**1.** This question is about the chemistry of compounds containing phosphorus.

When phosphorus(V) chloride, $PCl_5$, and ammonium chloride are heated together, the compound $P_3N_3Cl_6$ is formed, together with HCl gas.

$P_3N_3Cl_6$ has a cyclic structure, like the Kekulé structure of benzene.

i. Write an equation for the reaction of $PCl_5$ and ammonium chloride to form $P_3N_3Cl_6$.

_____ **[1]**

ii. Calculate the percentage by mass of P in $P_3N_3Cl_6$.

Give your answer to **2** decimal places.

percentage by mass of P = ..... % **[2]**

iii. Suggest **one** example of evidence that could show that $P_3N_3Cl_6$ has a Kekulé structure rather than a delocalised structure.

_____

_____

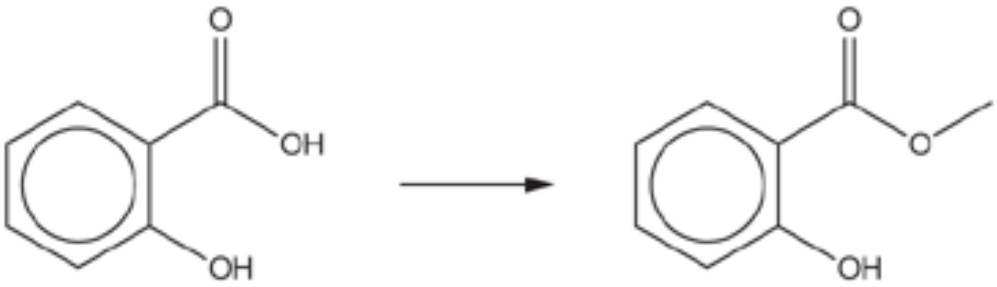
_____ **[1]**

iv. In a molecule of $P_3N_3Cl_6$ all the N and Cl atoms are bonded to P atoms.
Suggest a possible structure for a molecule of $P_3N_3Cl_6$.

**[2]**

**2.** Oil of wintergreen is a liquid used in medicine to relieve muscle pain.

Compound **H** is a component in oil of wintergreen and can be synthesised from compound **G**, as shown below.
The boiling point and density of compound **H** are stated.




**Compound G** **Compound H**

boiling point = 222 °C
density = 1.174 g cm$^{-3}$

A student prepares a sample of compound **H** by the method below.

| | |
|---|---|
| **Step 1** | Reflux 8.97 g of compound **G** for 30 minutes with an excess of methanol in the presence of a small amount of sulfuric acid as a catalyst. |
| **Step 2** | Add an excess of aqueous sodium carbonate, $Na_2CO_3(aq)$. Two layers are obtained. |
| **Step 3** | Purify the impure compound **H** that forms from the resulting mixture. |

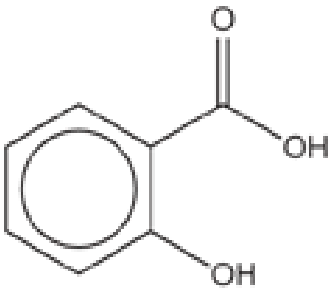
The student follows this method and obtains 5.32 g of pure compound **H**.

i. **In Step 2**, $Na_2CO_3(aq)$ removes the sulfuric acid catalyst **and** any unreacted compound **G** from the mixture.

Write equations for this removal.

Removal of sulfuric acid

Removal of unreacted compound **G**




**Compound G**

**[3]**

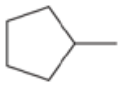
ii. Another student suggests that adding aqueous sodium hydroxide would be more effective in removing the sulfuric acid catalyst than $Na_2CO_3(aq)$.

Comment on whether the student's suggestion is an improvement for the preparation of compound **H**.

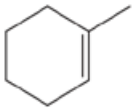
**[1]**

**3.** This question is about hydrocarbons.

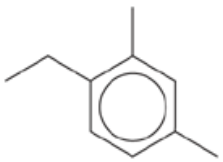
The structures of hydrocarbons **A–E** are shown below.



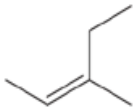
**A**



**B**



**C**



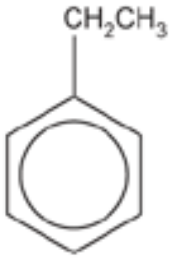
**D**

**E**

What is the systematic name of hydrocarbon **C**?

_____ **[1]**

**4(a).** Ethylbenzene, $C_6H_5CH_2CH_3$, can be prepared by reacting benzene with chloroethane, $CH_3CH_2Cl$, in the presence of $AlCl_3$. The $AlCl_3$ acts as a halogen carrier.




Ethylbenzene

**Ethylbenzene**

In the mechanism, chloroethane reacts with the halogen carrier to form a carbocation, which acts as the electrophile.

i. What is meant by the term **electrophile**?

_____ **[1]**

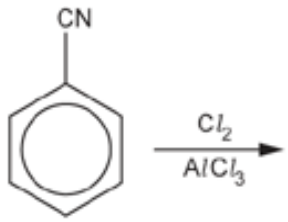
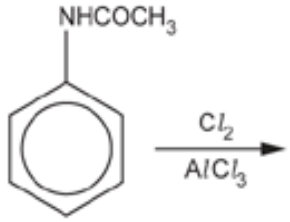
ii. Outline the mechanism for this reaction, including the role of $AlCl_3$ as a halogen carrier.

**[5]**

**(b).** The table shows directing effects for different groups in the electrophilic substitution of aromatic compounds.

| Directing effect | 2- and 4- directing | 3-directing |
|---|---|---|
| Group | −OH | $-NO_2$ |
| | $-NH_2$ | $-COCH_3$ |
| | $-NHCOCH_3$ | −CN |

i. Draw all organic products formed from monosubstitution reactions of the substituted benzene compounds shown below.

| Reaction | Monosubstituted Product(s) |
|---|---|
|   | |
|   | |

**[3]**

ii. The reactions of $C_6H_5NH_2$ are similar to the reactions of phenol.

Write an equation for the tri-substitution of $C_6H_5NH_2$ with chlorine.

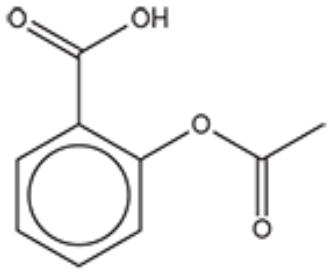
**[2]**

iii. Explain why chlorine reacts much more readily with $C_6H_5NH_2$ than with benzene.

**[3]**

**5.** Aspirin tablets are used for pain relief.

The structure of aspirin is shown below.




**Aspirin**

Aspirin reacts with hot NaOH(aq), under reflux.

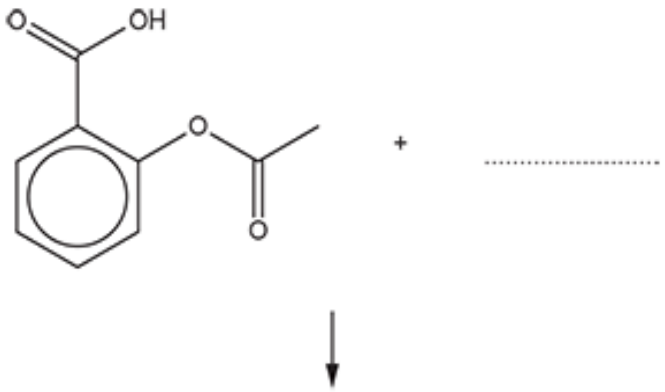
i. Draw a labelled diagram of suitable apparatus for reflux.

**[2]**

ii. In this reaction, 1 mol of aspirin reacts with 3 mol of hot NaOH(aq).

Complete the equation for the reaction of aspirin with an excess of hot NaOH(aq).

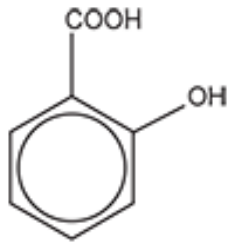
Show structures for organic compounds.




**[3]**

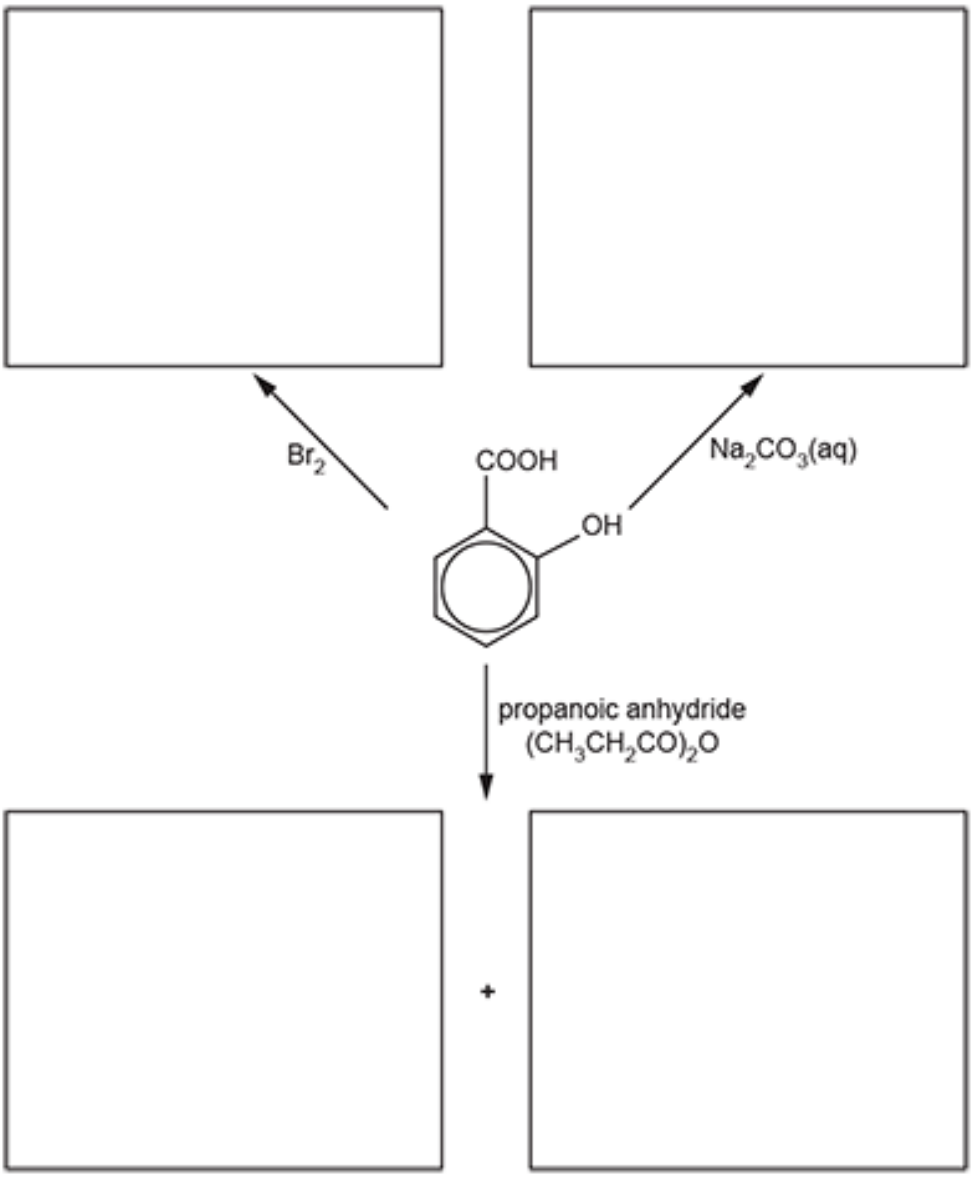
**6.** This question is about aromatic compounds containing the –COOH and –OH functional groups.

Salicylic acid, shown below, is used in the manufacture of some important medicines.




**Salicylic acid**

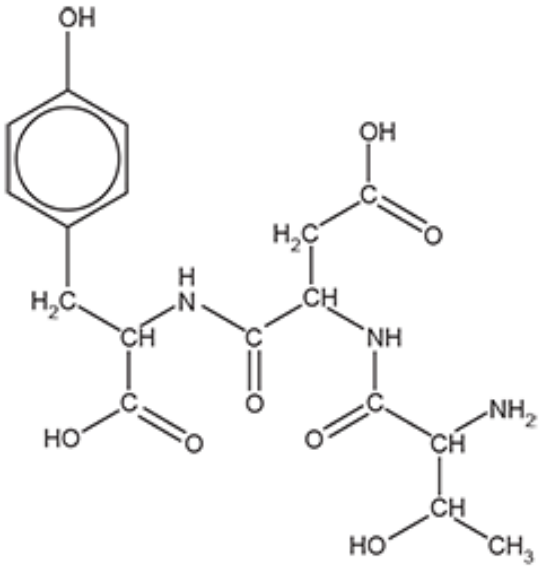
Complete the flowchart for reactions of salicylic acid, by adding the organic products in each box.




**[4]**

**7.** This question is about α-amino acids.

Three α-amino acids can react together to form compound **E**, shown below.



**Compound E**

i. How many optical isomers are possible for compound **E**?

---

**[1]**

ii. A student hydrolyses compound **E** with dilute hydrochloric acid, HCl (aq).

Draw the structures of the organic products formed by this hydrolysis.

**[4]**

**8.** 1,3-dinitrobenzene is a solid at room temperature.

A chemist prepares 1,3-dinitrobenzene as outlined below.

| | |
|---|---|
| **Step 1** | 12.5 $cm^3$ of nitrobenzene (density = 1.20 g $cm^{-3}$) is refluxed with concentrated nitric acid in the presence of concentrated sulfuric acid as a catalyst. |
| **Step 2** | The mixture is cooled. Impure crystals of 1,3-dinitrobenzene appear. |
| **Step 3** | The impure crystals are purified to obtain pure 1,3-dinitrobenzene. |

The chemist obtains 15.0 g of pure 1,3-dinitrobenzene.

Outline the mechanism for this reaction, including the role of $H_2SO_4$ as a catalyst.

**[5]**

**9.** Which ion(s) contain(s) bond angles of approximately 120º?

**1** $CH_3COO^-$
**2** $C_6H_5O^-$
**3** $(CH_3)_3C^+$
**A** 1, 2 and 3
**B** Only 1 and 2
**C** Only 2 and 3
**D** Only 1

Your answer ☐ **[1]**

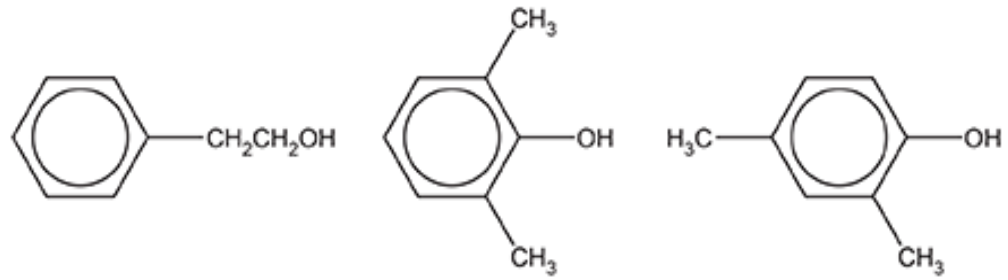
**10.** Which statement supports the delocalised model of benzene and **not** the Kekulé model?

**A** Sigma bonds overlap to form a π-system.
**B** The carbon-carbon bond lengths are all the same.
**C** The enthalpy change of hydrogenation is more exothermic than expected.
**D** Benzene is more reactive than alkenes with bromine.

Your answer ☐ **[1]**

**11(a).** This question is about the chemistry of aromatic compounds.

Compounds **J**, **K** and **L**, shown below, are structural isomers.




**Compound J** **Compound K** **Compound L**

i. What chemical test(s) could be used to confirm the presence of the phenol group in compounds **K** and **L**?

**[1]**

ii. A student thought that $^{13}C$ NMR spectroscopy could be used to distinguish between compounds **J**, **K** and **L**.

Explain, with reasoning, whether the student is correct.

**[3]**

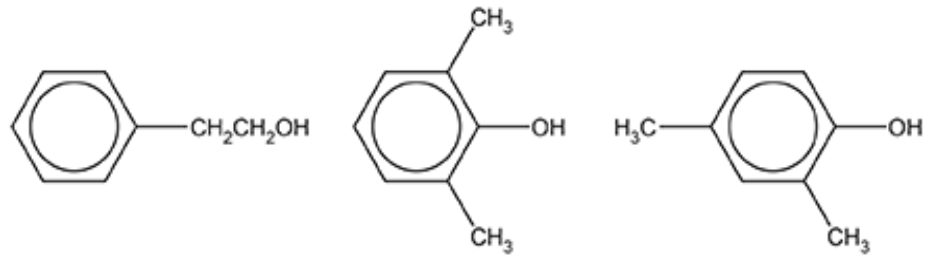
iii. Compound **J** is substituted at the 2- and 4- positions by chlorine in the presence of a catalyst.

Outline the mechanism for the 4 substitution of compound **J** by chlorine in the presence of a catalyst.

Show the role of the catalyst.

**[4]**

**(b).** Compounds **J**, **K** and **L**, shown below, are structural isomers.



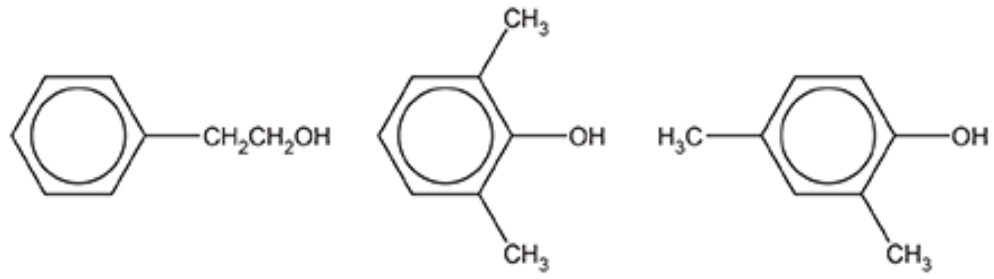

**Compound J** **Compound K** **Compound L**

Compounds **K** and **L** react with chlorine much more readily than compound **J**.

Explain why.

**[3]**

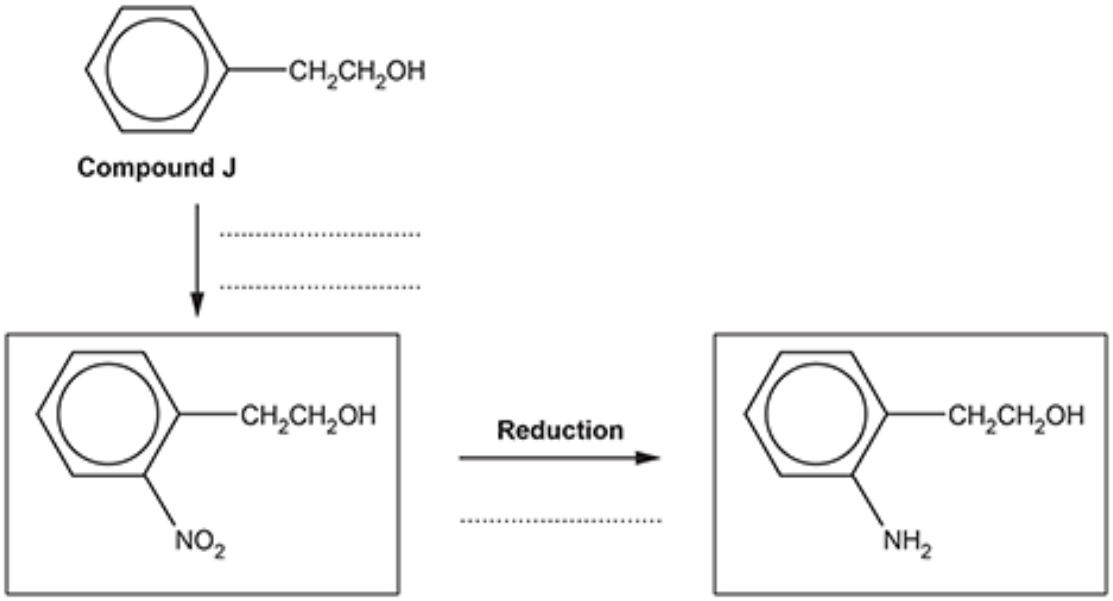
**(c).** Compounds **J**, **K** and **L**, shown below, are structural isomers.




**Compound J** **Compound K** **Compound L**

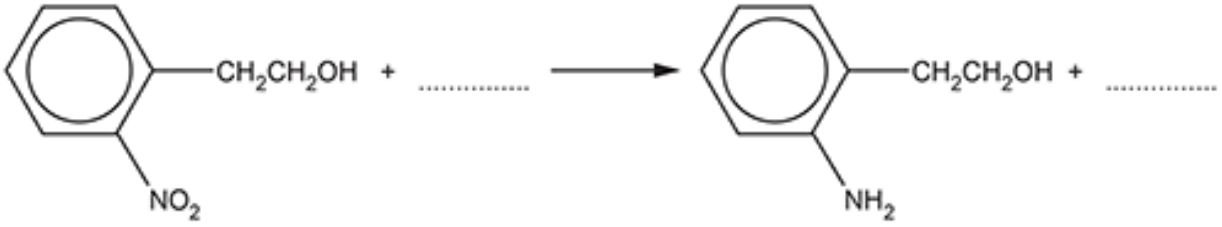
A two-stage synthesis of an amine from compound **J** is shown below.

i. Add the reagents for each stage of this synthesis.




**[2]**

ii. Fill in the equation for the reduction stage of this synthesis.




**[1]**

**12.** What is the number of sigma bonds in a molecule of methylbenzene?

**A** 7
**B** 10
**C** 12
**D** 15

Your answer ☐ **[1]**

**END OF QUESTION PAPER**