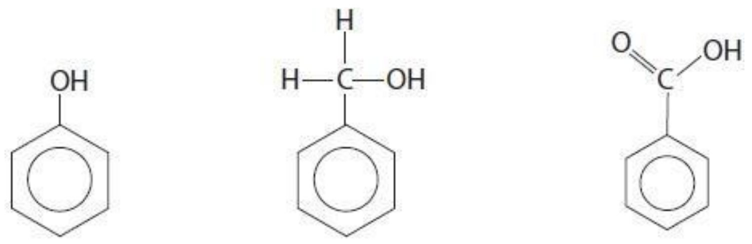
Questions

Q1.

This is a question about the analysis of three aromatic substances with —OH groups.



phenol phenylmethanol benzoic acid

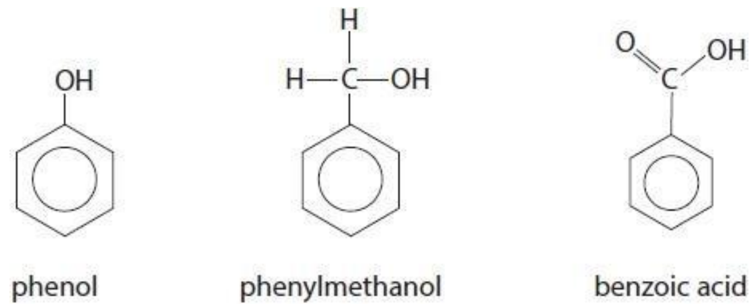
Write the equation for the **complete** combustion of phenol.
State symbols are not required.

(2)

(Total for question = 2 marks)

Q2.

This is a question about the analysis of three aromatic substances with —OH groups.



When burned in air, these aromatic compounds undergo **incomplete** combustion.

(i) Calculate the percentage composition by mass of carbon in both phenylmethanol and benzoic acid.

(3)

(ii) Give the expected observation when these aromatic compounds undergo incomplete combustion.

(1)

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(iii) Identify another **type** of organic compound which will also produce the same observation as in (ii).

(1)

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(iv) These combustion experiments must be carried out in a fume cupboard.

Explain why the front window of the fume cupboard must be below the safety line even with the exhaust fan switched on.

(2)

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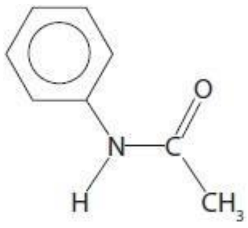
(Total for question = 7 marks)

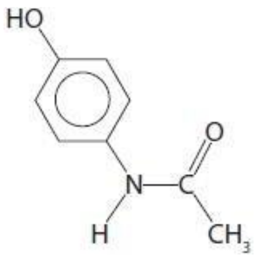
Q3.

Antifebrin was the trade name for N-phenylethanamide which was used as a painkiller until paracetamol was discovered.



Antifebrin

Paracetamol is structurally similar to Antifebrin, but has a hydroxy group attached directly to the benzene ring.



The bromination of the benzene ring in paracetamol occurs much more readily compared to the bromination of benzene.

Explain this increased reactivity.

(2)

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(Total for question = 2 marks)

Q4.

This question is about aluminium chloride.

At high temperatures, aluminium chloride exists as $AlCl_3$ molecules.

(i) Draw a dot-and-cross diagram of an aluminium chloride molecule, $AlCl_3$. Show the outer shell electrons only.

(1)

(ii) Predict the shape of an $AlCl_3$ molecule and the Cl−Al−Cl bond angle.

(2)

Shape of $AlCl_3$	
Cl–Al–Cl bond angle	

(iii) Aluminium chloride is used as a catalyst in the alkylation of benzene.

Draw the mechanism for the reaction between benzene and chloromethane using aluminium chloride as the catalyst.

Include an equation for the formation of the electrophile, and any relevant curly arrows.

(4)

(Total for question = 7 marks)

Q5.

This question is about the arenes, ethylbenzene, xylene, and phenol, which can be identified in wine samples using gas chromatography.

Ethylbenzene can be formed by the reaction of a chloroalkane with benzene, catalysed by aluminium chloride, $AlCl_3$.

(i) Draw the **displayed** formula of the chloroalkane required for this reaction.

(1)

(ii) Draw the mechanism for this reaction.

Include equations showing the role of the catalyst and how it is regenerated.

(5)

(iii) Explain whether phenol is likely to be less or more reactive than benzene with the chloroalkane from (i).

(3)

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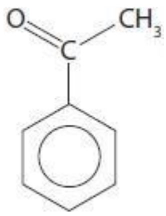
(Total for question = 9 marks)

Q6.

Phenylethanone is an ingredient in many types of chewing gum.



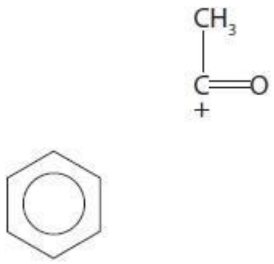
One method for the production of phenylethanone involves the reaction of benzene with ethanoyl chloride, CH_3COCl.

(i) Write the equation for the formation of the electrophile, CH_3CO^+, from ethanoyl chloride using the catalyst aluminium chloride.

(1)

(ii) Complete the diagram, including curly arrows, to show the mechanism for the reaction between this electrophile and benzene to produce phenylethanone. Include the regeneration of the catalyst.

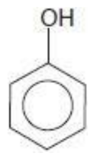
(4)



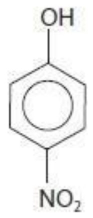
(Total for question = 5 marks)

Q7.

Phenol is a feedstock in the production of many organic molecules.

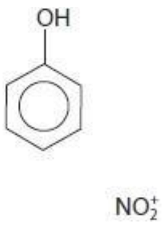


Phenol can be nitrated to produce 4-nitrophenol.



(i) The mechanisms of the nitration of phenol and of benzene are similar. Complete the diagram, using curly arrows, to show a possible mechanism for the reaction between the electrophile, NO_2^+, and phenol to produce 4-nitrophenol.

(3)



(ii) What is the mass, in grams, of 4-nitrophenol produced from 0.94 g of phenol if the yield of this isomer is 15%?

(1)

☐ **A** 0.14
☐ **B** 0.21
☐ **C** 0.68
☐ **D** 1.39

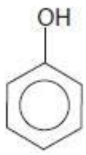
(iii) Draw **two** structural isomers of 4-nitrophenol which have a benzene ring.

(1)

(Total for question = 5 marks)

Q8.

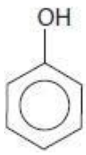
Phenol is a feedstock in the production of many organic molecules.



Phenol reacts with bromine water.

(i) Complete the equation for the reaction of phenol with excess bromine water, using the **skeletal** formula of the organic product.

(2)



\+ ....Br_2 $\rightarrow$

(ii) Compare and contrast the bromination of phenol with the bromination of benzene.

(3)

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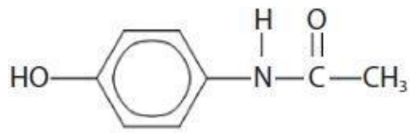
(Total for question = 5 marks)

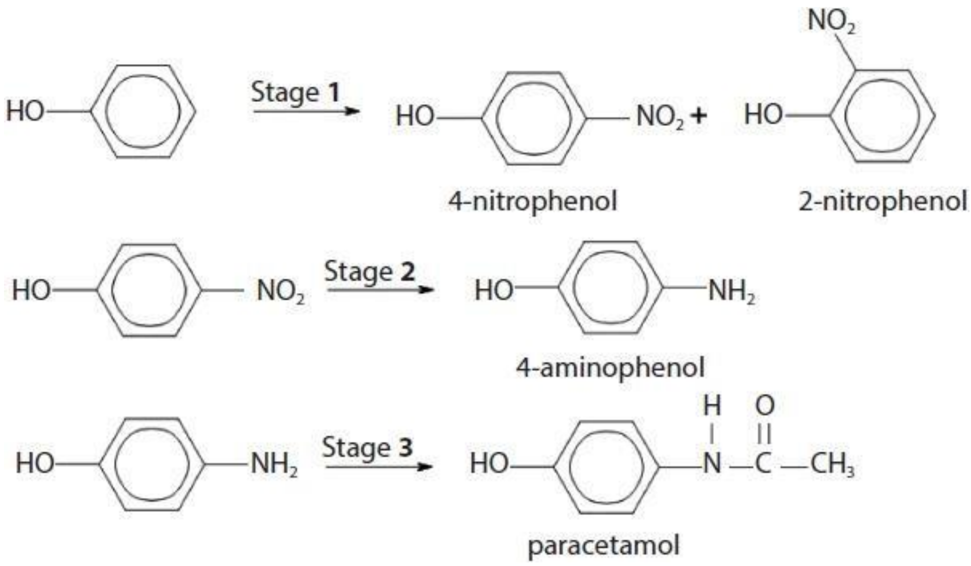
Q9.

This question is about the preparation and analysis of paracetamol.



paracetamol

Paracetamol may be prepared from phenol in three stages.



In Stage **1**, phenol is nitrated using dilute nitric acid.

The nitration of benzene requires concentrated nitric acid at 55°C with a catalyst of concentrated sulfuric acid.
Both these reactions are electrophilic substitution.

(i) Explain why phenol can be nitrated using milder conditions than benzene.

(2)

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(ii) A mixture of 2-nitrophenol and 4-nitrophenol is produced in Stage **1**.
They are separated by steam distillation.

The boiling temperature of 2-nitrophenol is 215°C and that of 4-nitrophenol is 279°C.
Explain, in terms of intermolecular forces, why 4-nitrophenol has a higher boiling temperature than 2-nitrophenol.
You may include a diagram in your answer.

(2)

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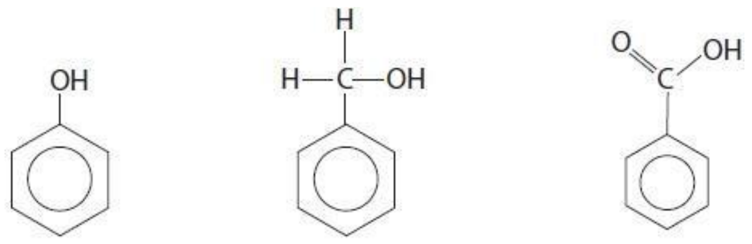
(Total for question = 4 marks)

Q10.

This is a question about the analysis of three aromatic substances with —OH groups.



phenol phenylmethanol benzoic acid

Spectroscopy is an effective means of distinguishing between molecules.

(i) Compare and contrast the infrared spectra of phenol, phenylmethanol and benzoic acid. Include relevant bonds and their wavenumber ranges using the Data Booklet.

(5)

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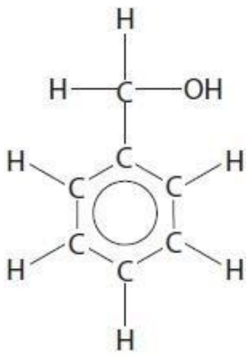
(ii) Predict the number of peaks present, and their chemical shifts, in the ^{13}C nuclear magnetic resonance (NMR) spectrum of phenylmethanol.
Use the information in the Data Booklet to help you.

(3)



phenylmethanol

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(iii) Give the formula of a fragment ion, with its *m*/*z* value, that you would expect to be present in the mass spectrum of benzoic acid but **not** in the mass spectrum of phenol or the mass spectrum of phenylmethanol.

(2)

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(Total for question = 10 marks)

Q11.

Explain the difference in the reactivity of bromine with benzene and with phenol.

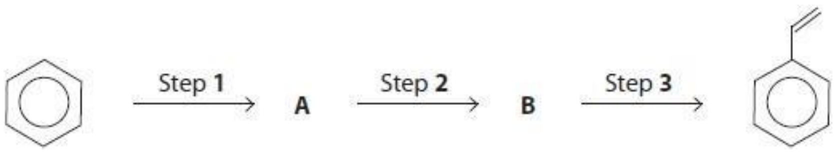
Include the type of reaction, the products that form, and any conditions required.
Mechanisms for the reactions are **not** required.

(6)

(Total for question = 6 marks)

Q12.

Phenylethene, commonly known as styrene, is an important substance in the production of polystyrene which is used for some types of plastic packaging. Phenylethene can be made from benzene in a three-step synthesis.



Some of the following compounds can be used to make phenylethene from benzene.

Aluminium chloride	Chloroethane	Ethanal	Ethanol
Ethanoic acid	Ethanoyl chloride	Ethene	Ether
Hydrochloric acid, concentrated	Lithium tetrahydridoaluminate(III)	Phosphoric acid, concentrated	Sulfuric acid, concentrated

Selecting **only** from these compounds, devise a synthetic pathway for converting benzene into phenylethene, clearly identifying compounds **A** and **B** and stating the appropriate conditions for each step.

(5)

(Total for question = 5 marks)