OCR

Tuesday 3 June 2014 – Afternoon

AS GCE CHEMISTRY A

F322/01 Chains, Energy and Resources

Candidates answer on the Question Paper.

OCR supplied materials:
- *Data Sheet for Chemistry A* (inserted)

Other materials required:
- Scientific calculator

Duration: 1 hour 45 minutes

MODIFIED LANGUAGE

* F 3 2 2 0 1 *

* 3 9 2 7 5 9 8 7 4 6 *

Candidate forename		Candidate surname	

Centre number						Candidate number				

INSTRUCTIONS TO CANDIDATES

- The Insert will be found inside this document.
- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Write your answer to each question in the space provided. If additional space is required, you should use the lined pages at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the bar codes.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets **[ ]** at the end of each question or part question.

Where you see this icon you will be awarded marks for the quality of written communication in your answer.

This means for example you should:
- ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear;
- organise information clearly and coherently, using specialist vocabulary when appropriate.

- You may use a scientific calculator.
- A copy of the *Data Sheet for Chemistry A* is provided as an insert with this question paper.
- You are advised to show all the steps in any calculations.
- The total number of marks for this paper is **100**.
- This document consists of **24** pages. Any blank pages are indicated.

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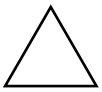
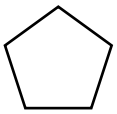
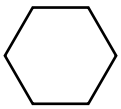
Answer **all** the questions.

1 This question is about cyclic organic compounds.

The table shows some information about cycloalkanes.

Cycloalkane	Skeletal formula	Boiling point/°C
Cyclopropane		–33
Cyclopentane		49
Cyclohexane		81

(a) These cycloalkanes are members of the same homologous series and have the same general formula.

(i) What is meant by the term *homologous series*?

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

(ii) State the general formula for these cycloalkanes.

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

(iii) Explain the increase in boiling points of the cycloalkanes shown in the table.

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

(b) The C–C–C bond angles in **cyclohexane** are 109.5°.

State and explain the shape around each carbon atom in cyclohexane.

shape .....

explanation .....

.....

[2]

(c) In the absence of ultraviolet radiation, **cyclopropane** undergoes an addition reaction with bromine.

Suggest the structure of the organic product formed in this reaction.

[1]

(d) Petrol contains both **cyclohexane**, C_6H_{12}, and hexane.

Cyclohexane can be prepared from hexane.

(i) Construct the equation for this reaction.

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

(ii) Suggest **one** advantage of adding cyclohexane to hexane in petrol.

.....

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

(e) **Cyclobutane** is another cycloalkane.

There are several **unsaturated** isomers of cyclobutane that are alkenes.

Two of these isomers are stereoisomers.

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

.....

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

(ii) Draw these **two** stereoisomers.

[2]

(f) In the presence of ultraviolet radiation, **cyclohexane** reacts with bromine.

A mixture of cyclic organic compounds is formed, including $C_6H_{11}Br$.

(i) Complete the table below to show the mechanism of the reaction between bromine and cyclohexane to form $C_6H_{11}Br$.

Include all possible termination steps in your answer.

Step	Equation
Initiation	.....
Propagation	....
Termination	....

[5]

(ii) The initiation step involves homolytic fission.

Explain why the initiation step is an example of *homolytic fission*.

.....

.....

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

(g) The reaction between cyclohexane and bromine in **(f)** also forms $C_6H_{10}Br_2$.

(i) Write an equation for the reaction of cyclohexane and bromine in the presence of ultraviolet radiation to form $C_6H_{10}Br_2$. Use molecular formulae.

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

(ii) Name **one** of the structural isomers of $C_6H_{10}Br_2$ formed in the reaction between cyclohexane and bromine.

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

[Total: 21]

2 1-Bromobutane, $CH_3CH_2CH_2CH_2Br$, reacts with methoxide ions, CH_3O^-, by nucleophilic substitution.

(a) Suggest how the methoxide ion can act as a nucleophile.

.....

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

(b) Using the 'curly arrow' model, suggest the mechanism for this reaction.

Show any relevant dipoles.

[3]

(c) 1-Iodobutane also reacts with methoxide ions.

Place a tick in one of the boxes to indicate how the use of 1-iodobutane would affect the rate of reaction compared with that of 1-bromobutane.

1-Iodobutane does not change the rate	
1-Iodobutane increases the rate	
1-Iodobutane decreases the rate	

Explain your answer.

.....

.....

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

(d) The ethanoate ion, CH_3COO^- also acts as a nucleophile when reacting with 1-bromobutane in a substitution reaction.

Draw the skeletal formula and give the name of the organic product formed in this reaction.

skeletal formula

name of product ..... **[2]**

(e) 1-Bromobutane (M_r, 136.9) can be made from a reaction of butan-1-ol, C_4H_9OH, as shown in the equation below.

$$C_4H_9OH + KBr + H_2SO_4 \longrightarrow C_4H_9Br + KHSO_4 + H_2O$$

(i) Calculate the atom economy for the formation of 1-bromobutane in this reaction.

atom economy = ... % **[1]**

(ii) Suggest a reactant, other than a different acid, that could be used to improve the atom economy of making 1-bromobutane by the same method.

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

(iii) A student prepares a sample of 1-bromobutane.

5.92 g of butan-1-ol are reacted with an excess of sulfuric acid and potassium bromide. After purification, 9.72 g of 1-bromobutane are collected.

Calculate the percentage yield.

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

percentage yield = ... % **[3]**

[Total: 12]

3 Hydrogen iodide, HI, is a colourless gas that can be made from the reaction of hydrogen, H_2, and iodine, I_2.

This reversible reaction is shown in **equilibrium 3.1** below.

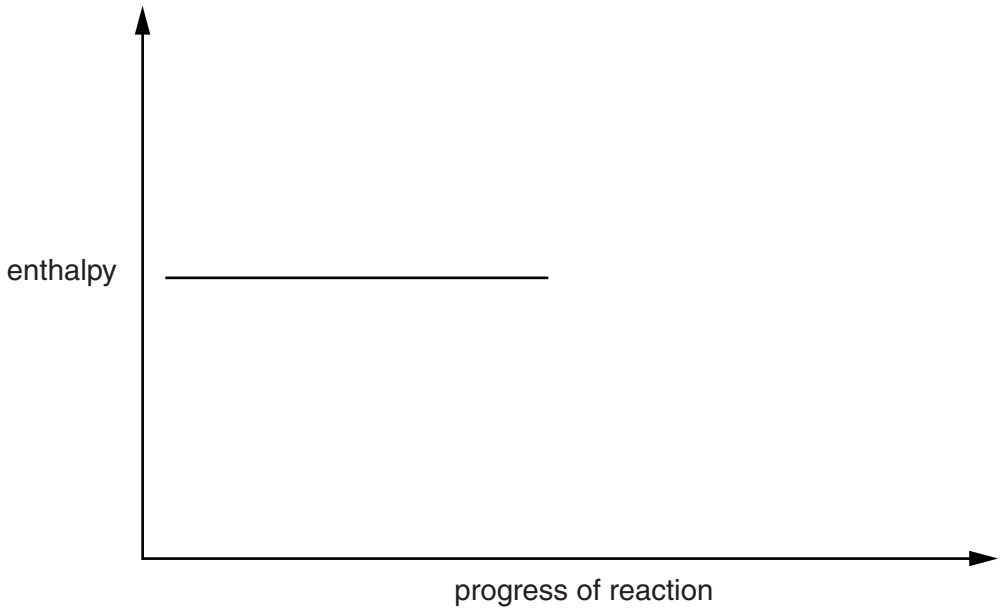
$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad \Delta H = -9\,kJ\,mol^{-1} \qquad \textbf{equilibrium 3.1}$$

The activation energy for the forward reaction is $173\,kJ\,mol^{-1}$.

(a) Complete the enthalpy profile diagram below for the forward reaction in **equilibrium 3.1**.

On your diagram:

- Label the activation energy, E_a
- Label the enthalpy change of reaction, ΔH
- Include the formulae of the reactants and products.



[2]

(b) Calculate the activation energy, E_a, for the reverse reaction.

E_a (reverse reaction) = ... $kJ\,mol^{-1}$ **[1]**

(c) When the reverse reaction takes place hydrogen iodide, HI, decomposes to form iodine and hydrogen.

Calculate the enthalpy change when $336\,dm^3$ of hydrogen iodide, measured at room temperature and pressure, decomposes.

Include the sign for enthalpy change in your answer.

enthalpy change ..... kJ **[2]**

(d) A student mixes hydrogen and iodine at room temperature and pressure and allows the mixture to reach dynamic equilibrium.

$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$ $\Delta H = -9\,kJ\,mol^{-1}$ **equilibrium 3.1**

(i) A closed system is required for dynamic equilibrium to be established.

State **one** other feature of this dynamic equilibrium.

.....

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

(ii) The student heats the equilibrium mixture keeping the volume constant.

Predict how the composition of the equilibrium mixture changes on heating.

Explain your answer.

.....

.....

.....

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

(iii) Predict and explain what effect, if any, an increase in the pressure would have on the position of the equilibrium.

effect .....

explanation .....

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

(e) Calculate the bond enthalpy for the H–I bond in **equilibrium 3.1**, given the following information.

Bond	Bond Enthalpy / kJ mol^{-1}
H–H	436
I–I	151

bond enthalpy ..... kJ mol^{-1} **[2]**

[Total: 11]

4 This question is about the determination of enthalpy changes.

(a) A student does an experiment to find the enthalpy change of reaction, ΔH_r, for the reaction below.

$$Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$$

In the experiment, 3.18 g of Na_2CO_3 are added to 50.0 g of 2.00 mol dm^{-3} HC*l*, an excess. The temperature of the reaction mixture increases by 5.5 °C.

Calculate ΔH_r, in kJ mol^{-1}.

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

The specific heat capacity, *c*, of the reaction mixture is 4.18 J g^{-1} K^{-1}.

ΔH_r = ... kJ mol^{-1} **[4]**

(b) The booster rocket of a spacecraft uses a mixture of aluminium and ammonium chlorate(VII), $NH_4Cl O_4$, as a fuel. The equation and some enthalpy changes are shown below.

$$3Al(s) + 3NH_4ClO_4(s) \longrightarrow Al_2O_3(s) + AlCl_3(s) + 6H_2O(g) + 3NO(g) \qquad \Delta H = -2677\,kJ\,mol^{-1}$$

Substance	Standard enthalpy change of formation, ΔH_f / kJ mol^{-1}
$NH_4ClO_4(s)$	–295
$Al_2O_3(s)$	–1676
$AlCl_3(s)$	–704
$H_2O(g)$	–242

(i) What is meant by the term *standard enthalpy change of formation*?

Give the standard conditions.

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

(ii) Write the equation for the reaction that represents the standard enthalpy change of formation of $NH_4ClO_4(s)$. Include state symbols.

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

(iii) Calculate the enthalpy change of formation of NO(g) using the data above.

enthalpy change of formation of NO(g) = ... kJ mol^{-1} **[3]**

[Total: 12]

5 Chloroethene, CH_2CHCl, can be polymerised to form poly(chloroethene).

(a) Write an equation to show the formation of this polymer. Use displayed formulae.

[2]

(b) Incineration of plastics containing poly(chloroethene) produces waste gases that can damage the environment.

Incineration done in the presence of oxygen produces carbon dioxide, carbon monoxide and hydrogen chloride as waste gases and one other non-toxic product.

(i) Write an equation for the incineration of the monomer, chloroethene, with oxygen.

[1]

(ii) Chemists have developed ways of removing hydrogen chloride from these waste gases. Sodium hydrogencarbonate, $NaHCO_3(s)$, is frequently used in industry for this purpose.

Explain how sodium hydrogencarbonate removes hydrogen chloride.

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

(c) Carbon dioxide is a greenhouse gas that is linked to global warming.

The greenhouse effect of carbon dioxide in the atmosphere is dependent on two factors.

What are these **two** factors?

1 .....

.....

2 .....

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[2]

(d) Chemists are trying to minimise climate change as a result of global warming.

One way is to use Carbon Capture and Storage (CCS). One method of CCS is to react the carbon dioxide with metal oxides.

(i) Write an equation to show this method of CCS.

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

(ii) State one other method of CCS.

.....

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

[Total: 8]

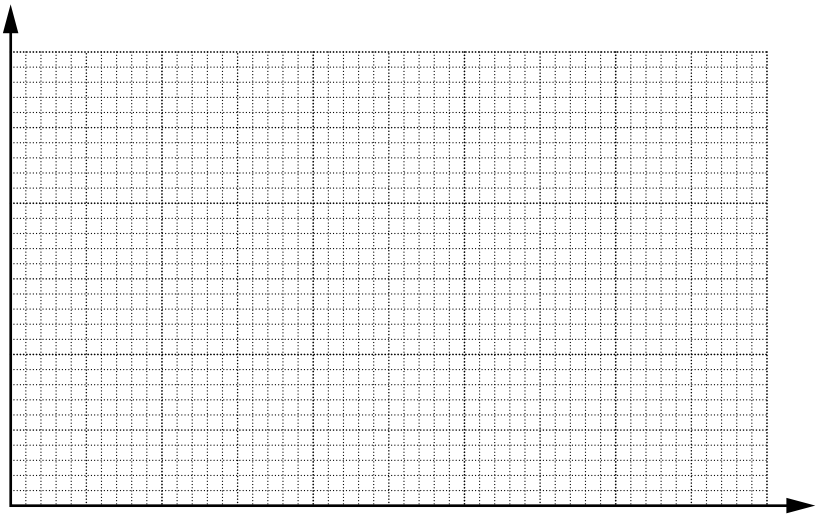
6 **(a)** Reaction rates can be increased or decreased by changing conditions of temperature and pressure.

(i) Explain how increasing the temperature increases the rate of reaction.

Include a labelled sketch of the Boltzmann distribution, on the grid below.

Label the axes.

Your answer needs to be clear and well organised using the correct terminology.



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..... **[4]**

(ii) Describe and explain the effect of decreasing the pressure on the rate of a reaction.

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

(b) Catalysts are used to speed up chemical reactions.

(i) Write an equation for an industrial preparation of ethanol which involves the use of an enzyme in yeast.

State a suitable temperature for this reaction and **one** other essential condition.

equation .....

temperature .....°C.

condition .....

[2]

(ii) Catalytic converters are used to decrease the emission of nitrogen monoxide and carbon monoxide from the internal combustion engine. These two gases react together on the surface of the catalyst.

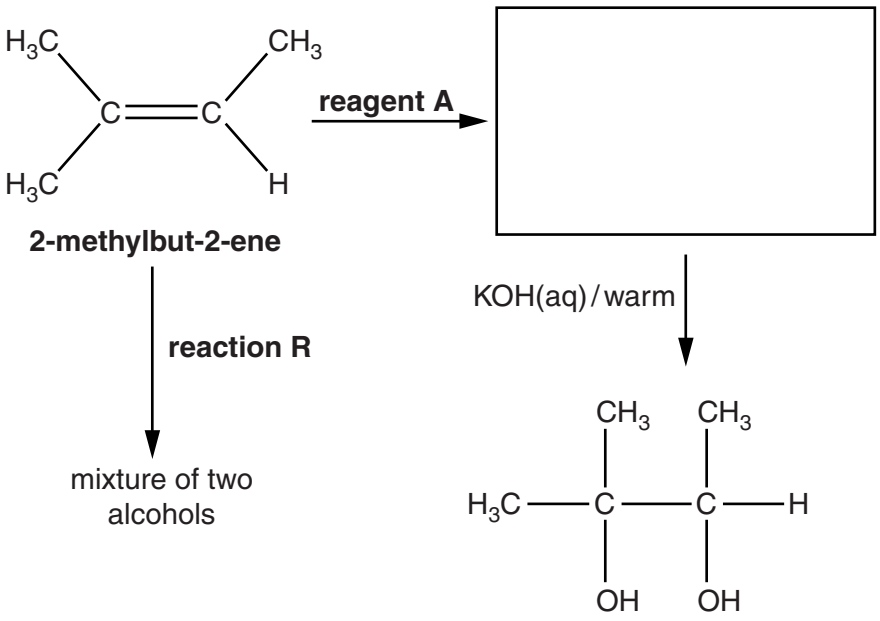
Write an equation for this reaction.

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

[Total: 9]

7 The flowchart shows how 2-methylbut-2-ene can be converted into a number of organic products.

(a) Complete the flowchart by drawing an organic structure in the box below.



[1]

(b) Identify reagent **A**.

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

(c) In the flowchart, **reaction R** forms a mixture of two alcohols that are structural isomers of $C_5H_{12}O$.

(i) State the reagents and conditions needed for **reaction R**.

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

(ii) What is meant by the term *structural isomers*?

.....

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

(iii) Draw the two structural isomers of $C_5H_{12}O$ formed in **reaction R**.

[2]

(iv) Suggest why 2-methylbut-2-ene is less soluble in water than either of the structural isomers formed.

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

(d) Describe the oxidation reactions of propan-1-ol when using a suitable oxidising agent.

Indicate how the use of different reaction conditions can control which organic product forms.

Include reagents, observations and equations in your answer.

In your equations, use structural formulae and use [O] to represent the oxidising agent.

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..... **[6]**

[Total: 14]

8 **(a)** Compound **B**, C_xH_yO, can be oxidised to form a ketone **C**.

0.035 mol of **B** has a mass of 2.59 g.

Compound **B** reacts with compound **D**, $C_3H_6O_2$, in the presence of an acid catalyst to form two compounds **E** and **F**.

- Calculate the molar mass of compound **B**.
- Give the structures of compounds **B**, **C**, **D**, **E** and **F**.

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..... **[6]**

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Question 8 continues on page 20

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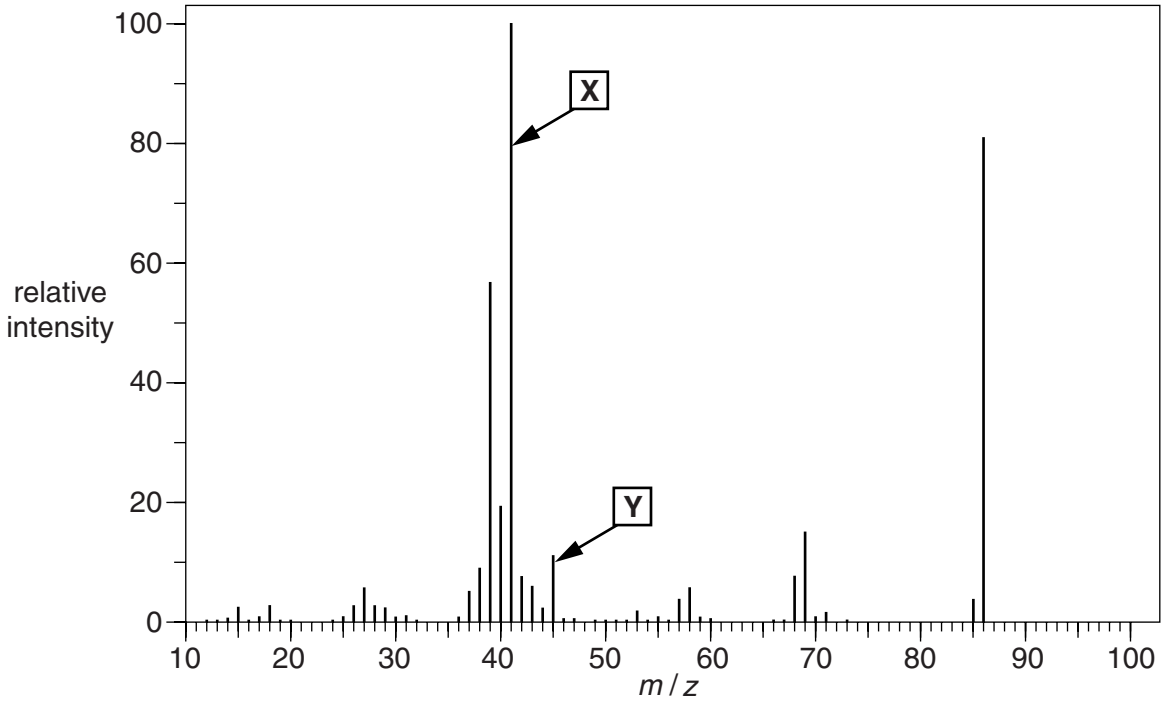
(b) Compound **G** is a branched-chain organic compound that does **not** have *E* and *Z* isomers.

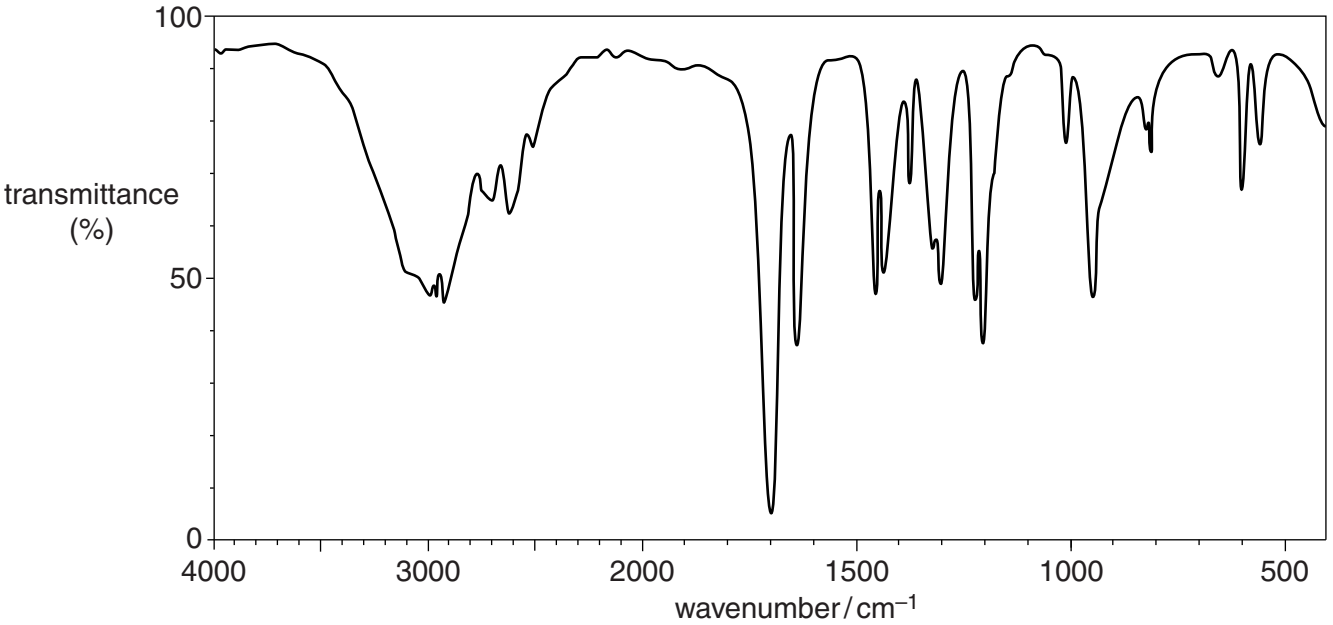
Elemental analysis of compound **G** gave the following percentage composition by mass: C, 55.8%; H, 7.0%; O, 37.2%.

The mass spectrum and infrared spectrum of compound **G** are shown below.

Mass spectrum



Infrared spectrum



- Calculate the empirical and molecular formulae for compound **G**.
- Write the formulae for the particles responsible for peak **X** and peak **Y** in the mass spectrum.
- Draw the structure of compound **G**.

*Explain fully your decision about the structure for compound **G** using all the evidence provided.*

[7]

[Total: 13]

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional answer space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margins.