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Wednesday 16 January 2013 – Morning

AS GCE CHEMISTRY A

F322/01 Chains, Energy and Resources

F3144401133

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

F3220 1

Candidate forename		Candidate surname	

Centre number						Candidate number				

INSTRUCTIONS TO CANDIDATES

- The Insert will be found in the centre of 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 Crude oil contains many hydrocarbons.

The table shows information about some of these hydrocarbons.

Hydrocarbon	Molecular formula	Boiling point / °C
Hexane	C_6H_{14}	69
3-Methylpentane	C_6H_{14}	63
2,2-Dimethylbutane	C_6H_{14}	50

(a) What is the empirical formula of hexane?

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

(b) Explain why hexane is both *saturated* and a *hydrocarbon*.

saturated

.....

.....

hydrocarbon

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

(c) Draw the skeletal formula for 2,2-dimethylbutane.

[1]

(d) Describe and explain the trend shown by the boiling points of the hydrocarbons in the table.

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

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(e) Decane, $C_{10}H_{22}$, can be cracked to form hexane and **one** other product.

Write an equation for this reaction.

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

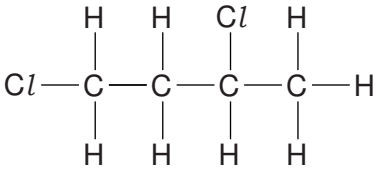
(f) In the presence of ultraviolet radiation, butane, C_4H_{10}, reacts with chlorine to form a large number of organic products.

Several of these products are structural isomers of $C_4H_8Cl_2$.

(i) Write an equation, using molecular formulae, for the formation of $C_4H_8Cl_2$ from butane.

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

(ii) Complete the table below about two of the structural isomers of $C_4H_8Cl_2$.

	Isomer 1	**Isomer 2**
Name	1,4-Dichlorobutane	.....
Displayed formula		

[2]

(g) The reaction between butane and chlorine is an example of radical substitution.

Initially, chlorobutane, C_4H_9Cl, is formed, which then reacts with more chlorine to form $C_4H_8Cl_2$.

(i) The first step of the reaction of C_4H_9Cl with chlorine is the homolytic fission of a chlorine molecule.

What is meant by the term *homolytic fission*?

.....

.....

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

(ii) Complete the missing species in the propagation steps below.

$$Cl \quad + \quad C_4H_9Cl \quad \rightarrow \quad \text{.....} \; + \; \text{.....}$$

$$\text{.....} \; + \; \text{.....} \quad \rightarrow \quad C_4H_8Cl_2 \; + \; \text{.....}$$

[2]

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(h) Butane, C_4H_{10}, undergoes incomplete combustion when there is a shortage of oxygen.

Write an equation for the incomplete combustion of butane.

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

[Total: 16]

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2 Phosphoric acid, H_3PO_4, can be manufactured by a two step process involving the reaction of phosphorus with oxygen, followed by a reaction with water.

$$P_4(s) + 5O_2(g) \longrightarrow P_4O_{10}(s) \qquad \Delta H_1 = -2984\,kJ\,mol^{-1}$$

$$P_4O_{10}(s) + 6H_2O(l) \longrightarrow 4H_3PO_4(l) \qquad \Delta H_2$$

(a) Explain why ΔH_1 represents the enthalpy change of formation of P_4O_{10}.

.....

.....

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

(b) Enthalpy changes of formation are shown in the table below.

Substance	Enthalpy change of formation, ΔH_f / kJ mol^{-1}
$P_4O_{10}(s)$	–2984
$H_2O(l)$	–286
$H_3PO_4(l)$	–1267

Calculate the enthalpy change of reaction, ΔH_2.

ΔH_2 = ... kJ mol^{-1} **[3]**

(c) Write the overall equation for the manufacture of H_3PO_4 from P_4.

Use this equation to explain why this process has a 100% atom economy.

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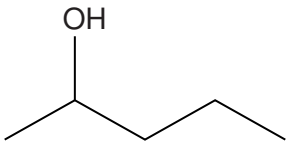
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..... **[2]**

[Total: 7]

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3 Pentan-2-ol, shown below, is a secondary alcohol.



(a) Pentan-2-ol can be converted into three alkenes, **A**, **B** and **C**, by the elimination of water.

- Two of the alkenes, **A** and **B**, are stereoisomers.
- The third alkene, **C**, is a structural isomer of both **A** and **B**.

This elimination often uses a catalyst.

(i) What is a suitable catalyst for this reaction?

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

(ii) Construct an equation, using molecular formulae, for the elimination of water from pentan-2-ol.

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

(iii) Explain what is meant by the terms *structural isomers* and *stereoisomers*.

structural isomers

.....

.....

.....

stereoisomers

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.....

[4]

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(iv) In the boxes below:

- draw the structures of stereoisomers **A** and **B**
- draw the structure of isomer **C**.

stereoisomer A

stereoisomer B

isomer C

[3]

(v) Stereoisomers **A** and **B** show *E*/*Z* isomerism.

State **two** features of these molecules that enable them to show *E*/*Z* isomerism.

.....

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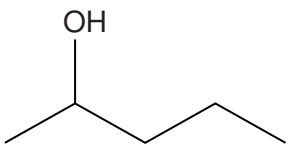
..... **[2]**

(b) Pentan-2-ol can be oxidised by heating under reflux with acidified aqueous potassium dichromate(VI).

Complete the equation for this oxidation.

Use a skeletal formula for the organic product.

Use [O] to represent the oxidising agent.



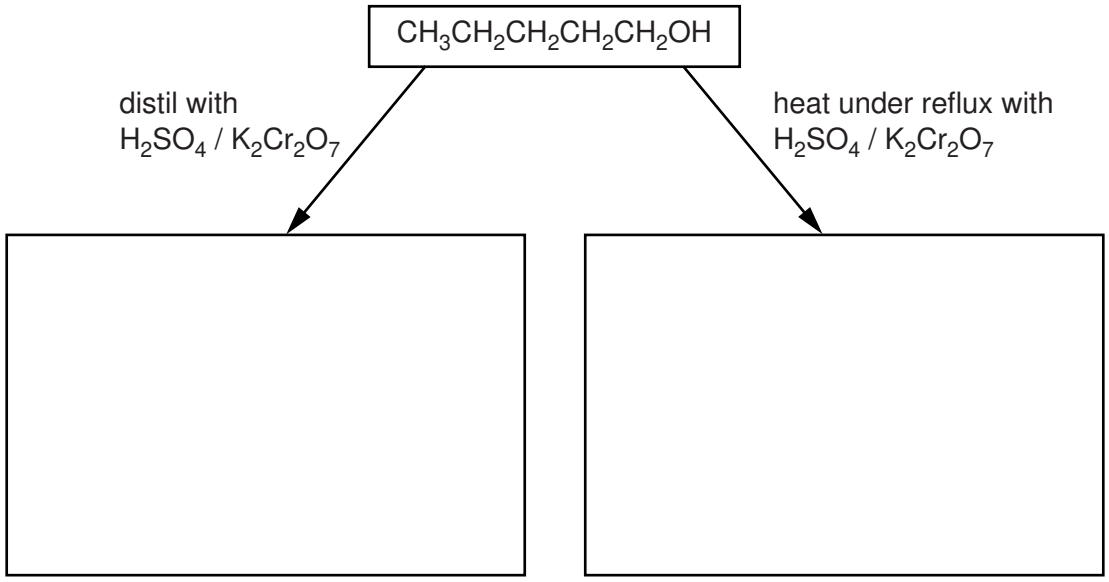
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[2]

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(c) Pentan-1-ol can also be oxidised but it gives two different products.

Complete the flowchart below to show the structures of the two organic products formed.



[2]

[Total: 15]

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Question 4 begins on page 10

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4 Methanol can be manufactured by the reaction of carbon dioxide with hydrogen.

$$3H_2(g) + CO_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g) \quad \textbf{equation 4.1}$$

In this reaction, 49.0 kJ of energy are released when 3 moles of H_2 react completely. This enthalpy change is called the enthalpy change of reaction, ΔH_r.

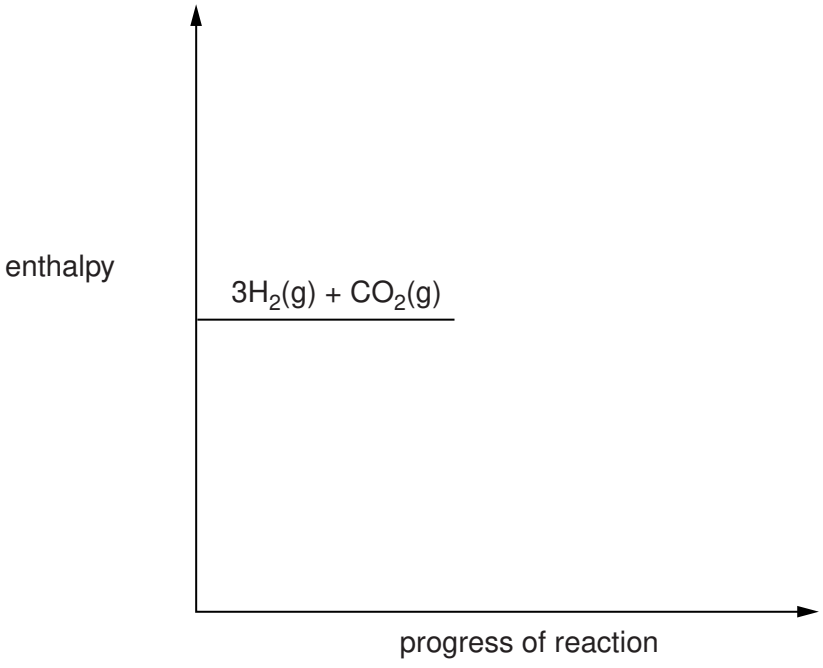
(a) Calculate the energy released when 1000 dm^3 of hydrogen, measured at room temperature and pressure, react completely with carbon dioxide.

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

energy released = ... kJ **[3]**

(b) Complete the enthalpy profile diagram for the forward reaction.

Label the activation energy, E_a, and the enthalpy change, ΔH_r.



[3]

(c) What is the enthalpy change of reaction for the **reverse** reaction?

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

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(d) A scientist estimates the activation energy for the forward reaction as +225 kJ mol^{-1}.

Using this information, estimate the activation energy of the **reverse** reaction.

activation energy = ... kJ mol^{-1} **[1]**

(e) The temperature of the equilibrium mixture in **equation 4.1** is **increased**.

Describe and explain what happens to the position of equilibrium.

.....

.....

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

(f) The total pressure of the equilibrium mixture in **equation 4.1** is **decreased**.

Describe and explain what happens to the position of equilibrium.

.....

.....

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

(g) The reaction uses a solid catalyst. This catalyst functions in a similar way to the catalyst used in catalytic converters.

Outline the stages that allow H_2 to react with CO_2 in the presence of a solid catalyst.

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

[Total: 15]

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5 Chloroethene, CH_2CHCl, is made from 1,2-dichloroethane, CH_2ClCH_2Cl.

$$CH_2ClCH_2Cl \longrightarrow CH_2CHCl + HCl \quad \textbf{equation 5.1}$$

(a) A chemical plant uses 19.80 tonnes of 1,2-dichloroethane to make 11.25 tonnes of chloroethene.

Calculate the percentage yield of chloroethene.

(1 tonne = 1.00×10^6 g)

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

(b) The table below shows some average bond enthalpies.

Bond	Average bond enthalpy / kJ mol^{-1}
C–H	+413
C–C	+347
C=C	+612
C–Cl	+346
H–Cl	+432

Using the average bond enthalpies in the table above, calculate the enthalpy change of reaction, ΔH_r, for **equation 5.1**.

ΔH_r = ... kJ mol^{-1} **[3]**

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(c) Chloroethene is used to make poly(chloroethene), PVC.

Write an equation, using **displayed formulae**, for the reaction to form poly(chloroethene) from its monomer.

[3]

(d) Waste polymers are often disposed of by combustion. The heat released can be used to generate electricity.

(i) Hydrogen chloride, HC*l*, is a toxic waste product formed by combustion of PVC.

Suggest how the HC*l* can be removed from the gases produced during the combustion of PVC.

.....

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

(ii) Some waste polymers are put into landfill sites. This uses up a valuable resource.

State **two** ways, other than landfill and combustion, of processing waste polymers.

1 .....

.....

2 .....

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

(iii) Chemists are trying to minimise the environmental damage caused by the disposal of waste polymers by developing new types of polymers.

Give an example of a type of polymer being developed to minimise environmental damage.

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

[Total: 13]

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6 Many reactions are catalysed by biological catalysts called enzymes.

Ethanol is manufactured by the enzyme-catalysed fermentation of glucose.

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

(a) Fermentation is an **exothermic** reaction.

Explain why. Use ideas about the enthalpy changes associated with bond breaking and bond making in your answer.

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

(b) Carbon dioxide is a greenhouse gas that has been linked to climate change.

(i) What happens within a carbon dioxide molecule when it absorbs infrared radiation?

.....

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

(ii) Chemists are developing methods for carbon capture and storage to minimise climate change.

Give **two** examples of carbon capture and storage.

1 .....

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2 .....

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[2]

(c) One benefit of using an enzyme to catalyse a reaction is that there is a large increase in the rate of reaction without the enzyme being used up.

State **two** other benefits, other than cost, of using enzymes to catalyse reactions.

1 .....

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2 .....

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[2]

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(d) Catalysts, such as enzymes, increase the rate of a reaction.

Explain why. Use a labelled Boltzmann distribution of molecular energies in your answer.

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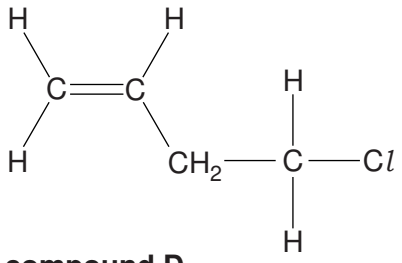
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..... **[5]**

[Total: 12]

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7 Compound **D** reacts by nucleophilic substitution and electrophilic addition.



compound D

Compound **D** reacts with KOH(aq) and with HBr(g).

The reaction with KOH(aq) is an example of a nucleophilic substitution and the reaction with HBr(g) is an example of electrophilic addition.

Describe these two reactions. For each reaction, include:

- an equation
- the structure of each organic product
- the mechanism, using the curly arrow model, showing any relevant dipole
- the type of bond fission that occurs.

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[Total: 12]

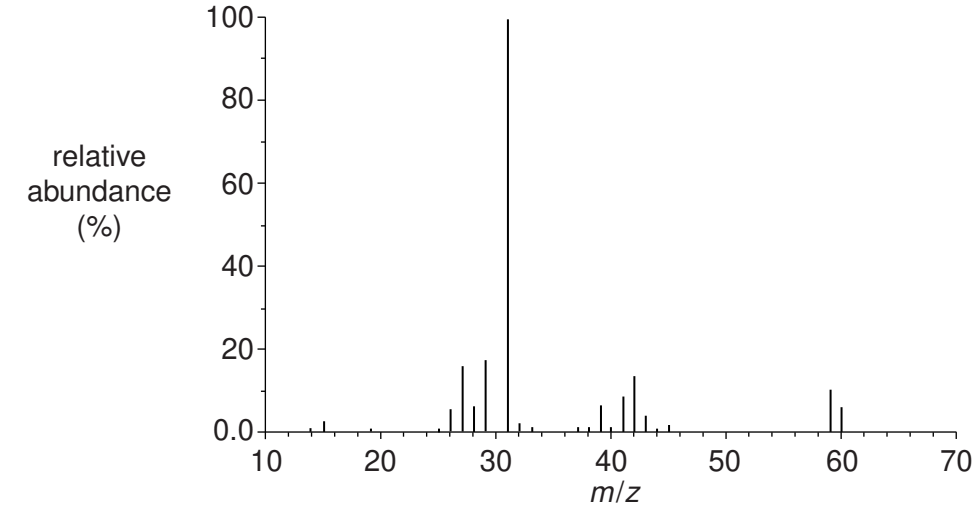
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8 Compound **X** is a saturated compound that contains carbon, hydrogen and oxygen only.

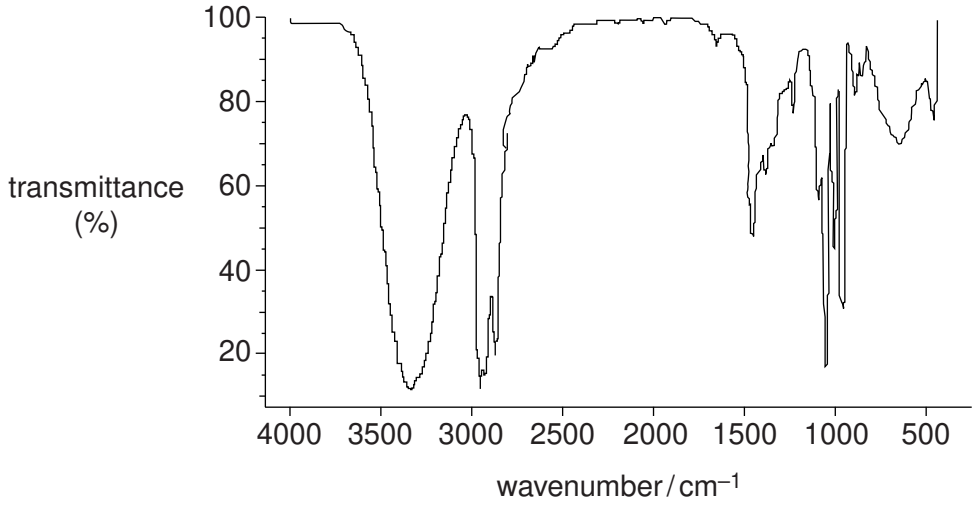
A scientist analyses a 1.00 g sample of compound **X** and finds it contains 0.133 g of hydrogen and 0.600 g of carbon.

The scientist also analyses compound **X** using mass spectrometry and infrared spectroscopy.

mass spectrum of X



IR spectrum of X



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The scientist finds that compound **X** reacts with ethanoic acid in the presence of a concentrated sulfuric acid catalyst to make compound **Y**.

Compound **Y** has the molecular formula $C_5H_{10}O_2$.

Using all the information, show the structures of compounds **X** and **Y**.
Include an equation for the reaction of compound **X** with ethanoic acid to make compound **Y**.

In your answer you should link the evidence with your explanation.

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ADDITIONAL ANSWER SPACE

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

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