Q1. Butane and propanal are compounds with M_r = 58.0, calculated using data from your Periodic Table.

(a) A mass spectrometer can be used to distinguish between samples of butane and propanal.

The table shows some precise relative atomic mass values.

Atom	Precise relative atomic mass
^{1}H	1.00794
^{12}C	12.00000

(i) Use data from the table to show that, to 3 significant figures, a more accurate value for the M_r of butane is 58.1

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(1)

(ii) State why the precise relative atomic mass quoted in the table for the ^{12}C isotope is exactly 12.00000

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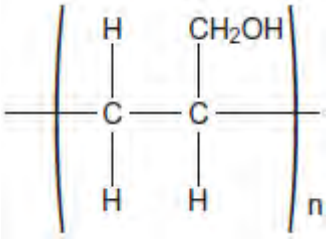
(1)

(b) Draw a **displayed formula** for the organic product that is formed when propanal is oxidised by warm Tollens' reagent.

(1)

(c) Prop−2−en−1−ol is an isomer of propanal and can be polymerised to form a polymer represented by the following structure.



(i) Draw the structure of prop−2−en−1−ol.

(1)

(ii) Deduce the type of polymerisation that results in the formation of this polymer from prop−2−en−1−ol.

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(1)

(iii) There are two functional groups in prop−2−en−1−ol. Each of these functional groups contains a bond with a characteristic absorption range in the infrared spectrum.

Use **Table A** on the Data Sheet to suggest a bond and its absorption range for each of the two functional groups.

Bond 1 ..... Absorption range .....

Bond 2 ..... Absorption range .....

(2)

(d) Compound **X** is another isomer of propanal. The infrared spectrum of **X** shows an absorption in the range 1680−1750 cm^{-1}.

(i) Draw the structure of **X**.

(ii) Which of the following, **A**, **B**, **C** or **D**, represents the type of isomerism shown by **X** and propanal?

Write the correct letter, **A**, **B**, **C** or **D**, in the box.

A chain isomerism
B E−Z isomerism
C functional group isomerism

D position isomerism

(1)
(Total 9 marks)

Q2. The manufacture of food grade phosphoric acid for use in cola drinks begins with the production of pure white phosphorus from the mineral fluoroapatite, $Ca_5F(PO_4)_3$

(a) Complete the following equation for the manufacture of phosphorus.

$$....Ca_5F(PO_4)_3 + 9SiO_2 + ...C \longrightarrow 9CaSiO_3 + CaF_2 + ...CO + ...P$$

(1)

(b) As the phosphorus cools, it forms white phosphorus, P_4

Give the oxidation state of phosphorus in each of the following.

P_4 .....

H_3PO_4 .....

(2)

(c) Fertiliser grade phosphoric acid is manufactured from sulfuric acid and calcium phosphate.
Use the following precise relative atomic mass data to show how mass spectrometry can be used to distinguish between pure sulfuric acid (H_2SO_4) and pure phosphoric acid (H_3PO_4) which both have M_r = 98 to two significant figures.

Atom	Precise relative atomic mass
^{1}H	1.00794
^{16}O	15.99491
^{31}P	30.97376
^{32}S	32.06550

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(1)

(d) Concentrated phosphoric acid is used as a catalyst in the hydration of propene to form the alcohol $CH_3CH(OH)CH_3$ as the main organic product.
The industrial name for this alcohol is isopropyl alcohol.

(i) State the meaning of the term *catalyst*.

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(Extra space) .....

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(1)

(ii) State the meaning of the term *hydration*.

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(Extra space) .....

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(1)

(iii) Write an equation for the hydration of propene to form isopropyl alcohol.
Give the IUPAC name for isopropyl alcohol.

Equation .....

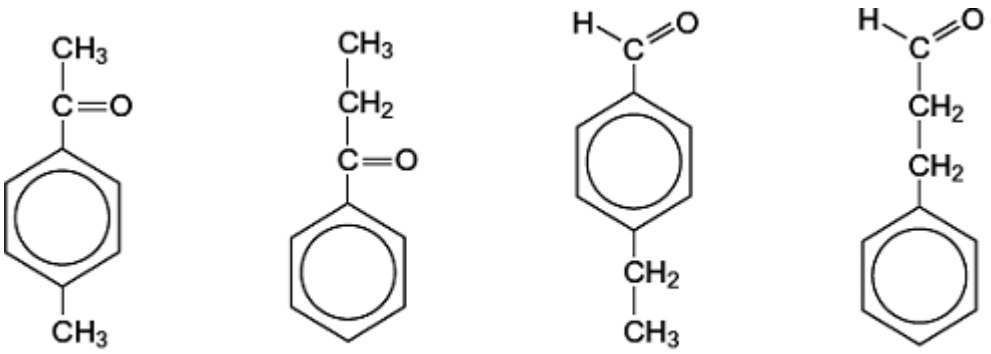
IUPAC name .....

(2)

(Total 8 marks)

Q3. Mass spectrometry is used by organic chemists to help distinguish between different compounds.

Four isomers of $C_9H_{10}O$, shown below, were analysed by mass spectrometry.



A **B** **C** **D**

The mass spectra obtained from these four isomers were labelled in random order as I, II, III and IV.

Each spectrum contained a molecular ion peak at *m/z* = 134

The data in the table below show the *m/z* values greater than 100 for the major peaks in each spectrum due to fragmentation of the molecular ion. The table also shows where no major peaks occurred.

Spectrum	*m/z* values for major peaks	No major peak at *m/z*
I	119	133, 105
II	133, 119 and 105	
III	133, 105	119
IV	105	133, 119

(a) Two of the molecular ions fragmented to form an ion with *m/z* = 133 by losing a radical.
Identify the radical that was lost.

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(1)

(b) Two of the molecular ions fragmented to form an ion with *m/z* = 119 by losing a

radical.
Identify the radical that was lost.

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(1)

(c) Three of the molecular ions fragmented to form ions with *m/z* = 105 by losing a radical with M_r = 29

Identify **two** different radicals with M_r = 29 that could have been lost.

Radical 1 .....

Radical 2 .....

(2)

(d) Consider the structures of the four isomers and the fragmentations indicated in parts (a) to (c).
Write the letter **A**, **B**, **C** or **D**, in the appropriate box below, to identify the compound that produces each spectrum.

Spectrum I ☐

Spectrum II ☐

Spectrum III ☐

Spectrum IV ☐

(4)
(Total 8 marks)

Q4. A scientist used mass spectrometry to analyse a sample of the air near a fertiliser factory. The sample of air included traces of a gas which was shown by its molecular ion to have a precise M_r = 44.00105

(a) State the meaning of the term *molecular ion*.

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(1)

(b) (i) Use the following data to show that the trace gas was dinitrogen oxide (N_2O).

Show your working.

Atom	Precise relative atomic mass
^{12}C	12.00000
^{14}N	14.00307
^{16}O	15.99491

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(1)

(ii) Propane is used as a fuel in the fertiliser factory. State why both propane and its combustion product, carbon dioxide, might have been identified as the trace gas if the scientist had used relative molecular masses calculated to one decimal place.

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(1)

(iii) State why the precise relative atomic mass for the ^{12}C isotope is exactly 12.00000

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(1)

(c) Dinitrogen oxide is formed when ammonia is oxidised according to the following equation.

$$2NH_3(g) + 2O_2(g) \rightarrow N_2O(g) + 3H_2O(l)$$

(i) Use the standard enthalpies of formation in the table below to calculate a value for the standard enthalpy change of this reaction.

	$NH_3(g)$	$O_2(g)$	$N_2O(g)$	$H_2O(l)$
$\Delta H_f^{\ominus}$/ kJ mol^{-1}	–46	0	+82	–286

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(3)

(ii) State **one** condition necessary for enthalpies of formation to be quoted as standard values at a specified temperature of 298 K.

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(1)
(Total 8 marks)