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

CANDIDATE NAME									
CENTRE NUMBER						CANDIDATE NUMBER				

* 2 7 4 4 3 8 4 4 9 6 *

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.

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1	
2	
3	
4	
5	
Total	

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

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

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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]

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

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

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(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]

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[Turn over

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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]

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(d) Radium reacts vigorously when added to water.

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(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]

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

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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]

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(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.

.....

.....

.....

.....

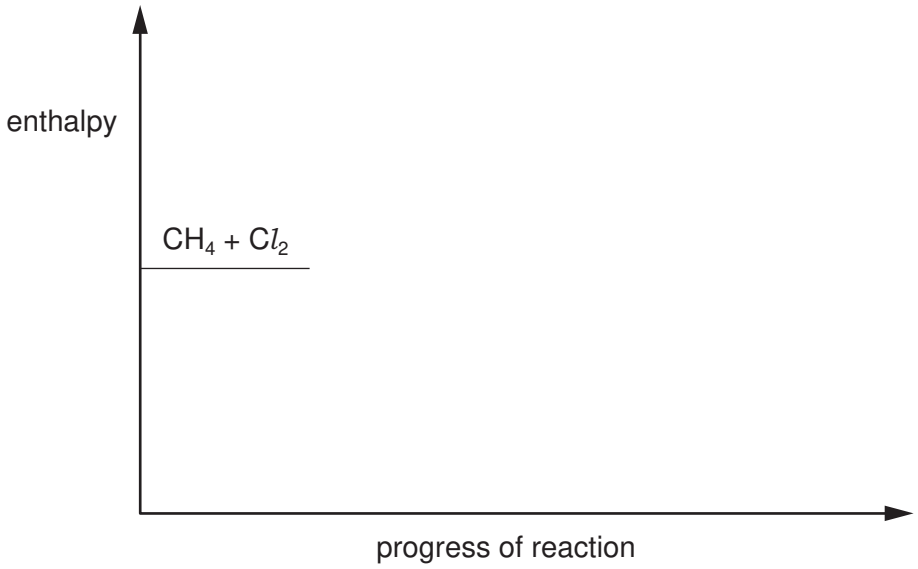
.....

.....

(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]

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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]

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

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

(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]

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.

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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]

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(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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