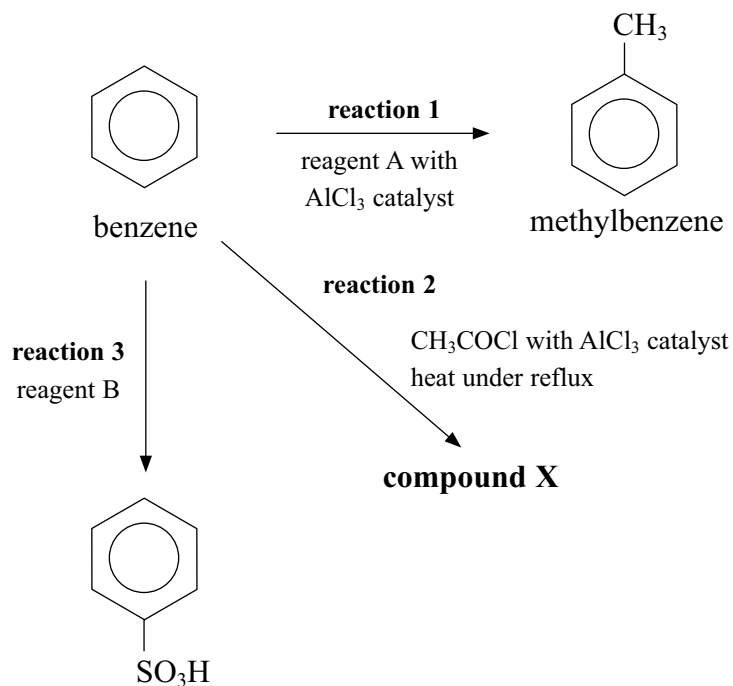


1 Some reactions of benzene are shown below.



(a) (i) Suggest the formula of reagent A in **reaction 1**.

(1)

(ii) Write the equation to show how the catalyst, AlCl_3 , reacts with reagent A to form the species which attacks the benzene ring.

(1)

(iii) Draw the structure of the intermediate ion formed when the species in (ii) attacks the benzene ring.

(1)

(b) The methylbenzene formed in **reaction 1** generally reacts in a similar way to benzene but faster, as the ring is said to be activated.

(i) Explain how the presence of a methyl group activates the benzene ring.

(1)

(ii) Use your answer to (i) to explain why methylbenzene reacts faster.

(1)

(c) (i) Draw the structural formula of **compound X**, formed in **reaction 2**.

(1)

(ii) The organic product of **reaction 2** is also formed when the same reactants, but with an aluminium catalyst, are heated using microwave radiation. Suggest two reasons why this technique may be considered 'greener'.

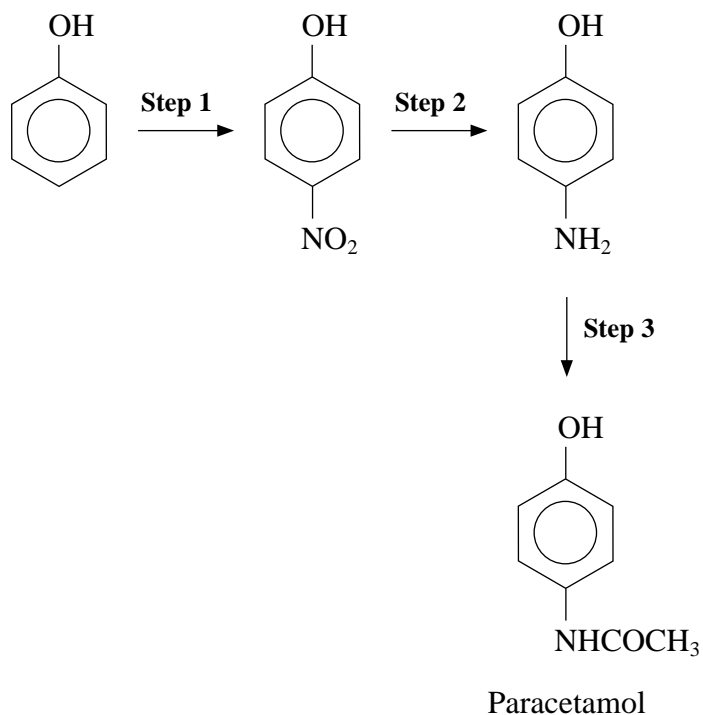
(2)

(d) Name reagent B needed for **reaction 3**.

(1)

(Total for Question 9 marks)

2 Paracetamol is possibly the most widely used analgesic (painkiller) in the world. It can be made from phenol as shown below.



(a) The nitration of phenol in **step 1** uses dilute nitric acid at room temperature, whereas the nitration of benzene requires a mixture of concentrated nitric and sulfuric acids at about 55°C.

(i) Give the mechanism for the nitration of **benzene**, including the equation for the reaction that produces the electrophile.

(4)

*(ii) Explain why phenol can be nitrated under much milder conditions than those required to nitrate benzene.

(2)

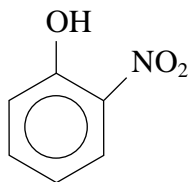
(iii) Suggest reagents that could be used **step 2**.

(2)

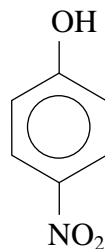
(iv) Suggest the name or formula of a reagent that could be used **step 3**.

(1)

*(b) In the nitration of phenol, **step 1**, two compounds are produced.



2-nitrophenol



4-nitrophenol

These compounds can be separated by steam distillation, since 2-nitrophenol is volatile in steam but 4-nitrophenol is not.

Describe briefly the technique of steam distillation and give ONE advantage of steam distillation over normal distillation.

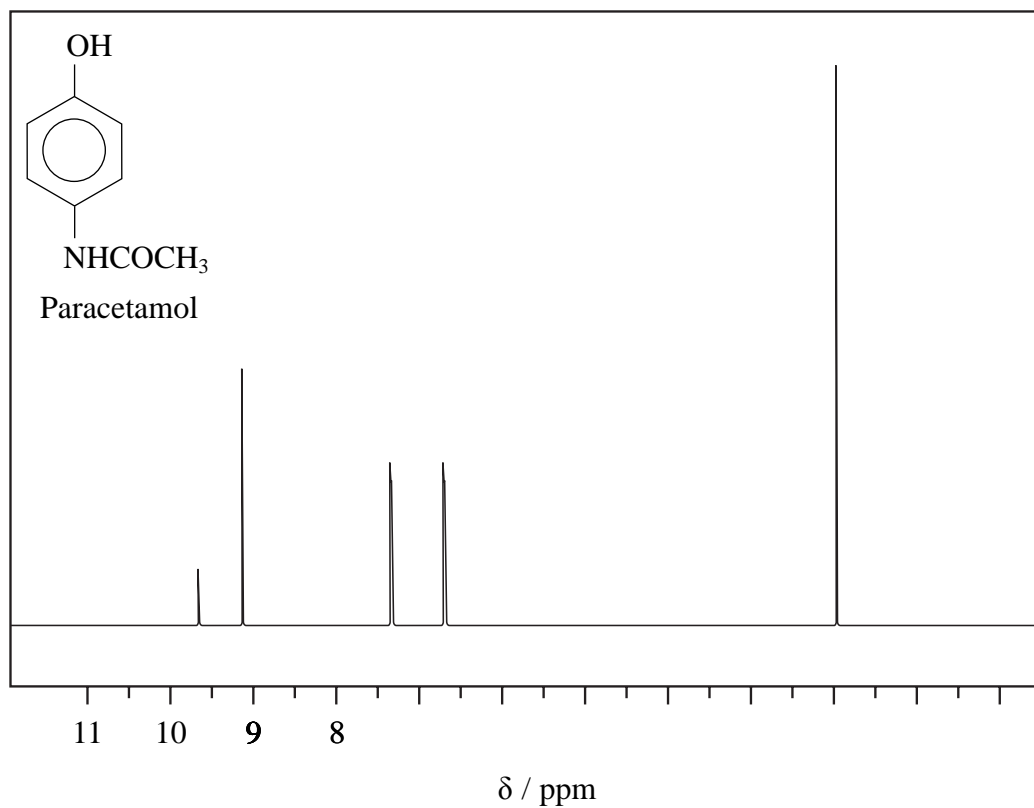
(3)

(c) The nmr spectrum of paracetamol is given below. The peaks at 6.7 and 7.4 ppm are due to the protons on the benzene ring and are both doublets.

Explain why these two peaks are doublets but all the other peaks are singlets.

[There is no need to refer to your data booklet]

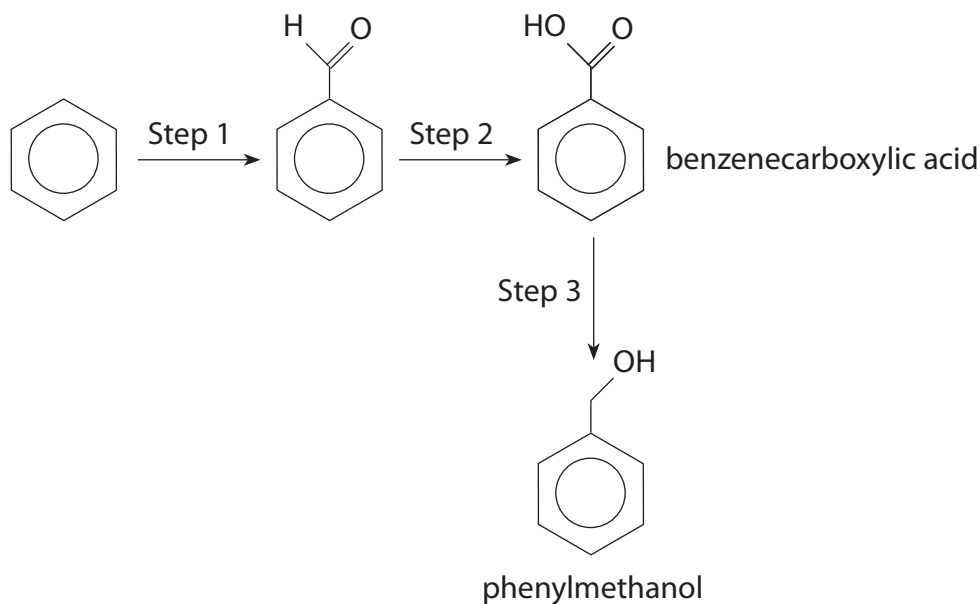
(2)



(Total for Question = 14 marks)

- 3 Benzenecarboxylic acid (benzoic acid) and phenylmethanol (benzyl alcohol) are compounds which occur naturally and have a wide range of uses. For example, benzenecarboxylic acid is used as a food preservative and phenylmethanol is used as a solvent.

A laboratory sequence for the preparation of these two compounds is shown below.



- (a) In the first step of the synthesis, benzene reacts with hydrogen chloride and carbon monoxide in the presence of aluminium chloride in an electrophilic substitution called the Gattermann-Koch reaction. The hydrogen chloride and carbon monoxide together behave as if they form the unstable species methanoyl chloride (HCOCl).
- (i) Explain why benzene undergoes substitution rather than addition reactions. A detailed description of the bonding in benzene is **not** required.

(2)

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(ii) Give the mechanism for step 1, including the formation of the electrophile.

(4)

(iii) Identify the reagents and essential conditions used in the remaining steps of the sequence. You may assume that the correct reaction temperatures are being used.

(4)

Step 2

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Step 3

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*(b) Phenol reacts faster than phenylmethanol in electrophilic substitution reactions.
Suggest why this is so.

(4)

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(Total for Question =14 marks)