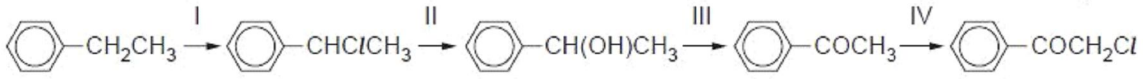
Q1.

Use

4 Chloroacetophenone (compound **D**, below) was formerly the most widely used tear gas, under the codename *CN*. It was used in warfare and in riot control. It can be synthesised from ethylbenzene, **A**, by the following route.

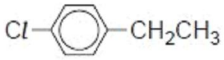


A **B** **C** **D**

(a) Suggest reagents and conditions for step I.

.....[1]

(b) Suggest reagents and conditions for converting ethylbenzene into compound **E**, an isomer of **B**.



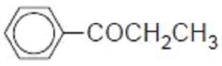
E

.....[1]

(c) Draw the structure of the product obtained by heating ethylbenzene with $KMnO_4$.

[1]

(d) Describe a test (reagents and observations) that would distinguish compound **C** from compound **F.**



F

reagents

.....

observation with **C**

.....

observation with **F**

.....

[2]

Use

(e) The efficiency of a tear gas is expressed by its 'intolerable concentration', I.C. The I.C. of the tear gas *CN* has been measured as $0.030\,g\,m^{-3}$ of air.
How many moles of chloroacetophenone need to be sprayed into a room of volume $60\,m^3$ in order to achieve this concentration?

.....

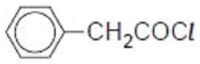
.....

.....[2]

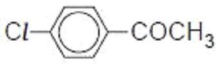
(f) Residues of *CN* can be destroyed by hydrolysis with an aqueous alkali.

D

Compounds **G** and **H** are isomers of compound **D**.



G



H

(i) Arrange the three isomers **D, G** and **H** in order of increasing ease of hydrolysis.

.....

(ii) Explain the reasoning behind your choice.

.....

.....

.....

[3]

[Total : 10]

Q2.

5 **(a)** State the reagents and conditions needed to convert benzene into

(i) chlorobenzene,

.....

(ii) bromobenzene,

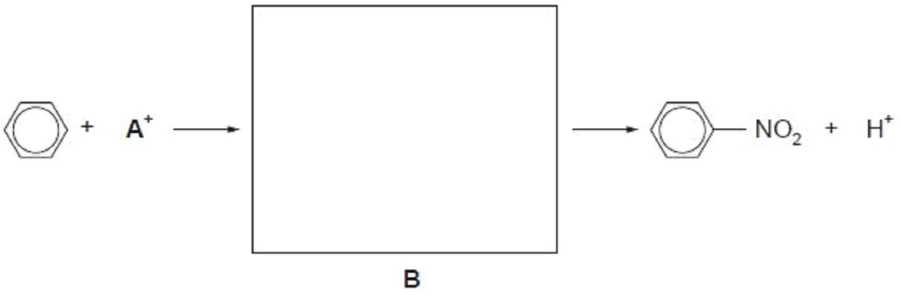
.....

(iii) nitrobenzene.

.....

[4]

(b) The nitration of benzene is a two-step reaction that can be represented as follows.



(i) Identify the cation A^+. .....

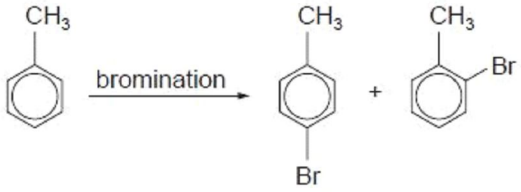
(ii) Draw the structure of the intermediate **B** in the box. [2]

Use

(c) The position of substitution during the electrophilic substitution of arenes is determined by the nature of the group already attached to the ring.

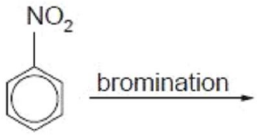
Electron-withdrawing groups such as $-CO_2H$ or $-NO_2$ direct the incoming group to the 3-position.

On the other hand, electron-donating groups such as $-CH_3$ or $-NH_2$ direct the incoming group to the 2- or 4- positions.

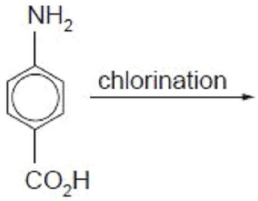


Use this information to suggest a likely structure for the organic product of each of the following reactions.

(i)



(ii)

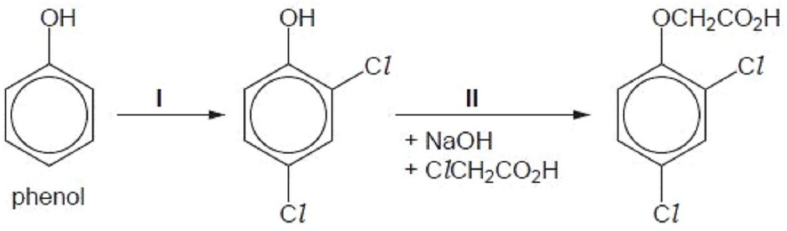


[2]

[Total: 8]

Q3.

(c) The acid $ClCH_2CO_2H$ features in the industrial synthesis of the important weedkiller 2,4-D.



phenol

2,4-D

(i) Suggest a possible reagent for reaction **I**.

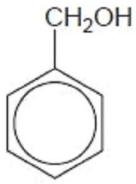
.....

(ii) What type of reaction is

reaction **I**, ...

reaction **II**? .....

(iii) Describe a test (reagents and observations) that would distinguish phenol from compound **A**.



compound **A**

reagents .....

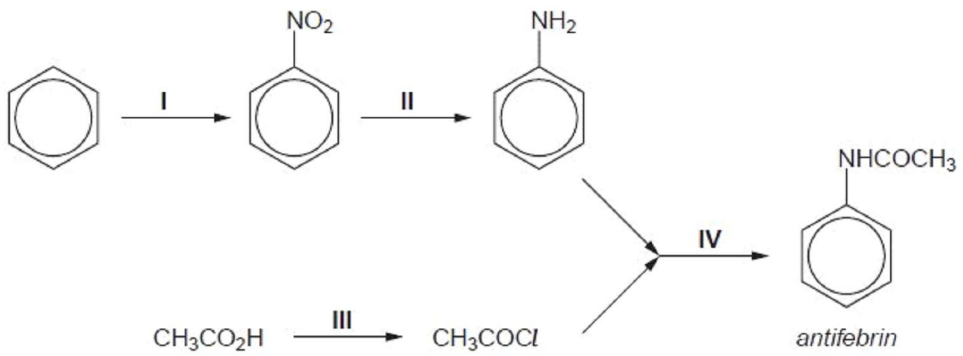
observation with phenol .....

observation with compound **A** .....

[5]

Q4.

6 The antipyretic (fever-reducing) drug *antifebrin* can be made from benzene and ethanoic acid by the following route.



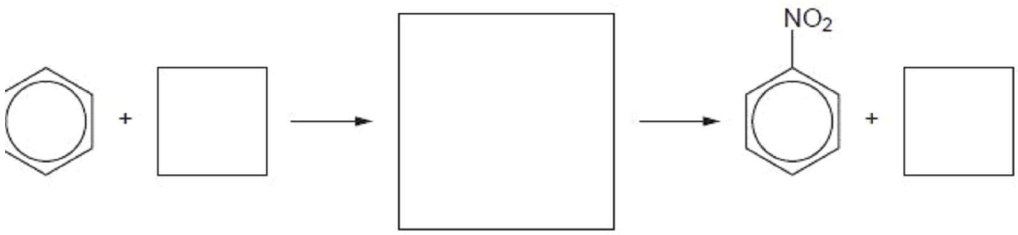
(a) **(i)** What type of reaction is reaction **I**?

.....

(ii) Suggest the reagents and conditions for reaction **I**.

.....

(iii) Complete the following scheme showing the mechanism of reaction **I**, by drawing appropriate formulae in the three boxes.



[6]

(b) **(i)** What type of reaction is reaction **II**?

.....

(ii) Suggest the reagents and conditions for reaction **II**.

.....

[2]

(c) Suggest the reagents and conditions for reaction **III**.

..... [1]

(d) **(i)** Apart from the benzene ring, name the functional group in *antifebrin*.

.....

(ii) What reagents and conditions are needed to hydrolyse *antifebrin*?

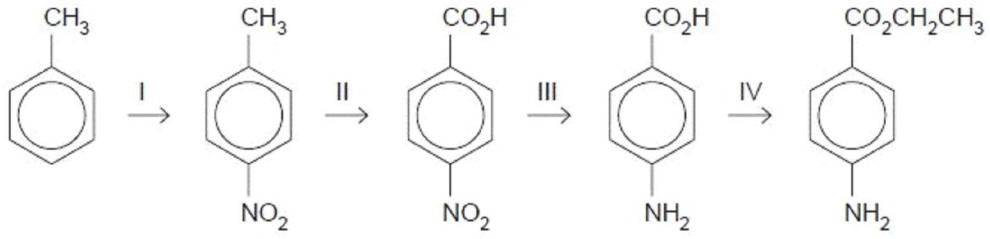
.....

[2]

[Total: 11]

Q5.

5 Benzocaine is an important local anaesthetic used in skin creams for sprains and other muscular pains. It can be made by the following route.



benzocaine

(a) Suggest reagents and conditions for each of the above four reactions.

I .....

II .....

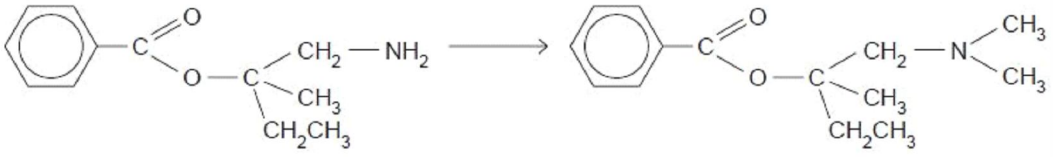
III .....

IV ..... [6]

(b) Draw steps to show the mechanism of reaction I.

[2]

(c) Another local anaesthetic is amylocaine, which can be made from compound **X**.



X amylocaine

(i) Apart from the benzene ring, name **two** functional groups in the molecule of compound **X**.

.....

.....

(ii) Explain whether compound **X** would be more or less basic than benzocaine.

.....

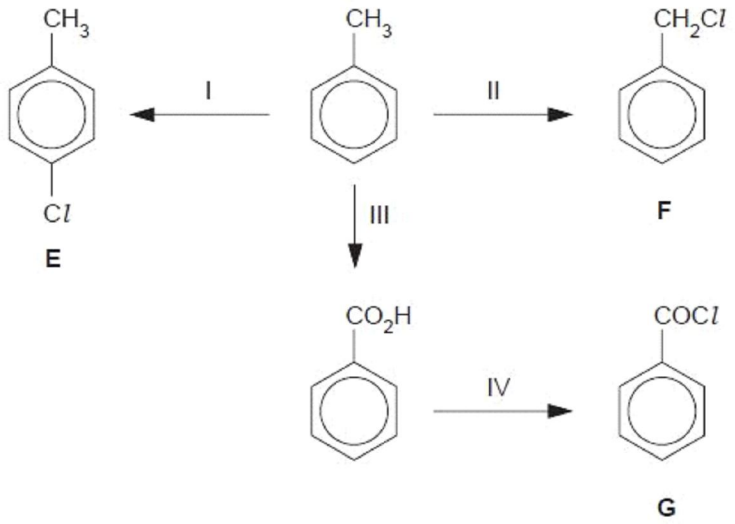
.....

[3]

[Total: 11]

Q6.

5 The following scheme shows some reactions of methylbenzene.



(a) Suggest reagents and conditions for reactions I to IV.

I .....

II .....

III .....

IV .....

[4]

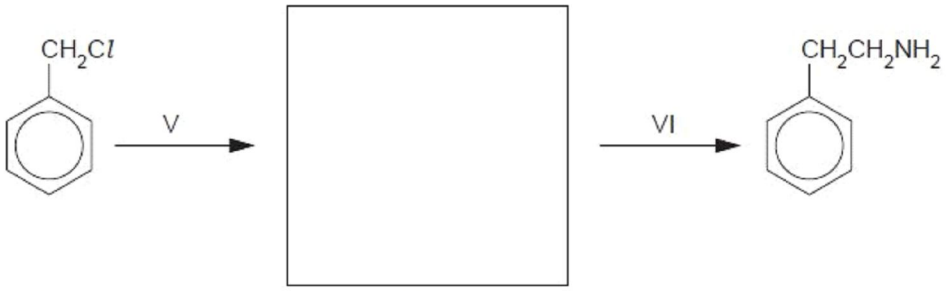
(b) What *type of reaction* is each of the following?

reaction I .....

reaction III .....

[2]

(c) Compound **F** can be converted into 2-phenylethylamine in a two-stage process. Suggest a structure for the intermediate, **H**, in the box below, and suggest reagents and conditions for the steps V and VI.



F **H**

reagents and conditions for step V .....

reagents and conditions for step VI .....

[4]

(d) The compounds **E**, **F** and **G** react at different rates with nucleophilic reagents. Draw structures for the products of each compound with the following reagents.
If no reaction occurs, write "***no reaction***" in the box.

compound	reagent	
	cold water	hot NaOH(aq)
E		
F		
G		

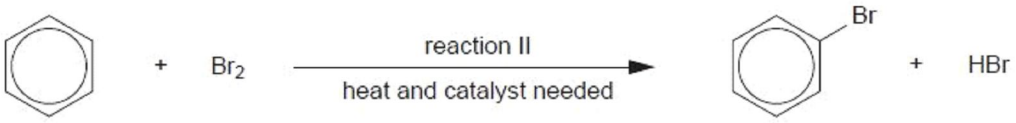
[6]

[Total: 16]

Q7.

5 Both ethene and benzene react with bromine, but the mechanisms and the types of products of the two reactions are different.

$H_2C{=}CH_2 + Br_2 \xrightarrow[\text{no heat, no light, no catalyst needed}]{\text{reaction I}} BrCH_2CH_2Br$



(a) State the *type of reaction* undergone in each of reactions I and II.

reaction I

.....

reaction II

.....

[2]

(b) In each of reactions I and II, the intermediate is a bromine-containing cation. In each of the following boxes, draw the intermediate and use curly arrows to show how it is converted into the product.

reaction I ⟶ intermediate ⟶ product

reaction II ⟶ intermediate ⟶ product

[4]

(c) Why do ethene and benzene differ in their reaction with bromine?

.....

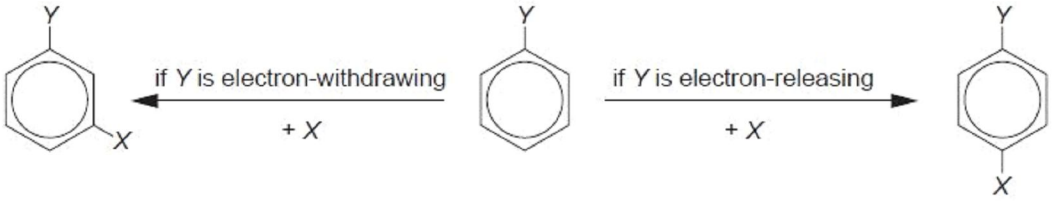
..... [1]

[Total: 7]

Q8.

6 The substituted benzene compound  can be further substituted.

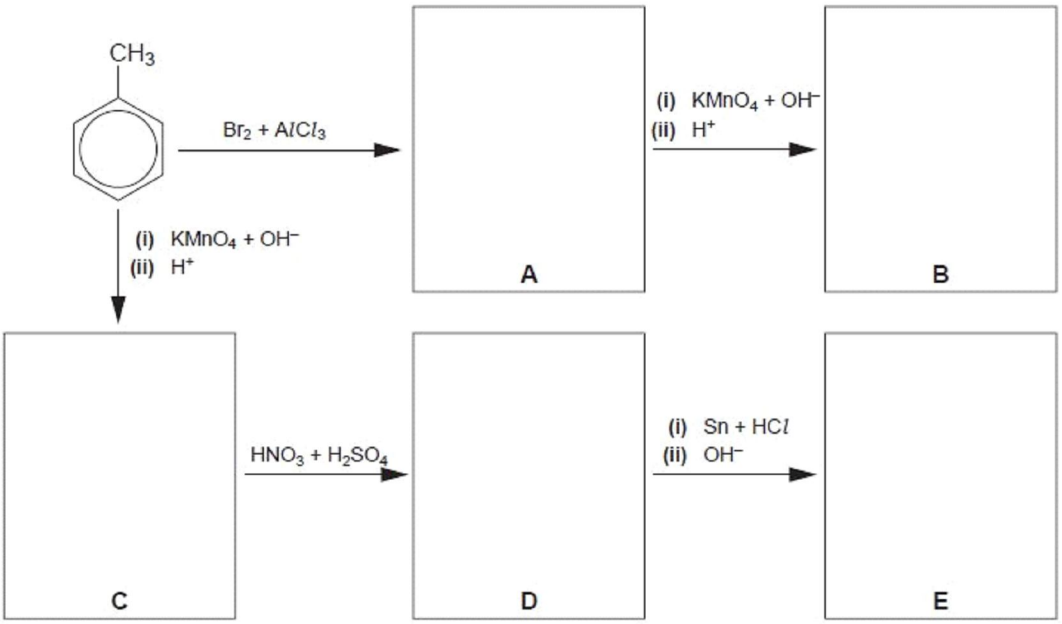
If *Y* is an electron-withdrawing group, the next substitution will be in position 3.
If *Y* is an electron-releasing group, the next substitution will be mostly in position 4.



The following table lists some electron-withdrawing and electron-releasing substituents.

electron-withdrawing groups	electron-releasing groups
$-NO_2$	$-CH_3$
$-COCH_3$	$-CH_2Br$
$-CO_2H$	$-NH_2$

Use the above information to draw relevant structural formulae in the boxes in the schemes below.



[5]

[Total: 5]

Q9.

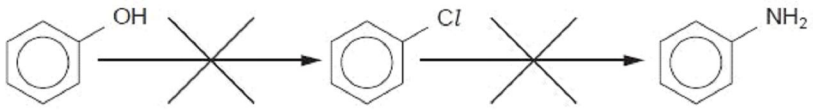
6 Phenol and chlorobenzene are less reactive towards certain reagents than similar non-aromatic compounds.
Thus hexan-1-ol can be converted into hexylamine by the following two reactions,

For Examiner's Use

$$CH_3(CH_2)_5OH \xrightarrow{I} CH_3(CH_2)_5Cl \xrightarrow{II} CH_3(CH_2)_5NH_2$$

hexan-1-ol — 1-chlorohexane — hexylamine

whereas neither of the following two reactions takes place.



(a) (i) Suggest reagents and conditions for

reaction I, ... ,

reaction II. ..... .

(ii) What *type of reaction* is reaction II? .....

(iii) Suggest a reason why chlorobenzene is much less reactive than 1-chlorohexane.

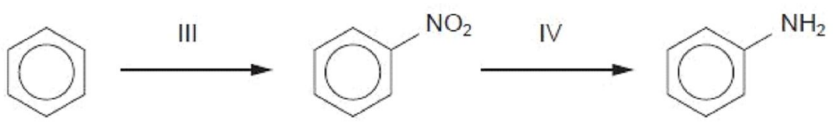
.....

.....

[4]

(b) Phenylamine can be made from benzene by the following two reactions.

For Examiner's Use



(i) Suggest reagents and conditions for

reaction III, ... ,

reaction IV. ..... .

(ii) State the *type of reaction* for

reaction III, ... ,

reaction IV. ..... .

[5]

(c) Suggest a reagent that could be used to distinguish phenylamine from hexylamine.

reagent and conditions .....

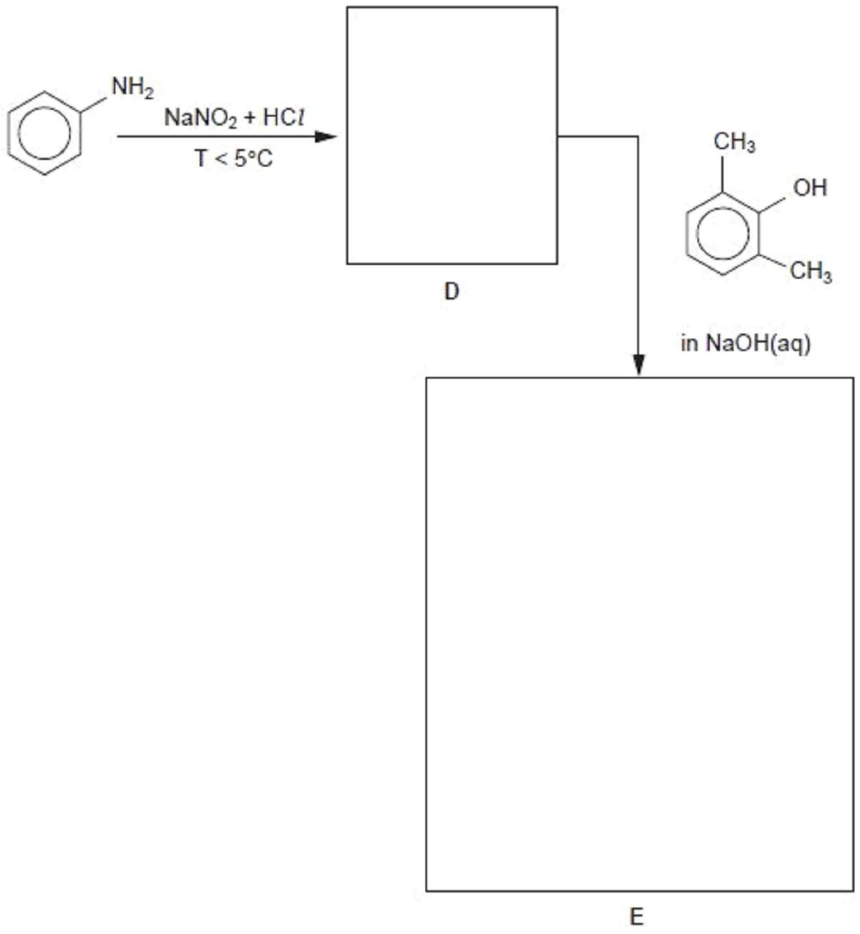
observation with phenylamine .....

observation with hexylamine.....

[2]

(d) Phenylamine is used to make azo dyes. In the following boxes draw the structural formula of the intermediate D and of the azo dye E.

For Examiner's Use



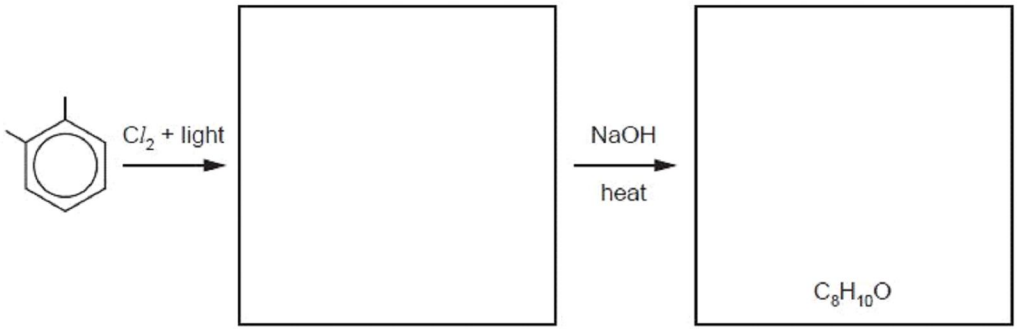
[2]

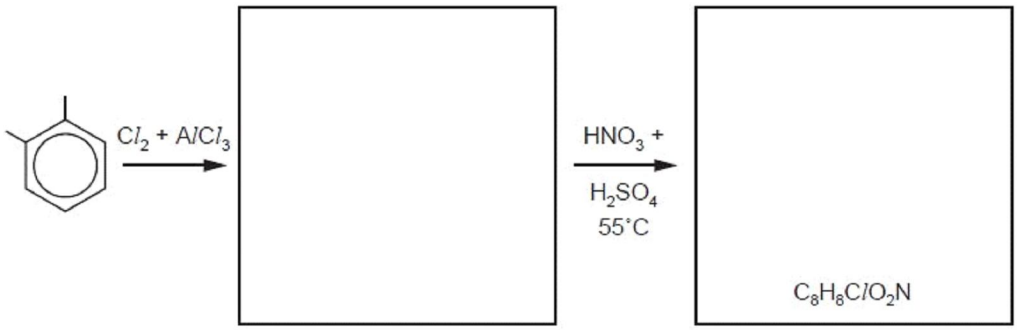
[Total: 13]

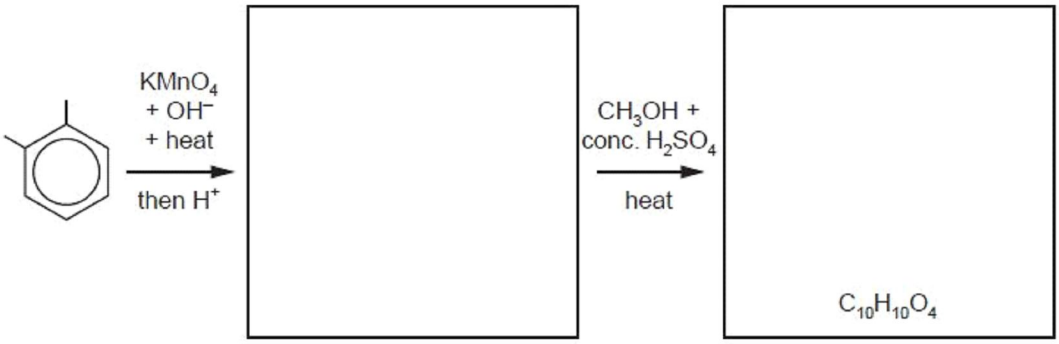
Q10.

7 Predict the products of the following reactions and draw their structures in the boxes provided. Note that the molecular formula of the final product is given in each case.

For Examiner's Use







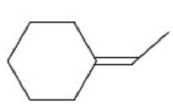
[6]

[Total: 6]

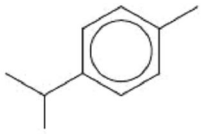
Q11.

(d) Predict the organic products of the following reactions and draw their structures in the boxes below. You may use structural or skeletal formulae as you wish.

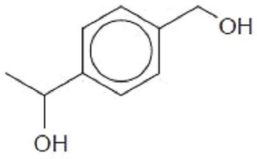
For Examiner's Use



hot conc. $MnO_4^- + H^+$



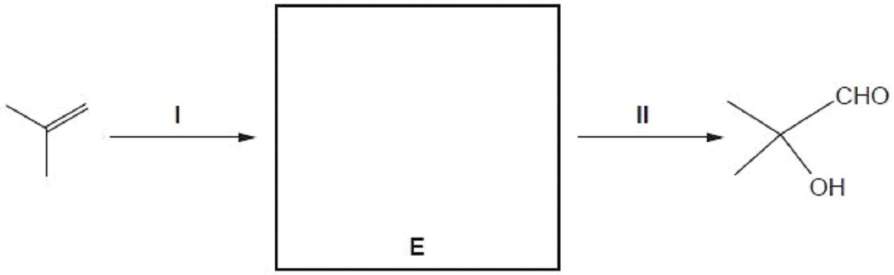
hot conc. $MnO_4^- + H^+$



hot $Cr_2O_7^{2-} + H^+$

[4]

(e) $KMnO_4$ and $K_2Cr_2O_7$ are the reagents that can be used to carry out the following transformation.



(i) Draw the structure of intermediate **E** in the box above.

(ii) Suggest reagents and conditions for the following.

reaction **I** .....

reaction **II** .....

[3]

Q12.

5 **(a)** **(i)** Briefly explain why the benzene molecule is planar.

For Examiner's Use

.....

.....

.....

(ii) Briefly explain why all the carbon-carbon bonds in benzene are the same length.

.....

.....

.....

[2]

(b) Benzene can be nitrated by warming it with a mixture of concentrated sulfuric and nitric acids.

(i) By means of an equation, illustrate the initial role of the sulfuric acid in this reaction.

.....

(ii) Name the type of reaction and describe the mechanism for the nitration reaction, including curly arrows showing the movement of electrons and all charges.

type of reaction .....

mechanism

[4]

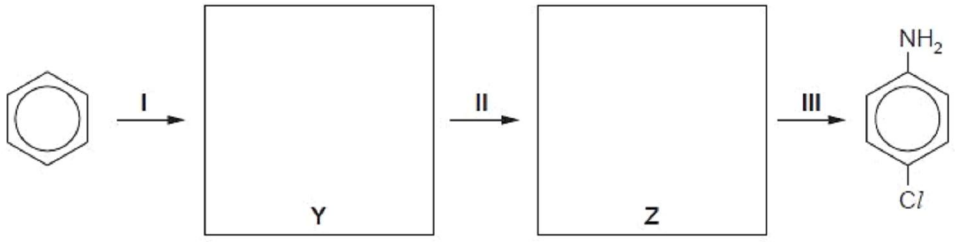
(c) State the reagents and conditions needed to convert benzene into chlorobenzene.

.....[1]

(d) Nitrobenzene undergoes further substitution considerably more slowly than chlorobenzene. In nitrobenzene the incoming group joins to the benzene ring in the 3-position, whereas in chlorobenzene the incoming group joins to the benzene ring in the 4-position.

For Examiner's Use

(i) Use these ideas to suggest the structures of the intermediate compounds **Y** and **Z** in the following synthesis of 4-chlorophenylamine.

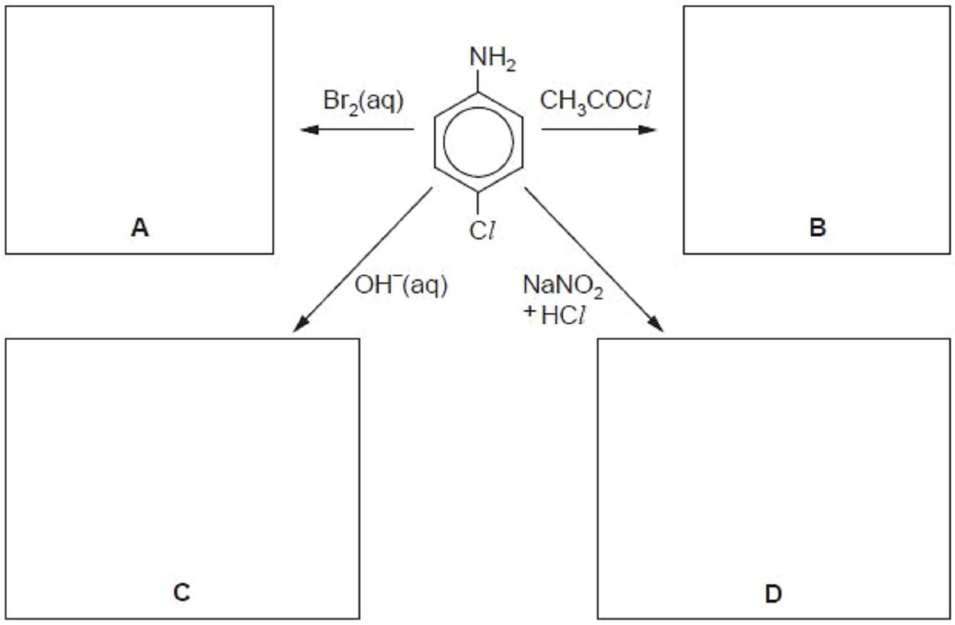


(ii) Suggest the reagents and conditions needed for reaction **III** in the above synthesis.

.....

.....

(iii) Suggest the structural formulae of the products **A**, **B**, **C** and **D** of the following reactions. If no reaction occurs write "no reaction" in the relevant box.



[8]

[Total: 15]

Q13.

5 **(a)** There are several ways of introducing chlorine atoms into organic molecules. State the reagents and conditions necessary to carry out the following transformations.

For Examiner's Use

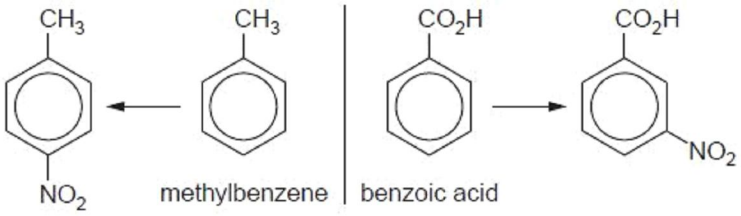
transformation	reagents + conditions
$C_2H_4 \longrightarrow C_2H_5Cl$	
$C_2H_5OH \longrightarrow C_2H_5Cl$	
$C_2H_6 \longrightarrow C_2H_5Cl$	
$C_2H_4 \longrightarrow C_2H_4Cl_2$	
$CH_3CO_2H \longrightarrow CH_3COCl$	
	
	

[6]

(b) **(i)** When treated with concentrated HNO_3 + H_2SO_4 at 55 °C, benzene produces nitrobenzene.
Outline the mechanism of this reaction. You should include all charges, and use curly arrows to represent the movement of electron pairs.

In aromatic substitution of monosubstituted benzenes, the orientation of an incoming group depends on the nature of the group already attached to the ring.
For example, using the same reagents and conditions as in **(i)**, methylbenzene and benzoic acid produce the following nitro compounds.

For Examiner's Use



(ii) Using this information as an aid, suggest a structure for compound **C** in the following synthesis of 3-bromobenzoic acid.

(iii) Suggest reagents and conditions for steps 1 and 2.

step 1	step 2

[6]

[Total: 12]

Q14.

5 **(a)** Describe and explain how the acidities of ethanol and phenol compare to that of water.

For Examiner's Use

.....

.....

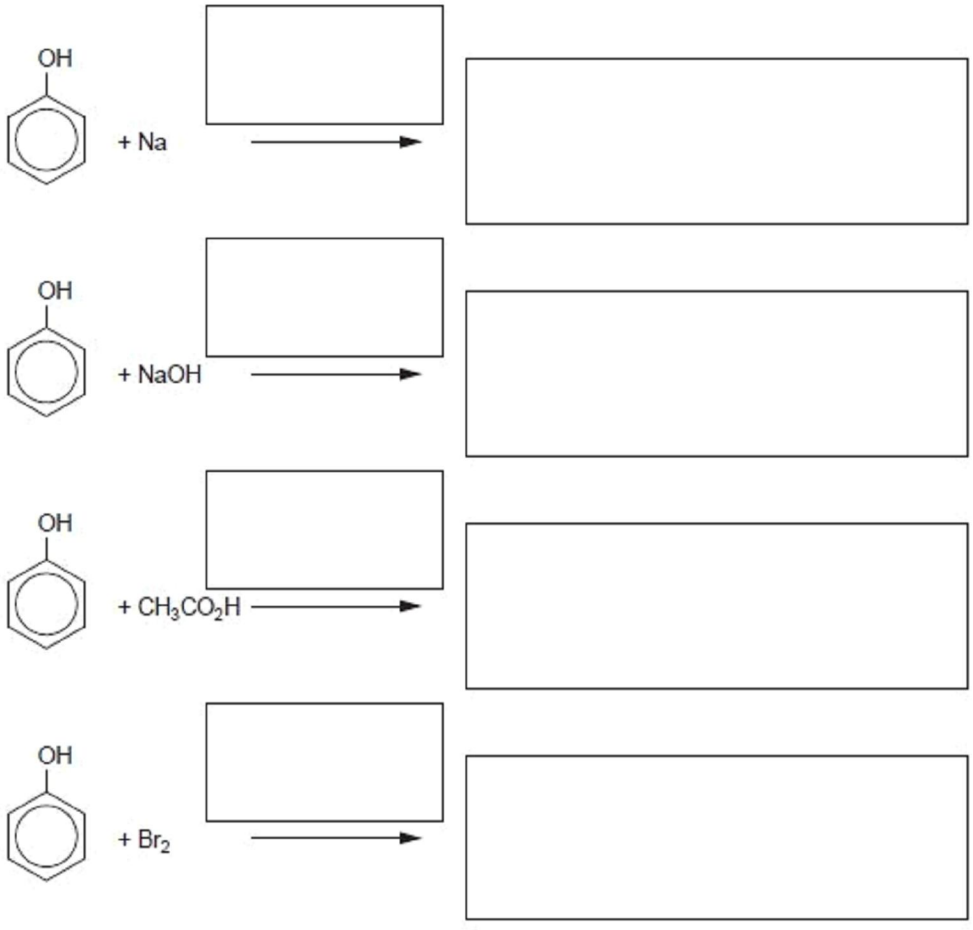
.....

.....

.....

.....[4]

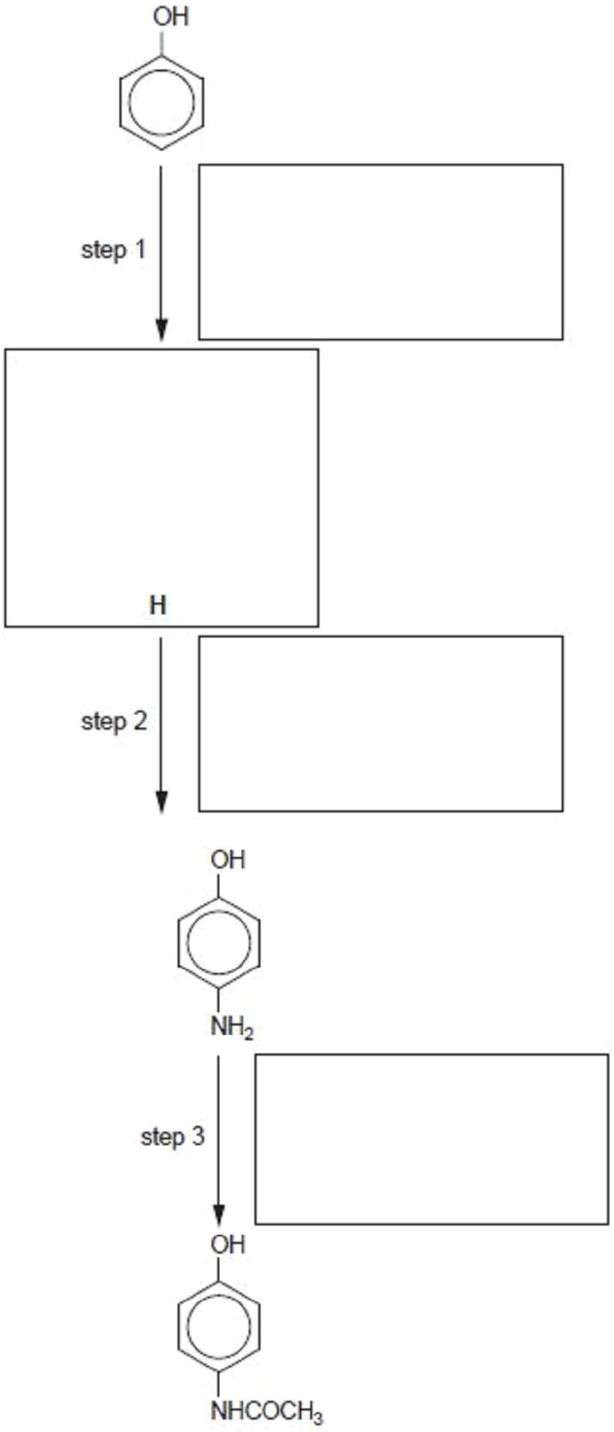
(b) Complete the following equations showing **all** the products of each of these reactions of phenol. Include reaction conditions where appropriate in the boxes over the arrows. If no reaction occurs write ***no reaction*** in the products box.



[5]

(c) The analgesic drug paracetamol can be synthesised from phenol by the following route. Suggest reagents and conditions for the each of three steps, and suggest the structure of the intermediate **H**. Write your answers in the boxes provided.

For Examiner's Use



paracetamol

[4]

[Total: 13]

Q15.

For Examiner Use

3 Indigo is the dye used in blue jeans. Although originally extracted from plants of the type *indigofera*, it is now almost entirely made artificially.

Indigo is insoluble in water but this disadvantage can be overcome by converting it into the water-soluble colourless leuco-indigo. If cloth soaked in a solution of leuco-indigo is left to dry in the air, the leuco-indigo is converted into the insoluble blue indigo, which is precipitated out onto the fibres of the cloth.

indigo leuco-indigo

(a) (i) Give the molecular formula of indigo.

.....

(ii) Name **three** functional groups in indigo.

.....

[3]

(b) (i) What *type of reaction* is the conversion of indigo into leuco-indigo?

.....

(ii) Suggest a laboratory reagent for this reaction.

.....

[2]

(c) Suggest **two** chemical tests that could be used to distinguish between indigo and leuco-indigo. Write your answers in the following table.

test	reagents and conditions	observation with indigo	observation with leuco-indigo
1			
2			

[5]

For Examiner Use

(d) When indigo is heated with hydrogen and a nickel catalyst, compound **A**, $C_{16}H_{28}N_2O_2$, is formed.

(i) Suggest a structure for **A**.

(ii) Calculate the volume of hydrogen, measured at room temperature and pressure, that would have been absorbed if 2.50 g of indigo had undergone this reaction.

volume = ...dm^3

[3]

(e) Suggest the structure of the product formed when indigo reacts with an excess of Br_2(aq).

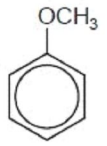
[3]

[Total: 16]

Q16.

For Examiner's Use

5 **(a)** Methoxybenzene reacts with $Br_2(aq)$ in a similar manner to phenol.



methoxybenzene

(i) Draw the structural formula of the product of the reaction between methoxybenzene and an excess of bromine.

(ii) Suggest a chemical reaction you could use to distinguish between methoxybenzene and phenol. State the reagent, describe the observations you would make, and give an equation for the reaction.

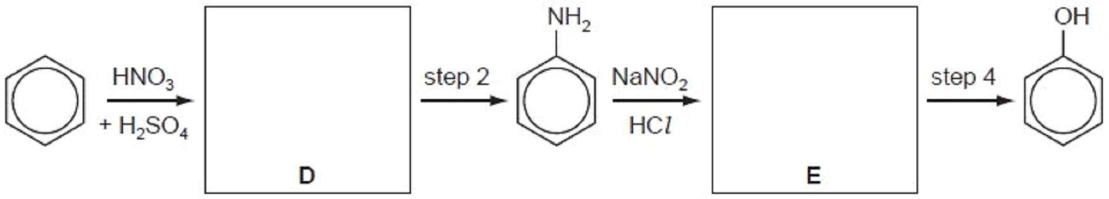
reagent .....

observation .....

equation

[4]

(b) Phenol can be synthesised from benzene by the following route.



(i) Suggest structures for compounds **D** and **E** and draw them in the boxes above.

(ii) Suggest reagents and conditions for

step 2, ...

step 4. .....

[4]

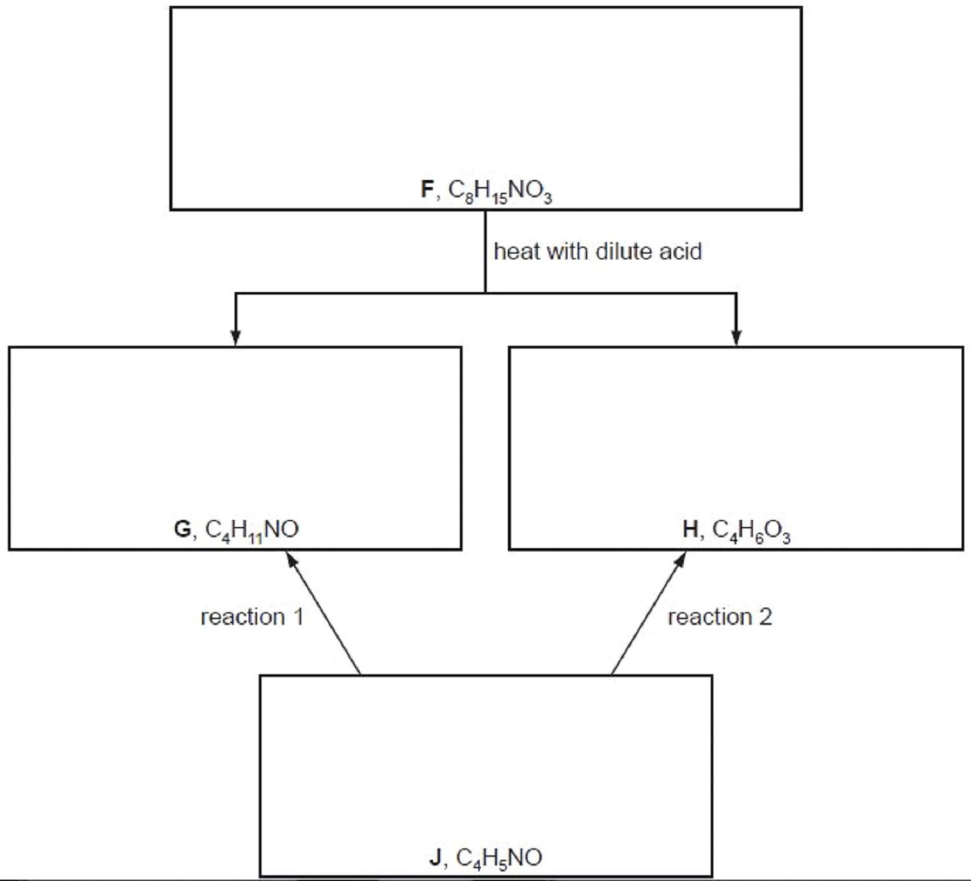
(c) The following chart shows some reactions of compound **F** which is a neutral compound.

For Examiner Use

G forms a salt with dilute H_2SO_4, whereas **H** forms a salt with NaOH(aq).

Both **G** and **H** can be obtained from compound **J** by separate one-step reactions (reaction 1 and reaction 2 below).

All four compounds **F**, **G**, **H** and **J** form a yellow precipitate with alkaline aqueous iodine.



(i) Suggest structures for **F**, **G**, **H** and **J**, and draw them in the boxes above.

(ii) Suggest reactants and conditions for

reaction 1, ...

reaction 2. .....

[6]

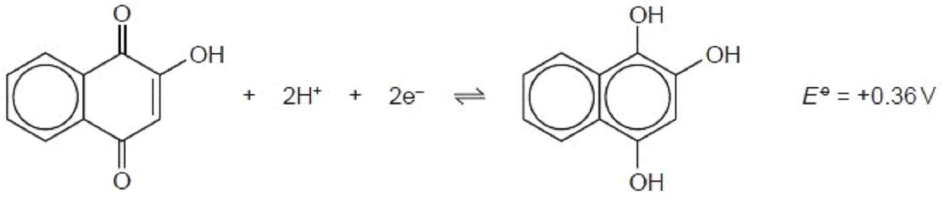
[Total: 14]

Q17.

For Examiner's Use

3 Lawsone is the dye that is extracted from the henna plant, *Lawsonia inermis*. Although its natural colour is yellow, lawsone reacts with the proteins in hair and skin to produce the characteristic brown henna colour.

Lawsone can readily be reduced to 1,2,4-trihydroxynaphthalene, compound **A**.



$E^{\ominus} = +0.36\,V$

lawsone 1,2,4-trihydroxynaphthalene, **A**

(a) (i) Name **three** functional groups in lawsone.

.....

.....

(ii) Describe a reaction (reagent with conditions) that you could use to distinguish lawsone from compound **A**.
Describe the observations you would make with **both** compounds.

.....

.....

.....

.....

(iii) Suggest a reagent that could be used to convert lawsone into compound **A** in the laboratory.

.....

.....

(iv) Draw the structural formula of the compound formed when lawsone is reacted with $Br_2(aq)$.

[6]

For Examiner's Use

(b) Compound **A** can be oxidised to lawsone by acidified $K_2Cr_2O_7$.

(i) Use the *Data Booklet* to calculate the $E^{\ominus}_{cell}$ for this reaction.

.....

(ii) Construct an equation for this reaction. Use the molecular formulae of lawsone, $C_{10}H_6O_3$, and compound **A**, $C_{10}H_8O_3$, in your equation.

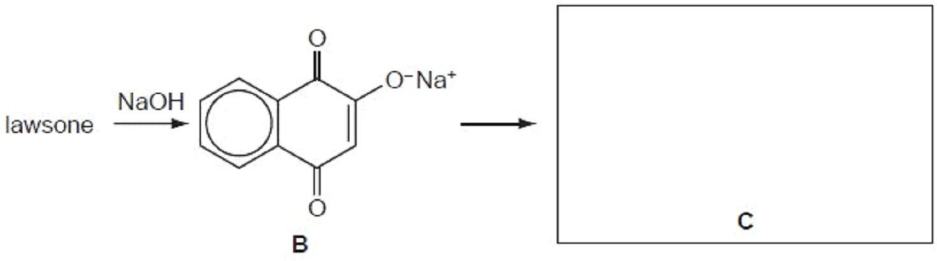
.....

(iii) When 20.0 cm^3 of a solution of compound **A** was acidified and titrated with 0.0500 mol dm^{-3} $K_2Cr_2O_7$, 7.50 cm^3 of the $K_2Cr_2O_7$ solution was needed to reach the end-point.
Calculate [**A**] in the solution.

[**A**] = ... mol dm^{-3}
[5]

(c) When lawsone is reacted with NaOH(aq), compound **B** is produced.

For Examiner Use

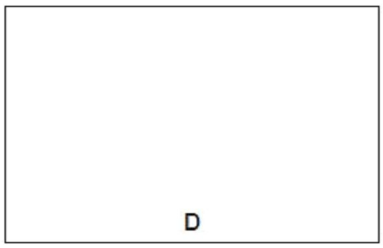


Reacting **B** with ethanoyl chloride, CH_3COCl, produces compound **C**, with the molecular formula $C_{12}H_8O_4$.

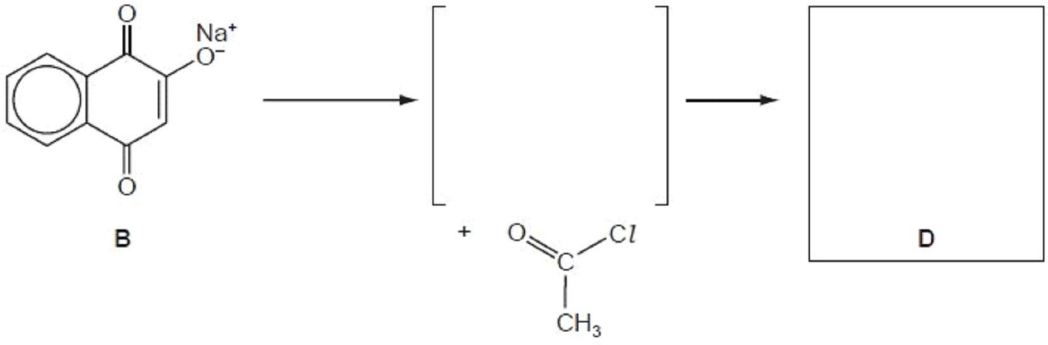
(i) Suggest the identity of compound **C**, and draw its structure in the box above.

Another compound, **D**, in addition to **C**, is produced in the above reaction. **D** is an isomer of **C** which contains the same functional groups as **C**, but in different positions.

(ii) Suggest a possible structure for **D**.



(iii) Suggest a mechanism for the formation of **D** from **B** and ethanoyl chloride by drawing relevant structures and curly arrows in the following scheme.



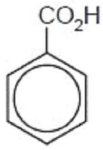
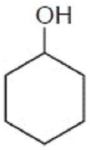
[3]

[Total: 14]

Q18.

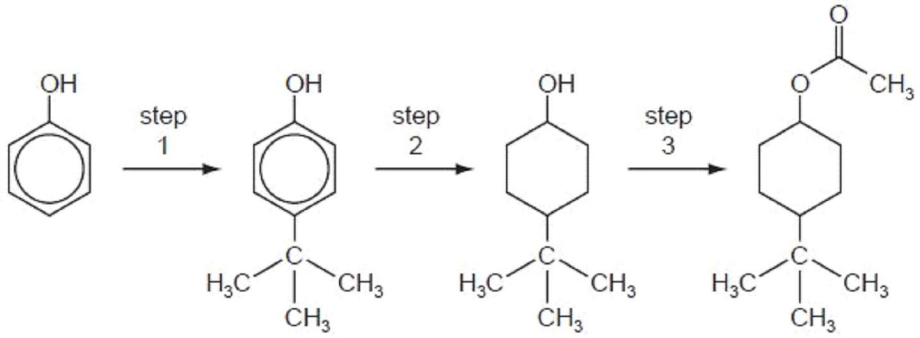
For Examin Use

5 **(a)** A series of experiments is carried out in which the reagent shown at the top of the column of the table is mixed, in turn, with each of the reagents at the side.
Complete the following table by writing in each box the formula of any gas produced.
Write **x** in the box if no gas is produced.
The first column has been completed as an illustration.

	H_2O			
Na	H_2			
KOH(aq)	**x**			
Na_2CO_3(aq)	**x**			

[5]

(b) Compound **C** is responsible for the pleasant aroma of apples. It can be prepared from phenol by the following 3-step synthesis.



A **B** **C**

(i) The only by-product of step 1 is HC*l*. Suggest the reagent that was used to react with phenol to produce compound **A**.

.....

(ii) What *type of reaction* is occurring in step 2?

.....

(iii) What reagents and conditions are required for step 3?

.....

(iv) State the reagent and conditions needed to convert **C** back to **B**, the reverse of step 3.

.....

[5]

(c) (i) Either compound **A** or compound **B**, or both, react with the following reagents. For each reagent draw the structure of the organic product formed with **A**, and with **B**. If no reaction occurs, write 'no reaction' in the relevant box.

Exa

reagent and conditions	product with **A**	product with **B**
an excess of $Br_2(aq)$		
heat with HBr		
pass vapour over heated Al_2O_3		
heat with acidified $K_2Cr_2O_7$		

(ii) Choose **one** of the above reactions to enable you to distinguish between **A** and **B**.

State below the observations you would make with each compound.

reagent	observation with **A**	observation with **B**

[7]

[Total: 17]

Q19.

3 **(a)** Describe the reagents and conditions required to form a nitro compound from the following.

(i) methylbenzene 

.....

(ii) phenol 

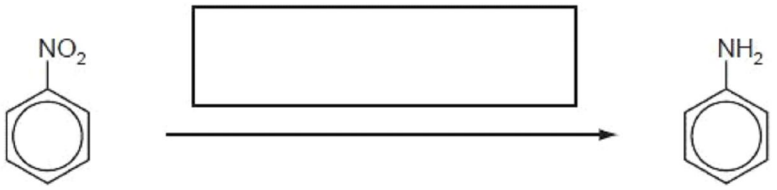
.....

[3]

(b) Draw the structure of the intermediate organic ion formed during the nitration of benzene.

[1]

(c) In the box over the arrow below, write the reagents needed to convert nitrobenzene into phenylamine.

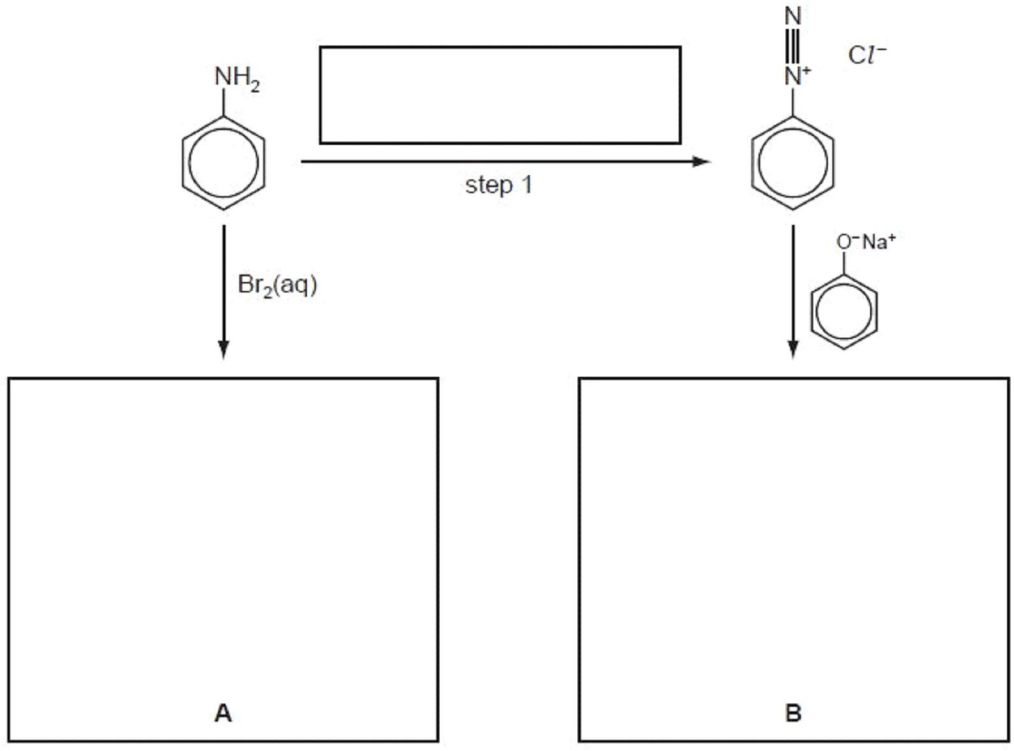


[1]

(d) Phenylamine can be converted into the organic compounds **A** and **B**.

(i) Suggest the structural formulae of **A** and **B** in the boxes below.

(ii) Suggest suitable reagents and conditions for step 1, and write them in the box over the arrow.



[3]

(e) When phenylamine is treated with propanoyl chloride a white crystalline compound, **C**, $C_9H_{11}NO$, is formed.

(i) Name the functional group formed in this reaction. .....

(ii) Calculate the percentage by mass of nitrogen in **C**.

percentage = ... %

(iii) Draw the structural formula of **C**.

[3]

[Total: 11]

Q20.

5 Benzene can be converted into nitrobenzene by a nitration reaction.

(a) State the reagents and conditions necessary to carry out this reaction.

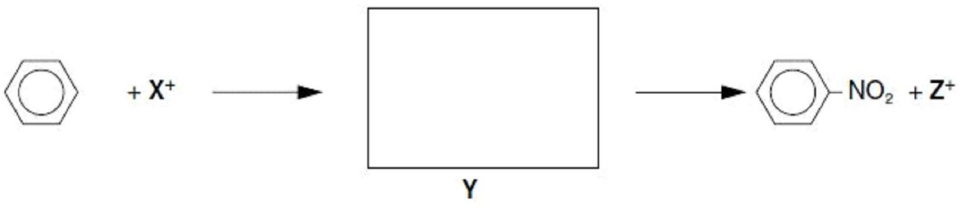
.....

.....[2]

(b) What type of reaction mechanism is this?

.....[1]

(c) The reaction proceeds via two steps:



(i) Draw the structure of the intermediate **Y** in the box.

(ii) Identify the cation X^+.....

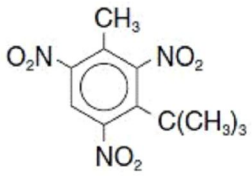
(iii) Identify the cation Z^+.....

(iv) Write an equation to show how X^+ is produced from the reagents.

.....

[5]

(d) Some aromatic poly-nitro compounds are used in perfumes as artificial musks. An example is 'Baur musk'.



Baur musk

(i) Draw the structural formula of the hydrocarbon that could be nitrated in order to produce Baur musk.

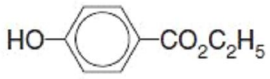
(ii) Suggest the structural formula of the compound formed by reacting Baur musk with an excess of tin and concentrated hydrochloric acid.

[2]

[Total: 10]

Q21.

4 Ethyl 4-hydroxybenzoate, **E**, is a permitted food preservative.



E

(a) Name **two** functional groups in **E**.

.....

.....[2]

(b) Draw the structures of the compounds formed when **E** reacts with

(i) sodium metal,

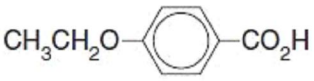
(ii) NaOH(aq) under reflux,

(iii) Br_2(aq).

[4]

(c) Compounds **F** and **G** are isomers of **E**.

F



G

(i) Suggest the order of acid strength of **E**, **F** and **G**.

.....

.....

(ii) Based on their relative acidities, suggest how samples of **E**, **F** and **G** could be distinguished from each other by the use of NaOH(aq) and Na_2CO_3(aq).

.....

.....

.....

.....

.....

[3]

[Total : 9]

Q22.

Use

7 Both phenol and phenylamine react similarly with aqueous bromine.

(a) State **two** observations you would make when these reactions take place.

.....

.....

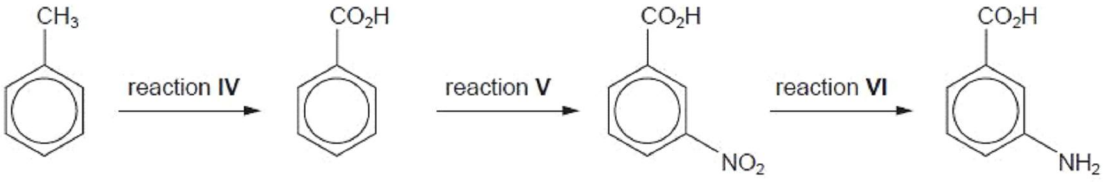
..... [2]

(b) Describe a simple test-tube reaction you could use to distinguish between phenol and phenylamine.

.....

.....[1]

(c) The compound 3-aminobenzoic acid can be prepared by the following series of reactions.



Suggest suitable reagents and conditions for

reaction **IV**, ...

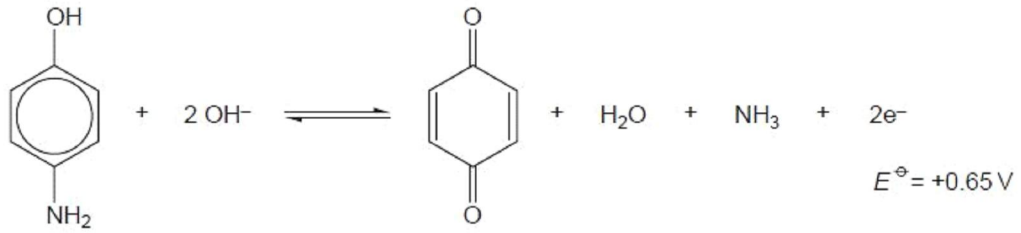
reaction **V**, ...

reaction **VI**. ..... [4]

[Total: 7]

Q23.

4 Rodinol is used as a photographic developer. In alkaline solution it is a mild reducing agent, providing electrons according to the following half equation.



rodinol

Rodinol 'develops' a latent photographic image by reducing activated silver bromide grains to silver metal and bromide ions.

(a) Construct a balanced equation for the reaction between rodinol and AgBr.

.....

.....

..... [1]

(b) Suggest, with a reason, how the basicity of rodinol might compare to that of ammonia.

.....

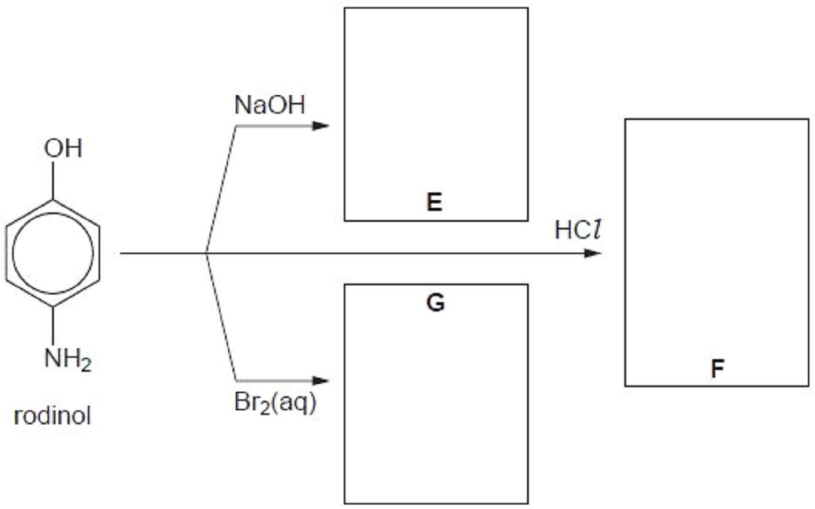
.....

.....

.....

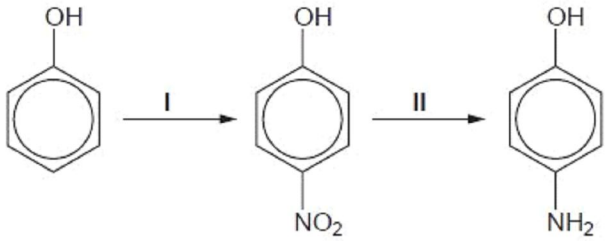
..... [2]

(c) Suggest structural formulae for the compounds **E**, **F** and **G** in the following chart of the reactions of rodinol.



[3]

(d) Rodinol can be synthesised from phenol by the following route.



(i) Suggest reagents and conditions for step **I**.

.....

(ii) What type of reaction is step **II**?

.....

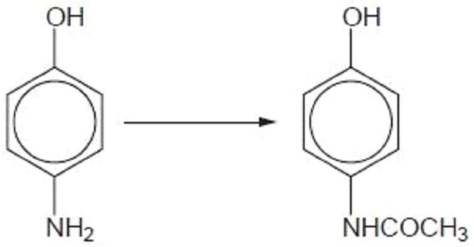
(iii) Place a tick in the box by the most suitable reagent for step **II**.

(place a tick in one box only)

H_3O^+ + heat	☐
$OH^-(aq)$ + heat	☐
$Cr_2O_7^{2-} + H^+$ + heat	☐
$HNO_3(aq)$	☐
Sn + HCl(aq)	☐
NH_3 in ethanol + heat/pressure	☐

[3]

(e) Rodinol is also an important intermediate in the commercial production of the analgesic drug *paracetamol*.



paracetamol

(i) Name **two** functional groups in *paracetamol*.

.....

.....

(ii) Suggest a reagent to convert rodinol into *paracetamol*.

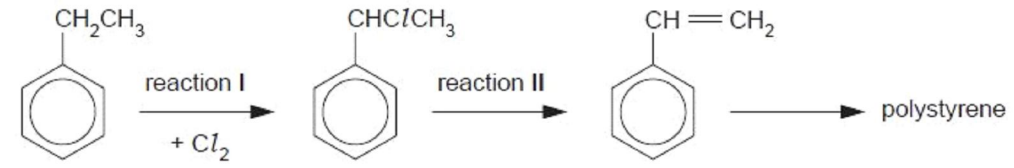
.....

[3]

[Total: 12]

Q24.

4 Ethylbenzene is an important starting material for making polystyrene (poly(phenylethene)).



ethylbenzene **B** phenylethene

(a) **(i)** State the conditions needed to carry out reaction **I** in the laboratory.

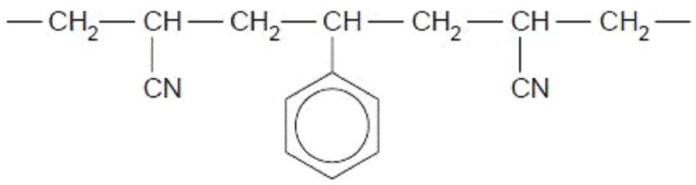
.....

(ii) State the reagent and conditions needed for reaction **II**.

.....

(iii) Draw the structure of the repeat unit of polystyrene.

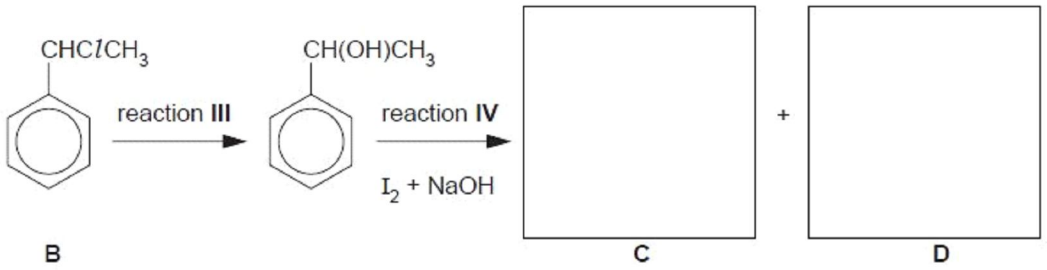
(iv) There are several polymers that consist of phenylethene co-polymerised with other monomers. The following formula shows part of the chain of one such co-polymer.



Deduce the structural formula of the other monomer.

[5]

(b) Compound **B** undergoes the following series of reactions.



(i) Suggest reagents and conditions for reaction **III**.

.....

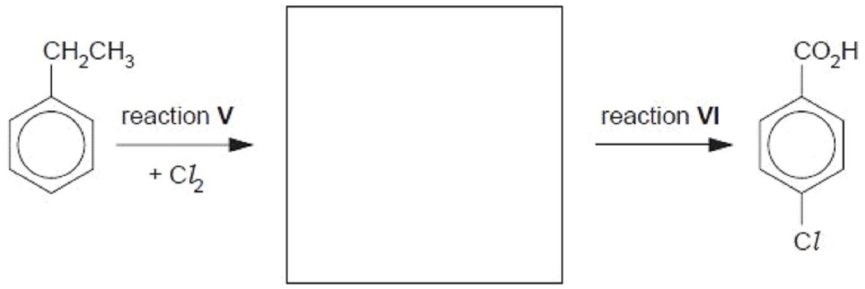
(ii) What would you see when reaction **IV** was carried out?

.....

(iii) Draw structures for **C** and **D** in the boxes above.

[4]

(c) Ethylbenzene can react with chlorine under a different set of conditions to give compound **E**, an isomer of compound **B**. Compound **E** undergoes the following reaction.



E

(i) Draw a structure for **E** in the box above.

(ii) Describe the conditions used for reaction **V**.

.....

(iii) State the reagents used for reaction **VI**.

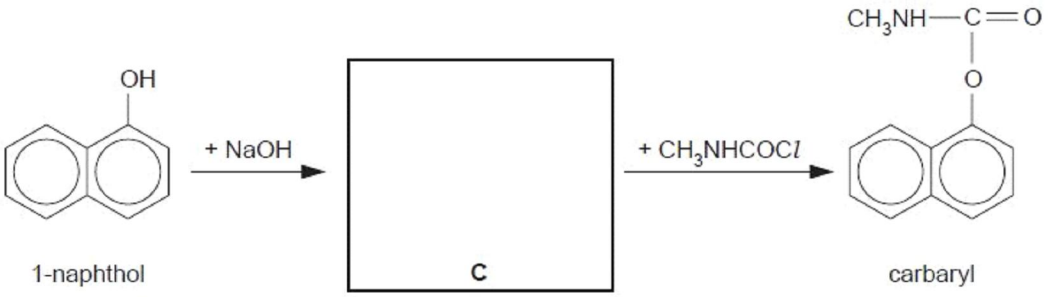
.....

[3]

[Total: 12]

Q25.

6 The phenol 1-naphthol is a starting point for the manufacture of carbaryl, an insecticide and a plant growth inhibitor.



(a) (i) Suggest a structure for the intermediate **C** and draw it in the box above.

(ii) Name the functional groups in carbaryl.

.....

.....

(iii) Suggest structures for the three products formed when carbaryl is hydrolysed.

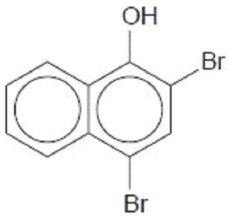
(iv) What reagents and conditions would you use for this hydrolysis?

.....

[7]

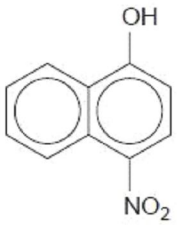
(b) Suggest reagents and conditions for converting 1-naphthol into each of the following compounds.

(i)



.....

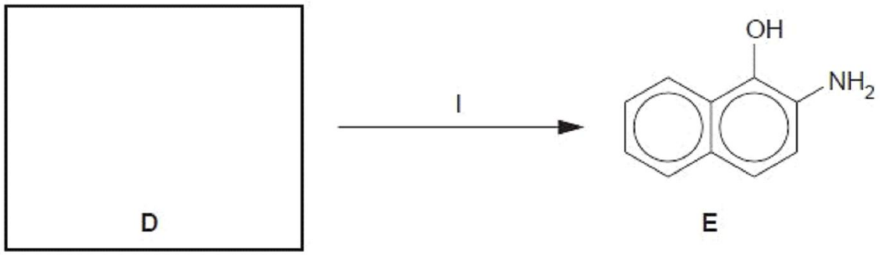
(ii)



.....

[2]

(c) Compound **D** is an isomer of 4-nitro-1-naphthol. **D** is formed as a by-product during the reaction in **b(ii)**. It can be converted into 2-amino-1-naphthol, **E**.



(i) Suggest the structural formula of the isomer **D**.

(ii) Suggest reagents needed for reaction I.

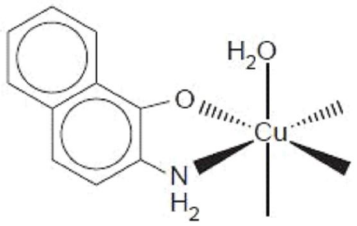
.....

(iii) Suggest the structural formula of the compound formed when compound **E** reacts with an excess of CH_3COCl.

[3]

(d) When an alkaline solution of compound **E** is added to a solution containing $Cu^{2+}(aq)$ ions, a pale green-blue precipitate **F** forms. Analysis of **F** shows that its formula is $Cu(C_{10}H_8NO)_2(H_2O)_2$.

(i) Complete the following structural formula of **F**.



When an excess of concentrated $NH_3(aq)$ is added to **F**, the precipitate dissolves to form a deep blue solution.

(ii) State the formula of the ion responsible for the deep blue colour.

.....

(iii) What type of reaction is occurring here?

.....

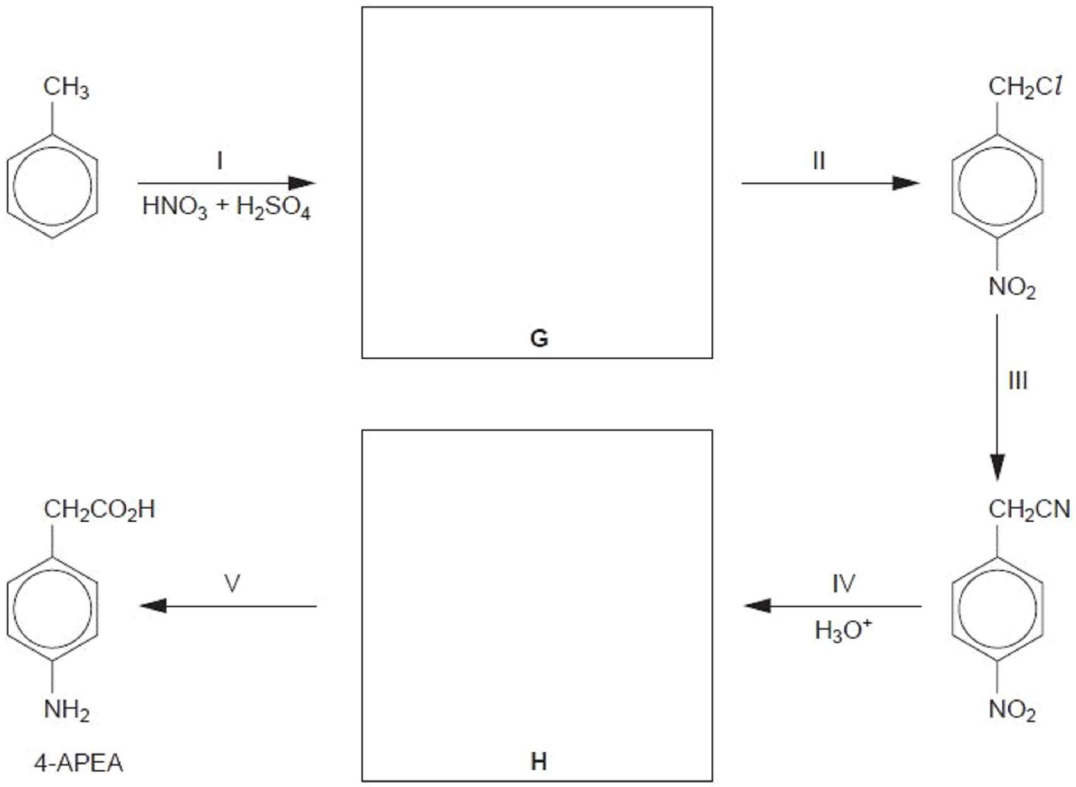
[3]

[Total: 15]

Q26.

5 (4-aminophenyl)ethanoic acid (4-APEA) and its derivatives are being investigated as possible drugs to treat chronic inflammation of the intestines.

The synthesis of 4-APEA from methylbenzene is shown in the following scheme.



(a) Draw the structures of the compounds **G** and **H** in the boxes above. [2]

(b) Suggest reagents and conditions for the following steps.

- step II

.....

- step III

.....

- step V

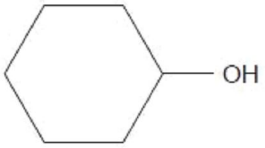
.....

[3]

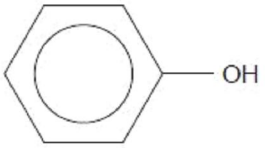
[Total: 5]

Q27.

4 Cyclohexanol and phenol are both solids with low melting points that are fairly soluble in water.



cyclohexanol



phenol

(a) Explain why these compounds are more soluble in water than their parent hydrocarbons cyclohexane and benzene.

.....

.....

..... [2]

(b) Explain why phenol is more acidic than cyclohexanol.

.....

.....

..... [2]

(c) For **each** of the following reagents, draw the structural formula of the product obtained for **each** of the two compounds. If no reaction occurs write ***no reaction*** in the box.

reagent	product with cyclohexanol	product with phenol
Na(s)		
NaOH(aq)		
$Br_2(aq)$		
$I_2(aq) + OH^-(aq)$		
an excess of acidified $Cr_2O_7^{2-}(aq)$		

[7]

(d) Choose **one** of the above five reagents that could be used to distinguish between cyclohexanol and phenol. Describe the observations you would make with each compound.

reagent .....

observation with cyclohexanol .....

observation with phenol .....

[2]

[Total: 13]

Q28.

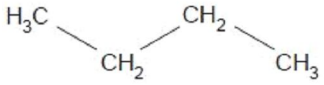
5 **(a)** All the carbon atoms in benzene lie in the same plane. This means that they are *coplanar*, but this is not the case with cyclohexane.

For Examiner's Use

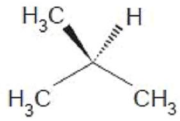
benzene

cyclohexane

By rotating the molecule around its several C–C bonds, all the carbon atoms in butane can be made to lie in the same plane, but this is not the case with methylpropane.

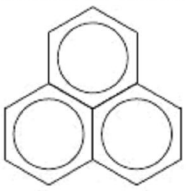


butane

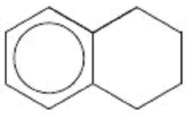


methylpropane

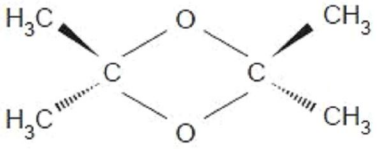
By considering the 3-dimensional geometry of the following five molecules, and allowing rotations around C–C bonds, decide whether or not the **carbon atoms** in each molecule **can be arranged** in a coplanar fashion. Then place a tick in the appropriate column in the table below.



A



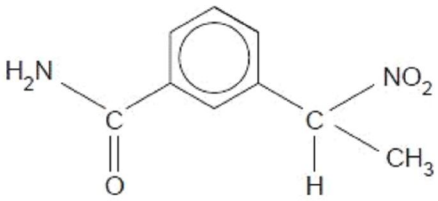
B



C

$CH_3CH(OH)CO_2H$

D



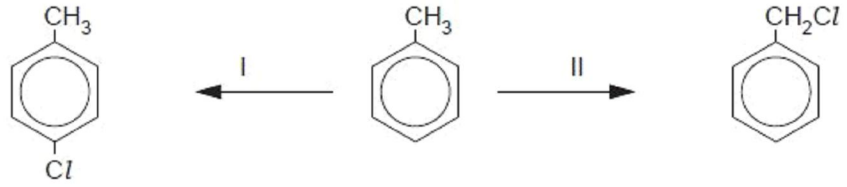
E

compound	all carbon atoms can be coplanar	not all carbon atoms can be coplanar
A		
B		
C		
D		
E		

[3]

(b) Methylbenzene can react with chlorine under different conditions to give the monochloro derivatives **F** and **G**.

For Examiner Use



F **G**

Suggest reagents and conditions for each reaction.

reaction I

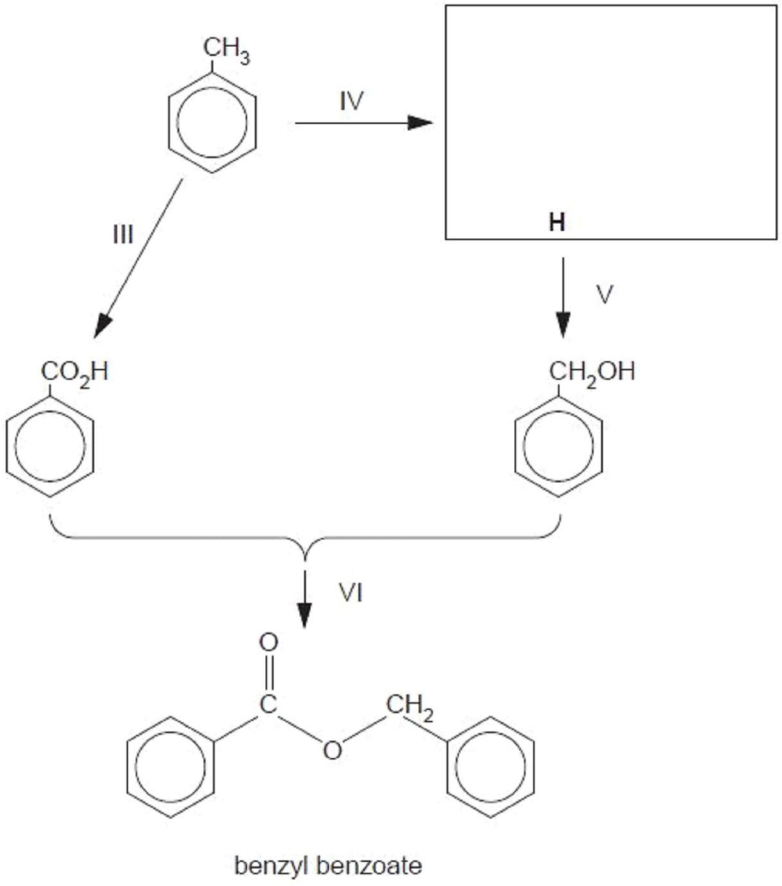
.....

reaction II

.....[2]

(c) Benzyl benzoate is a constituent of many perfumery products, and has also been used in the treatment of the skin condition known as scabies. It can be made from methylbenzene by the following route, which uses one of the chlorination reactions from **(b)**.

For Examiner's Use



benzyl benzoate

(i) Draw the structural formula of the intermediate **H** in the box above.

(ii) Suggest reagents and conditions for each reaction.

reaction III

.....

reaction V

.....

reaction VI

.....

(iii) State the type of reaction occurring during

reaction III,

.....

reaction V.

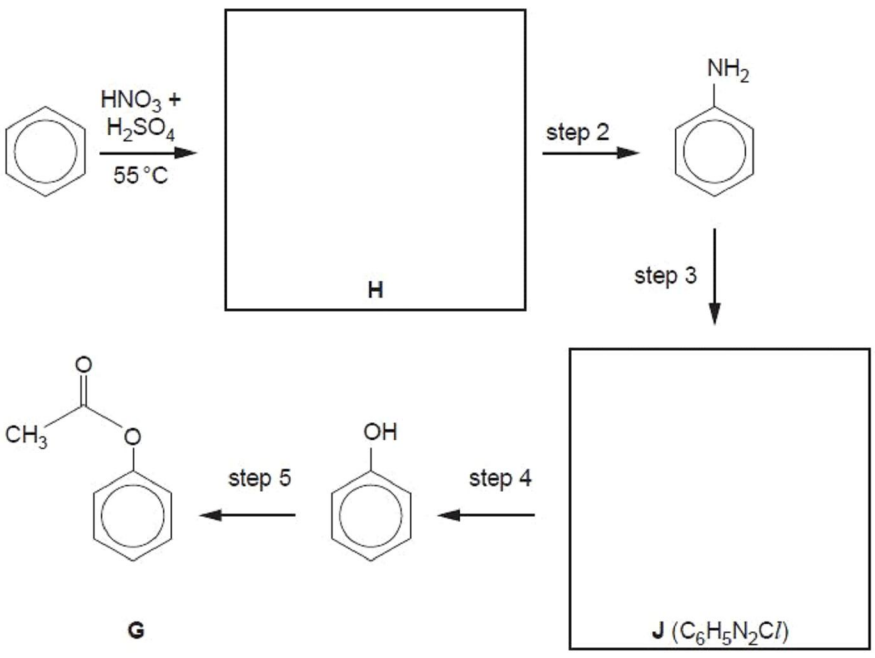
.....

[6]

[Total: 11]

Q29.

5 **(a)** Compound **G** can be synthesised from benzene by the route shown below.



(i) **Name** the functional group formed in step 5.

.....

(ii) Draw the structures of the intermediates **H** and **J** in the boxes above.

(iii) Suggest reagents and conditions for the following.

step 2 .....

step 3 .....

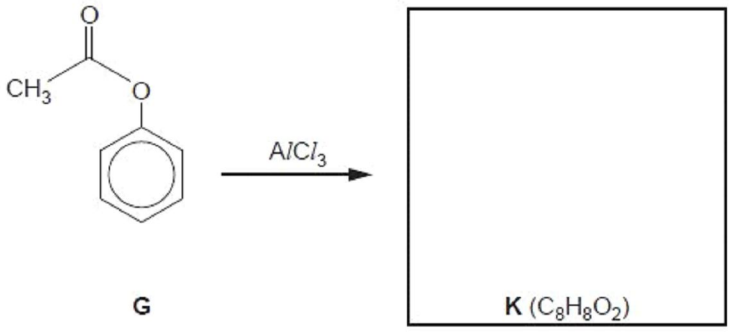
step 4 .....

step 5 .....

[7]

For Examiner's Use

(b) In a reaction discovered just over 100 years ago by the German chemist Karl Fries, compound **G** is converted into compound **K** when it is heated with $AlCl_3$. Compound **K** is a structural isomer of **G**.



G **K** ($C_8H_8O_2$)

Compound **K** is a 1,4-disubstituted benzene derivative. It is insoluble in water, but dissolves in NaOH(aq). It gives a white precipitate with Br_2(aq), and a yellow precipitate with alkaline aqueous iodine.

(i) What is meant by the term *structural isomerism*?

.....

.....

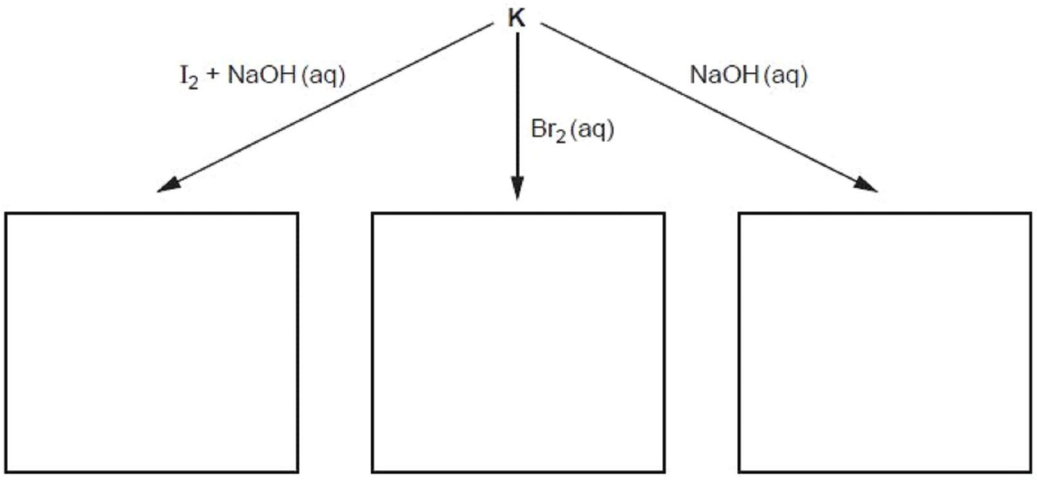
(ii) Use the information given above to **name** two functional groups in compound **K**.

.....

.....

(iii) Suggest the structural formula of **K**, and draw it in the box above.

(iv) Suggest structures for the aromatic products of the following reactions.



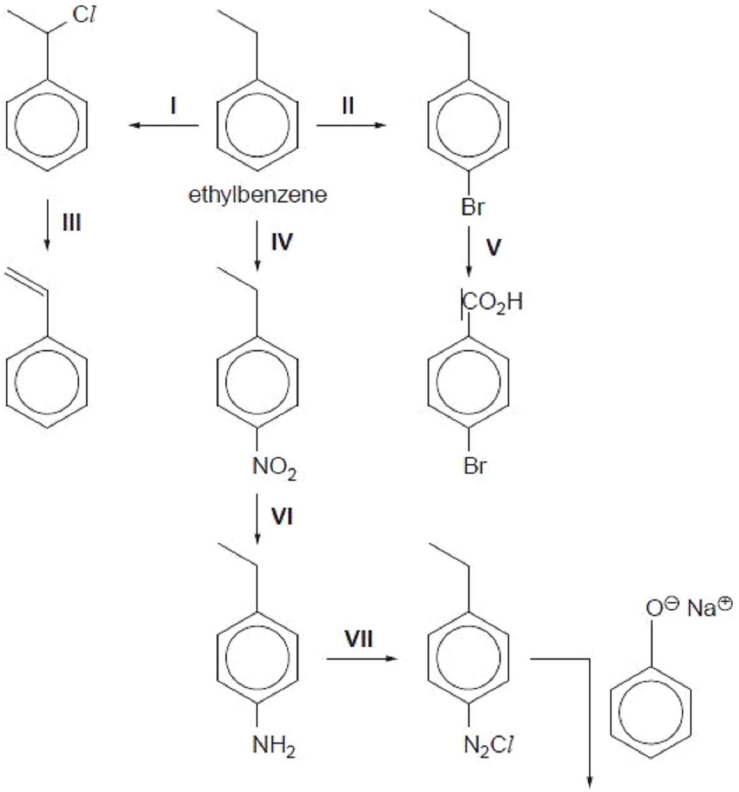
[7]

[Total: 14]

Q30.

4 The following chart shows some reactions of ethylbenzene and compounds produced from it.

For Examiner's Use



X

(i) Draw the structure of compound **X** in the box provided in the chart above.

(ii) Suggest reagents and conditions for each of the reactions, writing them in the spaces below.

For Examiner's Use

reaction I .....

reaction II .....

reaction III .....

reaction IV .....

reaction V .....

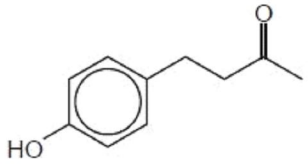
reaction VI .....

reaction VII .....

[Total: 8]

Q31.

5 Compound **G** is a naturally occurring aromatic compound that is present in raspberries.



compound **G**

(a) Identify the functional groups present in compound **G**.

.....

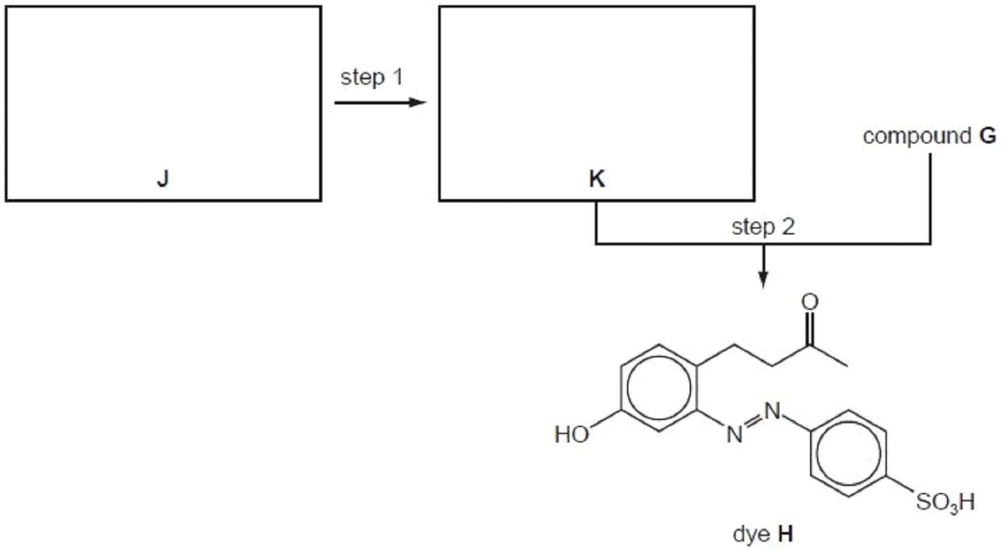
..... [2]

(b) Complete the following table with information about the reactions of the three stated reagents with compound **G**.

reagent	observation	structure of organic product	type of reaction
sodium metal			
aqueous bromine			
aqueous alkaline iodine			

[8]

(c) The dye **H** can be made from compound **G** by the route shown below.



dye **H**

(i) Draw the structures of the amine **J** and the intermediate **K** in the boxes above.

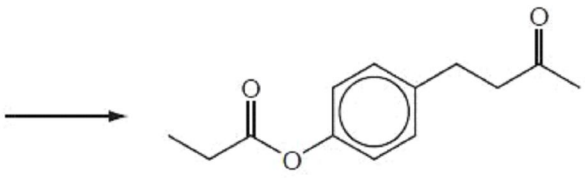
(ii) Suggest reagents and conditions for

step 1, ...

step 2. .....

[5]

(d) Suggest a reaction scheme by which compound **G** and propanoic acid could be converted into compound **L**.



compound **L**

[3]

[Total: 18]

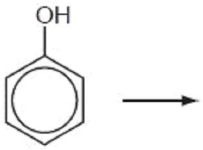
Q32.

5 **(a)** Bromine reacts with a variety of organic compounds.
For each of the following reactions,

- complete and **balance the equation**, including the structural formula of the organic product,
- state the specific conditions (if any) under which the reaction takes place and the *type of reaction* that occurs.

For Examin Use

(i) .....Br_2 +



reaction conditions .....

type of reaction .....

(ii) .....Br_2 +

reaction conditions .....

type of reaction .....

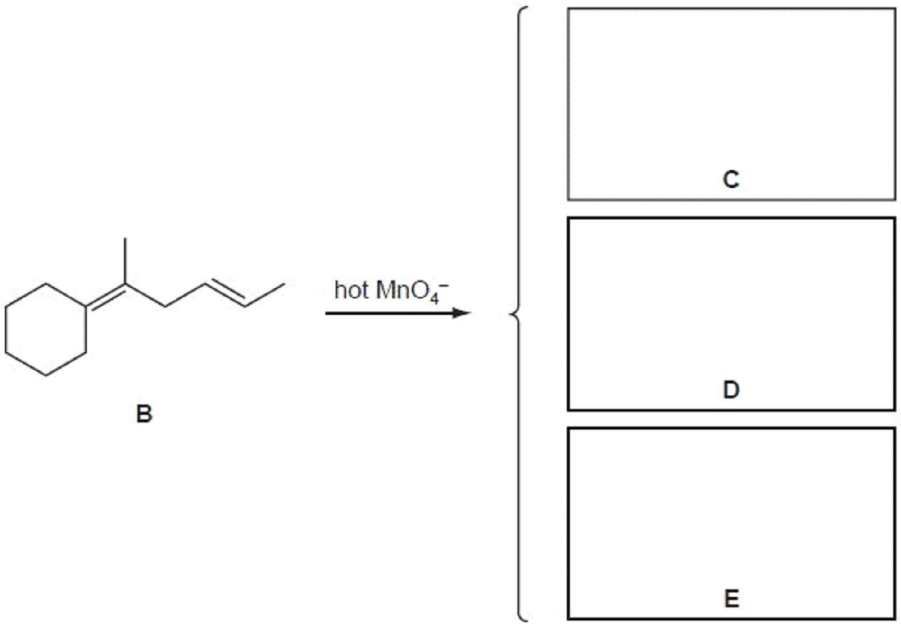
(iii) .....Br_2 +

reaction conditions .....

type of reaction .....

[10]

(b) When hydrocarbon **B** is heated with concentrated manganate(VII) ions, three organic compounds, **C**, **D** and **E**, are formed.



B

(i) Suggest the identities of compounds **C**, **D** and **E**, drawing their structures in the boxes above.

(ii) Use the relevant letter, **C**, **D** or **E**, to identify which of your compounds will react with each of the following reagents.
Each reagent may react with more than one of **C**, **D** and **E**, in which case state **all** the compounds that may react with each reagent.

- 2,4-dinitrophenylhydrazine .....
- alkaline aqueous iodine .....
- aqueous sodium hydroxide .....

[6]

[Total: 16]