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

CANDIDATE NAME									
CENTRE NUMBER						CANDIDATE NUMBER				

CHEMISTRY **9701/21**

Paper 2 Structured Questions AS Core **October/November 2011**

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, Centre number and candidate number on all the work you hand in.
Write in dark blue or black pen.
You may use a pencil for any diagrams, graphs, or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE ON ANY BARCODES.

Answer **all** questions.
You may lose marks if you do not show your working or if you do not use appropriate units.
A Data Booklet is provided.

The number of marks is given in brackets [ ] at the end of each question or part question.
At the end of the examination, fasten all your work securely together.

For Examiner's Use	
1	
2	
3	
4	
5	
Total	

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

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

For Examiner's Use

1 Compound **A** is an organic compound which contains carbon, hydrogen and oxygen.

When 0.240 g of the vapour of **A** is slowly passed over a large quantity of heated copper(II) oxide, CuO, the organic compound **A** is completely oxidised to carbon dioxide and water. Copper is the only other product of the reaction.

The products are collected and it is found that 0.352 g of CO_2 and 0.144 g of H_2O are formed.

(a) In this section, give your answers to <u>three</u> decimal places.

(i) Calculate the mass of carbon present in 0.352 g of CO_2.

Use this value to calculate the amount, in moles, of carbon atoms present in 0.240 g of **A**.

(ii) Calculate the mass of hydrogen present in 0.144 g of H_2O.

Use this value to calculate the amount, in moles, of hydrogen atoms present in 0.240 g of **A**.

(iii) Use your answers to calculate the mass of oxygen present in 0.240 g of **A**.

Use this value to calculate the amount, in moles, of oxygen atoms present in 0.240 g of **A**.

[6]

(b) Use your answers to **(a)** to calculate the empirical formula of **A**.

For Examiner's Use

[1]

(c) When a 0.148 g sample of **A** was vapourised at 60°C, the vapour occupied a volume of 67.7 cm^3 at a pressure of 101 kPa.

(i) Use the general gas equation $pV = nRT$ to calculate M_r of **A**.

M_r =.....

(ii) Hence calculate the molecular formula of **A**.

[3]

(d) Compound **A** is a liquid which does **not** react with 2,4-dinitrophenylhydrazine reagent or with aqueous bromine.

Suggest **two** structural formulae for **A**.

[2]

(e) Compound **A** contains only carbon, hydrogen and oxygen.

Explain how the information on the opposite page about the reaction of **A** with CuO confirms this statement.

.....

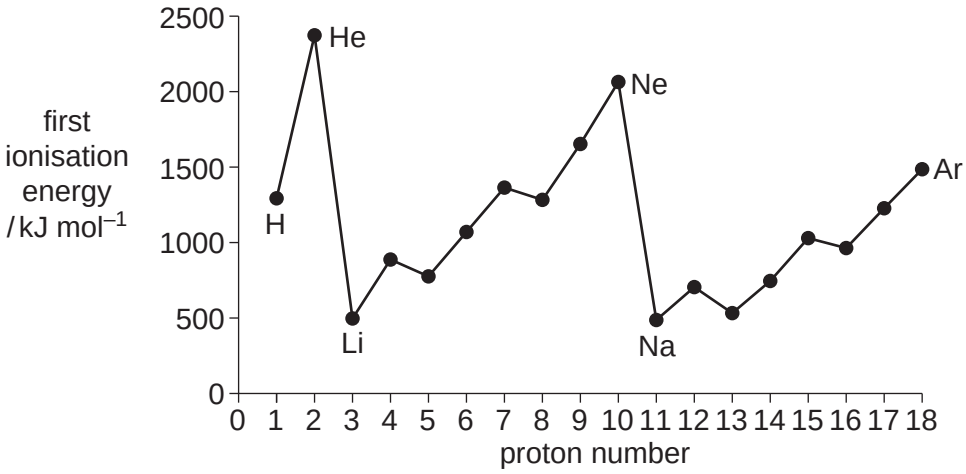
..... [1]

[Total: 13]

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.

For Examiner's Use

element	Na	Mg	A*l*	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]

[Turn over

3 For some chemical reactions, such as the thermal decomposition of potassium hydrogencarbonate, $KHCO_3$, the enthalpy change of reaction cannot be measured directly.

In such cases, the use of Hess' Law enables the enthalpy change of reaction to be calculated from the enthalpy changes of other reactions.

(a) State Hess' Law.

.....

.....

..... [2]

In order to determine the enthalpy change for the thermal decomposition of potassium hydrogencarbonate, two separate experiments were carried out.

experiment 1

30.0 cm^3 of 2.00 mol dm^{-3} hydrochloric acid (an excess) was placed in a conical flask and the temperature recorded as 21.0 °C.
When 0.0200 mol of potassium carbonate, K_2CO_3, was added to the acid and the mixture stirred with a thermometer, the maximum temperature recorded was 26.2 °C.

(b) (i) Construct a balanced equation for this reaction.

.....

(ii) Calculate the quantity of heat produced in **experiment 1**, stating your units.
Use relevant data from the *Data Booklet* and assume that all solutions have the same specific heat capacity as water.

(iii) Use your answer to **(ii)** to calculate the enthalpy change per mole of K_2CO_3.
Give your answer in kJ mol^{-1} and include a sign in your answer.

(iv) Explain why the hydrochloric acid must be in an excess.

.....

..... [4]

experiment 2

For Examiner's Use

The experiment was repeated with 0.0200 mol of potassium hydrogencarbonate, $KHCO_3$.
All other conditions were the same.
In the second experiment, the temperature fell from 21.0 °C to 17.3 °C.

(c) (i) Construct a balanced equation for this reaction.

.....

(ii) Calculate the quantity of heat absorbed in **experiment 2**.

(iii) Use your answer to **(ii)** to calculate the enthalpy change per mole of $KHCO_3$.
Give your answer in kJ mol^{-1} and include a sign in your answer.

[3]

(d) When $KHCO_3$ is heated, it decomposes into K_2CO_3, CO_2 and H_2O.

$$2KHCO_3 \longrightarrow K_2CO_3 + CO_2 + H_2O$$

Use Hess' Law and your answers to **(b)(iii)** and **(c)(iii)** to calculate the enthalpy change for this reaction.
Give your answer in kJ mol^{-1} and include a sign in your answer.

[2]

[Total: 11]

4 But-1-ene, $CH_3CH_2CH=CH_2$, is an important compound in the petrochemical industry.

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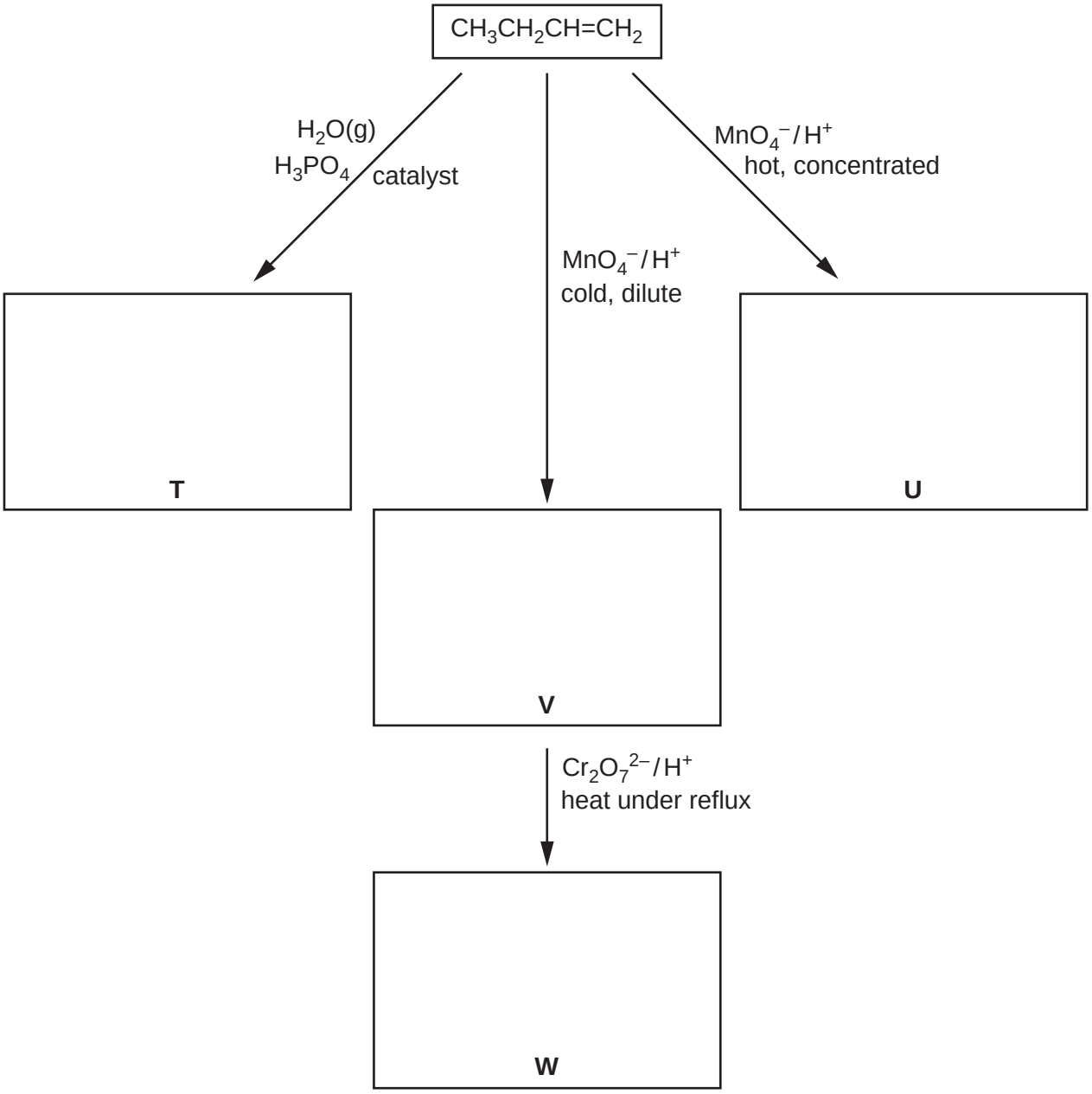
(a) Some reactions of but-1-ene are given below.

In **each** empty box, draw the structural formula of the organic compound formed.



[5]

(b) Compound **T** reacts with compound **U**.

Draw the **displayed** formula of the organic product of this reaction.

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[2]

[Total: 7]

5 Astronomers using modern telescopes of various types have found many molecules in the dust clouds in space. Many of these molecules are those of organic compounds and astronomers constantly look for evidence that amino acids such as aminoethanoic acid, $H_2NCH_2CO_2H$, are present.

One molecule that has been found in the dust clouds is hydroxyethanal, $HOCH_2CHO$.

(a) Hydroxyethanal contains two functional groups.

(i) Name, **as fully as you can**, each of the functional groups present in hydroxyethanal.

1 .....

2 .....

(ii) For **each** functional group, identify a reagent that will react with this group and **not** react with the other functional group present.
In each case, describe what would be observed when this reaction is carried out.

functional group 1 reagent .....

observation.....

functional group 2 reagent .....

observation..... [7]

(b) Give the **skeletal** formulae of the organic compounds formed when hydroxyethanal is reacted separately with the following.

(i) $NaBH_4$

(ii) $Cr_2O_7^{2-}/H^+$ under reflux conditions

[2]

In a school or college laboratory, it is possible to convert a sample of hydroxyethanal into aminoethanoic acid in a three-step process.

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$$HOCH_2CHO \xrightarrow{\text{step 1}} \mathbf{X} \xrightarrow{\text{step 2}} \mathbf{Y} \xrightarrow{\text{step 3}} H_2NCH_2CO_2H$$

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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