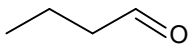
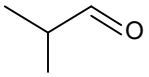
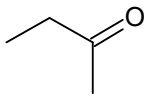
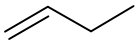
Section A: Questions using reactions and stereoisomerism

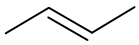
1 Isomers **A** and **B** have the molecular formula C_4H_8O
When warmed with Tollens' reagent:
A gives a silver mirror
B does not give a silver mirror
Draw a possible structure for compounds **A** and **B**

A  or 

B 

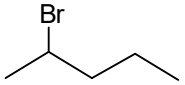
2 Compounds **C, D** and **E** have the molecular formula C_4H_8
C and **D** decolourise bromine water but **E** does not.
D exists as two stereoisomers but **C** does **not** show stereoisomerism.
Draw a possible structure for each of compounds **C**, **D** and **E.**

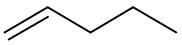
C  or 

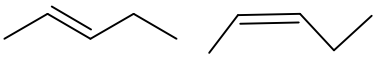
D 

E  or 

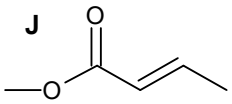
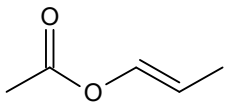
3 Compound **F** is a straight chain halogenoalkane with the molecular formula $C_5H_{11}Br$.
When compound **F** reacts with hot, ethanolic sodium hydroxide a mixture of three alkenes **G**,**H** and **I** can be formed. **G** and **H** are a pair of E-Z stereoisomers.
I does not show stereoisomerism.
Draw a possible structure for each of compounds **F**,**G**, **H** and **I.**

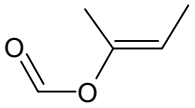
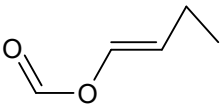
F 

I 

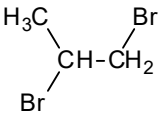
G and **H** 

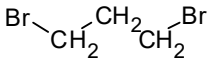
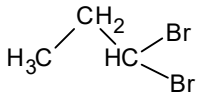
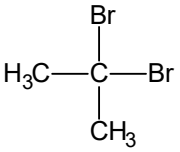
4 Compound **J** is an ester with the molecular formula $C_5H_8O_2$ that shows E-Z stereoisomerism.
Draw a possible structure for compound **J**

J  or 

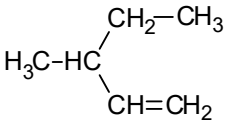
or  or 

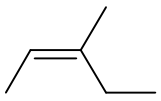
5 Compounds **K** and **L** have the molecular formula $C_3H_6Br_2$
K shows optical activity but **L** does not.
Draw a possible structure for compounds **K** and **L.**

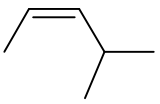
K 

 or  or 

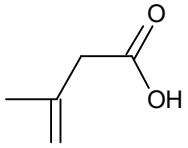
6 Compounds **M**, **N** and **O** have the molecular formula C_6H_{12}
All three are branched-chain molecules and none is cyclic.
M can represent a pair of optical isomers.
N can represent a pair of E-Z stereoisomers.
O can represent another pair of E-Z stereoisomers different from **N**.
Draw a possible structure for each of compounds **M**, **N** and **O.**

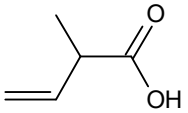
M 

N or O 

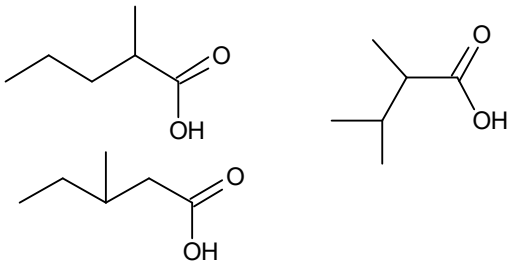
N or O 

7 Compounds **P** and **Q** have the molecular formula $C_5H_8O_2$
Both **P** and **Q** react with aqueous sodium carbonate to produce bubbles of carbon dioxide gas
P has a branched carbon chain and does **not** show stereoisomerism.
Q is an optically active.
Draw a possible structure for compounds **P** and **Q.**

P 

Q. 

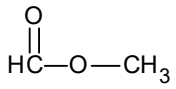
8 Compounds **R, S** and **T** are all isomers with the molecular formula $C_6H_{12}O_2$
They all react with aqueous sodium carbonate to produce carbon dioxide.
They all have asymmetric carbon atom.
Draw a possible structure for each of compounds **R, S** and **T**

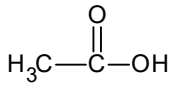


Section B: Questions using IR data

1 Compounds **A** and **B** have the molecular formula $C_2H_4O_2$

Each has an absorption in its infra-red spectrum at about 1700 cm^{-1} but only **B** has a broad absorption at 3350 cm^{-1}
Draw a possible structure for compounds **A** and **B**

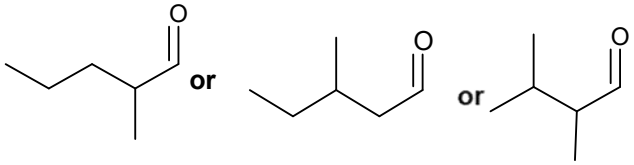
A 

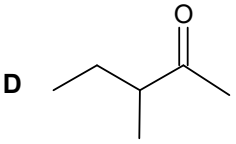
B 

2 Compounds **C** and **D** have the molecular formula $C_6H_{12}O$

Each exists as a pair of optical isomers and each has an absorption at about 1700 cm^{-1} in its infrared spectrum. **C** forms a silver mirror with Tollens' reagent but **D** does not.

Draw a possible structure for compounds **C** and **D.**

C 

D 

3 Compound **E**, $C_6H_{12}O_2$, is a neutral compound and is formed by the reaction between compounds **F** and **G** in the presence of a small amount of concentrated sulfuric acid.
F and **G** can both be formed from propanal by different redox reactions.
F has an absorption in its infra-red spectrum at 1750 cm^{-1}.
Draw a possible structure for compounds **E**, **F** and **G**.

E $CH_3CH_2CO_2CH_2CH_2CH_3$

F $CH_3CH_2CO_2H$

G $CH_3CH_2CH_2OH$

4 Isomers **H** and **I** have the molecular formula $C_5H_{12}O$
Both **H** and **I** have broad absorptions in the region 3230 - 3550 cm^{-1}
H reacts with acidified potassium dichromate but does **not** react with concentrated sulfuric acid
I does **not** react with acidified potassium dichromate but reacts with concentrated sulfuric acid
Draw a possible structure for compounds **H** and **I**

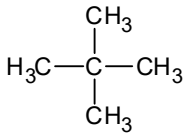
H $(CH_3)_3CCH_2OH$

I $(CH_3)_2C(OH)CH_2CH_3$

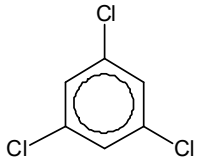
Section C: Questions using NMR data – number of peaks

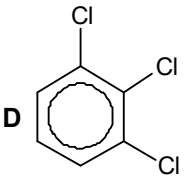
1 Compounds **A** and **B** have the molecular formula C_5H_{12}
In their ^1H NMR spectra, **A** has three peaks and **B** has only one.
Draw the structures for compounds **A** and **B.**

A $CH_3CH_2CH_2CH_2CH_3$

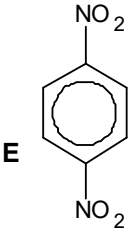
B 

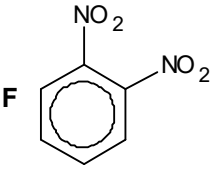
2 Compounds **C** and **D** both have the molecular formula $C_6H_3Cl_3$
C has two peaks in its ^{13}C NMR spectrum
D has four peaks in its ^{13}C NMR spectrum
Draw the structures for compounds **C** and **D.**

C 

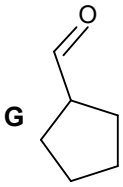
D 

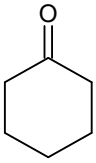
3 Compounds **E** and F have the molecular formula $C_6H_4N_2O_4$ and both are dinitrobenzenes.
E has two peaks in its ^{13}C NMR spectrum.
F has three peaks in its ^{13}C NMR spectrum.
Draw the structures for compounds **E** and **F.**

E 

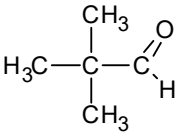
F 

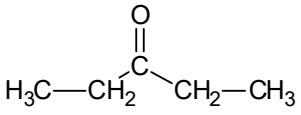
4 G and **H** are cyclic compounds with the molecular formula $C_6H_{10}O$.
Both have four peaks in their ^{13}C NMR spectra.
Each has an absorption at about 1700 cm^{-1} in their infrared spectrums.
G forms a silver mirror with Tollens' reagent but **H** does not.
Draw the structures for compounds **G** and **H.**

G 

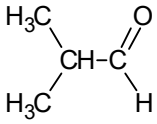
H 

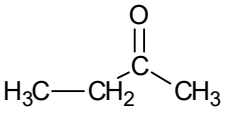
5 Compounds **I** and **J** have the molecular formula $C_5H_{10}O$.
Both have two peaks in their ^1H NMR spectra.
I forms a silver mirror with Tollens' reagent but **J** does not.
Draw the structures for compounds **I** and **J.**

I 

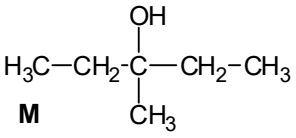
J 

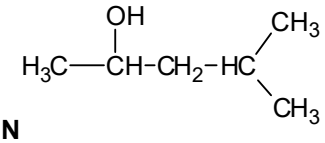
6 Compounds **K** and **L** have the molecular formula C_4H_8O
K gives a silver mirror with Tollens' reagent but **L** does not
K and **L** both have an absorption at about 1700 cm^{-1} in their infrared spectra
K has three peaks and **L** has four peaks in their ^{13}C NMR spectra:
Draw the structures for compounds **K** and **L**.

K 

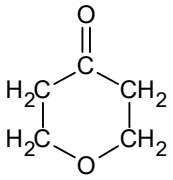
L 

7 Compounds **M** and **N** are alcohols with the molecular formula $C_6H_{14}O$
M as four peaks and **N** has six peaks in their ^1H NMR spectra
M does not react with acidified potassium dichromate(VI)
N exists as optical isomers.
Draw the structures for compounds **M** and **N.**

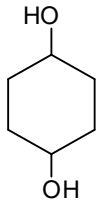
M 

N 

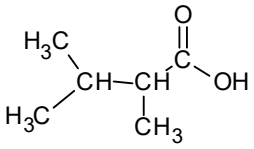
8 Compound **O** has the molecular formula $C_5H_8O_2$
O is a cyclic compound.
O has an absorption at about 1700 cm^{-1} in its infrared spectrums and has two peaks in its ^1H NMR spectrum.
Draw the structure for compound **O.**



9 Compound **P** is a cyclic compound with the molecular formula $C_6H_{12}O_2$
The infrared spectrum of compound **P** does not show an absorption in the region 1680–1750 cm^{-1} but does have an absorption at 3270 cm^{-1}
Compound **P** has two peaks in its ^{13}C NMR spectrum and three peaks in its ^1H NMR spectrum.
Draw the structure of compound **P**.

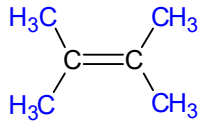


10 Compound **Q** has the molecular formula $C_6H_{12}O_2$
Compound **Q** reacts with aqueous sodium carbonate to produce carbon dioxide.
Compound **Q** has a chiral centre and has five peaks in its ^{13}C NMR spectrum.
Draw the structure for compound **Q.**

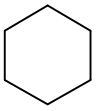


11 Compounds **R** and **S** have the molecular formula C_6H_{12}.
Both have only one peak in their ^1H NMR spectra.
R reacts with aqueous bromine but **S** does not.
Draw the structures for compounds **R** and **S**.

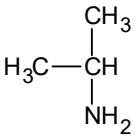
R



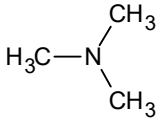
S



12 Isomers **T** and **U** have the molecular formula C_3H_9N
T has absorptions in the 3350–3450 cm^{-1} region of their infrared spectra but **U** has no absorptions at wavenumbers greater than 3100 cm^{-1}
Compound **T** has three peaks in its ^1H NMR spectra and **U** has one peak.
Draw the structures for compounds **T** and **U**.

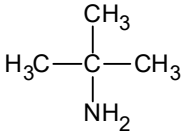


T

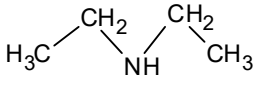


U

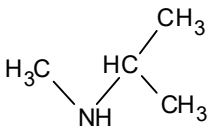
13 Compounds **W, X, Y,** and **Z** have the molecular formula $C_4H_{11}N$
W is a primary amine and has two peaks in its ^1H NMR spectrum.
X and **Y** are secondary amines. In their ^{13}C NMR spectra, **X** has two peaks and **Y** has three.
Z is a tertiary amine.
Draw a possible structure for compounds **W, X, Y,** and **Z**.



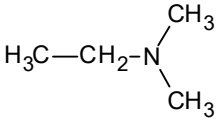
W



X

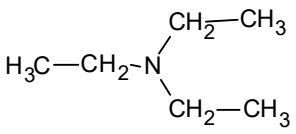


Y

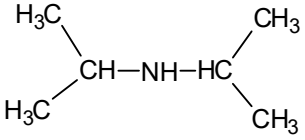


Z

14 Compounds **A** and **B** have the molecular formula $C_6H_{15}N$
A is a tertiary amine with two peaks in its ^1H NMR spectrum.
B is a secondary amine with three peaks in its ^1H NMR spectrum.
Draw the structures of **A** and **B**.

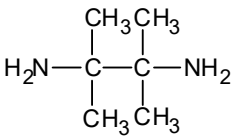


A

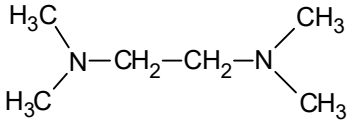


B

15 Compounds **C** and **D** have the molecular formula $C_6H_{16}N_2$
C contains two primary amine groups and has two peaks in its ^{13}C NMR spectrum.
D contains two tertiary amine groups and has two peaks in its ^{13}C NMR spectrum.
Draw a structure for compounds **C** and **D.**

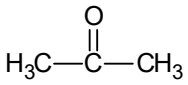


C

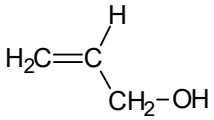


D

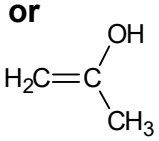
16 Compounds **E** and **F** have the molecular formula C_3H_6O
E has an absorption at 1715 cm^{-1} in its infrared spectrum and has one peak in its ^1H NMR. spectrum.
F has absorptions at 3300 cm^{-1} and at 1645 cm^{-1} in its infrared spectrum and does **not** show *E–Z* isomerism.
Draw a possible structure for compounds **E** and **F.**



E

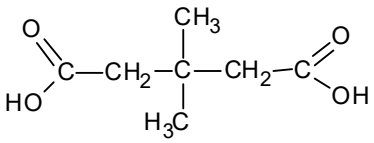


or



F

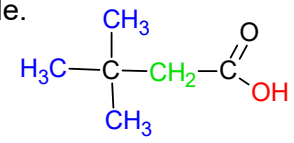
17 Compound **G** has molecular formula $C_7H_{12}O_4$
1 mol of **G** reacts exactly with 2 mol of sodium hydroxide.
G has four peaks in its ^{13}C NMR spectrum and three peaks in its ^1H NMR spectrum.
Suggest a structure for **G**



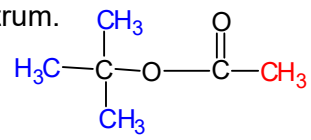
G

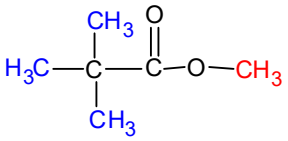
Section D: Questions with ^{1}H HMR splitting, integration ratio and shift data

1 Compound **A** has the molecular formula $C_6H_{12}O_2$
Compound **A** reacts with aqueous sodium carbonate to produce carbon dioxide.
Compound **A** has three singlet peaks in its ^{1}H HMR spectrum.
Draw the structure for compound **A.**

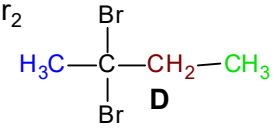


2 Compounds **B** and **C** are esters with the molecular formula $C_6H_{12}O_2$.
Both **B** and **C** have only two peaks in their ^{1}H NMR spectrum.
The integration ratio for both **B** and **C** is 3:1
Draw possible structures for compounds **B** and **C.**

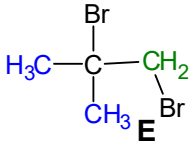




3 Compounds **D** and **E** both have the molecular formula $C_4H_8Br_2$
D has a singlet, a triplet and a quartet in its ^{1}H NMR spectrum.
E has two singlets in its ^{1}H NMR spectrum.
Draw the structures for compounds **D** and **E**.



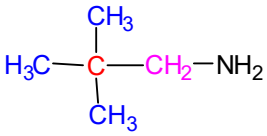
D

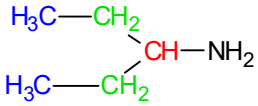


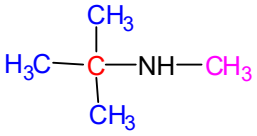
E

4 Compounds **F**, **G**, **H** and **I** have the molecular formula $C_5H_{13}N$.
F, **G**, and **H** all have 3 peaks in their ^{13}C NMR spectrums.
F and **G** are primary amines
H is a secondary amine.
I is a tertiary amine. Its ^{1}H NMR spectrum has three peaks. One of the peaks is a doublet.

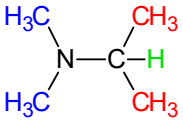
Draw a possible structure for compounds **F**, **G**, **H** and **I**.







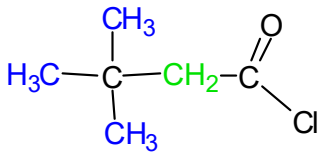
H



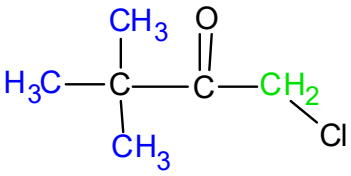
I

5 Compounds **J** and **K** have the molecular formula $C_6H_{11}OCl$
J and **K** both have an absorption at about 1700 cm^{-1} in their infrared spectra.
J and **K** each have two singlet peaks only in their ^{1}H NMR spectra.
In both spectra the integration ratio for the two peaks is 2:9

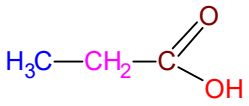
Draw the structures for compounds **J** and **K**.
Suggest which compound would react more vigorously with water.



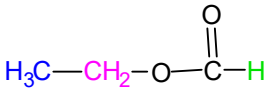
Acyl chloride reacts faster with water



6 Compounds **L** and **M** have the molecular formula $C_3H_6O_2$
L effervesces with aqueous sodium hydrogencarbonate but **M** does not.
L and **M** both have a quartet, a triplet and a singlet peak in their ^1H NMR spectra.
Draw the structures of compounds **L** and **M.**

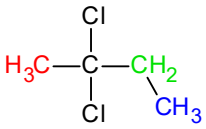


L

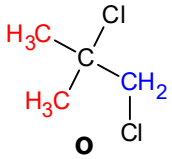


M

7 Compounds **N** and **O** have the molecular formula $C_4H_8Cl_2$
Compound **N** has a ^1H NMR spectrum which only contains a singlet, a triplet and a quartet with an integration ratio of 3:3:2 respectively.
Compound **O** has a ^1H NMR spectrum which only contains two singlets with an integration ratio of 3:1.
Draw the structures of compounds **N** and **O**.

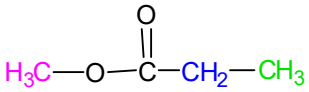


N

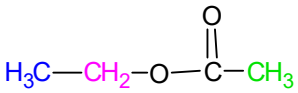


o

8 Compounds **P** and **Q** have the molecular formula $C_4H_8O_2$
P and **Q** both have strong absorptions in the 1700–1750 cm^{-1} region.
Neither **P** and **Q** react with aqueous sodium carbonate.
In their ^1H NMR spectra, **P** has a quartet at δ= 2.3 ppm and **Q** has a quartet at δ = 4.1 ppm.
Draw the structures of compounds **P** and **Q**

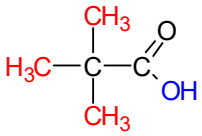


P

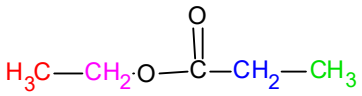


Q

9 Compounds **R** and **S** have the molecular formula $C_5H_{10}O_2$
R and **S** both have strong absorptions in the 1700–1750 cm^{-1} region
R effervesces with aqueous sodium hydrogencarbonate but **S** does not.
Compound **R** has a ^1H NMR spectrum which has two singlets with an integration ratio 9:1
Compound **S** has a ^1H NMR spectrum which has two triplets and two quartets with integration ratio 3:3:2:2
Draw the structures of compounds **R** and **S**

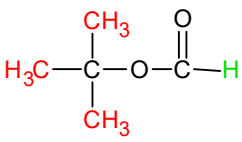


R

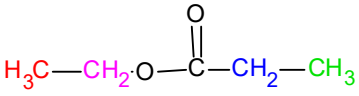


S

10 Compounds **T** and **U** have the molecular formula $C_5H_{10}O_2$
T and **U** both have strong absorptions in the 1700–1750 cm^{-1} region.
Neither **T** and **U** react with aqueous sodium carbonate.
The ^1H NMR spectrum of **T** consists of two singlets
The ^1H NMR spectrum of **U** consists of two quartets and two triplets.
Draw the structures of compounds **T** and **U**

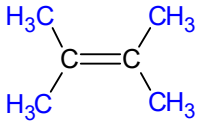


T

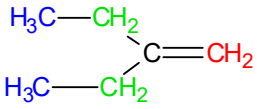


u

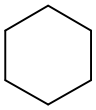
11 Compounds **V, W** and **X** have the molecular formula C_6H_{12}
V and **W** have an absorption in their infra-red spectrum at about 1650 cm^{-1} and neither shows E-Z stereoisomerism.
X has no absorptions between 1500 and 2900 cm^{-1}
The ^1H NMR spectrum of **V** consists of one singlet.
The ^1H NMR spectrum of **W** consists of a singlet, a triplet and a quartet.
The ^1H NMR spectrum of **X** only has one peak
Draw a structure for compounds **V, W** and **X**



V



W



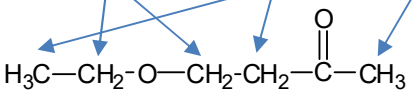
X

Section E: Questions where reasoning is needed

1 Compound **A** has the molecular formula of $C_6H_{12}O_2$
The table shows information about the ^1H NMR spectrum for compound **A**

Chemical shift δ / ppm	3.8	3.5	2.6	2.2	1.2
Integration ratio	2	2	2	3	3
Splitting pattern	triplet	quartet	triplet	singlet	triplet

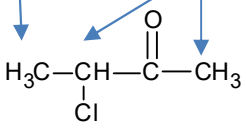
Deduce the structure of compound **A and** explain your reasoning



2 Compound **B** has the molecular formula C_4H_7ClO.
It does not produce misty fumes when added to water.
The infra-red spectrum of **B** contains a major absorption at 1724 cm^{-1}.
The ^1H NMR spectrum of **B** shows 3 peaks. Information about the 3 peaks is given in the table.

	Peak 1	Peak 2	Peak 3
Integration value	3	3	1
Splitting pattern	doublet	singlet	quartet

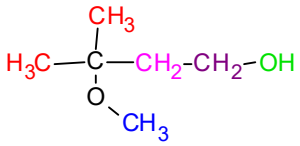
Deduce the structure of compound **B and** explain your reasoning



3 The molecular formula of compound **C** is $C_6H_{12}O_2$
C has a peak at wavenumber 3500 cm^{-1} in its infra red spectrum. It does not have a peak in the range 1680 to 1750 cm^{-1}
When **C** is warmed with acidified potassium dichromate(VI) a green solution is formed.
The ^1H NMR spectrum of **C** contains five peaks.
Information about the 5 peaks is given in the table.

Chemical shift δ/ppm	3.8	3.2	3.1	1.4	1.1
Integration ratio	2	3	1	2	6
Splitting patterns	triplet	singlet	singlet	triplet	singlet

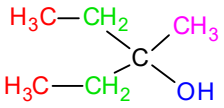
Deduce the structure of compound **C and** explain your reasoning



4 The molecular formula of compound **D** is $C_6H_{14}O$
D has a peak at wavenumber 3400 cm^{-1} in its infra red spectrum. It does not have a peak in the range 1680 to 1750 cm^{-1}
The ^1H NMR spectrum of **D** contains four peaks.
Information about the four peaks is given in the table.

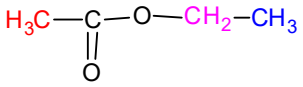
Chemical shift δ/ppm	1.5	1.2	1.1	0.9
Integration ratio	4	1	3	6
Splitting patterns	quartet	singlet	singlet	triplet

Deduce the structure of compound **D and** explain your reasoning.



5 The molecular formula of an ester compound **E** is $C_4H_8O_2$
The ^1H NMR spectrum of **E** contains three peaks.
Information about the three peaks is given in the table.

Chemical shift, δ/ppm	4.1	2	1.2
Integration ratio	2	3	3
Splitting patterns	quartet	singlet	triplet

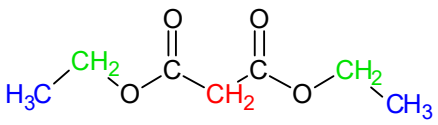


Deduce the structure of compound **E and** explain your reasoning.

6 Compound **F** has molecular formula $C_7H_{12}O_4$
Compound **F** does not react with acidified potassium dichromate.
Compound **F** reacts with sodium hydroxide to produce ethanol as one of the products.
Compound **F** has four peaks in its ^{13}C NMR spectrum.
The ^1H NMR spectrum of **F** contains three peaks.
Information about the three peaks is given in the table.

Chemical shift, δ/ppm	3.9	3.4	1.3
Integration ratio	4	2	6
Splitting patterns	quartet	singlet	triplet

Deduce the structure of compound **G and** explain your reasoning.



7 Compound **G** has molecular formula $C_7H_{12}O_3$
Compound **G** has a peak in the range 1680 to 1750 cm^{-1}
Compound **G** has seven peaks in its ^{13}C NMR spectrum.
The ^{1}H NMR spectrum of **G** contains five peaks.
Information about the five peaks is given in the table.

Chemical shift δ/ppm	4.10	2.60	2.56	2.19	1.26
Integration ratio	2	2	2	3	3
Splitting patterns	quartet	triplet	triplet	singlet	triplet

Deduce the structure of compound **G and** explain your reasoning.