Candidate forename		Candidate surname	

Centre number						Candidate number				

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

AS GCE

F322

CHEMISTRY A

Chains, Energy and Resources

THURSDAY 19 JANUARY 2012: Afternoon
DURATION: 1 hour 45 minutes

SUITABLE FOR VISUALLY IMPAIRED CANDIDATES

Candidates answer on the Question Paper.

OCR SUPPLIED MATERIALS:

Data Sheet for Chemistry A **(inserted)**

OTHER MATERIALS REQUIRED:

Scientific calculator

READ INSTRUCTIONS OVERLEAF

DC (LEO/SW) 12MEP01048 55624/1

INSTRUCTIONS TO CANDIDATES

- **Write your name, centre number and candidate number in the boxes on the first page. 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.**

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.**

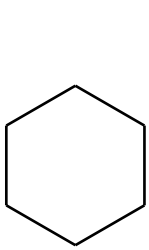
  This means for example you should:

  - **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.**

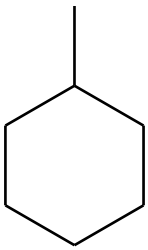
Answer ALL the questions.

1 Crude oil is a source of many hydrocarbons.

The skeletal formulae of some of these hydrocarbons are shown below.



A



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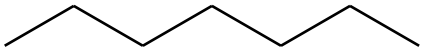

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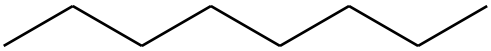

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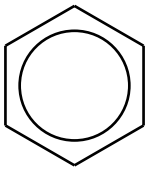

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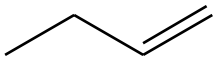

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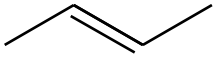

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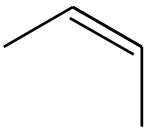

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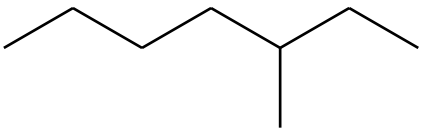


I

(a) Explain why compound A is both *saturated* and a *hydrocarbon*.

_____

_____

_____

_____ **[2]**

(b) What is the empirical formula for compound A?

_____ **[1]**

(c) Give the letters, A, B, C, D, E, F, G, H or I, of two hydrocarbons that are structural isomers of each other.

_____ **and** _____ **[1]**

(d) The petroleum industry processes straight chain alkanes into cyclic hydrocarbons such as A, B and E.

(i) Explain why the petroleum industry processes straight chain alkanes into cyclic hydrocarbons.

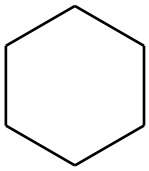
_____

_____ **[1]**

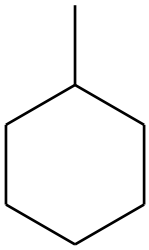
(ii) Hydrocarbon C can be processed into the cyclic hydrocarbon B.

Construct an equation for this reaction.

[1]



A



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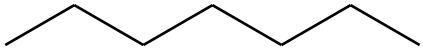

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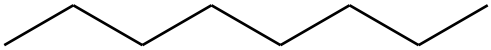

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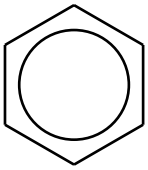

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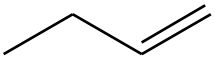

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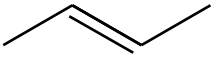

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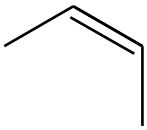

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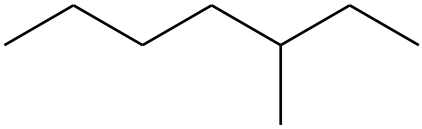


I

(e) Explain why hydrocarbon D has a higher boiling point than hydrocarbon C.

_____

_____

_____

_____ **[2]**

(f) Hydrocarbons G and H are stereoisomers of each other.

Explain what is meant by the term *stereoisomerism*.

_____

_____

_____

_____ **[2]**

(g) Construct the equation for the COMPLETE combustion of hydrocarbon C.

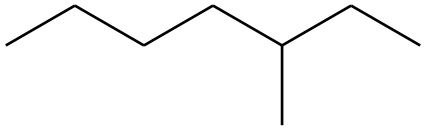
_____ **[2]**

(h) A hydrocarbon molecule, $C_{16}H_{34}$, is cracked to form an octane molecule and two molecules of but-2-ene.

Construct the equation for this reaction.

_____ **[1]**

(i) Compound I is 3-methylheptane. It does not contain a functional group.



I

(i) What is meant by the term *functional group*?

_____

_____

_____ **[1]**

(ii) Compound I reacts with chlorine in the presence of ultraviolet radiation to give several structural isomers of $C_8H_{17}Cl$.

How many STRUCTURAL isomers could be formed in this reaction?

_____ **[1]**

(iii) The mechanism of the reaction involves radicals.

What is meant by the term *radical*?

_____

_____ **[1]**

[Total: 16]

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2 Ethanoic acid, CH_3COOH, is used to make esters.

Some information about two of the processes used to make ethanoic acid is given below.

PROCESS 1

This is a one-step process that involves the reaction of methanol with carbon monoxide.

$$CH_3OH + CO \rightarrow CH_3COOH$$

The conditions used are 180 °C and 30 atmospheres pressure. A rhodium/iodine catalyst is used.

The percentage yield for this process is 99%.

PROCESS 2

This involves the oxidation of naphtha, a fraction obtained from crude oil.

Liquid naphtha is oxidised using air at a temperature of 180 °C and 50 atmospheres pressure. No catalyst is needed.

A large variety of other products are also formed in this oxidation.

(a) Suggest THREE advantages of making ethanoic acid using PROCESS 1 rather than PROCESS 2.

_____

_____

_____

_____

_____

_____

_____ **[3]**

(b) The other products formed in PROCESS 2 are carboxylic acids, aldehydes and ketones.

A research chemist investigates some of these other products of PROCESS 2.

(i) The research chemist isolates product, J.

The infrared spectrum of J is shown opposite.

The chemist also finds that 0.172 g of a pure sample of J contains 2.00×10^{-3} mol of J.

Suggest, with reasons, ONE possible structure for J.

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

_____

_____

_____

_____

_____

_____

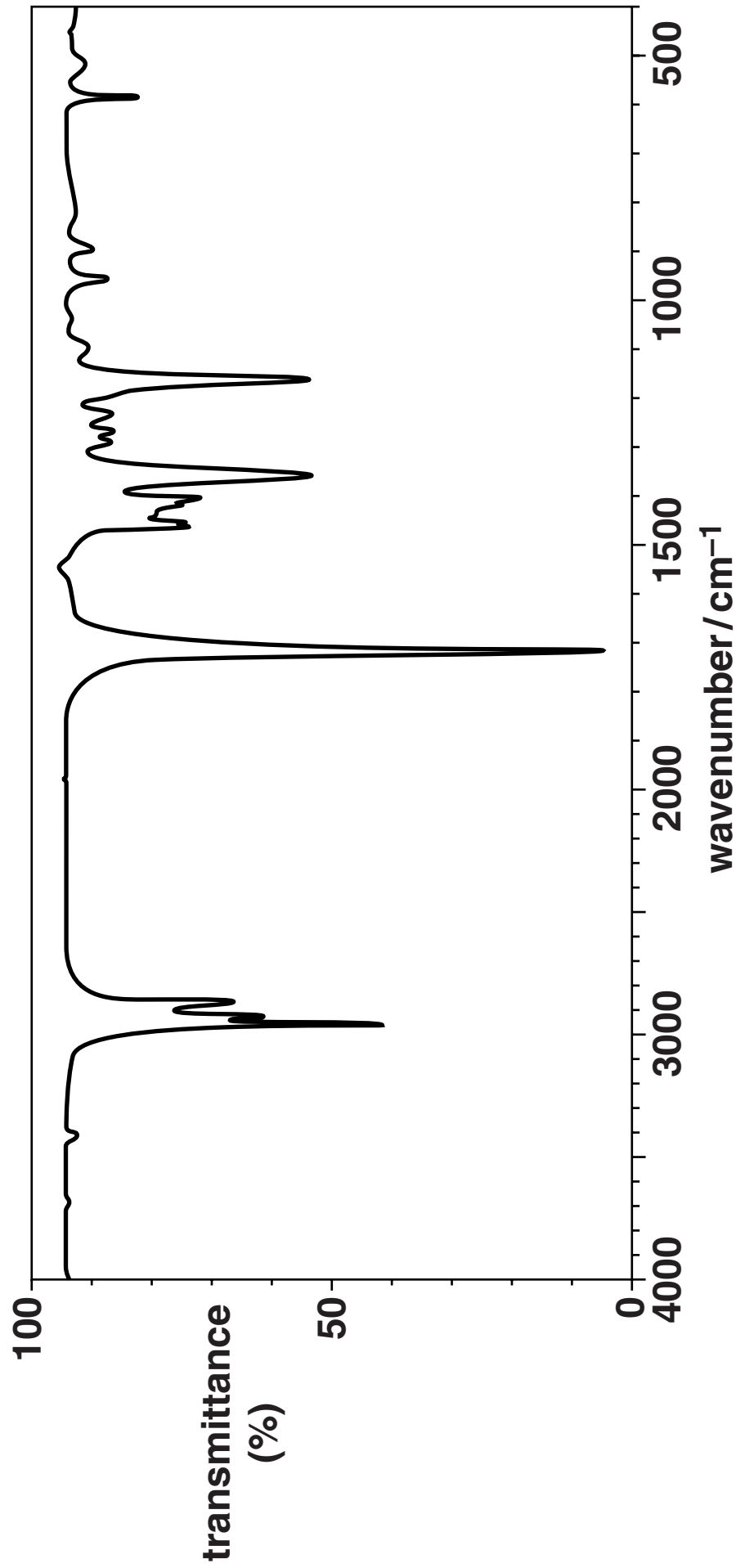
_____

_____

_____

_____

_____ **[5]**


transmittance (%)
100
50
0
4000
3000
2000
1500
1000
500
wavenumber / cm⁻¹

(ii) The chemist isolates another product, the carboxylic acid, K.

K has the molecular formula $C_4H_8O_2$.

Suggest a possible structure and name for K.

structure

name _____ [2]

(c) Ethanoic acid is used in the manufacture of the ester, propyl ethanoate.

Describe how ethanoic acid is converted into propyl ethanoate.
Include an equation in your answer.

_____

_____

_____

_____

_____

_____ [4]

[Total: 14]

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3 Enthalpy changes can be determined directly or indirectly.

(a) A student investigates the reaction between magnesium and dilute hydrochloric acid.

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

The student determines the enthalpy change for this reaction.

In her experiment, she reacts 0.486 g of magnesium with 50.0 cm^3 of 2.00 mol dm^{-3} $HCl(aq)$. The $HCl(aq)$ is in excess.

The temperature of the solution changes from 19.2 °C to 32.0 °C.

(i) Calculate the energy released, in kJ, during this reaction.

The specific heat capacity of the solution = 4.18 J g^{-1} K^{-1}.

The density of the solution is 1.00 g cm^{-3}.

energy = _____ kJ [2]

(ii) Calculate the amount, in moles, of magnesium used by the student.

amount = _____ mol [1]

(iii) Calculate the enthalpy change of reaction.

Give your answer to THREE significant figures.

enthalpy change of reaction = _____ kJ mol^{-1} [3]

(b) The student wants to determine the enthalpy change of formation of calcium carbonate, $CaCO_3(s)$.

$$Ca(s) + C(s) + 1\tfrac{1}{2}O_2(g) \rightarrow CaCO_3(s)$$

(i) What is meant by the term *standard enthalpy change of formation*?
You should state the standard conditions in your answer.

_____

_____

_____

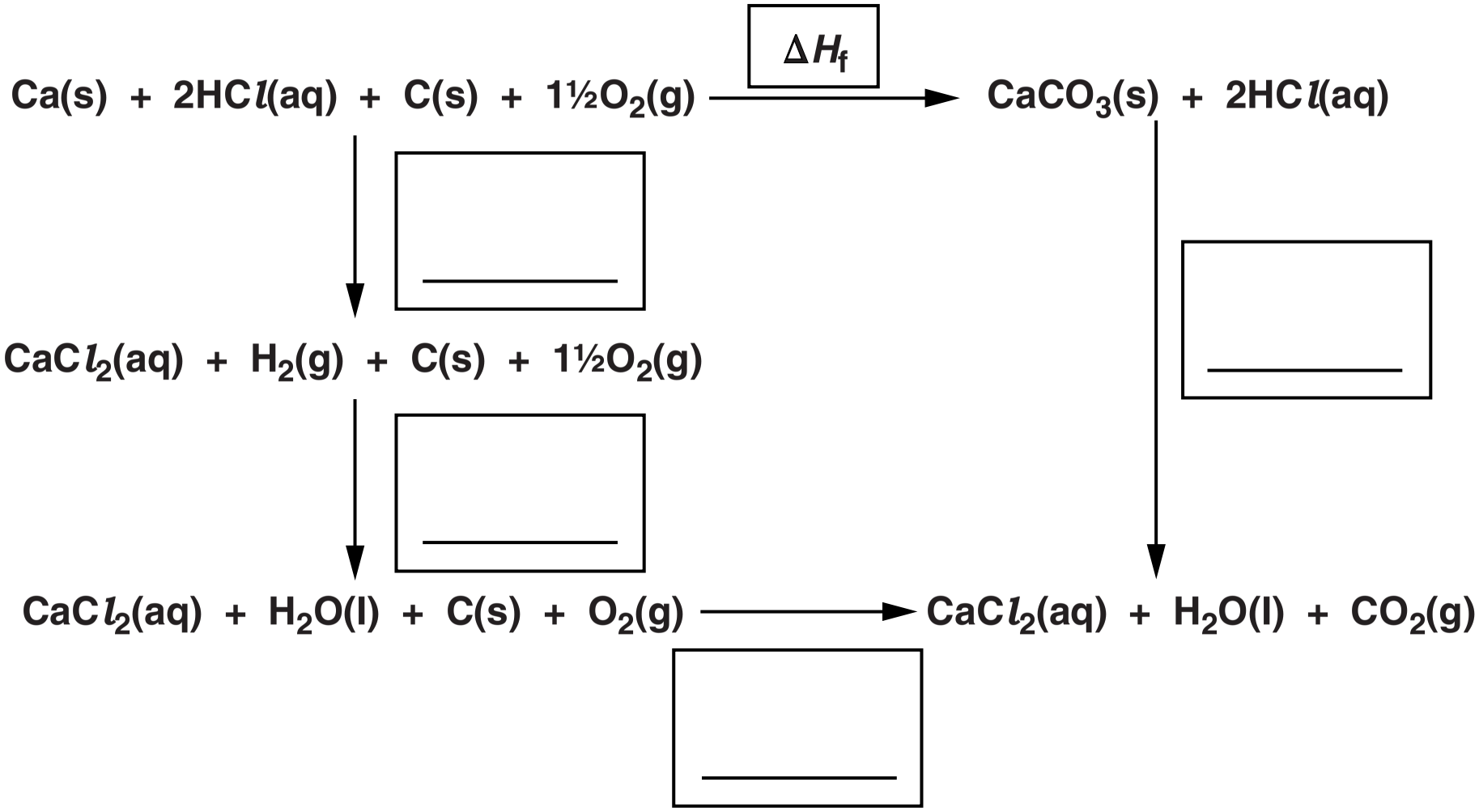
_____ **[3]**

(ii) Using the following data and enthalpy cycle,

- **fill in the boxes on the enthalpy cycle, opposite, with the correct enthalpy change values**
- **calculate the enthalpy change of formation, ΔH_f, of $CaCO_3(s)$.**

REACTION	ENTHALPY CHANGE, ΔH / kJ mol^{-1}
$C(s) + O_2(g) \rightarrow CO_2(g)$	–393
$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$	–285
$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$	–54
$Ca(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2(g)$	–168

19



ΔH_f = _____ kJ mol^{-1} [3]

[Total: 12]

4 Hydrogen and chlorine are reacted together to form hydrogen chloride.

$$H_2(g) + Cl_2(g) \rightarrow 2HCl(g) \qquad \Delta H = -184 \text{ kJ mol}^{-1}$$

(a) Calculate the bond enthalpy for the H–Cl bond using the information in the table below.

BOND	BOND ENTHALPY / kJ mol^{-1}
H–H	+436
Cl–Cl	+243

bond enthalpy = _____ kJ mol^{-1} [2]

(b) The reaction is repeated at a HIGHER pressure.

Describe and explain what happens to the rate of the reaction between $H_2(g)$ and $Cl_2(g)$.

_____

_____

_____

_____

_____ **[2]**

$H_2(g) + Cl_2(g) \rightarrow 2HCl(g) \quad \Delta H = -184 \text{ kJ mol}^{-1}$

(c) The reaction is repeated again. This time the temperature is DECREASED.

Describe and explain, by drawing appropriately labelled Boltzmann distributions, what happens to the rate of reaction between $H_2(g)$ and $Cl_2(g)$.

_____

_____

_____

_____

_____ **[5]**

(d) The mechanism of the reaction between $H_2(g)$ and $Cl_2(g)$ involves initiation, propagation and termination.

(i) The initiation step is the homolytic fission of the covalent bond in a chlorine molecule.

Write an equation to show this homolytic fission.

_____ **[1]**

(ii) Complete the following equations which show the propagation steps.

$Cl + H_2 \rightarrow$ _____ + _____

$H + Cl_2 \rightarrow$ _____ + _____ **[2]**

(iii) Suggest equations for TWO termination steps.

_____

_____ **[2]**

[Total: 14]

5 Sulfuric acid is made from sulfur, oxygen and water in a three-stage process.
This can be represented by the following overall equation.

$$2S(s) + 3O_2(g) + 2H_2O(l) \rightarrow 2H_2SO_4(l)$$

(a) Explain why the overall process to make sulfuric acid has an atom economy of 100%.

_____

_____

_____ **[1]**

(b) A factory uses 51.4 tonnes of sulfur to manufacture 147 tonnes of H_2SO_4.

What is the percentage yield of H_2SO_4?

Give your answer to TWO significant figures.
(1 tonne = 1×10^6 g)

percentage yield = _____ % [3]

(c) One of the reactions involved in making sulfuric acid converts sulfur dioxide, SO_2, into sulfur trioxide, SO_3.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \quad \Delta H = -197 \text{ kJ mol}^{-1}$$

This reaction can be carried out at 450 °C and 3 atmospheres pressure in the presence of a V_2O_5 catalyst.

Under these conditions the position of equilibrium is almost completely on the right-hand side.

(i) A research chemist investigates this reaction. He uses a temperature of 450 °C and 3 atmospheres pressure.
The research chemist does NOT use the catalyst.

Predict the changes, if any, on each of the following.

position of equilibrium

_____

rate of backward reaction

_____ **[2]**

(ii) The temperature of the reaction mixture is INCREASED to 600 °C.

State and explain what will happen to the position of equilibrium.

_____

_____

_____

_____ **[1]**

(iii) The pressure of the reaction mixture is DECREASED to 2 atmospheres.

State and explain what will happen to the position of equilibrium.

_____

_____

_____

_____ **[1]**

(d) Concentrated H_2SO_4 is used as an acid catalyst in the elimination of water from alcohols.

There are several alcohols that are structural isomers with the formula $C_5H_{11}OH$. When these alcohols are heated with H_2SO_4 they form alkenes.

$$C_5H_{11}OH \rightarrow C_5H_{10} + H_2O$$

(i) Pentan-1-ol is a structural isomer of $C_5H_{11}OH$ that is a primary alcohol.

Draw the structure of another structural isomer of $C_5H_{11}OH$ that is a primary alcohol.

[1]

(ii) Pentan-2-ol is a structural isomer of $C_5H_{11}OH$ that is a secondary alcohol.
Pentan-2-ol is heated with H_2SO_4.

Three alkenes are formed, L, M and N.

- **L and M are stereoisomers.**
- **N is a structural isomer of the stereoisomers L and M.**

Draw the structures for alkenes L, M and N.

alkene L

alkene M

alkene N

[3]

(iii) One structural isomer of $C_5H_{11}OH$ is an alcohol that CANNOT be oxidised by heating with acidified potassium dichromate(VI).

Draw the structure of this alcohol.

[1]

[Total: 13]

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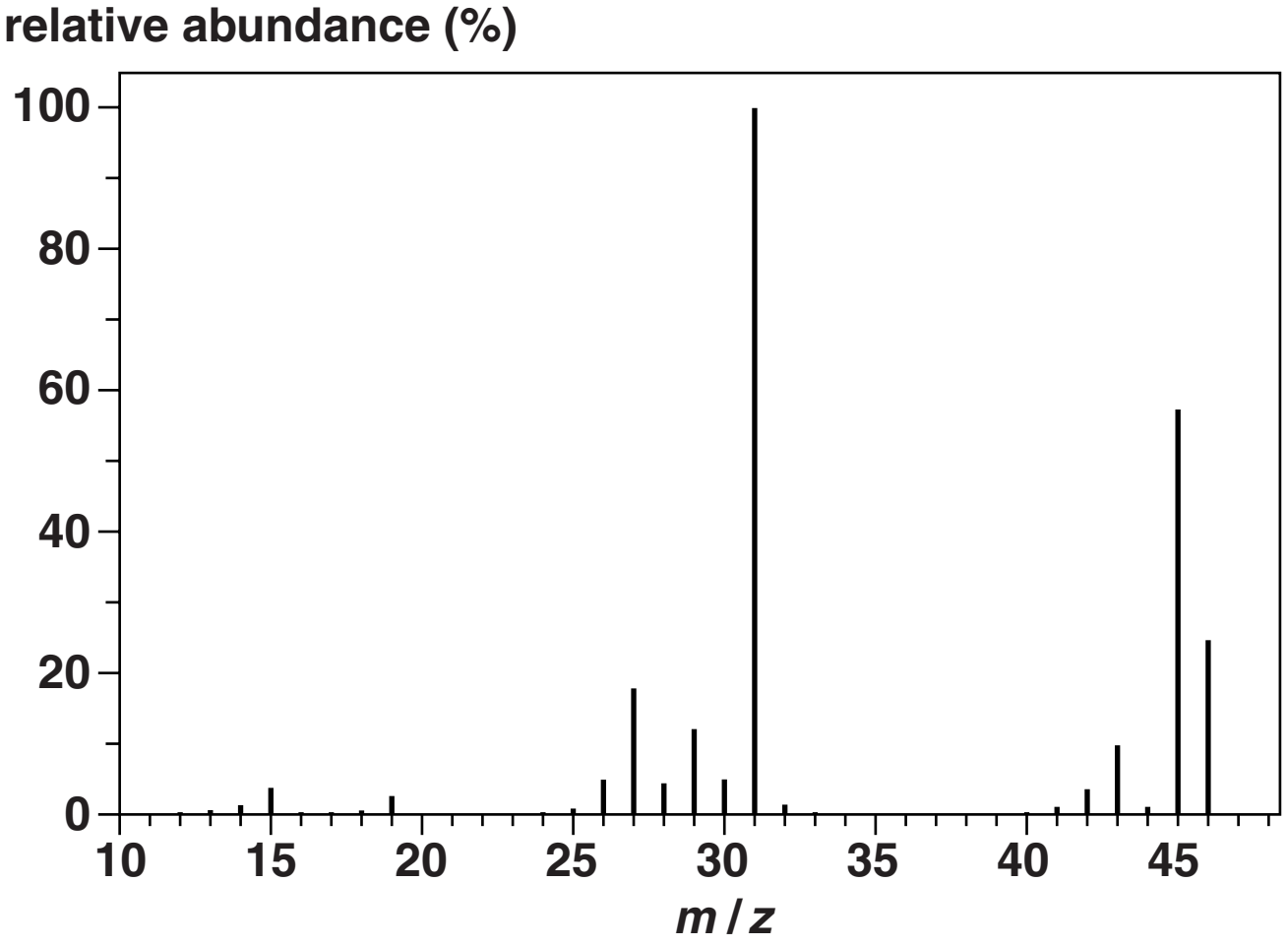
6 Mass spectrometry is used in analysis.

(a) Compound O contains carbon, hydrogen and oxygen.

The mass spectrum of compound O is shown below.



(i) Identify the *m*/*z* value that corresponds to the molecular ion.

_____ **[1]**

(ii) Write the formula of the ion that gives rise to the peak at *m*/*z* = 31.

_____ **[1]**

(iii) Suggest the molecular formula for O.

_____ [1]

(b) A scientist analyses a sample of Moon rock. She uses mass spectrometry to find out which metal the sample contains.

The mass spectrum of the sample shows *m*/*z* peaks as shown in the table.

m/*z* VALUE	PERCENTAGE ABUNDANCE (%)
63	72.2
65	27.8

Positive ions, X^+, of the metal were responsible for the two *m*/*z* peaks.

Identify the metal X by calculating its relative atomic mass to ONE DECIMAL PLACE.

relative atomic mass of X = _____

metal X = _____ [3]

[Total: 6]

7 Chlorofluorocarbons, CFCs, were once used as propellants in aerosols. CFCs contribute to ozone depletion in the upper atmosphere.

(a) A CFC has the formula CF_2Cl_2.

State the three-dimensional shape of a CF_2Cl_2 molecule and the F–C–Cl bond angle.

shape _____

bond angle _____ **[2]**

(b) Two reasons that CF_2Cl_2 was used as an aerosol propellant are that it has low reactivity and will not hydrolyse in water.

(i) State ONE other reason why CF_2Cl_2 was developed for use as an aerosol.

_____

_____ **[1]**

(ii) Suggest why CF_2Cl_2 does NOT hydrolyse in water.

_____

_____

_____ **[1]**

(c) Explain, with the aid of equations, how the presence of CFCs in the upper atmosphere leads to ozone depletion.

_____

_____

_____

_____

_____ **[3]**

(d) Why are scientists concerned about ozone depletion?

_____

_____

_____ **[1]**

(e) International agreements have reduced the use of CFCs. However the concentration of atmospheric CFCs has hardly changed.

Suggest TWO reasons why.

_____

_____

_____

_____

_____ **[2]**

[Total: 10]

8 Cyclopentene is a cyclic alkene.

(a) The flowchart, opposite, shows some reactions involving cyclopentene and cyclopentanol.

Complete the partial structures in the boxes to show compounds P, Q and R, the main organic products of the reactions. [3]

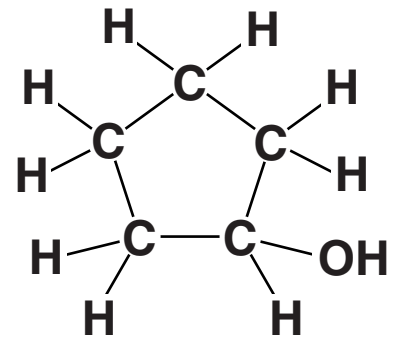
(b) What would be the colour change in the reaction between cyclopentene and bromine?

_____ to _____ [1]

(c) Cyclopentene can be polymerised to give poly(cyclopentene).

Draw a section of poly(cyclopentene) to show TWO repeat units.

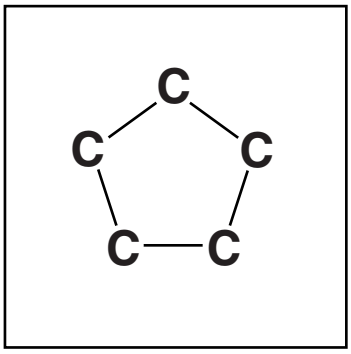
[1]



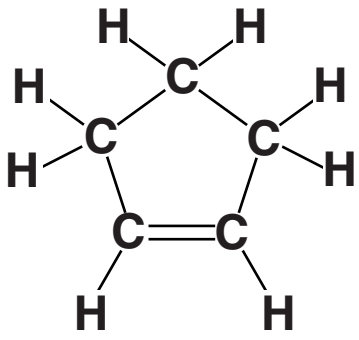
CYCLOPENTANOL

$K_2Cr_2O_7(aq) / H_2SO_4(aq)$

reflux

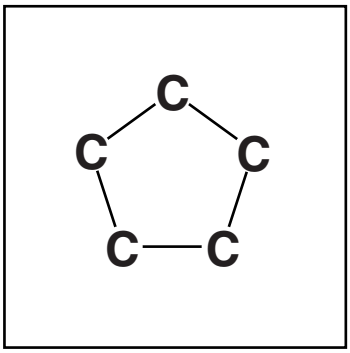


compound P



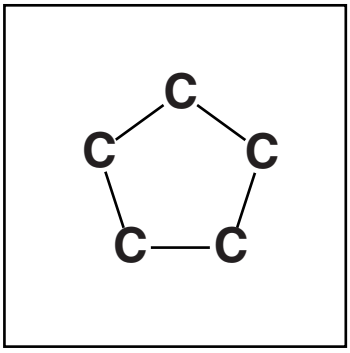
CYCLOPENTENE

H_2 with Ni catalyst



compound Q

Br_2

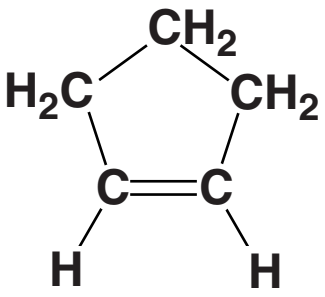


compound R

(d) Cyclopentene reacts with HC*l* by electrophilic addition.

Use the curly arrow model to complete the mechanism for this reaction.

In your answer include any relevant dipoles, the intermediate and the product.

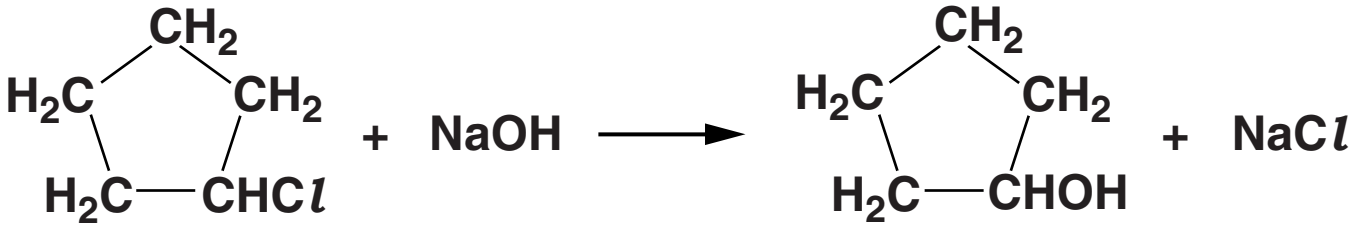


INTERMEDIATE

PRODUCT

[5]

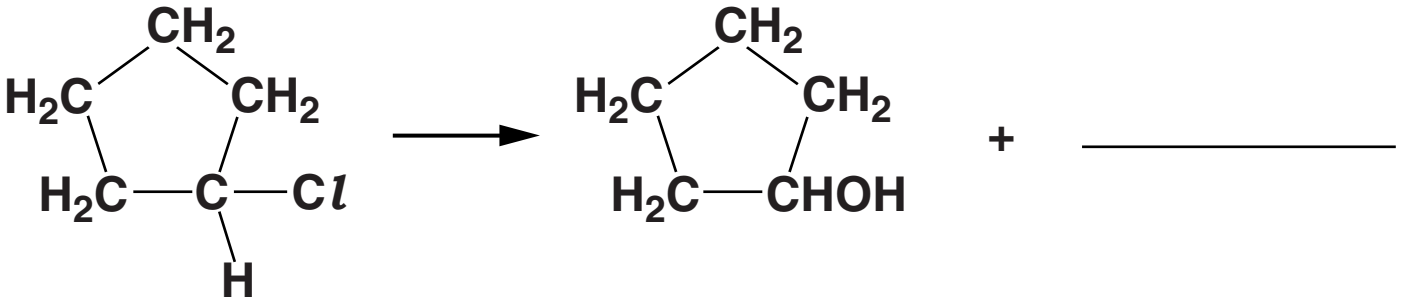
(e) Chlorocyclopentane can be hydrolysed by heating with aqueous sodium hydroxide.



Use the curly arrow model to complete the mechanism for this hydrolysis reaction.

Include in your answer, relevant dipoles, the name of the mechanism and the type of bond fission.

In your answer you should use the correct technical terms, spelled correctly.



HO^- PRODUCTS

name of mechanism _____

type of bond fission _____ **[5]**

[Total: 15]

END OF QUESTION PAPER

ADDITIONAL PAGE

IF ADDITIONAL SPACE IS REQUIRED, YOU SHOULD USE THE LINED PAGES BELOW. THE QUESTION NUMBER(S) MUST BE CLEARLY SHOWN.

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