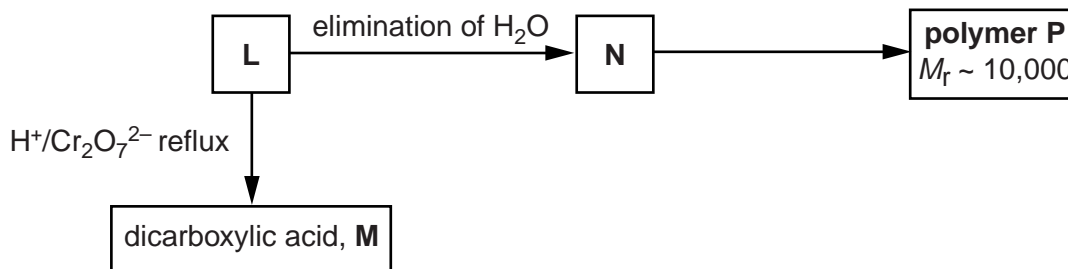


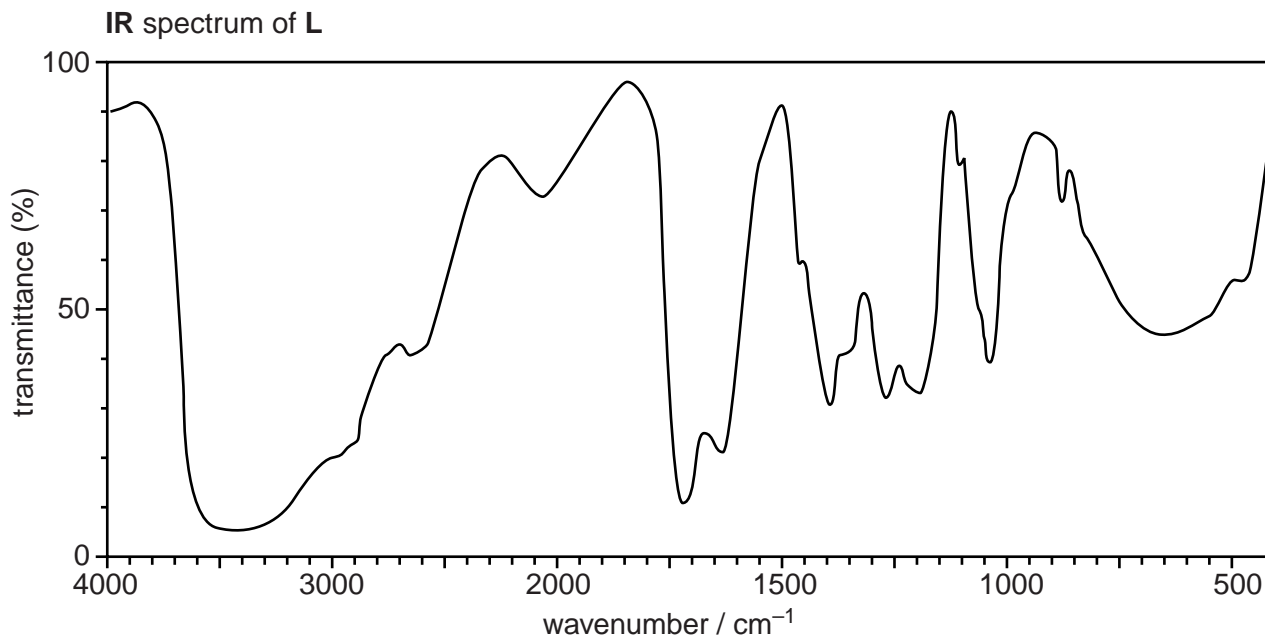
1 L, M, N and P are straight-chain organic compounds containing C, H and O only.

The flowchart shows reactions involving these compounds.



Analysis of compound L shows the following.

- Percentage composition by mass: C, 40.00%; H, 6.67%; O, 53.33%.
- Relative molecular mass of 90.0.
- The infrared spectrum below.



(a) Calculate the empirical and molecular formulae of compound L.

Show your working.

.....

.....

.....

.....

.....

[3]

**(b)** Analyse the information and spectrum to determine the structures of **L** and **M**.

Include an equation for the reaction of **L** to form **M**.

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

**(c)** Determine the structures of compounds **N** and **P**.

Estimate the number of repeat units in polymer **P** and write the equation for the formation of **P** from **N**.

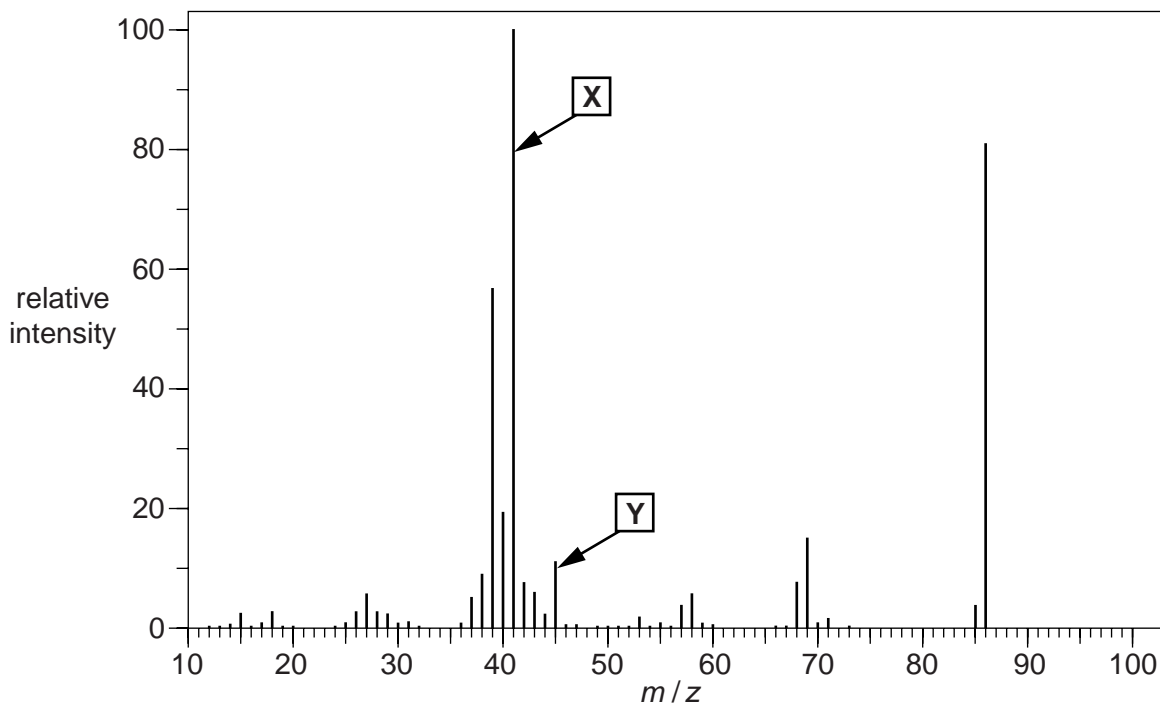
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..... [4]

[Total: 12]

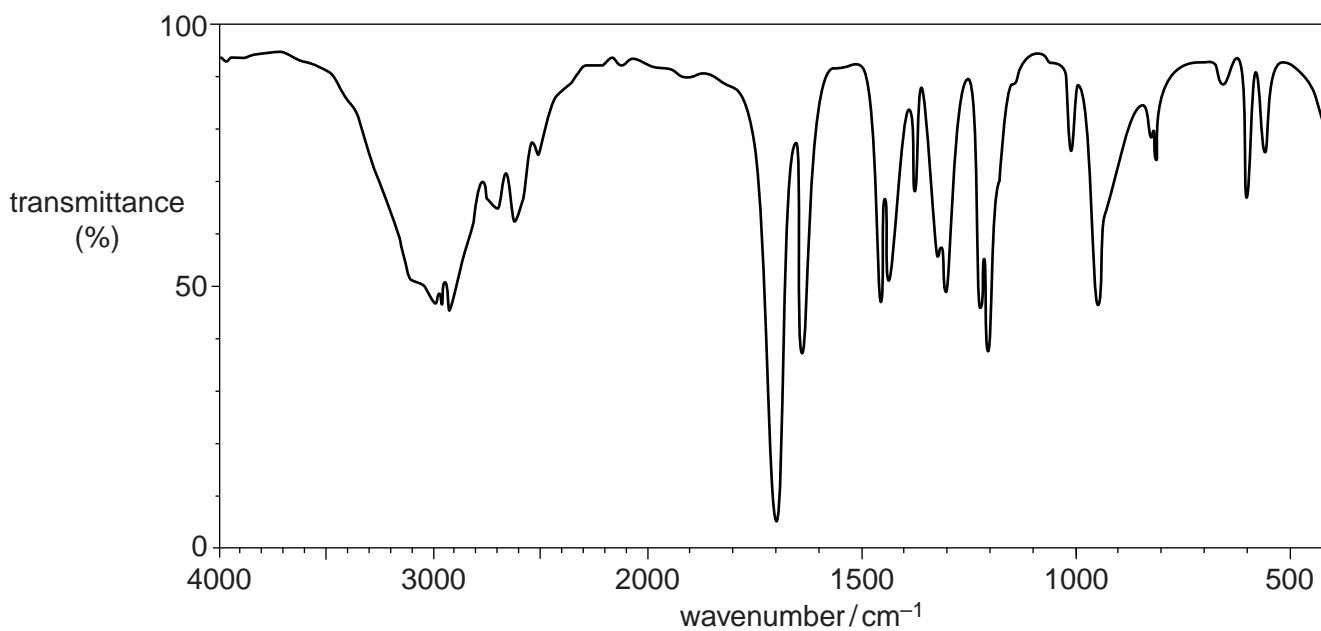


- (b) Compound **G** is a branched-chain organic compound that does **not** have *E* and *Z* isomers. Elemental analysis of compound **G** gave the following percentage composition by mass: C, 55.8%; H, 7.0%; O, 37.2%. The mass spectrum and infrared spectrum of compound **G** are shown below.

**Mass spectrum**



**Infrared spectrum**

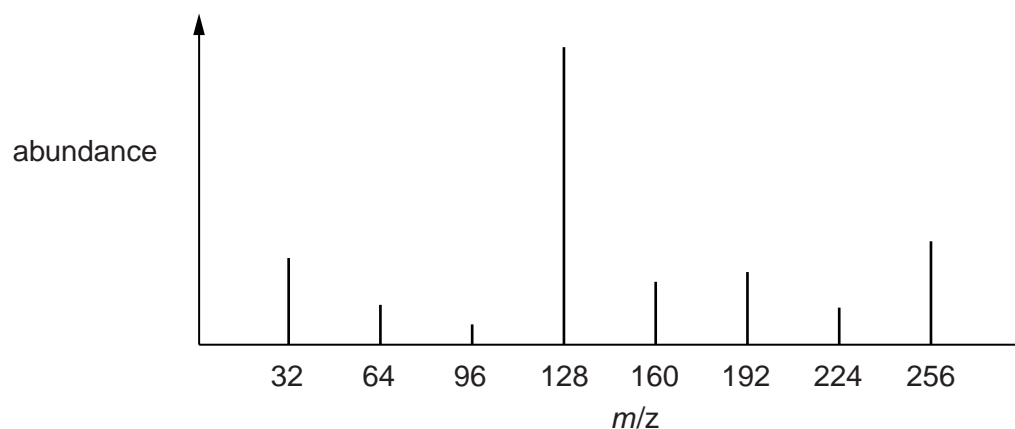




3 Mass spectrometry and infrared spectroscopy are used in analysis.

(a) The element sulfur exists as molecules,  $S_n$ .

The mass spectrum that would be given by a sample of sulfur is shown below.  
All the sulfur atoms are the same isotope.



(i) State the  $m/z$  value of the molecular ion.

..... [1]

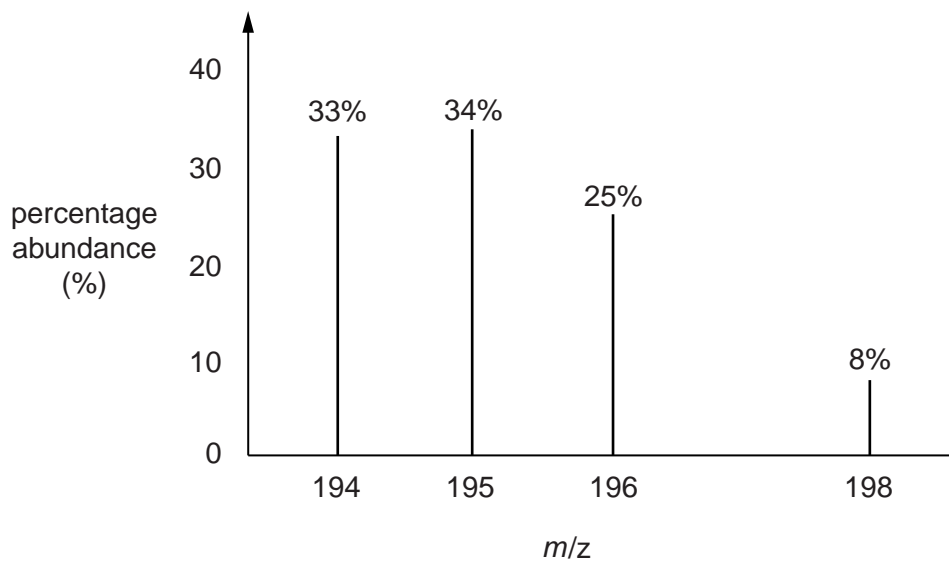
(ii) Suggest the formula for a molecule of sulfur.

..... [1]

(iii) What is the formula for the fragment ion with  $m/z = 128$ ?

..... [1]

- (b) A sample of an element, **L** is analysed using mass spectrometry. The mass spectrum is shown below.



Calculate the relative atomic mass of **L**.  
Give your answer to **one** decimal place.

relative atomic mass of **L** = ..... [2]

- (c) Give an everyday use for infrared spectroscopy.

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





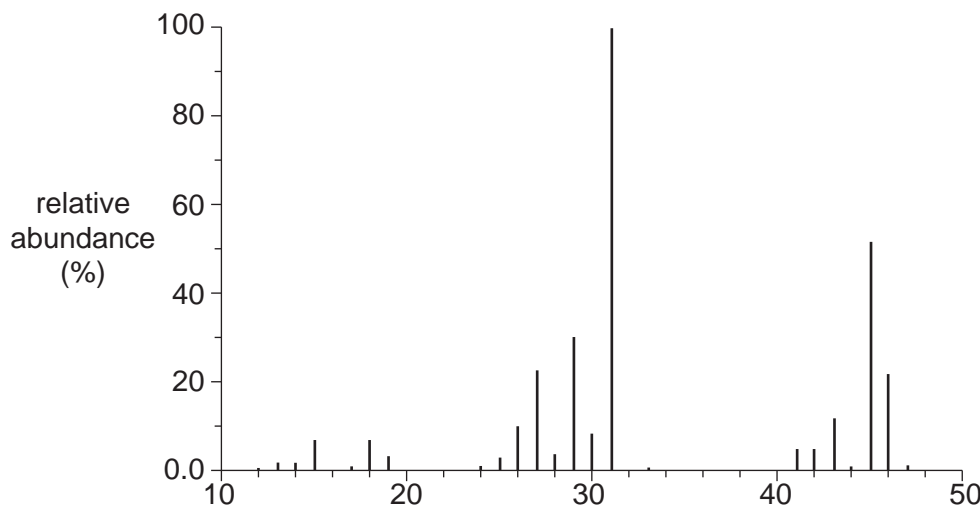
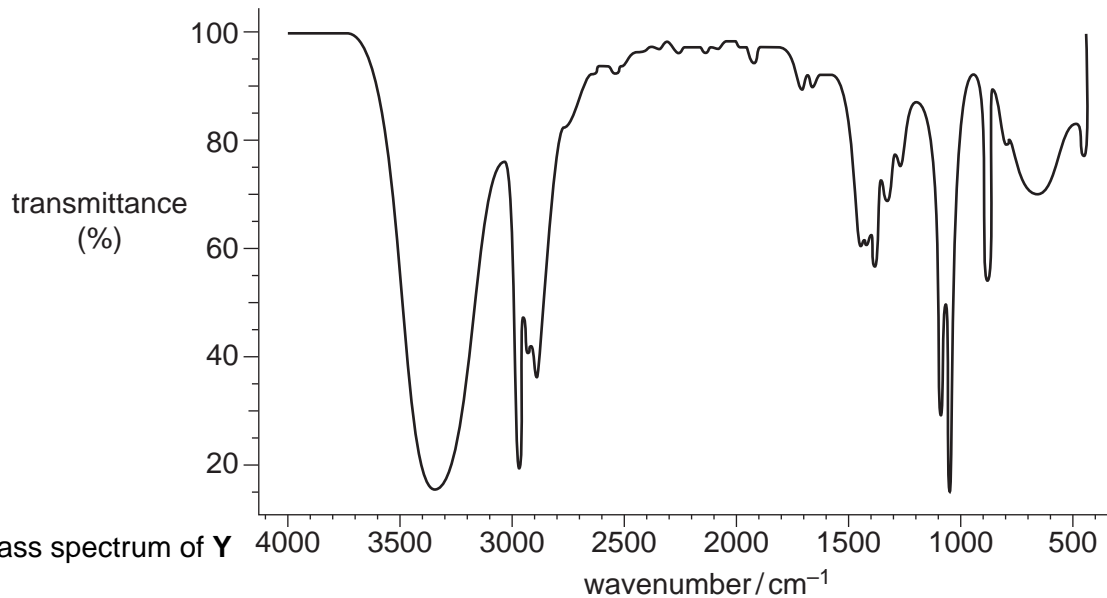
- 4 Compound **X** and compound **Y** react together to make an ester **Z**. Samples of **X** and **Y** were analysed by a research chemist. A summary of the chemist's results are shown below.

**Analysis of compound X**

type of analysis	evidence
infrared spectroscopy	absorption at $1720\text{ cm}^{-1}$ and a very broad absorption between $2500$ and $3300\text{ cm}^{-1}$
percentage composition by mass	C, 48.65%; H, 8.11%; O, 43.24%
mass spectrometry	molecular ion peak at $m/z = 74.0$

**Analysis of compound Y**

infrared spectrum of **Y**





5 Infrared spectroscopy and mass spectrometry are used to identify substances.

(a) Police use breathalysers to detect ethanol in the breath of drivers.

(i) Some modern breathalysers use infrared spectroscopy.

Suggest **two** characteristic infrared absorptions that could be used to identify the presence of ethanol vapour.

1 .....  $\text{cm}^{-1}$

2 .....  $\text{cm}^{-1}$  [2]

(ii) Some older breathalysers used the redox reaction between acidified dichromate(VI) ions and ethanol. A colour change was seen which indicated the presence of ethanol in the breath.

What is the colour change that would be seen in this breathalyser if ethanol was present in the breath?

..... to ..... [1]

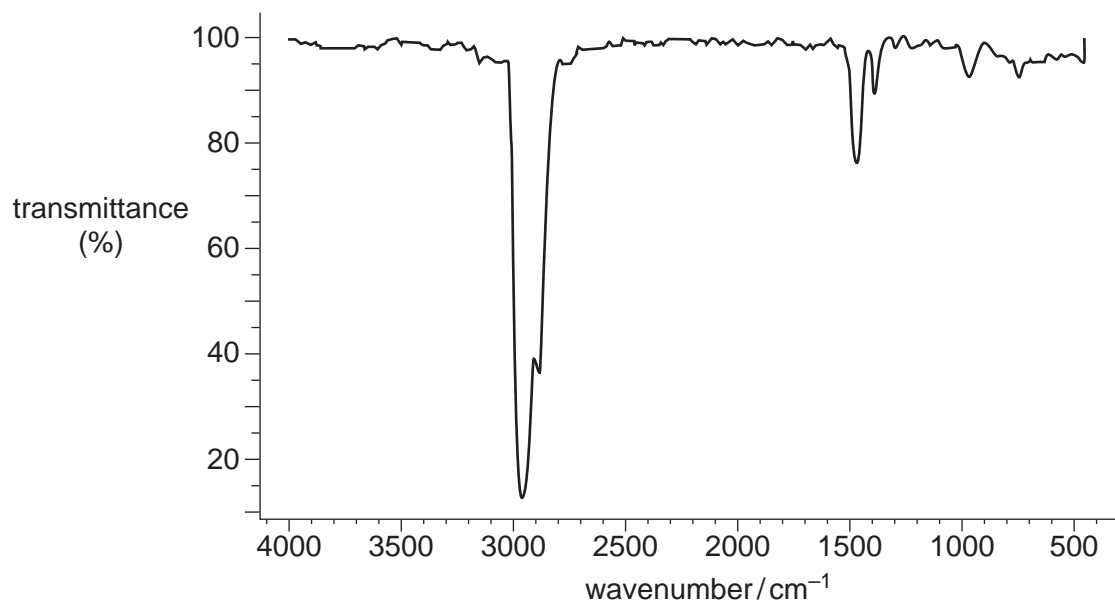
(iii) Give an equation to show the reaction between acidified dichromate(VI) ions and ethanol.

Use [O] to represent the acidified dichromate(VI) ions, the oxidising agent.

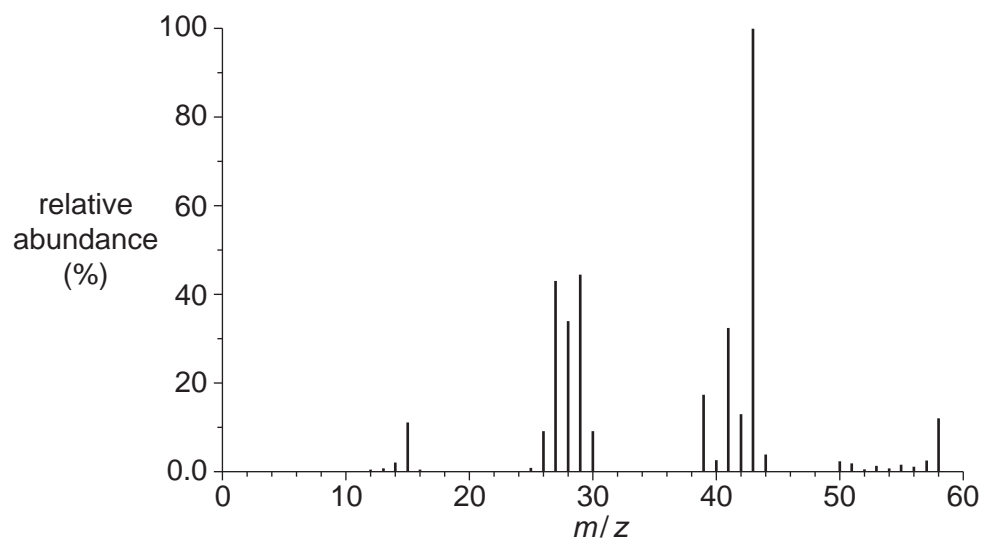
..... [2]

- (b) Infrared spectroscopy and mass spectrometry are used in the search for organic molecules in outer space.

Compound **A** has been analysed by infrared spectroscopy.



The mass spectrum of compound **A** is shown below.



(i) A research chemist concludes that compound **A** is a hydrocarbon.

What evidence is there to support this conclusion?

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

(ii) How does the mass spectrum confirm that compound **A** has a molecular formula of  $C_4H_{10}$ ?

..... [1]

(iii) Draw the structural isomers of  $C_4H_{10}$ .

[1]

(iv) Identify the fragment ions that give rise to the following peaks in the mass spectrum.

$m/z$  15 is .....

$m/z$  29 is .....

$m/z$  43 is .....

[3]

(v) Use your answer to part (iv) to identify which of the isomers in part (iii) is compound **A**. Explain your reasoning.

[1]

[Total: 13]