

WJEC A-LEVEL CHEMISTRY • UNIT 2

CHEMISTRY



EXAM QUESTION PACK

2.8 INSTRUMENTAL ANALYSIS

SCORE

/44

PERCENTAGE

%

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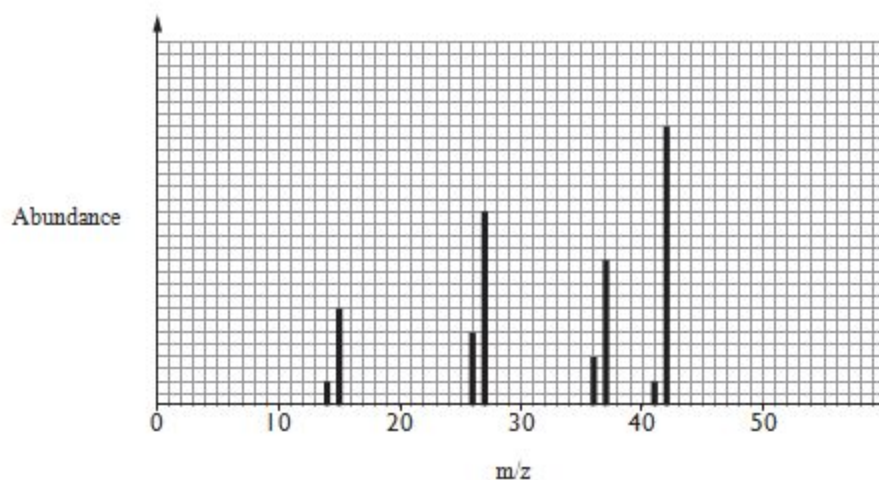
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1. (a) Compound **X** is a straight-chain hydrocarbon that consists of 85.7 % carbon by mass.

(i) Find the **empirical** formula of compound **X**

[3]

(ii) Some peaks from the mass spectrum of **X** are shown below.



Use the empirical formula and the mass spectrum to find the molecular formula of **X**. Show your workings

[2]

(iii) Suggest what information the presence of the peak at m/z 15 gives about the structure of **X**.

[1]

(b) Butene, C_4H_8 , is an alkene. Draw **displayed** formulae for three **straight-chain** isomers of C_4H_8 . [3]

(Total 9)

2. (a) Propene reacts with hydrogen bromide to give 2-bromopropane.

(i) Draw the mechanism for this reaction.

[3]

(ii) Explain why the product of this reaction is mainly 2-bromopropane rather than 1-bromopropane

[2]

(b) Compound **C** is a compound of carbon, hydrogen and bromine only. Bromine has two isotopes, ^{79}Br and ^{81}Br , in equal abundance. Use all the information below to deduce the structure of compound **C**, giving your reasoning. [6]

[6]

QWC[1]

- Compound **C** contains 29.8% carbon, 4.2% hydrogen and 66.0% bromine by mass.
- The mass spectrum of compound **C** contains peaks at m/z of 15, 41 and a pair of peaks at 120 and 122.
- The infrared spectrum of compound **C** has absorptions at 550 cm^{-1} , 1630 cm^{-1} and 3030 cm^{-1} .
- Compound **C** is a *Z*-isomer.

[illegible]

(Total 12)

3. (a) An acid **F** was known to be one of the following.



A sample of 1.20 g of acid **F** was burned in excess oxygen. 1.79 g of carbon dioxide was formed.

- (i) Calculate the mass of carbon present in the sample of acid **F**. [1]

Mass of carbon = ... g

- (ii) The mass of hydrogen in the sample is 0.061 g. Assuming that the rest of the sample is oxygen, calculate the mass of oxygen in the sample.

[1]

Mass of oxygen = ... g

- (iii) Use your answers to parts (i) and (ii) to find the empirical formula of acid **F**.

[2]

Empirical formula

(iv) State the identity of acid **F**. Show clearly how you reached this conclusion.

[1]

(v) Describe a chemical test that would distinguish between Acid 1 and Acid 2. You should include the expected results

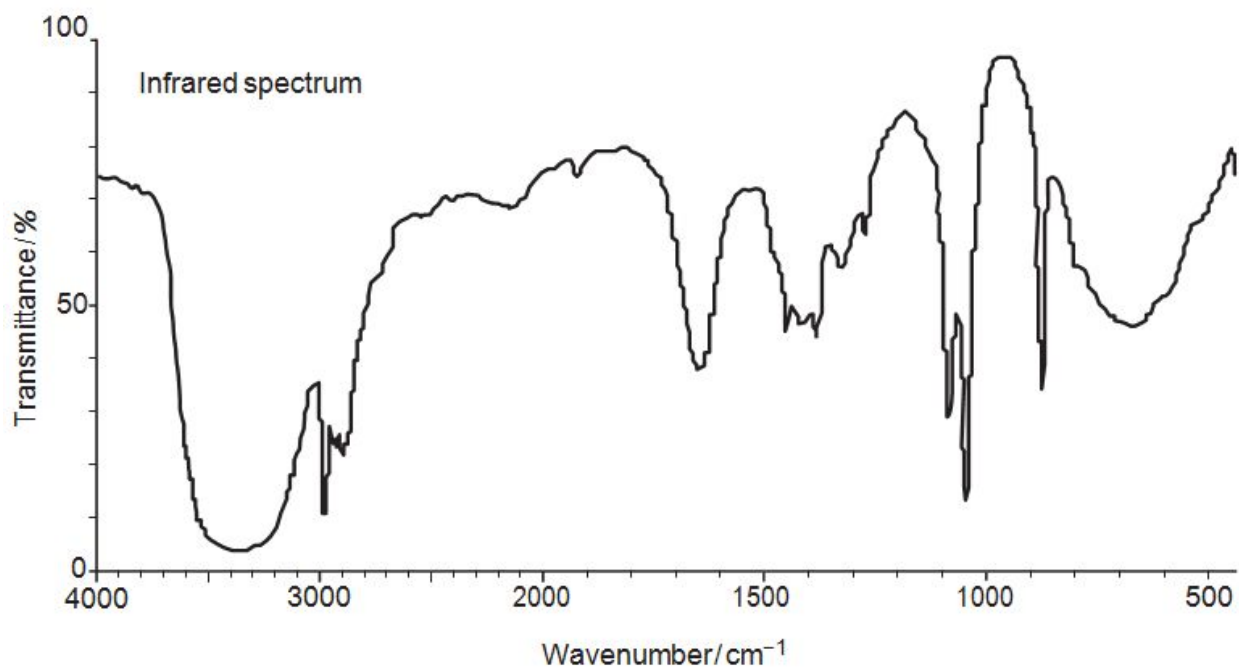
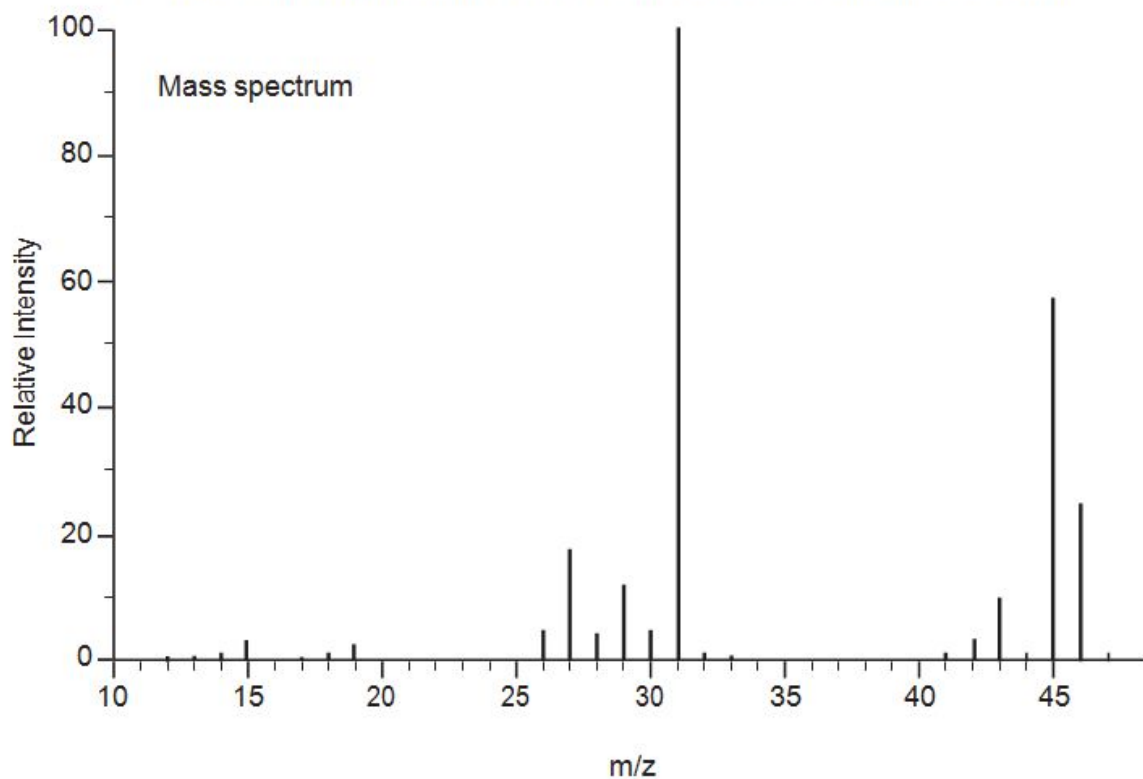
[1]

(vi) Draw the structural formula of the alcohol that can be oxidised to form Acid 2.

[1]

(b) Spectra give much information about the structure of organic compounds.

The mass spectrum and infrared spectrum of ethanol, $\text{C}_2\text{H}_5\text{OH}$, are shown.



(i) What can be deduced by the presence of the peak at m/z 46 in the mass spectrum?

[1]

(ii) What can be deduced by the presence of the peak at m/z 15 in the mass spectrum?

[1]

(iii) What can be deduced by the presence of an absorption peak at 3100 to 3500 cm^{-1} in the infrared spectrum?

[1]

(c) Ethene can be converted into ethanol and ethanol can be converted into ethene.

For each conversion, state the reagent(s) used and the conditions needed.

[4]

ethene to ethanol

ethanol to ethene

(Total 14)

4. This question concerns isomers with molecular formula $\text{C}_5\text{H}_{10}\text{O}_2$.

(a) Isomers **P**, **Q**, **R** and **S** all react with aqueous sodium carbonate to produce carbon dioxide.

Isomer **P** is a straight-chain compound.

Isomer **Q** contains a chiral carbon centre.

Isomer **R** has only two peaks in its NMR spectrum, both of which are singlets.

Draw the displayed formulae for all **four** isomers.

[4]

(b) Isomer **T** is a neutral, sweet-smelling compound and is formed by the reaction between compounds **X** and **Y** in the presence of concentrated sulfuric acid.

Compound **X** has an absorption in its infrared spectrum at 1750 cm^{-1} and a broad absorption around 3000 cm^{-1} .

Compound **Y** can be formed directly from ethanal.

(i) Use **all** the information given to name compounds **X** and **Y**, giving your reasoning. Draw the displayed formula for isomer **T**.

[4] QWC [2]

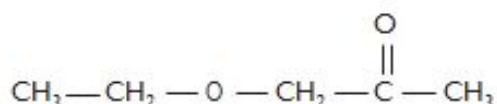
(ii) I. State the reagent needed to form compound **Y** from ethanal

[1]

II. State the role of sulfuric acid in the formation of **T**

[1]

(c) Isomer **U** has the structural formula shown below.



List the peaks which would be found in the NMR spectrum of isomer **U**. Identify which protons are responsible for each peak, giving the approximate chemical shift (ppm) and the splitting of the peak. [4]

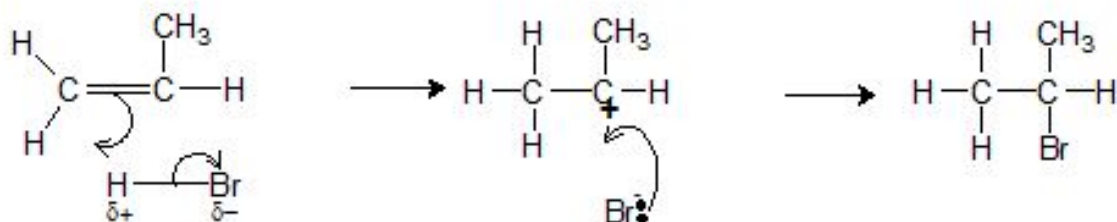
(d) Explain which one of isomers **P**, **T** and **U** would have the highest boiling temperature.

[3] QWC [1]

(Total 20)

2.

- (a) (i) 1 mark for arrows in first diagram; 1 mark for arrow in second diagram;
1 mark for all charges



2 max if incorrect isomer given

[3]

- (ii) 2-bromopropane formed from a secondary carbocation (1)
Secondary carbocations are more stable than primary carbocations (1)
[2]

- (b) Empirical formula = C_3H_5Br (1)

Molecular formula = C_3H_5Br

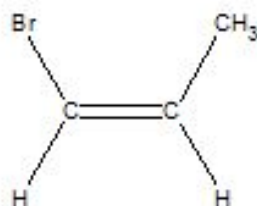
(must show use of mass spectrum to gain this mark) (1)

Two molecular ion peaks as there are two isotopes of bromine (1)

Peaks at 15 = CH_3^+ and 41 = $C_3H_5^+$ (1)

550 cm^{-1} = C-Br 1630 cm^{-1} = C=C 3030 cm^{-1} = C-H (1)

Molecule is:



(1)

[6]

QWC: legibility of text, accuracy of spelling, punctuation and grammar, clarity of meaning [1]

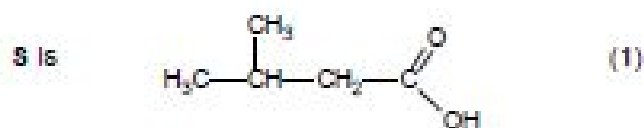
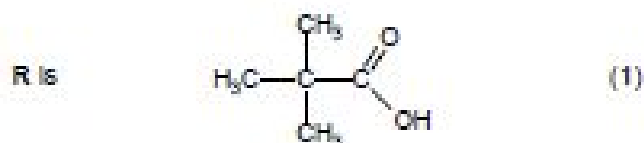
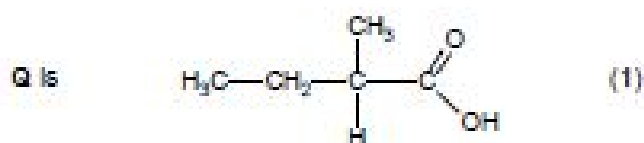
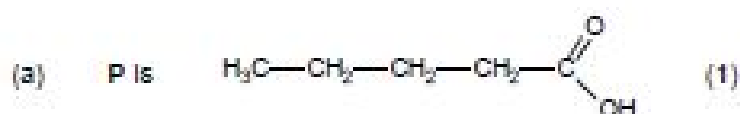
Total [12]

3.

- (a) (i) Mass C = $1.79 \times 12/44 = 0.488$ (g) [1]
- (ii) Mass O = 0.65 (g) ecf from part (i) [1]
- (iii) C : H : O = $0.488/12 : 0.061/1 : 0.65/16 = 0.0407 : 0.061 : 0.0406$ (1)
= 2:3:2 empirical formula is $C_2H_3O_2$ (1)
No ecf from incorrect ratios [2]
- (iv) Mr of empirical formula = 59 so molecular formula is $C_4H_6O_4$ so
F is acid 2/ molecular formula acid 1 is $C_5H_8O_2$ so empirical formula is
not $C_2H_3O_2$ molecular formula acid 2 is $C_4H_6O_4$ so empirical formula is
 $C_2H_3O_2$ [1]
- (v) Bromine turns from brown/red-brown to colourless for Acid 1 [1]
- (vi)
- $$\begin{array}{ccccccc} & H & H & H & H & & \\ & | & | & | & | & & \\ HO & -C & -C & -C & -C & -OH \\ & | & | & | & | & & \\ & H & H & H & H & & \end{array}$$
- [1]
- (b) (i) Mr / molecular ion (is 46) [1]
- (ii) CH_3 (present) [1]
- (iii) OH (present) [1]
- (c) Ethene to ethanol: steam (1)
 H_3PO_4 (catalyst) (1)
Ethanol to ethene: conc H_2SO_4 / Al_2O_3 / pumice (1)
High temperature > $150^\circ C$ for H_2SO_4
> $300^\circ C$ for Al_2O_3 / pumice (1) [4]

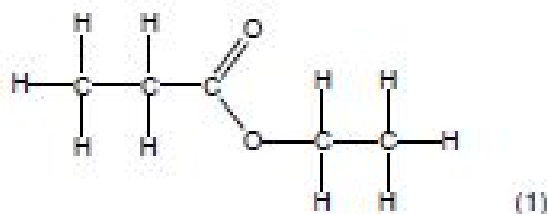
Total [14]

4.



[4]

- (b) (i) T neutral and sweet-smelling therefore an ester (1)
 Infrared spectrum at 1750 cm^{-1} shows C=O and at 3000 cm^{-1} shows O-H therefore X is an acid (1)
 Y is an alcohol, formed from ethanal must be ethanol (1)
 5 carbons in ester therefore X must be propanoic acid (1)
 Structure of T is



(Maximum 4 marks) [4]

QWC Legibility of text; accuracy of spelling, punctuation and grammar, clarity of meaning (1)
 Selection of a form and style of writing appropriate to purpose and to complexity of subject matter (1) [2]

- (ii) I Reagent to form Y is NaBH_4 / LiAlH_4 [1]
 II Sulfuric acid acts as a catalyst / removes water so pushes equilibrium to right [1]

(c)	$\text{CH}_3(\text{CH}_2)$	0.1 to 2.0 ppm triplet (1)	
	$(\text{CH}_2)\text{CH}_2\text{O}$	3.5 to 4.0 ppm quadruplet (1)	
	CH_2CO	2.5 to 3.0 ppm singlet (1)	
	CH_3CO	2.0 to 2.5 ppm singlet (1)	[4]

- (d) Isomer P (1)
- Only P can form hydrogen bonds between molecules (1)
- Hydrogen bonds are the strongest intermolecular bonds / need more energy to break hydrogen bonds (1) [3]

QWC The information is organised clearly and coherently, using specialist vocabulary where appropriate [1]

Total [20]