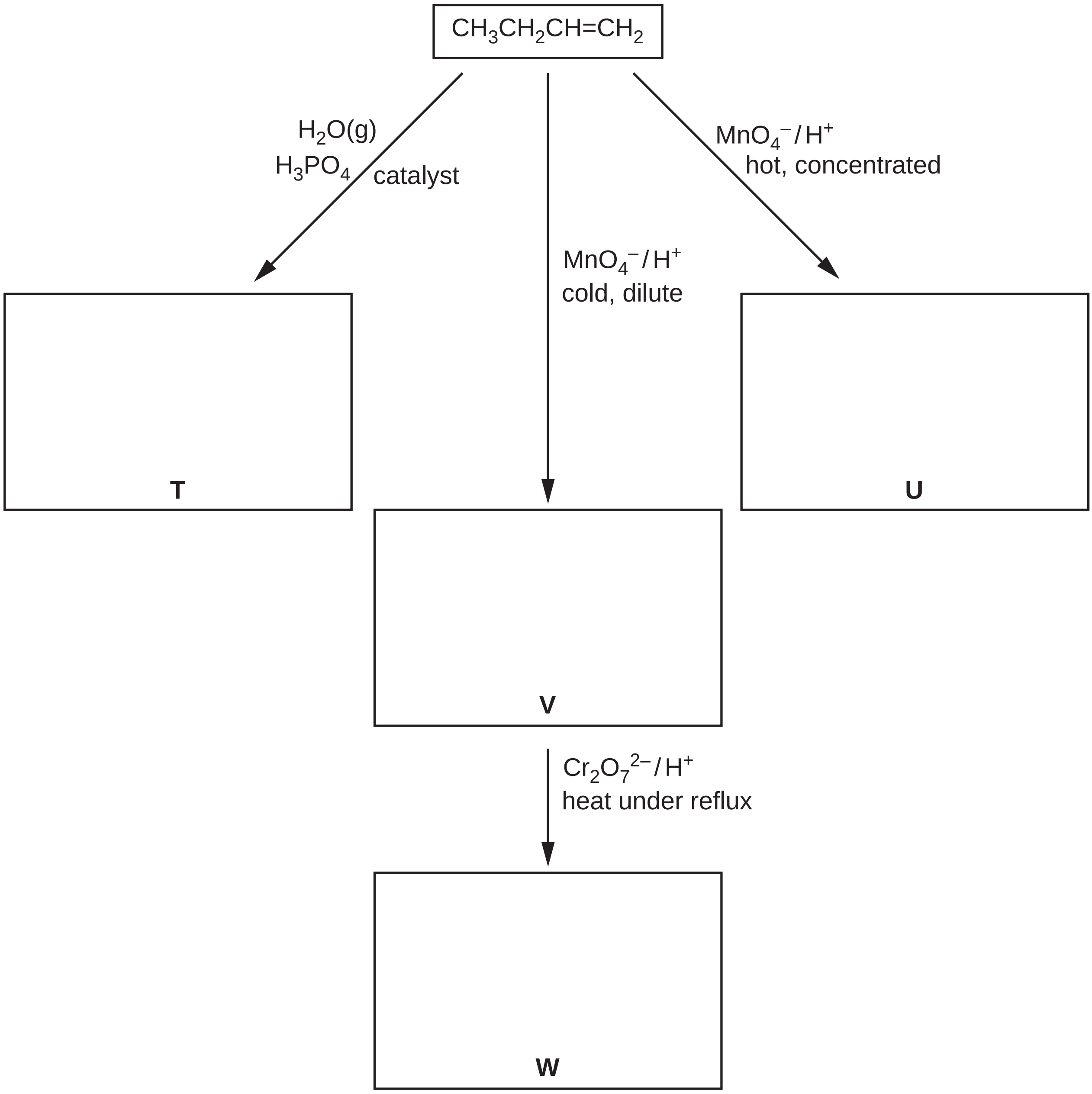
[Total: 11]

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]

For Examiner's Use

(b) Compound **T** reacts with compound **U**.

Draw the **displayed** formula of the organic product of this reaction.

[2]

[Total: 7]

For Examiner's Use

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]

For Examiner's Use

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]

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS

GCE Advanced Subsidiary Level and GCE Advanced Level

MARK SCHEME for the October/November 2011 question paper for the guidance of teachers

9701 CHEMISTRY

9701/21 Paper 2 (AS Structured Questions), maximum raw mark 60

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

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1 (a) (i) mass of C = $\frac{12 \times 0.352}{44}$ = 0.096g (1)

n(C) = $\frac{0.096}{12}$ = 0.008 (1)

(ii) mass of H = $\frac{2 \times 0.144}{18}$ = 0.016g (1)

n(H) = $\frac{0.016}{1}$ = 0.016 (1)

(iii) mass of oxygen = 0.240 – (0.096 + 0.016) = 0.128g (1)

n(O) = $\frac{0.128}{16}$ = 0.008 (1)

allow ecf at any stage [6]

(b) C : H : O = 0.008: 0.016 : 0.008 = 1:2:1

allow C : H : O = $\frac{0.096}{12} : \frac{0.016}{1} : \frac{0.128}{16}$ = 1:2:1

gives CH_2O (1) [1]

(c) (i) $M_r = \frac{mRT}{pV} = \frac{0.148 \times 8.31 \times 333}{1.01 \times 10^5 \times 67.7 \times 10^{6}}$ (1)

= 59.89

allow 59.9 or 60 (1)

(ii) $C_2H_4O_2$ (1) [3]

(d) CH_3CO_2H (1)

HCO_2CH_3 (1) [2]

(e) the only products of the reaction are the two oxides H_2O and CO_2 and copper (1) [1]

[Total: 13]

2 **(a)** $S(g) \rightarrow S^+(g) + e$
correct equation (1)
correct state symbols (1) [2]

(b) **from Na to Ar**,
electrons are added to the same shell/have same shielding (1)
electrons are subject to increasing nuclear charge/proton number (1)
electrons are closer to the nucleus **or** atom gets smaller (1) [3]

(c) **(i)** **Mg and A*l***
in Mg outermost electron is in 3s **and**
in A*l* outermost electron is in 3p (1)

3p electron is at higher energy **or**
is further away from the nucleus **or**
is more shielded from the nucleus (1)

(ii) **S and P**
for S one 3p orbital has paired electrons **and**
for P 3p sub-shell is singly filled (1)

paired electrons repel (1) [4]

(d) **(i) and (ii)**

element	Na	Mg	A*l*	Si	P	S
conductivity	high	high	—	moderate	low	low
melting point	low	high	—	high	low	low
	(1)	(1)		(1)	(1)	(1)

one mark for each correct column [5]

(e) germanium/Ge (1) [1]

[Total: 15]

3 **(a)** the overall enthalpy change/energy change/ΔH for a reaction (1)

is independent of the route taken **or**
is independent of the number of steps involved
provided the initial and final conditions are the same (1) [2]

(b) **(i)** $K_2CO_3 + 2HCl \rightarrow 2KCl + H_2O + CO_2$ (1)

(ii) heat produced $= m \times c \times \delta T = 30.0 \times 4.18 \times 5.2$
$= 652.08$ J per 0.0200 mol of K_2CO_3 (1)

(iii) 0.020 mol $K_2CO_3 \equiv 652.08$ J

1 mol $K_2CO_3 \equiv \dfrac{652.08 \times 1}{0.0200} = 32604$ J

enthalpy change = –32.60 kJmol ^{1} (1)

(iv) to prevent the formation of $KHCO_3$ **or**
to ensure complete neutralisation (1) [4]

(c) **(i)** $KHCO_3 + HCl \rightarrow KCl + H_2O + CO_2$ (1)

(ii) heat absorbed $= m \times c \times \delta T = 30.0 \times 4.18 \times 3.7$
$= 463.98$ J per 0.0200 mol of $KHCO_3$ (1)

(iii) 0.020 mol $KHCO_3 \equiv 463.98$ J

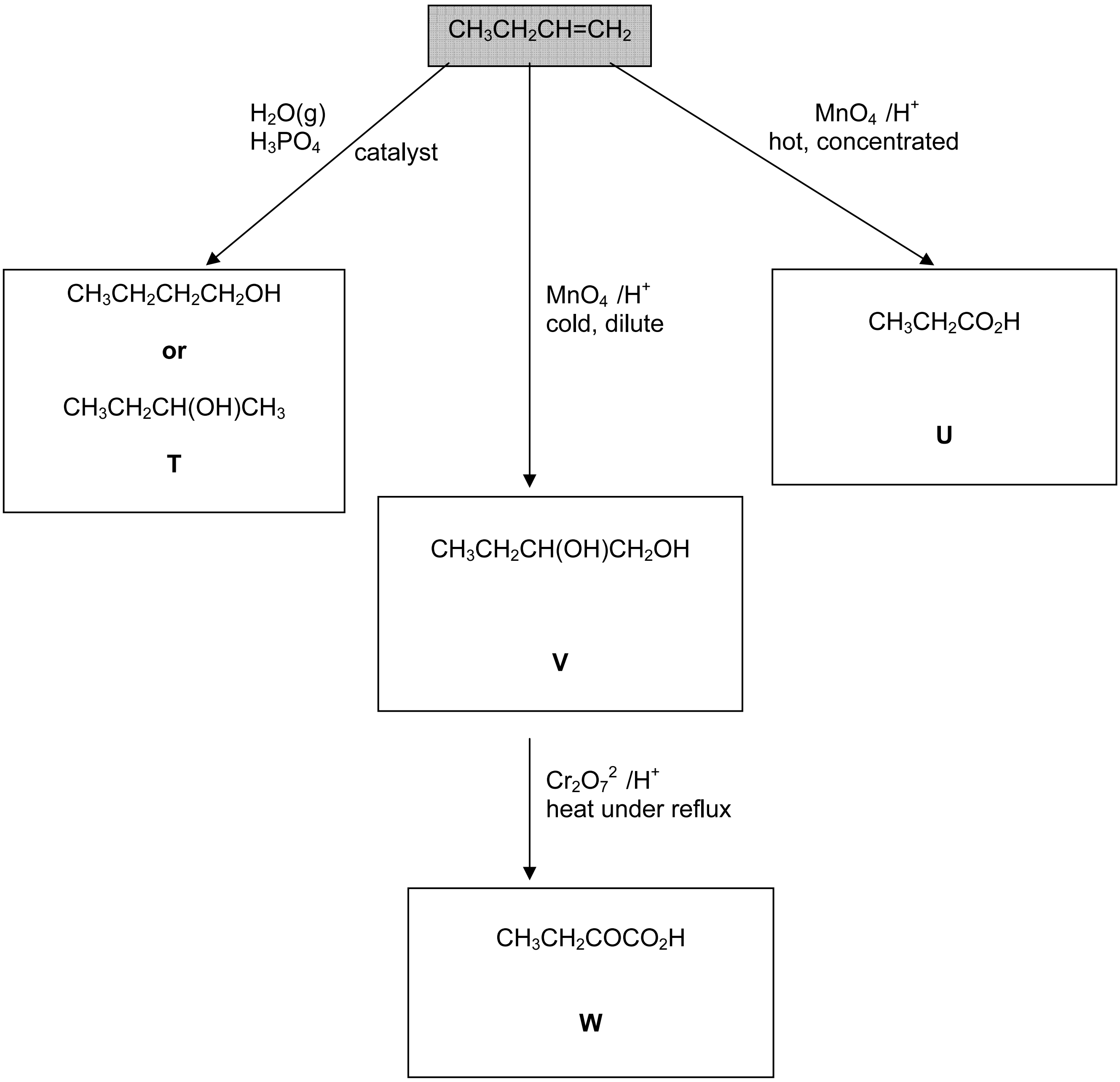
1 mol $KHCO_3 \equiv \dfrac{463.98 \times 1}{0.0200} = 23199$ J

enthalpy change = +23.20 kJmol ^{1} (1) [3]

(d) $\Delta H = 2 \times (+23.20) - (-32.60) = +79.00$ kJ mol ^{1} (2) [2]

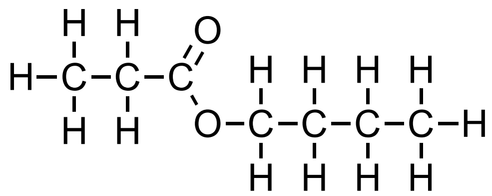
[Total: 11]

4 (a)

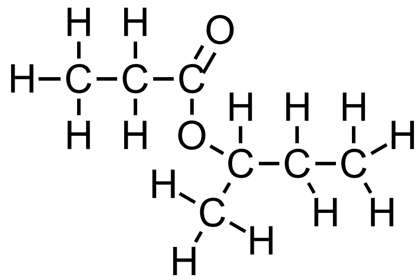


correct **T**	(1)	
correct **U**	(1)	
correct **V**	(1)	
correct > CO group in **W**	(1)	
correct –CO_2H group in **W**	(1)	[5]

(b) **T + U**



or



correct structures (1)
correctly displayed ester group (1) [2]

[Total: 7]

5 (a) (i) 1 primary (1)
alcohol **not** hydroxyl (1)

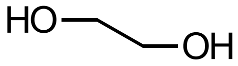
2 aldehyde **not** carbonyl (1)

(ii)

test 1			
reagent	Na	$PCl_3/PCl_5/PBr_3$	RCO_2H/H^+
observation	gas/H_2/effervescence/ fizzing	HCl/HBr steamy fumes	fruity smell
test 2			
reagent	Tollens' reagent	Fehling's reagent	2,4-dinitro-phenylhydrazine
observation	Ag mirror/silver/ black ppt	brick-red ppt red ppt	orange/red/yellow ppt/solid

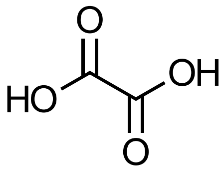
only award the observation mark if reagent is correct (4) [7]

(b) (i)



(1)

(ii)



(1) [2]

5 (c)

route	starting compound	**first reagent**	intermediate **X**	**second reagent**	intermediate **Y**	**third reagent**	final compound
A/1	$HOCH_2CHO$	PCl_3 PCl_5 $SOCl_2$ etc.	$ClCH_2CHO$	$K_2Cr_2O_7/H^+$ $KMnO_4/H^+$ $KMnO_4/OH$ Tollens' or Fehling's reagents	$ClCH_2CO_2H$	NH_3	$H_2NCH_2CO_2H$
A/2	$HOCH_2CHO$	HBr P/Br_2 etc.	$BrCH_2CHO$	$K_2Cr_2O_7/H^+$ $KMnO_4/H^+$ $KMnO_4/OH$ Tollens' or Fehling's reagents	$BrCH_2CO_2H$	NH_3	$H_2NCH_2CO_2H$
B/1	$HOCH_2CHO$	PCl_3 PCl_5 $SOCl_2$ etc.	$ClCH_2CHO$	NH_3	H_2NCH_2CHO	$K_2Cr_2O_7/H^+$ $KMnO_4/H^+$ $KMnO_4/OH$ Tollens' or Fehling's reagents	$H_2NCH_2CO_2H$
B/2	$HOCH_2CHO$	HBr P/Br_2 etc.	$BrCH_2CHO$	NH_3	H_2NCH_2CHO	$K_2Cr_2O_7/H^+$ $KMnO_4/H^+$ $KMnO_4/OH$ Tollens' or Fehling's reagents	$H_2NCH_2CO_2H$
C	$HOCH_2CHO$	Tollens' or Fehling's reagents	$HOCH_2CO_2H$	KBr/conc. H_2SO_4	$BrCH_2CO_2H$	NH_3	$H_2NCH_2CO_2H$
mark		(1)	(1)	(1)	(1)	(1)	

[5]

[Total: 14]

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.

UNIVERSITY of CAMBRIDGE
International Examinations

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]

For Examiner's Use

(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]

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.

$$CH_2 = CH_2(g) \quad + \quad HF(g) \quad \longrightarrow \quad CH_3CH_2F(g) \qquad \Delta H^{\ominus} = -73\,\mathrm{kJ\,mol^{-1}}$$

C–F bond energy = ... $\mathrm{kJ\,mol^{-1}}$ [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.

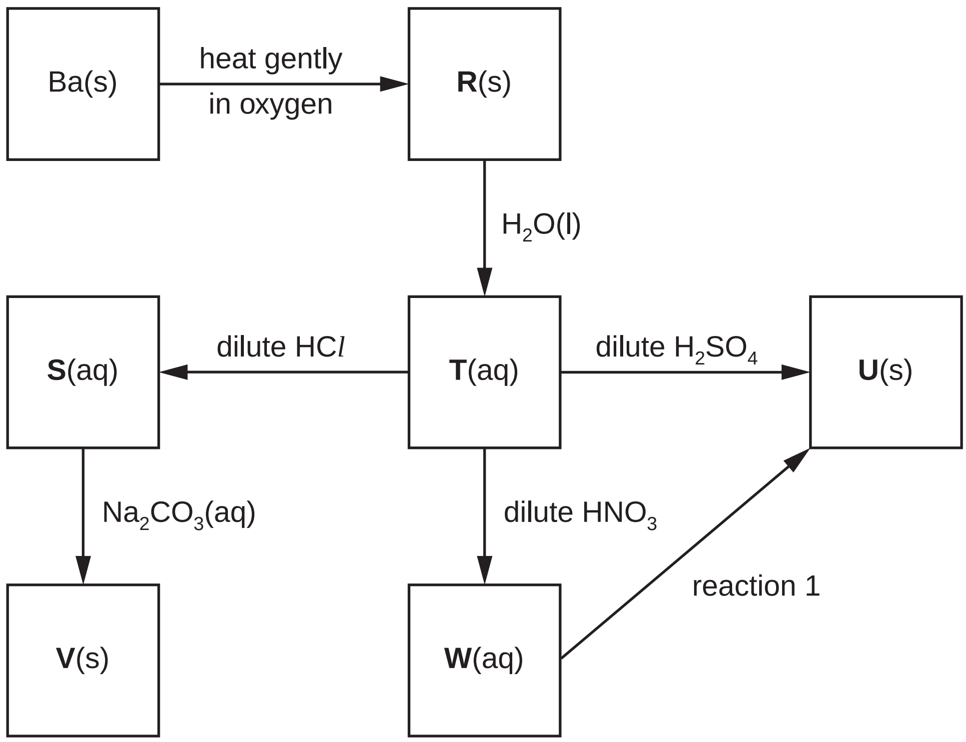
(e) What shape is the SF_6 molecule?

.... [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.

For Examiner's Use

reagent ....

equation ....

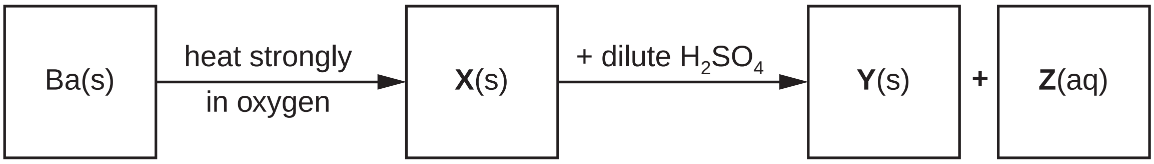
[4]

(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]

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For Examiner's Use

4 Chlorine is manufactured by electrolysis from brine, concentrated aqueous sodium chloride.

(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.

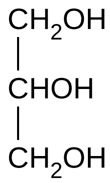
.... [7]

[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 ....

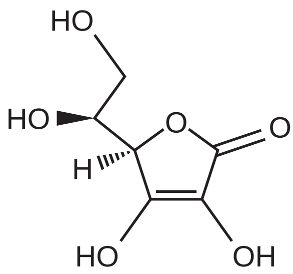
[6]

Animal fats and vegetable oils can become rancid because of oxidation. The rancid fat or oil has an unpleasant smell and taste.

For Examiner's Use

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

GCE Advanced Subsidiary Level and GCE Advanced Level

MARK SCHEME for the May/June 2011 question paper

for the guidance of teachers

9701 CHEMISTRY

9701/22 Paper 2 (AS Structured Questions), maximum raw mark 60

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1 **(a)** $K_c = \dfrac{[CH_3CH_2R][H_20]}{[CH_3CH_2H][ROH]}$ (1)

no units (1) [2]

(b) **(i)** $n(\text{NaOH}) = \dfrac{22.5 \times 2.00}{1000} = 0.045$ (1)

(ii) $n(\text{NaOH}) = n(\text{HC}l) = 0.005$ (1)

(iii) $CH_3CO_2H + NaOH \rightarrow CH_3CO_2Na + H_2O$ (1)

(iv) $n(\text{NaOH}) = 0.045 – 0.005 = 0.04$
allow ecf on **(i)** and/or **(ii)** (1) [4]

(c) **(i)** $n(\text{NaOH})$ **and** $n(CH_3CO_2H) = 0.04$ (1)
$n(CH_3CO_2R)$ **and** $n(H_2O) = 0.06$ (1)

(ii) $K_c = \dfrac{0.06 \times 0.06}{0.04 \times 0.04} = 2.25$

allow ecf on wrong values in **(b)(i)**
allow ecf on wrong expression in **(a)** (1) [3]

(d) E_a for reaction with ester is high **or**
E_a for reaction with acid is low
or
reaction with ester is slow **or**
reaction with acid is fast (1) [1]

(e) equilibrium moves to RHS/more ester would be formed (1)
to maintain value of K_c **or**
to restore system to equilibrium (1) [2]

[Total: 12]

2 **(a)** $CH_2{=}CH_2 + HF \rightarrow CH_3CH_2F$

bonds	4 C-H	1640	bonds	5 C-H	2050
broken	1 C=C	610	made	1 C-C	350
/kJ mol^{1}	1 H-F	<u>562</u>	/kJ mol^{1}	1 C-F	<u>*E*</u>
		2812			(2400 + *E*)

breaking reactant bonds requires
4 x 410 + 610 + 562 = 2812 kJ mol^{1} (1)

making product bonds gives

5 x 410 + 350 + *E* = (2400 + *E*) kJ mol^{1} (1)

$\Delta H^{\ominus}_{reaction}$ = - (2400 + *E*) + 2812 = – 73 kJ mol^{1} (1)

(2400 + *E*) = 2812 + 73 = 2885 kJ mol^{1}

E = 2885 - 2400 = 485 kJ mol^{1} (1)

allow ecf on wrong bond energy values and/or incorrect arithmetic [4]

(b) any **two** from
non-toxic
unreactive
volatile
non-flammable
easily liquefied (1 + 1) [2]

(c) in CCl_2F_2
C-Cl bond energy is 340 kJ mol 1 and is weaker than C-F or C-H bonds (1)
C-Cl bond is broken by uvl **or**
Cl free radicals are formed (1) [2]

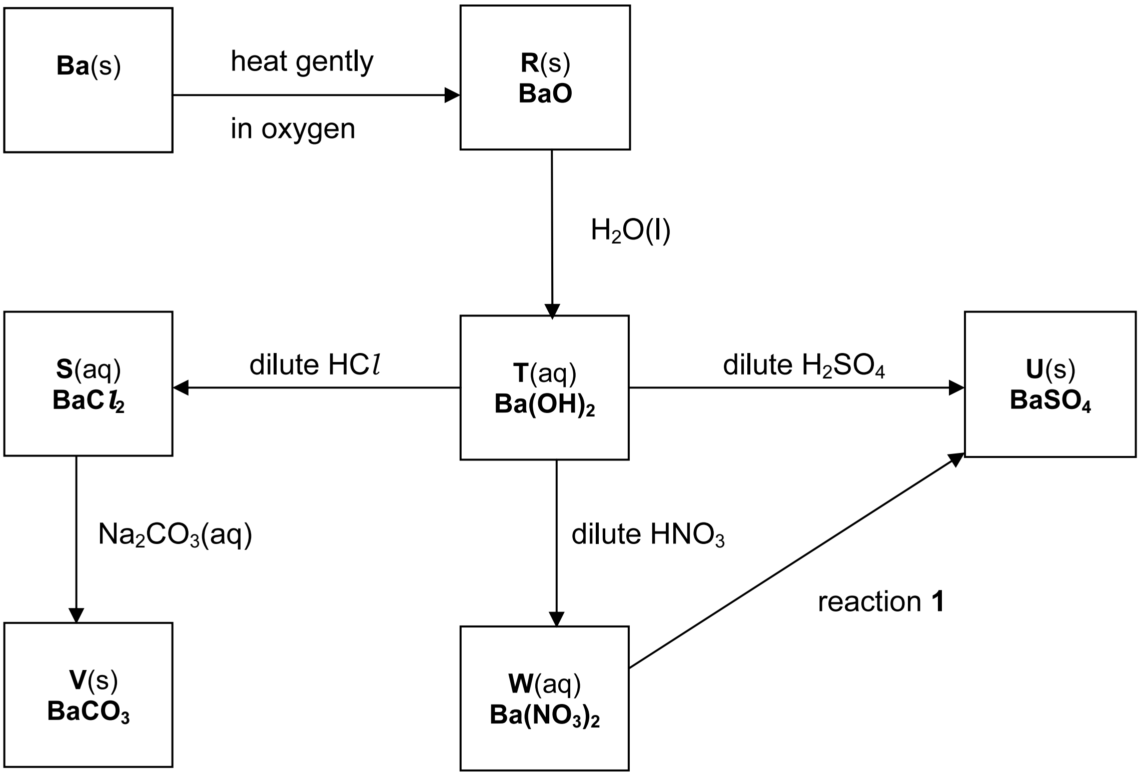
(d) **(i)** the trapping of reflected heat from the Earth in the lower atmosphere producing global warming

(ii) CO_2/carbon dioxide (1) [3]

(e) octahedral (1) [1]

[Total: 12]

3



(a) **R** BaO (1)
S $BaCl_2$ (1)
T $Ba(OH)_2$ (1)
U $BaSO_4$ (1)
V $BaCO_3$ (1)
W $Ba(NO_3)_2$ (1) [6]

(b) **(i)** **T** to **W**
$Ba(OH)_2 + 2HNO_3 \rightarrow Ba(NO_3)_2 + 2H_2O$ (1)

heat on **V**
$BaCO_3 \rightarrow BaO + CO_2$ (1)

(ii) **T** to **V**
CO_2 (1)
$Ba(OH)_2 + CO_2 \rightarrow BaCO_3 + H_2O$ (1) [4]

(c) $Na_2SO_4(aq)/K_2SO_4(aq)$ or any soluble sulfate (1) [1]

(d) (i) Ba:O = $\frac{81.1}{137} : \frac{18.9}{16}$ (1)

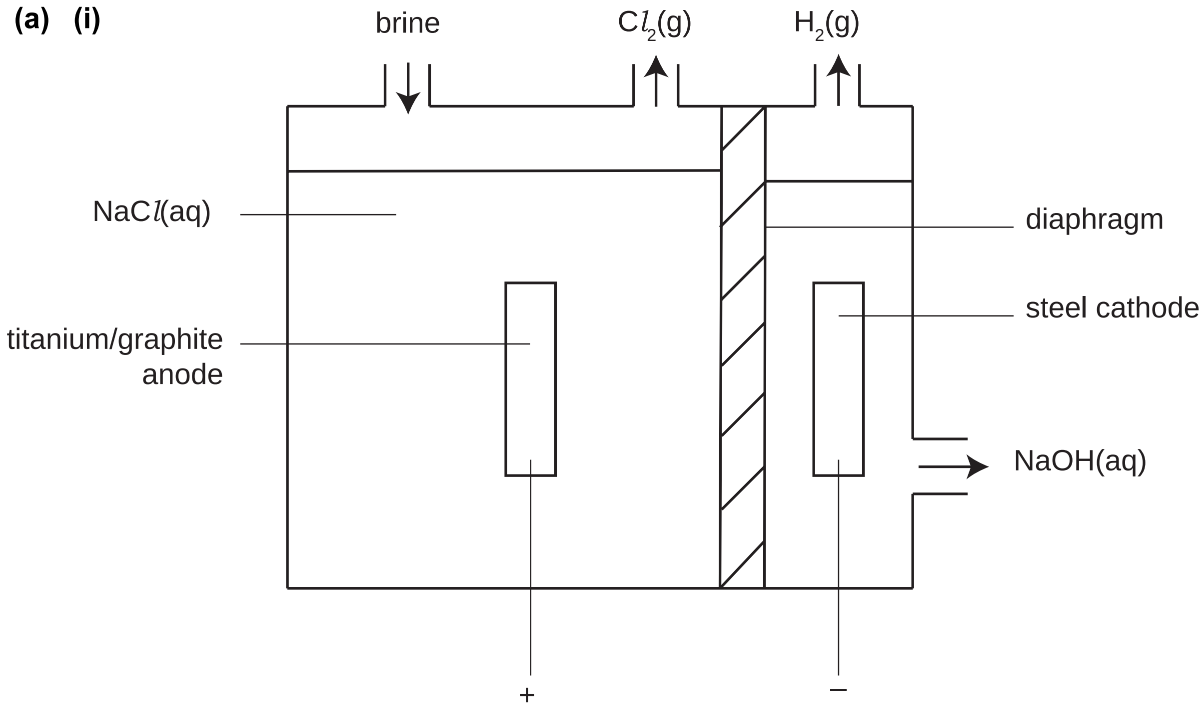
= 0.59 : 1.18
= 1 : 2
gives BaO_2 (1)

(ii) $BaSO_4$ (1)

(iii) $BaO_2 + H_2SO_4 \rightarrow BaSO_4 + H_2O_2$ (1) [4]

[Total: 15]

4 (a) (i)



titanium/graphite anode identified correctly (1)
steel cathode identified correctly (1)
diaphragm identified correctly (1)
all three outlets correctly shown (1) [4]

(ii) **anode** $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$ (1)

cathode $2H^+(aq) + 2e^- \rightarrow H_2(g)$

or $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$ (1) [2]

(iii) sodium hydroxide (1) [1]

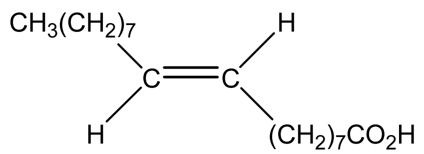
[Total: 7]

5 **(a)** $CH_2OCO(CH_2)_{16}CH_3$
|
$CHOCO(CH_2)_{16}CH_3$
|
$CH_2OCO(CH_2)_{16}CH_3$

all three alcohol groups must be esterified (1) [1]

(b) dilute HC*l* **or** dilute H_2SO_4 **or** dilute mineral acid
or NaOH(aq) **followed by** dilute acid (1) [1]

(c)



(1) [1]

(d) **(i)** fatty acid that contains more than one C=C bond (1)

(ii) hydrogen (1)
nickel/Raney nickel/platinum/palladium (1) [3]

(e) **(i)** $CH_3(CH_2)_7CHO$ (1)
$OHC(CH_2)_7CX$ (1)

(ii) 2,4-dinitrophenylhydrazine (1)
yellow/orange/red precipitate (1)

(iii) Tollens' reagent **or** Fehling's/Benedict's solution (1)
silver mirror/ **or** brick red ppt.
grey precipitate (1) [6]

(f) **(i)** two (1)

(ii) ester (1) [2]

[Total: 14]

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 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.

DC (NH) 49196

[Turn over

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]

For Examiner's Use

(b) Use your answers to **(a)** to calculate the empirical formula of **A**.

[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.

....

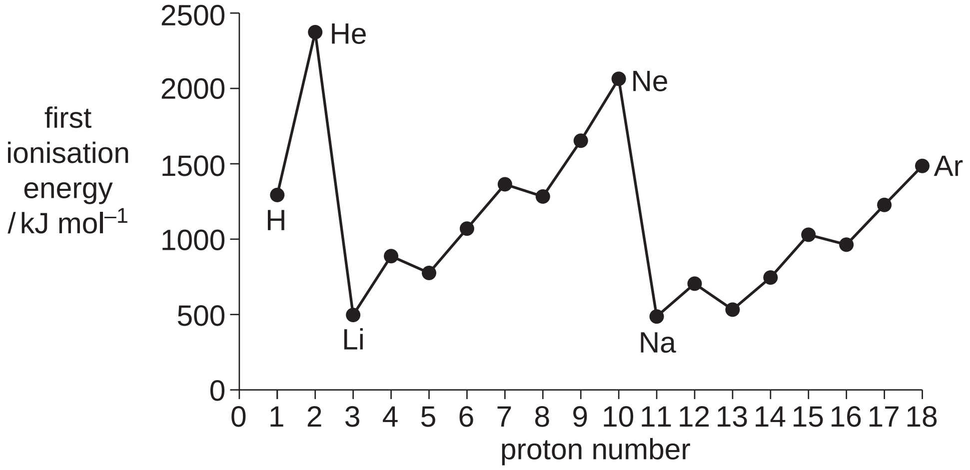
.... [1]

[Total: 13]

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.

For Examiner's Use

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.

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]

For Examiner's Use

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]

For Examiner's Use

experiment 2

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.

$$2KHCO_3 \rightarrow K_2CO_3 + CO_2 + H_2O$$

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.

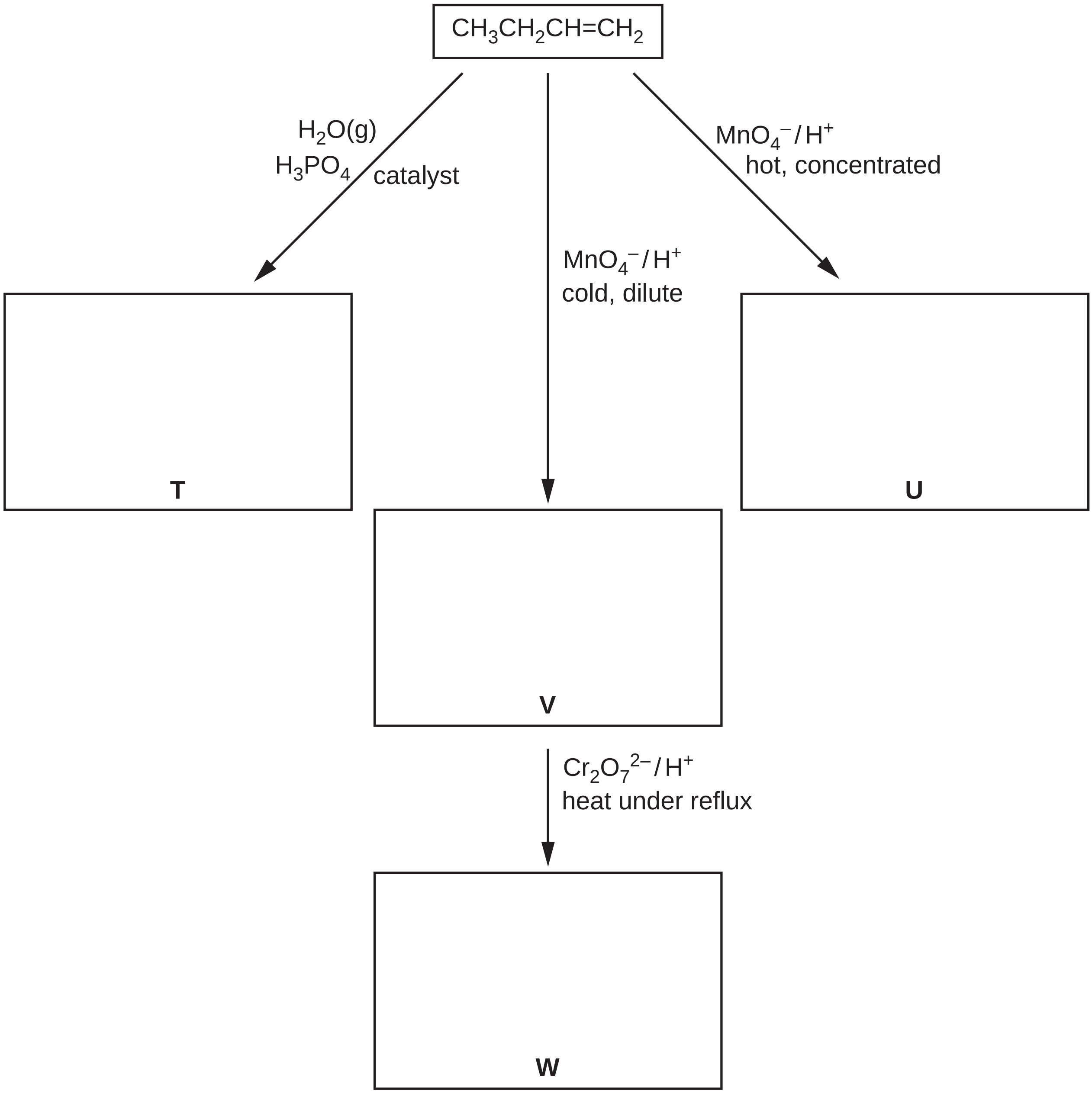
[2]

[Total: 11]

4 But-1-ene, $CH_3CH_2CH{=}CH_2$, is an important compound in the petrochemical industry.

(a) Some reactions of but-1-ene are given below.

In **each** empty box, draw the structural formula of the organic compound formed.



[5]

For Examiner's Use

(b) Compound **T** reacts with compound **U**.

Draw the **displayed** formula of the organic product of this reaction.

[2]

[Total: 7]

For Examiner's Use

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]

For Examiner's Use

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]

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS

GCE Advanced Subsidiary Level and GCE Advanced Level

MARK SCHEME for the October/November 2011 question paper for the guidance of teachers

9701 CHEMISTRY

9701/22 Paper 2 (AS Structured Questions), maximum raw mark 60

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

Mark schemes must be read in conjunction with the question papers and the report on the examination.

- Cambridge will not enter into discussions or correspondence in connection with these mark schemes.

Cambridge is publishing the mark schemes for the October/November 2011 question papers for most IGCSE, GCE Advanced Level and Advanced Subsidiary Level syllabuses and some Ordinary Level syllabuses.

1 **(a)** **(i)** mass of C = $\frac{12 \times 0.352}{44}$ = 0.096g (1)

n(C) = $\frac{0.096}{12}$ = 0.008 (1)

(ii) mass of H = $\frac{2 \times 0.144}{18}$ = 0.016g (1)

n(H) = $\frac{0.016}{1}$ = 0.016 (1)

(iii) mass of oxygen = 0.240 – (0.096 + 0.016) = 0.128g (1)

n(O) = $\frac{0.128}{16}$ = 0.008 (1)

allow ecf at any stage [6]

(b) C : H : O = 0.008: 0.016 : 0.008 = 1:2:1

allow C : H : O = $\frac{0.096}{12} : \frac{0.016}{1} : \frac{0.128}{16}$ = 1:2:1

gives CH_2O (1) [1]

(c) **(i)** $M_r = \frac{mRT}{pV} = \frac{0.148 \times 8.31 \times 333}{1.01 \times 10^5 \times 67.7 \times 10^{6}}$ (1)

= 59.89

allow 59.9 or 60 (1)

(ii) $C_2H_4O_2$ (1) [3]

(d) CH_3CO_2H (1)

HCO_2CH_3 (1) [2]

(e) the only products of the reaction are the two oxides H_2O and CO_2 and copper (1) [1]

[Total: 13]

2 **(a)** $S(g) \rightarrow S^+(g) + e$
correct equation (1)
correct state symbols (1) [2]

(b) **from Na to Ar**,
electrons are added to the same shell/have same shielding (1)
electrons are subject to increasing nuclear charge/proton number (1)
electrons are closer to the nucleus **or** atom gets smaller (1) [3]

(c) **(i)** **Mg and A*l***
in Mg outermost electron is in 3s **and**
in A*l* outermost electron is in 3p (1)

3p electron is at higher energy **or**
is further away from the nucleus **or**
is more shielded from the nucleus (1)

(ii) **S and P**
for S one 3p orbital has paired electrons **and**
for P 3p sub-shell is singly filled (1)

paired electrons repel (1) [4]

(d) **(i) and (ii)**

element	Na	Mg	A*l*	Si	P	S
conductivity	high	high	—	moderate	low	low
melting point	low	high	—	high	low	low
	(1)	(1)		(1)	(1)	(1)

one mark for each correct column [5]

(e) germanium/Ge (1) [1]

[Total: 15]

3 **(a)** the overall enthalpy change/energy change/ΔH for a reaction (1)

is independent of the route taken **or**
is independent of the number of steps involved
provided the initial and final conditions are the same (1) [2]

(b) **(i)** $K_2CO_3 + 2HCl \rightarrow 2KCl + H_2O + CO_2$ (1)

(ii) heat produced $= m \times c \times \delta T = 30.0 \times 4.18 \times 5.2$
$= 652.08$ J per 0.0200 mol of K_2CO_3 (1)

(iii) 0.020 mol $K_2CO_3 \equiv 652.08$ J

1 mol $K_2CO_3 \equiv \dfrac{652.08 \times 1}{0.0200} = 32604$ J

enthalpy change = –32.60 kJmol 1 (1)

(iv) to prevent the formation of $KHCO_3$ **or**
to ensure complete neutralisation (1) [4]

(c) **(i)** $KHCO_3 + HCl \rightarrow KCl + H_2O + CO_2$ (1)

(ii) heat absorbed $= m \times c \times \delta T = 30.0 \times 4.18 \times 3.7$
$= 463.98$ J per 0.0200 mol of $KHCO_3$ (1)

(iii) 0.020 mol $KHCO_3 \equiv 463.98$ J

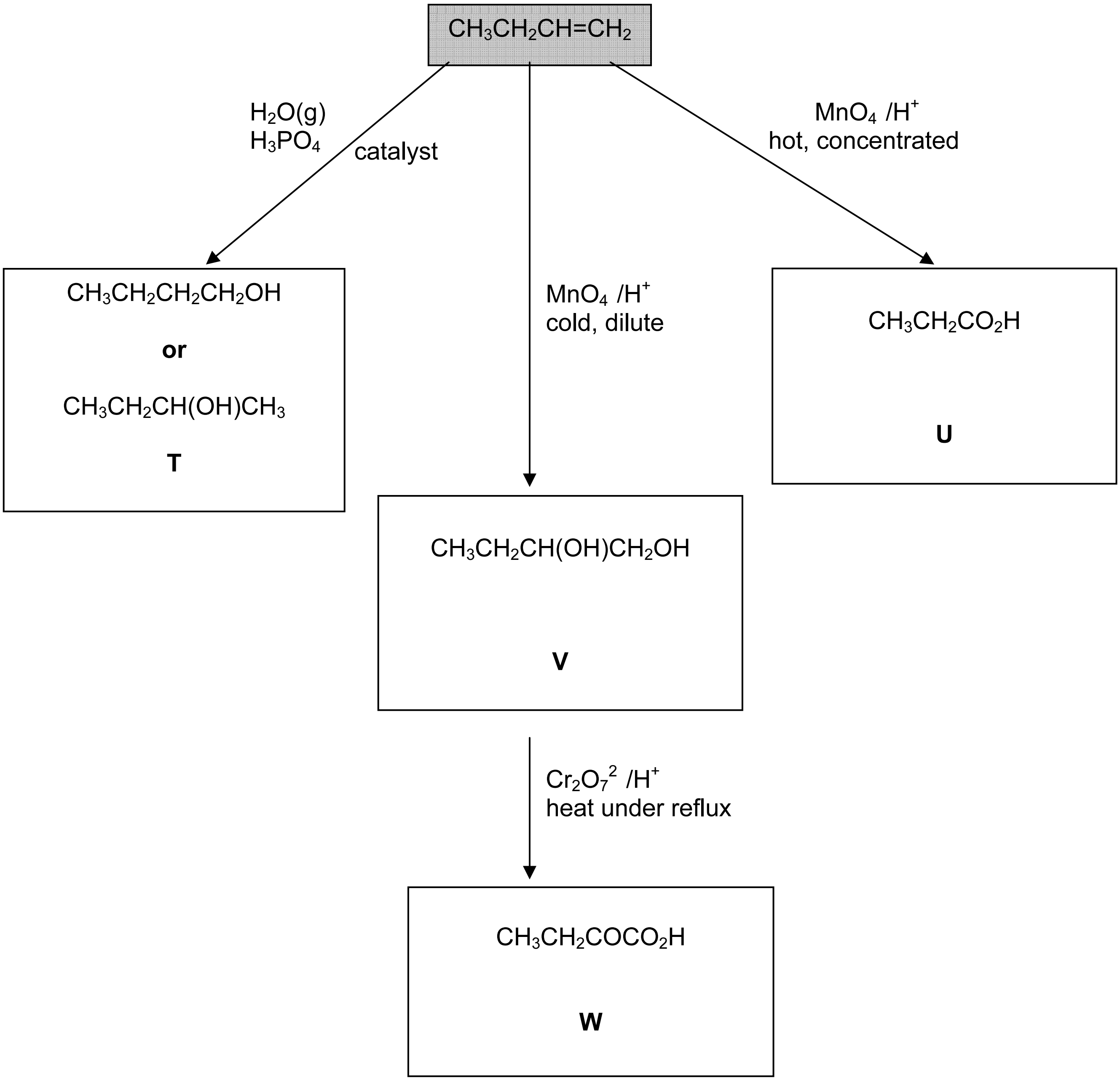
1 mol $KHCO_3 \equiv \dfrac{463.98 \times 1}{0.0200} = 23199$ J

enthalpy change = +23.20 kJmol 1 (1) [3]

(d) $\Delta H = 2 \times (+23.20) - (-32.60) = +79.00$ kJ mol 1 (2) [2]

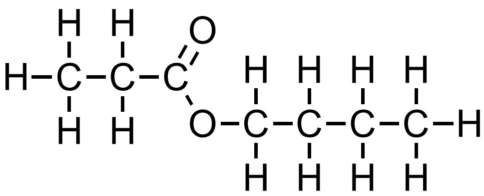
[Total: 11]

4 (a)

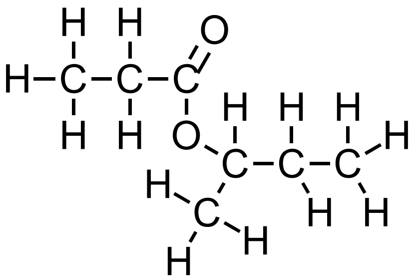


correct **T** (1)
correct **U** (1)
correct **V** (1)
correct > CO group in **W** (1)
correct –CO_2H group in **W** (1) [5]

(b) T + U



or



correct structures (1)
correctly displayed ester group (1) [2]

[Total: 7]

5 (a) (i) 1 primary (1)
alcohol **not** hydroxyl (1)

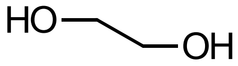
2 aldehyde **not** carbonyl (1)

(ii)

test 1			
reagent	Na	PCl_3/PCl_5/PBr_3	RCO_2H/H^+
observation	gas/H_2/effervescence/ fizzing	HC*l*/HBr steamy fumes	fruity smell
test 2			
reagent	Tollens' reagent	Fehling's reagent	2,4-dinitro- phenylhydrazine
observation	Ag mirror/silver/ black ppt	brick-red ppt red ppt	orange/red/yellow ppt/solid

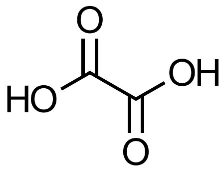
only award the observation mark if reagent is correct (4) [7]

(b) (i)



(1)

(ii)



(1) [2]

5 (c)

route	starting compound	**first reagent**	intermediate **X**	**second reagent**	intermediate **Y**	**third reagent**	final compound
A/1	$HOCH_2CHO$	PCl_3 PCl_5 $SOCl_2$ etc.	$ClCH_2CHO$	$K_2Cr_2O_7/H^+$ $KMnO_4/H^+$ $KMnO_4/OH$ Tollens' or Fehling's reagents	$ClCH_2CO_2H$	NH_3	$H_2NCH_2CO_2H$
A/2	$HOCH_2CHO$	HBr P/Br_2 etc.	$BrCH_2CHO$	$K_2Cr_2O_7/H^+$ $KMnO_4/H^+$ $KMnO_4/OH$ Tollens' or Fehling's reagents	$BrCH_2CO_2H$	NH_3	$H_2NCH_2CO_2H$
B/1	$HOCH_2CHO$	PCl_3 PCl_5 $SOCl_2$ etc.	$ClCH_2CHO$	NH_3	H_2NCH_2CHO	$K_2Cr_2O_7/H^+$ $KMnO_4/H^+$ $KMnO_4/OH$ Tollens' or Fehling's reagents	$H_2NCH_2CO_2H$
B/2	$HOCH_2CHO$	HBr P/Br_2 etc.	$BrCH_2CHO$	NH_3	H_2NCH_2CHO	$K_2Cr_2O_7/H^+$ $KMnO_4/H^+$ $KMnO_4/OH$ Tollens' or Fehling's reagents	$H_2NCH_2CO_2H$
C	$HOCH_2CHO$	Tollens' or Fehling's reagents	$HOCH_2CO_2H$	KBr/conc. H_2SO_4	$BrCH_2CO_2H$	NH_3	$H_2NCH_2CO_2H$
mark		(1)	(1)	(1)	(1)	(1)	

[5]

[Total: 14]

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

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

3660957283

CHEMISTRY **9701/23**

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	
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Total	

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DC (SM/SW) 27050/3

UNIVERSITY *of* CAMBRIDGE International Examinations

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

For Examiner's Use

1 Methanoic acid, HCO_2H, was formerly known as formic acid because it is present in the sting of ants and the Latin name for ant is *formica*. It was first isolated in 1671 by John Ray who collected a large number of dead ants and extracted the acid from them by distillation.

In this question, you should give all numerical answers to two significant figures.

At room temperature, pure methanoic acid is a liquid which is completely soluble in water.

When we are stung by a 'typical' ant a solution of methanoic acid, **A**, is injected into our skin.

Solution **A** contains 50% by volume of pure methanoic acid.

A 'typical' ant contains $7.5 \times 10^{-6}\,dm^3$ of solution **A**.

(a) **(i)** Calculate the volume, in cm^3, of solution **A** in one ant.

volume = ... cm^3

(ii) Use your answer to **(i)** to calculate the volume, in cm^3, of pure methanoic acid in one ant.

volume = ... cm^3

(iii) Use your answer to **(ii)** to calculate how many ants would have to be distilled to produce $1\,dm^3$ of pure methanoic acid.

number = ...

[3]

When we are stung by an ant, the amount of solution **A** injected is 80% of the total amount of solution **A** present in one ant.

For Examiner's Use

The density of pure methanoic acid is 1.2 g cm^{-3}.

(b) (i) Calculate the volume, in cm^3, of **pure** methanoic acid injected in one ant sting.

volume = ... cm^3

(ii) Use your answer to **(i)** to calculate the mass of methanoic acid present in one ant sting.

mass = ... g
[3]

Bees also sting us by using methanoic acid. One simple treatment for ant or bee stings is to use sodium hydrogencarbonate, $NaHCO_3$.

(c) (i) Construct a balanced equation for the reaction between methanoic acid and sodium hydrogencarbonate.

....

(ii) In a typical bee sting, the mass of methanoic acid injected is 5.4×10^{-3} g.
Calculate the mass of $NaHCO_3$ needed to neutralise one bee sting.

mass = ... g
[3]

[Total: 9]

2 The kinetic theory of gases is used to explain the large scale (macroscopic) properties of gases by considering how individual molecules behave.

For Examiner's Use

(a) State **two** basic assumptions of the kinetic theory as applied to an ideal gas.

(i) ....

....

(ii) ....

....
[2]

(b) State **two** conditions under which the behaviour of a real gas approaches that of an ideal gas.

(i) ....

(ii) ....
[2]

(c) Place the following gases in decreasing order of ideal behaviour.

ammonia, neon, nitrogen

most ideal .... **least ideal**

Explain your answer.

....

....
[3]

(d) By using the kinetic-molecular model, explain why a liquid eventually becomes a gas as the temperature is increased.

....

....

....

.... [2]

(e) Ethane, CH_3CH_3, and fluoromethane, CH_3F are *iso*-electronic, that is they have the same total number of electrons in their molecules.

Calculate the **total** number of electrons in one molecule of CH_3F.

[1]

(f) The boiling points of these two compounds are given below.

compound	bp / K
CH_3CH_3	184.5
CH_3F	194.7

Suggest explanations for the following.

(i) the close similarity of the boiling points of the two compounds

....

....

(ii) the slightly higher boiling point of CH_3F

....

....

[2]

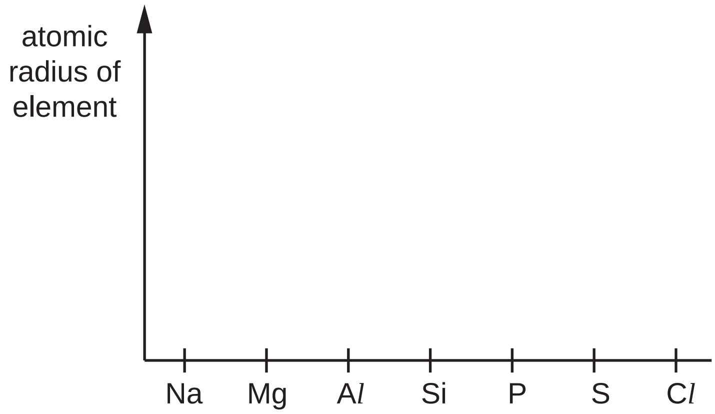
[Total: 12]

For Examiner's Use

For Examiner's Use

3 Elements in the same period of the Periodic Table show trends in physical and chemical properties. The grids on this page and on the opposite page refer to the elements of the third period, Na to C*l*.
On **each** of these grids, draw a clear sketch to show the variation of the stated property.
Below **each** grid, briefly explain the variation you have described in your sketch.
For each explanation you should refer to the important factors that cause the differences in the property you are describing.

(a)



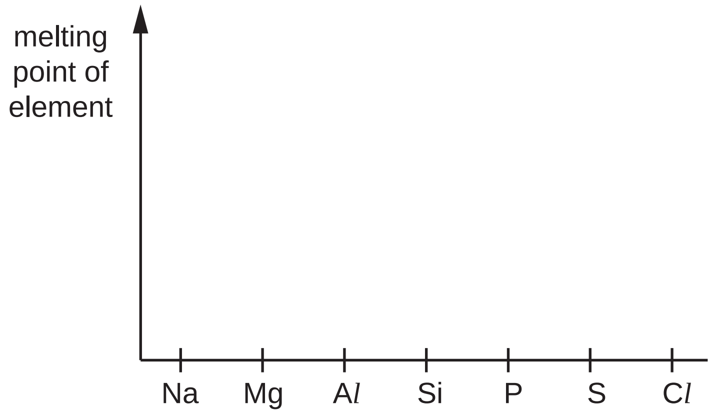
explanation ....

....

....

.... [3]

(b)



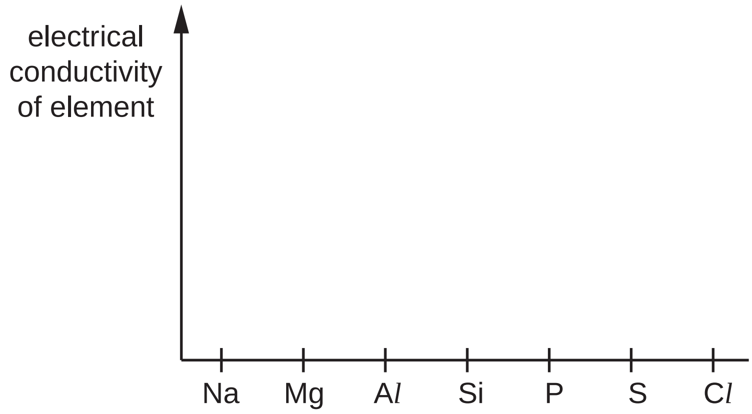
explanation ....

....

....

.... [4]

(c)



explanation ....

....

....

....

[4]

(d) The melting points of some of the oxides of the elements sodium to sulfur are given in the table below.

compound	Na_2O	MgO	Al_2O_3	SiO_2	P_4O_6	SO_2
mp / K	1193	3173	2313	1883	297	198

(i) What type of bond is broken when **each** of the following compounds is melted?

Na_2O ....

SiO_2 ....

P_4O_6 ....

(ii) Identify **one** of these six oxides that has no reaction at all with water.

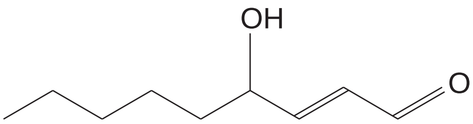
....

[4]

[Total: 15]

For Examiner's Use

4 The compound *trans*-4-hydroxy-2-nonenal (HNE) is thought to lead to infections of the lung when cigarettes are smoked.



$CH_3(CH_2)_4CH(OH)CH{=}CHCHO$

***trans*-4-hydroxy-2-nonenal**

(a) What is the empirical formula of *trans*-4-hydroxy-2-nonenal?

.... [1]

(b) **(i)** HNE contains an alkene group. Name as fully as you can **two** other functional groups which are present in the HNE molecule.

....

....

(ii) How would you confirm the presence of the alkene group in HNE? State the reagent used and the observation you would make.

reagent ....

observation .... [5]

HNE is a reactive compound.

For Examiner's Use

(c) Give the structural formulae of all of the carbon-containing compounds formed in each case when HNE is reacted separately with the following reagents.

(i) hot concentrated manganate(VII) ions in acid solution

(ii) hot phosphorus trichloride, PCl_3

(iii) sodium tetrahydridoborate(III), $NaBH_4$

[4]

[Total: 10]

For Examiner's Use

5 Fermentation of sugars by bacteria or moulds produces many different organic compounds.

One compound present in fermented molasses is 2-ethyl-3-methylbutanoic acid which gives a distinctive aroma to rum.

$$(CH_3)_2CHCH(C_2H_5)CO_2H$$

2-ethyl-3-methylbutanoic acid

(a) (i) What is the molecular formula of 2-ethyl-3-methylbutanoic acid?

(ii) How many chiral carbon atoms are present in a molecule of 2-ethyl-3-methylbutanoic acid? If none write 'none'.

....

[2]

A sample of 2-ethyl-3-methylbutanoic acid may be prepared in a school or college laboratory by the oxidation of 2-ethyl-3-methylbutan-1-ol, $(CH_3)_2CHCH(C_2H_5)CH_2OH$.

(b) (i) State the reagent(s) that would be used for this oxidation.
Describe what colour change would be seen.

reagent(s) ....

colour change from .... to ....

This reaction is carried out by heating the reacting chemicals together.

(ii) What could be the main organic impurity present in the sample of the acid?

Explain your answer.

....

....

....

(iii) State whether a distillation apparatus or a reflux apparatus should be used.

Explain your answer.

....

....

....

[6]

(c) A structural isomer of 2-ethyl-3-methylbutan-1-ol is 2-ethyl-3-methylbutan-2-ol, $(CH_3)_2CHC(OH)(C_2H_5)CH_3$.

For Examiner's Use

What colour change would be seen if this were heated with the reagents you have given in **(b)(i)**?
Explain your answer as clearly as you can.

....

....

.... [3]

An isomer of 2-ethyl-3-methylbutanoic acid which is an ethyl ester is a very strong smelling compound which is found in some wines.

(d) This ethyl ester contains a branched hydrocarbon chain and is chiral.

Draw the displayed formula of this ethyl ester.

Identify the chiral carbon atom with an asterisk (*).

[3]

[Total: 14]

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS

GCE Advanced Subsidiary Level and GCE Advanced Level

MARK SCHEME for the May/June 2011 question paper

for the guidance of teachers

9701 CHEMISTRY

9701/23 Paper 2 (AS Structured Questions), maximum raw mark 60

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

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1 Throughout this question, deduct **one mark only** for sig. fig. error.

(a) (i) the volume of solution **A** present in one 'typical ant' is
$7.5 \times 10^{6} \times 1000 = 7.5 \times 10^{3}$ cm^3 (1)

(ii) the volume of pure methanoic acid in one 'typical ant' is
$7.5 \times 10^{3} \times \frac{50}{100} = 3.75 \times 10^{3}$ gives 3.8×10^{3} cm^3

allow ecf on **(i)** (1)

(iii) no. of ants = $\frac{1000}{3.8 \times 10^{3}} = 263157.8947$ gives 2.6×10^5

use of 3.75×10^{3} gives $266666.6667 = 2.7 \times 10^5$ (1) [3]

(b) (i) the volume of solution **A**, in one ant bite is
$\frac{80}{100} \times 7.5 \times 10^{3} = 6.0 \times 10^{3}$ cm^3

allow ecf on **(a)(i)** (1)

the volume of pure methanoic acid in one bite is
$\frac{50}{100} \times 6.0 \times 10^{3} = 3.0 \times 10^{3}$ cm^3

allow ecf on first part of **(b)(i)** (1)

(ii) the mass of methanoic acid in one bite is
$3.0 \times 10^{3} \times 1.2 = 3.6 \times 10^{3}$ g

allow ecf on **(b)(i)** (1) [3]

(c) (i) $HCO_2H + NaHCO_3 \rightarrow HCO_2Na + H_2O + CO_2$ (1)

(ii) 46 g $HCO_2H \equiv$ 84 g $NaHCO_3$ (1)

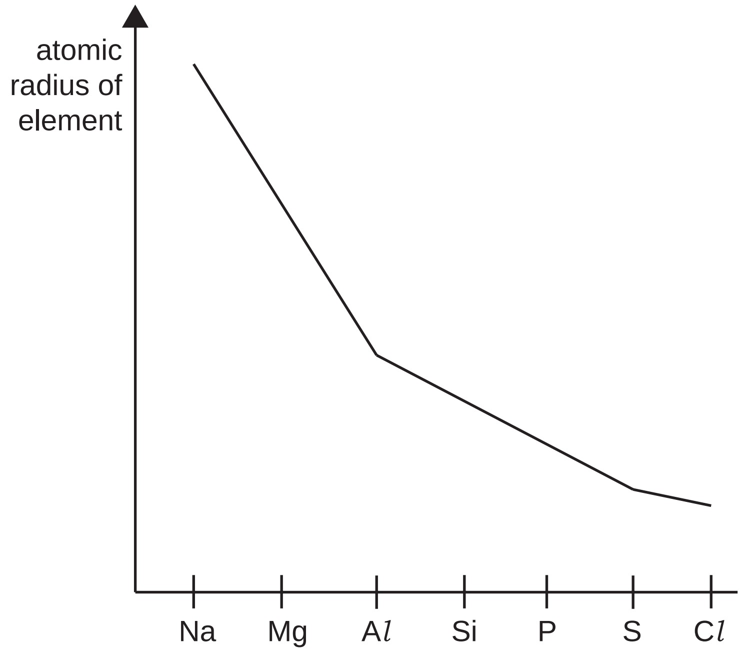
5.4×10^{3} g $HCO_2H \equiv \frac{84 \times 5.4 \times 10^{3}}{46}$ g $NaHCO_3$
$= 9.860869565 \times 10^{3}$
$= 9.9 \times 10^{3}$ g $NaHCO_3$ (1) [3]

[Total: 9]

2	**(a)**	there are no inter-molecular forces present between ideal gas molecules ideal gas molecules have no volume collisions between ideal gas molecules are perfectly elastic ideal gas molecules behave as rigid spheres	(any 2)	[2]
	(b)	high temperature low pressure	(1) (1)	[2]
	(c)	**most ideal** ..... neon..... nitrogen..... ammonia..... **least ideal** nitrogen has stronger van der Waals' forces than argon ammonia has hydrogen bonding as well as van der Waals' forces	(1) (1) (1)	[3]
	(d)	with increasing temperature, average kinetic energy of molecules increases intermolecular forces are more easily broken	 (1) (1)	[2]
	(e)	18	(1)	[1]
	(f)	**(i)** both have very similar/same van der Waals' forces	(1)	
		(ii) CH_3F has permanent dipole	(1)	[2]

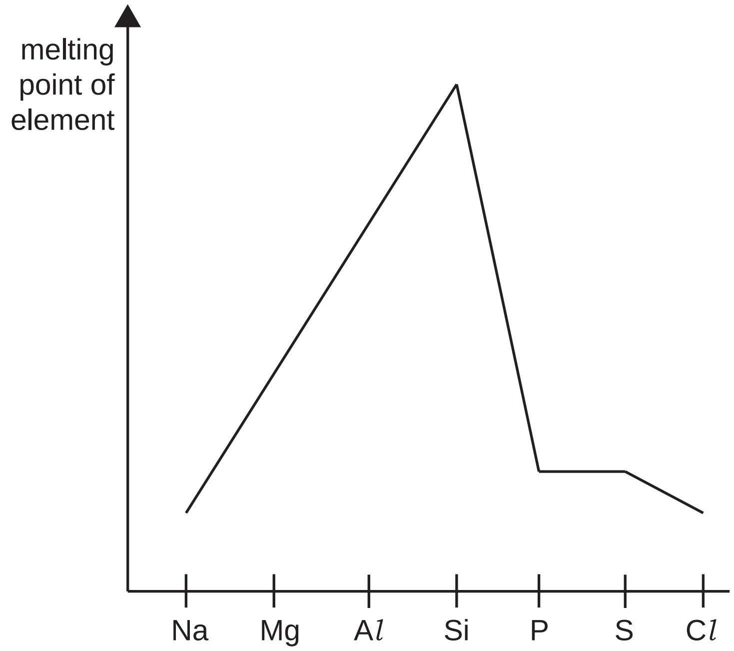
[Total: 12]

3 (a)



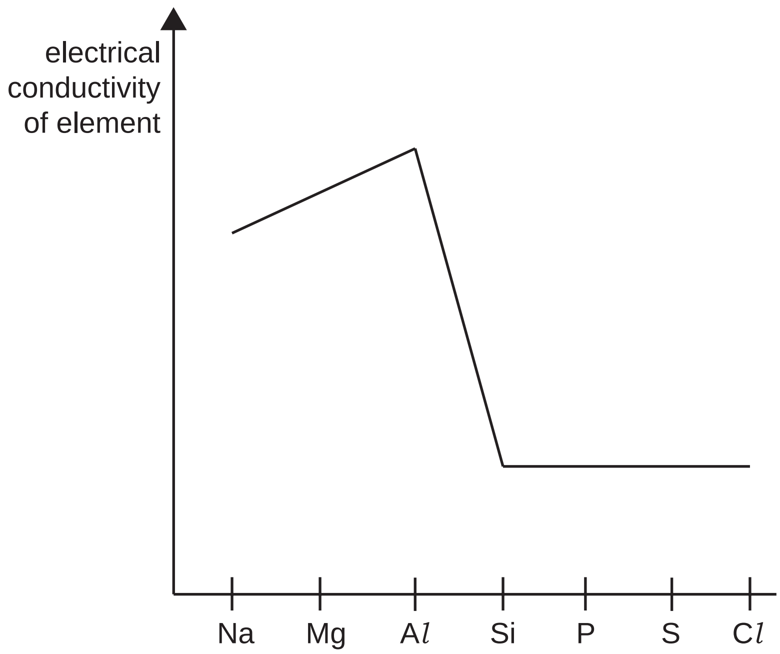
general shape of curve	(1)	
for Na → Ar		
nuclear charge increases	(1)	
electrons are added to same shell	(1)	[3]

(b)



general shape of curve	(1)	
Na, Mg and Al have metallic bonding	(1)	
Si is giant molecular	(1)	
P, S, and Cl are simple molecular	(1)	[4]

(c)



general shape of curve	(1)	
Na, Mg and A*l* have increasing no. of outer shell electrons	(1)	
Si is a semi-conductor	(1)	
P, S and C*l* are covalent/simple molecular	(1)	[4]

(d) (i)	Na_2O	ionic	(1)	
	SiO_2	covalent	(1)	
	P_4O_6	van der Waals' forces/induced dipoles	(1)	
(ii)	Al_2O_3 **or** SiO_2		(1)	[4]

[Total: 15]

4	**(a)**	$C_9H_{16}O_2$		(1)	[1]
	(b) (i)	aldehyde **not** carbonyl		(1)	
		secondary		(1)	
		alcohol		(1)	
	(ii)	Br_2/bromine	**allow** $KMnO_4/H^+$	(1)	
		decolourised	decolourised	(1)	[5]
	(c) (i)	$CH_3(CH_2)_4COCO_2H$		(1)	
		HO_2CCO_2H **or** CO_2		(1)	
	(ii)	$CH_3(CH_2)_4CH(Cl)CH{=}CHCHO$		(1)	
	(iii)	$CH_3(CH_2)_4CH(OH)CH{=}CHCH_2OH$		(1)	[4]

[Total: 10]

5 **(a)** **(i)** $C_7H_{14}O_2$ (1)

(ii) one (1) [2]

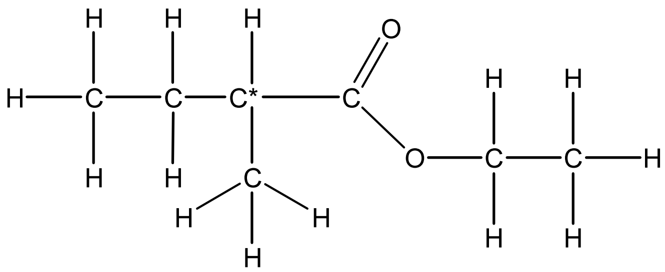
(b) **(i)** $Cr_2O_7^{2}$ /H^+ (1)
from orange (1)
to green (1)

(ii) 2-ethyl-3-methylbutanal/$(CH_3)_2CHCH(C_2H_5)CHO$/the corresponding aldehyde (1)
partial oxidation of alcohol will produce aldehyde (1)

(iii) reflux **because**
the alcohol must be fully oxidised (1) [6]

(c) none (1)
alcohol is tertiary (1)
cannot be oxidised (1) [3]

(d)



correct structure (1)
fully displayed –$CO_2C_2H_5$ group (allow ecf on wrong esters) (1)
correct chiral C atom (allow ecf on wrong esters) (1) [3]

[Total: 14]

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

CANDIDATE NAME	

CENTRE NUMBER		CANDIDATE NUMBER	

8469906161

CHEMISTRY **9701/23**

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.

DC (CB (SE)) 32712/5

UNIVERSITY *of* CAMBRIDGE
International Examinations

[Turn over

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

For Examiner's Use

1 Sulfur, S, and polonium, Po, are both elements in Group VI of the Periodic Table.

Sulfur has three isotopes.

(a) Explain the meaning of the term *isotope*.

....

....

....[2]

(b) A sample of sulfur has the following isotopic composition by mass.

isotope mass	32	33	34
% by mass	95.00	0.77	4.23

Calculate the relative atomic mass, A_r, of sulfur to **two** decimal places.

A_r = ...

[2]

(c) Isotopes of polonium, proton number 84, are produced by the radioactive decay of several elements including thorium, Th, proton number 90.

The isotope ^{213}Po is produced from the thorium isotope ^{232}Th.

Complete the table below to show the atomic structures of the isotopes ^{213}Po and ^{232}Th.

	number of		
isotope	protons	neutrons	electrons
^{213}Po			
^{232}Th			

[3]

Radiochemical reactions, such as nuclear fission and radioactive decay of isotopes, can be represented by equations in which the nucleon (mass) numbers must balance and the proton numbers must also balance.

For Examiner's Use

For example, the nuclear fission of uranium-235, ${}^{235}_{92}U$, by collision with a neutron, ${}^{1}_{0}n$, produces strontium-90, xenon-143 and three neutrons.

$${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{90}_{38}Sr + {}^{143}_{54}Xe + 3\,{}^{1}_{0}n$$

In this equation, the nucleon (mass) numbers balance because: 235 + 1 = 90 + 143 + (3x1).

The proton numbers also balance because: 92 + 0 = 38 + 54 + (3x0).

(d) In the first stage of the radioactive decay of ${}^{232}_{90}Th$, the products are an isotope of element *E* and an alpha-particle, ${}^{4}_{2}He$.

(i) By considering nucleon and proton numbers only, construct a balanced equation for the formation of the isotope of *E* in this reaction.

$${}^{232}_{90}Th \rightarrow \text{................} + {}^{4}_{2}He$$

Show clearly the nucleon number and proton number of the isotope of *E*.

nucleon number of the isotope of *E* ....

proton number of the isotope of *E* ....

(ii) Hence state the symbol of the element *E*.

.... [3]

[Total: 10]

2 When 0.42 g of a gaseous hydrocarbon **A** is slowly passed over a large quantity of heated copper(II) oxide, CuO, **A** is completely oxidised.

The products are collected and it is found that 1.32 g of CO_2 and 0.54 g of H_2O are formed. Copper is the only other product of the reaction.

(a) **(i)** Calculate the mass of carbon present in 1.32 g of CO_2.

Use this value to calculate the amount, in moles, of carbon atoms present in 0.42 g of **A**.

(ii) Calculate the mass of hydrogen present in 0.54 g of H_2O.

Use this value to calculate the amount, in moles, of hydrogen atoms present in 0.42 g of **A**.

(iii) It is thought that **A** is an alkene rather than an alkane.

Use your answers to **(i)** and **(ii)** to deduce whether this is correct.

Explain your answer.

....

.... [5]

For Examiner's Use

(b) Analysis of another organic compound, **B**, gave the following composition by mass: C, 64.86%; H, 13.50%, O, 21.64%.

(i) Use these values to calculate the empirical formula of **B**.

(ii) The empirical and molecular formulae of **B** are the same.

B is found to be chiral.

Draw displayed formulae of the two optical isomers of this compound, indicating with an asterisk (*) the chiral carbon atom.

(iii) There are three other structural isomers of **B** which are not chiral but which contain the same functional group as **B**.

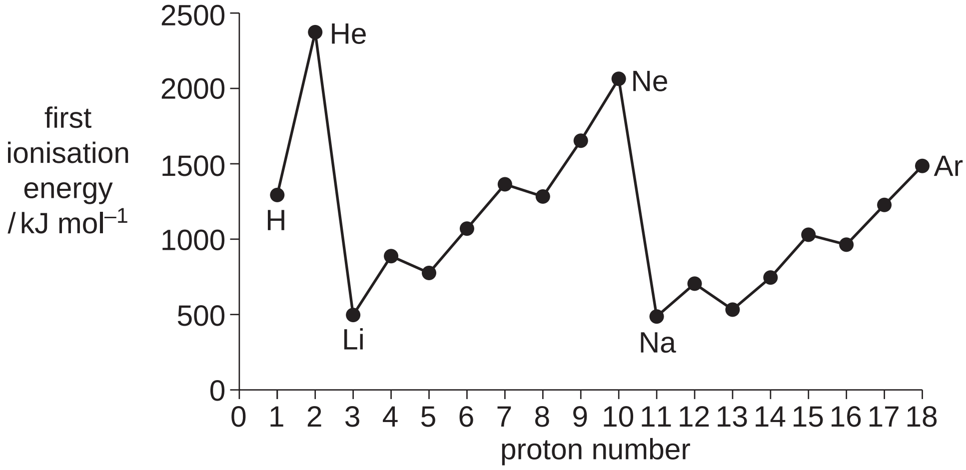
In the boxes below, draw the structural formulae of these isomers.

[7]

[Total: 12]

3 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 carbon.

.... [2]

(b) **(i)** Explain why sodium has a lower first ionisation energy than magnesium.

....

....

(ii) Explain why magnesium has a higher first ionisation energy than aluminium.

....

....

(iii) Explain why helium, He, and neon, Ne, occupy the two highest positions on the diagram.

....

....

(iv) Explain why the first ionisation energy of argon, Ar, is lower than that of neon, which is lower than that of helium.

....

....

....

[8]

For Examiner's Use

(c) **(i)** The first ionisation energies of the elements Na to Ar show a variation. Some physical properties show similar variations.

The atomic radius of the elements decreases from Na to C*l*.

Give a brief explanation of this variation.

....

....

(ii) The cations formed by the elements Na to A*l* are smaller than the corresponding atoms.

Give a brief explanation of this change.

....

....
[3]

(d) The oxides of the elements of the third Period behave differently with NaOH(aq) and HC*l* (aq). In some cases, no reaction occurs.

Complete the table below by writing a balanced equation for any reaction that occurs, with heating if necessary. If you think no reaction takes place write 'no reaction'.

You do not need to include state symbols in your answers.

.....MgO(s) + ... NaOH (aq) $\rightarrow$
.....MgO(s) + ... HC*l* (aq) $\rightarrow$
.....Al_2O_3(s) + ... NaOH (aq) + ...H_2O (l) $\rightarrow$
.....Al_2O_3(s) + ... HC*l* (aq) $\rightarrow$
.....SO_2(g) + ... NaOH (aq) $\rightarrow$
.....SO_2(g) + ... HC*l* (aq) $\rightarrow$

[6]

[Total: 19]

For Examiner's Use

4 The structural formulae of six different compounds, **P – U**, are given below.

$CH_3CH{=}CHCH_2CH_3$	$CH_3CH_2COCH_2CH_3$	$CH_2{=}CHCH_2CH_2CH_3$
P	**Q**	**R**
$CH_3CH_2CH_2CH_2CH_2OH$	$HOCH_2CH_2CH(OH)CH_3$	$CH_3CH_2CH_2OCH_2CH_3$
S	**T**	**U**

(a) **(i)** What is the empirical formula of compound **T**?

....

(ii) Draw the skeletal formula of compound **S**.

[2]

(b) **(i)** Compounds **S** and **U** are isomers.

What type of isomerism do they show?

....

(ii) Two of the six formulae **P – U** can **each** be drawn in two forms which are known as stereoisomers.

Which two compounds have formulae that can be drawn in two forms?

What type of stereoisomerism does each show?

Identify each compound by its letter.

compound	type of stereoisomerism

[3]

For Examiner's Use

(c) Compound **S** can be converted into compound **R**.

(i) What type of reaction is this?

....

(ii) What reagent would you use for this reaction?

....

(iii) Write the structural formula of the compound formed when **T** undergoes the same reaction using an excess of the reagent you have used in **(c)(ii)**.

.... [3]

(d) Compound **P** may be converted into compound **Q** in a two-step reaction.

$$\underset{\mathbf{P}}{CH_3CH{=}CHCH_2CH_3} \xrightarrow{\text{step 1}} \text{intermediate} \xrightarrow{\text{step 2}} \underset{\mathbf{Q}}{CH_3CH_2COCH_2CH_3}$$

(i) What is the structural formula of the intermediate compound formed in this sequence?

(ii) Outline how step 1 may be carried out to give this intermediate compound.

....

....

....

(iii) What reagent would be used for step 2?

.... [4]

[Total: 12]

5 Each of the three organic compounds, **V**, **W**, and **X**, has the empirical formula CH_2O. The number of carbon atoms in each of their molecules is shown in the table.

For Examiner's Use

compound	number of C atoms
V	1
W	2
X	3

V gives a brick red precipitate when warmed with Fehling's reagent; **W** and **X** do not.

W is a fruity smelling liquid.

In **X**, the carbon atoms are bonded directly to one another.

X gives an effervescence when shaken with $Na_2CO_3(aq)$; **V** and **W** do not.

(a) Give the structural formula of **V**.

[1]

(b) **(i)** What functional group is present in **W**?

....

(ii) Give the structural formula of **W**.

[2]

(c) When **X** is heated under reflux with acidified $K_2Cr_2O_7$, the product, **Y**, gives no reaction with 2,4-dinitrophenylhydrazine reagent.

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

(ii) Give the structural formula of **Y**, the compound formed from **X**.

[2]

(d) When **X** is warmed with a little concentrated sulfuric acid, a small amount of a cyclic compound, **Z**, is formed.

For Examiner's Use

Z has the molecular formula $C_6H_8O_4$.

(i) Suggest a displayed formula for **Z**.

(ii) What type of reaction occurs when **Z** is formed from **X**?

....

[2]

[Total: 7]

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS

GCE Advanced Subsidiary Level and GCE Advanced Level

MARK SCHEME for the October/November 2011 question paper for the guidance of teachers

9701 CHEMISTRY

9701/23 Paper 2 (AS Structured Questions), maximum raw mark 60

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1 **(a)** same proton number/atomic number (1)
different mass number/nucleon number (1) [2]

(b) $A_r = \dfrac{(32 \times 95.00) + (33 \times 0.77) + (34 \times 4.23)}{100}$ (1)

$= \dfrac{3040 + 25.41 + 143.82}{100} = \dfrac{3209.23}{100}$

which gives $A_r = 32.09$ (1) [2]

(c)

	number of		
isotopes	protons	neutrons	electrons
^{213}Po	84	129	84
^{232}Th	90	142	90

allow **one mark** for each correct column
if there are no 'column' marks,
allow **maximum one mark** for a correct row (3 × 1) [3]

(d) **(i)** nucleon no. is 228 (1)
proton no. is 88 (1)

(ii) Ra **not** radium (1) [3]

[Total: 10]

2 **(a)** **(i)** mass of C = $\dfrac{12 \times 1.32}{44}$ = 0.36g (1)

n(C) = $\dfrac{0.36}{12}$ = 0.03 (1)

(ii) mass of H = $\dfrac{2 \times 0.54}{18}$ = 0.06 g (1)

n(H) = $\dfrac{0.06}{1}$ = 0.06 (1)

(iii) yes **because** 0.03 mol of C are combined with 0.06 mol of H **or**
C : H ratio is 1 : 2 **or**
empirical formula is CH_2 (1) [5]

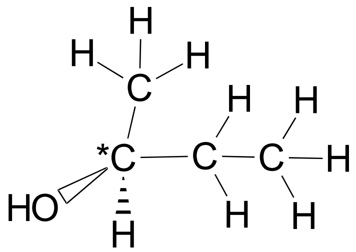
(b) (i) $C : H : O = \frac{64.86}{12} : \frac{13.50}{1} : \frac{21.64}{16}$ (1)

$= 5.41 : 13.50 : 1.35$

$= 4 : 10 : 1$

gives $C_4H_{10}O$ (1)

(ii)



correct compound **and** correct chiral C* (1)
correct mirror object/ mirror
image relationship in 3D (1)

(iii)

$CH_3CH_2CH_2CH_2OH$	H | CH_3CCH_2OH | CH_3	OH | CH_3CCH_3 | CH_3
(1)	(1)	(1)

[7]

[Total: 12]

3 (a) $C(g) \rightarrow C^+(g) + e$
correct equation (1)
correct state symbols (1) [2]

(b) (i) Na and Mg
Mg has greater nuclear charge/more protons than Na (1)

in both atoms, the 3s electrons are in the same orbital/
same energy level/same shell (1)

(ii) Mg and A*l*
in A*l* outermost electron is in 3p rather than 3s (1)

3p electron is at higher energy **or**
is further away/is more shielded from nucleus (1)

(iii) He and Ne
both He and Ne have the highest nuclear charges in their Period (1)

(iv) He, Ne, and Ar
going down the group,

valence/outer shell electrons are farther from the nucleus (1)

there is greater shielding (1)

attraction between valence electrons and nucleus is less **or**
effective nuclear charge is less (1) [8]

(c) (i) from Na to C*l*
increased nuclear charge/nuclear attraction (1)

(ii) cation has fewer electrons than atom **or**
cation has lost outer electrons **or**
cation has fewer shells (1)

but cation has same nuclear charge as atom **or**
proton number is the same (1) [3]

3 (d) ignore any state symbols

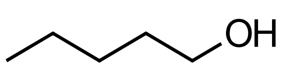
MgO(s)	+	$NaOH$(aq)			→	NO REACTION	(1)
MgO(s)	+	**2**HCl(aq)			→	$MgCl_2$ + H_2O	(1)
Al_2O_3(s)	+	**2**$NaOH$(aq)	+	**3**H_2O(l)	→	**2**$NaAl(OH)_4$ **or**	
Al_2O_3(s)	+	**2**$NaOH$(aq)	+	H_2O(l)	→	**2**$NaAlO_2$ + $2H_2O$ **or**	(1)
Al_2O_3(s)	+	**6**$NaOH$(aq)	+	**3**H_2O(l)	→	**2**$Na_3Al(OH)_6$	
Al_2O_3(s)	+	**6**HCl(aq)			→	**2**$AlCl_3$ + **3**H_2O **or**	(1)
Al_2O_3(s)	+	**6**HCl(aq)			→	Al_2Cl_6 + **3**H_2O	
SO_2(g)	+	$NaOH$(aq)			→	$NaHSO_3$ **or**	(1)
SO_2(g)	+	**2**$NaOH$(aq)			→	Na_2SO_3 + H_2O	
SO_2(g)	+	HCl(aq)			→	NO REACTION	(1)

[6]

[Total: 19]

4 (a) (i) C_2H_5O (1)

(ii)



(1) [2]

(b) (i) functional group isomerism
or structural isomerism (1)

do **not** allow 'functional isomerism' or positional isomerism

(ii)

compound	type of isomerism
P	*cis-trans* **or** geometrical
T	optical

(1 + 1) [3]

(c) (i) dehydration/elimination (1)

(ii) conc. H_2SO_4 / P_4O_{10} / Al_2O_3 / H_3PO_4 / pumice (1)

(iii) CH_2=CHCH=CH_2

allow CH_2=C=CHCH_3 (1) [3]

(d) (i) $CH_3CH_2CH(OH)CH_2CH_3$ (1)

(ii) steam with H_3PO_4 catalyst **or**
conc. H_2SO_4 then water (1 + 1)

only allow condition mark if reagent mark has been given

(iii) $Cr_2O_7^{2}$ /H^+ **or**
MnO_4 /H^+ (1) [4]

[Total: 12]

5 (a) V is HCHO (1) [1]

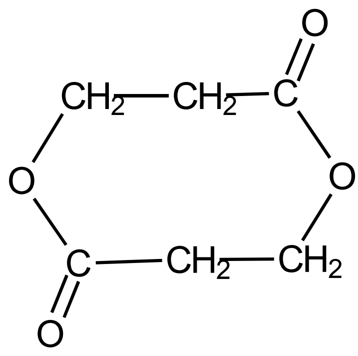
(b) (i) ester (1)

(ii) W is HCO_2CH_3 (1) [2]

(c) (i) X is $HOCH_2CH_2CO_2H$ (1)

(ii) Y is $HO_2CCH_2CO_2H$ (1) [2]

(d) **(i)** **Z** is



(1)

(ii) esterification **or**
dehydration **or**
elimination **or**
condensation (1) [2]

[Total: 7]

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

CANDIDATE NAME			
CENTRE NUMBER		CANDIDATE NUMBER	

1182281800

CHEMISTRY **9701/21**

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	
5	
Total	

This document consists of **11** printed pages and **1** blank page.

IB12 06_9701_21/3RP

For Examiner's Use

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

1 Oxides are compounds which usually contain oxygen combined with one other element.

Oxides are classified as follows.

acidic alkaline amphoteric basic

(a) **Using these terms only**, complete the table to describe the oxides of the elements of the third period of the Periodic Table sodium to sulfur.

Na_2O	MgO	Al_2O_3	SiO_2	P_4O_{10}	SO_2	Cl_2O_7
						acidic

[4]

(b) Give the names of **two** elements from sodium to chlorine which form more than one oxide.

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

(c) Sodium reacts with water.

(i) Describe, as fully as you can, what you would see when a piece of sodium is reacted with water.

....

....

....

(ii) Write an equation for the reaction of sodium with water.

....

[4]

For Examiner's Use

(d) Sulfur dioxide is present in small, but significant, amounts in the Earth's atmosphere.

(i) State **one** way by which sulfur dioxide enters the atmosphere.

....

(ii) Give the formula of another sulfur compound which is formed in the atmosphere from sulfur dioxide.

....

(iii) What are the environmental consequences of the compound you have identified in **(ii)**?

....

[3]

(e) Sulfur dioxide is used as a food preservative.
What property of sulfur dioxide enables it to act in this way?

.... [1]

(f) Another sulfur compound which is present in the Earth's atmosphere is carbonyl sulfide, OCS. The sequence of atoms in the molecule is oxygen-carbon-sulfur and the molecule is **not** cyclic.

(i) Draw a 'dot-and-cross' diagram of the OCS molecule.
Show outer electrons only.

(ii) Suggest a value for the O – C – S bond angle.

....

[2]

[Total: 15]

For Examiner's Use

2 Ammonium sulfate, $(NH_4)_2SO_4$, is widely used as a fertiliser.

In order to determine its percentage purity, a sample of ammonium sulfate fertiliser was analysed by reacting a known amount with an excess of NaOH(aq) and then titrating the unreacted NaOH with dilute HC*l*.

(a) Ammonium sulfate reacts with NaOH in a 1 : 2 ratio.
Complete and balance the equation for this reaction.

$$(NH_4)_2SO_4 + 2NaOH \rightarrow ....NH_3 + ... + ...$$

[2]

(b) A 5.00 g sample of a fertiliser containing $(NH_4)_2SO_4$ was warmed with 50.0 cm^3 (an excess) of 2.00 mol dm^{-3} NaOH.

When all of the ammonia had been driven off, the solution was cooled.

The remaining NaOH was then titrated with 1.00 mol dm^{-3} HC*l* and 31.2 cm^3 were required for neutralisation.

(i) Write a balanced equation for the reaction between NaOH and HC*l*.

....

(ii) Calculate the amount, in moles, of HC*l* in 31.2 cm^3 of 1.00 mol dm^{-3} HC*l*.

(iii) Calculate the amount, in moles, of NaOH in 50.0 cm^3 of 2.00 mol dm^{-3} NaOH.

(iv) Use your answers to **(i)**, **(ii)** and **(iii)** to calculate the amount, in moles, of NaOH used up in the reaction with $(NH_4)_2SO_4$.

For Examiner's Use

(v) Use your answer to **(iv)** and the equation in **(a)** to calculate the amount, in moles, of $(NH_4)_2SO_4$ that reacted with NaOH.

(vi) Use your answer to **(v)** to calculate the mass of $(NH_4)_2SO_4$ that reacted with NaOH.

(vii) Hence, calculate the percentage purity of the ammonium sulfate fertiliser.

[7]

[Total: 9]

For Examiner's Use

3 Methanol, CH_3OH, is considered to be a possible alternative to fossil fuels, particularly for use in vehicles.

Methanol can be produced from fossil fuels and from agricultural waste. It can also be synthesised from carbon dioxide and hydrogen.

(a) Define, with the aid of an equation which includes state symbols, the standard enthalpy change of formation of carbon dioxide.

equation ....

definition ....

....

.... [3]

(b) Relevant $\Delta H_f^{\ominus}$ values for the reaction that synthesises methanol are given in the table.

compound	$\Delta H_f^{\ominus}$ / kJ mol^{-1}
$CO_2(g)$	–394
$CH_3OH(g)$	–201
$H_2O(g)$	–242

(i) Use these values to calculate $\Delta H^{\ominus}_{reaction}$ for this synthesis of methanol.

Include a sign in your answer.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$$

$\Delta H^{\ominus}_{reaction}$ = ...kJ mol^{-1}

(ii) Suggest **one** possible environmental advantage of this reaction. Explain your answer.

....

....

[5]

For Examiner's Use

(c) The synthesis of methanol is carried out at about 500 K with a pressure of between 40 and 100 atmospheres (between 4×10^6 Pa and 10×10^7 Pa) and using a catalyst. The use of such conditions will affect both the rate of reaction and the equilibrium yield.

In the spaces below, explain the effects of higher temperature, higher pressure, and the use of a catalyst on the **equilibrium yield** of methanol.

higher temperature

effect ....

explanation ....

....

higher pressure

effect ....

explanation ....

....

use of catalyst

effect ....

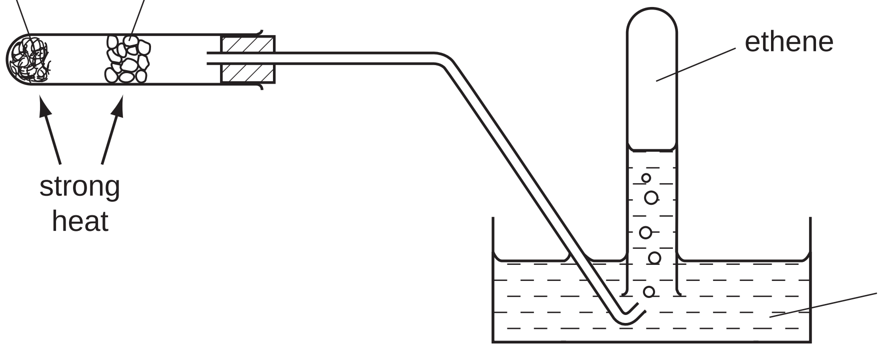
explanation ....

....
[6]

[Total: 14]

For Examiner's Use

4 One method of preparing ethene in a school or college laboratory is from ethanol by using the apparatus shown below.



(a) (i) Write a balanced equation for this reaction.

....

(ii) What *type of reaction* is this?

....

(iii) Give the chemical name of a reagent other than pumice that could be used to carry out this reaction. It is not necessary to use the same apparatus.

....

[3]

(b) Ethene is bubbled into two separate test-tubes, one containing aqueous hydrogen bromide and the other containing cold, dilute acidified potassium manganate(VII).

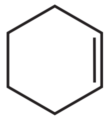
In **each** case, describe any colour changes you would see and give the structural formula of the organic product.

	aqueous hydrogen bromide	cold, dilute acidified potassium manganate(VII)
colour at start		
colour after reaction		
structural formula of organic product		

[4]

For Examiner's Use

(c) Cyclohexene has the following structural formula.



(i) What is the molecular formula of cyclohexene?

....

(ii) Draw the structural formula of the compound formed when cyclohexene is reacted with bromine.

(iii) State as fully as you can what *type of reaction* this is.

....

(iv) Draw the structural formula of the compound formed when cyclohexene is reacted with hot concentrated acidified potassium manganate(VII).

[5]

[Total: 12]

For Examiner's Use

5 Organic compounds which contain oxygen may contain alcohol, aldehyde, carboxylic acid, ester or ketone functional groups. The functional groups may be identified by their reactions with specific reagents.

Compound **X** has the empirical formula CH_2O and M_r of 90.

(a) There is no reaction when **X** is treated with $NaHCO_3$.

What functional group does this test show to be **not** present in **X**?

.... [1]

(b) When 0.600 g of **X** is reacted with an excess of Na, 160 cm^3 of H_2, measured at room temperature and pressure, is produced.

(i) What functional group does this reaction show to be present in **X**?

....

(ii) Use the data to calculate the amount, in moles, of hydrogen **atoms** produced from 0.600 g of **X**.

(iii) Hence, show that each molecule of **X** contains **two** of the functional groups you have given in **(i)**.

[4]

For Examiner's Use

(c) When **X** is warmed with Fehling's reagent, a brick red precipitate is formed. Treatment of **X** with 2,4-dinitrophenylhydrazine reagent produces an orange solid.

(i) What functional group do these reactions show to be present in **X**? Draw the displayed formula of this functional group.

(ii) Use your answers to **(b)(i)**, **(b)(ii)** and **(c)(i)** to deduce the structural formula of **X**.

(iii) What is the structural formula of the organic product of the reaction of **X** with Fehling's reagent?

[3]

(d) Compound **X** can be both oxidised and reduced.

(i) Give the structural formula of the compound formed when **X** is reacted with $NaBH_4$ under suitable conditions.

(ii) Give the structural formula of the compound formed when **X** is heated under reflux with acidified $K_2Cr_2O_7$.

[2]

[Total: 10]

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS

GCE Advanced Subsidiary Level and GCE Advanced Level

MARK SCHEME for the May/June 2012 question paper

for the guidance of teachers

9701 CHEMISTRY

9701/21 Paper 2 (AS Structured Questions), maximum raw mark 60

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

Mark schemes must be read in conjunction with the question papers and the report on the examination.

- Cambridge will not enter into discussions or correspondence in connection with these mark schemes.

Cambridge is publishing the mark schemes for the May/June 2012 question papers for most IGCSE, GCE Advanced Level and Advanced Subsidiary Level syllabuses and some Ordinary Level syllabuses.

1 **(a)**

Na_2O	MgO	Al_2O_3	SiO_2	P_4O_{10}	SO_2	Cl_2O_7
alkaline	basic	amphoteric	acidic	acidic	acidic	acidic

Na_2O is alkaline – allow basic (1)

MgO is basic – allow alkaline (1)

Al_2O_3 is amphoteric (1)

SiO_2, P_4O_{10}, and SO_2 are **all** acidic (1) [4]

(b) any **two** from:
sodium, phosphorus, sulfur and chlorine
two names required (1) [1]

(c) **(i)** any **three** from:
floats
vigorous/violent reaction occurs
melts/forms a sphere
moves
disappears – allow dissolves
effervescence/gas produced (any 3)

(ii) $Na + H_2O \rightarrow NaOH + ½H_2$
or
$2Na + 2H_2O \rightarrow 2NaOH + H_2$ (1) [4]

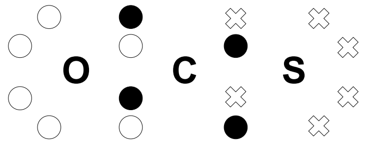
(d) **(i)** combustion of fossil fuels – e.g. from car engines
from car exhausts **or**
during the extraction of metals from sulfide ores or
volcanic eruptions/burning sulfur from volcanoes or
burning biomass (1)

(ii) H_2SO_4
or
SO_3 allow H_2SO_3 **formula required** (1)

(iii) acid rain
or
its consequences e.g. damage to buildings,
damage to crops, plants, marine life
deforestation
or
SO_3 is toxic (1) [3]

(e) it is a reducing agent/antioxidant
or
it kills bacteria (1) [1]

(f) **(i)**



(1)

(ii) 180° (1) [2]

[Total: 15]

2 **(a)** $(NH_4)_2SO_4 + 2NaOH \rightarrow \mathbf{2}NH_3 + \mathbf{Na_2SO_4} + \mathbf{2H_2O}$

correct products (1)

correctly balanced equation (1) [2]

(b) **(i)** $NaOH + HCl \rightarrow NaCl + H_2O$ (1)

(ii) $n(HCl) = \frac{31.2}{1000} \times 1.00 = 0.0312 = 0.03$ (1)

(iii) $n(NaOH) = \frac{50.0}{1000} \times 2.00 = 0.10$ (1)

(iv) n(NaOH) used up = 0.10 – 0.0312 = 0.0688 = 0.07 (1)

(v) $n[(NH_4)_2SO_4] = \frac{0.0688}{2} = 0.0344 = 0.03$ (1)

(vi) mass of $(NH_4)_2SO_4$ = 0.0344 × 132 = 4.5408 = 4.54 (1)

(vii) percentage purity $= \frac{4.5408 \times 100}{5.00} = 90.816 = 90.8$ (1) [7]

[Total: 9]

3 (a) $C(s) + O_2(g) \rightarrow CO_2(g)$ (1)
the enthalpy change/energy change/heat change when
one mole of a compound/CO_2 (1)
is formed from its elements in their standard states (1) [3]

(b) (i)

	$CO_2(g)$	+	$3H_2(g)$	$\rightleftharpoons$	$CH_3OH(g)$	+	$H_2O(g)$
$\Delta H^{\ominus}_f$/kJ mol $^{-1}$	–394		0		–201		–242

$\Delta H^{\ominus}_{reaction}$ = –201 + (–242) – (–394) (1)
–49 kJ mol $^{-1}$ (1)
correct sign (1)

(ii) removal of CO_2 from the atmosphere (1)
CO_2 is a greenhouse gas/causes global warming (1) [5]

(c) In this part, in each case, the 'effect' must be correctly stated in order to gain the explanation mark.

higher temperature
yield is reduced/equilibrium goes to LHS (1)
because forward reaction is exothermic/reverse reaction is endothermic (1)

higher pressure
yield is increased **or** equilibrium goes to RHS (1)
fewer moles/molecules on RHS **or** more moles/molecules on LHS (1)

use of catalyst
yield does not change (1)
forward and backward rates speeded up by same amount (1) [6]

[Total: 14]

4 **(a)** **(i)** $C_2H_5OH \rightarrow C_2H_4 + H_2O$ (1)

(ii) elimination **or** dehydration (1)

(iii) phosphoric acid **or** concentrated sulfuric acid
sulfuric acid must be 'concentrated'
allow aluminium oxide (1) [3]

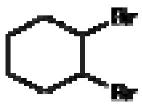
(b)

	with HBr	**with MnO_4^-**
colour at start	colourless	purple **or** pink
colour after reaction	colourless	colourless **or** decolourised
structural formula of product	CH_3CH_2Br	$HOCH_2CH_2OH$

with hydrogen bromide
from colourless **to** colourless **both** colours required
do not allow 'clear' instead of colourless (1)
CH_3CH_2Br (1)
with potassium manganate(VII)
from purple/pink **to** colourless/decolourised **both** colours required (1)
$HOCH_2CH_2OH$ (1) [4]

(c) **(i)** C_6H_{10} (1)

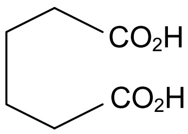
(ii)



accept answers which have $–CH_2–$ in the ring (1)

(iii) electrophilic (1)
addition (1)

(iv)



or

$HO_2C(CH_2)_4CO_2H$ **or**
$HO_2CCH_2CH_2CH_2CH_2CO_2H$ (1)
accept answers which have $–CH_2–$ in the ring [5]

[Total: 12]

5 **(a)** carboxylic acid **or** –CO_2H **or** –COOH (1) [1]

(b) **(i)** alcohol (1)

(ii) $n(H_2) = \dfrac{160}{24000} = 6.67 \times 10^{\ 3}$ mol (1)

n(H atoms) = $2 \times 6.67 \times 10^{\ 3}$ mol = $1.33 \times 10^{\ 2}$ mol (1)

(iii) $n(\mathbf{X}) = \dfrac{0.600}{90} = 6.67 \times 10^{\ 3}$ mol

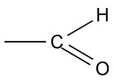
$n(\mathbf{X}) : n$(H atoms) = $6.67 \times 10^{\ 3} : 1.33 \times 10^{\ 2}$

= 1 : 2

since each –OH group produces one H atom

there are two –OH groups (1) [4]

(c) **(i)**



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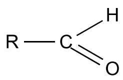

(1)

(ii) $HOCH_2CH(OH)CHO$ as the minimum

allow the *gem* diols $(HO)_2CHCH_2CHO$ **or** $CH_3C(OH)_2CHO$ (1)

(iii) $HOCH_2CH(OH)CO_2H$ or $HOCH_2CH(OH)CO_2$ (1) [3]

(d) **(i)** $HOCH_2CH(OH)CH_2OH$ (1)

(ii) HO_2CCOCO_2H (1) [2]

[Total: 10]

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

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1	
2	
3	
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Total	

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IB12 06_9701_22/3RP

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]

For Examiner's Use

(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'.

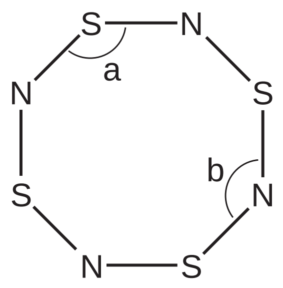
element	Does the chloride dissolve or react?	approximate pH of the resulting solution
Na		
A*l*		
Si		

(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]

For Examiner's Use

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 $\Delta H^\ominus_{reaction}$ for the synthesis of methanol, using the following equation. Include a sign in your answer.

$$CO(g) + 2H_2(g) \rightarrow CH_3OH(g)$$

$\Delta H^\ominus_{reaction}$ = ...kJ mol^{-1}

[3]

For Examiner's Use

(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

....

....

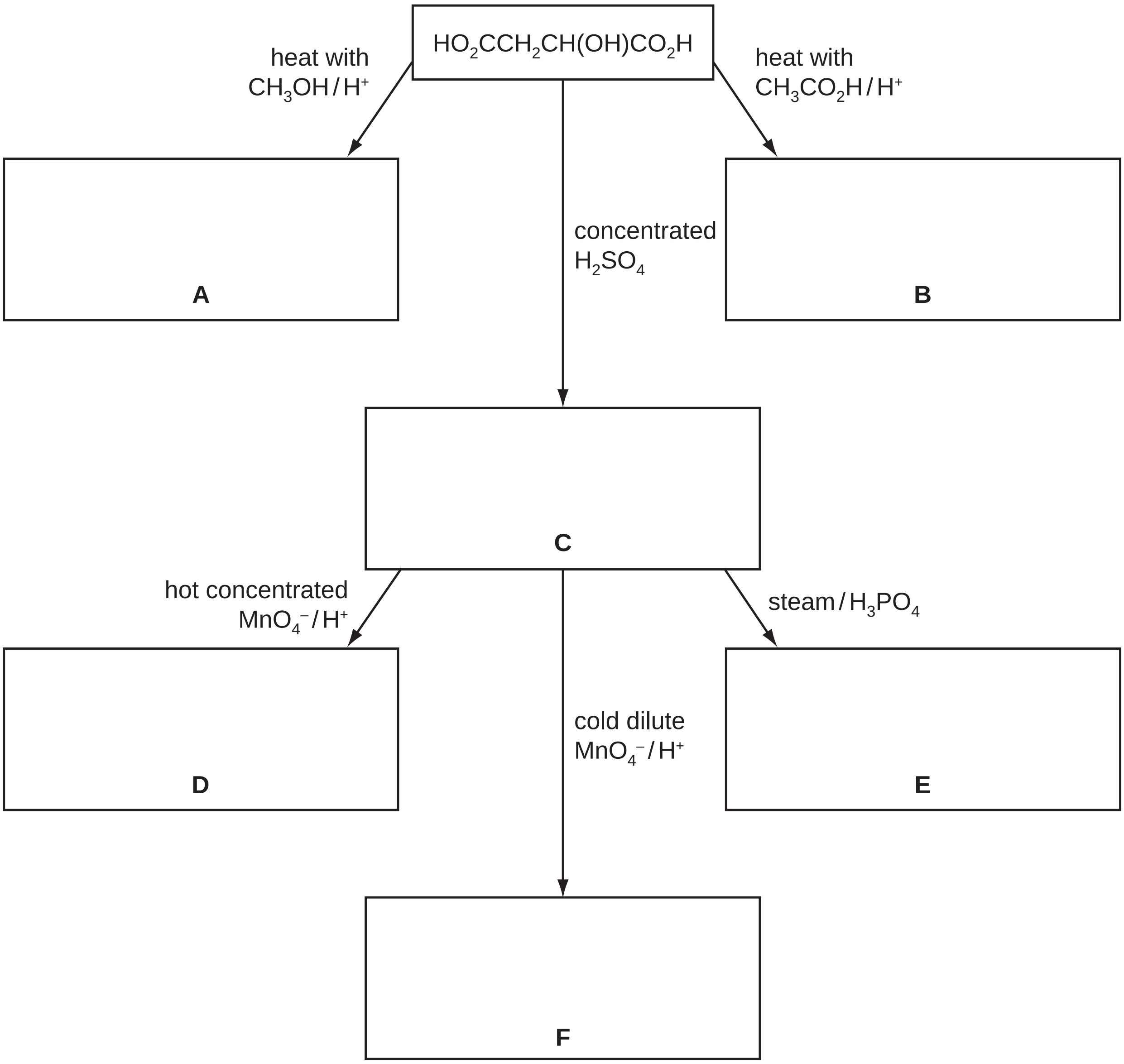
....
[6]

[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]

For Examiner's Use

(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]

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS

GCE Advanced Subsidiary Level and GCE Advanced Level

MARK SCHEME for the May/June 2012 question paper

for the guidance of teachers

9701 CHEMISTRY

9701/22 Paper 2 (AS Structured Questions), maximum raw mark 60

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

Mark schemes must be read in conjunction with the question papers and the report on the examination.

- Cambridge will not enter into discussions or correspondence in connection with these mark schemes.

Cambridge is publishing the mark schemes for the May/June 2012 question papers for most IGCSE, GCE Advanced Level and Advanced Subsidiary Level syllabuses and some Ordinary Level syllabuses.

1 **(a)** **(i)** silicon/Si **or** phosphorus/P (1)

(ii) sodium **or** sulfur **name required** (1)

(iii) white solid formed/white fumes seen
chlorine gas decolourised
aluminium glows **or** burns any two (2)

(iv) $2Al(s) + 3Cl_2(g) \rightarrow Al_2Cl_6(s)$ **or**
$2Al(s) + 3Cl_2(g) \rightarrow 2AlCl_3(s)$
equation (1)
state symbols (1)

(v) outer shell of electrons is full/has a complete octet **or**
valence shell of electrons is full/has a complete octet **or**
activation energy is too high **or**
ionisation energy is too high (1) [7]

(b) **(i)**

element	Does the chloride dissolve or react?	approximate pH of the resulting solution
Na	dissolve	7
A*l*	react	1 to 4
Si	react	1 to 4

one mark for each correct answer (6 × 1)

(ii) hydrolysis (1) [7]

(c) **(i)** around the N atom there is only one lone pair
around the S atom there are two lone pairs **both** (1)

(ii) angle (a) **or** sulfur – **no mark for this**

because two lone pairs repel more than one lone pair **or**
lone pair-lone pair repulsions are stronger
than lone pair-bond pair repulsions (1) [2]

[Total: 16]

2 **(a)** $CH_3OH(l) + {}^3/_2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$ (1)
the enthalpy change/heat change/heat evolved when
one mole of CH_3OH (1)
is completely burned **or**
is burned in an excess of air/oxygen (1) [3]

(b) $\Delta H^{\ominus}_{reaction} = -283 + 2(-286) - (-726)$ (1)
$= -129$ kJ mol^{1} (1)
correct sign (1) [3]

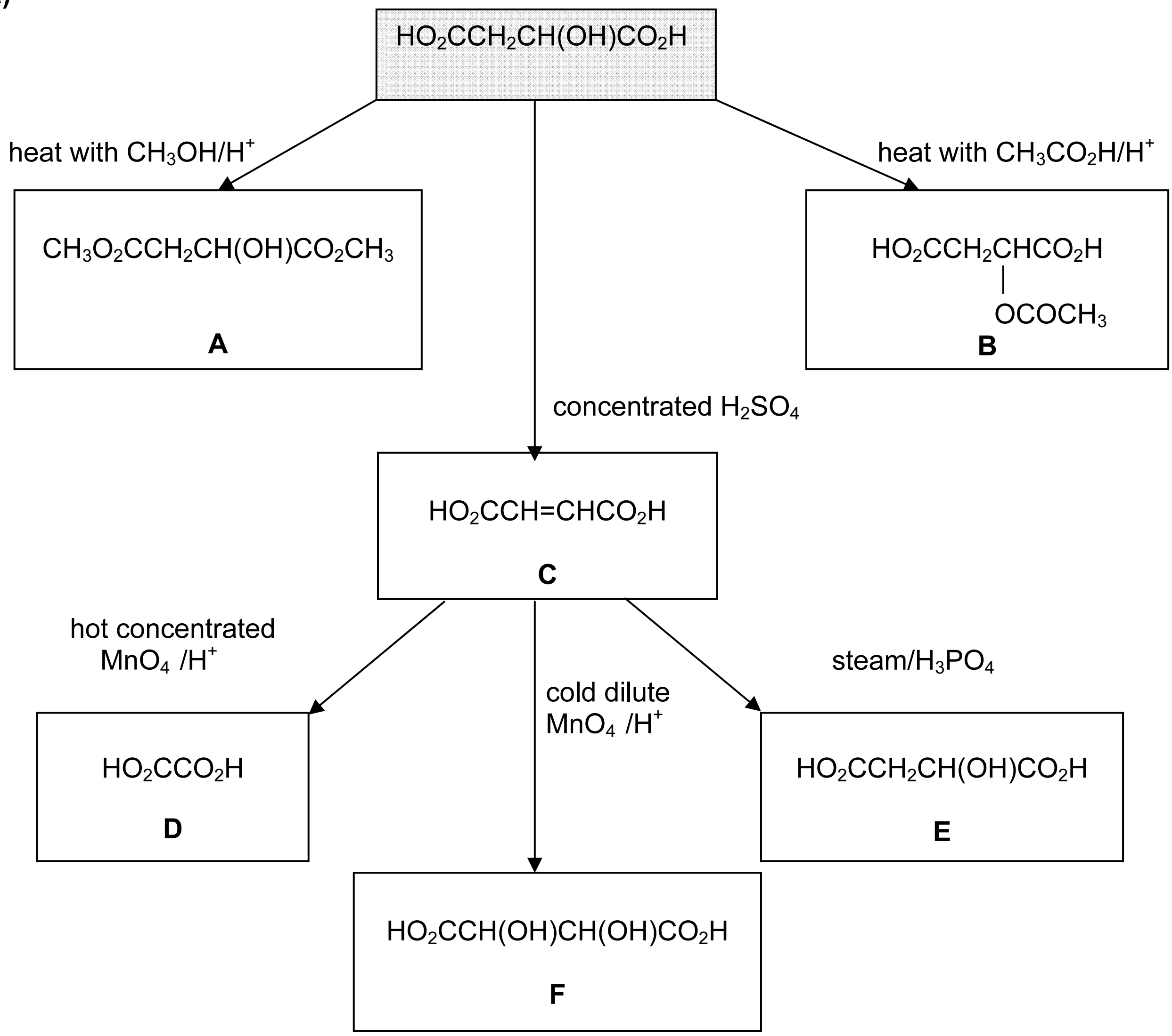
(c) **pressure**
increases rate (1)
by increasing frequency of collisions **or**
by increasing concentration of reactants (1)

temperature
increases rate (1)
because more molecules have energy $>E_a$ (1)

catalyst
increases rate (1)
by providing an alternative route of lower E_a (1) [6]

[Total: 12]

3 (a)

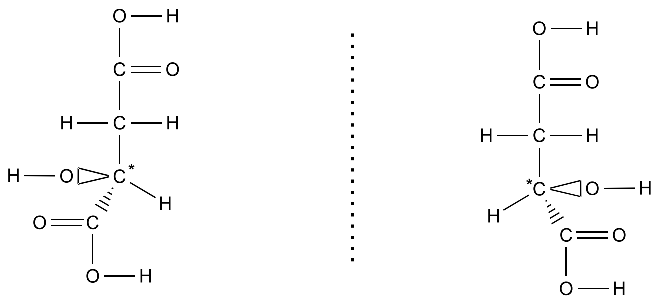


give one mark for each correct compound (6 × 1) [6]

(b)	malic acid into **C**	dehydration **or** elimination	(1)	
	C into **D**	oxidation	(1)	
	C into **E**	addition **or** hydration	(1)	[3]

(c) solvents **or** perfumes **or** flavourings (1) [1]

(d) (i)



correct compound (malic acid) shown as a pair of enantiomers in 3D (1)
chiral carbon (*) atom correctly identified (1)
structure **fully** displayed (1)

(ii)

give one for each correct **skeletal formula** (1 + 1)

correct *cis* (or Z) **and** *trans* (or E) labels (1) [6]

(e) C : H : O = $\frac{37.5}{12} : \frac{4.17}{1} : \frac{58.3}{16}$

= 3.13 : 4.17 : 3.64 (1)

= 1 : 1.33 : 1.16 (1)

= 6 : 8 : 7

empirical formula is $C_6H_8O_7$ (1) [3]

[Total: 19]

4 (a)

reagent	**R_2CHOH**	**RCHO**	**RCO_2H**	**RCO_2R'**	**RCOR'**
$NaHCO_3$			✓		
Na	✓		✓		
$Cr_2O_7^{2}$ /H^+	✓	✓			

give one mark for each correct tick (5 × 1) [5]

(b) (i) alcohol **or** ROH
not hydroxyl **or** phenol **or** –OH (1)

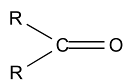
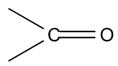
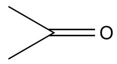
(ii) $n(H_2) = \frac{80}{24000} = 3.3 \times 10^{3}$ mol (1)

n(H atoms) = 2 × 3.3 × 10 ^{3} mol = 6.6 × 10 ^{3} mol (1)

(iii) $n(\mathbf{G}) = \frac{0.30}{90} = 3.3 \times 10^{3}$ mol

n(**G**) : n(H atoms) = 3.3 × 10 ^{3} : 6.6 × 10 ^{3}
= 1 : 2
so each –OH group produces one H atom (1) [4]

(c) (i)

 **or**  **or**  and **'ketone'** (1)

(ii) **G** is $HOCH_2COCH_2OH$ as the minimum (1)
allow the *gem* diol $CH_3COCH(OH)_2$ [2]

(d) (i) **H** is HO_2CCOCO_2H as the minimum (1)

(ii) **J** is $HOCH_2CH(OH)CH_2OH$ as the minimum (1) [2]

[Total: 13]

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

CANDIDATE NAME											
CENTRE NUMBER							CANDIDATE NUMBER				

1536187828

CHEMISTRY **9701/23**

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	
5	
Total	

This document consists of **11** printed pages and **1** blank page.

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UNIVERSITY *of* CAMBRIDGE International Examinations

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

For Examiner's Use

1 Although the actual size of an atom cannot be measured exactly, it is possible to measure the distance between the nuclei of two atoms. For example, the 'covalent radius' of the Cl atom is assumed to be half of the distance between the nuclei in a Cl_2 molecule. Similarly, the 'metallic radius' is half of the distance between two metal atoms in the crystal lattice of a metal. These two types of radius are generally known as 'atomic radii'.
The table below contains the resulting atomic radii for the elements of period three of the Periodic Table, Na to Cl.

element	Na	Mg	Al	Si	P	S	Cl
atomic radius / nm	0.186	0.160	0.143	0.117	0.110	0.104	0.099

(a) (i) Explain qualitatively this variation in atomic radius.

....

....

....

....

....

(ii) Suggest why it is not possible to use the same type of measurement for argon, Ar.

....

....

[4]

(b) (i) Use the *Data Booklet* to complete the following table of radii of the cations and anions formed by some of the period three elements.

radius of cation / nm			radius of anion / nm		
Na^+	Mg^{2+}	Al^{3+}	P^{3-}	S^{2-}	Cl^-

For Examiner's Use

(ii) Explain the differences in size between the cations and the corresponding atoms.

....

....

....

(iii) Explain the differences in size between the anions and the corresponding atoms.

....

....

....

[5]

(c) Each of the elements Na to C*l* forms at least one oxide. Na_2O is an ionic oxide, SO_2 is a covalent oxide. Both oxides react with water.

(i) Write an equation for the reaction of **each** of these oxides with water.

Na_2O ....

SO_2 ....

(ii) What is the pH of the resulting solution in **each** case?

Na_2O .... SO_2 ....

(iii) Write an equation for the reaction that occurs between the products of your reactions in **(i)**.

....

[5]

[Total: 14]

For Examiner's Use

2 Washing soda is hydrated sodium carbonate, $Na_2CO_3.xH_2O$.

A student wished to determine the value of x by carrying out a titration, with the following results.

5.13 g of washing soda crystals were dissolved in water and the solution was made up to 250 cm^3 in a standard volumetric flask. 25.0 cm^3 of this solution reacted exactly with 35.8 cm^3 of 0.100 mol dm^{-3} hydrochloric acid and carbon dioxide was produced.

(a) (i) Write a balanced equation for the reaction between Na_2CO_3 and HCl.

....

(ii) Calculate the amount, in moles, of HCl in the 35.8 cm^3 of solution used in the titration.

(iii) Use your answers to **(i)** and **(ii)** to calculate the amount, in moles, of Na_2CO_3 in the 25.0 cm^3 of solution used in the titration.

(iv) Use your answer to **(iii)** to calculate the amount, in moles, of Na_2CO_3 in the 250 cm^3 of solution in the standard volumetric flask.

For Examiner's Use

(v) Hence calculate the mass of Na_2CO_3 present in 5.13 g of washing soda crystals.

[6]

(b) Use your calculations in **(a)** to determine the value of x in $Na_2CO_3.xH_2O$.

[2]

[Total: 8]

For Examiner's Use

3 With the prospect that fossil fuels will become increasingly scarce in the future, many compounds are being considered for use in internal combustion engines. One of these is DME or dimethyl ether, CH_3OCH_3. DME is a gas which can be synthesised from methanol. Methanol can be obtained from biomass, such as plant waste from agriculture.

(a) Define, with the aid of an equation which includes state symbols, the standard enthalpy change of combustion, $\Delta H^{\ominus}_{c}$, for DME at 298 K.

equation ....

definition ....

....

.... [3]

(b) DME may be synthesised from methanol. Relevant enthalpy changes of formation, $\Delta H^{\ominus}_{f}$, for this reaction are given in the table below.

compound	$\Delta H^{\ominus}_{f}$ / kJ mol^{-1}
$CH_3OH(l)$	–239
$CH_3OCH_3(g)$	–184
$H_2O(l)$	–286

Use these values to calculate $\Delta H^{\ominus}_{reaction}$ for the synthesis of DME, using the following equation. Include a sign in your answer.

$$2CH_3OH(l) \rightarrow CH_3OCH_3(g) + H_2O(l)$$

$\Delta H^{\ominus}_{reaction}$ = ... kJ mol^{-1}
[3]

For Examiner's Use

(c) DME and ethanol are isomers with the molecular formula C_2H_6O.

(i) Draw the displayed formula of DME and of ethanol.

DME	ethanol

(ii) What type of isomerism do DME and ethanol show?

.... [2]

(d) DME is a gas at room temperature while ethanol is a liquid.

(i) Which intermolecular force exists between ethanol molecules, which causes ethanol to be a liquid at room temperature?

....

(ii) Draw a diagram that clearly shows this intermolecular force.
Your diagram should show any lone pairs or dipoles present that you consider to be important. You should represent at least two molecules in your diagram.

[4]

[Total: 12]

4 But-2-ene, $CH_3CH{=}CHCH_3$, is an important compound which is obtained from the cracking of hydrocarbons present in crude oil.

(a) Give **two** different conditions under which long chain hydrocarbons may be cracked.

....

....

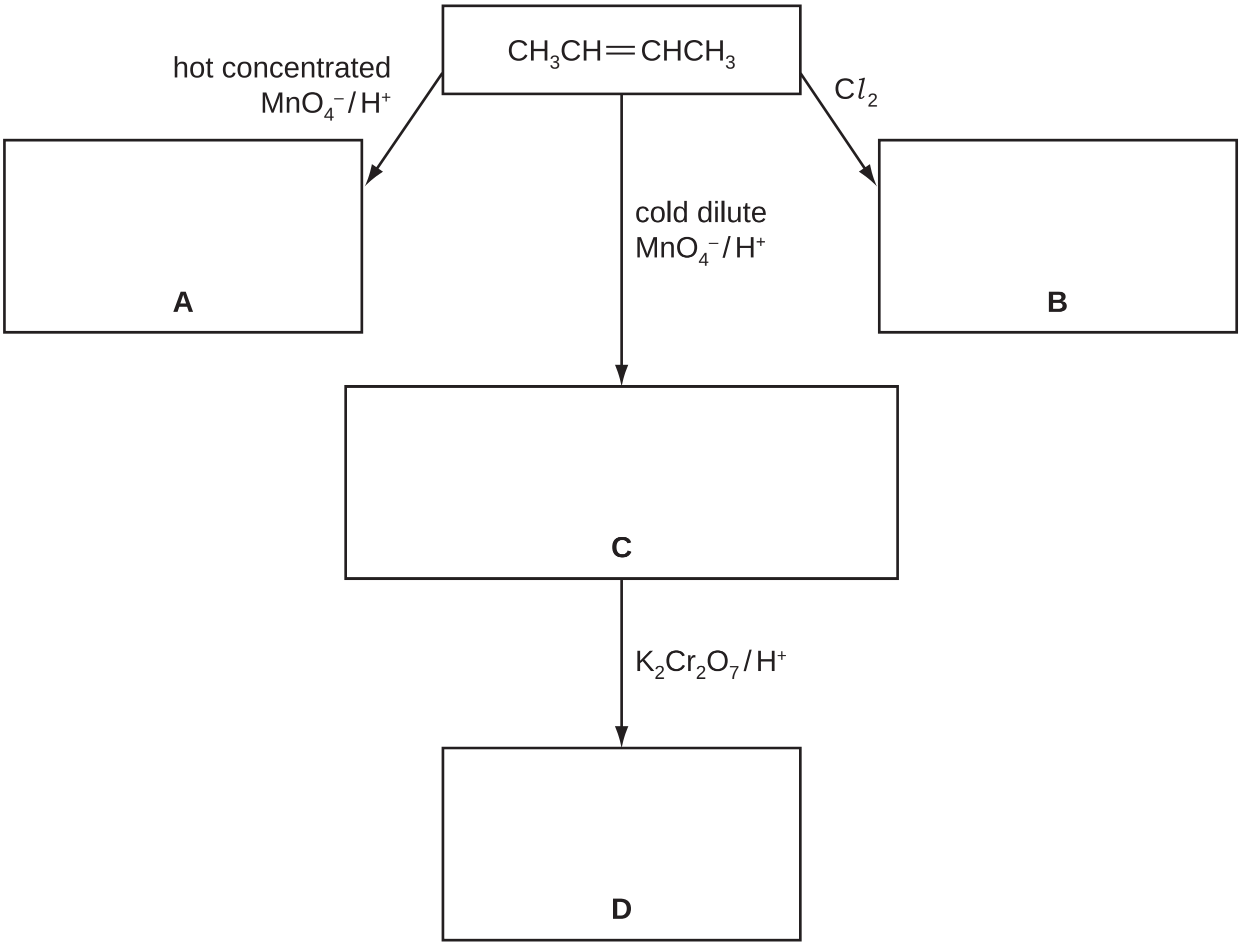
.... [2]

(b) Dodecane, $C_{12}H_{26}$, is a long chain hydrocarbon which is present in crude oil and which can be cracked to form but-2-ene and an alkane.

Write a balanced equation for this reaction.

.... [1]

(c) Some reactions of but-2-ene are shown below.
In the boxes below, give the **structural** formulae of the organic compounds **A** to **D**.



[4]

For Examiner's Use

(d) **(i)** Draw the **skeletal** formula of compound **D**.

(ii) By using the letters **A** to **D** as appropriate, identify those compounds which are chiral. If there are none, write 'none'.

....

[3]

(e) But-2-ene can be polymerised to give poly(butene).

Draw the **structural** formula of a portion of the polymer chain in poly(butene) showing **two** repeat units.

[1]

(f) Compound **C** is a liquid which can be reacted with concentrated sulfuric acid to give a gas, **E**, which will decolourise aqueous bromine when passed through it.

(i) Suggest the **structural** formula of **E**.

(ii) Suggest the **structural** formula of the product of the reaction between **E** and an excess of bromine.

(iii) What *type of reaction* occurs between **E** and an excess of bromine?

....

[3]

[Total: 14]

For Examiner's Use

5 Many naturally occurring organic compounds contain oxygen. Such compounds may contain alcohol, aldehyde, carboxylic acid, ester or ketone functional groups. These functional groups may be identified by their reactions with specific reagents.

Compound **F** is a white solid which has the molecular formula $C_3H_6O_3$.

Compound **F** is soluble in water. Addition of $NaHCO_3$ to this solution produces a colourless gas, **G**, which turns lime water milky.

(a) **(i)** What is the identity of the gas **G**?

....

(ii) What functional group does this test show to be present in **F**?

....

[2]

(b) When **F** is heated with concentrated sulfuric acid, a colourless liquid **H** is produced. When cold dilute acidified $KMnO_4$ is shaken with **H**, the solution becomes colourless.

(i) What *type of reaction* occurs when **H** is formed from **F**?

....

(ii) Use your answers to **(a)(ii)** and **(b)(i)** to deduce the structural formula of the colourless liquid **H**.

[4]

For Examiner's Use

(c) Compound **F** will react with sodium.

Calculate the volume of H_2, measured at room temperature and pressure, which will be produced when 0.600 g of **F** is reacted with an excess of Na.

[4]

(d) There are two structural isomers of **F** that give the reactions described in **(a)** and **(b)**.

(i) Suggest two structural formulae for these isomers.

J	**K**

(ii) Isomers **J** and **K** can both be oxidised.
What will be produced when **each** of the isomers **J** and **K** is heated under reflux with acidified $K_2Cr_2O_7$?

product from **J**	product from **K**

[2]

[Total: 12]

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS

GCE Advanced Subsidiary Level and GCE Advanced Level

MARK SCHEME for the May/June 2012 question paper

for the guidance of teachers

9701 CHEMISTRY

9701/23 Paper 2 (AS Structured Questions), maximum raw mark 60

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1 **(a)** **(i)** **from Na to Cl**
nuclear charge increases (1)
electrons are in the same shell/have the same shielding (1)
nuclear attraction increases (1)

(ii) argon does not form any bonds/compounds **or**
argon exists as single atoms/is monatomic (1) [4]

(b) **(i)**

radius of cation/nm			radius of anion/nm		
Na^{+}	Mg^{2+}	Al^{3+}	P^{3}	S^{2}	Cl
0.095	0.065	0.050	0.212	0.184	0.181

(1)

(ii) cations contain fewer electrons than the corresponding atoms **or**
cations contain fewer electrons than they do protons (1)
nucleus has a greater attraction (1)

(iii) anions contain more electrons than the corresponding atoms **or**
anions contain more electrons than they do protons (1)
nucleus has a smaller attraction (1) [5]

(c) **(i)** $Na_2O + H_2O \rightarrow 2NaOH$ (1)
$SO_2 + H_2O \rightarrow H_2SO_3$ (1)

(ii) for Na_2O 10 to 14 (1)
for SO_2 1 to 4 (1)

(iii) $NaOH + H_2SO_3 \rightarrow NaHSO_3 + H_2O$ **or**
$2NaOH + H_2SO_3 \rightarrow Na_2SO_3 + 2H_2O$ (1) [5]

[Total: 14]

2 **(a)** **(i)** $Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$ (1)

(ii) $n(HCl) = \dfrac{35.8}{1000} \times 0.100 = 3.58 \times 10^{\ 3}$ (1)

(iii) $n(Na_2CO_3) = \dfrac{35.8}{2} \times 10^{\ 3} = 1.79 \times 10^{\ 3}$ mol in 25.0 cm^3 (1)

(iv) $n(Na_2CO_3) = 1.79 \times 10^{\ 3} \times 10 = 1.79 \times 10^{\ 2}$ mol in 250 cm^3 (1)

(v) mass of $Na_2CO_3 = 1.79 \times 10^{\ 2} \times 106 = 1.90g$
M_r of $Na_2CO_3 = 106$ (1)
mass of $Na_2CO_3 = 1.90$ g (1) [6]

(b) $n(H_2O)$ in 5.13 g of washing soda $= \dfrac{5.13 \quad 1.90}{18} = 1.79 \times 10^{\ 1}$ mol (1)
$n(Na_2CO_3)$ in 5.13 g of washing soda $= 1.79 \times 10^{\ 2}$ mol
$n(H_2O) : n(Na_2CO_3) = 10 : 1$ (1)

or
1.90 g Na_2CO_3 are combined with 3.23.g H_2O
106 g Na_2CO_3 are combined with $\dfrac{3.23 \times 106}{1.90} = 180.2$ g H_2 (1)
this is 10 mol of H_2O (1)

or
$1.79 \times 10^{\ 2}$ mol $Na_2CO_3.xH_2O \equiv 5.13$ g of washing soda
1 mol $Na_2CO_3.xH_2O \equiv \dfrac{5.13}{1.79 \times 10^{\ 2}} = 286.6$ g (1)
$Na_2CO_3 = 106$ and $H_2O = 18$ hence $x = 10$ (1) [2]

[Total: 8]

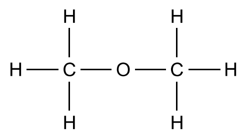
3 **(a)** $CH_3OCH_3(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$ (1)
the enthalpy change/heat change/heat evolved when
one mole of CH_3OCH_3/a compound (1)
is completely burned **or**
burned in an excess of air/oxygen (1) [3]

(b)

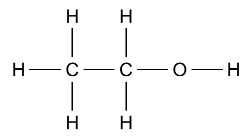
	$2CH_3OH(l)$	$\rightarrow$	$CH_3OCH_3(g)$	+	$H_2O(l)$
$\Delta H^{\ominus}_f$ /kJ mol ^{1}	2(–239)		–184		–286

$\Delta H^{\ominus}_{reaction}$ = –184 + (–286) – 2(–239) (1)
= +8 kJ mol ^{1} (1)
correct sign (1) [3]

(c) **(i)**



DME



ethanol

both correct (1)

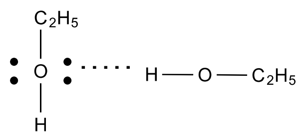
(ii) structural isomerism **or** functional group isomerism (1) [2]

(d) **(i)** hydrogen bonds (1)

(ii) lone pair on O atom of C_2H_5OH (1)

correct dipole O^{δ} —$H^{\delta+}$ on bond in one molecule of ethanol (1)

hydrogen bond shown between lone pair of an O atom and a hydrogen atom, i.e.



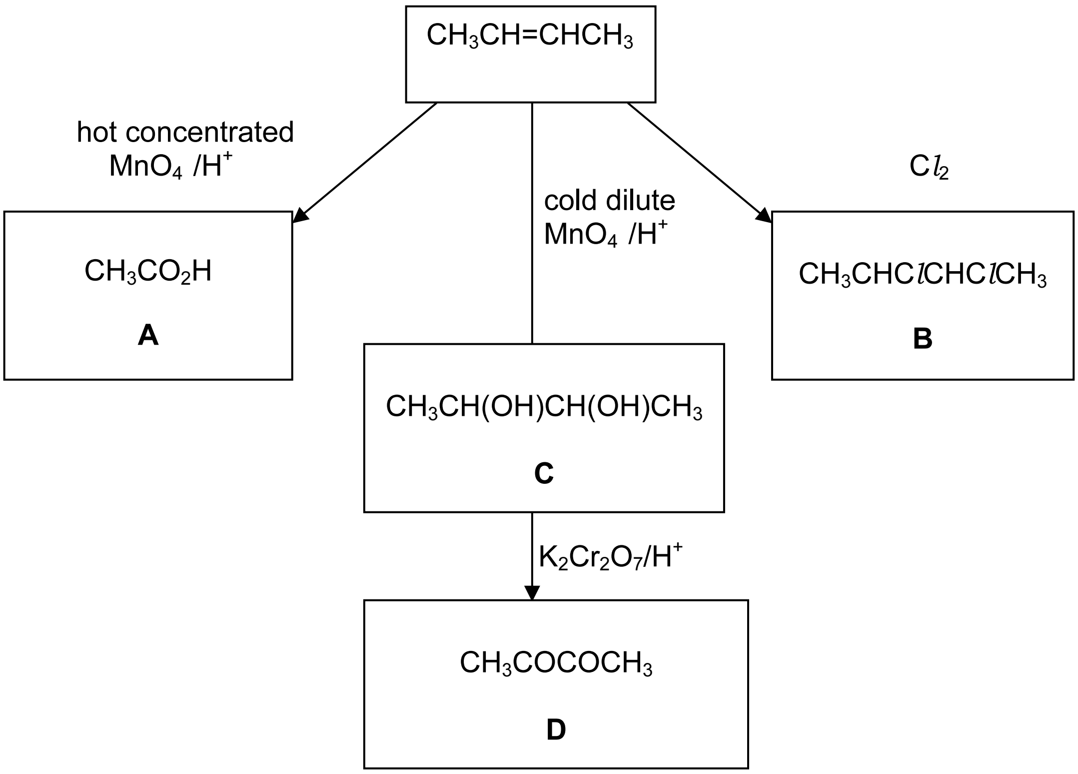
(1) [4]

[Total: 12]

4 **(a)** high temperature and high pressure (1)
high temperature and catalyst (1) [2]

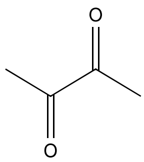
(b) $C_{12}H_{26} \rightarrow C_4H_8 + C_8H_{18}$ **or**
$C_{12}H_{26} \rightarrow 2C_4H_8 + C_4H_{10}$ (1) [1]

(c)



(4 × 1) [4]

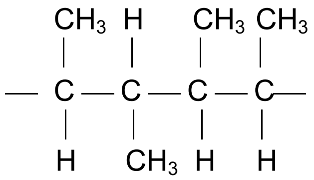
(d) **(i)**



(1)

(ii) compound **B** (1)
compound **C** (1) [3]

(e)



allow any orientation of CH_3– groups (1) [1]

(f) **(i)** $CH_2=CH—CH=CH_2$
allow $CH_3CHOHCH=CH_2$ and $CH_3C\equiv CCH_3$ (1)

(ii) $CH_2BrCHBrCHBrCH_2Br$
allow $CH_3CBr_2CBr_2CH_3$ from $CH_3CHOHCH=CH_2$
allow $CH_3CHOHCHBrCH_2Br$ from $CH_3C\equiv CCH_3$ (1)

(iii) electrophilic addition
both words required (1) [3]

[Total: 14]

5 **(a)** **(i)** CO_2/carbon dioxide (1)

(ii) carboxylic acid **or** $–CO_2H$ **or** –COOH (1) [2]

(b) **(i)** dehydration **or** elimination (1)

(ii) **H** contains >C=C< bond (1)
H contains $–CO_2H$ group (1)
H is $CH_2{=}CHCO_2H$ (1) [4]

(c) $n(\mathbf{F}) = \dfrac{0.600}{90} = 6.67 \times 10^{\;3}$ mol (1)
F contains one –OH group and one $–CO_2H$ group
hence one mole of **F** produces one mole of H_2 with Na (1)
$n(H_2) = 6.67 \times 10^{\;3}$ mol (1)
vol. of $H_2 = 6.67 \times 10^{\;3} \times 24000$ cm^3
= 160 cm^3 at room temperature and pressure (1)
[4]

(d) **(i)**

$HOCH_2CH_2CO_2H$	$CH_3CH(OH)CO_2H$
J	**K**

one isomer correct (1)

(ii)

$HO_2CCH_2CO_2H$	CH_3COCO_2H
product from J	**product from K**

one oxidation product correct (1) [2]

[Total: 12]

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

CANDIDATE NAME			
CENTRE NUMBER		CANDIDATE NUMBER	

7635733974

CHEMISTRY **9701/21**

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

UNIVERSITY of CAMBRIDGE International Examinations

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

For Examiner's Use

1 A sample of a fertiliser was known to contain ammonium sulfate, $(NH_4)_2SO_4$, and sand only.

A 2.96 g sample of the solid fertiliser was heated with 40.0 cm^3 of NaOH(aq), an excess, and all of the ammonia produced was boiled away.

After cooling, the remaining NaOH(aq) was exactly neutralised by 29.5 cm^3 of 2.00 mol dm^{-3} HC*l*.

In a separate experiment, 40.0 cm^3 of the original NaOH(aq) was exactly neutralised by 39.2 cm^3 of the 2.00 mol dm^{-3} HC*l*.

(a) (i) Write balanced equations for the following reactions.

NaOH with HC*l*

....

$(NH_4)_2SO_4$ with NaOH

....

(ii) Calculate the amount, in moles, of NaOH present in the 40.0 cm^3 of the original NaOH(aq) that was neutralised by 39.2 cm^3 of 2.00 mol dm^{-3} HC*l*.

(iii) Calculate the amount, in moles, of NaOH present in the 40.0 cm^3 of NaOH(aq) that remained after boiling the $(NH_4)_2SO_4$.

(iv) Use your answers to **(ii)** and **(iii)** to calculate the amount, in moles, of NaOH that reacted with the $(NH_4)_2SO_4$.

For Examiner's Use

(v) Use your answers to **(i)** and **(iv)** to calculate the amount, in moles, of $(NH_4)_2SO_4$ that reacted with the NaOH.

(vi) Hence calculate the mass of $(NH_4)_2SO_4$ that reacted.

(vii) Use your answer to **(vi)** to calculate the percentage, by mass, of $(NH_4)_2SO_4$ present in the fertiliser.
Write your answer to a suitable number of significant figures.

[9]

(b) 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]

(c) Large quantities of ammonia are manufactured by the Haber process.
Not all of this ammonia is used to make fertilisers.
State **one** large-scale use for ammonia, **other than** in the production of nitrogenous fertilisers.

.... [1]

[Total: 12]

2 Ammonium nitrate fertiliser is manufactured from ammonia. The first reaction in the manufacture of the fertiliser is the catalytic oxidation of ammonia to form nitrogen monoxide, NO. This is carried out at about 1×10^3 kPa (10 atmospheres) pressure and a temperature of 700 to 850 °C.

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H^\ominus = -906\,\text{kJ mol}^{-1}$$

(a) Write the expression for the equilibrium constant, K_p, stating the units.

K_p =

units .... [2]

(b) What will be the effect on the yield of NO of **each** of the following?
In each case, explain your answer.

(i) increasing the temperature

....

....

....

(ii) decreasing the applied pressure

....

....

....
[4]

For Examiner's Use

(c) The standard enthalpy changes of formation of $NH_3(g)$ and $H_2O(g)$ are as follows.

$NH_3(g)$, $\Delta H_f^\ominus$ = –46.0 kJ mol^{-1} $H_2O(g)$, $\Delta H_f^\ominus$ = –242 kJ mol^{-1}

Use these data and the value of $\Delta H^\ominus_{reaction}$ given below to calculate the standard enthalpy change of formation of NO(g).
Include a sign in your answer.

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H^\ominus = -906\ \text{kJ mol}^{-1}$$

[4]

[Total: 10]

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 floats on cold water and reacts readily with it.

....

(ii) An element that forms an oxide that is a reducing agent.

....

(iii) The element that has the smallest first ionisation energy.

....

(iv) The element which has a giant molecular structure **and** forms an oxide which has a simple molecular structure.

....

(v) The element in Period 3 (Na to Ar) that has the smallest anion.

....

(vi) The element in Period 3 (Na to Ar) which forms a chloride with a low melting point and an oxide with a very high melting point.

....

[6]

For Examiner's Use

(b) 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).

(i) An oxide which when placed in water for a long time has no reaction with it.

....

(ii) An oxide which dissolves readily in water to give a strongly alkaline solution.

....

(iii) Two acidic oxides formed by the same element.

.... and ....

(iv) An oxide which is amphoteric.

....

[5]

(c) Fluorine reacts with other elements in Group VII to form a number of different compounds. Two such compounds and their boiling points are given in the table.

compound	ClF_3	BrF_3
boiling point / °C	12	127

(i) The two molecules have similar electronic configurations.
Showing outer electrons only, draw a 'dot-and-cross' diagram of the bonding in ClF_3.

(ii) The two molecules have the same shape.
Suggest why the boiling points are significantly different.

....

....

....

....

[4]

[Total: 15]

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For Examiner's Use

4 Organic chemistry is the chemistry of carbon compounds. The types of organic reactions that you have studied are listed below.

addition	elimination	hydrolysis
oxidation	reduction	substitution

Addition and substitution reactions are further described as follows.

electrophilic	nucleophilic	free radical

Complete the table below.
Fill in the central column by using **only** the types of reaction given in the lists above.
Use **both** lists when appropriate.
In the right hand column give the formula(e) of the reagent(s) you would use to carry out the reaction given.

organic reaction	type of reaction	reagent(s)
$CH_3CH_2CH_2CH_2Br \rightarrow CH_3CH_2CH_2CH_2NH_2$		
$CH_3CH_2CH_2CH_2OH \rightarrow BrCH_2CH_2CH_2CH_2OH$		
$CH_3COCH_3 \rightarrow CH_3C(OH)(CN)CH_3$		
$CH_3CH(OH)CH_2CH_3 \rightarrow CH_3CH{=}CHCH_3$		

[Total: 11]

For Examiner's Use

5 Crotonaldehyde, $CH_3CH{=}CHCHO$, occurs in soybean oils.

(a) In the boxes below, write the **structural formula** of the organic compound formed when crotonaldehyde is reacted separately with each reagent under suitable conditions.
If you think no reaction occurs, write 'NO REACTION' in the box.

reaction	reagent	product
A	Br_2 in an inert organic solvent	
B	PCl_3	
C	H_2 and Ni catalyst	
D	$NaBH_4$	
E	$K_2Cr_2O_7/H^+$	

[5]

(b) Crotonaldehyde exists in more than one stereoisomeric form.
Draw the **displayed formulae** of the **stereoisomers** of crotonaldehyde.
Label **each** isomer.

[3]

For Examiner's Use

(c) Draw the **skeletal formula** of crotonaldehyde.

[1]

(d) The product of reaction E in the table opposite will react with a solution containing acidified manganate(VII) ions.
Draw the **structural formulae** of the organic products when the reagent is

(i) cold, dilute;

(ii) hot, concentrated.

[3]

[Total: 12]

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CAMBRIDGE INTERNATIONAL EXAMINATIONS

GCE Advanced Subsidiary Level and GCE Advanced Level

MARK SCHEME for the May/June 2013 series

9701 CHEMISTRY

9701/21 Paper 2 (AS Structured Questions), maximum raw mark 60

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

Mark schemes should be read in conjunction with the question paper and the Principal Examiner Report for Teachers.

Cambridge will not enter into discussions about these mark schemes.

Cambridge is publishing the mark schemes for the May/June 2013 series for most IGCSE, GCE Advanced Level and Advanced Subsidiary Level components and some Ordinary Level components.

1 **(a)** **(i)** $NaOH + HCl \rightarrow NaCl + H_2O$ (1)

$(NH_4)_2SO_4 + 2NaOH \rightarrow 2NH_3 + Na_2SO_4 + 2H_2O$ (1)

allow ionic equations in each case

(ii) $n(NaOH) = n(HCl) = \dfrac{39.2 \times 2.00}{1000} = 0.0784$ (1)

(iii) $n(NaOH) = n(HCl) = \dfrac{29.5 \times 2.00}{1000} = 0.059$ (1)

(iv) $n(NaOH) = 0.0784 – 0.059 = 0.0194$ (1)

(v) $n[(NH_4)_2SO_4] = \dfrac{0.0194}{2} = 9.7 \times 10^{3}$ (1)

(vi) mass of $(NH_4)_2SO_4 = 9.7 \times 10^{3} \times 132.1 = 1.2814$ g (1)

(vii) % of $(NH_4)_2SO_4 = \dfrac{1.2814 \times 100}{2.96} = 43.30405405 = 43.3$

give one mark for the correct expression (1)
give one mark for answer given as 43.3 – i.e. to 3 sig. fig. (1)
allow ecf where appropriate [9]

(b) fertiliser in the river causes
excessive growth of aquatic plants/algae **or** algal bloom (1)
when plants and algae die O_2 is used up **or** fish or aquatic life die (1) [2]

(c) manufacture of HNO_3 **or** explosives **or** nylon **or**
as a cleaning agent **or** as a refrigerant
not detergent (1) [1]

[Total:12]

2 (a) K_P $\dfrac{p(NO)^4\,p(H_2O)^6}{p(NH_3)^4\,p(O_2)^5}$ (1)

atmospheres **or** Pa **or** kPa (1)
allow ecf on incorrect powers [2]

(b) (i) increasing temperature
yield of NO is decreased **or** reaction moves to LHS (1)
forward reaction is exothermic (1)

(ii) decreasing the pressure
yield of NO is increased **or** reaction moves to RHS (1)
more moles/molecules of gas on RHS **or**
fewer moles/molecules of gas on LHS (1) [4]

(c) let $\Delta H_f^{\ominus}$ for NO be y kJ mol $^{-1}$

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$$

$\Delta H_f^{\ominus}$ 4 × (–46.0) $\qquad$ $4y$ $\qquad$ 6 × (–242) (1)

$\Delta H^{\ominus}_{reaction}$ = $4y$ + [6 × (–242)] – [4 × (–46.0)] (1)
= $4y$ – 1452 + 184

$\Delta H^{\ominus}_{reaction}$ is –906 kJmol $^{-1}$ so
$4y$ = –906 + 1452 – 184 = 362 (1)
whence y = $\Delta H_f^{\ominus}$ for NO = +90.5 kJ mol $^{-1}$
+ sign is required (1) [4]

[Total: 10]

3 **(a)** penalise (–1) for names of elements

(i) Na **or** K **or** Li (1)

(ii) S **or** C **or** N **or** P (1)

(iii) K (1)

(iv) C (1)

(v) C*l* (1)

(vi) A*l* **or** Si (1) [6]

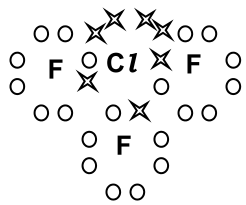
(b) **(i)** Al_2O_3 **or** SiO_2 (1)

(ii) Na_2O (1)

(iii) P_2O_3 **or** P_4O_6 **and** P_2O_5 **or** P_4O_{10} **or** SO_2 **and** SO_3 (1+1)

(iv) Al_2O_3 (1) [5]

(c) **(i)**



3 bonding pairs **and**
2 lone pairs around C*l* atom (1)
3 lone pairs on **each** of the F atoms (1)

(ii) **either**

referring to van der Waals' forces in BrF_3

van der Waals' **or**
intermolecular forces are greater/stronger (1)
because there are more electrons in BrF_3 than in ClF_3 (1)

OR referring to permanent dipoles

permanent dipole **or** intermolecular forces are stronger/greater in BrF_3 (1)
because BrF_3 has a larger permanent dipole than ClF_3

OR because difference in electronegativity is larger between Br and F than between C*l* and F (1)

part **(ii)** has a maximum of 2 marks (max 2) [4]

[Total: 15]

4 Types of reaction used must come from the list in the question.

organic reaction	type of reaction	reagent(s)
$CH_3CH_2CH_2CH_2Br \rightarrow$ $CH_3CH_2CH_2CH_2NH_2$	nucleophilic (1) substitution (1)	NH_3 (1)
$CH_3CH_2CH_2CH_2OH \rightarrow$ $BrCH_2CH_2CH_2CH_2OH$	free radical (1) substitution (1)	Br_2 **or** Br_2 in an organic solvent (1) **not** $Br_2(aq)$
$CH_3COCH_3 \rightarrow$ $CH_3C(OH)(CN)CH_3$	nucleophilic (1) addition (1)	HCN **or** HCN and CN **or** NaCN/KCN + H^+ (1)
$CH_3CH(OH)CH_2CH_3$ $\rightarrow CH_3CH{=}CHCH_3$	elimination (1) **not** dehydration	conc. H_2SO_4 **or** P_4O_{10} **or** Al_2O_3 **or** H_3PO_4 (1)

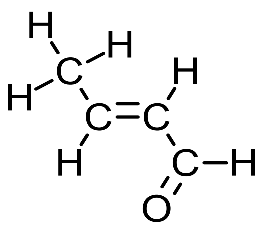
[Total: 11]

5 (a)

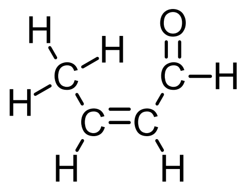
reaction	reagent	product
A	Br_2 in an inert organic solvent	$CH_3CHBrCHBrCHO$
B	PCl_3	NO REACTION
C	H_2 and Ni catalyst	$CH_3CH_2CH_2CH_2OH$
D	$NaBH_4$	$CH_3CH{=}CHCH_2OH$
E	$K_2Cr_2O_7/H^+$	$CH_3CH{=}CHCO_2H$

one mark for each correct answer [5]

(b)



trans **or** E



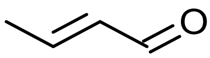
cis **or** Z

two correct structures (1)

both correctly labelled (1)

correctly displayed -CHO group (1) [3]

(c)



(1) [1]

(d) (i) $CH_3CH(OH)CH(OH)CO_2H$ (1)

(ii) CH_3CO_2H (1)
HO_2CCO_2H (1) [3]

allow ecf on candidate's answer to E in **(a)**

[Total: 12]

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

CANDIDATE NAME	

CENTER NUMBER		CANDIDATE NUMBER	

5561830943

CHEMISTRY (US) **9185/23**

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

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Answer **all** questions.
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The number of marks is given in brackets [ ] at the end of each question or part question.

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Total	

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For Examiner's Use

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

1 Carbon disulfide, CS_2, is a volatile, flammable liquid which is produced in small quantities in volcanoes.

(a) The sequence of atoms in the CS_2 molecule is sulfur to carbon to sulfur.

(i) Draw a 'dot-and-cross' diagram of the carbon disulfide molecule.
Show outer electrons only.

(ii) Suggest the shape of the molecule and state the bond angle.

shape ....

bond angle ....
[3]

(b) Carbon disulfide is readily combusted to give CO_2 and SO_2.

(i) Construct a balanced equation for the complete combustion of CS_2.

....

(ii) Define the term *standard enthalpy change of combustion*, $\Delta H_c^{\ominus}$.

....

....

....
[3]

For Examiner's Use

(c) Calculate the standard enthalpy change of formation of CS_2 from the following data. Include a sign in your answer.

standard enthalpy change of combustion of CS_2 = $-1110\,kJ\,mol^{-1}$

standard enthalpy change of formation of CO_2 = $-395\,kJ\,mol^{-1}$

standard enthalpy change of formation of SO_2 = $-298\,kJ\,mol^{-1}$

[3]

(d) Carbon disulfide reacts with nitrogen monoxide, NO, in a 1:2 molar ratio.
A yellow solid and two colorless gases are produced.

(i) Construct a balanced equation for the reaction.

....

(ii) What is the change in the oxidation number of sulfur in this reaction?

from .... to ....

[3]

[Total: 12]

For Examiner's Use

2 Methanol, CH_3OH, can be produced industrially by reacting carbon monoxide, CO, with hydrogen, H_2.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = -91\,kJ\,mol^{-1}$$

The process is carried out at 4×10^3 kPa (40 atmospheres) and 1150 K.

(a) (i) State Le Chatelier's Principle.

....

....

.... [2]

(ii) From your understanding of Le Chatelier's Principle, state the conditions of temperature and pressure that could be used in order to produce an increased yield of methanol in this process.
In **each** case, explain why the yield would increase.

temperature ....

explanation ....

....

pressure ....

explanation ....

....
[4]

For Examiner's Use

(b) The carbon monoxide for use in the production of methanol may be formed by reacting carbon dioxide with hydrogen.

$$CO_2(g) + H_2(g) \rightleftharpoons CO(g) + H_2O(g) \qquad K_c = 1.44 \text{ at } 1200\,K$$

A mixture containing 0.70 mol of CO_2, 0.70 mol of H_2, 0.30 mol of CO and 0.30 mol of H_2O was placed in a 1 dm^3 flask and allowed to come to equilibrium at 1200 K.

Calculate the amount, in moles, of each substance present in the equilibrium mixture at 1200 K.

	CO_2	+	H_2	$\rightleftharpoons$	CO	+	H_2O
initial moles	0.70		0.70		0.30		0.30

[4]

[Total: 10]

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		A*l*	Si	P	S	C*l*	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 has molecules which consist of single atoms.

....

(ii) An element that has a molecule which contains exactly four atoms.

....

(iii) The element that is a liquid at room temperature and pressure.

....

(iv) The element in Period 3 (Na to Ar) that has the largest atomic radius.

....

(v) The element in Period 3 (Na to Ar) that has the highest melting point.

....

(vi) The element in Period 3 (Na to Ar) that forms the largest anion.

....

(vii) An element that reacts with water to give a solution that can behave as an oxidizing agent.

....

[7]

For Examiner's Use

(b) The formulae and melting points of some of the oxides of the elements in Period 3, Na to C*l*, are given in the table.

formula of oxide	Na_2O	MgO	Al_2O_3	SiO_2	P_4O_6	SO_2	Cl_2O_7
m.p. / °C	1132	2830	2054	1710	24	–73	–92

(i) Give the formulae of **two** of these oxides that have simple molecular structures.

.... and ....

(ii) Give the formula of one of these oxides that will give no reaction with water when placed in it for a long time.

....

(iii) Give the formula of the product formed when MgO is reacted with SO_2.

....

[4]

(c) The melting points of the elements Si to C*l* are given in the table.

element	Si	P	S	C*l*
m.p. / °C	1414	44	115	–102

(i) Explain why the melting point of Si is very much greater than those of the other three elements.

....

....

(ii) Suggest why the melting points of the other three elements are in the order S > P > C*l*.

....

....

....

....

[4]

[Total: 15]

For Examiner's Use

4 Compound **Q**, heptan-2-one, is found in some blue cheeses.

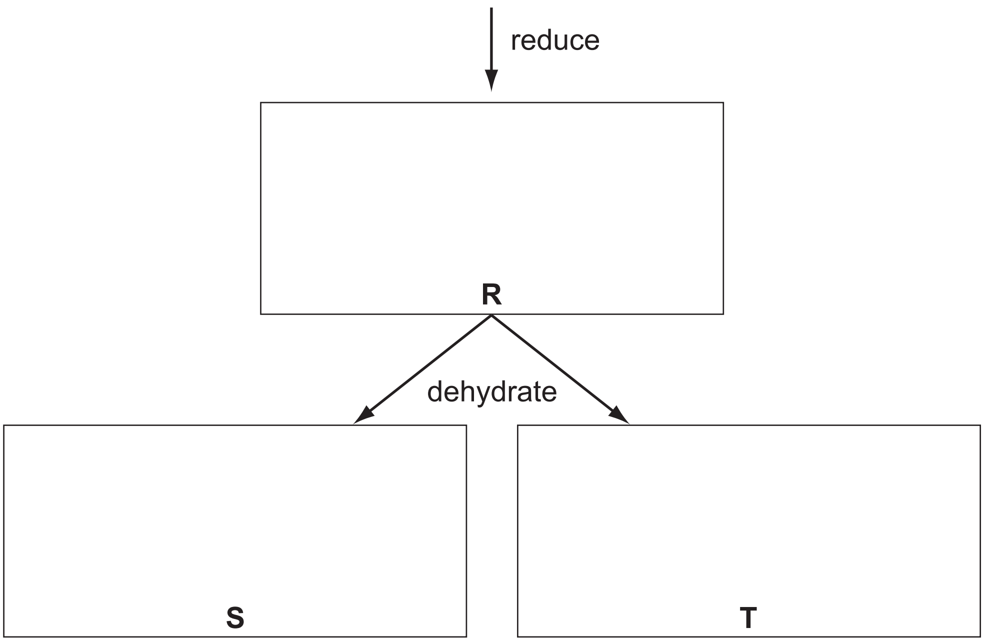
$$CH_3(CH_2)_4COCH_3$$

compound **Q**

(a) Compound **Q** may be reduced to **R**.
Compound **R** may be dehydrated to give two different products, **S** and **T**.

(i) In the boxes below, draw the **structural formulae** of **R**, **S**, and **T**.

$$CH_3(CH_2)_4COCH_3$$



(ii) State the reagents that would be used for **each** of these reactions in a school or college laboratory.

reduction ....

dehydration ....

[5]

For Examiner's Use

(b) In the boxes below, write the **structural formula** of the organic compound formed when **Q** is reacted separately with each reagent under suitable conditions.
If you think no reaction occurs, write 'NO REACTION' in the box.

Tollens' reagent	
HCN	
$K_2Cr_2O_7 / H^+$	

[3]

(c) The first stage of cheese making is to produce 2-hydroxypropanoic acid (lactic acid) from milk.

$CH_3CH(OH)CO_2H$

lactic acid

Other than the use of a pH indicator, what reagent could you use to confirm the presence of some lactic acid in a sample of heptan-2-one?
State what observation you would make.

reagent ....

observation .... [2]

[Total: 10]

[Turn over

For Examiner's Use

5 Compounds containing the allyl group, $CH_2=CHCH_2–$, have pungent smells and are found in onions and garlic.
Allyl alcohol, $CH_2=CHCH_2OH$, is a colorless liquid which is soluble in water.

(a) Allyl alcohol behaves as a primary alcohol and as an alkene.

Give the structural formula of the organic compound formed when allyl alcohol is reacted separately with each of the following reagents.

(i) acidified potassium dichromate(VI), heating under reflux

(ii) bromine in an inert organic solvent

(iii) cold, dilute, acidified potassium manganate(VII)

(iv) hot, concentrated, acidified potassium manganate(VII)

[5]

(b) Allyl alcohol undergoes the following reactions.

(i) When reacted with concentrated HCl at 100 °C, $CH_2=CHCH_2Cl$ is formed.

State as fully as you can what *type of reaction* this is.

....

(ii) When reacted with MnO_2 at room temperature, $CH_2=CHCHO$ is formed.

What *type of reaction* is this?

....

[2]

For Examiner's Use

(c) Allyl alcohol can be converted into propanal in two steps.

$$CH_2{=}CHCH_2OH \xrightarrow{\text{step I}} CH_3CH_2CH_2OH \xrightarrow{\text{step II}} CH_3CH_2CHO$$

(i) What reagents and conditions would be used for **each** step?

step I

reagent(s) ....

condition(s) ....

step II

reagent(s) ....

condition(s) ....

(ii) Allyl alcohol and propanal are isomers.

What form of isomerism do they display?

....

[5]

(d) Allyl alcohol may also be converted into propanal by using a ruthenium(IV) catalyst in water.

$$CH_2{=}CHCH_2OH \xrightarrow{\text{ruthenium(IV) catalyst}} CH_3CH_2CHO$$

Suggest what is unusual about this single step reaction.

....

.... [1]

[Total: 13]

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CAMBRIDGE INTERNATIONAL EXAMINATIONS

GCE Advanced Subsidiary Level and GCE Advanced Level

MARK SCHEME for the May/June 2013 series

9185 CHEMISTRY (US)

9185/23 Paper 2 (AS Structured Questions), maximum raw mark 60

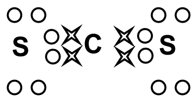
This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

Mark schemes should be read in conjunction with the question paper and the Principal Examiner Report for Teachers.

Cambridge will not enter into discussions about these mark schemes.

Cambridge is publishing the mark schemes for the May/June 2013 series for most IGCSE, GCE Advanced Level and Advanced Subsidiary Level components and some Ordinary Level components.

1 (a) (i)



S atom has 6 **and C** atom has 4 electrons (1)

S=C double bonds (4 electrons) clearly shown (1)

(ii) linear **and** 180° (1) [3]

(b) (i) $CS_2 + 3O_2 \rightarrow CO_2 + 2SO_2$ (1)

(ii) enthalpy change when 1 mol of a substance (1)

is burnt in an excess of oxygen/air

or is completely combusted

under standard conditions (1) [3]

(c)

	CS_2	+	$3O_2$	$\rightarrow$	CO_2	+	$2SO_2$	
$\Delta H_f^{\ominus}$/kJ mol ^{1}	x				–395		2(–298)	(1)

$\Delta H_{reaction}$ = –395 + 2(–298) – x = –1110 kJ mol ^{1} (1)

gives x = –395 + (–596) + 1110 = +119 kJ mol ^{1} (1) [3]

(d) (i) $CS_2 + 2NO \rightarrow CO_2 + 2S + N_2$
or
$CS_2 + 2NO \rightarrow CO + 2S + N_2O$

correct products (1)

correct equation (1)

(ii) from –2 to 0 **both** required (1) [3]

[Total: 12]

2	**(a)**	**(i)**	if the conditions of a system in equilibrium are changed	(1)	
			the position of equilibrium moves so as to reduce that change	(1)	[2]
		(ii)	lower temperature	(1)	
			because the forward reaction is exothermic	(1)	
			higher pressure	(1)	
			because the forward reaction shows a reduction in volume **or** there are fewer molecules/moles on RHS of equilibrium	(1)	[4]

(b)

	CO_2	+	H_2	$\rightleftharpoons$	CO	+	H_2O		
initial moles	0.70		0.70		0.30		0.30		
equil. moles	(0.70–x)		(0.70–x)		(0.30+x)		(0.30+x)	(1)	
equil. concn.	$\frac{(0.70-x)}{1}$		$\frac{(0.70-x)}{1}$		$\frac{(0.30+x)}{1}$		$\frac{(0.30+x)}{1}$		

$K_c = \frac{(0.30+x)^2}{(0.70-x)^2} = 1.44$ (1)

gives x = 0.25 (1)
at equilibrium,
$n(CO_2) = n(H_2) = 0.70 - 0.25 = 0.45$ moles
and
$n(CO) = n(H_2O) = 0.3 + 0.25 = 0.55$ moles (1) [4]

[Total: 10]

3	**(a)**	**(i)**	He **or** Ne **or** Ar **or** Kr	(1)	
		(ii)	P **or** As	(1)	
		(iii)	Br	(1)	
		(iv)	Na allow Ar	(1)	
		(v)	Si	(1)	
		(vi)	P allow Si	(1)	
		(vii)	C*l* **or** F **or** Br	(1)	[7]
	(b)	**(i)**	any **two** from P_4O_6, SO_2 and Cl_2O_7	(1+1)	
		(ii)	Al_2O_3 **or** SiO_2	(1)	
		(iii)	$MgSO_3$	(1)	[4]
	(c)	**(i)**	Si is giant molecular/giant covalent **or**		
			P, S, and C*l* are simple molecular	(1)	
		(ii)	the molecules are S_8, P_4, Cl_2	(1)	
			larger molecules have more electrons	(1)	
			and hence greater van der Waals' forces	(1)	[4]

[Total: 15]

4 (a) (i)

$CH_3(CH_2)_4COCH_3$

$\downarrow$ reduce

$CH_3(CH_2)_4CH(OH)CH_3$

R

dehydrate

$CH_3(CH_2)_4CH{=}CH_2$ **S**	$CH_3(CH_2)_3CH{=}CHCH_3$ **T**

one mark for each correct compound, **R**, **S** and **T**

allow correct *cis* **and** *trans* versions of compound **T** for 2 marks (3 × 1)

(ii) reduction

$NaBH_4$ **or** $LiAlH_4$ **or** H_2/Ni **or** Na/C_2H_5OH (1)

dehydration

P_4O_{10}/P_2O_5 **or** H_3PO_4 **or** conc. H_2SO_4 **or** Al_2O_3 (1) [5]

(b)

Tollens' reagent	NO REACTION
HCN	$CH_3(CH_2)_4C(OH)(CN)CH_3$
$K_2Cr_2O_7/H^+$	NO REACTION

one mark for each correct answer (3 × 1) [3]

(c) Na_2CO_3 **or** $NaHCO_3$ effervescence/colourless gas
or
Na colourless gas
or
PCl_3/PCl_5 etc. steamy fumes
or
C_2H_5OH/conc. H_2SO_4 sweet smell of ester
or
$K_2Cr_2O_7/H^+$ orange solution becomes green

correct reagent (1)

correct observation (1) [2]

[Total: 10]

5	**(a)**	**(i)**	CH_2=$CHCO_2H$	(1)	
		(ii)	$BrCH_2CHBrCH_2OH$	(1)	
		(iii)	product is $HOCH_2CH(OH)CH_2OH$		
			correct addition across >C=C<	(1)	
			original –CH_2OH remains	(1)	
		(iv)	HO_2CCO_2H	(1)	[5]
	(b)	**(i)**	nucleophilic substitution	(1)	
		(ii)	oxidation	(1)	[2]
	(c)	**(i)**	**step I**		
			H_2	(1)	
			heat with Ni catalyst	(1)	
			step II		
			acidified $K_2Cr_2O_7$	(1)	
			heat **or** distil off product	(1)	
		(ii)	structural isomerism **or** functional group isomerism	(1)	[5]
	(d)		**both** oxidation **and** reduction have occurred **or**		
			disproportionation has taken place	(1)	[1]

[Total: 13]