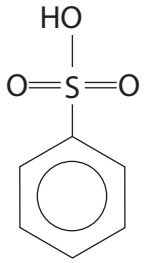
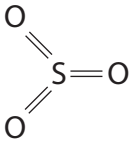
1 (a) Benzenesulfonic acid (structure I) may be prepared from benzene. The reaction is a typical electrophilic substitution in which the electrophile is sulfur trioxide (structure II).



Structure I



Structure II

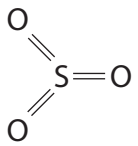
(i) Identify the reagent used as the source of sulfur trioxide in this preparation.

(1)

.....

(ii) On the formula of sulfur trioxide below, show the partial charges on each atom and explain how they arise.

(2)



Structure II

.....

.....

(iii) Suggest why sulfur trioxide is an effective electrophile.

(1)

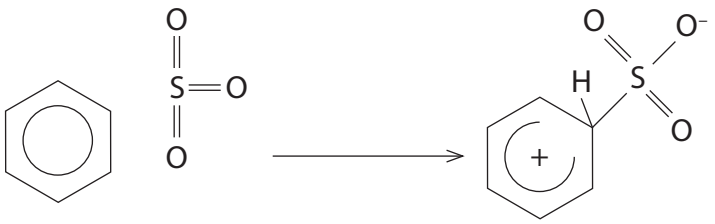
.....

.....

(b) The mechanism for the electrophilic substitution reaction between benzene and sulfur trioxide to form benzenesulfonic acid is similar to that for the nitration of benzene.

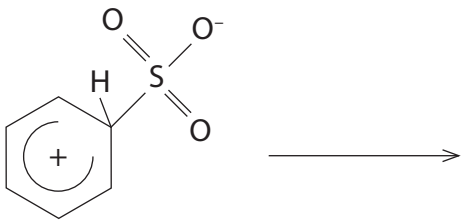
(i) Complete the first step of this mechanism by adding two curly arrows.

(2)



(ii) The mechanism for the formation of benzenesulfonic acid has two further steps. Complete the mechanism, showing curly arrows where appropriate.

(3)

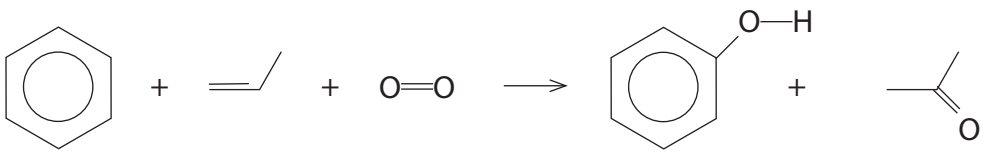


(c) At one time the main industrial use for benzenesulfonic acid was in the manufacture of phenol in a two-stage process. In the first stage, benzenesulfonic acid was reacted with sodium hydroxide forming an intermediate organic compound along with sodium sulfite, Na_2SO_3, and water. In the second stage, the intermediate organic compound was reacted with hydrochloric acid to form phenol.

(i) Write the two equations for the manufacture of phenol by this method. State symbols are not required.

(2)

(ii) Nowadays, phenol is manufactured using the Hock process which is summarised below.



Suggest why the Hock process is preferred.

(2)

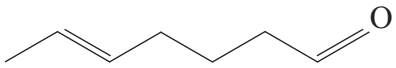
.....

.....

.....

.....

(Total for Question = 13 marks)

2 The molecule  is sometimes known as melonal as it smells similar to watermelon.

(a) Give the systematic name for melonal.

(2)

.....

(b) (i) Melonal can be prepared by the oxidation of a compound, **X**. Suggest the formula of compound **X** and the names or formulae of the reagents needed to oxidize **X**.

(3)

Compound **X**

Reagents needed for oxidation .....

.....

(ii) Briefly suggest a practical measure to maximise the yield of melonal in (b)(i). Justify your answer.

(2)

.....

.....

.....

.....

(c) Infrared spectra can be used to confirm the presence of functional groups in a molecule. Use page 5 of the data booklet to suggest the position of two absorptions and the identity of the bonds responsible which can confirm the presence of the two functional groups in melonal.

(2)

Wavenumber range / cm^{-1}	Bond	Functional group present in melonal

(d) The mass spectrum of melonal shows small peaks at *m/e* 57 and *m/e* 83.

Give the formula of each of the fragments most likely to have caused these peaks.

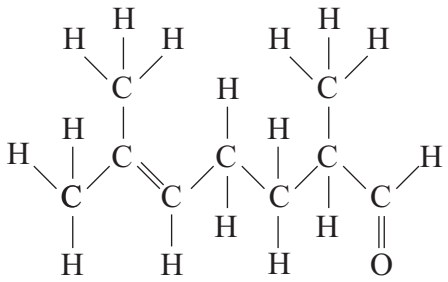
(2)

m/e 57.....

m/e 83.....

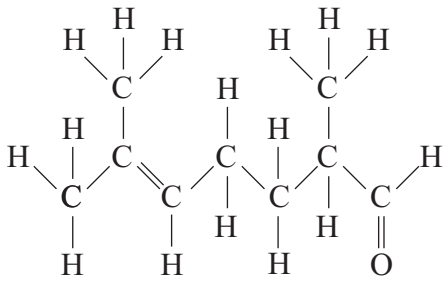
(e) (i) On the displayed formula below, circle the hydrogen atom that has a triplet peak in the proton nmr spectrum of melonal.

(1)



(ii) On the displayed formula below, circle the atom that gives rise to a peak at a chemical shift of δ 9.65 ppm in the proton nmr spectrum of melonal. Refer to page 7 of the data booklet.

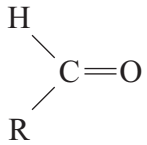
(1)



(f) Aldehydes react with HCN in the presence of CN^- ions.

(i) Give the mechanism for this reaction, using the simplified displayed formula below.

(3)

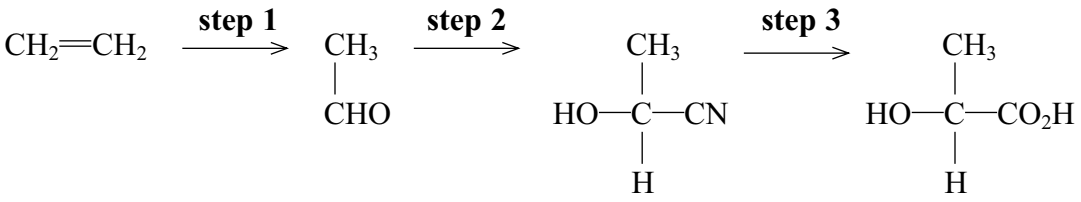


(ii) The product of this reaction has a chiral centre. Would you expect the reaction to produce a solution that rotates the plane of plane-polarized light? Explain your answer.

(3)

(Total for Question 19 marks)

3 A sequence of reactions for the production of lactic acid is shown below.



lactic acid

(a) (i) Name the type and mechanism of the reaction in **step 2**.

(2)

.....

(ii) Which **two** substances need to be added to ethanal to carry out the reaction in **step 2**?

(2)

.....

.....

(iii) Give the mechanism for the reaction in **step 2**, using curly arrows to show movements of electron pairs.

(3)

*(iv) The product of **step 2** is not optically active even though it has a chiral carbon atom in its formula. Explain, by reference to the mechanism, the reason for the lack of optical activity.

(2)

.....

.....

.....

.....

.....

(b) What reactant, or combination of reactants, is needed to carry out **step 3**?

(1)

.....

(c) (i) What is the systematic name of lactic acid?

(1)

.....

(ii) Lactic acid molecules can combine to form a biodegradable polymer, poly(lactic acid) or PLA. Draw a section of the polymer with **two** units of the polymer chain and showing all bonds.

(1)

(iii) Suggest why PLA is biodegradable.

(1)

.....

.....

(iv) Lactic acid can be prepared from ethene as shown in the scheme. Lactic acid also forms when milk turns sour.

Suggest **one** reason why it would be advantageous to make lactic acid from milk rather than from ethene.

(1)

.....

.....

.....

.....

(Total for Question 14 marks)