Q1.

This question is about hydrocarbons.

(a) Eicosane ($C_{20}H_{42}$) can be cracked by heating to 700 K in the presence of a catalyst.

The products are

- an aromatic hydrocarbon C_8H_{10}
- an alkane C_6H_{14}
- another alkane.

$$C_{20}H_{42} \longrightarrow C_8H_{10} + C_6H_{14} + \_\_\_\_\_$$

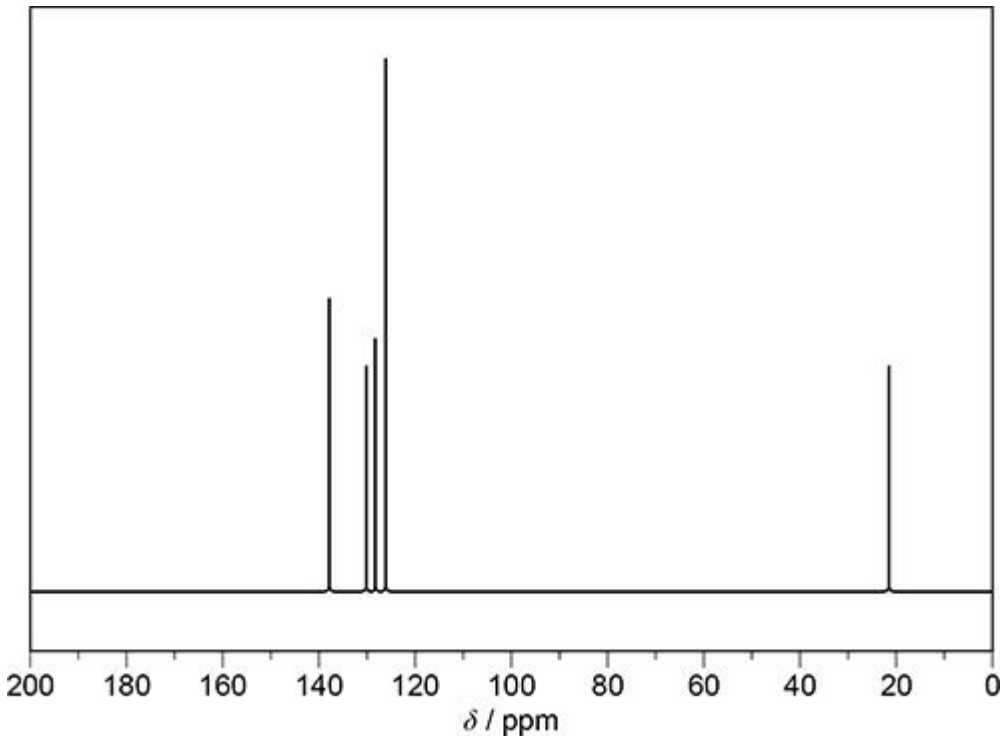
Complete the equation for this reaction.

Give a suitable catalyst for this reaction.

Catalyst _____

(2)

(b) The figure below shows the ^{13}C NMR spectrum for the aromatic hydrocarbon C_8H_{10}



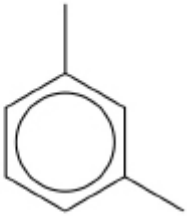
Which of these is the structure of C_8H_{10}?

Tick (✓) **one** box.

A

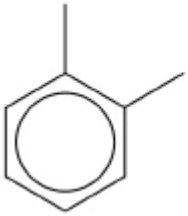
☐

B



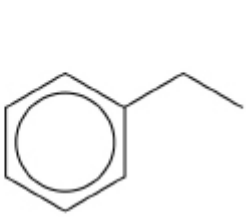
☐

C



☐

D



☐

(1)

(c) Cracking can also be done without a catalyst, using a temperature of 1200 K and a pressure of 7000 kPa

State the type of product that is formed in high percentage in this type of cracking.

_____

(1)

(d) A sample of butane has a volume of 20 cm^3 at room temperature and pressure.

The sample is burned completely in 1350 cm^3 of air.

The final mixture is cooled to room temperature and pressure.

$$C_4H_{10} + 6\tfrac{1}{2}\ O_2 \longrightarrow 4\ CO_2 + 5\ H_2O$$

Calculate the total volume of gas in the final mixture.
Assume that air contains 21% by volume of oxygen.

Total volume of gas remaining _____ cm^3

(4)

(e) Natural gas is used in power stations to produce electricity.

Natural gas contains sulfur impurities. Sulfur dioxide forms when these impurities are burned.

State an environmental problem caused by sulfur dioxide.

Give the formula of a compound that is used to help remove sulfur dioxide from the combustion products.

Environmental problem _____

Formula of compound _____

_____

(2)

(Total 10 marks)

Q2.

Compounds **V**, **W**, **X** and **Y** are isomers with the molecular formula $C_5H_{10}O_2$

Isomers **V** and **W** are carboxylic acids with formulas that can be written as C_4H_9COOH

(a) Give an equation for the reaction of C_4H_9COOH with sodium hydrogencarbonate.

_____

(1)

(b) Isomer **V** has an asymmetric carbon atom.

Deduce the structure of **V**.

(1)

(c) Isomer **W** has four peaks in its ^1H NMR spectrum.

Deduce the structure of **W**.

Deduce the integration ratio for the four peaks in the ^1H NMR spectrum of **W**.

Structure

Integration ratio _____

(2)

(d) Isomer **X** has three singlets with integration ratio 1:3:6 in its ^1H NMR spectrum.

Deduce the structure of **X**.

Explain why the peaks in the ^1H NMR spectrum are singlets.

Structure

Explanation _____

_____

(2)

(e) The table below shows information about the peaks in the ^{1}H NMR spectrum of isomer **Y**.

Chemical shift δ / ppm	Integration ratio	Splitting pattern
3.65	2	singlet
1.19	3	singlet

Draw the parts of the structure of **Y** that can be deduced from each of these peaks.

Deduce the structure of **Y**.

State how many peaks are in the ^{13}C NMR spectrum of **Y**.

Part of structure from peak at δ = 3.65 ppm

Part of structure from peak at δ = 1.19 ppm

Structure of **Y**

Number of peaks in ^{13}C NMR spectrum of **Y** _____

(6)

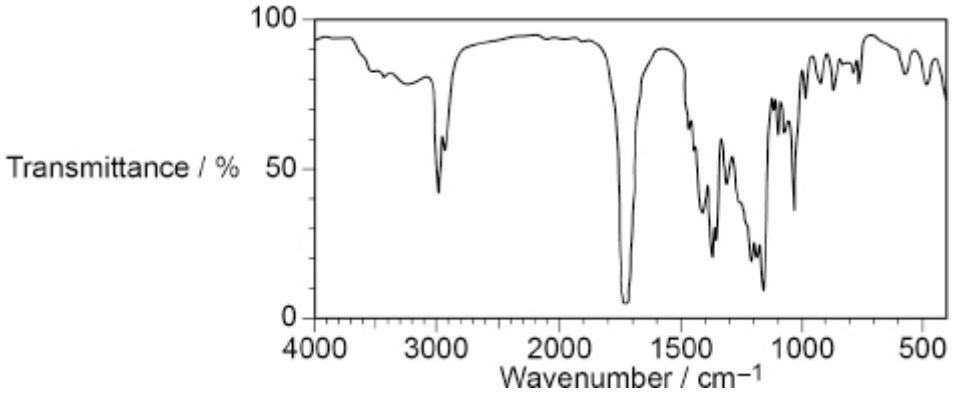
(Total 12 marks)

Q3.

This question is about compound **Z**, with molecular formula $C_7H_{12}O_3$

Figure 1 shows the infrared spectrum of **Z**.

Figure 1



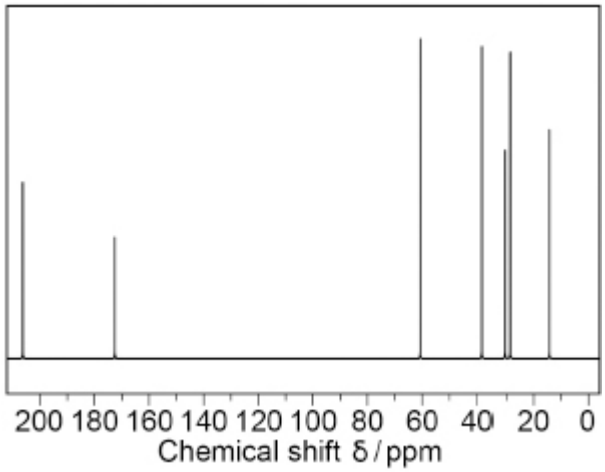
(a) Identify the bond that causes the absorption at 1725 cm^{-1}

_____

(1)

Figure 2 shows the ^{13}C NMR spectrum of **Z**.

Figure 2



(b) How many different carbon environments are there in a molecule of **Z**?

	5	6	7	8
Tick ✓ **one** box				

(1)

(c) State the type of carbon environment that causes the peak at δ = 174 ppm

Use **Table C** in the Data Booklet to help you answer this question.

_____

(1)

(d) The table below shows data from the ^{1}H NMR spectrum for compound **Z**.

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

Explain what can be deduced from the splitting patterns and chemical shift values for the peaks at δ = 4.10 ppm and at δ = 1.26 ppm

Deduce the part of the structure of **Z** that causes the peaks at δ = 4.10 ppm and δ = 1.26 ppm

Use **Table B** in the Data Booklet to help you answer this question.

Peak at δ = 4.10 ppm _____

_____

_____

Peak at δ = 1.26 ppm _____

_____

_____

Part of structure

(5)

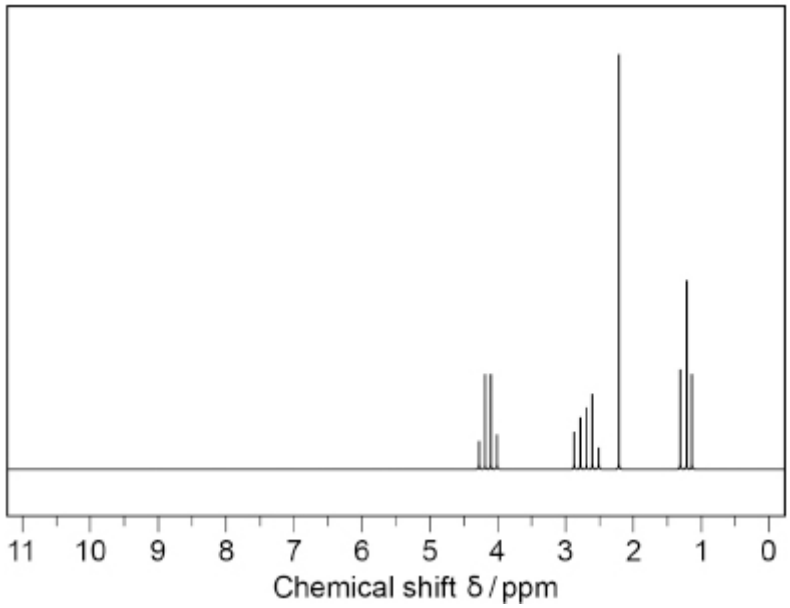
(e) Deduce the part of the structure of **Z** that causes the peak at δ = 2.19 ppm

Part of structure

(1)

Figure 3 shows the ^{1}H NMR spectrum of compound **Z**.

Figure 3



(f) Suggest why it would be difficult to determine the structure of **Z** using the spectrum in **Figure 3**, without the information in the table in part (d).

_____

_____

_____

_____

(1)

(g) Deduce the structure of **Z**.

(1)

(Total 11 marks)

Q4.

This question is about compound **X** with the empirical formula C_2H_4O

Figure 1 shows the infrared spectrum of **X**.

Figure 2 shows the ^{13}C NMR spectrum of **X**.

The ^{1}H NMR spectrum of **X** shows four peaks with different chemical shift values. The table below gives data for these peaks.

Figure 1

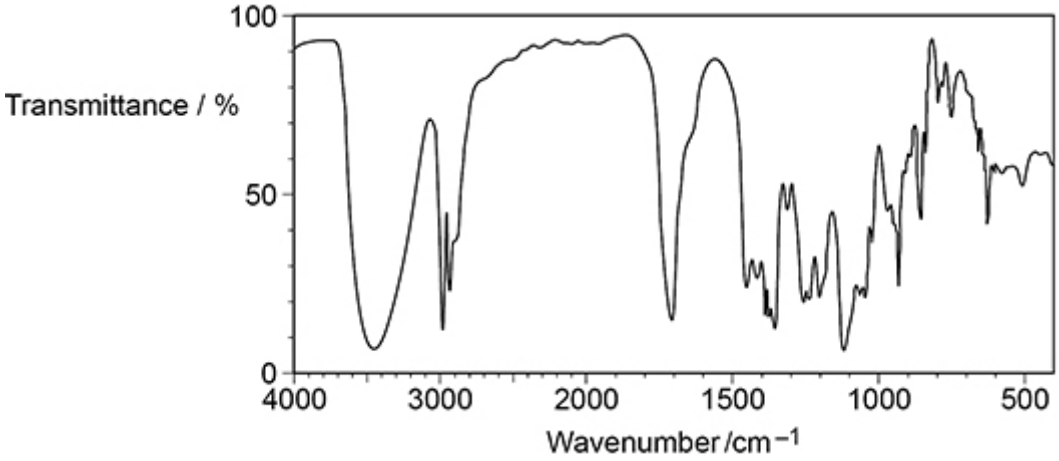
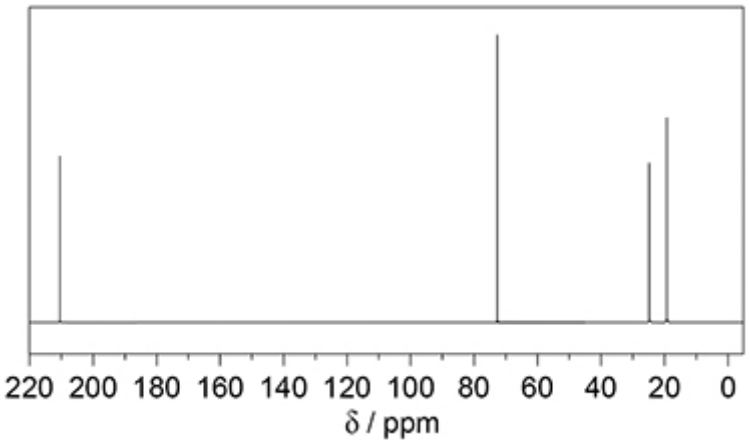


Figure 2



Chemical shift δ / ppm	3.9	3.7	2.1	1.2
Splitting pattern	quartet	singlet	singlet	doublet
Integration value	1	1	3	3

Show how information from **Figure 1**, **Figure 2** and the table can be used to deduce the structure of compound **X**.

(Total 6 marks)