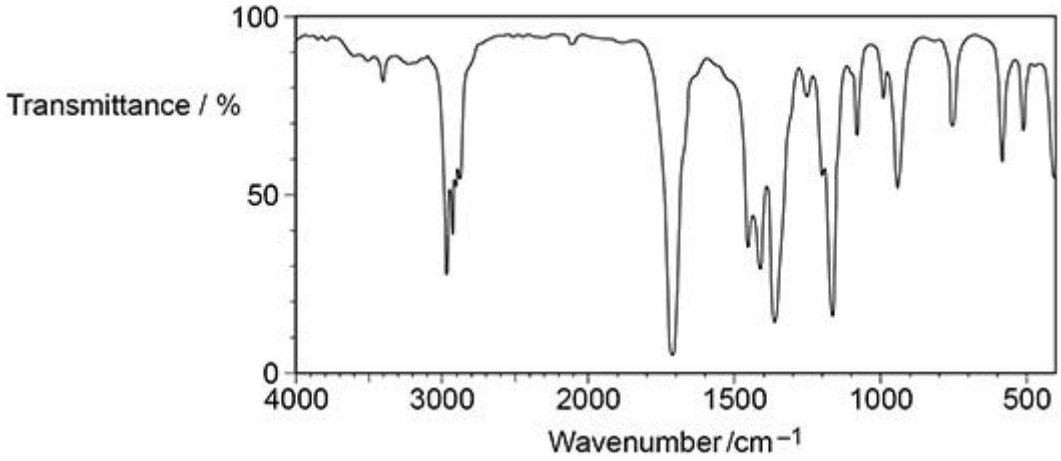
Q1.

This question is about spectroscopy.

(a) Compound **K** has molecular formula C_4H_8O
Figure 1 shows the infrared spectrum of **K**.

Figure 1



Which functional group does **K** contain?

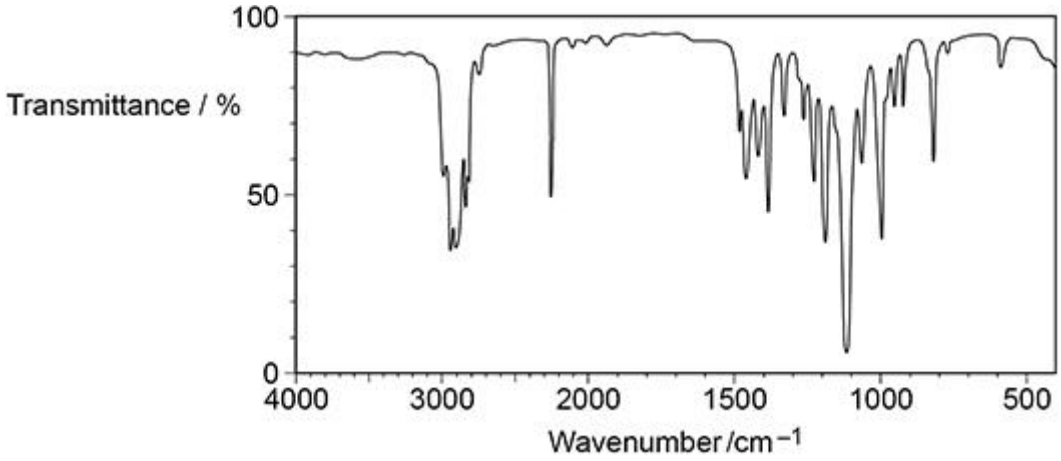
Tick (✓) **one** box.

Functional Group				
alcohol	alkene	amine	carbonyl	nitrile

(1)

(b) Compound **L** has molecular formula C_4H_7NO
Figure 2 shows the infrared spectrum of **L**.

Figure 2



L reacts with H_2 in the presence of a nickel catalyst to give compound **M**.

Suggest **three** ways in which the infrared spectrum of **M** is different from the infrared spectrum of **L**.

1 _____

_____

2 _____

_____

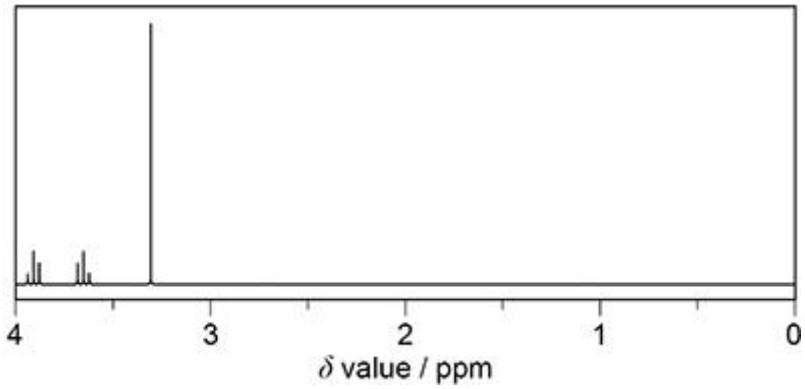
3 _____

_____

(3)

(c) **Figure 3** shows the ^1H NMR spectrum of **Q**, C_3H_7ClO

Figure 3



The table below shows the chemical shifts (δ values) and integration values for each peak.

δ value / ppm	3.95	3.65	3.35
Integration value	0.6	0.6	0.9

Deduce the structure of **Q**.

Explain your answer.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

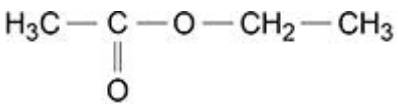
_____

(5)

(Total 9 marks)

Q2.

Which statement does **not** support the suggestion that an unknown organic compound is



A Its ^{1}H NMR spectrum has 3 peaks with an integration ratio of 2:3:3 ⬭

B Its ^{13}C NMR spectrum has 3 peaks. ⬭

C Its infrared spectrum has an absorption at 1735 cm^{-1} ⬭

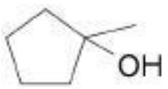
D It has 36.36% by mass of oxygen and 9.09% by mass of hydrogen. ⬭

(Total 1 mark)

Q3.

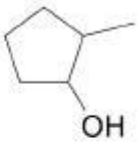
This question is about the structural isomers shown.

P

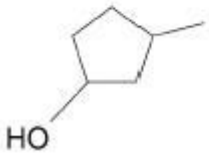


Q

R

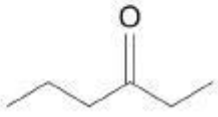


S



T

U



(a) Identify the isomer(s) that would react when warmed with acidified potassium dichromate(VI).

State the expected observation when acidified potassium dichromate(VI) reacts.

Isomer(s)

_____

Expected observation

_____

_____

(2)

(b) Identify the isomer(s) that would react with Tollens' reagent.

State the expected observation when Tollens' reagent reacts.

Isomer(s)

_____

Expected observation

_____

_____

(2)

(c) Separate samples of each isomer are warmed with ethanoic acid and a few drops of concentrated sulfuric acid. In each case the mixture is then poured into a solution of sodium hydrogencarbonate.

Identify the isomer(s) that would react with ethanoic acid.

Suggest a simple way to detect if the ethanoic acid reacts with each isomer.

Give a reason why the mixture is poured into sodium hydrogencarbonate solution.

Isomer(s)

_____

Suggestion

_____

_____

_____

Reason

_____

_____

(3)

(d) State the type of structural isomerism shown by isomers **P**, **Q**, **R** and **S**.

_____

(1)

(e) Describe fully how infrared spectra can be used to distinguish between isomers **R**, **S** and **T**.
Use data from **Table A** in the Data Booklet in your answer.

_____

_____

_____

_____

_____

_____

_____

_____

(4)

(f) State why mass spectrometry using electrospray ionisation is **not** a suitable method to distinguish between the isomers.

_____

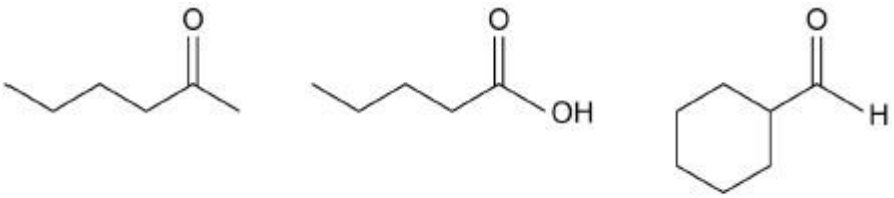
_____

(1)

(Total 13 marks)

Q4.

The structures of three organic compounds A, B and C are shown.



Compound **A** Compound **B** Compound **C**

These compounds can be distinguished by simple test-tube reactions.

For each pair of compounds in questions **(a)** and **(b)**, give a reagent (or combination of reagents) that could be added separately to each compound to distinguish between them.

State what is observed in each case.

(a) Compounds **A** and **B**

Reagent _____

Observation with **A** _____

_____

Observation with **B** _____

_____

(3)

(b) Compounds **A** and **C**

Reagent _____

Observation with **A** _____

_____

Observation with **C** _____

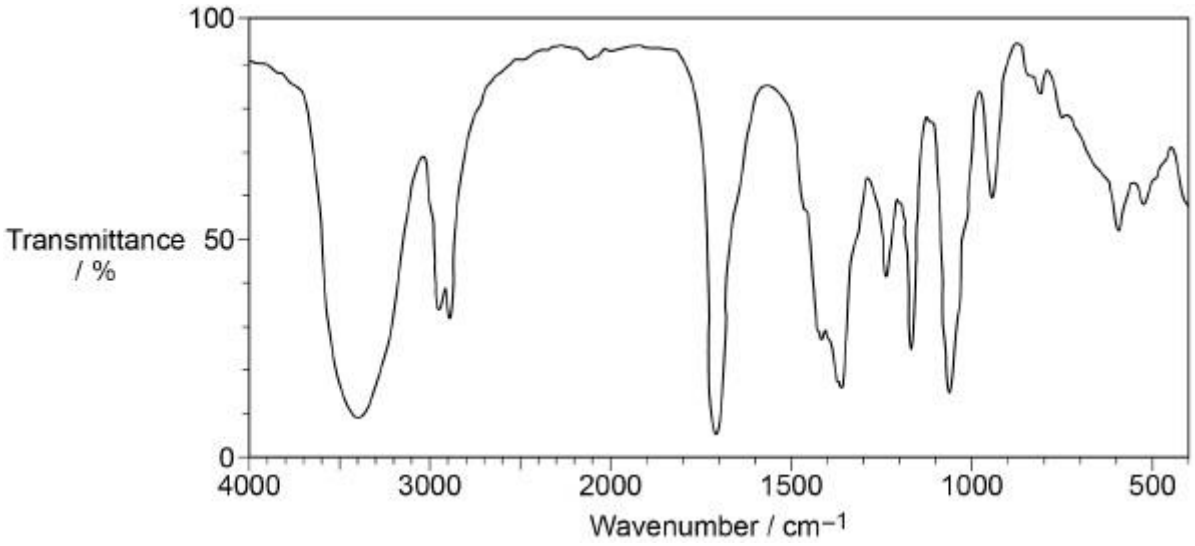
_____

(3)

(Total 6 marks)

Q5.

The infrared spectrum of an organic compound is shown.



Which compound produces this spectrum?

A ethanoic acid ⬭

B 4-hydroxybutanone ⬭

C propan-1-ol ⬭

D prop-2-en-1-ol ⬭

(Total 1 mark)

Q6.

This question is about isomers.

(a) Give a reagent and observations for a test-tube reaction to distinguish between 2-methylbutan-1-ol and 2-methylbutan-2-ol.

Reagent

_____

_____

Observation with 2-methylbutan-1-ol _____

_____

_____

Observation with 2-methylbutan-2-ol _____

_____

_____

(3)

(b) Compounds **A** and **B** both have the molecular formula $C_4H_8Br_2$
A has a singlet, a triplet and a quartet in its ^1H NMR spectrum.
B has only two singlets in its ^1H NMR spectrum.

Draw a structure for each of **A** and **B**.

A **B**

(2)

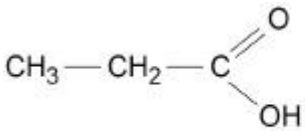
(c) Compounds **C** and **D** both have the molecular formula $C_6H_3Br_3$
C has two peaks in its ^{13}C NMR spectrum.
D has four peaks in its ^{13}C NMR spectrum.

Draw a structure for each of **C** and **D**

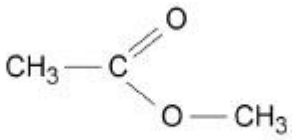
C **D**

(2)

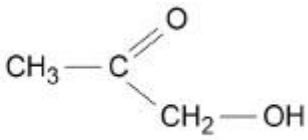
(d) Compounds **E**, **F**, and **G** are isomers.



E



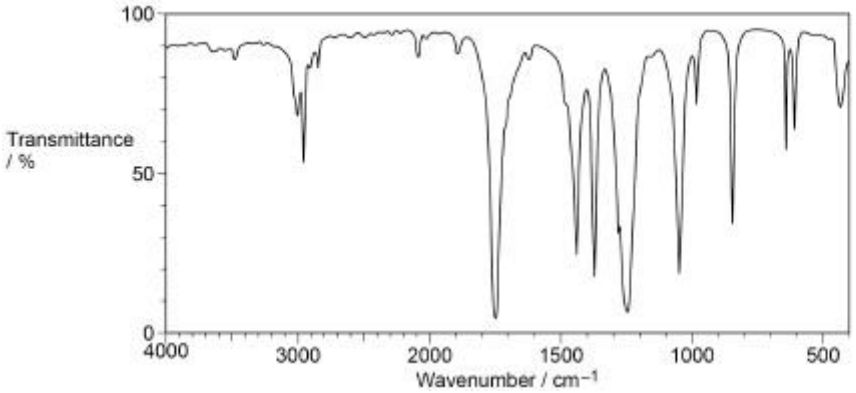
F

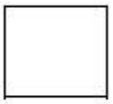


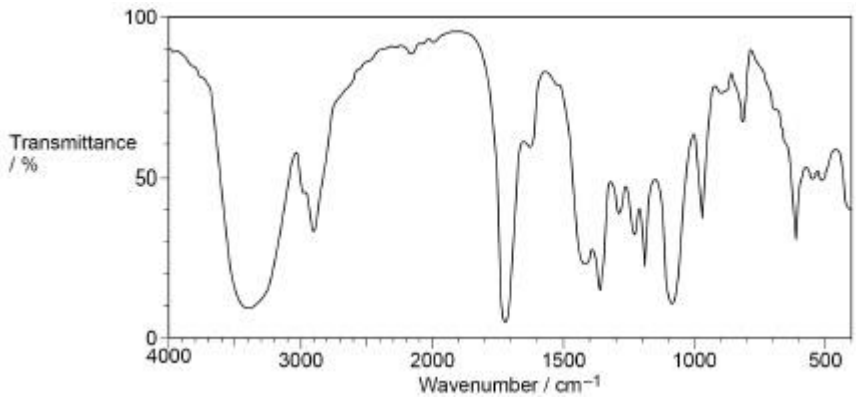
G

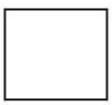
The diagrams below show the infrared spectra of these isomers, but not necessarily in the same order.

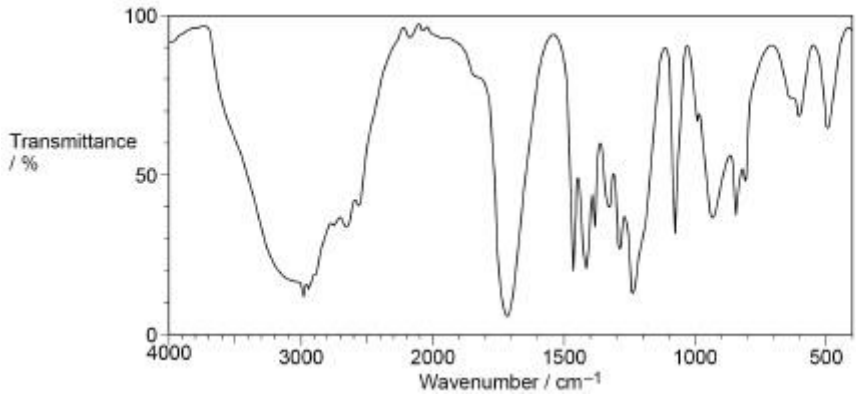
Label each spectrum with the correct letter **E**, **F**, and **G** in the box.

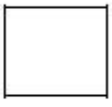










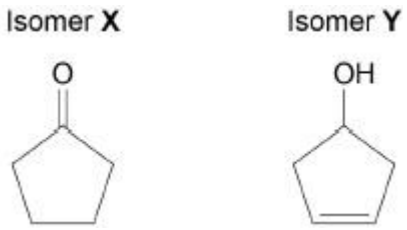


(1)

(Total 8 marks)

Q7.

Isomers **X** and **Y** have the molecular formula C_5H_8O



(a) Give the IUPAC name for isomer **X**.

_____

(1)

(b) Explain how and why isomers **X** and **Y** can be distinguished by comparing **each** of their

- boiling points
- ^{13}C NMR spectra
- infrared spectra.

Use data from Tables **A** and **C** in the Data Booklet in your answer.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(6)

(Total 7 marks)

Q8.

Three reagents are added separately to four organic compounds.

Which row shows the correct observations?

		Sodium hydrogen carbonate	**Acidified potassium dichromate(VI)**	**Tollens' reagent**	
A	**Propan-1-ol**	effervescence	orange solution turns green	no visible change	⬭
B	**Propanal**	no visible change	orange solution turns green	silver mirror	⬭
C	**Propanone**	no visible change	no visible change	silver mirror	⬭
D	**Propanoic acid**	effervescence	no visible change	silver mirror	⬭

(Total 1 mark)

Q9.

Four compounds, all colourless liquids, are

- butan-2-ol
- butanal
- butanone
- 2-methylpropan-2-ol

Two of these compounds can be identified using different test-tube reactions.

Describe these **two** test-tube reactions by giving reagents and observations in each case.
Suggest how the results of a spectroscopic technique could be used to distinguish between the **other** two compounds.

_____

_____

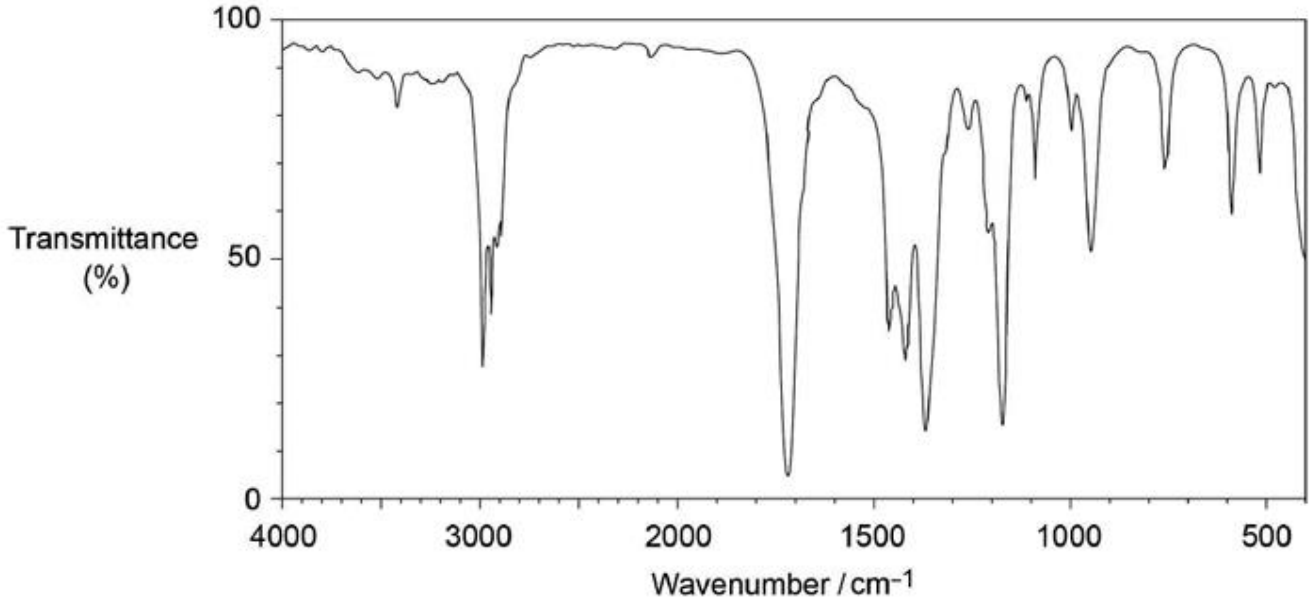
_____

_____

(Total 6 marks)

Q10.

The infrared spectrum of an organic compound is shown.



Which compound produces this spectrum?

A butanone ⬭

B ethanol ⬭

C pent-2-ene ⬭

D propanoic acid ⬭

(Total 1 mark)

Q11.

Which compound forms a molecular ion with a different precise molecular mass from the other three?

A butanone ⬭

B cyclobutanol ⬭

C dimethylpropane ⬭

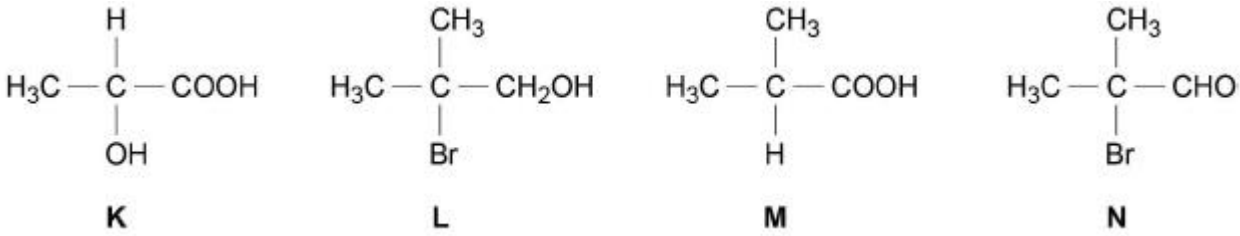
D methylpropanal ⬭

(Total 1 mark)

Q12.

Test-tube reactions can be used to identify the functional groups in organic molecules.

You are provided with samples of each of the four compounds.



K **L** **M** **N**

Describe how you could distinguish between all four compounds using the minimum number of tests on each compound.

You should describe what would be observed in each test.

_____

_____

_____

_____

_____

_____

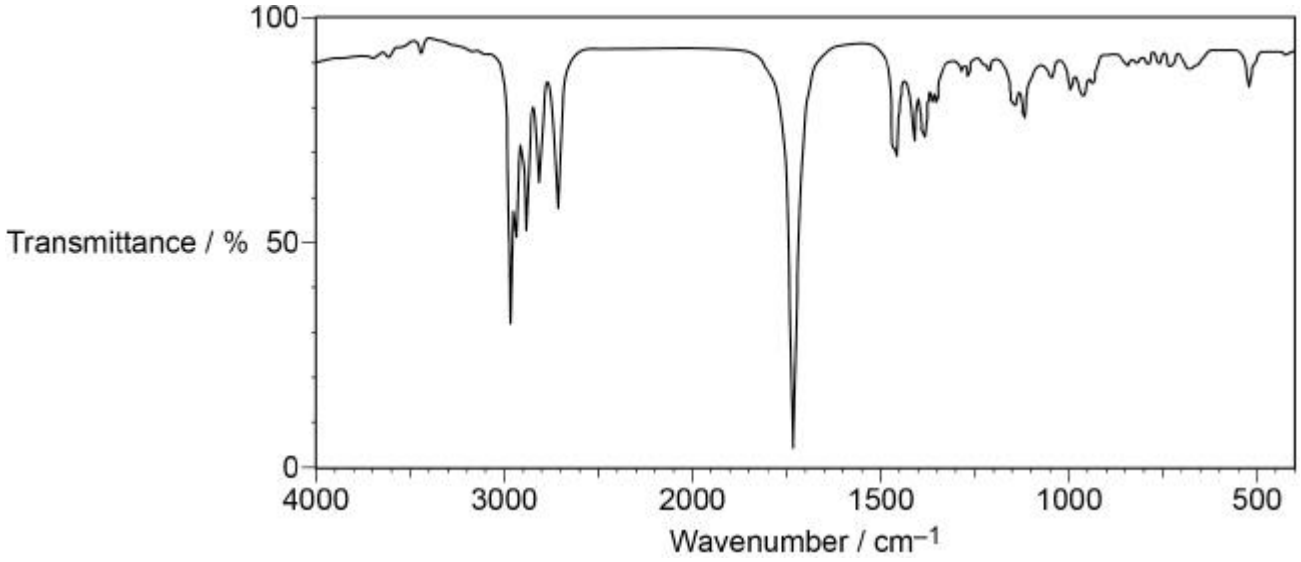
_____

_____

(Total 6 marks)

Q13.

Which compound gives this infrared spectrum?



A 1-bromobutane ⬭

B butan-1-ol ⬭

C butanal ⬭

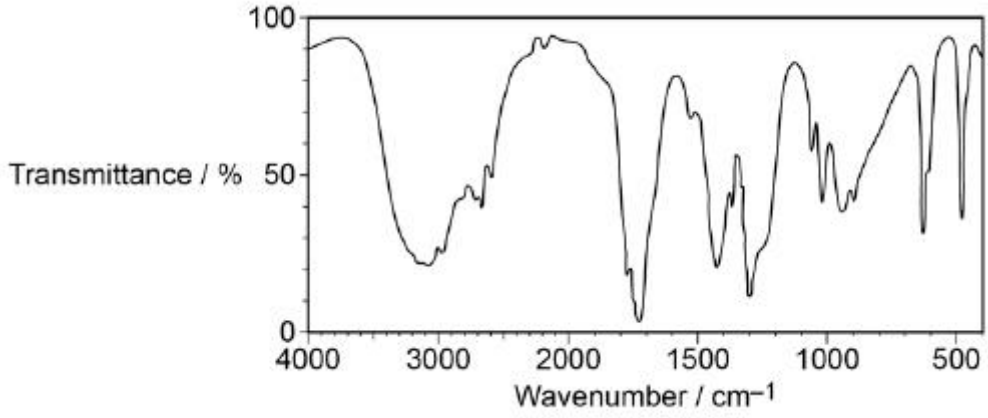
D butanoic acid ⬭

(Total 1 mark)

Q14.

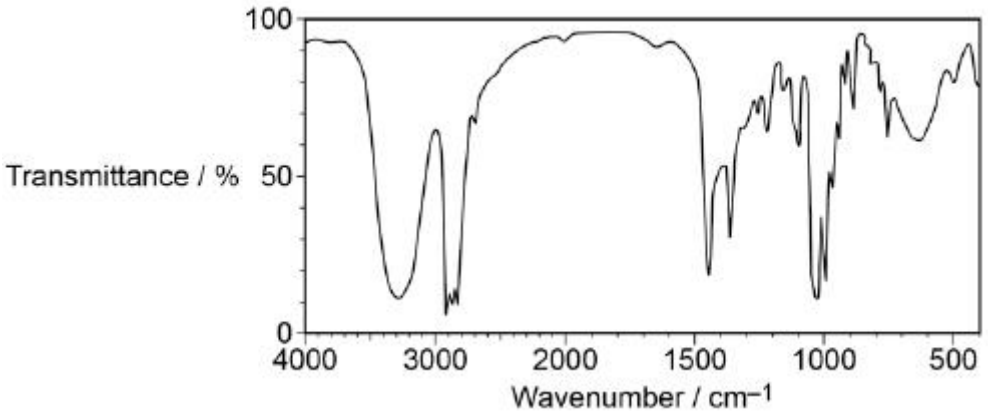
Which of these infrared spectra could represent a carboxylic acid?

A

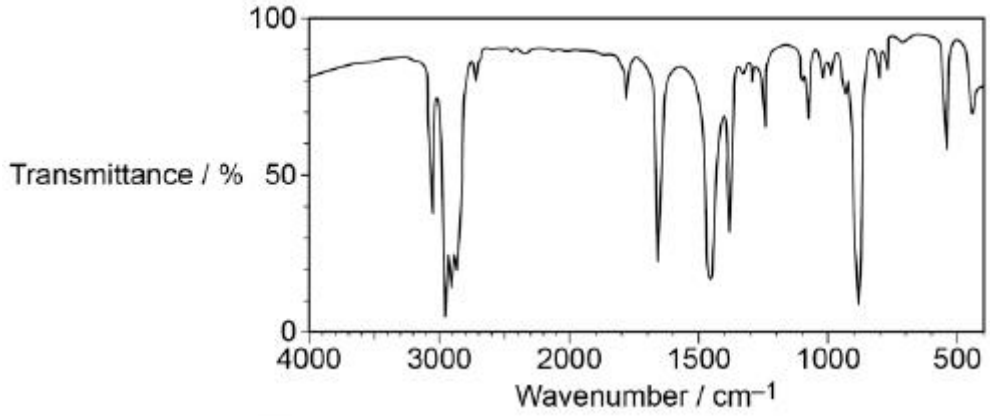


⬭

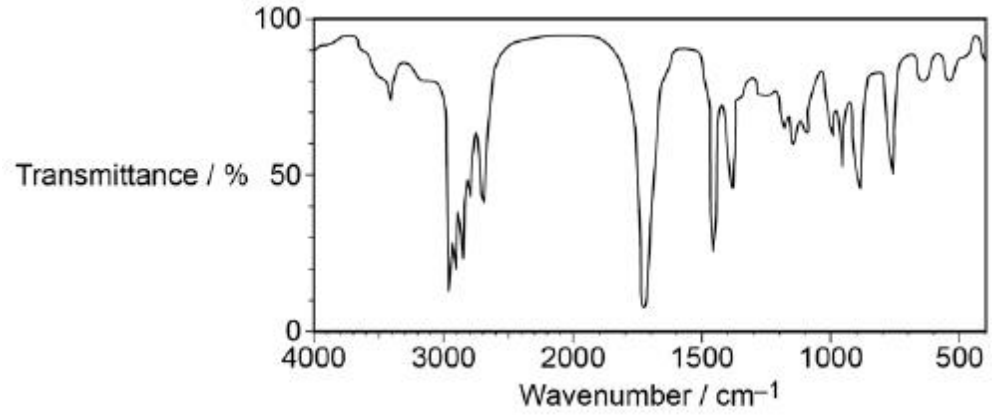
B



C



D



(Total 1 mark)

Q15.

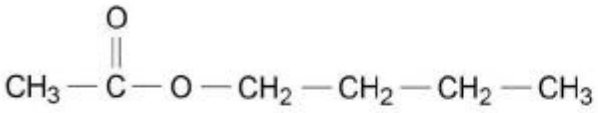
^{1}H NMR, ^{13}C NMR and infrared spectroscopy are used in organic chemistry to distinguish between compounds and to identify them.

(a) Give the skeletal formula of the compound that is used as the standard when recording a ^{13}C NMR spectrum.

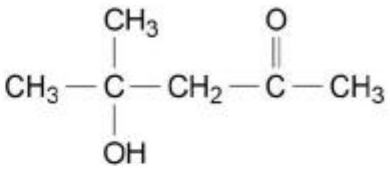
(1)

(b) Four isomers of $C_6H_{12}O_2$, **P**, **Q**, **R** and **S**, shown in **Figure 1**, were analysed by
^{13}C NMR spectrometry.

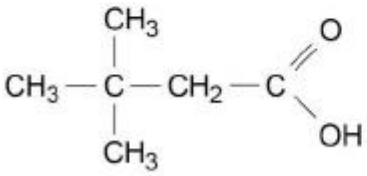
Figure 1



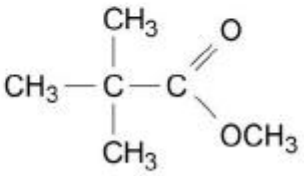
P



Q



R



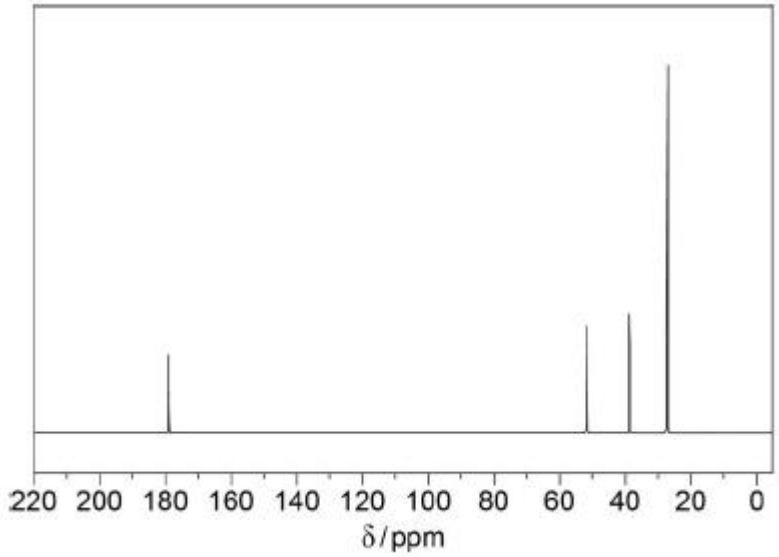
S

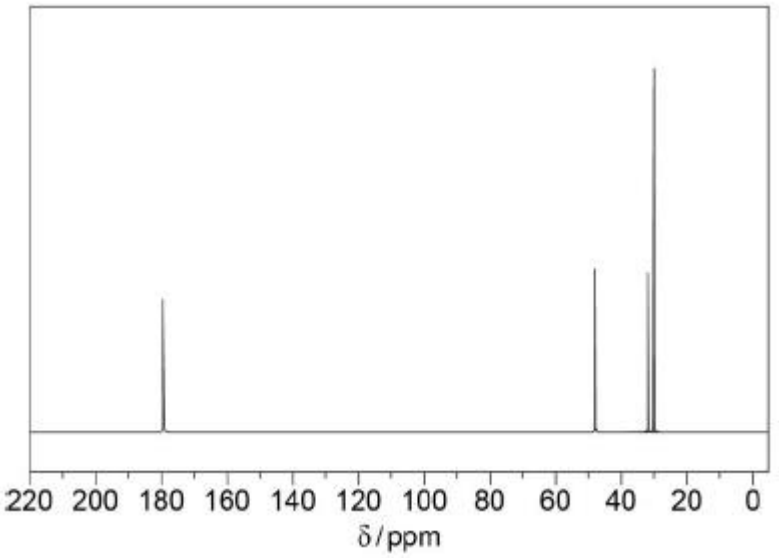
The ^{13}C NMR spectra of three of these isomers are shown in **Figure 2**.

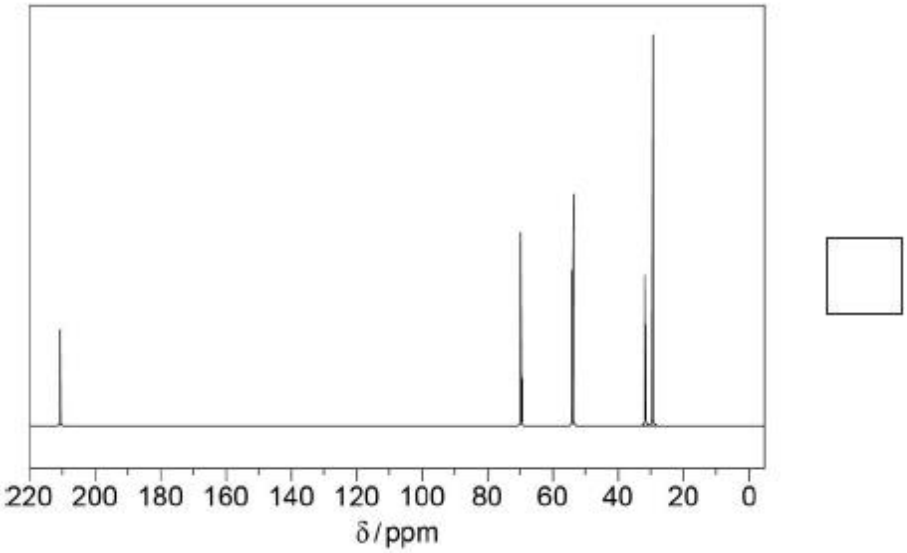
Use **Table C** in the Data Booklet to help you to identify which isomer produces each spectrum.

Write the letter of each isomer opposite its spectrum in **Figure 2**.

Figure 2



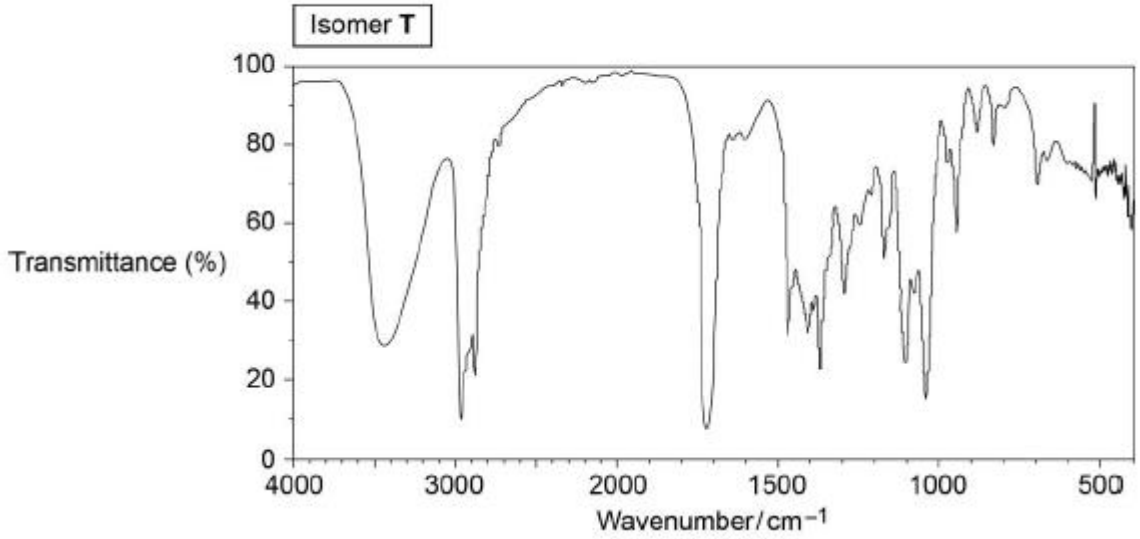


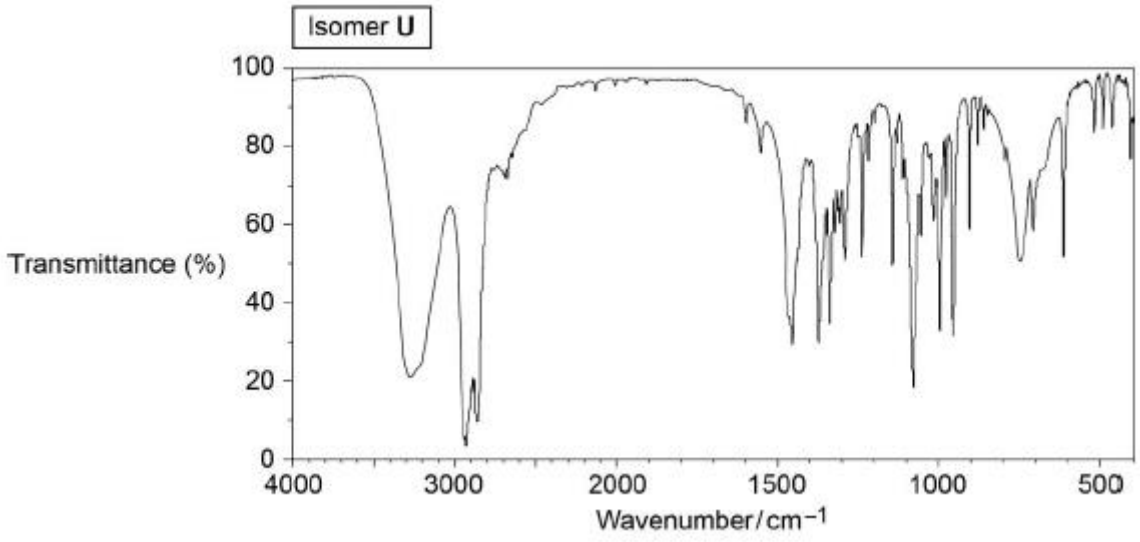


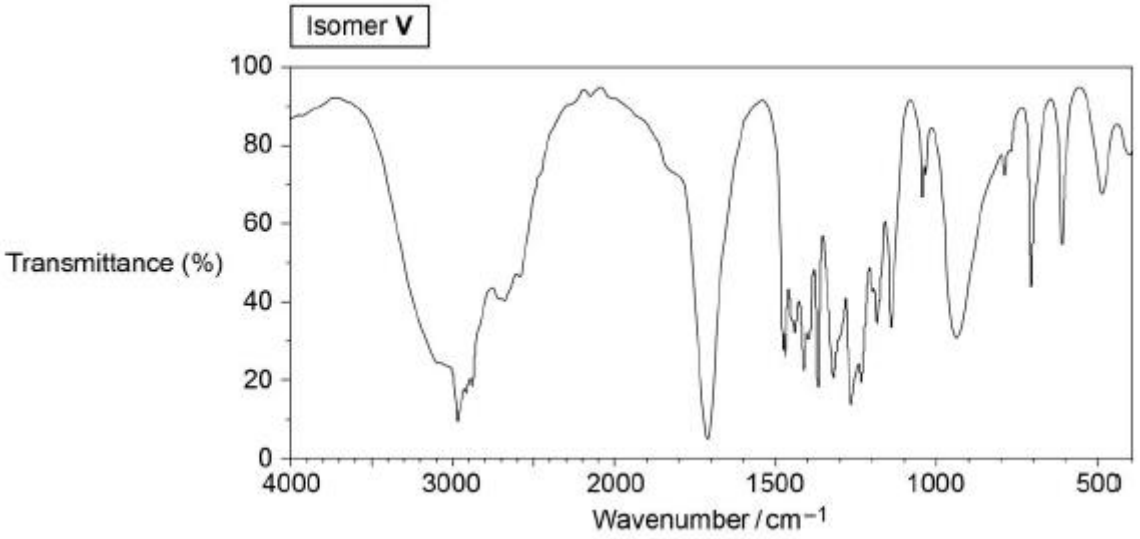
(3)

(c) The infrared spectra shown in **Figure 3** are those of three different isomers of $C_6H_{12}O_2$, isomers **T**, **U** and **V**.

Figure 3







Identify the functional group(s) present in each isomer **T**, **U** and **V** of $C_6H_{12}O_2$ using **Table A** in the Data Booklet.

Explain your answer.

(6)

(d) The integration values for the peaks in the ^{1}H NMR spectrum of **X**, a different isomer of $C_6H_{12}O_2$, are given in the table below.

Chemical shift, δ/ppm	3.7	3.5	2.6	2.2	1.1
Integration value	0.6	0.6	0.6	0.9	0.9
Splitting pattern	triplet	quartet	triplet	singlet	triplet

Deduce the simplest ratio of the relative numbers of protons in each environment in compound **X**.

(1)

(e) Use the data in the table above and **Table B** in the Data Booklet to help you answer this question.

Deduce the part of the structure of **X** that causes the signal at δ= 3.5 and the part of the structure at **X** that causes the signal at δ=2.2.

Explain the splitting patterns of these peaks.

Signal at δ= 3.5

Signal at δ= 2.2

(4)

(f) Deduce the structure of compound **X**, $C_6H_{12}O_2$

Use your answer from part **(e)** to help you.

You are **not** required to explain how you deduced the structure.

_____

_____

_____

_____

(2)

(Total 17 marks)

Q16.

The infrared spectrum (**Figure 1**) and the ^{1}H NMR spectrum (**Figure 2**) of compound **R** with molecular formula $C_6H_{14}O$ are shown.

Figure 1

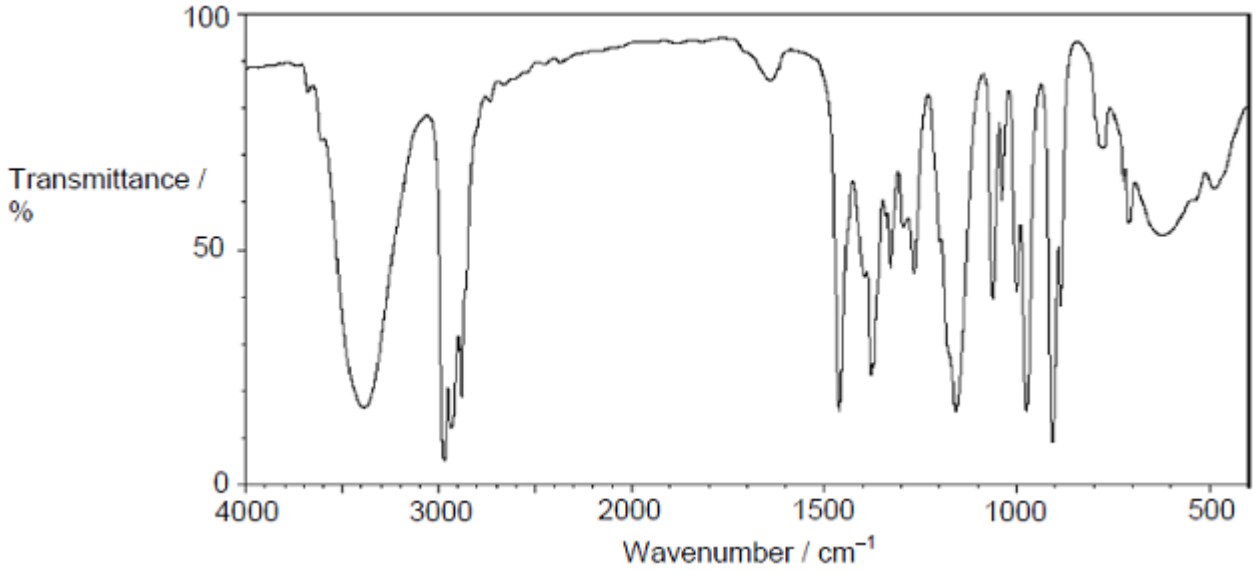
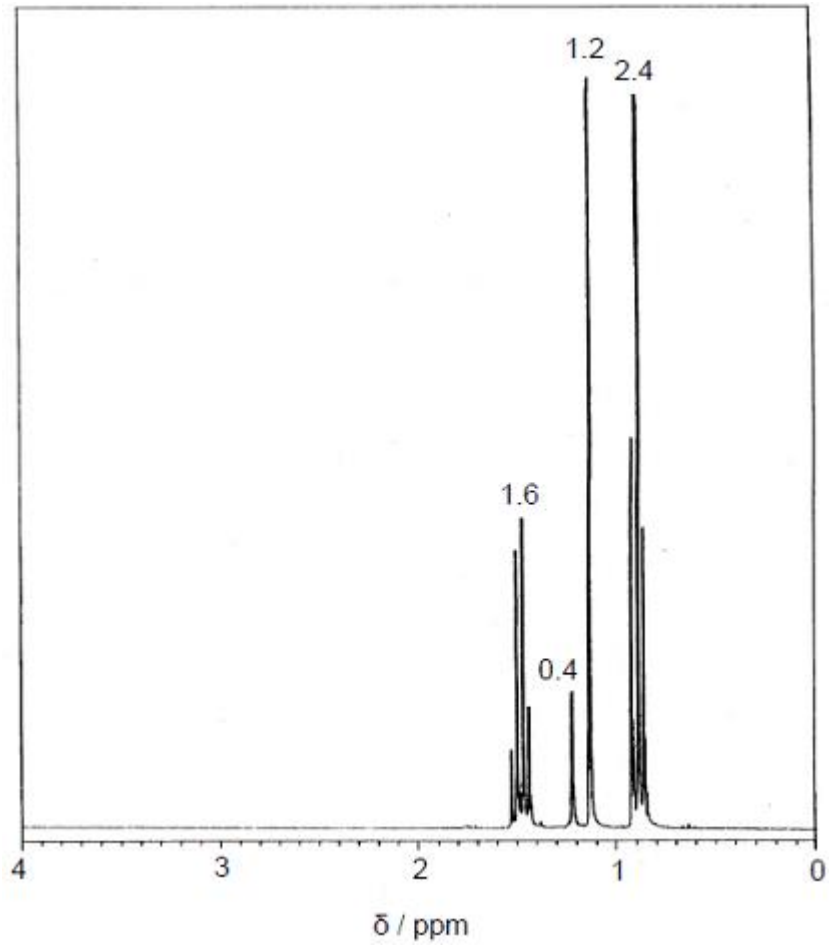


Figure 2



The relative integration values for the NMR peaks are shown on **Figure 2**.

Deduce the structure of compound **R** by analysing **Figure 1** and **Figure 2**.
Explain each stage in your deductions.

Use **Table A** and **Table B** on the Data Sheet.

(Total 8 marks)