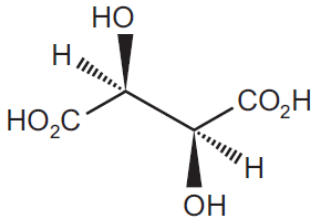
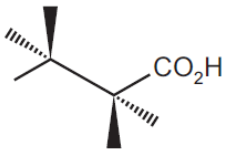
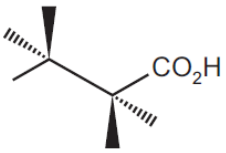
Organic Chemistry

(ii) One stereoisomer of tartaric acid is shown.



Complete the diagrams showing two other stereoisomers of tartaric acid.

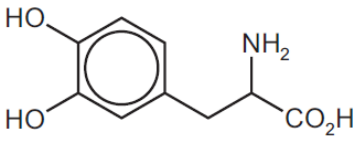




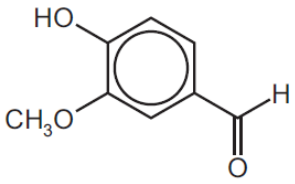
[4]

w/14/qp43

5 L-DOPA is used in the treatment of Parkinson's disease. It can be prepared from vanillin.



L-DOPA



vanillin

(a) L-DOPA and vanillin each contain an aromatic benzene ring.
Describe, with the aid of a diagram, the bonding and shape of a molecule of benzene, C_6H_6.

.....

.....

.....

.....

.....

..... [5]

(b) A student carried out some reactions with samples of L-DOPA and vanillin using reagents **X**, **Y** and **Z**.

- Reagent **X** reacted with L-DOPA **and** with vanillin.
- Reagent **Y** reacted with L-DOPA but **not** with vanillin.
- Reagent **Z** reacted with vanillin but **not** with L-DOPA.

Assume that the CH_3O– group in vanillin does not react.
Suggest possible identities of reagents **X**, **Y** and **Z** and give the structures of the organic products that were formed.

Reagent **X** .....

product with L-DOPA

product with vanillin

Reagent **Y** .....

product with L-DOPA

Reagent **Z** .....

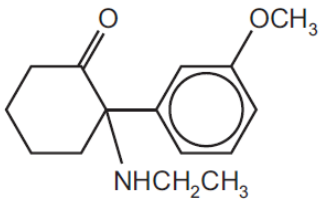
product with vanillin

[7]

[Total: 12]

w/14/qp43

6 Methoxetamine is a derivative of the pharmaceutical drug, ketamine.



methoxetamine

(a) (i) What is the molecular formula of methoxetamine?

.....

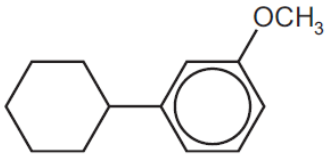
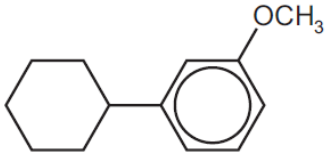
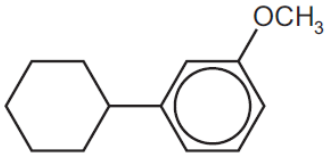
(ii) On the diagram above, **circle** any chiral centres that are present in methoxetamine.

(iii) Name **two** functional groups in methoxetamine, in addition to the aryl group.

.....

[4]

(b) In the table, complete the structure of each of the compounds formed when methoxetamine is reacted with the following reagents.
State the type of reaction in each case.

reagent	structure of product	type of reaction
(i) $LiAlH_4$		
(ii) $HCl(aq)$		
(iii) CH_3COCl		

[6]

[Total: 10]

w/14/qp43

5 **(a)** Organohalogen compounds can undergo hydrolysis.

$$R\text{–}Cl + H_2O \rightarrow R\text{–}OH + HCl$$

State the relative rates of hydrolysis of the following compounds.

$CH_3CH_2CH_2Cl$ CH_3CH_2COCl C_6H_5Cl

Explain your answer.

.....

.....

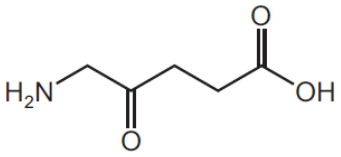
.....

.....

.....

..... [3]

(b) Aminolaevulinic acid is involved in the synthesis of haemoglobin and chlorophyll.



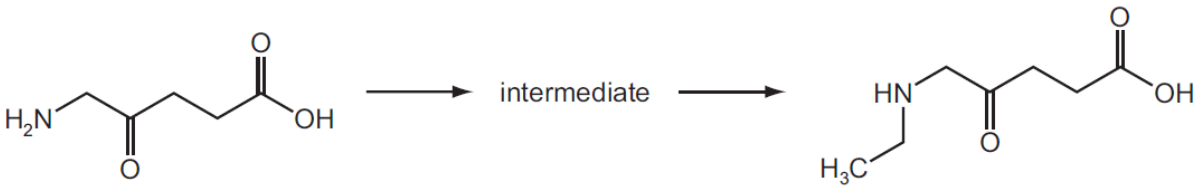
aminolaevulinic acid

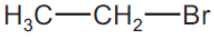
Name the **three** functional groups in aminolaevulinic acid.

..... [2]

(c) Aminolaevulinic acid reacts readily with bromoethane.

(i) Show the mechanism of the **first step** of this reaction on the diagram. Include all necessary curly arrows, lone pairs and relevant dipoles.





(ii) Name the mechanism in **(c)(i)**.

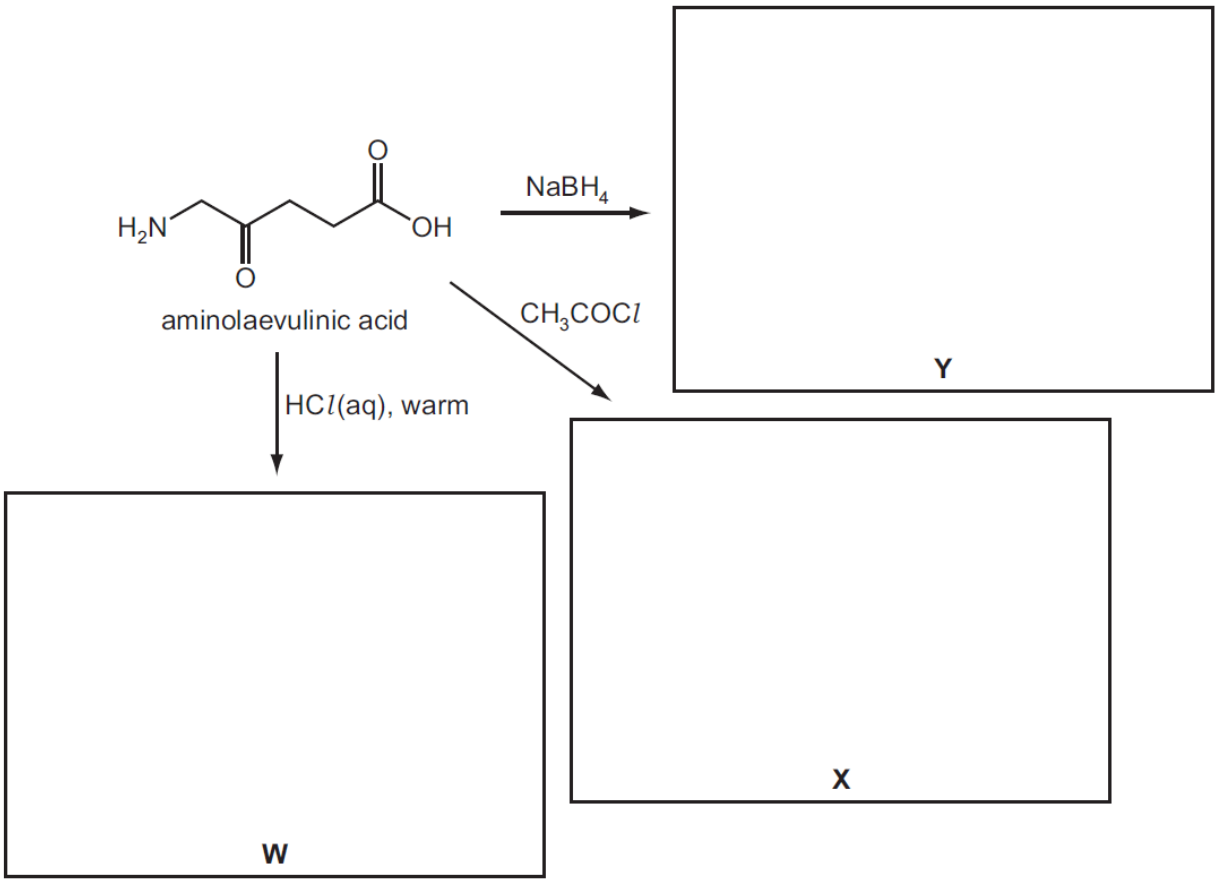
.....

(iii) Identify the non-organic product formed in this reaction.

.....

[5]

(d) Three reactions of aminolaevulinic acid are shown. Draw the structures of the products **W**, **X** and **Y** in the boxes below.



[3]

(e) Aminolaevulinic acid can undergo polymerisation.

Draw the structure of the polymer showing **two** repeat units. The linkages between the monomer units should be shown fully displayed.

[2]

[Total: 15]

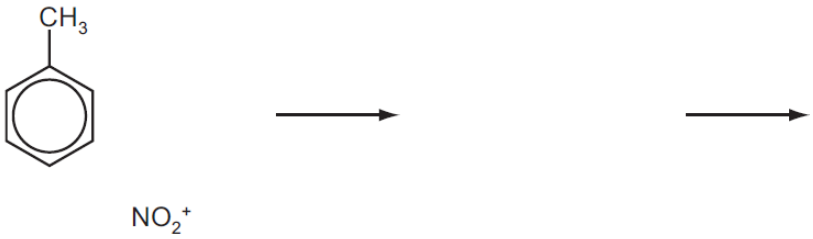
w/14/qp41

4 **(a)** Methylbenzene undergoes electrophilic substitution with nitronium ions, NO_2^+.
Nitronium ions are generated by the reaction between concentrated sulfuric acid and concentrated nitric acid.

(i) Construct an equation for the formation of nitronium ions, NO_2^+, by this method.

.....

(ii) Complete the scheme to show the mechanism for this reaction. Use curly arrows to show the movement of electron pairs.



[4]

(b) **(i)** Describe and explain the relative acidities of chloroethanoic acid and ethanoic acid.

.....

.....

.....

(ii) Describe and explain the relative acidities of phenol and ethanol.

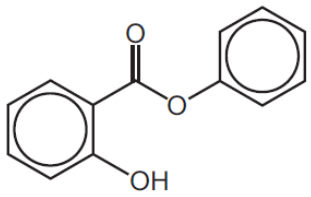
.....

.....

.....

[3]

(c) Phenyl 2-hydroxybenzoate is an antiseptic.



phenyl 2-hydroxybenzoate

Complete the following table about the reactions of phenyl 2-hydroxybenzoate with the three reagents.

reagent	structure of product(s)		type of reaction
Na			
excess $Br_2(aq)$			
excess hot NaOH(aq)			

[6]

[Total: 13]

w/14/qp41

6 Naturally-occurring α-amino acids, $RCH(NH_2)CO_2H$, can be classified as *amphiprotic* substances. An amphiprotic substance is one which can act as both a Brønsted-Lowry acid and base.

α-amino acid	R group
alanine	CH_3–
aspartic acid	HO_2CCH_2–
glycine	H–
lysine	$H_2N(CH_2)_4$–
threonine	$CH_3CH(OH)$–
serine	$HOCH_2$–

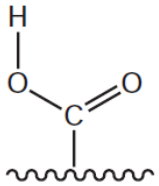
(a) What is the Brønsted-Lowry definition of an acid?

.....

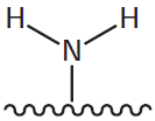
.....

[1]

(b) **(i)** All α-amino acids are soluble in water since they can form hydrogen bonds with water molecules and can also exist as zwitterions.
Draw diagrams to show how the carboxylic acid and amino groups of alanine can form hydrogen bonds with water molecules.



carboxylic acid



amino group

(ii) Draw the structure of the zwitterionic form of glycine.

[5]

(c) The amino acid alanine can be formed by the reaction of $CH_3CHClCO_2H$ with an excess of ammonia.
Outline a mechanism for this reaction using curly arrows.

[3]

(d) Amino acids can form different ions at different pH values.
Suggest the structures of the ions formed from the α-amino acids below at the respective pH value.

lysine at pH 1	aspartic acid at pH 14

[2]

(e) **(i)** How many different **di**peptides is it possible to synthesise, each containing two of the three amino acids alanine, serine and lysine?

.....

(ii) Write the structural formula of one of these dipeptides incorporating serine and alanine.

[3]

(f) Most naturally-occurring amino acids have a chiral centre and exhibit stereoisomerism.

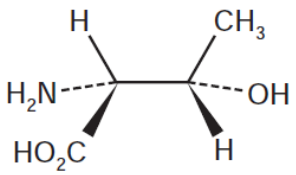
(i) Define the term *stereoisomerism*.

.....

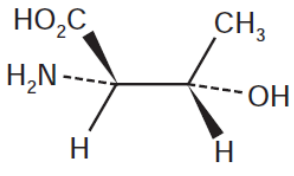
.....

There are **four** optical isomers of threonine.

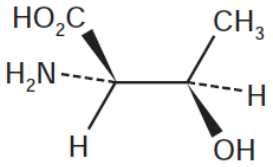
Some of these optical isomers are drawn below.



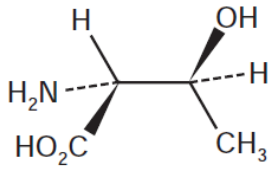
F



G



H



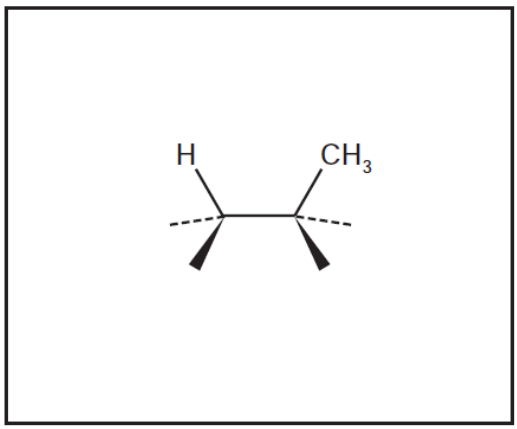
J

When answering this question, remember that completely free rotation about a C–C single bond occurs in these compounds.

(ii) Which of the structures **G**, **H** or **J** is identical to structure **F**? .....

(iii) The other two of the structures **G**, **H** or **J** represent **two** of the **three** other possible optical isomers of threonine.

Complete the following partial structure of the **fourth** optical isomer.



[3]

[Total: 17]

w/13/qp43

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

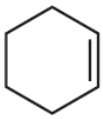
- complete and **balance the equation**, including the structural formula of the organic product,
- state the specific conditions (if any) under which the reaction takes place and the *type of reaction* that occurs.

(i) .....Br_2 + 

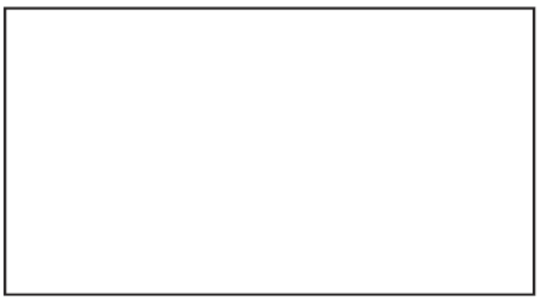
reaction conditions .....

type of reaction .....

(ii) .....Br_2 +  

reaction conditions .....

type of reaction .....

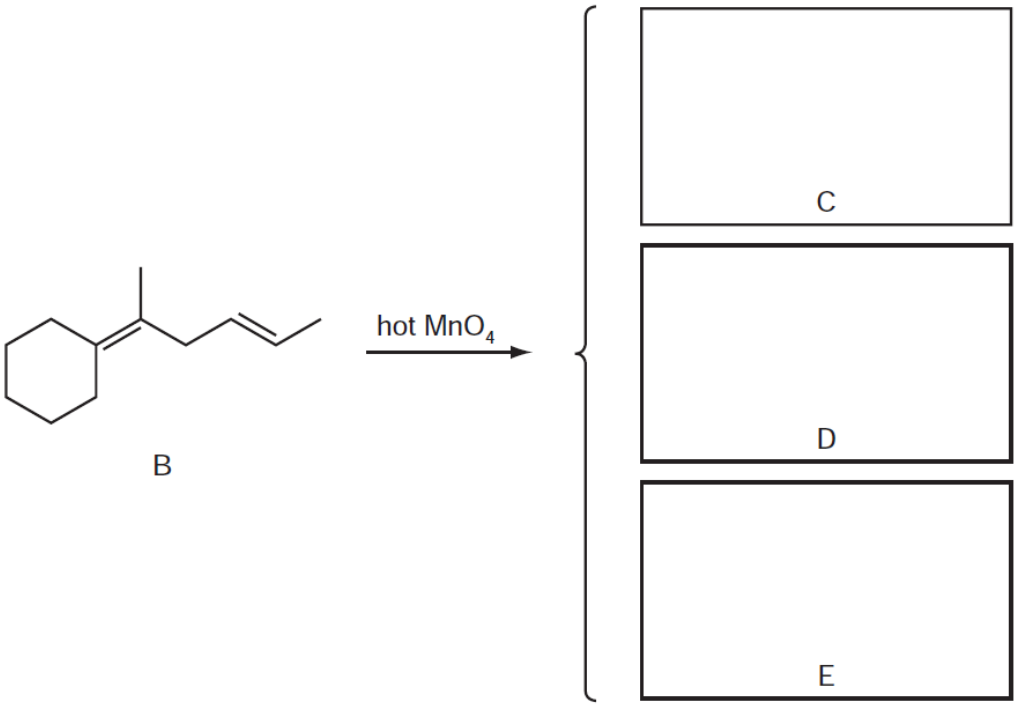
(iii) .....Br_2 +  

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.



(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.

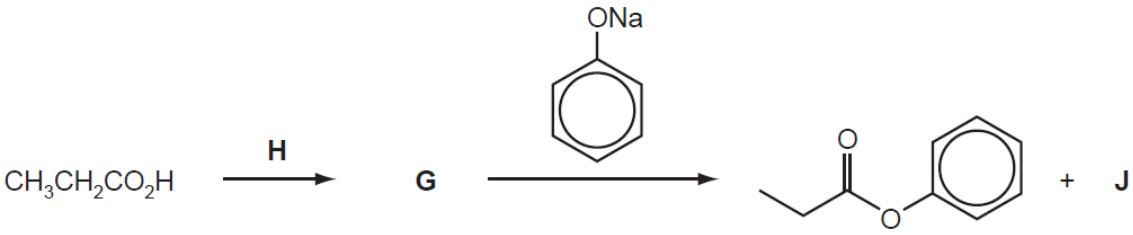
- 2,4-dinitrophenylhydrazine .....
- alkaline aqueous iodine .....
- aqueous sodium hydroxide .....

[6]

[Total: 16]

w/13/qp43

(e) Phenyl propanoate cannot be made directly from propanoic acid and phenol.
Suggest the identities of the intermediate **G**, the reagent **H** and the by-product **J** in the following reaction scheme.



G is .....

H is .....

J is .....

[2]

w/13/qp41

4 **(a)** Explain what is meant by the term *bond energy*.

.....

.....

[2]

(b) **(i)** Describe and explain the trend in bond energies of the C–X bond in halogenoalkanes, where X = F, C*l*, Br or I.

.....

.....

(ii) Describe the relationship between the reactivity of halogenoalkanes, RX, and the bond energies of the C–X bond.

.....

.....

[3]

(c) Use the *Data Booklet* to suggest an explanation as to why CFCs such as CF_2Cl_2 are much more harmful to the ozone layer than fluorocarbons such as CF_4 or hydrocarbons such as butane, C_4H_{10}.

.....

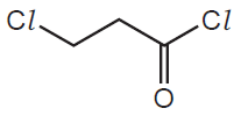
.....

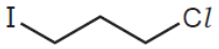
.....

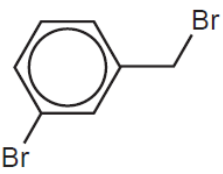
.....

[3]

(d) Predict the products of the following reactions and draw their structures in the boxes below. The molecular formula of each product is given, where X = C*l*, Br or I.

H_2O +  → $C_3H_5O_2X$

H_2O +  → C_3H_7OX

H_2O +  → C_7H_7OX

[3]

(e) Ethane reacts with chlorine according to the following equation.

$$C_2H_6 + Cl_2 \rightarrow C_2H_5Cl + HCl$$

(i) State the conditions needed for this reaction.

.....

(ii) State the *type of reaction* occurring here.

.....

One of the steps during this reaction is the following process.

$$Cl^{\bullet} + CH_3CH_3 \rightarrow HCl + CH_3CH_2^{\bullet}$$

(iii) Use the *Data Booklet* to calculate the enthalpy change, ΔH, of this step.

ΔH = ... kJ mol^{-1}

(iv) Use the *Data Booklet* to calculate the enthalpy change, ΔH, of the similar reaction:

$$I^{\bullet} + CH_3CH_3 \rightarrow HI + CH_3CH_2^{\bullet}$$

ΔH = ... kJ mol^{-1}

(v) Hence suggest why it is **not** possible to make iodoethane by reacting together iodine and ethane.

.....

(vi) Complete the following equations of some possible steps in the formation of chloroethane.

$Cl_2 \rightarrow$ .....

$Cl^{\bullet} + CH_3CH_3 \rightarrow HCl + CH_3CH_2^{\bullet}$

$CH_3CH_2^{\bullet}$ + ... → ..... + ...

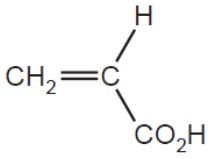
..... + ... → CH_3CH_2Cl

[8]

[Total: 19]

w/13/qp41

5 Super-absorbent polymers have the ability to absorb 200-300 times their own mass of water. They are classified as hydrogels and they are widely used in personal disposable hygiene products such as babies' nappies (diapers).
These polymers are commonly made by the polymerisation of compound **K** mixed with sodium hydroxide in the presence of an initiator.



K

(a) (i) Explain what is meant by the term *polymerisation*.

.....

.....

(ii) What type of polymerisation is involved in the formation of hydrogels?

.....

(iii) Describe the changes in chemical bonding that occur during the polymerisation of **K**.

.....

.....

[3]

(b) *Acrylic acid* is the common name for compound **K**.
Suggest the systematic (chemical) name of **K**.

.....

[1]

(c) (i) Draw the structure of at least **two** repeat units of the polymer formed by the above method from acrylic acid, **K**, when mixed with NaOH.

(ii) The C–C–C bond angle in compound **K** changes when the polymer is formed.
State and explain how the C–C–C bond angle differs between a molecule of **K** and the polymer.

angle changes from ..... to .....

explanation .....

.....

[4]

(d) **(i)** Draw a detailed diagram of a portion of the polymer you have drawn in **(c)(i)** to explain how it can absorb a large volume of water.

(ii) A student added 0.10 g of the polymer to 10 cm^3 of aqueous copper(II) sulfate solution.
Predict, with a reason, what you expect to observe.

.....

.....

[4]

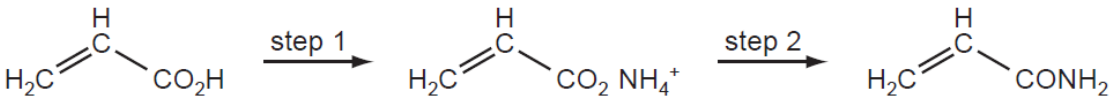
(e) Compound **L**, CH_2=CHCONH$_2$, can also be polymerised to form a super-absorbent polymer.

(i) Name the **two** functional groups in compound **L**.

.....

.....

Compound **K** can be converted into compound **L** by the following two-step route.



K **L**

(ii) Suggest a reagent for step 1.

.....

(iii) What other product is formed in step 2?

.....

(iv) State the reagents and conditions necessary to re-form **K** from **L**.

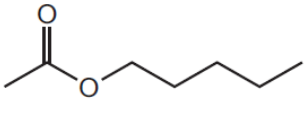
.....

[5]

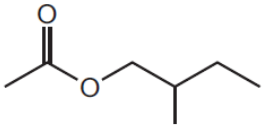
[Total: 17]

w/13/qp41

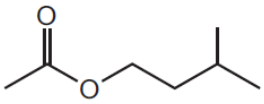
3 The following four isomeric esters with the molecular formula $C_7H_{14}O_2$ are used as artificial flavours in drinks and sweets to give a pear, banana or plum taste to foodstuffs.



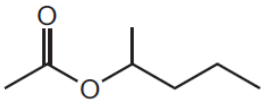
A



B



C



D

(a) In each of the spaces below, write one or more of the letters **A-D**, as appropriate.

(i) Which of these compounds can exist as optical isomers?

.....

(ii) On hydrolysis, which of these compounds produce(s) a secondary alcohol?

.....

[3]

(b) The hydrolysis of all these compounds produces ethanoic acid, CH_3CO_2H, as one of the products.

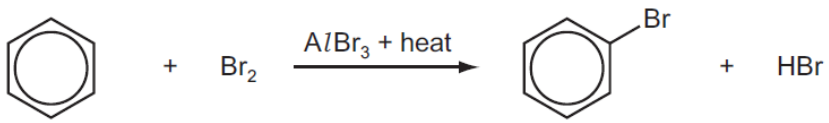
State the reagents and conditions needed for this hydrolysis.

..... [1]

s/14/qp42

4 Both ethene and benzene react with bromine.

$$H_2C{=}CH_2 + Br_2 \xrightarrow[\text{temperature}]{\text{room}} BrCH_2CH_2Br$$



(a) What *type of reaction* is the reaction of bromine with

(i) ethene,

.....

(ii) benzene?

.....

[1]

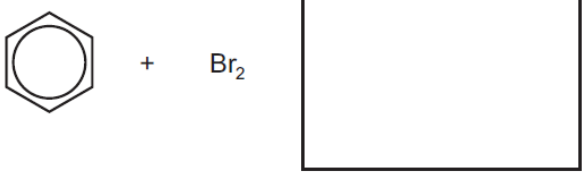
(b) Write an equation to show the formation of the electrophile during the reaction between bromine and benzene.

..... [1]

(c) Each of these reactions involves an intermediate.

(i) Draw the structure of the intermediate in each reaction.

$$H_2C{=}CH_2 + Br_2 \rightarrow$$



(ii) Suggest why the product of the reaction between bromine and benzene, bromobenzene, is still unsaturated.

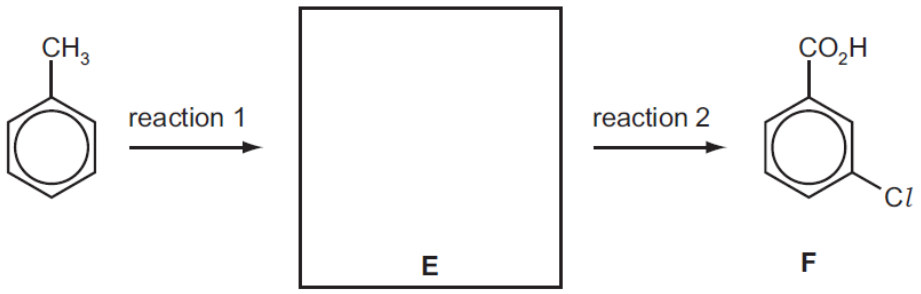
.....

[3]

(d) When methylbenzene is nitrated, 4-nitromethylbenzene is formed, but when benzoic acid is nitrated, 3-nitrobenzoic acid is produced.

Consider the following synthesis of 3-chlorobenzoic acid, **F**, from methylbenzene.
Use the information given above to suggest

- the structure of the intermediate **E**,
- the reagents and conditions needed for reactions 1 and 2.



reagents and conditions for reaction 1

.....

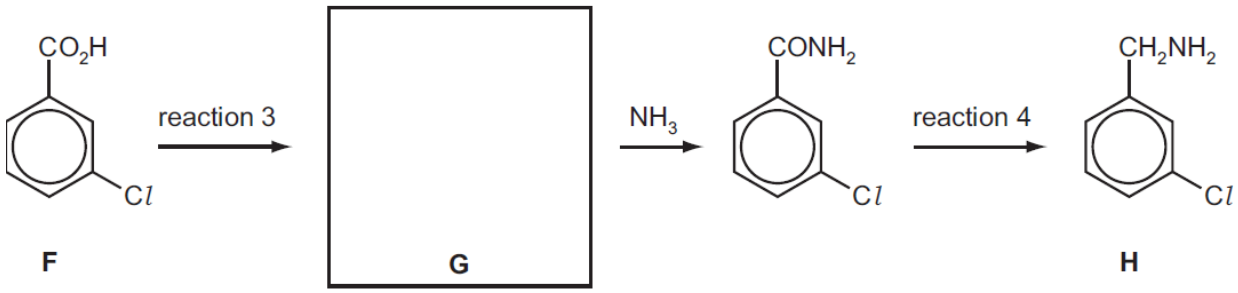
reagents and conditions for reaction 2

.....

[3]

(e) Consider the following synthesis of 3-chlorophenylmethylamine, **H**, from **F**.
Suggest

- the structure of the intermediate **G**,
- the reagents for reactions 3 and 4.



reagents for reaction 3

.....

reagents for reaction 4

.....

[3]

[Total: 11]

s/14/qp42

5 Although now remembered for his music, the Russian composer Alexander Borodin was a chemist. He is credited with the discovery of the *aldol reaction*, a product of which is compound **J**. **J** shows the following properties:

- its molecular formula is $C_4H_8O_2$,
- it is neutral,
- it reacts with sodium metal,
- it reacts with Fehling's solution,
- it does not react with aqueous bromine.

(a) Suggest which functional groups are responsible for the reactions with

(i) sodium,

.....

(ii) Fehling's solution.

.....

[2]

(b) The result of the bromine test shows a functional group is absent from compound **J**. Suggest the identity of this functional group.

..... [1]

(c) In the boxes below, draw three possible **straight-chain** structures for **J** that fit the above results, and that are structural isomers of each other.

K

L

M

[3]

(d) Compound **J** reacts with alkaline aqueous iodine to give a pale yellow precipitate.

(i) Which functional group does this reaction show that **J** contains?

.....

(ii) Which of your three structures **K**, **L** or **M** contains this group and is therefore **J**?

.....

[2]

(e) Compound **J** exists as stereoisomers.

(i) Name the type of stereoisomerism shown by **J**.

.....

(ii) Draw two structures of **J** to illustrate this stereoisomerism.

[2]

[Total: 10]

s/14/qp42

8 Polymers consist of monomers joined by either addition or condensation reactions.

(a) Name an example of a synthetic addition polymer and a synthetic condensation polymer.

addition polymer .....

condensation polymer .....

[2]

(b) Addition polymers are long-term pollutants in the environment but condensation polymers are often biodegradable.

(i) What *type of reaction* occurs when condensation polymers biodegrade?

.....

(ii) Identify **two** functional groups that could undergo this type of reaction.

.....

[2]

(c) Petroleum is a non-renewable resource from which a wide range of useful polymers is currently produced. Current polymer research is looking at renewable plant material as a potential source of monomers.

Two monomers obtained from plants are shown.

$CH_3CH(OH)COOH$ $HOCH_2COOH$

Draw the displayed formula of the repeat unit of a polymer using **both** monomers.

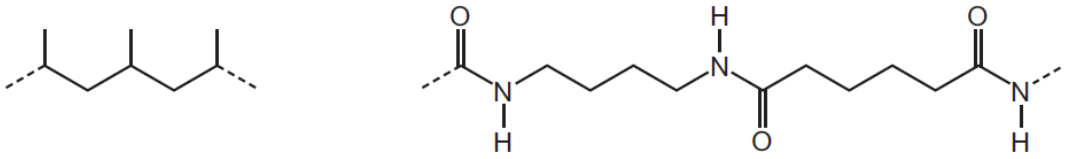
[2]

(d) Monomers obtained from plant sources do not usually form addition polymers.
Suggest why this is.

.....

..... [1]

(e) The diagrams show sections of two polymers **Y** and **Z**.



Y **Z**

(i) What would be the main force between the chains in each polymer?

Y .....

Z .....

(ii) Which is likely to be the more hydrophilic of these two polymers? Explain your answer.

.....

.....

[3]

[Total: 10]

s/14/qp42

5 The two compounds **V** and **W** are isomers with the molecular formula C_4H_8O, and show the following properties and reactions.

- Both compounds react with sodium metal, and both decolourise bromine water.
- Compound **V** forms a yellow precipitate with alkaline aqueous iodine, whereas compound **W** does not.
- When reacted with cold $KMnO_4(aq)$, both **V** and **W** produce the same neutral compound **X**, $C_4H_{10}O_3$.
- Both **V** and **W** exist as pairs of stereoisomers.

(a) Suggest which functional groups are responsible for the reactions with

(i) sodium,

.....

(ii) bromine water,

.....

(iii) alkaline aqueous iodine.

.....

[3]

(b) Suggest structures for **V** and **W**.

V

W

[2]

(c) State the type of stereoisomerism shown by compound **V** and draw the structures of the stereoisomers.

type of stereoisomerism .....

structures of stereoisomers

isomer 1

isomer 2

[2]

(d) Suggest the structure of the neutral compound **X**.

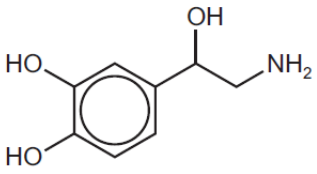
X

[1]

[Total: 8]

s/14/qp41

4 Noradrenaline is a hormone and neurotransmitter, which is released during stress to stimulate the heart and increase blood pressure.



noradrenaline

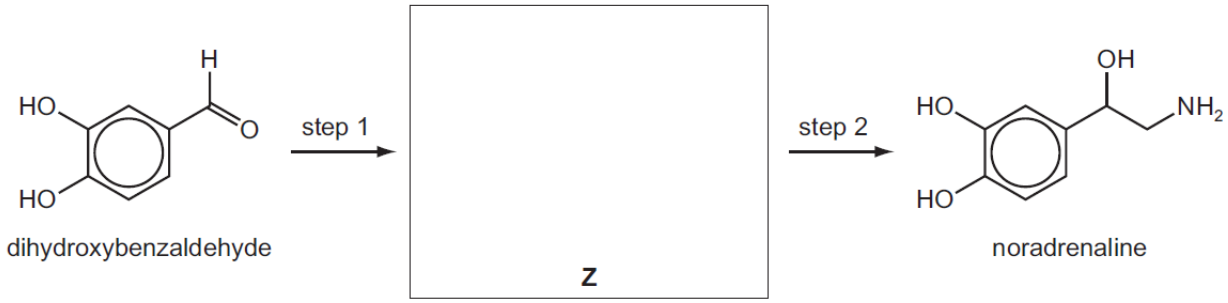
(a) State the **names** of **three** functional groups in the noradrenaline molecule.

.....

.....

..... [3]

(b) **(i)** Consider the following two-stage synthesis of noradrenaline from dihydroxybenzaldehyde.



dihydroxybenzaldehyde

noradrenaline

- Draw the structure of the intermediate **Z** in the box.
- Suggest reagents for steps 1 and 2.

step 1 .....

step 2 .....

(ii) Dihydroxybenzaldehyde reacts with $Br_2(aq)$.

- Describe what you would see during this reaction.

.....

- Draw the structure of the product.

[5]

(c) Draw the structures of the products when noradrenaline is reacted with

(i) dilute NaOH(aq),

(ii) dilute HC*l*(aq),

(iii) an excess of ethanoyl chloride, CH_3COCl.

[4]

(d) Name the **new** functional groups formed in the reaction in **(c)(iii)**.

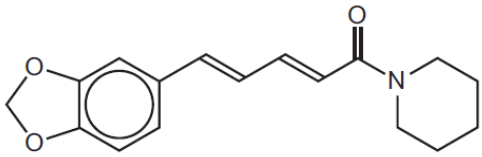
.....

..... [2]

[Total: 14]

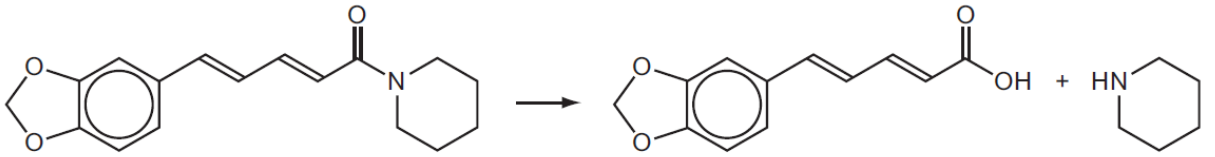
s/14/qp41

3 Piperine is the compound responsible for the hot taste of black pepper.



piperine

Piperine is an amide and can be broken down as follows:



piperine piperic acid piperidine

(a) Suggest reagents and conditions for this reaction.

..... [1]

(b) **(i)** How many stereoisomers are there with the same structural formula as piperic acid (including piperic acid itself)?

.....

(ii) Draw the skeletal structure of a stereoisomer of piperic acid, different to the one shown above.

(iii) Suggest structures for the compounds that would be formed when piperic acid is treated with an **excess** of hot concentrated acidified $KMnO_4$.

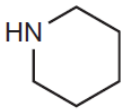
[4]

(c) **(i)** Write the expression for K_w.

.....

(ii) Use your expression and the value of K_w in the *Data Booklet* to calculate the pH of 0.150 mol dm^{-3} NaOH(aq).

(iii) The pH of a 0.150 mol dm^{-3} solution of piperidine is 11.9.



piperidine

Suggest why this answer differs from your answer in **(c)(ii)**.

.....

.....

(iv) How would you expect the basicity of piperidine to compare to that of ammonia? Explain your reasoning.

.....

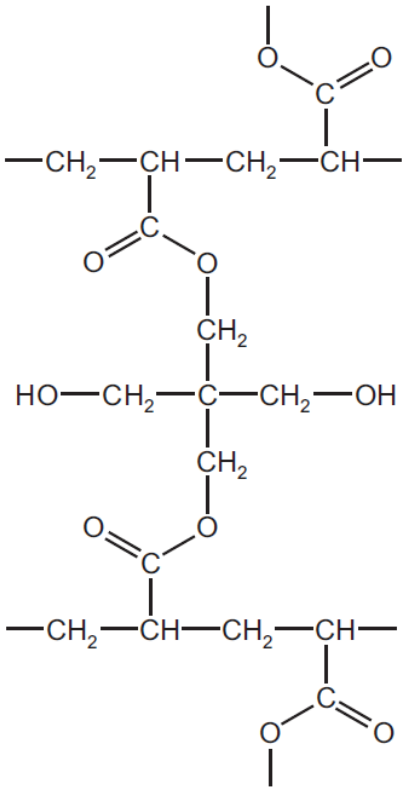
.....

[5]

s/14/qp41

8 In recent years there has been considerable interest in a range of polymers known as 'hydrogels'. These polymers are hydrophilic and can absorb large quantities of water.

(a) The diagram shows part of the structure of a hydrogel.



The hydrogel is formed from chains of one polymer which are cross-linked using another molecule.

(i) Draw the structure of the monomer used in the polymer chains.

(ii) State the type of polymerisation used to form these chains.

.....

.....

(iii) Draw the structure of the molecule used to cross-link the polymer chains.

(iv) During the cross-linking, a small molecule is formed as a by-product. Identify this molecule.

.....

[5]

(b) Once a hydrogel has absorbed water, it can be dried and re-used many times. Explain why this is possible, referring to the structure on the opposite page.

.....

.....

.....

[2]

(c) Not every available side chain in the polymer is cross-linked, and the amount of cross-linking affects the properties of the hydrogel.

(i) The amount of cross-linking has little effect on the ability of the gel to absorb water. Suggest why this is the case.

.....

.....

.....

(ii) Suggest **one** property of the hydrogel that will change if more cross-linking takes place. Explain how the increased cross-linking brings about this change.

.....

.....

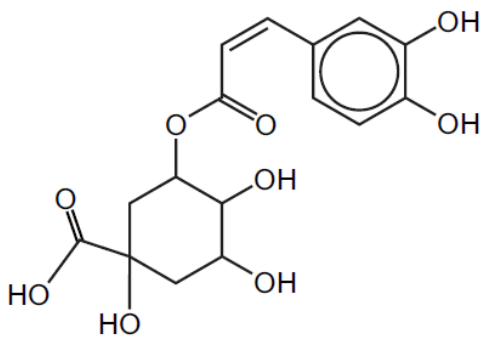
.....

[3]

[Total: 10]

s/13/qp42

5 Coffee beans contain chlorogenic acid.



chlorogenic acid

(a) (i) Draw circles around any chiral centres in the above structure.

(ii) Write down the molecular formula of chlorogenic acid.

.....

(iii) How many moles of $H_2(g)$ will be evolved when 1 mol of chlorogenic acid reacts with an excess of sodium metal?

.....

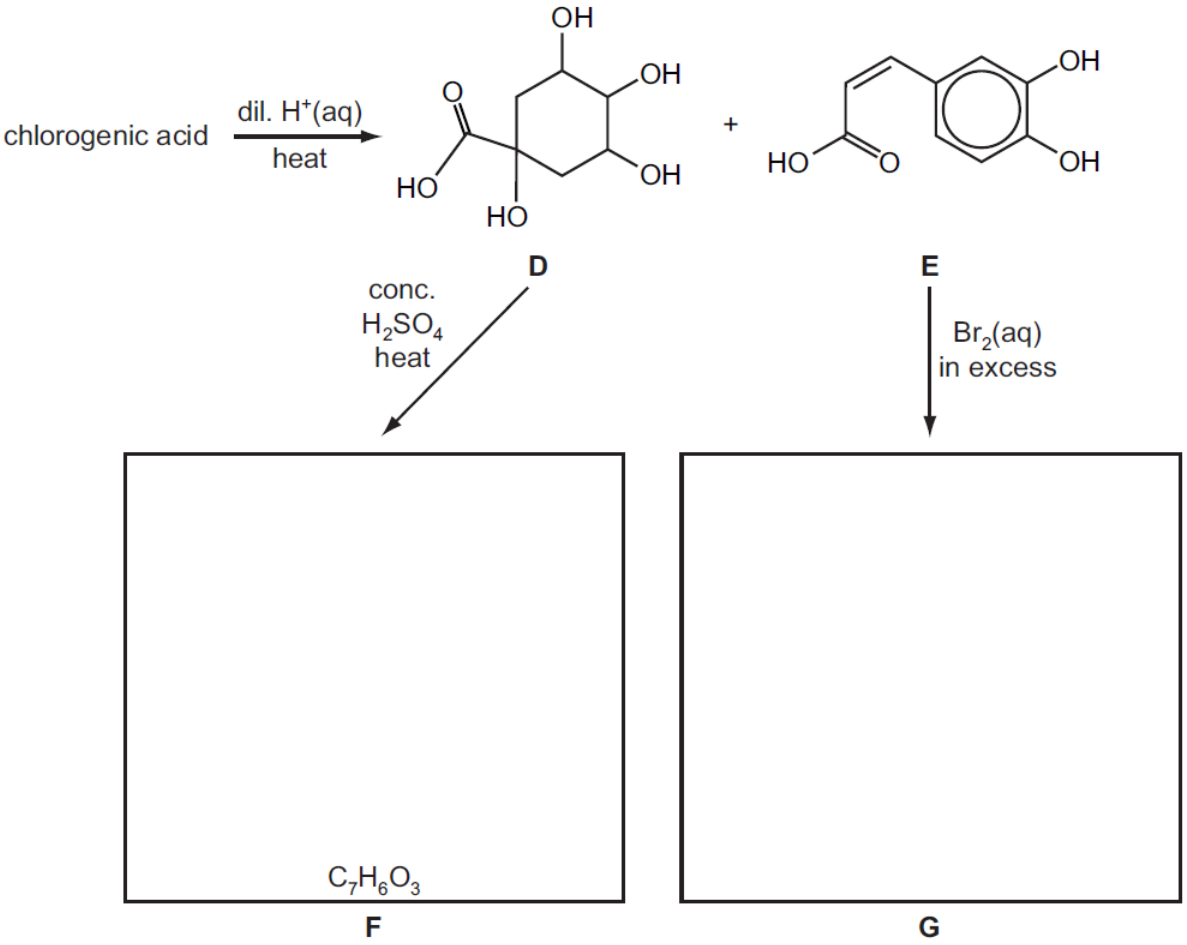
(iv) How many moles of NaOH(aq) will react with 1 mol of chlorogenic acid under each of the following conditions?

in the cold .....

on heating .....

[6]

(b) On heating with dilute aqueous acid, chlorogenic acid produces two compounds, **D** and **E**.



(i) What *type of reaction* is chlorogenic acid undergoing when **D** and **E** are formed?

.....

When compound **D** is heated with concentrated H_2SO_4, compound **F**, $C_7H_6O_3$, is formed.

Compound **F** evolves $CO_2(g)$ when treated with $Na_2CO_3(aq)$, and decolourises $Br_2(aq)$, giving a white precipitate. It does not, however, decolourise cold dilute acidified $KMnO_4$.

When compound **E** is treated with an excess of $Br_2(aq)$, compound **G** is produced.

(ii) If the test with cold dilute acidified $KMnO_4$ had been positive, which functional group would this have shown to be present in **F**?

.....

(iii) **Name** the functional groups in compound **F** that would react with the following.

$Na_2CO_3(aq)$ ..... $Br_2(aq)$ .....

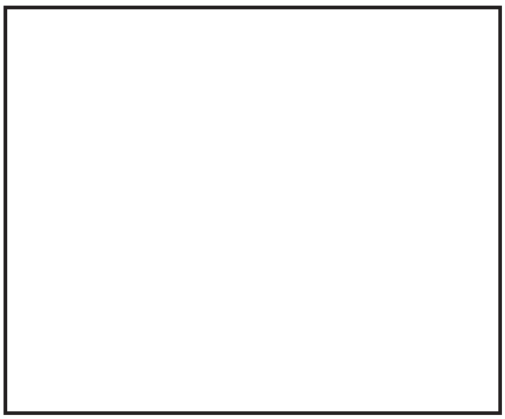
(iv) Suggest structures for compounds **F** and **G** and draw them in the relevant boxes above.

(v) Compound **E** is one of a pair of stereoisomers.

What type of stereoisomerism is shown by compound **E**?

.....

(vi) Draw the structure of the other stereoisomer in the box below.



[8]

(c) Calculate the volume of 0.1 mol dm^{-3} NaOH that is needed to react completely with 0.1 g of compound **E**.

volume = ... cm^3
[3]

[Total: 17]

s/13/qp42

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

(i) methylbenzene 

.....

(ii) phenol 

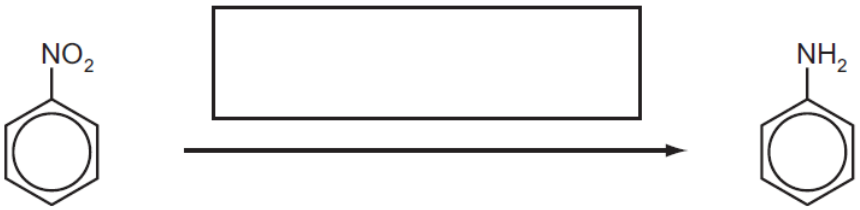
.....

[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.

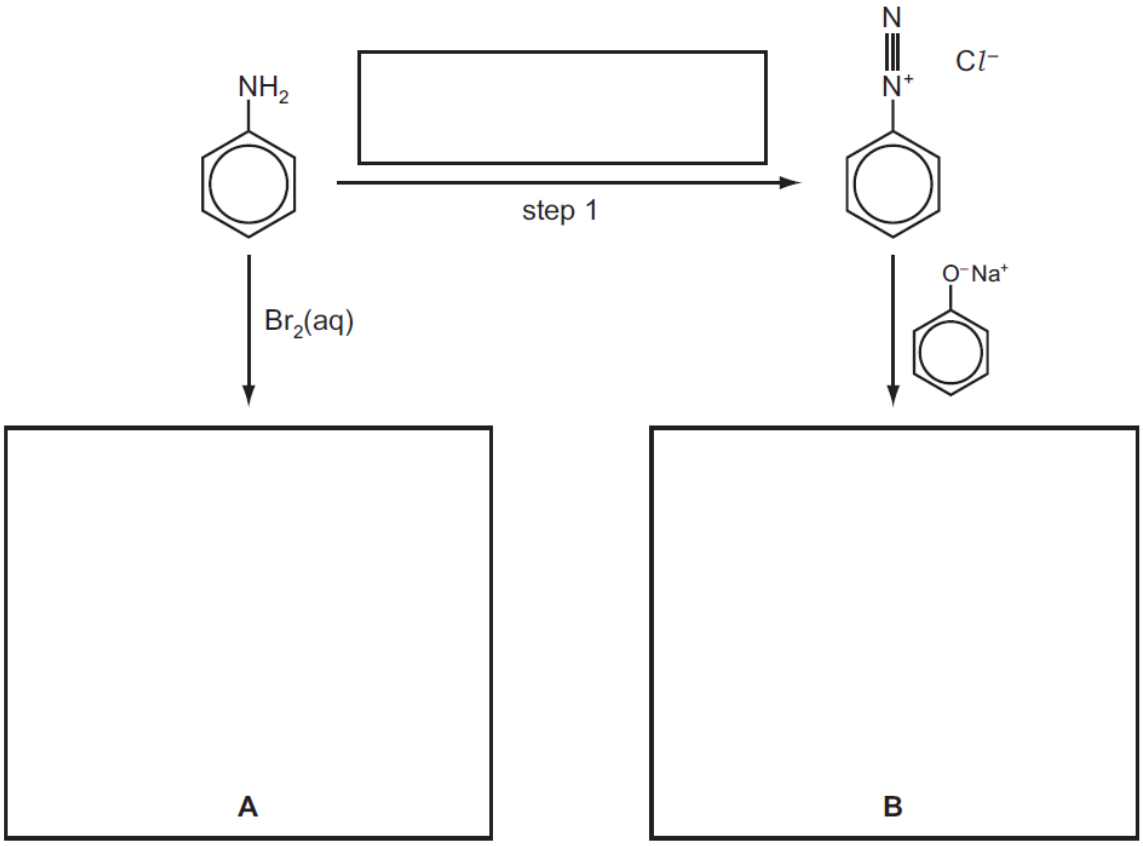


[1]

(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**.

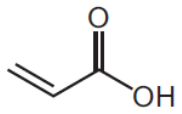
percentage = ... %

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

[3]

[Total: 11]

8 In recent years there has been a lot of interest in polymers in the form of gels that absorb aqueous materials. One of the largest uses of these polymers is in disposable nappies (diapers). The gel which is used in this case is a polymer of propenoic acid.



propenoic acid

(a) (i) Draw a section of the polymer of propenoic acid showing **two** repeat units.

(ii) By what type of chemical reaction is this polymer formed?

.....

(iii) By what type of bonding is water held on the polymer?

.....

[3]

(b) For some disposable nappies (diapers), the monomer is a mixture of propenoic acid and sodium propenoate. The properties of the polymer are influenced by the proportion of sodium salt in the monomer mixture.

(i) Suggest and explain how the difference in the structure of this polymer compared to one formed only from propenoic acid might affect the water absorbing properties of the polymer.

.....

.....

.....

(ii) Suggest a property the polymer should have in order to be used in disposable products.

.....

[3]

(c) A variation on the gel used for disposable nappies (diapers) containing more sodium propenoate has been used to treat soils contaminated by heavy metals such as lead (Pb^{2+}) and cadmium (Cd^{2+}). Suggest why the gel is effective.

.....

.....

.....

[2]

(d) Another variation on this type of polymer is used in hair gels. In these, the polymer chains are cross-linked by a compound known as pentaerythritol.

pentaerythritol

(i) By what type of chemical reaction are the cross-links in this polymer formed?

.....

(ii) It is important that the gel should be easily washed out of hair. What is it about the structure of the polymer that allows this to happen?

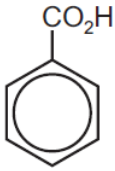
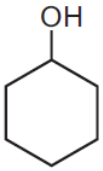
.....

[2]

[Total: 10]

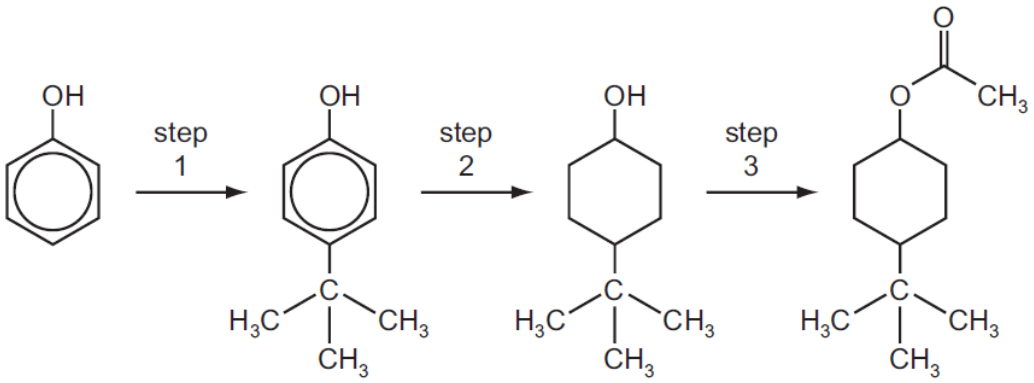
s/13/qp41

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.

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]

s/13/qp41

4 Because of the lack of reactivity of the nitrogen molecule, extreme conditions need to be used to synthesise ammonia from nitrogen in the Haber process.

(a) Suggest an explanation for the lack of reactivity of the nitrogen molecule, N_2.

.....

.....

[1]

(b) Under conditions of high temperature, nitrogen and oxygen react together to give oxides of nitrogen.

(i) Write an equation for a possible reaction between nitrogen and oxygen.

.....

(ii) State **two** situations, one natural and one as a result of human activities, in which nitrogen and oxygen react together.

.....

.....

(iii) What is the main environmental effect of the presence of nitrogen oxides in the atmosphere?

.....

[4]

(c) Describe and explain how the basicities of ethylamine and phenylamine compare to that of ammonia.

.....

.....

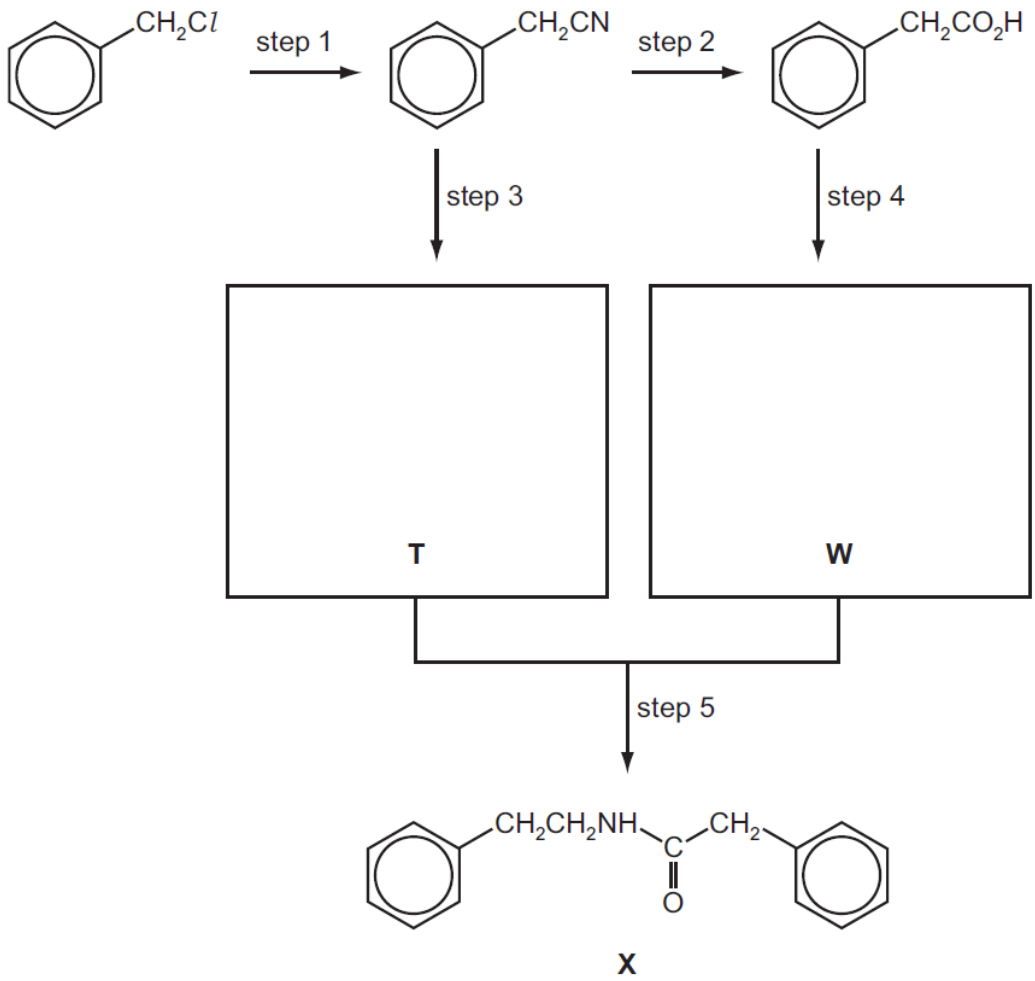
.....

.....

.....

[4]

(d) Compound **X** is a useful intermediate in the synthesis of pharmaceuticals.
X can be synthesised from chloromethylbenzene according to the following scheme.



X

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

step 1 .....

step 2 .....

(ii) Suggest reagents and conditions for

step 1, ...

step 2. .....

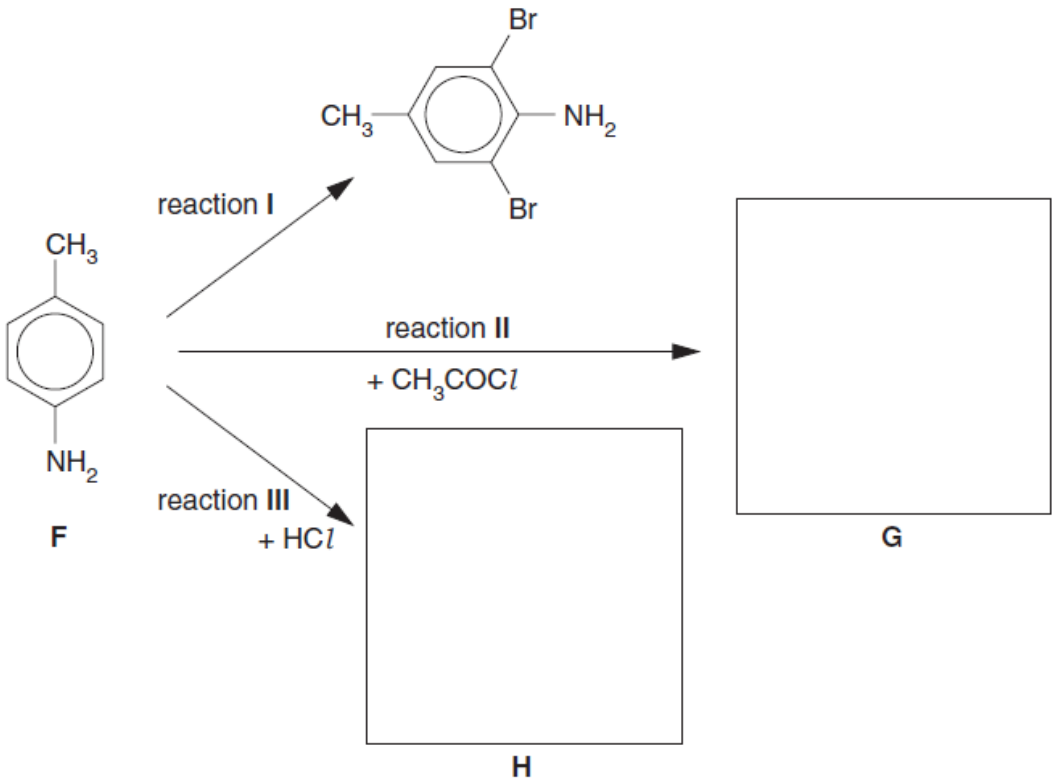
(iii) Draw the structures of the intermediates **T** and **W** in the boxes above.

[6]

[Total: 15]

s/13/qp41

5 4-Amino-1-methylbenzene, **F**, is a useful starting material for making several dyes. The following chart shows some of its reactions.



(a) **(i)** Suggest reagents and conditions for reaction **I**.

.....

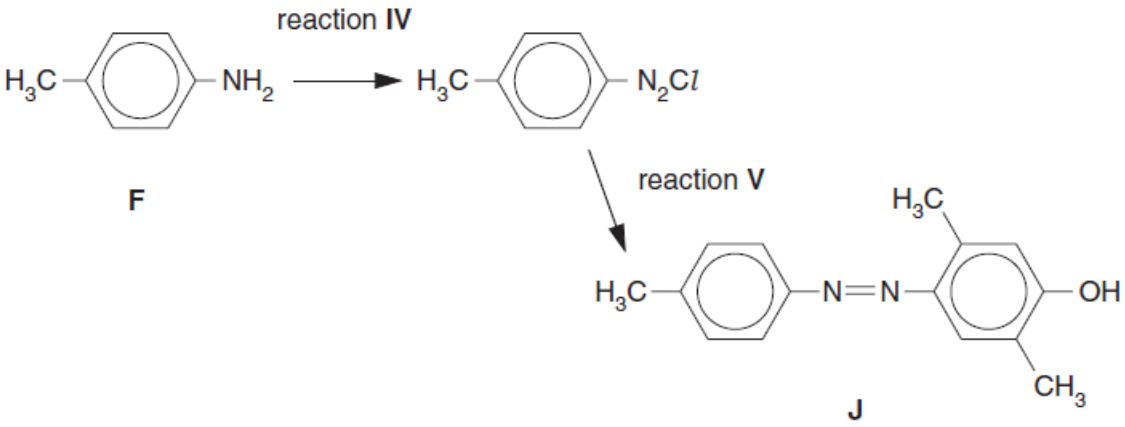
(ii) Draw the structural formulae of compounds **G** and **H** in the boxes above.

(iii) Name the functional group you have drawn in compound **G**.

.....

[4]

(b) The dye **J** can be made from **F** by the following series of reactions.



Suggest reagents and conditions for

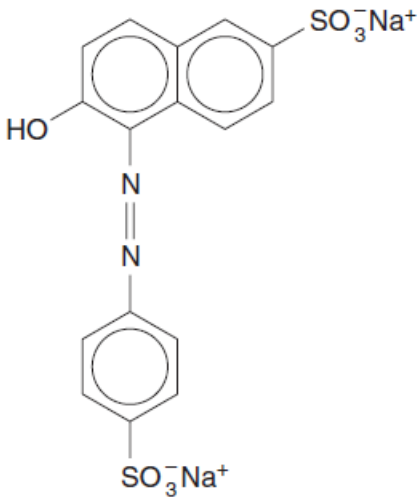
(i) reaction **IV**, ...

(ii) reaction **V**.

.....

[4]

(c) Many dyestuffs used as food colourings, such as Sunset Yellow, contain sodium sulphonate ($-SO_3^-Na^+$) groups attached to the rings. Suggest, with an explanation, a reason for this.



Sunset Yellow

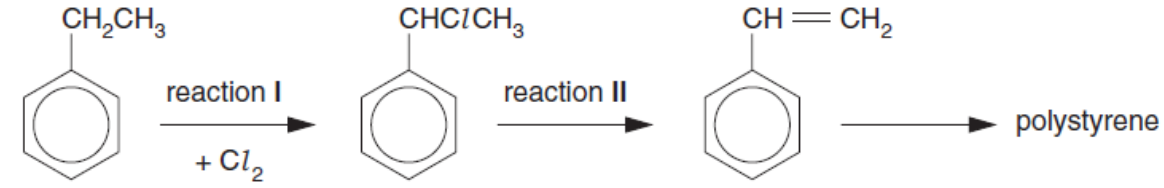
.....

.....

..... [2]

[Total: 10]

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.

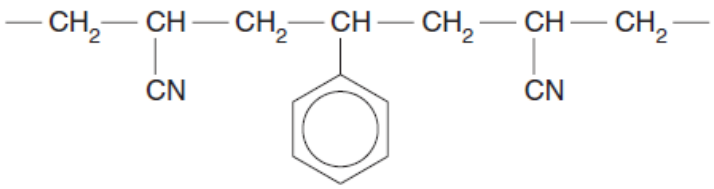
.....

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

.....

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

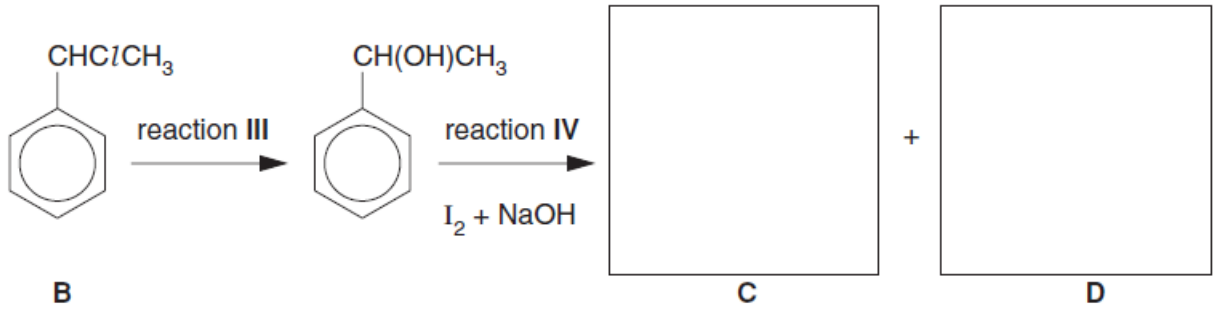
(iv) There are several polymers that consist of phenylethene co-polymerised with other monomers. The following formula shows part of the chain of one such co-polymer.



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**.

.....

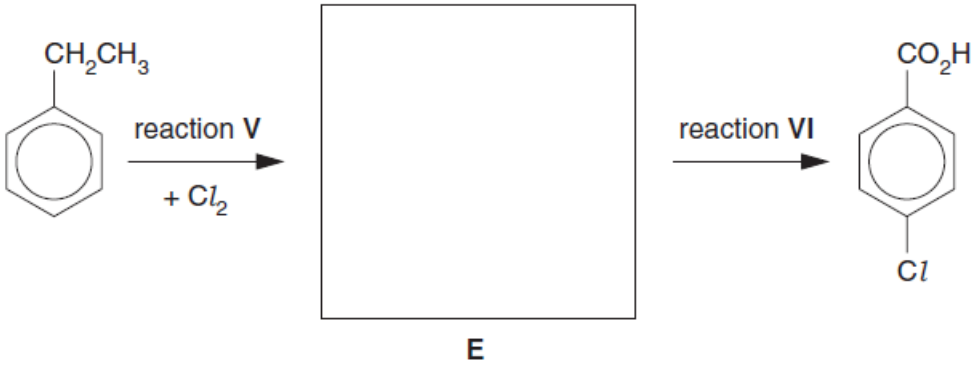
(ii) What would you see when reaction **IV** was carried out?

.....

(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.



(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]

w/06/qp4

Use

7 Both phenol and phenylamine react similarly with aqueous bromine.

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

.....

.....

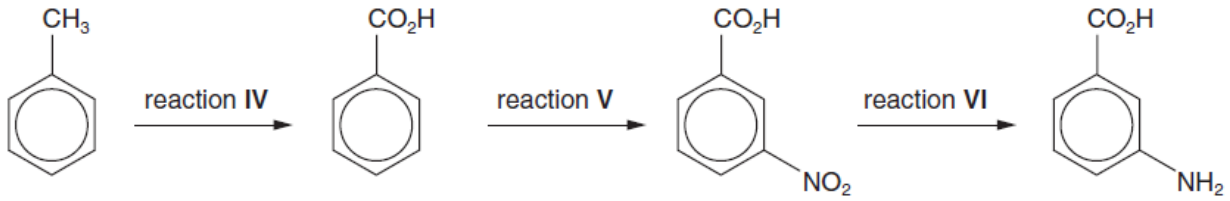
..... [2]

(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**, ...

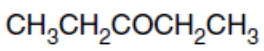
reaction **V**, ...

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

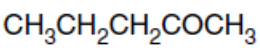
[Total: 7]

w/04/qp4

6 Compounds **D** and **E** are both ketones.



D



E

(a) State which one of these compound reacts with alkaline aqueous iodine, and draw the structural formulae of the products formed during this reactions.

(i) compound (**D** or **E**) .....

(ii) products

..... [3]

(b) The reduction of **D** with $NaBH_4$ produces just one alcohol, but a similar reduction of **E** produces two isomers in equal amounts. Explain these observations, drawing structures where appropriate.

.....

.....

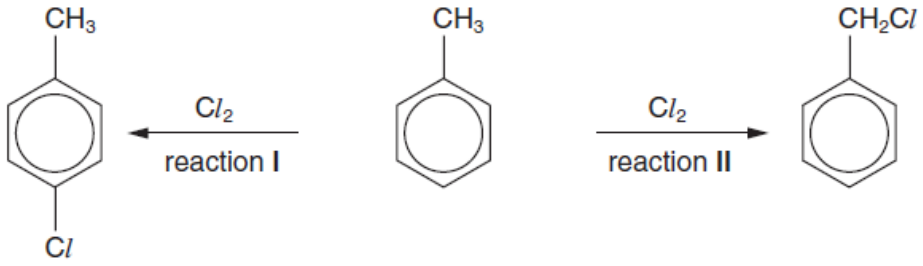
[3]

[Total: 6]

w/04/qp4

5 This question is concerned with organochlorine compounds.

(a) State the conditions needed to produce the two compounds **A** and **B.**



A **B**

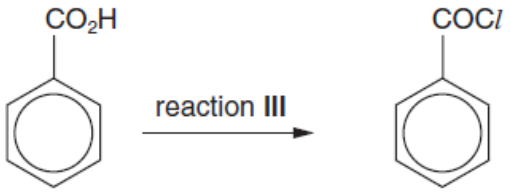
(i) conditions for reaction **I**

.....

(ii) conditions for reaction **II**

..... [2]

(b) State the reagent needed to carry out the following reaction.



C

reagent for reaction **III**: ..... [1]

(c) The three chloro-compounds **A**, **B** and **C** vary in their ease of hydrolysis.

(i) Place a tick in the box corresponding to the correct relative rates of hydrolysis. [the symbol '>' means 'faster than']

	place **one** tick only in this column
A > **B** > **C**	
A > **C** > **B**	
B > **A** > **C**	
B > **C** > **A**	
C > **B** > **A**	
C > **A** > **B**	

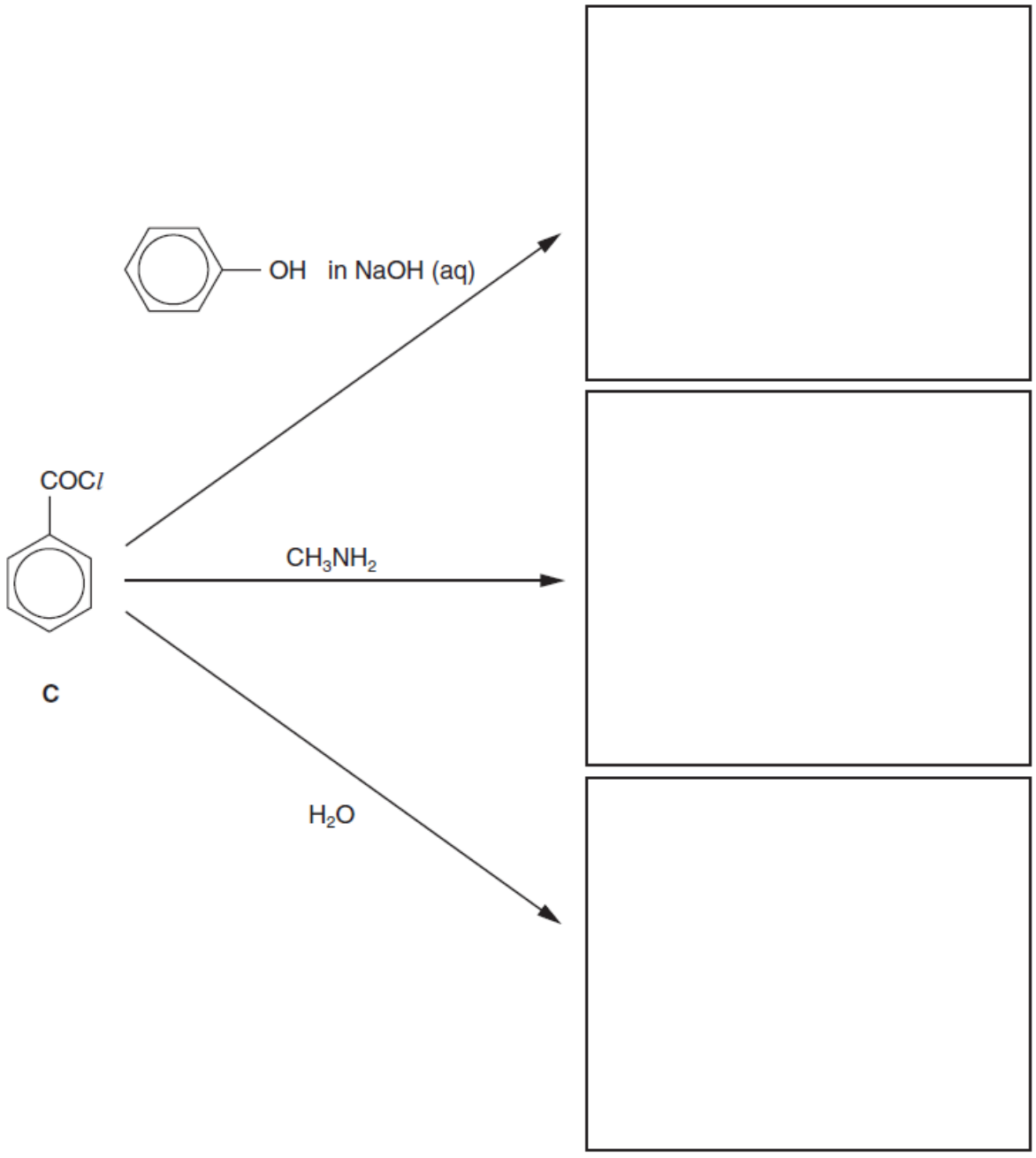
(ii) Suggest an explanation for these differences in reactivity.

.....

.....

..... [3]

(d) Draw the structural formulae of the organic products of the following reactions of compound **C**.

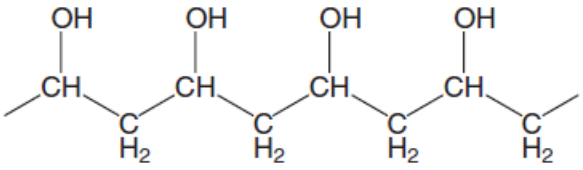


[3]

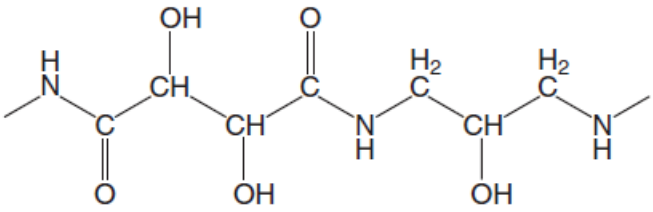
[Total: 9]

w/04/qp4

5 Hydrophilic polymers find important uses in the manufacture of contact lenses and wound dressings. Their chemical structures allow them to bond with water molecules, which keeps them soft and flexible. Sections of two hydrophilic polymers are shown below.



H



J

(a) What type of polymerisation has produced

(i) polymer **H**? .....

(ii) polymer **J**? .....

[2]

(b) What type of attractions might occur between these polymers and molecules of water?

..... [1]

(c) Chains of polymer **H** can be 'cross-linked', i.e. joined together, by reaction with a small bifunctional molecule.

(i) Which one of the following molecules would be most suitable for such cross-linking?

(place a tick in one box only)

$HOCH_2CH_2OH$	☐
$H_2NCH_2CH_2NH_2$	☐
$HOCH_2CH_2CO_2H$	☐
$HO_2CCH_2CH_2CO_2H$	☐
$H_2NCH_2CH_2CO_2H$	☐

(ii) What type of bond would be formed during the cross-linking?

.....

[2]

(d) **(i)** Suggest the reagents and conditions needed to hydrolyse polymer **J** into its monomers.

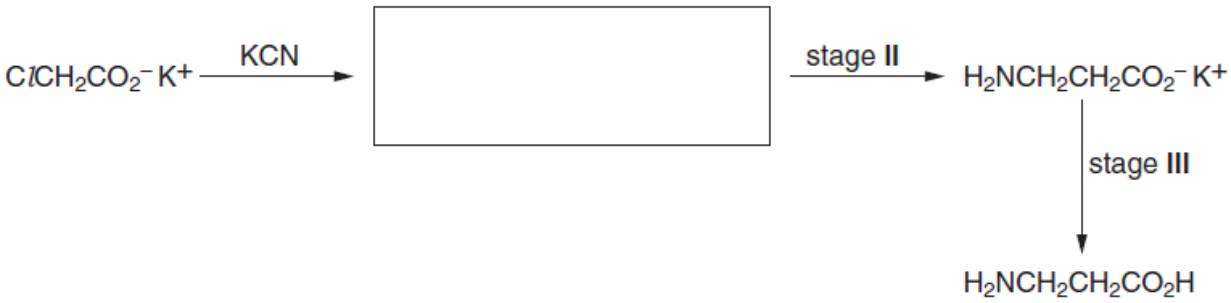
.....

(ii) Draw the structural formulae of the two products of this hydrolysis reaction.

.....

[3]

(e) The last compound in the list in **(c)(i)** above is 3-aminopropanoic acid. This can be made from potassium chloroethanoate by the following 3-stage route.



(i) In the box above write the structure of the intermediate in this route.

(ii) Suggest reagents and conditions for

stage **II** .....

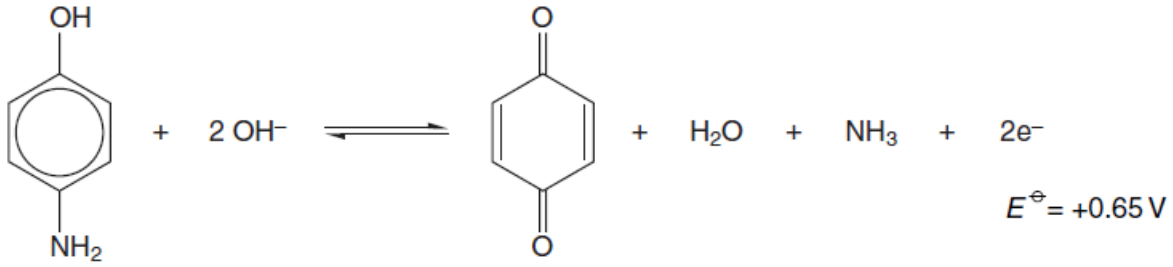
stage **III** .....

[3]

[Total: 11]

w/05/qp4

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]

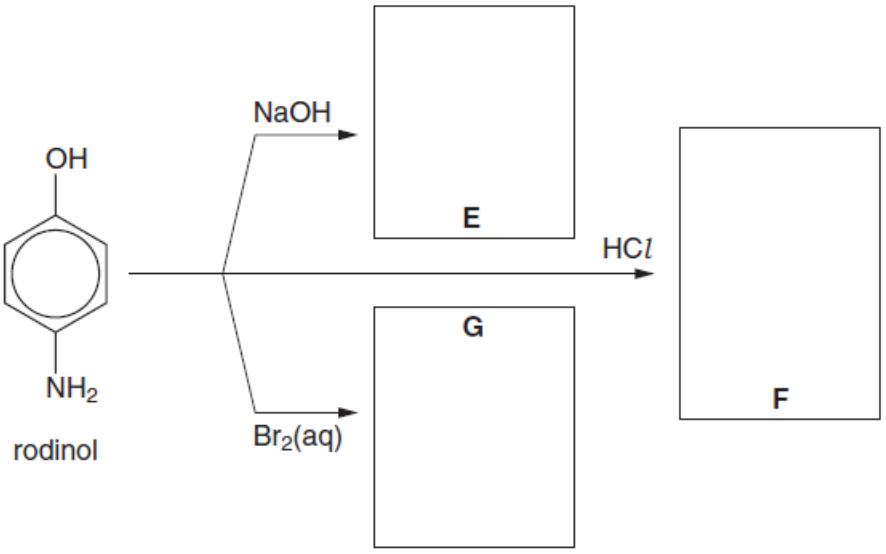
(b) Suggest, with a reason, how the basicity of rodinol might compare to that of ammonia.

.....

.....

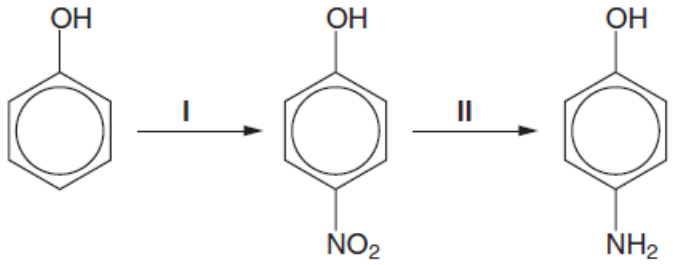
..... [2]

(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**?

.....

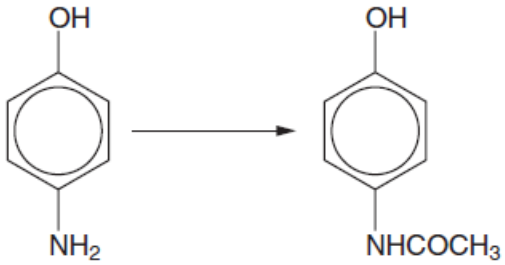
(iii) Place a tick in the box by the most suitable reagent for step **II**.

(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]

5 The amino acid alanine, **K**, can be obtained from 2-hydroxypropanoic acid, **H**, by the following route.

$$CH_3CH(OH)CO_2H \xrightarrow{I} CH_3CHClCO_2H \xrightarrow{II} CH_3CH(NH_2)CO_2H$$

H **J** **K**

(a) Suggest a test you could use to distinguish **H** from its isomer 3-hydroxypropanoic acid, **L**.

$$HOCH_2CH_2CO_2H$$
L

reagents .....

observation with **H** .....

observation with **L** .....[2]

(b) How would the acidity of chloropropanoic acid, **J**, compare with that of propanoic acid? Briefly explain your answer.

.....

.....

.....[2]

(c) Alanine reacts with both acids and bases.

Write an equation for the reaction between alanine and sodium hydroxide, drawing the displayed formula of the organic product.

[2]

(d) In solution, alanine exists as a zwitterion. Draw the structure of this ion.

[1]

(e) Alanine is one of about 20 amino acids that make up proteins.

(i) What type of bond joins amino acids together in proteins?

.....

(ii) Draw the displayed formula of the compound formed when two alanine molecules are joined by this bond.

[2]

(f) An excess of benzoic acid in the body (present as a preservative in many foodstuffs, or formed by oxidation of aromatic compounds present in food) is excreted as hippuric acid, **M**.

M

(i) Suggest a reagent that could be reacted with glycine in the laboratory to form hippuric acid.

.....

(ii) Suggest the reagents and conditions needed to re-form glycine from hippuric acid.

.....

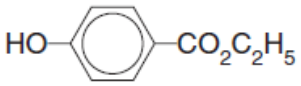
.....

[3]

[Total : 12]

w/03/qp4

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

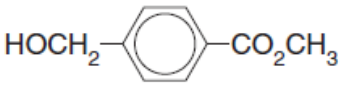
(i) sodium metal,

(ii) NaOH(aq) under reflux,

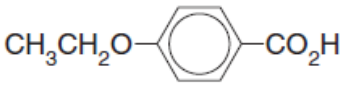
(iii) Br_2(aq).

[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).

.....

.....

.....

.....

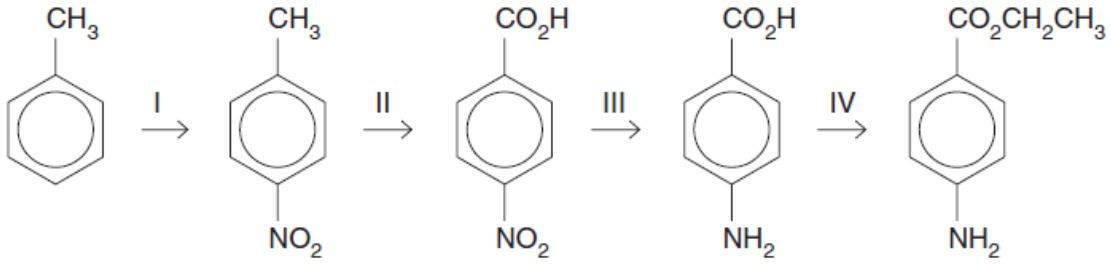
.....

[3]

[Total : 9]

w/03/qp4

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 .....

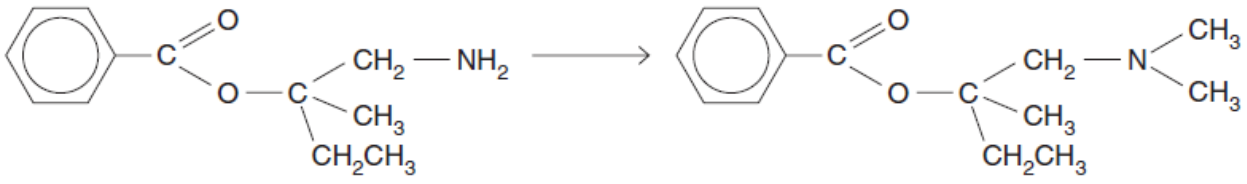
III .....

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.

.....

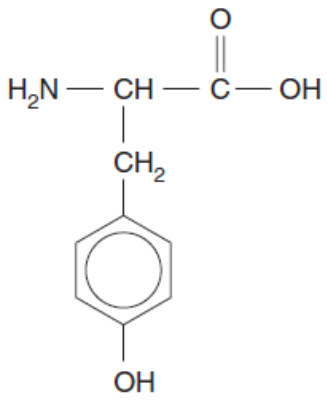
.....

[3]

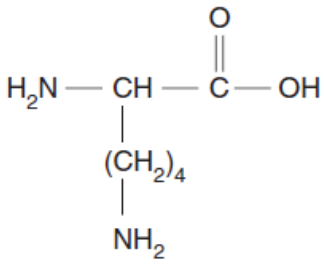
[Total: 11]

s/06/qp4

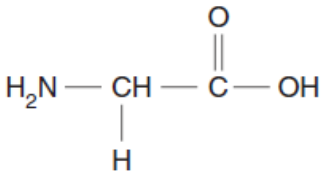
4 The amino acids tyrosine, lysine and glycine are constituents of many proteins.



tyrosine



lysine



glycine

(a) State the reagents and conditions you could use to break proteins down into amino acids.

..... [2]

(b) Draw a ring around each chiral centre in the above molecules. [1]

(c) In aqueous solution amino acids exist as zwitterions. Draw the zwitterionic structure of glycine.

..... [1]

(d) For each of the following reactions, draw the structure of the organic compound formed.

(i) glycine + excess NaOH(aq)

.....

(ii) tyrosine + excess NaOH(aq)

.....

(iii) lysine + excess HC*l* (aq)

.....

(iv) tyrosine + excess Br_2(aq)

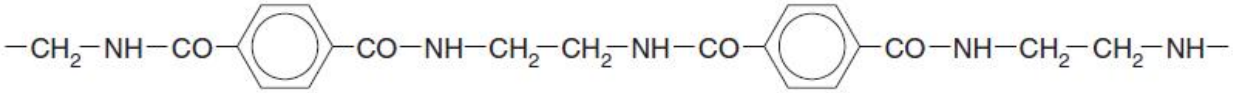
.....

[5]

(e) Draw the structural formula of a tripeptide formed from **all three** of these amino acids, showing clearly the peptide bonds.

..... [2]

(f) The formula of part of the chain of a synthetic polyamide is shown below.



(i) Identify the repeat unit of the polymer by drawing square brackets around it on the above formula.

(ii) Draw the structures of the **two** monomers from which the polymer could be made.

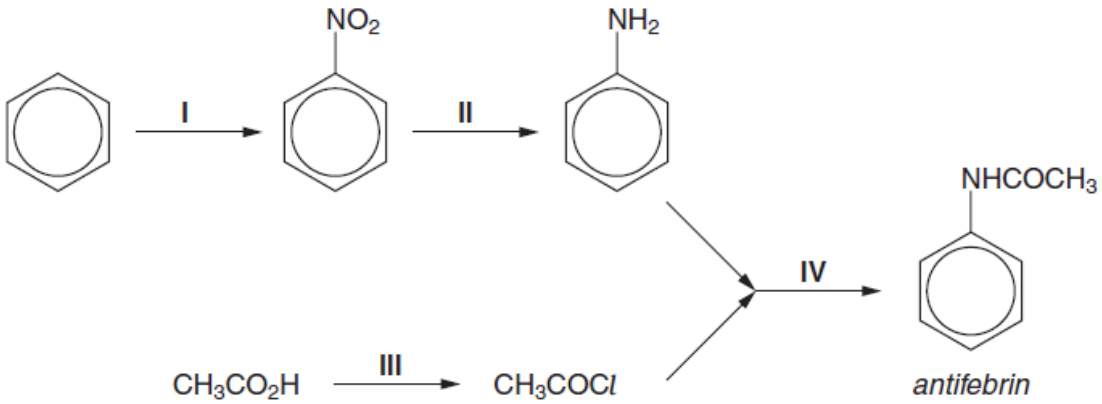
.....

[3]

[Total: 14]

s/06/qp4

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



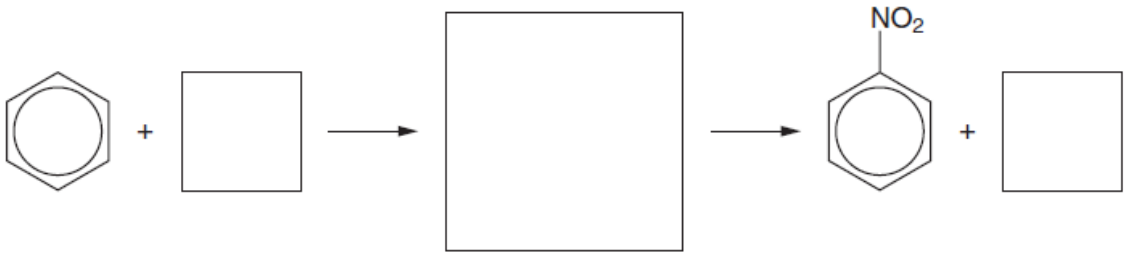
(a) **(i)** What type of reaction is reaction **I**?

.....

(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*?

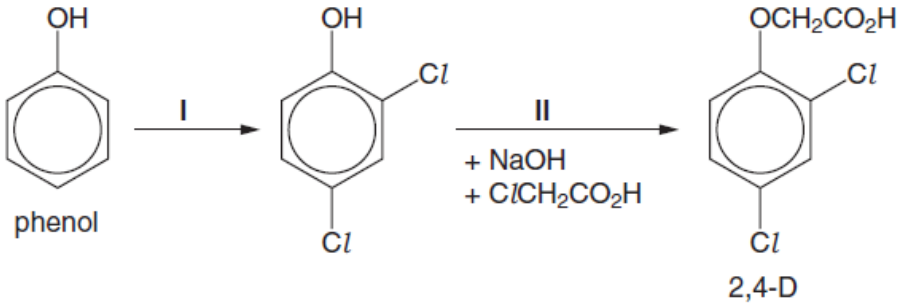
.....

[2]

[Total: 11]

s/05/qp4

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



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

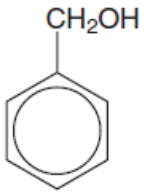
.....

(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]

[Total: 11]

s/05/qp4

(e) In a possible industrial synthesis of ethanol, the complex $Fe(CO)_5$ catalyses the reaction between carbon monoxide, hydrogen and methanol according to the following equation.

$$CH_3OH + 2CO + H_2 \xrightarrow[300\,atm]{200\,^{\circ}C} CH_3CH_2OH + CO_2$$

Describe a test (reagents and observations) that would distinguish ethanol from methanol.

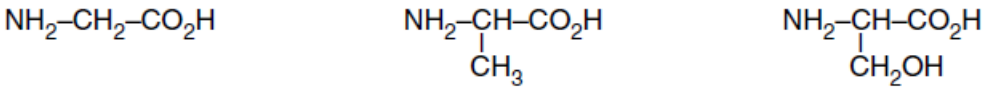
reagents .....

observation with methanol .....

observation with ethanol ..... [2]

s/05/qp4

6 Much research has been carried out in recent years investigating the exact structure of silk. The silk of a spider's web is at least five times as strong as steel, and twice as elastic as nylon. A silk fibre is composed of many identical protein chains, which are mainly made from the amino acids glycine, alanine and serine, with smaller amounts of four other amino acids.



glycine alanine serine

(a) Amino acids can exist as zwitterions. Draw the zwitterionic structure for glycine.

[1]

(b) Amino acids can act as acids or bases. Write equations to show:

(i) the reaction between alanine and HC*l*(aq),

.....

(ii) the reaction between serine and NaOH(aq).

.....

[2]

(c) Draw the structural formula of a portion of the silk protein, showing three amino acid residues. Label a peptide bond on your structure.

[3]

(d) What *type* of polymer is silk protein?

.....[1]

(e) The M_r of a silk protein molecule is about 600,000. Assuming it is made from equal amounts of the above three amino acids, calculate the average number of amino acid residues in the protein chain. [M_r (glycine) = 75; M_r (alanine) = 89; M_r (serine) = 105]

number of residues = ... [3]

[Total: 10]

s/04/qp4

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

(i) chlorobenzene,

.....

(ii) bromobenzene,

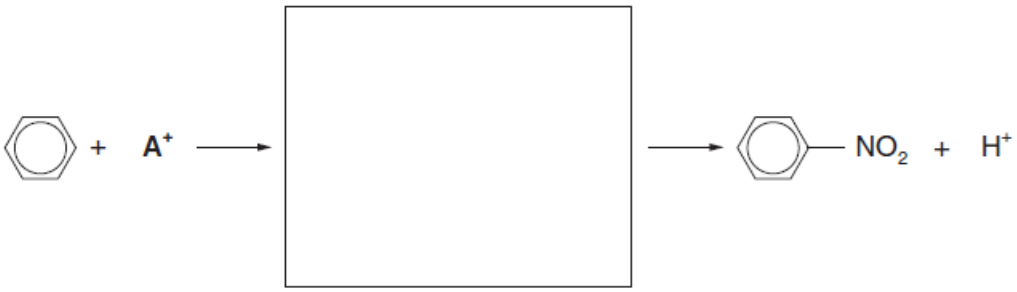
.....

(iii) nitrobenzene.

.....

[4]

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



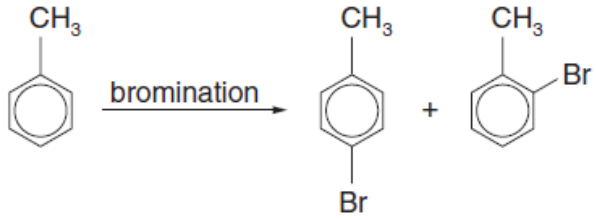
(i) Identify the cation A^+. .....

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

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

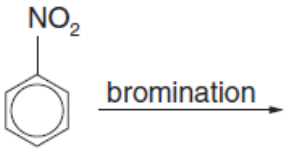
Electron-withdrawing groups such as $-CO_2H$ or $-NO_2$ direct the incoming group to the 3-position.

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

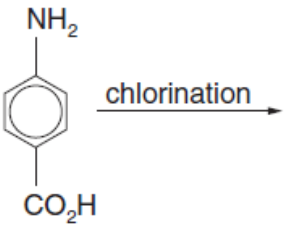


Use this information to suggest a likely structure for the organic product of each of the following reactions.

(i)



(ii)



[2]

[Total: 8]

s/04/qp4

4 This question is about the reactions of some functional groups.

(a) (i) Draw the structural formula of an amide of your choice containing **four** carbon atoms.

(ii) What reagents and conditions are needed to hydrolyse this amide?

.....

(iii) Write a balanced equation showing the hydrolysis of the amide whose structural formula you drew in part **(i)**.

.....[4]

(b) (i) Draw the structural formula of an acyl chloride containing three carbon atoms.

(ii) What starting material and reagent are needed to form this acyl chloride?

.....

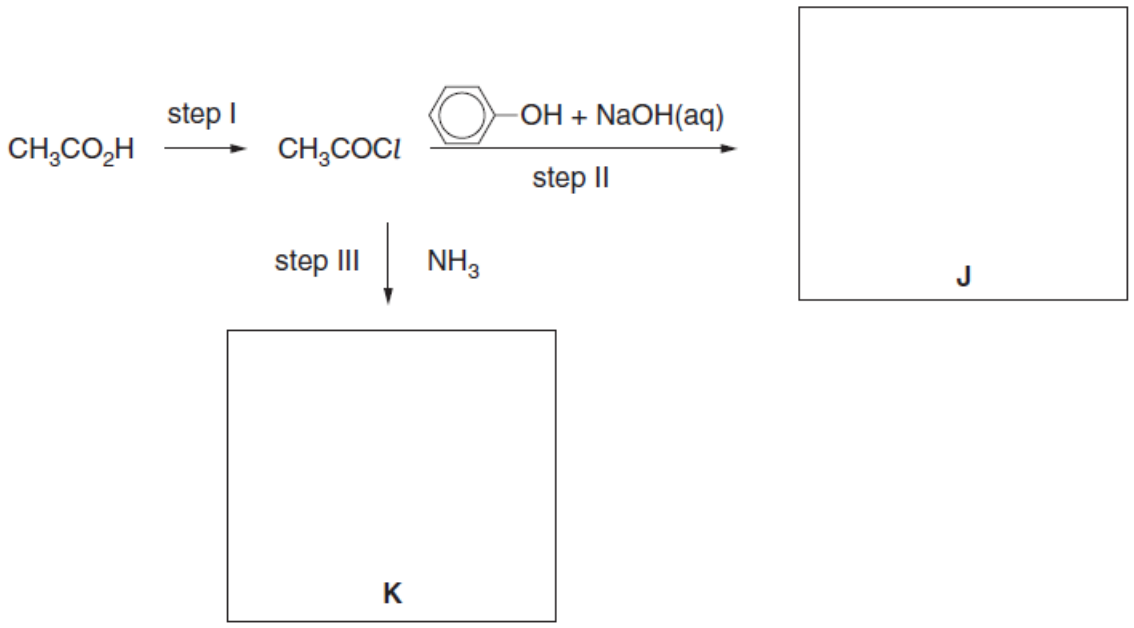
(iii) Write a balanced equation showing the formation of an ester containing five carbon atoms from the acyl chloride you drew in part **(i)**.

.....[3]

[Total: 7]

s/04/qp4

5 **(a)** Acyl chlorides are useful intermediates for making various acid derivatives. The following reaction scheme shows some of the reactions of ethanoyl chloride.



(i) Suggest a reagent for step I.

.....

(ii) Write an equation showing the reaction between phenol and NaOH(aq), the reagents in step II.

.....

(iii) Draw the structural formulae of products **J** and **K** in the boxes above.

[4]

(b) The diacid **L** occurs naturally and is used as a food additive to enhance the acidic flavour in some fruit drinks.

$HO_2CCH_2CH_2CO_2H$
L

When the diacyl chloride of **L** is reacted with $HOCH_2CH_2OH$, a polymer is formed.

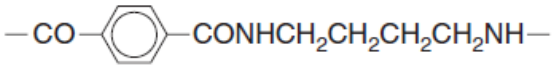
(i) What type of polymerisation is occurring here?

.....

(ii) Write an equation showing the reaction between **one** mole of the diacyl chloride of **L** and **two** moles of $HOCH_2CH_2OH$.

[3]

(c) The following formula represents a section of another polymer.



(i) What type of polymer is this?

.....

(ii) Draw the structural formula of each of the monomers that make up this polymer.

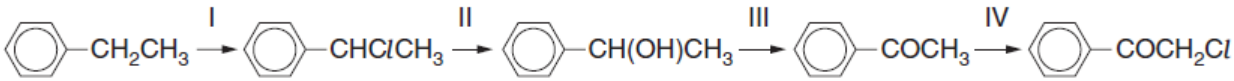
[3]

[Total : 10]

s/03/qp4

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.

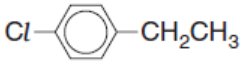


A **B** **C** **D**

(a) Suggest reagents and conditions for step I.

.....[1]

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



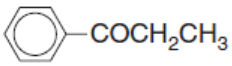
E

.....[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]

(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?

.....

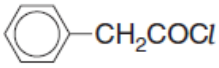
.....

.....[2]

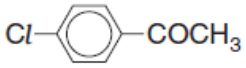
(f) Residues of *CN* can be destroyed by hydrolysis with an aqueous alkali.

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.

.....

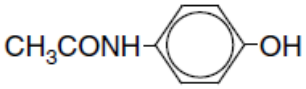
.....

.....
[3]

[Total : 10]

s/03/qp4

5 The common analgesic drug paracetamol has the following structure.



(a) Name the **two** functional groups in the paracetamol molecule

..... and ..... [2]

(b) Draw the structural formulae of the molecules or ions formed when paracetamol reacts with

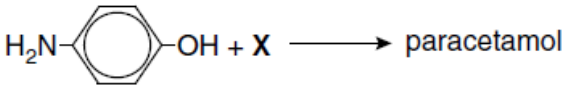
(i) $Br_2(aq)$,

(ii) NaOH(aq) in the cold,

(iii) NaOH(aq) under reflux.

[3]

(c) Paracetamol can be synthesised by reacting 4-aminophenol with compound **X**.



(i) Suggest a possible identity of **X**.

.....

(ii) What reagent would you use to convert ethanoic acid, CH_3CO_2H, into **X**?

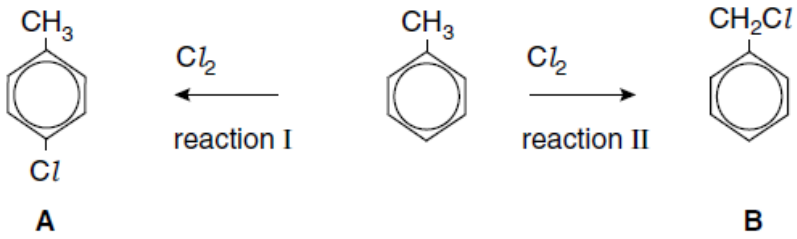
.....

[2]

[Total: 7]

s/02/qp4

6 Methylbenzene can react with chlorine in two ways, depending on the conditions of the reaction.



(a) State the condition needed for

(i) reaction I,

.....

(ii) reaction II.

.....

[2]

(b) One of the two compounds **A** and **B** reacts with NaOH(aq), but the other is inert.

(i) Which one (**A** or **B**) does **not** react? Give a reason for your answer.

.....

.....

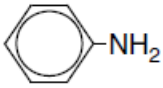
(ii) Write an equation for the reaction with NaOH(aq) that does occur.

[2]

[Total: 4]

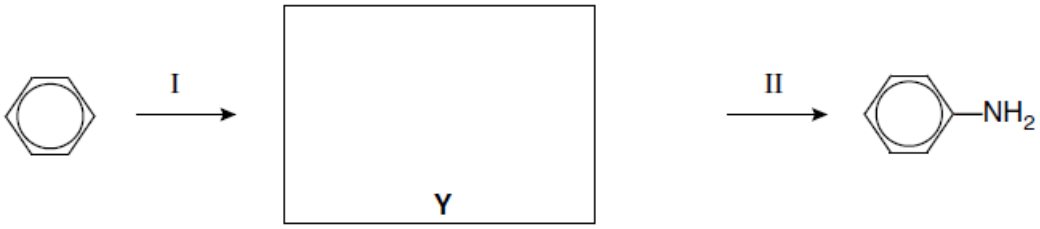
s/02/qp4

7 Phenylamine is an important intermediate compound for the production of dyes.



phenylamine

(a) Phenylamine can be synthesised from benzene in two steps. Draw the structural formula of the intermediate **Y** in the scheme below, and suggest reagents and conditions for steps I and II.



reagent + conditions for step I .....

reagent + conditions for step II .....

[4]

(b) Phenylamine is a weak base.

(i) Write an equation showing phenylamine acting as a base.

(ii) How would you expect its basicity to compare with that of ammonia?

.....

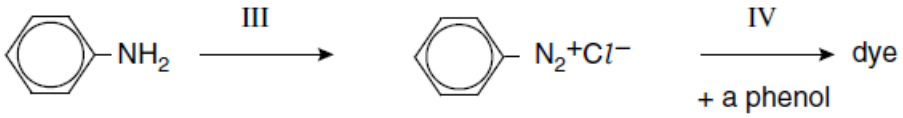
(iii) Explain the reasoning for your answer in **(ii)**.

.....

.....

[3]

(c) Dyes can be made from phenylamine by first converting it into benzenediazonium chloride, and then coupling this with a phenol.



(i) State the reagents and condition needed for step III.

.....

(ii) What reagent is the phenol dissolved in for step IV to be effective?

.....

(iii) Suggest the structural formula of the dye formed when benzenediazonium chloride is coupled with 2-methylphenol.

[4]

[Total: 11]

s/02/qp4

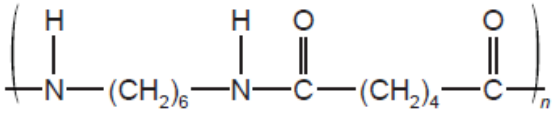
8 The physical properties of polymers depend on the average relative molecular mass of the polymer chains and on the functional groups present in the monomers.

The presence of side-chains in addition polymers can increase the spacing between polymer chains in the bulk substance and hence reduce the overall density.

In condensation polymers it is the *nature* of the side-chain that is often more important since this can lead to cross-linking of the polymer chains forming a three-dimensional structure.

(a) For each of the following polymers, give the structure of the monomer(s) and state the *type of reaction* used to produce the polymer.

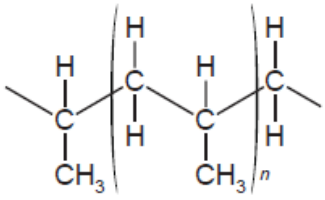
polymer **A**



monomer(s)

type of reaction .....

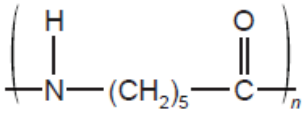
polymer **B**



monomer(s)

type of reaction .....

polymer **C**



monomer(s)

type of reaction .....

[5]

(b) Look at the structures of the three polymers and answer the following questions.

(i) Suggest why the density of **B** is lower than that of **A**.

.....

.....

(ii) Which polymer will have the weakest forces between chains, and what is the nature of these forces?

.....

.....

[2]

[Total: 7]

w/12/qp43

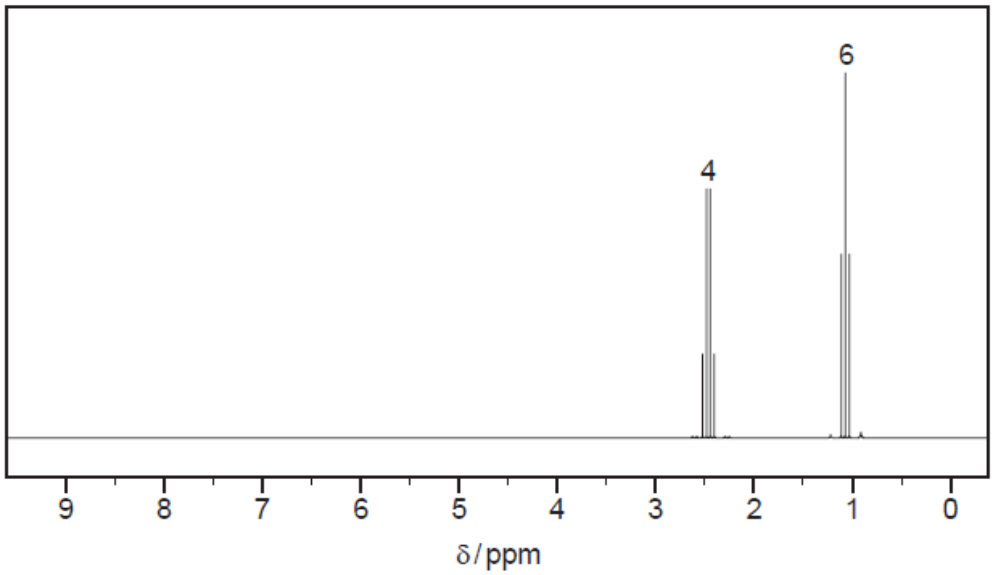
7 Although the chemical reactions of compounds remain important pointers to their functional groups, instrumental techniques such as mass spectrometry and NMR spectroscopy are increasingly used to determine molecular structures.

(a) Compound **J** was analysed using these two techniques with the following results.

The mass spectrum showed that

- the M peak was at *m/e* 86,
- the ratio of heights of the M and M+1 peaks was 23.5 : 1.3.

The NMR spectrum is shown below.



(i) Use the data to determine the number of carbon and hydrogen atoms present in **J**, showing your working.

(ii) Use the information given above and your answer to **(i)** to identify the other element present in **J**.

.....

(iii) Determine the structure of **J**, explaining how you reach your conclusion.

structure of **J**

explanation .....

.....

[5]

5 **(a)** **(i)** Explain why ethylamine is basic.

.....

.....

(ii) Write an equation showing ethylamine acting as

a base, ...

a nucleophile. .....

(iii) Why is phenylamine less basic than ethylamine?

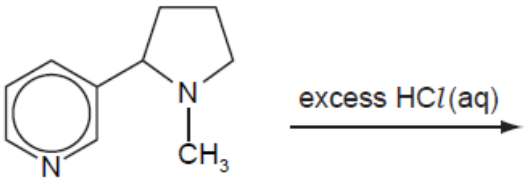
.....

.....

.....

Alkaloids are naturally-occurring compounds that act as bases.

(iv) Suggest the structure of the product, **E**, of the reaction between the alkaloid nicotine and an excess of HC*l*(aq).



nicotine

excess HC*l*(aq) →

E

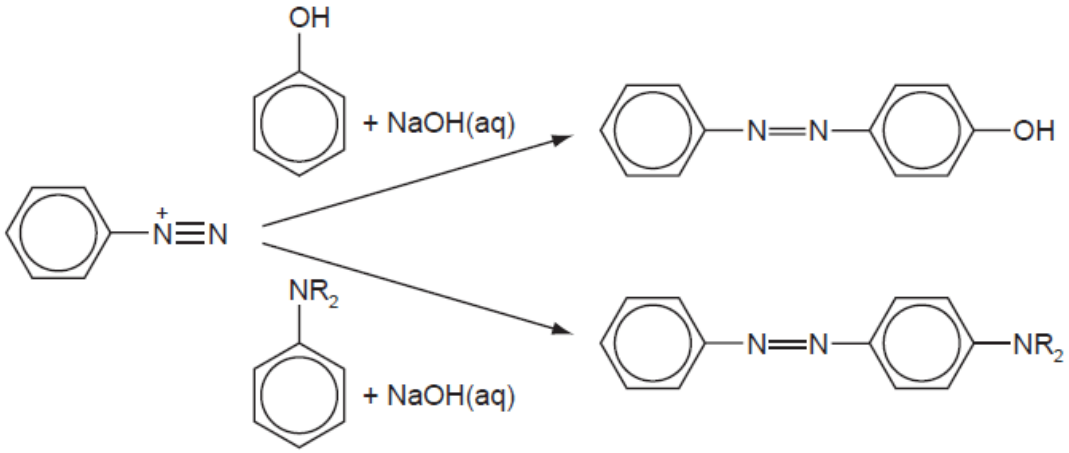
[6]

(b) Phenylamine, and substituted phenylamines, are used to make cloth dyes and food colourants.
The first step in this process is the production of a diazonium salt.

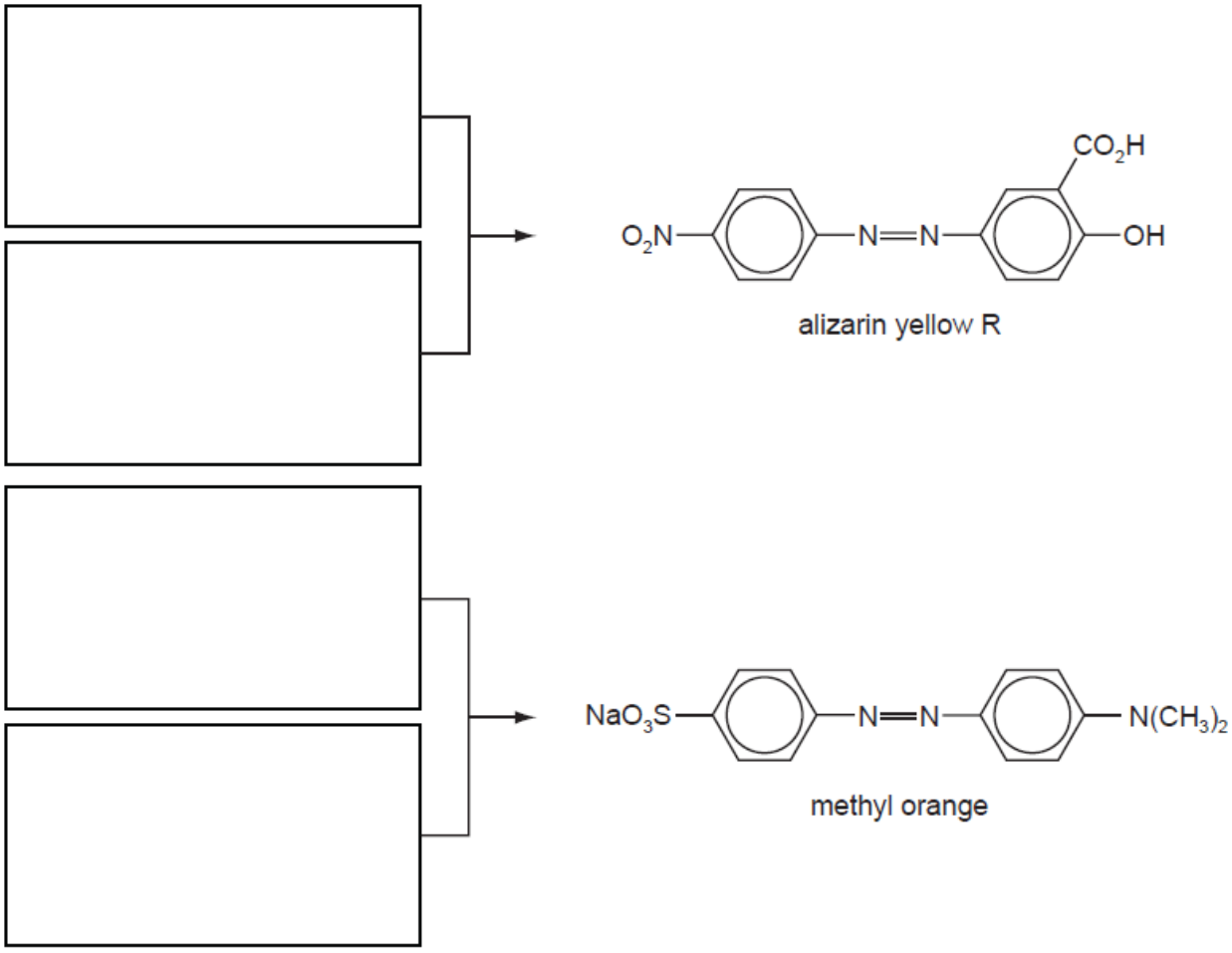
(i) State the reagents and conditions necessary for this reaction.

.....

The diazonium salt is then reacted with a phenol or an aryl amine in alkaline solution.



(ii) Suggest the starting materials needed to synthesise the following dyes.
Draw their structures in the boxes provided.



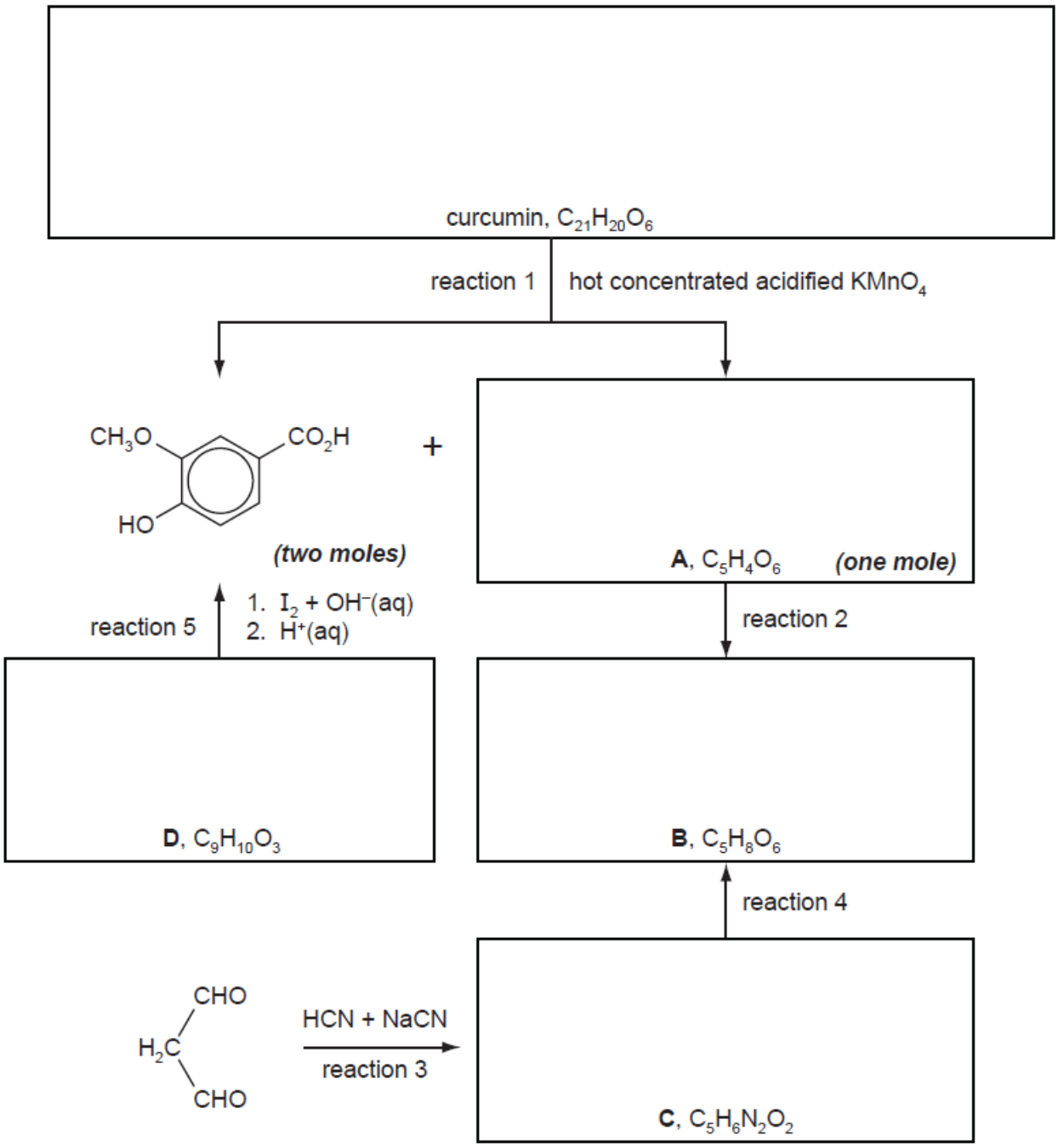
(iii) Suggest what effect the NaO_3S- group in methyl orange has on its properties. This group has no effect on the colour of the compound.

.....

[7]

[Total: 13]

4 The compound responsible for the yellow colour of the spice turmeric is curcumin. Its molecular structure can be deduced from the following series of reactions. The CH_3O- group that is present in curcumin may be regarded as unreactive.



Curcumin and compounds **A** and **D** all react with 2,4-dinitrophenylhydrazine reagent.

Compounds **A** and **B** effervesce with $Na_2CO_3(aq)$, but curcumin, and compounds **C** and **D**, do not.

Curcumin reacts with $Br_2(aq)$ and with cold dilute acidified $KMnO_4$

(a) **(i)** Name the functional group common to curcumin and compounds **A** and **D**.

.....

(ii) Name the functional group common to compounds **A** and **B**.

.....

[2]

(b) **(i)** Suggest the structures of compounds **B**, **C** and **D**, and draw their structural formulae in the relevant boxes opposite.

(ii) Suggest suitable reagents and conditions for reaction 4.

.....

[4]

(c) **(i)** Name the *type of reaction* for reaction 2.

.....

(ii) Suggest a reagent for reaction 2.

.....

(iii) Suggest the structure of compound **A**, and draw its structural formula in the relevant box opposite.

[3]

(d) **(i)** **Name** the functional group in curcumin that reacts with cold dilute acidified $KMnO_4$.

.....

(ii) **Name two** functional groups in curcumin that react with $Br_2(aq)$.

.....

[2]

(e) Suggest a structure for curcumin and draw its structural formula in the relevant box opposite. [2]

[Total: 13]

w/12/qp43

(e) Fehling's reagent is an alkaline solution of Cu^{2+} ions complexed with tartrate ions. It is used in organic chemistry to test for a particular functional group.

(i) **Name** the functional group involved.

.....

(ii) Describe the appearance of a positive result in this test.

.....

(iii) Write an equation for the reaction between Cu^{2+} and OH^- ions and a two-carbon compound containing the functional group you named in **(i)**.

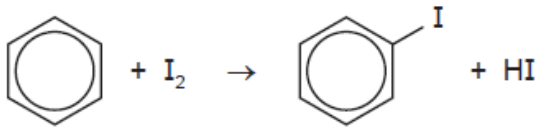
.....

[3]

w/12/qp43

(c) The iodination of benzene requires the presence of nitric acid.

(i) Using bond enthalpies from the *Data Booklet*, calculate the enthalpy change for the following reaction.



w/12/qp43

---

8 The increasing awareness of the diminishing supply of crude oil has resulted in a number of initiatives to replace oil-based polymers with those derived from natural products. One such polymer, 'polylactide' or PLA, is produced from corn starch and has a range of applications.

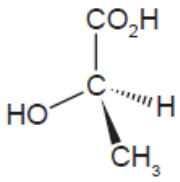
(a) The raw material for the polymer, lactic acid (2-hydroxypropanoic acid), is formed by the fermentation of corn starch using enzymes from bacteria.

(i) Calcium hydroxide is added to the fermentation tanks to prevent the production of lactic acid from slowing down.
Why might high acidity reduce the effectiveness of the enzymes?

.....

.....

(ii) The structure of lactic acid is shown.



What type of reaction takes place in this polymerisation?

.....
[2]

(b) Lactic acid exists in two stereoisomeric forms. Draw the other form in the box.

[1]

(c) One of the reasons PLA has attracted so much attention is that it is biodegradeable. This does, however, restrict some potential uses. The simple polymer has a melting point of around 175 °C, but softens between 60-80 °C. However, its thermoplastic properties enable it to have a range of uses in fibres and in food packaging.

(i) Explain why PLA would **not** be a suitable packaging material for foods pickled in vinegar.

.....

.....

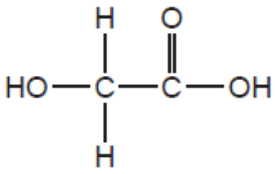
(ii) PLA containers are not used for hot drinks. Suggest why.

.....

.....

[2]

(d) Lactic acid can also be co-polymerised with glycolic acid.



glycolic acid

(i) Draw a section of the co-polymer showing one repeat unit.

(ii) Suggest what type(s) of bonding will occur between chains of this co-polymer, indicating the groups involved.

.....

.....

.....

(iii) Suggest one property in which the co-polymer differs from PLA.

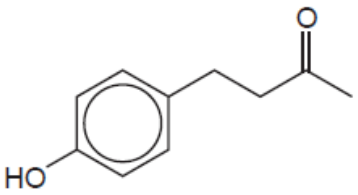
.....

.....

[5]

[Total: 10]

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**.

.....

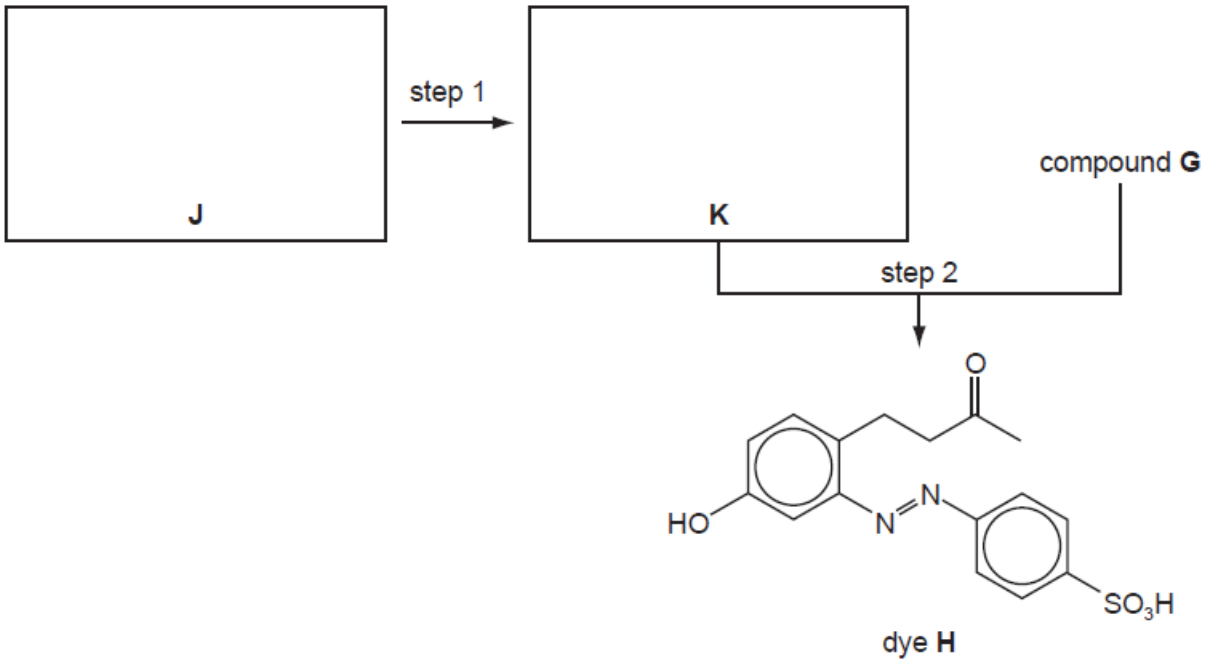
..... [2]

(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.

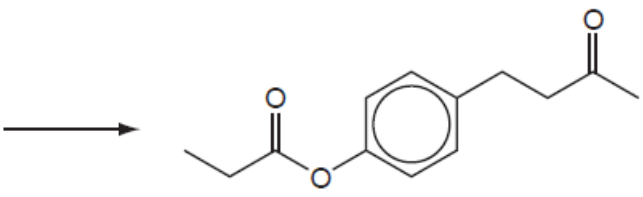
(ii) Suggest reagents and conditions for

step 1, ...

step 2. .....

[5]

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



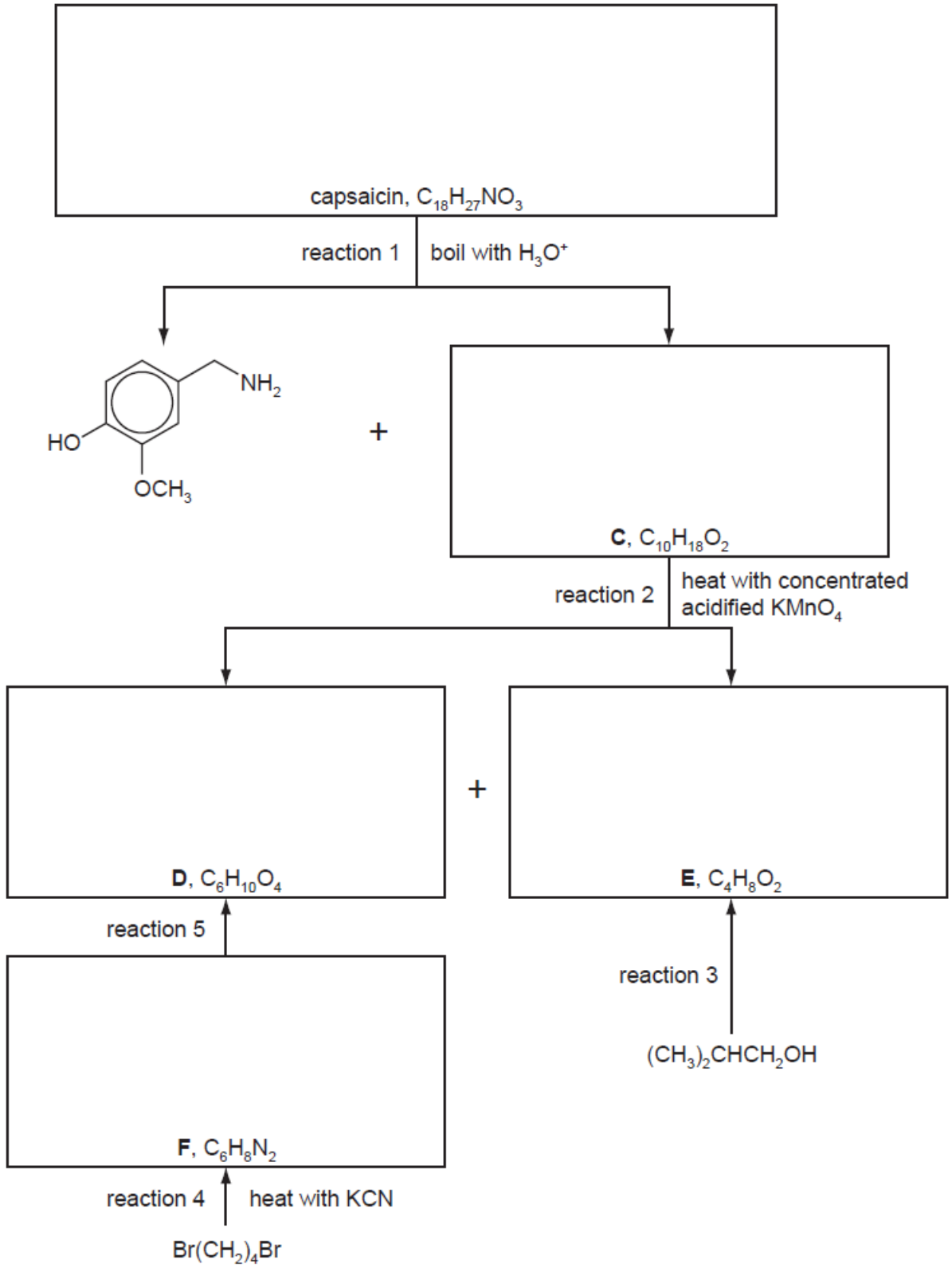
compound **L**

[3]

[Total: 18]

w/12/qp41

4 The compound responsible for the hot taste of chilli peppers is capsaicin. Its molecular structure can be deduced by the following reaction scheme.



Compounds **C**, **D** and **E** all react with $Na_2CO_3(aq)$.

Answer the following questions.

(a) Suggest reagents and conditions for reaction 3.

..... [1]

(b) What *type of reaction* is reaction 4?

..... [1]

(c) Suggest reagents and conditions for reaction 5.

..... [1]

(d) Name the functional group in **C** that has reacted with hot concentrated acidified $KMnO_4$.

..... [1]

(e) Suggest the name of the functional group in capsaicin that has reacted in reaction 1.

..... [1]

(f) Work out structures for compounds **C–F** and capsaicin, and draw their structural formulae in the boxes opposite. [5]

[Total: 10]

w/12/qp41

5 Alkanes are generally considered to be unreactive compounds, showing an inertness to common reagents such as NaOH, H_2SO_4, and $K_2Cr_2O_7$.

(a) Suggest a reason why these reagents **do not** attack an alkane such as CH_4.

.....

[1]

(b) When a mixture of chlorine and ethane gas is exposed to strong sunlight, an explosion can occur due to the fast exothermic reaction.
Under more controlled conditions, however, the following reaction occurs.

$$C_2H_6 + Cl_2 \longrightarrow C_2H_5Cl + HCl$$

(i) What is the name of this type of reaction?

.....

(ii) Use equations to describe the mechanism of this reaction, naming the steps involved.

.....

.....

.....

.....

.....

.....

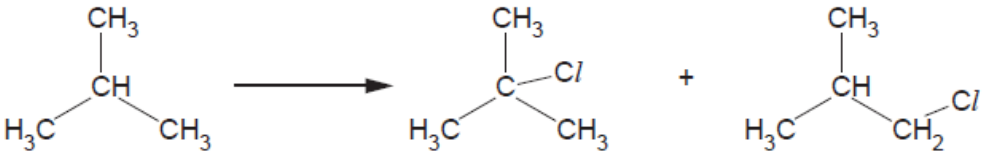
(iii) This reaction can produce organic by-products, in addition to C_2H_5Cl.
Draw the structural formulae of three possible organic by-products. Two of your by-products should contain 4 carbon atoms per molecule.
Briefly describe how each by-product could be formed.

structural formula of by-product	formed by

(iv) It is found by experiment that, during this type of reaction, primary, secondary and tertiary hydrogen atoms are replaced by chlorine atoms at different rates, as shown in the following table.

reaction	relative rate
$RCH_3 \rightarrow RCH_2Cl$	1
$R_2CH_2 \rightarrow R_2CHCl$	7
$R_3CH \rightarrow R_3CCl$	21

Using this information, and considering the number of hydrogen atoms of each type (primary, secondary or tertiary) within the molecule, predict the relative ratio of the two possible products **J** and **K** from the chlorination of 2-methylpropane. Explain your answer.



2-methylpropane **J** **K**

ratio **J** / **K** = ...

explanation:

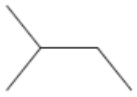
.....

.....

.....

[10]

(c) In the boxes below draw the **skeletal** formulae of **four** different structural isomers of $C_5H_{11}Cl$ that could be obtained from the chlorination of 2-methylbutane. Indicate any chiral centres in your structures by an asterisk (*).



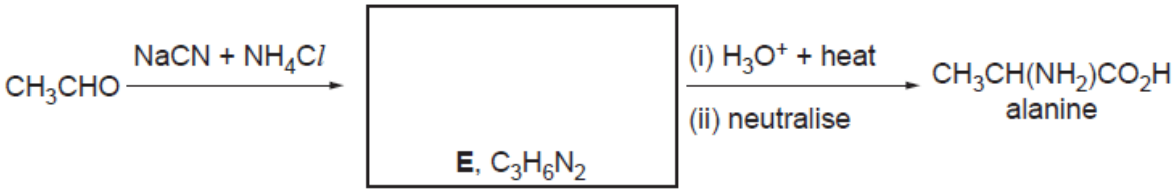
2-methylbutane

$+ Cl_2 \longrightarrow C_5H_{11}Cl + HCl$

[5]

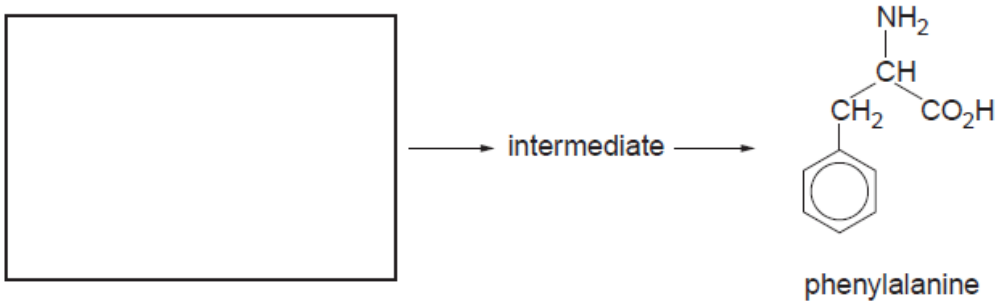
[Total: 16]

3 **(a)** Amino acids such as alanine are essential building blocks for making proteins. They can be synthesised by a general reaction of which the following is an example.



(i) Suggest the structure of the intermediate compound **E** by drawing its structural formula in the box above.

(ii) Suggest, in the box below, the structural formula of the starting material needed to synthesise phenylalanine by the above general reaction.



[2]

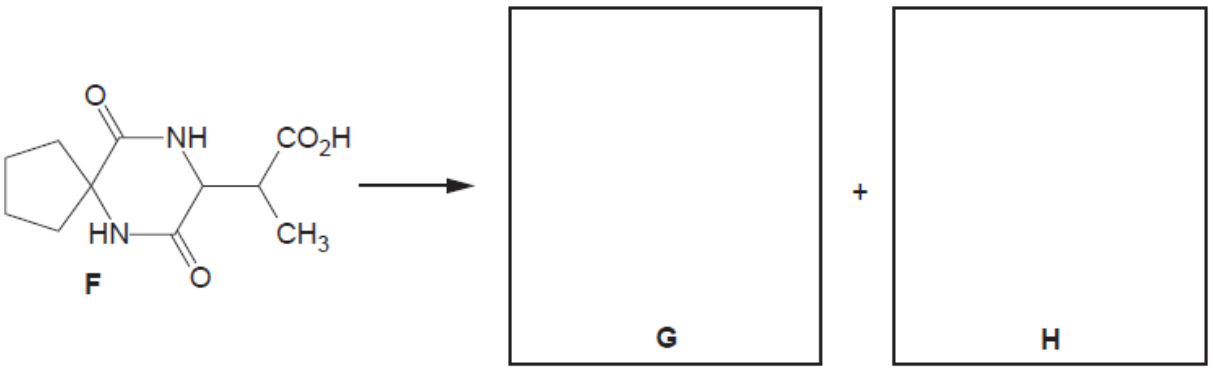
(b) **(i)** What is a *protein*?

.....

(ii) Using alanine as an example, draw a diagram to show how proteins are formed from amino acids. Show two repeat units in your answer.

[3]

(c) The hydrolysis of compound **F** produces two compounds **G** and **H**.



(i) State the reagents and conditions needed for this hydrolysis.

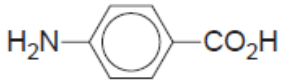
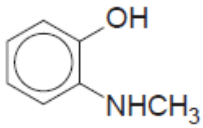
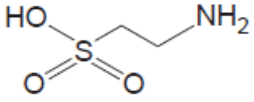
.....

(ii) Draw the structures of the two products **G** and **H** in the boxes above.

[3]

(d) **(i)** Draw the zwitterionic structure of alanine.

(ii) Suggest the structural formulae of the zwitterions that could be formed from the following compounds.

compound	zwitterion
	
	
	

[4]

w/11/qp43

8 In today's world we make use of a wide range of different polymers. These polymers are often substitutes for traditional materials, but may have more useful properties.

(a) Complete the table identifying one traditional material that has been replaced by each polymer.

traditional material	modern polymer and its use
	PVC in packaging
	Terylene in fabrics
	polycarbonate bottle

[2]

(b) Throwing away articles made from polymers after use is a major environmental concern for **two** main reasons. Identify **each** of these reasons and suggest a strategy that has been adopted to try to overcome each of these.

reasons : .....

.....

.....

strategy 1 : .....

.....

strategy 2 : .....

.....

[3]

(c) One suggestion for the disposal of polymers is to use them as a fuel to provide energy for small-scale power stations or district heating schemes.
Identify one polymer which would be **unsuitable** for this use, explaining the reason behind this.

polymer .....

reason .....

.....

.....

[2]

(d) Polymers can be either thermoplastic or thermosetting.

Name a thermoplastic polymer. .....

State which type of polymerisation produces thermoplastic polymers, explaining your answer in terms of the structure of the polymer.

.....

.....

.....

.....

[3]

[Total: 10]

w/11/qp41

5 Compound **C** has the molecular formula $C_7H_{14}O$. Treating **C** with hot concentrated acidified $KMnO_4(aq)$ produces two compounds, **D**, C_4H_8O, and **E**, $C_3H_4O_3$. The results of four tests carried out on these three compounds are shown in the following table.

test reagent	result of test with		
	compound **C**	compound **D**	compound **E**
$Br_2(aq)$	decolourises	no reaction	no reaction
Na(s)	fizzes	no reaction	fizzes
$I_2(aq) + OH^-(aq)$	no reaction	yellow precipitate	yellow precipitate
2,4-dinitrophenylhydrazine	no reaction	orange precipitate	orange precipitate

(a) State the functional groups which the above four reagents test for.

(i) $Br_2(aq)$

.....

(ii) Na(s)

.....

(iii) $I_2(aq) + OH^-(aq)$

.....

(iv) 2,4-dinitrophenylhydrazine

.....

[4]

(b) Based upon the results of the above tests, suggest structures for compounds **D** and **E**.

D, C_4H_8O

E, $C_3H_4O_3$

[2]

(c) Compound **C** exists as two stereoisomers.

Draw the structural formula of **each** of the two isomers, and state the type of stereoisomerism involved.

type of stereoisomerism .....
[3]

[Total: 9]

w/11/qp41

4 **(a)** **(i)** Write the equation for a reaction in which ethylamine, $C_2H_5NH_2$, acts as a Brønsted-Lowry base.

.....

(ii) Ammonia, ethylamine and phenylamine, $C_6H_5NH_2$, are three nitrogen-containing bases.

Place these three compounds in order of basicity, with the most basic first.

most basic		least basic

(iii) Explain why you have placed the three compounds in this order.

.....

.....

.....

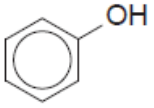
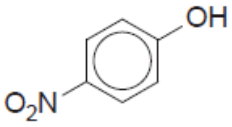
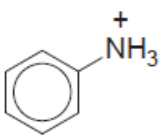
.....

[4]

(b) **(i)** Write an equation for a reaction in which phenol, C_6H_5OH, acts as a Brønsted-Lowry acid.

.....

The pK_a values for phenol, 4-nitrophenol and the phenylammonium ion are given in the table.

compound	pK_a
	10.0
	7.2
	4.6

(ii) Suggest an explanation for the difference in the pK_a values of phenol and nitrophenol.

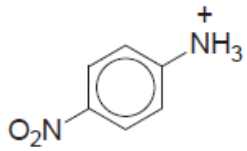
.....

.....

.....

.....

(iii) Using the information in the table opposite, predict which of the following pK_a values is the most likely for the 4-nitrophenylammonium ion.



Place a tick (✓) in the box beside the value you have chosen.

pK_a	
1.0	
4.5	
7.0	
10.0	

(iv) Explain your answer to part **(iii)**.

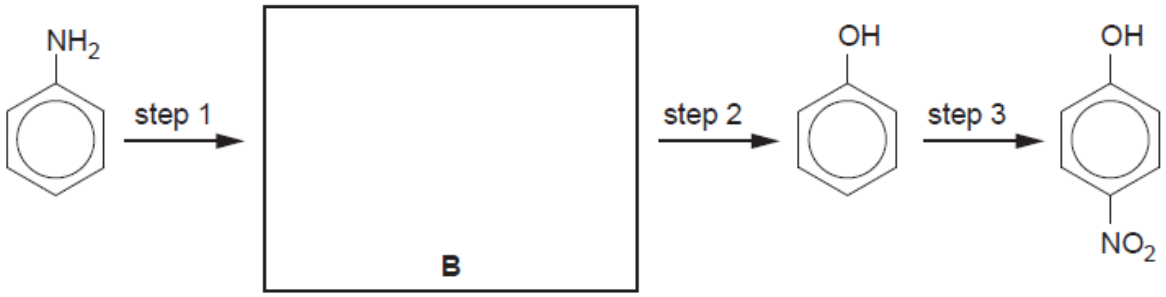
.....

.....

.....

[5]

(c) Phenylamine can be converted to 4-nitrophenol by the following steps.



(i) Suggest the identity of intermediate **B** by drawing its structure in the box above.

(ii) Suggest reagents and conditions for the three steps in the above scheme.

	reagent(s)	conditions
step 1		
step 2		
step 3		

[5]

[Total: 14]

(c) Halogenoalkanes can undergo *homolytic fission* in the upper atmosphere.

(i) Explain the term *homolytic fission*.

.....

.....

(ii) Suggest the most likely organic radical that would be formed by the homolytic fission of bromochloromethane, CH_2BrCl. Explain your answer.

.....

.....

.....

[3]

(d) The reaction between propane and chlorine produces a mixture of many compounds, four of which are structural isomers with the molecular formula $C_3H_6Cl_2$.
Draw the structural or skeletal formulae of these isomers, and indicate any chiral atoms with an asterisk (*).

[3]

(d) Polymers may be formed by two different types of chemical reaction.
Name the two types of reaction and write an equation to illustrate each reaction type.

name .....

equation .....

name .....

equation .....

[3]

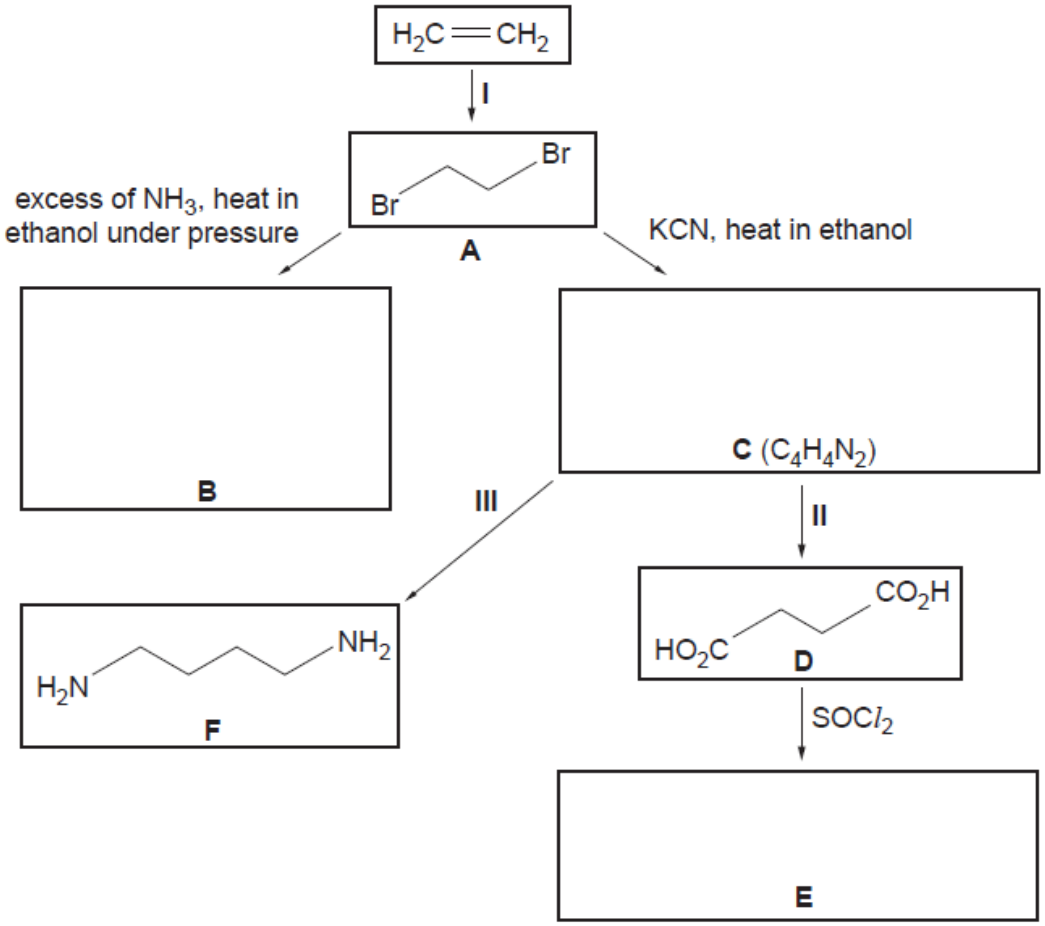
(e) The breakdown of polymers, such as carbohydrates and proteins in the body is important for digestion. What type of reaction is generally involved?

.....[1]

[Total: 10]

w/10/qp43

6 The following scheme outlines the production of some compounds from ethene.



(a) (i) Suggest the reagent and conditions for reaction **I**.

.....

(ii) Describe the mechanism of reaction **I** by means of a diagram. Include all whole, partial and induced charges, and represent the movements of electron pairs by curly arrows.

[3]

(b) Suggest the identities of compounds **B**, **C** and **E**, and draw their structures in the boxes opposite. [3]

(c) Suggest reagents and conditions for

reaction **II**,

.....

reaction **III**.

.....[2]

(d) During reaction **II** the nitrogen atoms are lost from the organic molecule. Suggest the identity of the nitrogen-containing ion produced during this reaction.

.....[1]

(e) Compounds **E** and **F** react together to give a polymer and an inorganic product.

(i) Draw **one** repeat unit of this polymer.

(ii) Identify the inorganic product.

.....[2]

(f) A 0.100 mol dm^{-3} solution of compound **D** has a pH of 2.60.

(i) Calculate the $[H^+]$ in this solution.

.....

.....

(ii) Hence calculate the value of K_a of compound **D**.

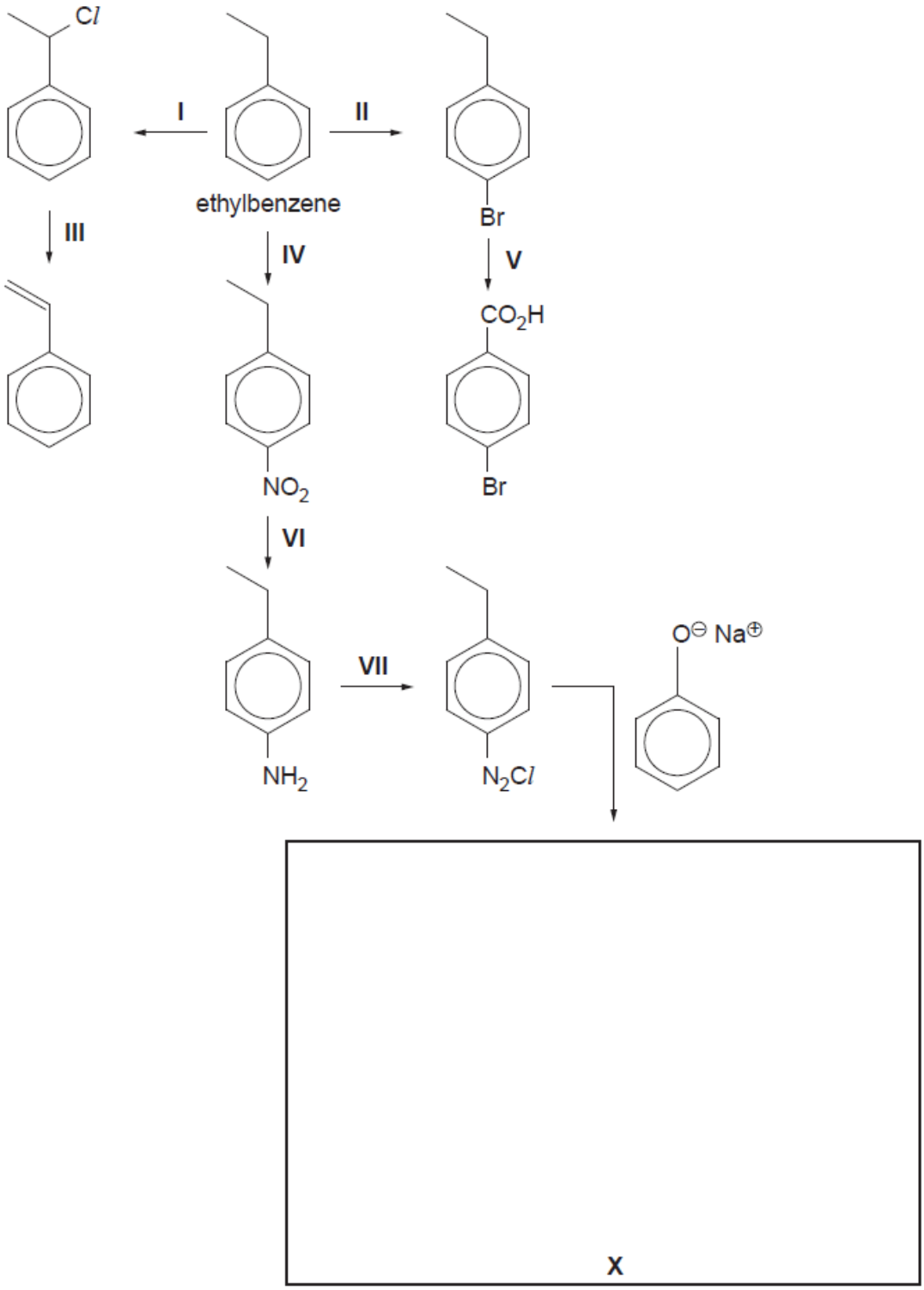
.....

.....
[2]

[Total: 13]

w/10/qp43

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



(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.

reaction I .....

reaction II .....

reaction III .....

reaction IV .....

reaction V .....

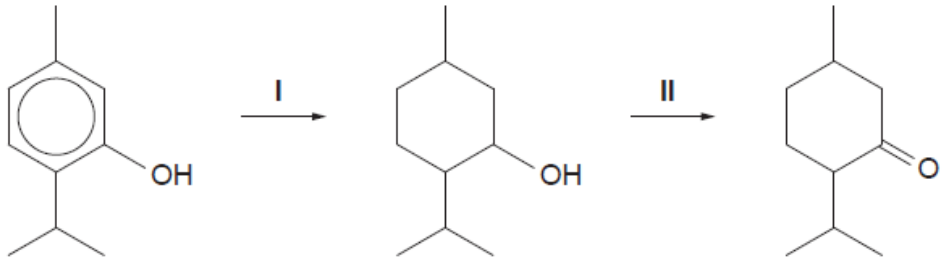
reaction VI .....

reaction VII .....

[Total: 8]

w/10/qp43

3 Menthol and menthone, the main constituents of oil of peppermint, can be made synthetically from thymol by the following route.



thymol menthol menthone

(a) State the *type of reaction* of

- reaction **I**, ...
- reaction **II**. .....

[2]

(b) Suggest **one** test for **each** of the three compounds that would give a positive result with the stated compound but a negative result with **both** the other two compounds.

thymol

test .....

observation .....

menthol

test .....

observation .....

menthone

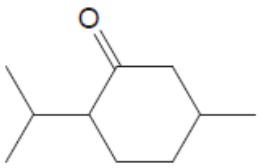
test .....

observation .....[6]

[Total: 8]

w/10/qp43

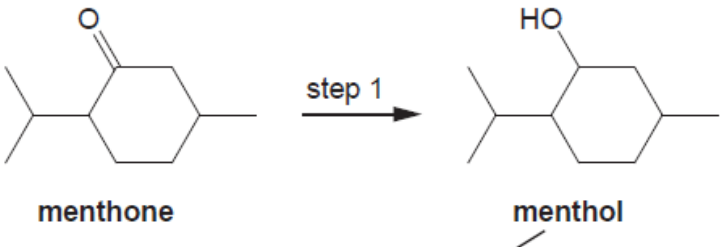
6 Menthone, $C_{10}H_{18}O$, is a cyclic ketone that occurs in oil of peppermint.



menthone

(a) Use asterisks (*) on the formula above to identify any chiral centres in the molecule of menthone. [2]

(b) Menthone can be reduced to menthol, which can be dehydrated to a mixture of two alkenes, **L** and **M**.



menthone **menthol**

step 2

L	+	**M**

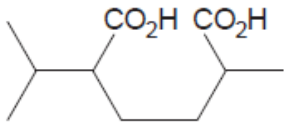
(i) Suggest reagents for

step 1, ...

step 2. .....

(ii) Suggest structures for **L** and **M** and draw them in the boxes above. [4]

(c) When heated with concentrated, acidified $KMnO_4(aq)$, one of the two alkenes **L** or **M** produces the dicarboxylic acid **N**.



N

(i) Give the letter of the alkene that produced **N** by this reaction.

.....

(ii) Suggest the structure of the product, **P**, of the reaction between the other alkene you have drawn and hot concentrated acidified $KMnO_4$.

P

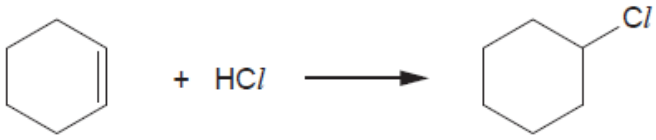
(iii) Suggest **one** chemical test that would enable you to distinguish between **N** and **P**.

reagent(s).....

observation.....

[3]

(d) Chlorocyclohexane can be prepared by bubbling $HCl(g)$ through a solution of cyclohexene.

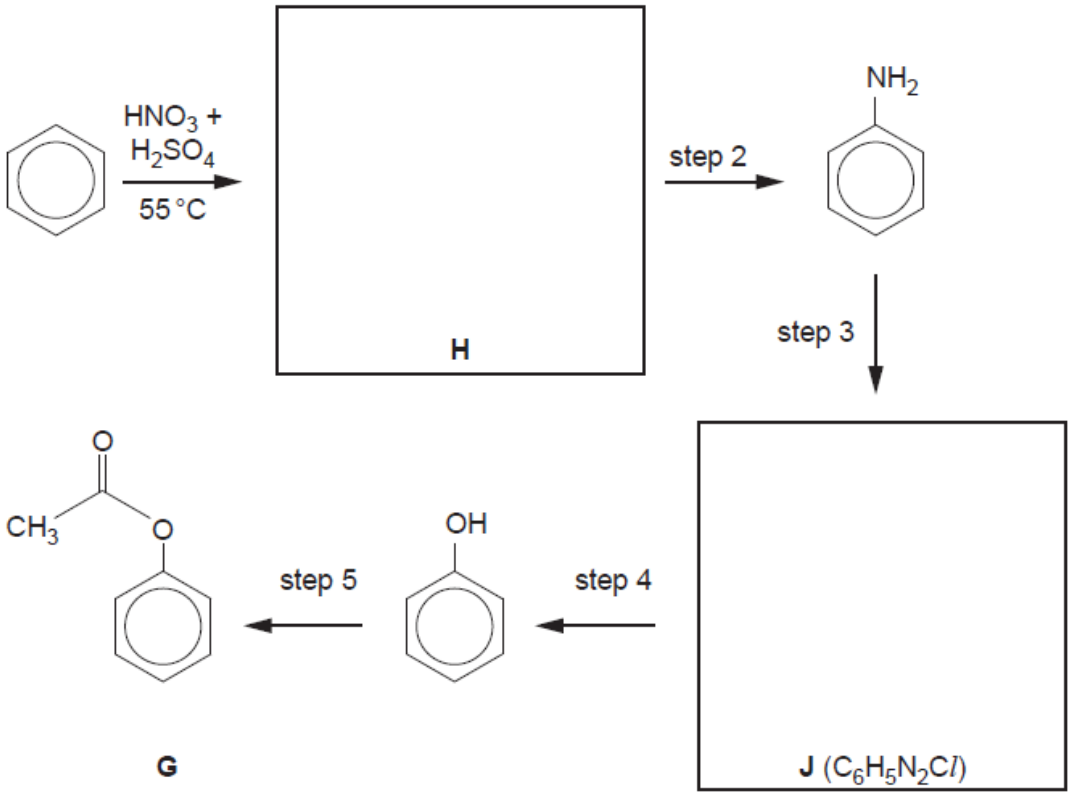


Suggest the mechanism of this 2-stage reaction by means of a diagram. Include all whole or partial charges, and represent the movements of electron pairs by curly arrows.

[3]

[Total: 12]

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 .....

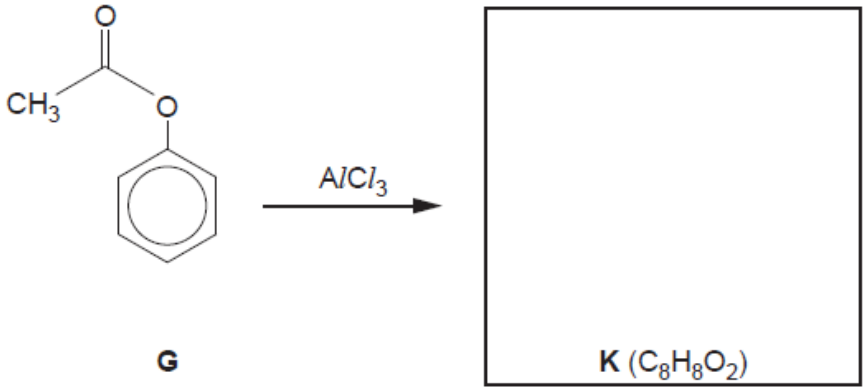
step 3 .....

step 4 .....

step 5 .....

[7]

(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**.



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*?

.....

.....

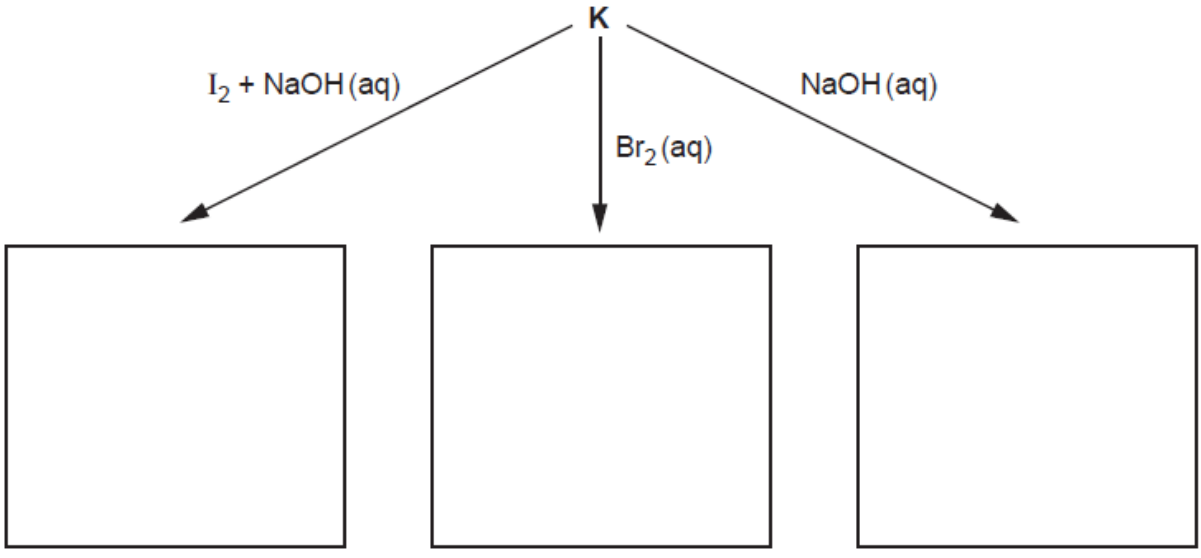
(ii) Use the information given above to **name** two functional groups in compound **K**.

.....

.....

(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.



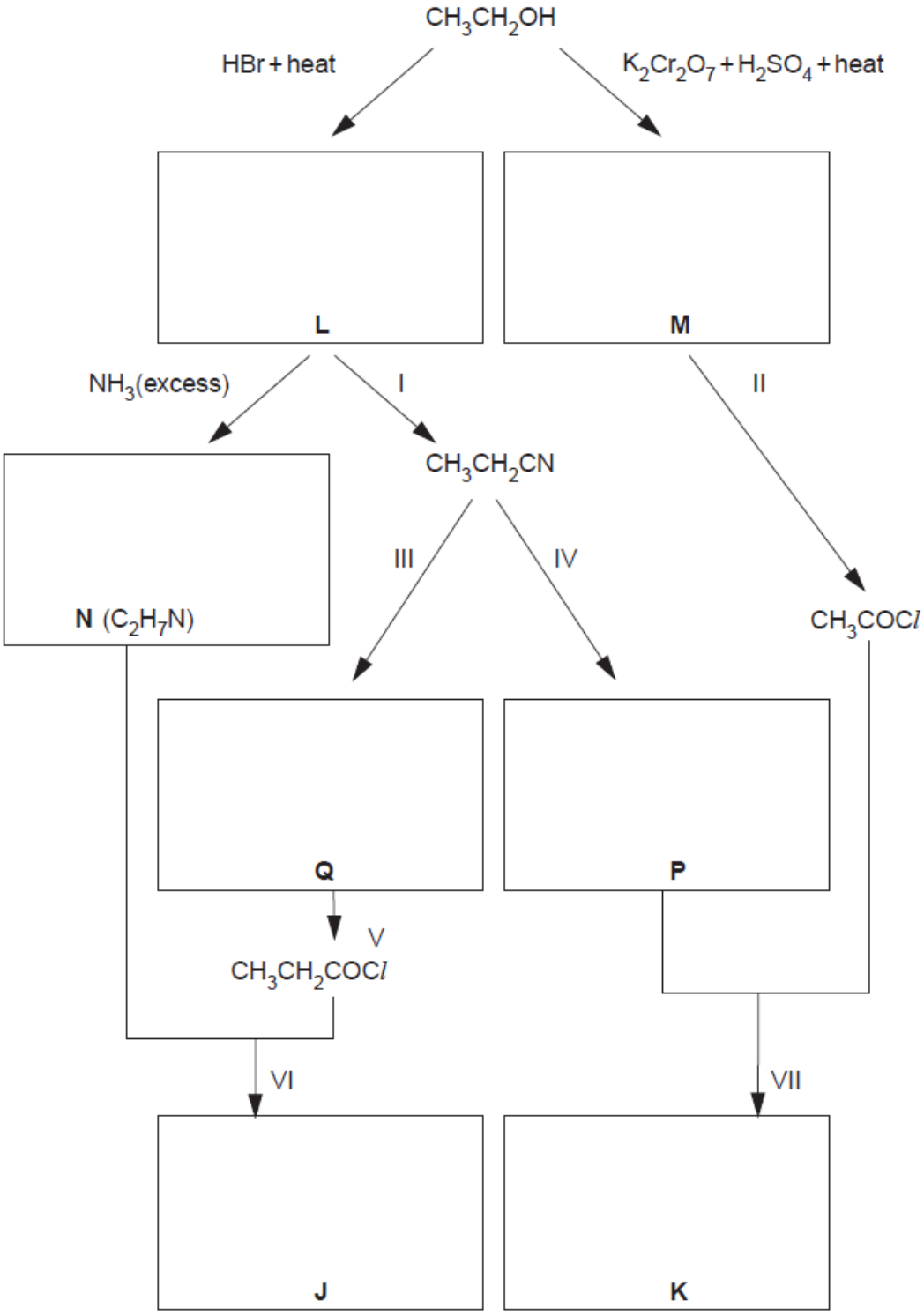
[7]

[Total: 14]

w/10/qp41

6 Compounds **J** and **K** are isomers with the molecular formula $C_5H_{11}NO$, and they contain the same functional group.

They may both be obtained from ethanol by the following routes.



(a) Draw the structural formulae of the lettered compounds **J** to **Q** in the boxes above. [7]

(b) Suggest reagents and conditions for the following.

reaction I

.....

reaction II

.....

reaction IV

.....[3]

(c) What *type of reaction* is occurring in

reaction IV,

.....

reaction VI?

.....[2]

(d) **(i)** Name the functional group that is common to compounds **J** and **K**.

.....

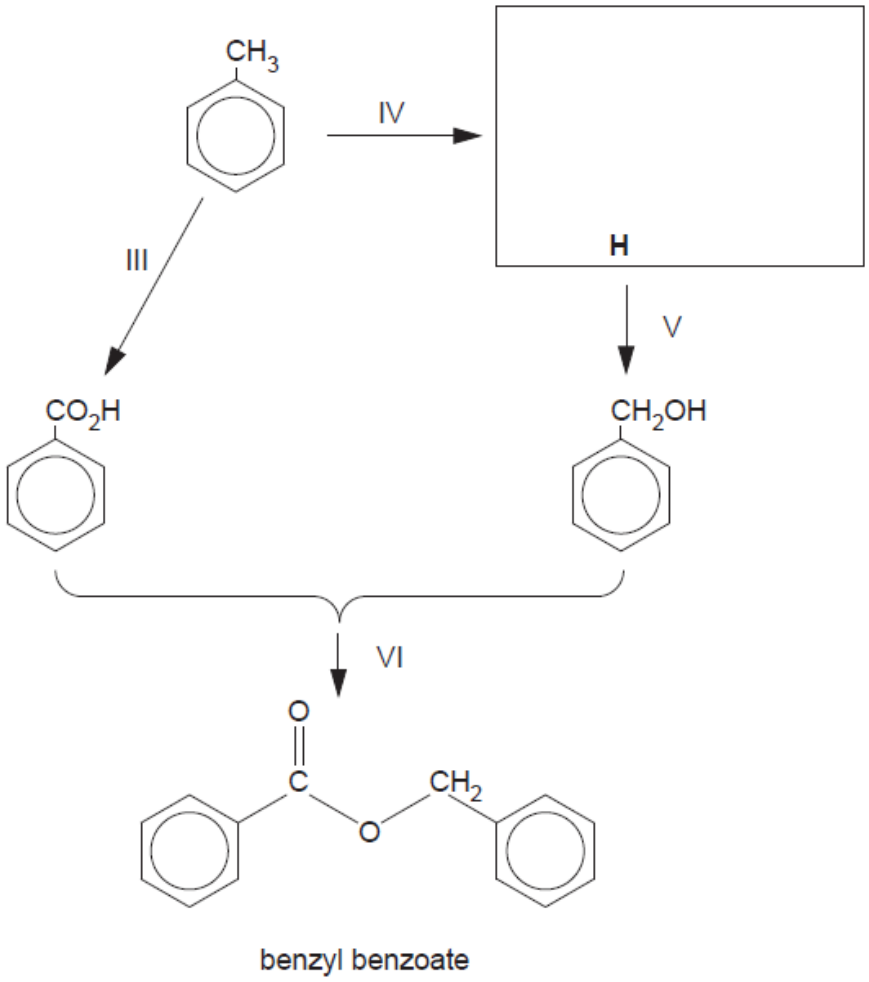
(ii) Name the functional group that is common to compounds **N** and **P**.

.....[2]

[Total: 14]

w/09/qp42

(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)**.



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.

.....

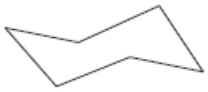
[6]

[Total: 11]

w/09/qp42

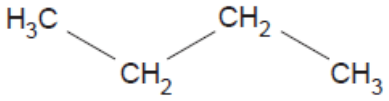
5 **(a)** All the carbon atoms in benzene lie in the same plane. This means that they are *coplanar*, but this is not the case with cyclohexane.

benzene

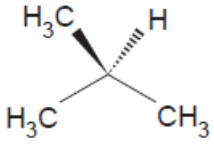


cyclohexane

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.

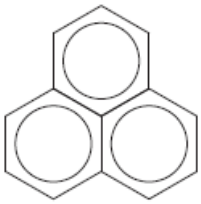


butane

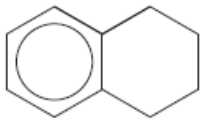


methylpropane

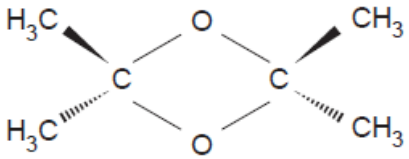
By considering the 3-dimensional geometry of the following five molecules, and allowing rotations around C–C bonds, decide whether or not the **carbon atoms** in each molecule **can be arranged** in a coplanar fashion. Then place a tick in the appropriate column in the table below.



A



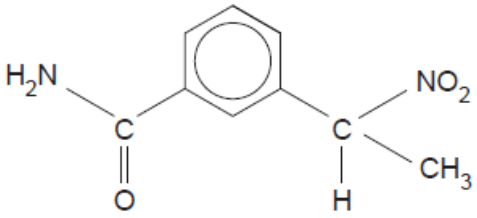
B



C

$CH_3CH(OH)CO_2H$

D

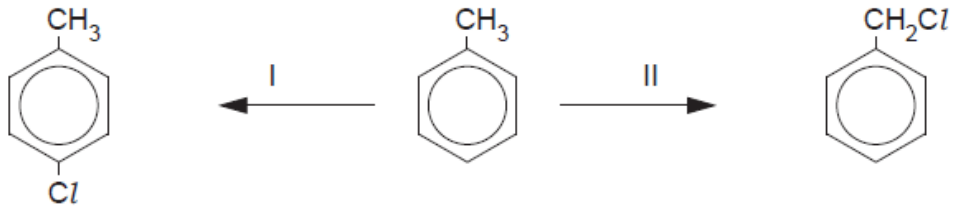


E

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**.



F **G**

Suggest reagents and conditions for each reaction.

reaction I

.....

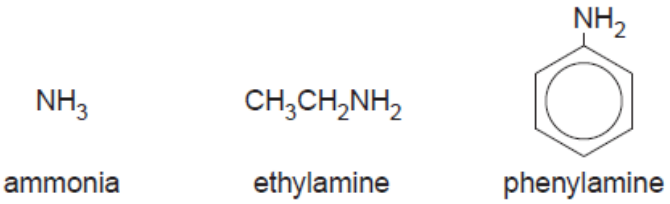
reaction II

.....[2]

w/09/qp42

---

2 **(a)** Describe and explain how the basicities of ammonia, ethylamine and phenylamine differ.



ammonia ethylamine phenylamine

.....

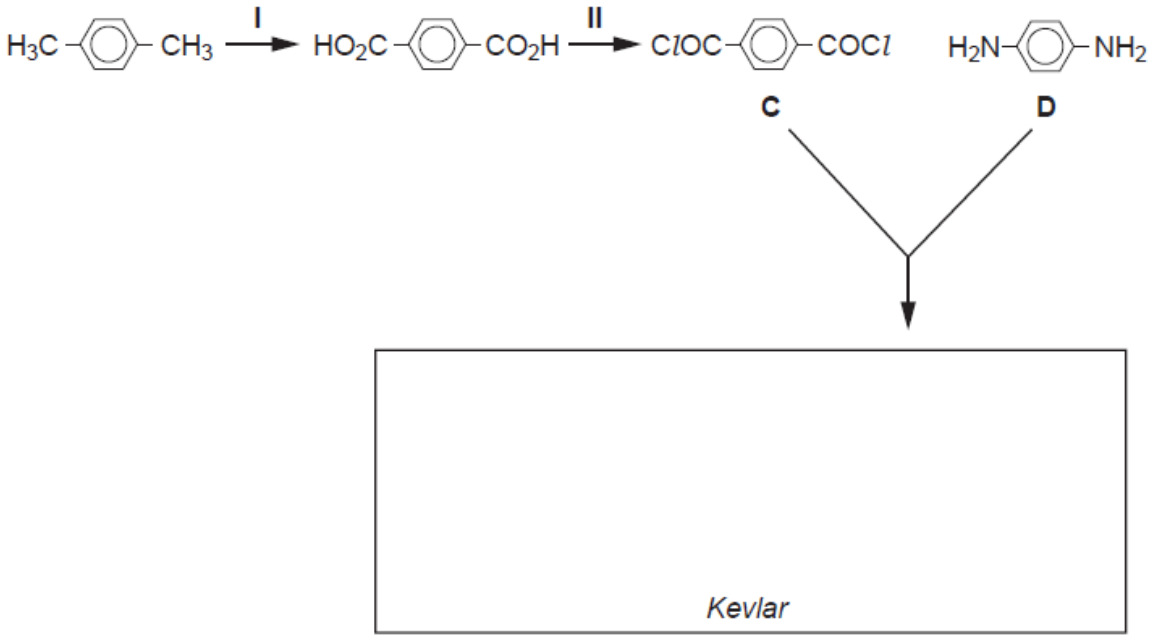
.....

.....

.....[3]

w/09/qp42

5 *Kevlar* is a tough polyamide used in bullet-proof vests and high-specification bicycle tyres. It can be manufactured by the following process.



(a) **(i)** Suggest reagents and conditions for

reaction **I**, ...

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

(ii) Draw the structural formula of **one** repeat unit of *Kevlar* in the box above.

[4]

(b) The di-acid chloride **C** reacts with a variety of reagents. Suggest the structural formulae of the products of the reaction of **C** with

(i) CH_3NH_2,

(ii) $HOCH_2CH_2OH$.

[3]

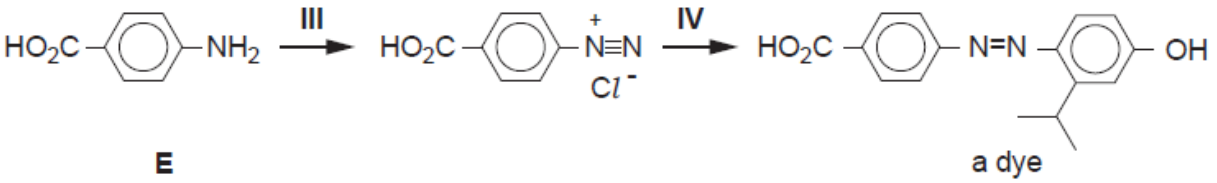
(c) The diamine **D** also reacts with a variety of reagents. Suggest the structural formulae of the products of the reaction of **D** with

(i) HC*l*(aq),

(ii) Br_2(aq).

[3]

(d) 4-aminobenzoic acid, **E**, is a useful intermediate for making dyes.



E a dye

Suggest reagents and conditions for

reaction **III**, ...

reaction **IV**. .....

[4]

(e) 4-aminobenzoic acid, **E**, forms a zwitterion.

(i) What is meant by the term *zwitterion*?

.....

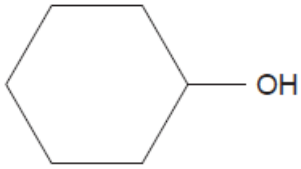
.....

(ii) Draw the structural formula of the zwitterion formed from 4-aminobenzoic acid.

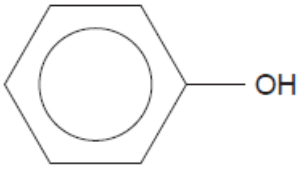
[2]

[Total: 16]

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]

w/09/qp41

4 **(a)** The viscosity of engine oil can be improved by the addition of certain medium chain-length polymers.

A portion of the chain of one such polymer is shown below.

$$-CH_2CH(CH_2CH_2CH_3)CH_2CH(CH_2CH_2CH_3)CH_2-$$

On average, the molecules of the medium-chain polymer contain 40 carbon atoms.

(i) Suggest the structure of the monomer.

.....

(ii) How many monomer units are incorporated into the average molecule of the polymer?

.....

[2]

(b) Used car engine oil can be recycled for use as a fuel by the processes of distillation and cracking.

(i) Assuming a typical molecule of engine oil has the formula $C_{40}H_{82}$, suggest an equation for a cracking reaction that could produce diesel fuel with the formula $C_{16}H_{34}$ and other hydrocarbons only.

.....

(ii) What conditions are needed for this cracking reaction?

.....

(iii) Considering only the bonds broken and the bonds formed during the reaction, use the *Data Booklet* to calculate the enthalpy change for the reaction you wrote in **(b)(i)**.

.....

.....

.....

(iv) Comment on how the conditions you described in **(b)(ii)** relate to the enthalpy change you calculated in **(b)(iii)**.

.....

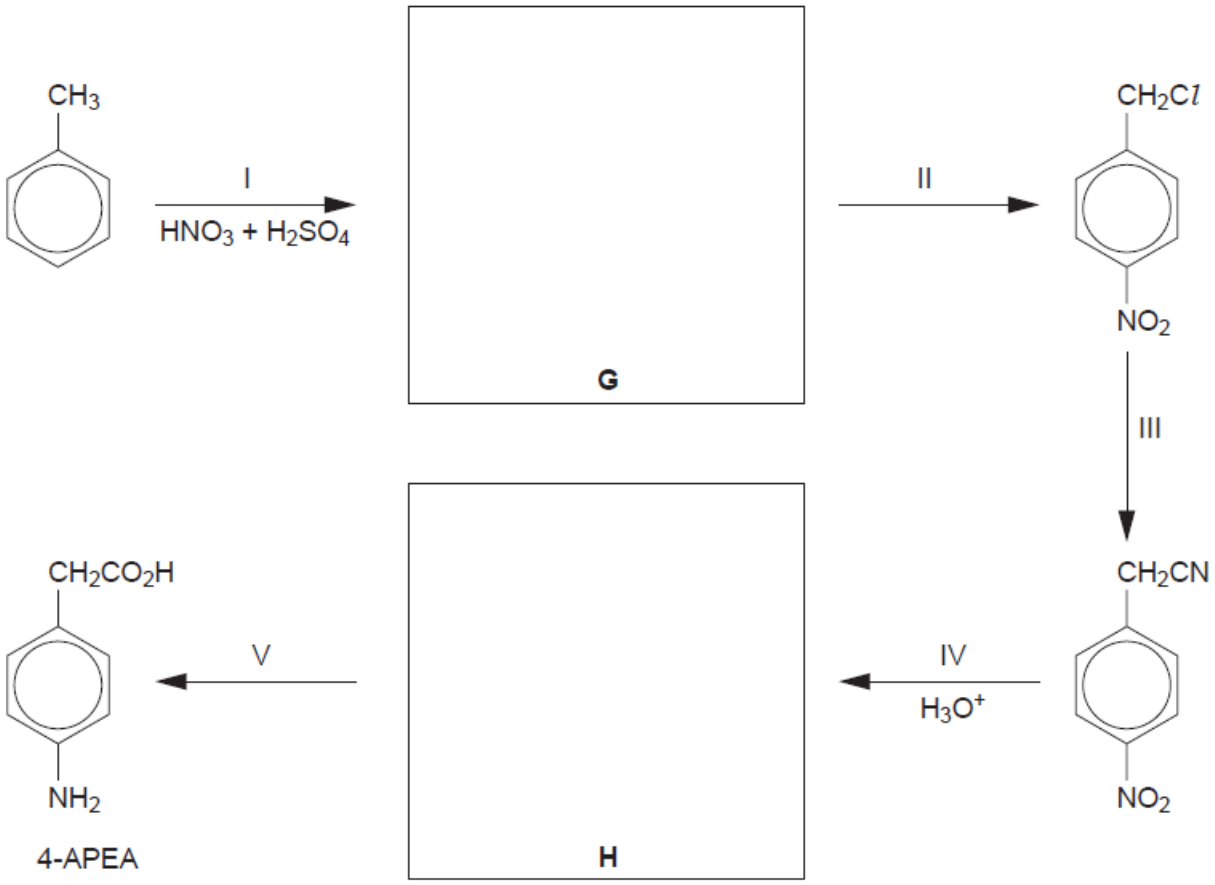
.....

[4]

[Total: 6]

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]

w/08/qp4

6 Suggest a test or simple reaction you could carry out on each of the following pairs of compounds to enable them to be distinguished.

(a) $CH_3COCH_2CH_2CH_3$ **J** $CH_3CH_2COCH_2CH_3$ **K**

(i) description of test or reaction

.....

.....

(ii) observation with compound **J**

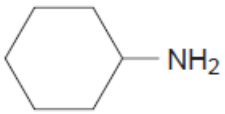
.....

(iii) observation with compound **K**

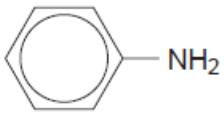
.....

[2]

(b)



L



M

(i) description of test or reaction

.....

.....

(ii) observation with compound **L**

.....

(iii) observation with compound **M**

.....

[2]

(c) CH_3CH_2COCl **N** $CH_3CH_2CH_2Cl$ **P**

(i) description of test or reaction

.....

.....

(ii) observation with compound **N**

.....

(iii) observation with compound **P**

.....

[2]

(d) $CH_3CH_2CONH_2$ **Q** $CH_3CH_2CH_2NH_2$ **R**

(i) description of test or reaction

.....

.....

(ii) observation with compound **Q**

.....

(iii) observation with compound **R**

.....

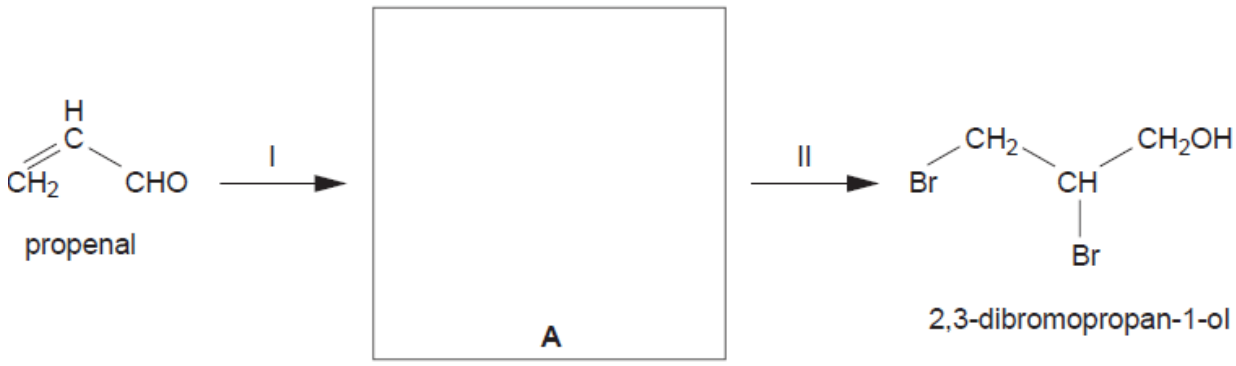
[2]

[Total: 8]

w/08/qp4

Esters of 2,3-dibromopropan-1-ol with phosphoric acid are useful flame retardants used in plastics and fibres.

2,3-dibromopropan-1-ol can be made from propenal by the following two-stage process.



(b) (i) Draw the structure of the intermediate **A** in the box opposite.

(ii) Suggest reagents and conditions for

- reaction I,

.....

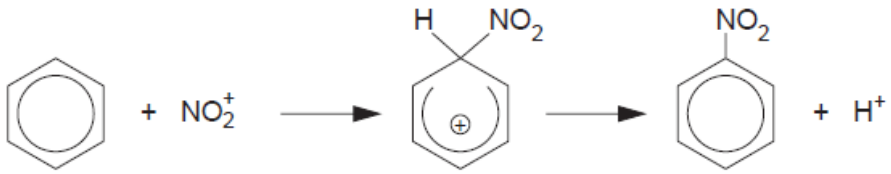
- reaction II.

.....

[3]

w/08/qp4

7 The nitration of benzene occurs in the following steps.



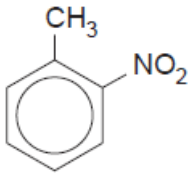
(a) What reagents and conditions are needed for this reaction?

.....[2]

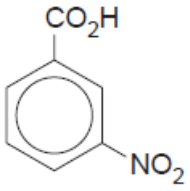
(b) Write an equation showing how the electrophile NO_2^+ is formed from the reagents.

.....[1]

(c) The nitration of methylbenzene produces mainly 2-nitromethylbenzene, whereas the nitration of benzoic acid produces mainly 3-nitrobenzoic acid.

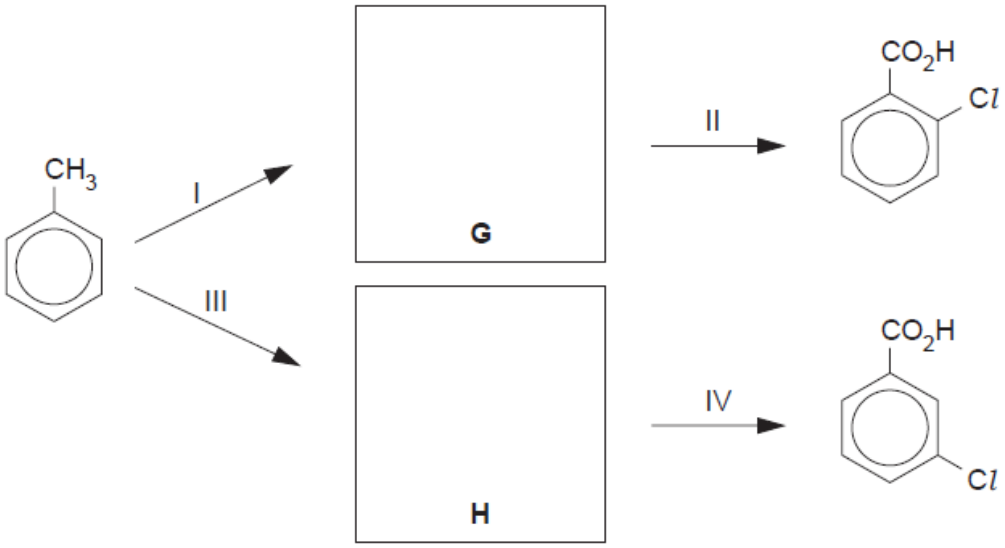


2-nitromethylbenzene



3-nitrobenzoic acid

Use this information to suggest suitable intermediates **G** and **H** in the following two 2-stage syntheses of chlorobenzoic acids, and suggest suitable reagents for reactions I to IV.



reagents:

reaction I ..... reaction II .....

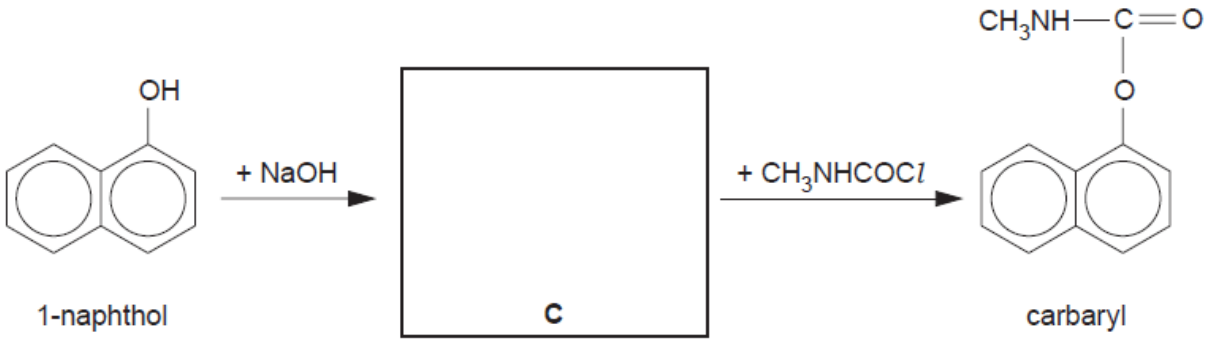
reaction III ..... reaction IV .....

[4]

[Total: 7]

w/07/qp4

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.

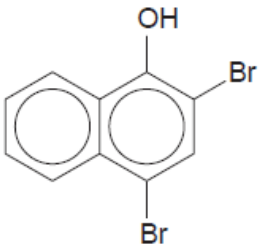
(iv) What reagents and conditions would you use for this hydrolysis?

.....

[7]

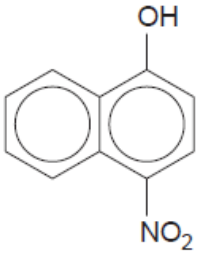
(b) Suggest reagents and conditions for converting 1-naphthol into each of the following compounds.

(i)



.....

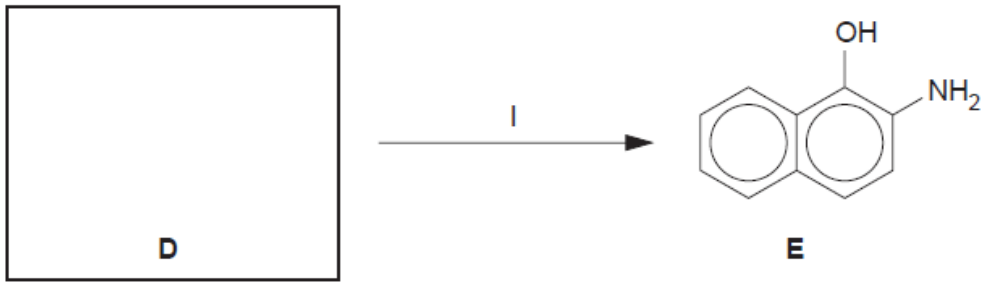
(ii)



.....

[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]

w/07/qp4

(b) The pK_a values of four carboxylic acids are listed in the table below.

acid	formula of acid	pK_a
1	$CH_3CH_2CO_2H$	4.9
2	$CH_3CHClCO_2H$	2.8
3	$CH_3CCl_2CO_2H$	1.4
4	$CH_2ClCH_2CO_2H$	4.1

(i) Describe and explain the trend in acid strength shown by acids 1, 2 and 3.

.....

.....

.....

.....

(ii) Suggest an explanation for the difference in the pK_a values for acids 2 and 4.

.....

.....

w/07/qp4

5 **(a)** Describe and explain how the acidities of $CHCl_2CO_2H$ and CH_2ClCO_2H compare to each other, and to the acidity of ethanoic acid.

.....

.....

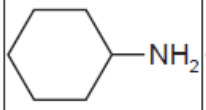
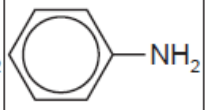
.....

.....

.....

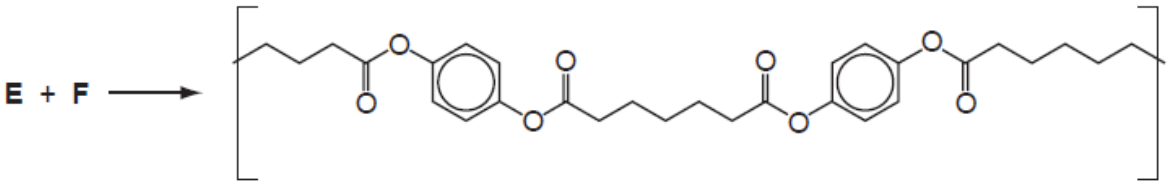
[3]

(b) For each of the following pairs of compounds, suggest one chemical test (reagents and conditions) that would distinguish between them.
State the observations you would make with each compound, writing 'none' if appropriate.

first compound	second compound	test (reagents and conditions)	observation with first compound	observation with second compound
				
CH_3CH_2COCl	CH_3COCH_2Cl			
CH_3CH_2CHO	CH_3COCH_3			

[7]

(c) The following diagram shows a section (not a repeat unit) of a polymer, **G**, that can be made from the two monomers **E** and **F**.



polymer **G**

(i) What *type of polymerisation* made this polymer?

.....

(ii) Draw the structures of the two monomers **E** and **F**.

E

F

(iii) Suggest the conditions needed to make polymer **G** from **E** and **F** in the laboratory.

.....

.....

.....

(iv) One of the monomers, **E** or **F**, could be changed to make a more rigid polymer of a similar chemical type to **G**.
Suggest which of your two monomers could be changed, and suggest a structure for the new monomer.

Monomer to be changed (**E** or **F**) .....

Structural formula of the new monomer

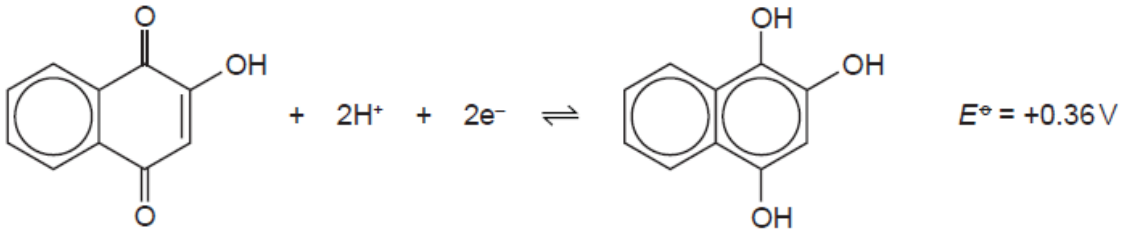
[6]

[Total: 16]

s/12/qp42

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]

(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.

.....

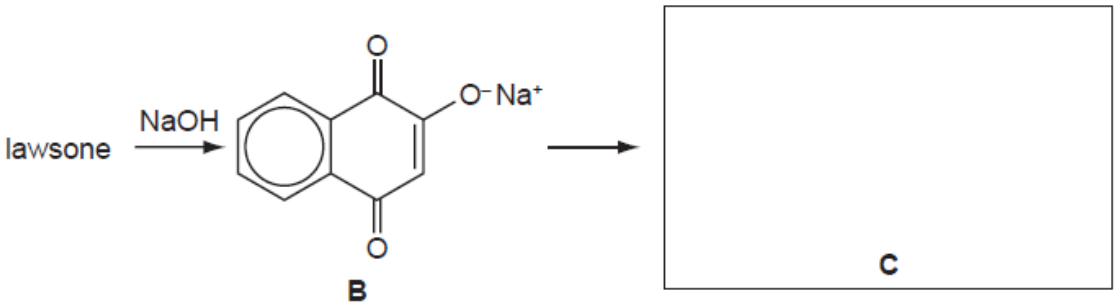
(ii) Construct an equation for this reaction. Use the molecular formulae of lawsone, $C_{10}H_6O_3$, and compound **A**, $C_{10}H_8O_3$, in your equation.

.....

(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.

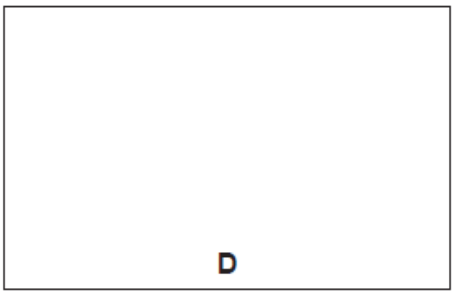


Reacting **B** with ethanoyl chloride, CH_3COCl, produces compound **C**, with the molecular formula $C_{12}H_8O_4$.

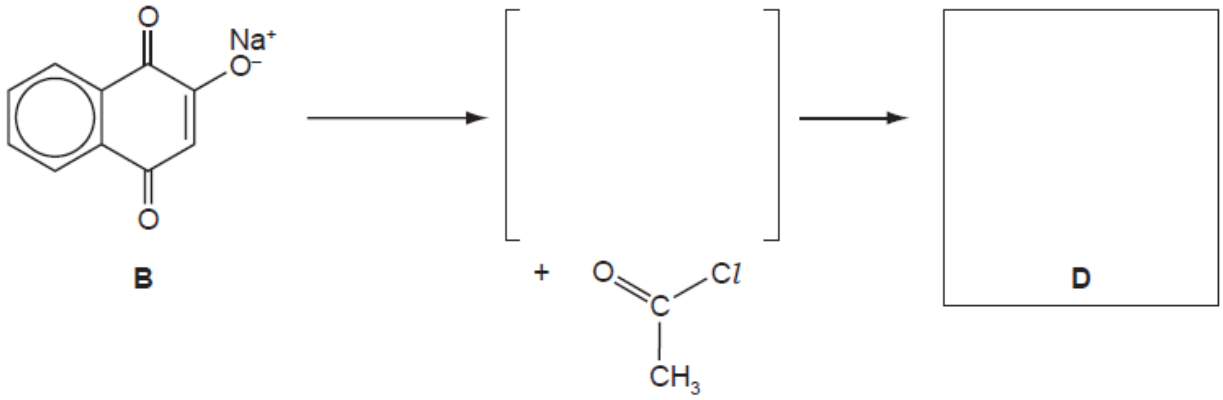
(i) Suggest the identity of compound **C**, and draw its structure in the box above.

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]

s/12/qp42

8 Some of the most commonly used polymers are formed by the polymerisation of ethene, C_2H_4. The presence of side-chains affects the bulk properties of an addition polymer. Unbranched polymers pack closer together than polymers with several side-chains.

Poly(ethene) exists in two different forms LDPE (low density poly(ethene)) which has lots of side-chains, and HDPE (high density poly(ethene)) in which there are fewer and shorter side-chains.

(a) Explain with the aid of sketches why the presence of side-chains causes a difference in density in poly(ethene).

.....

.....

..... [2]

(b) By reference to the type of bonding between the poly(ethene) chains, explain why LDPE has a lower melting point that HDPE.

.....

.....

..... [2]

(c) Polymerisation can take place by two different methods depending on the monomers involved. The two methods are addition and condensation.
Give **two** differences between the methods.

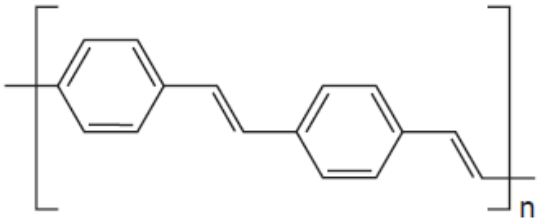
1. .....

.....

2. .....

.....
[2]

(d) There has been a great deal of commercial interest in the development of polymers that can conduct electricity and/or emit light. A length of one such polymer is shown.



(i) Suggest how this polymer conducts electricity.

.....

(ii) Suggest the molecular geometry required for this molecule to conduct.

Explain your answer.

.....

.....

(iii) What is the empirical formula of this polymer?

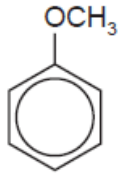
.....

[4]

[Total: 10]

s/12/qp41

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.

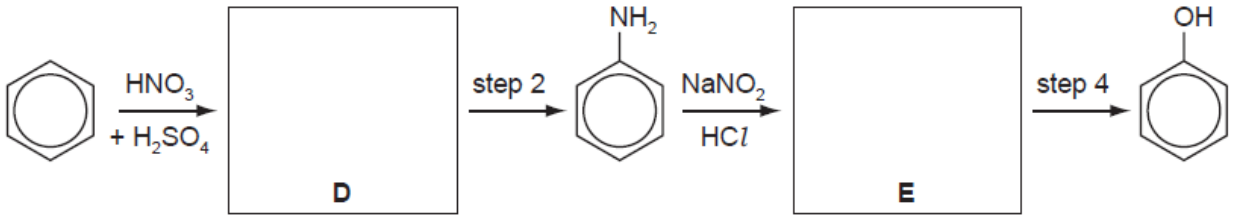
reagent .....

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. .....

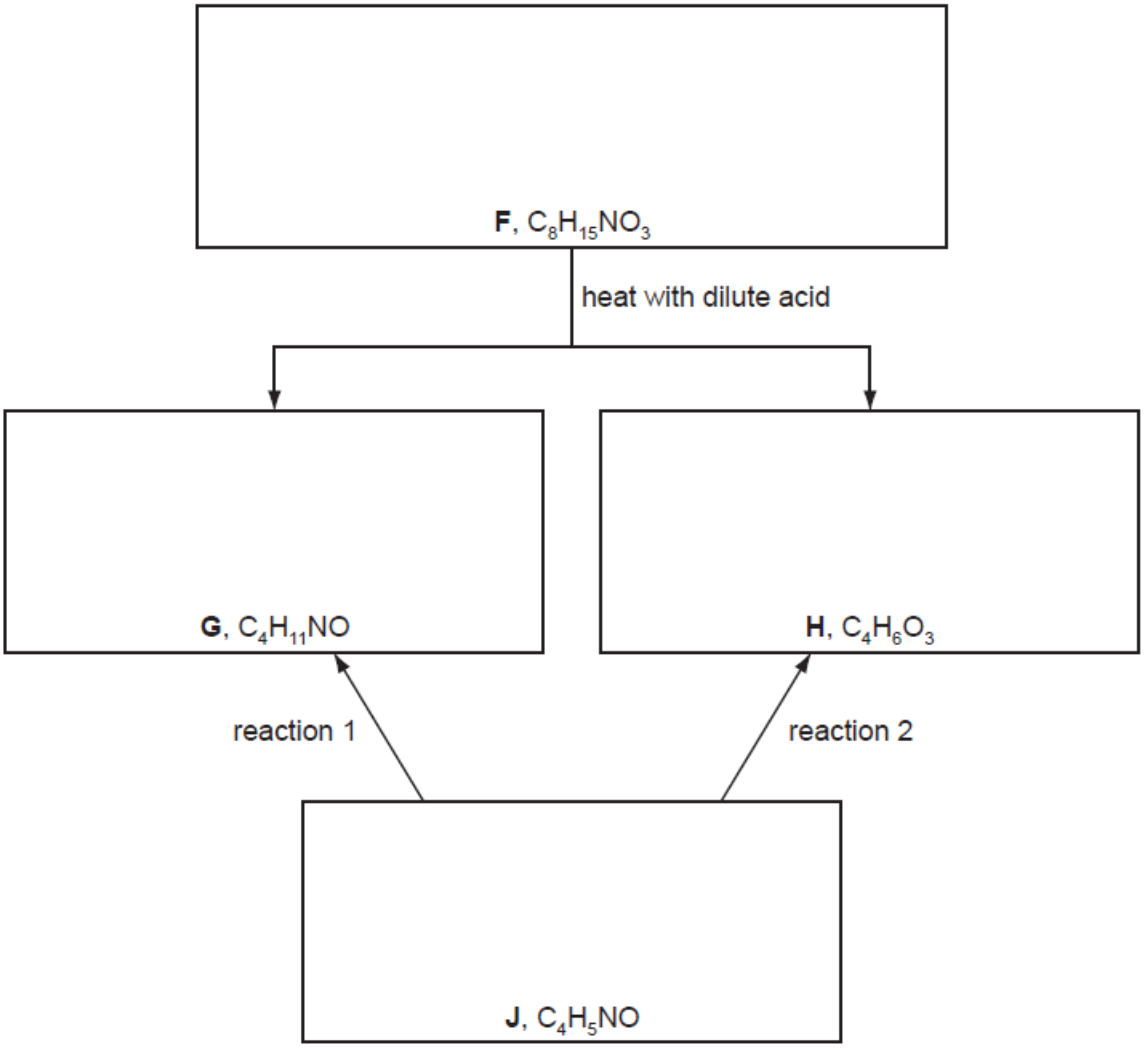
[4]

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

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]

s/12/qp41

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]

(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]

s/12/qp41

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

.....

.....

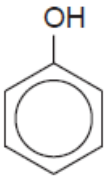
.....

.....

.....

.....[4]

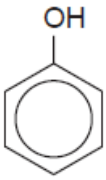
(b) Complete the following equations showing **all** the products of each of these reactions of phenol. Include reaction conditions where appropriate in the boxes over the arrows. If no reaction occurs write ***no reaction*** in the products box.



+ Na →

+ NaOH →

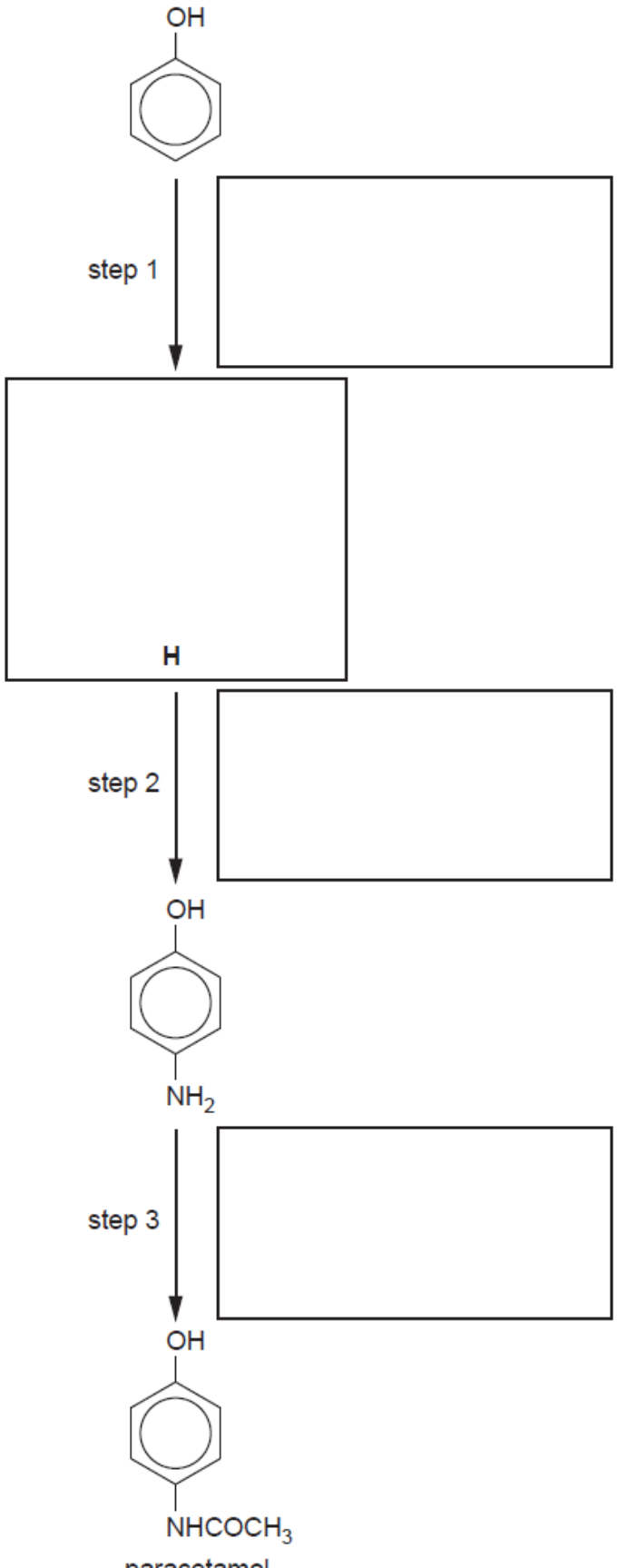
+ CH_3CO_2H →



+ Br_2 →

[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.



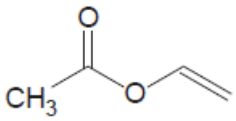
paracetamol

[4]

[Total: 13]

s/11/qp43

4 **(a)** Polyvinyl acetate, PVA, is a useful adhesive for gluing together articles made from wood, paper or cardboard. The monomer of PVA is ethenyl ethanoate, **B**.

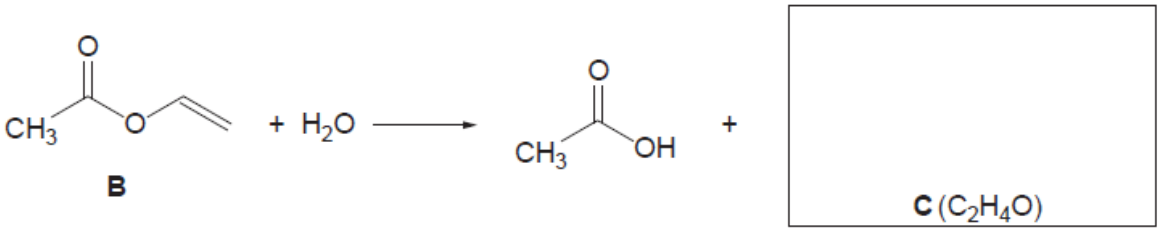


B

PVA is formed from **B** by the process of addition polymerisation.

(i) Draw a section of the PVA molecule containing at least 2 monomer molecules, and identify clearly the repeat unit.

The ester **B** can be hydrolysed in the usual way, according to the following equation.



B **C** (C_2H_4O)

(ii) Use this information to suggest a possible structure for **C** and draw it in the box above.

When substance **C** is extracted from the product mixture, it is found that it does **not** decolourise $Br_2(aq)$, but it **does** form a pale yellow precipitate with alkaline aqueous iodine.

(iii) Suggest a structure for **C** that fits this new information.

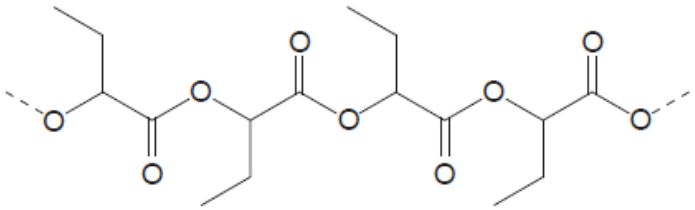
(iv) Suggest a confirmatory test for the functional group in the structure you have drawn in **(iii)**. Your answer should include the reagent you would use and the observation you would make.

.....

.....

[6]

(b) The following diagram represents a section of another polymer.



D

(i) On the above formula draw brackets, [ ], around the atoms that make up the repeat unit of this polymer.

(ii) Name the functional group in polymer **D**.

.....

(iii) Suggest and draw the structure of the monomer, **E**, that could form this polymer.

(iv) What *type of polymerisation* is involved in making polymer **D** from its monomer?

.....

(v) What is the relationship between the repeat unit of polymer **D** and the repeat unit of PVA?

.....

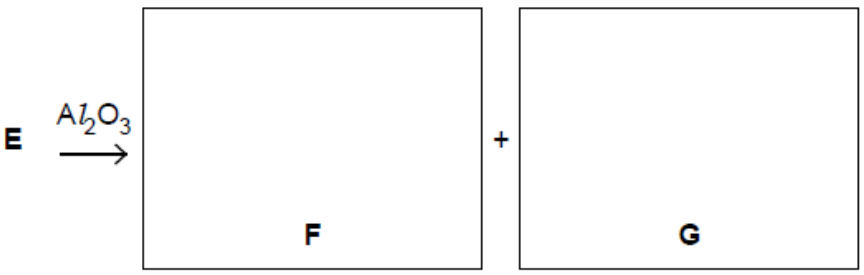
[5]

(c) Monomer **E** exists as two stereoisomers. Heating either isomer with Al_2O_3 gives a mixture of two unsaturated carboxylic acids **F** and **G**, which are stereoisomers of each other.

(i) Name the *type of stereoisomerism* shown by compound **E**.

.....

(ii) Suggest structures for **F** and **G**, and name the type of stereoisomerism they show.



type of isomerism .....

[4]

[Total: 15]

9 In today's world, many traditional materials have been replaced by different sorts of polymers. This includes rigid polymers such as those used in car bodies to replace steel and flexible polymers like those used in textiles to replace cotton or wool.

(a) **(i)** To form a polymer, what is the **minimum** number of functional groups that the monomer must possess?

.....

(ii) Illustrate your answer to **(i)** with the structure of a possible monomer.

[2]

(b) State **two** differences between addition and condensation polymerisation.

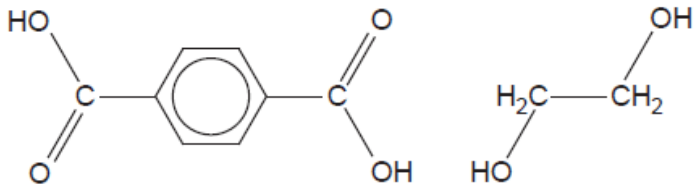
(i) .....

.....

(ii) .....

.....[2]

(c) The polymer formed from the co-polymerisation of the two monomers shown is known as *Terylene*.



benzene-1, 4-dicarboxylic acid **ethane-1-2-diol**

(i) The two monomers react by condensation polymerisation. What other molecule is formed in this reaction?

.....

(ii) Draw the structure of **one** repeat unit of *Terylene*.

(iii) What is the name given to polymers containing the same functional group as *Terylene*?

..... [4]

(d) The monomers ethene and but-1-ene can also co-polymerise to form a polyalkene, but this does not produce a regular alternating structure like *Terylene*. Explain why this is the case, drawing diagrams if you wish.

.....

.....

.....

.....

s/11/qp41

6 **(a)** The reaction producing tri-iodomethane (iodoform) can be used as a test for the presence of certain groups within a molecule.

(i) State the reagents and conditions used for this reaction.

.....

(ii) Write the structural formula of **one** functional group that would give a positive result with this iodoform reaction.

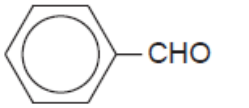
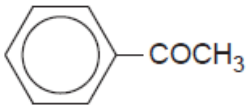
.....

(iii) What do you observe in a positive test?

.....

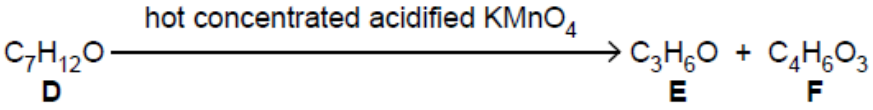
.....

(iv) In the following table place a tick (✓) in the column against each compound that would give a positive result with this test, and a cross (✗) against each compound that would give a negative result.

compound	result
CH_3OH	
CH_3CH_2OH	
CH_3CHO	
CH_3CO_2H	
	
	

[6]

(b) The iodoform test can be used, along with other reactions, to work out the structures of unknown compounds.
Use the information in the table below to deduce the structures of the compounds in the following scheme, and draw these structures in the boxes provided.



Results of tests (✓ indicates a positive result; ✗ indicates a negative result)

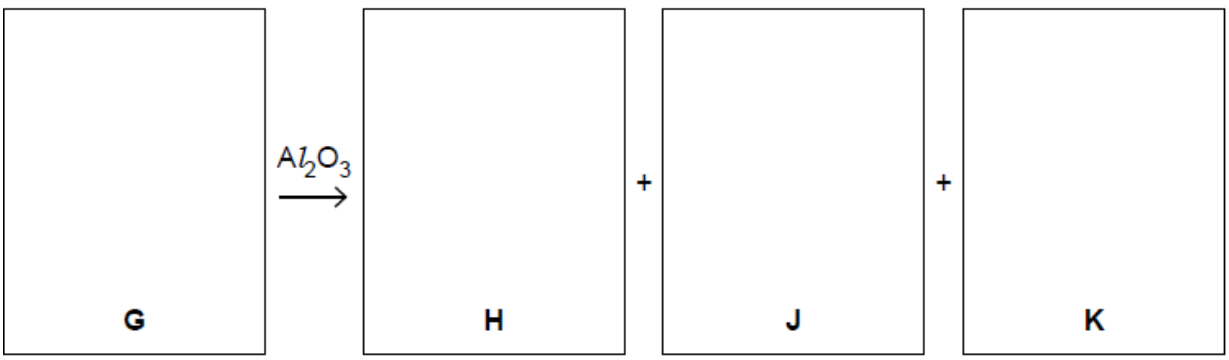
test	results of tests with each compound		
	D	**E**	**F**
iodoform	✗	✓	✓
Fehling's solution	✓	✗	✗
2,4-dinitrophenyl-hydrazine reagent	✓	✓	✓
Na_2CO_3(aq)	✗	✗	✓

structures

D($C_7H_{12}O$)	**E**(C_3H_6O)	**F**($C_4H_6O_3$)

[3]

(c) Treatment of compound **F** with $NaBH_4$ gives compound **G**, $C_4H_8O_3$. Heating **G** with Al_2O_3 gives a mixture of three isomeric unsaturated carboxylic acids **H**, **J** and **K**, $C_4H_6O_2$, two of which are stereoisomers of each other.
Suggest structures for **G**, **H**, **J**, and **K**, and name the type of stereoisomerism shown.



type of stereoisomerism .....[5]

[Total: 14]

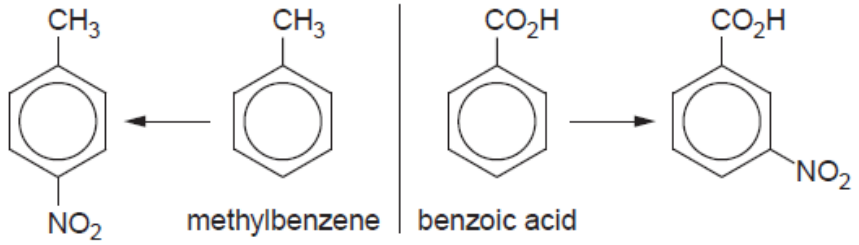
5 **(a)** There are several ways of introducing chlorine atoms into organic molecules. State the reagents and conditions necessary to carry out the following transformations.

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

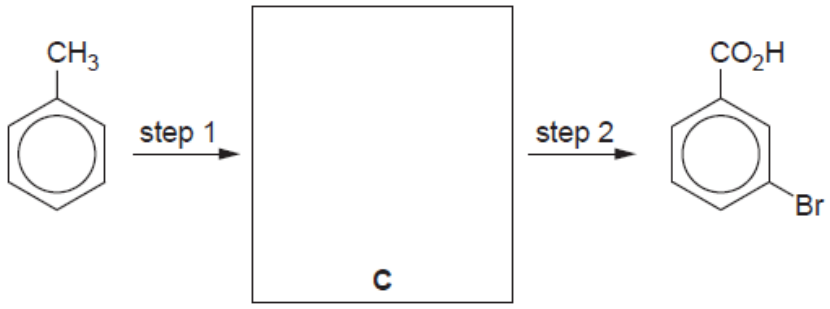
[6]

(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.



(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]

s/11/qp41

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

.....

.....

.....

(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

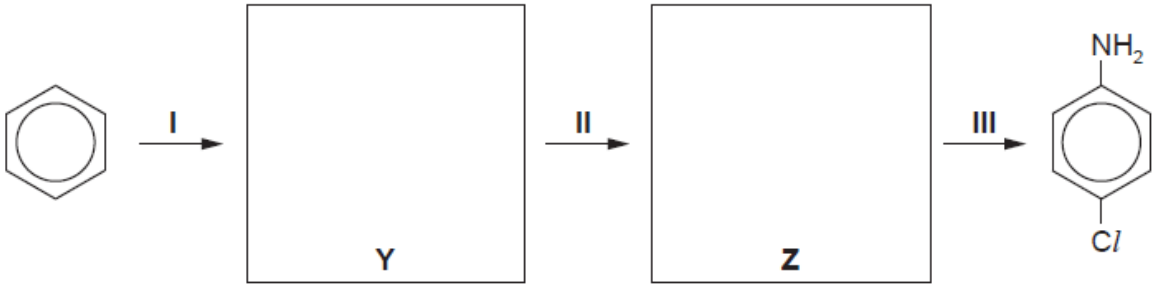
[4]

(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.

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

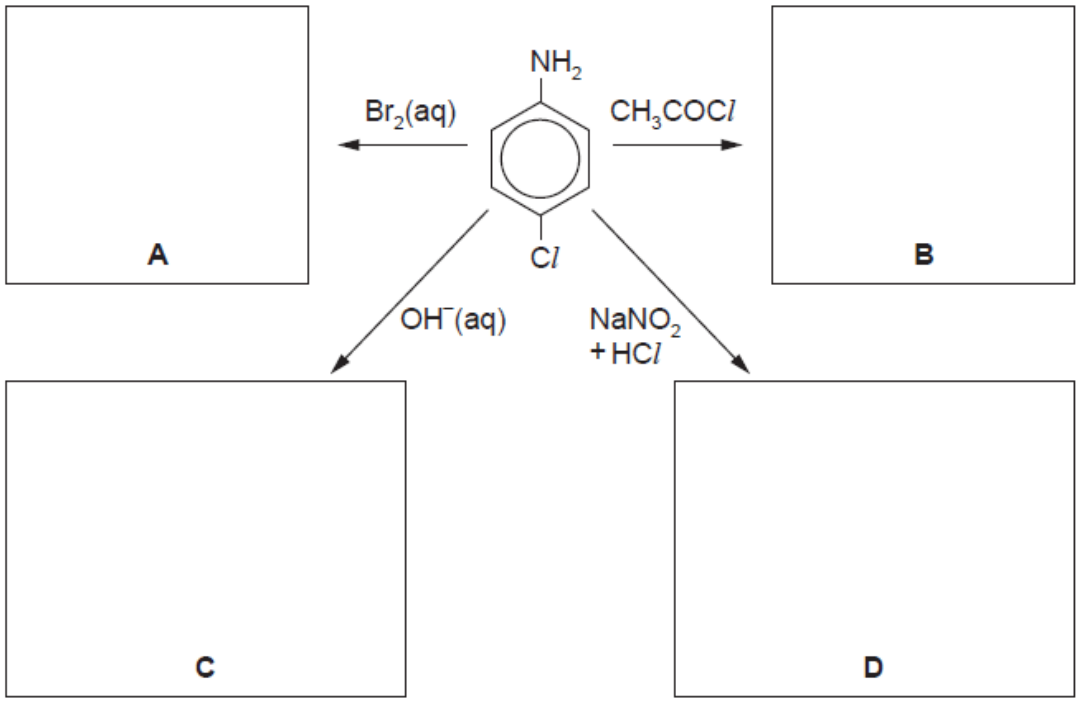


(ii) Suggest the reagents and conditions needed for reaction **III** in the above synthesis.

.....

.....

(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.

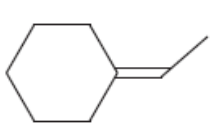


[8]

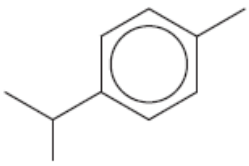
[Total: 15]

s/10/qp43

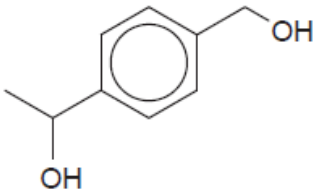
(d) Predict the organic products of the following reactions and draw their structures in the boxes below. You may use structural or skeletal formulae as you wish.



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



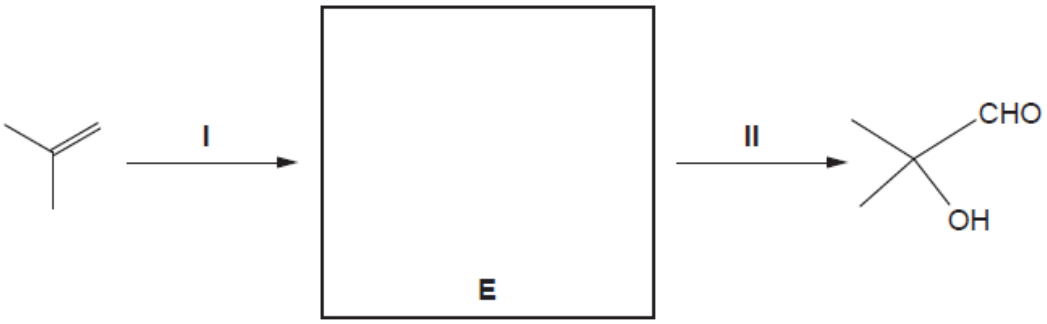
hot conc. $MnO_4^- + H^+$



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.

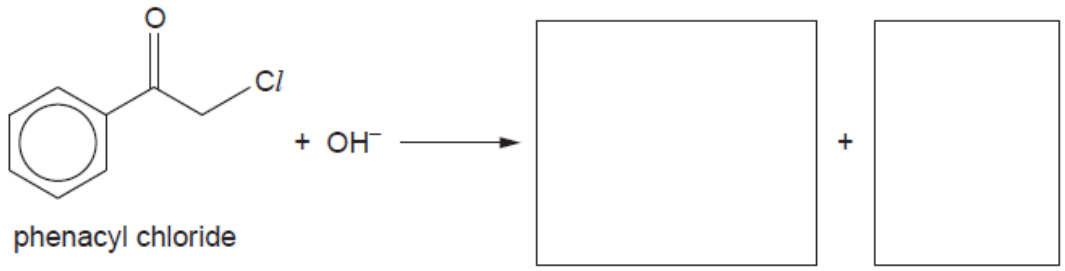
reaction **I** .....

reaction **II** .....

[3]

1 Phenacyl chloride has been used as a component of some tear gases. Its lachrymatory and irritant properties are due to it reacting with water inside body tissues to produce hydrochloric acid.

It undergoes a nucleophilic substitution reaction with NaOH(aq).



phenacyl chloride

(a) Write the formulae of the products of this reaction in the two boxes above. [2]

When the rate of this reaction was measured at various concentrations of the two reagents, the following results were obtained.

experiment number	[phenacyl chloride]	[NaOH]	relative rate
1	0.020	0.10	1.0
2	0.030	0.10	1.5
3	0.025	0.20	2.5

(b) **(i)** What is meant by the term *order of reaction*?

.....

(ii) Use the above data to deduce the order with respect to each reactant. Explain your reasoning.

.....

.....

.....

.....

.....

(iii) Write the overall rate equation for the reaction.

.....

(iv) Describe the mechanism for this reaction that is consistent with your overall rate equation.
You should show all intermediates and/or transition states and partial charges, and you should represent the movements of electron pairs by curly arrows.

[7]

(c) (i) Describe an experiment that would show that CH_3COCl reacts with water at a much faster rate than phenacyl chloride. Include the reagents you would use, and the observations you would make with each chloride.

.....

.....

.....

.....

.....

.....

.....

(ii) Suggest an explanation for this difference in reactivity.

.....

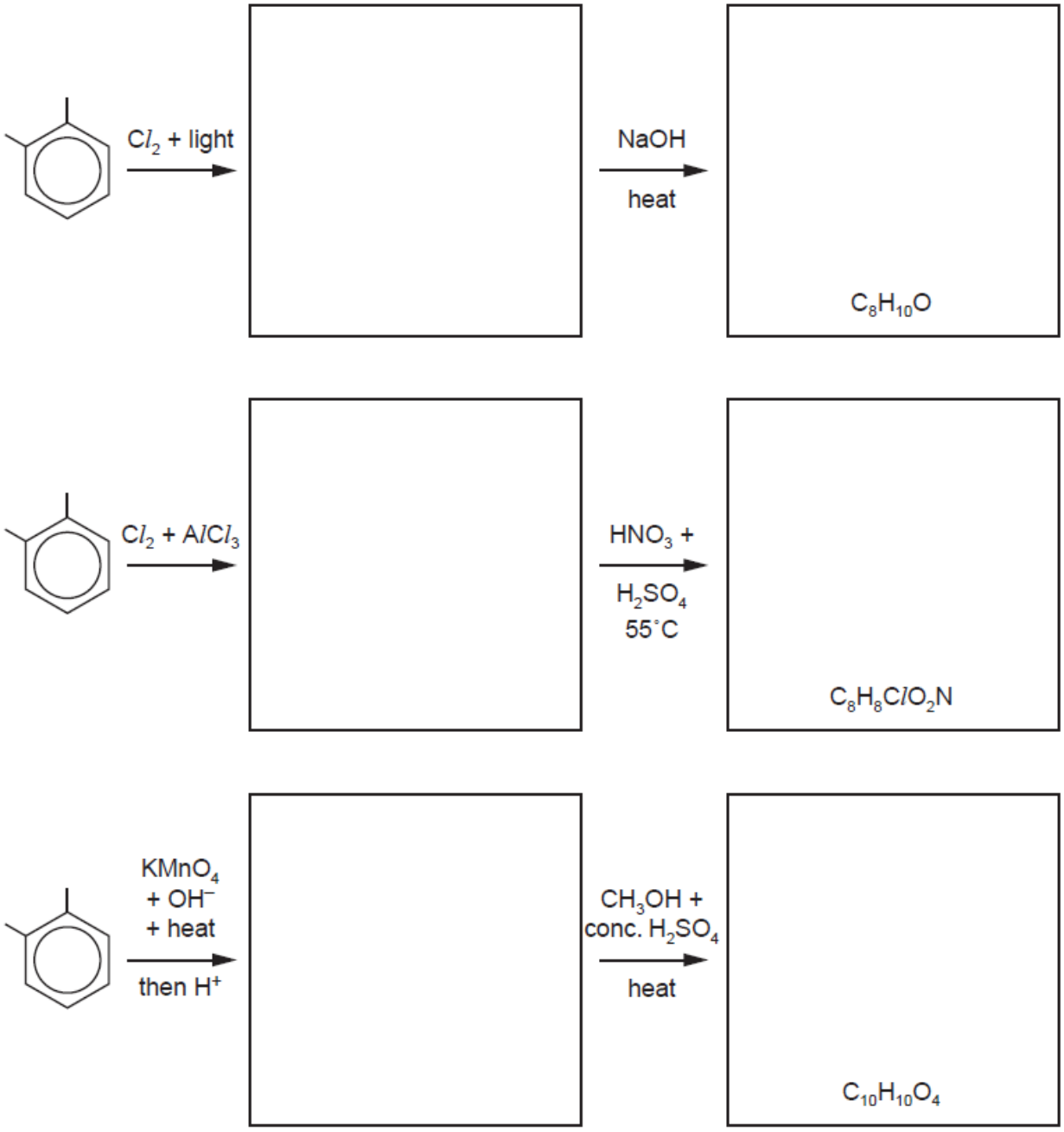
.....

[4]

[Total: 13]

s/10/qp43

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.



[6]

[Total: 6]

s/10/qp41

6 Acyl chlorides are useful intermediates in organic syntheses.

(a) (i) State a suitable reagent for converting carboxylic acids into acyl chlorides.

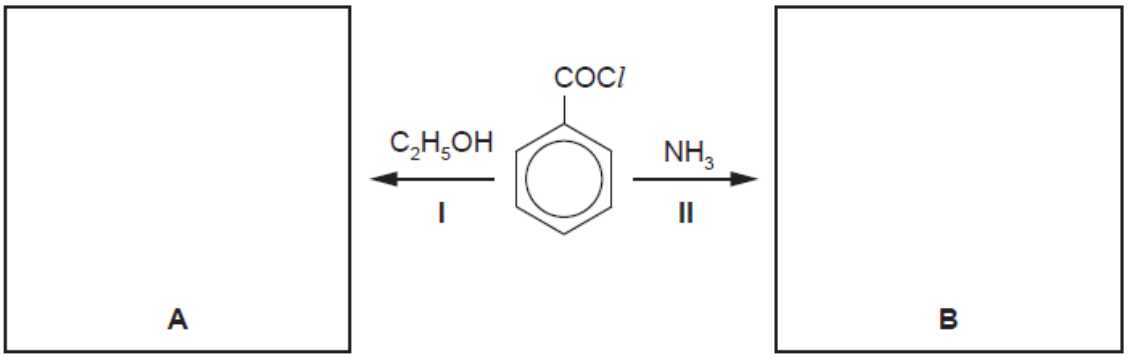
.....

(ii) Construct an equation for the reaction between ethanoic acid, CH_3CO_2H, and the reagent you have stated in **(i)**.

.....

[2]

(b) (i) In the boxes provided draw the structures of the compounds formed when benzoyl chloride undergoes the following reactions.



(ii) Name the functional group in

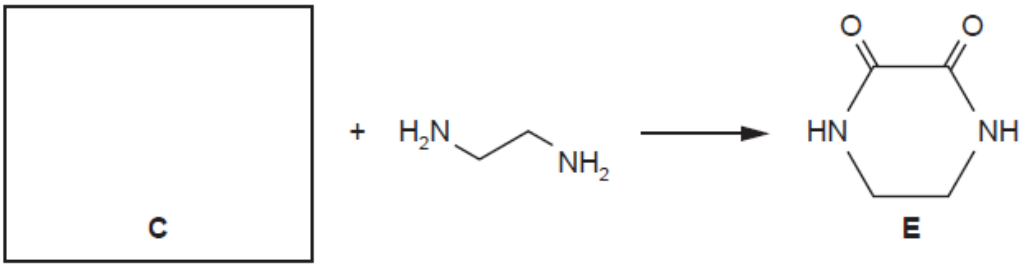
- compound **A** .....
- compound **B** ..... .

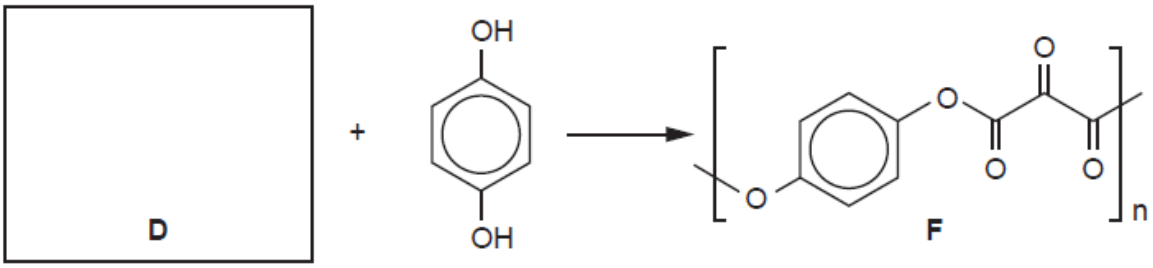
(iii) What *type of reaction* is reaction **II**?

.....

[5]

(c) **(i)** Suggest suitable acyl chlorides to use in the following reaction. Draw their structures in the boxes provided.





Compound **E** dissolves in, but does not react with, cold water.

(ii) Suggest the major type of intermolecular interaction that occurs between **E** and water.

.....

(iii) A solution of the diamine $H_2NCH_2CH_2NH_2$ in water has pH = 11 but a solution of **E** in water has pH = 7. Suggest why this is the case.

.....

.....

(iv) What type of polymer is compound **F**?

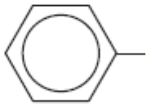
.....

[5]

[Total: 12]

s/10/qp41

4 Ethanolamine and phenylamine are two organic bases that are industrially important. Ethanolamine is a useful solvent with basic properties, whilst phenylamine is an important starting material in the manufacture of dyes and pharmaceuticals.
The following table lists some of their properties, together with those of propylamine.

compound	formula	M_r	boiling point/ °C	solubility in water
propylamine	$CH_3CH_2CH_2NH_2$	59	48	fairly soluble
ethanolamine	$HOCH_2CH_2NH_2$	61	170	very soluble
phenylamine		93	184	sparingly soluble

(a) Suggest why the boiling point of ethanolamine is much higher than that of propylamine. Draw a diagram to illustrate your answer.

.....

.....

[2]

(b) Describe and explain the relative basicities of propylamine and phenylamine.

.....

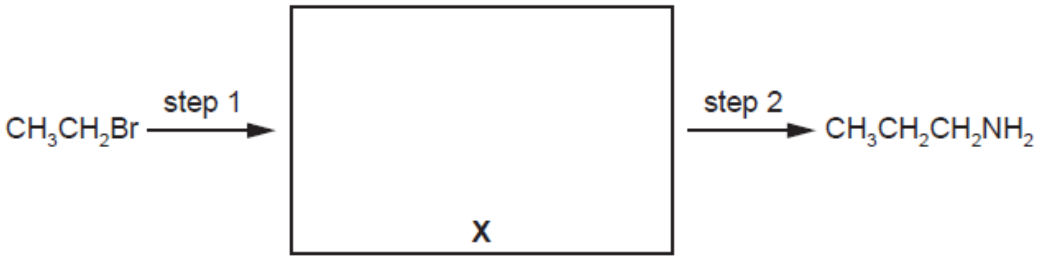
.....

.....[2]

(c) Write an equation showing ethanolamine acting as a Brønsted-Lowry base.

.....[1]

(d) Propylamine can be synthesised from bromoethane by the following route.



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

(ii) Suggest reagents and conditions for

step 1 .....

step 2 .....

[3]

(e) Apart from their relative basicities, ethanolamine and phenylamine differ in many of their reactions.
For **each** of these two compounds, describe **one** test that would give a positive result with the stated compound, but a negative result with the other.

ethanolamine

test .....

observation .....

phenylamine

test .....

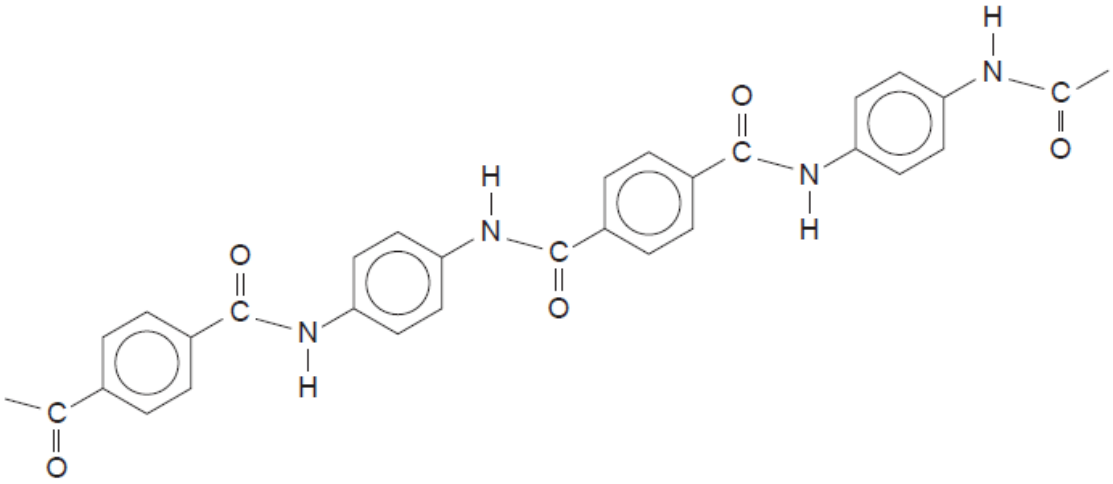
observation .....

[4]

[Total: 12]

s/10/qp41

9 **(a)** Spider silk is a natural polymer which has an exceptional strength for its weight. *Kevlar* is a man-made polymer designed to have similar properties. It has a wide variety of uses from sporting equipment to bullet-proof vests.



Kevlar

(i) In *Kevlar*, the polymer strands line up to form strong sheets with bonds between the strands.

On the diagram above, draw part of a second polymer chain showing how bonds could be formed between the chains.

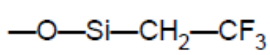
(ii) Suggest what type of bonds these are.

.....

(iii) Draw **two** possible monomer molecules for making the polymer *Kevlar*.

[5]

(b) The transport of oil by sea has resulted in a number of oil spills in recent years. As well as a waste of a valuable resource, these have caused major environmental problems. Traditional sorbent materials absorb water and sink. Researchers have developed new sorbent materials to help collect the spilled oil. The sorbent consists of a material called 'hydrophobic aerogels'. This is a network of silicon(IV) oxide with some of the silicon atoms attached to fluorine-containing groups.



The introduction of these fluorine-containing groups allows the oil to be absorbed but not the water. Tests show that these materials can absorb more than 200 times their mass of oil without sinking.

(i) Suggest what the word **hydrophobic** means.

.....

(ii) Suggest why the fluorine-containing groups allow oil to pass through but not water molecules.

.....

.....

.....

.....

(iii) Suggest another important fluorine-containing polymer that repels water-containing materials.

.....

[4]

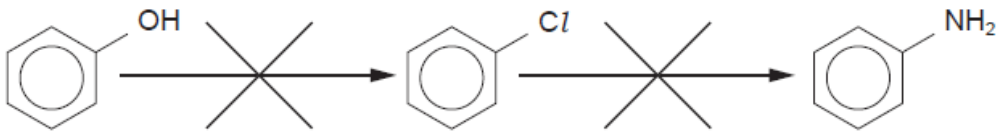
[Total: 9]

s/08/qp4

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,

$$\underset{\text{hexan-1-ol}}{CH_3(CH_2)_5OH} \xrightarrow{\text{I}} \underset{\text{1-chlorohexane}}{CH_3(CH_2)_5Cl} \xrightarrow{\text{II}} \underset{\text{hexylamine}}{CH_3(CH_2)_5NH_2}$$

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? .....

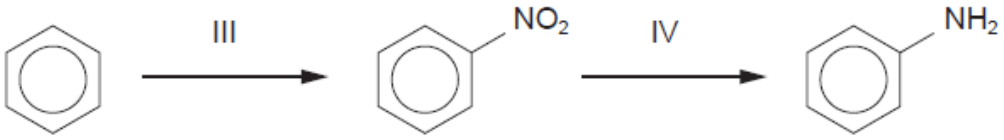
(iii) Suggest a reason why chlorobenzene is much less reactive than 1-chlorohexane.

.....

.....

[4]

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



(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.

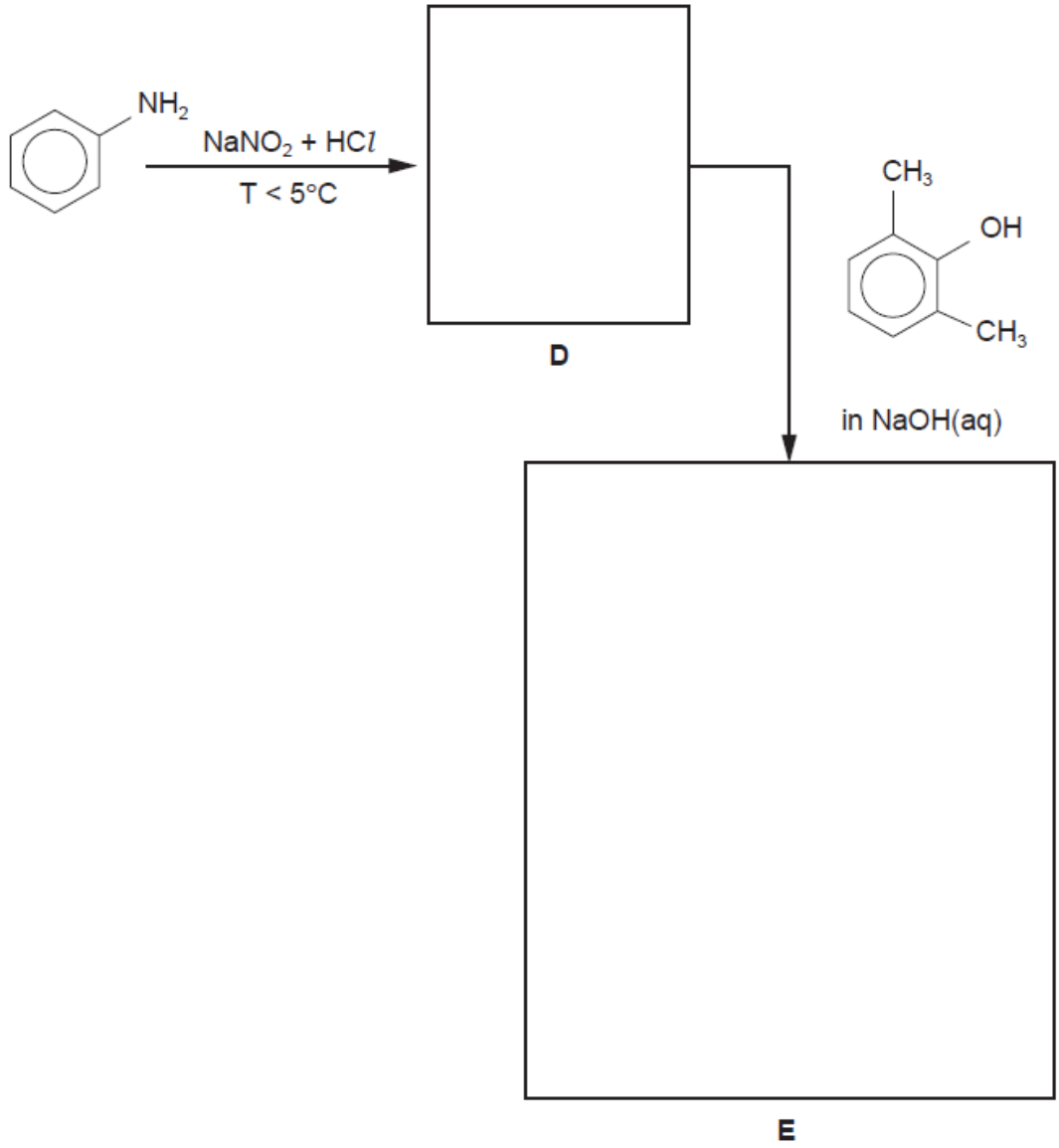
reagent and conditions .....

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**.



[2]

[Total: 13]

s/09/qp4

5 **(a)** In the following boxes draw the structural formulae of **three** alcohols having straight (i.e. unbranched) chains, with the molecular formula $C_5H_{12}O$.

A **B** **C**

[2]

Use the letters **A**, **B** or **C** as appropriate when answering the following questions. Each letter may be used once, more than once or not at all.

(b) Which of the alcohols are chiral? .....[1]

(c) **(i)** Which of these alcohols react with alkaline aqueous iodine? .....

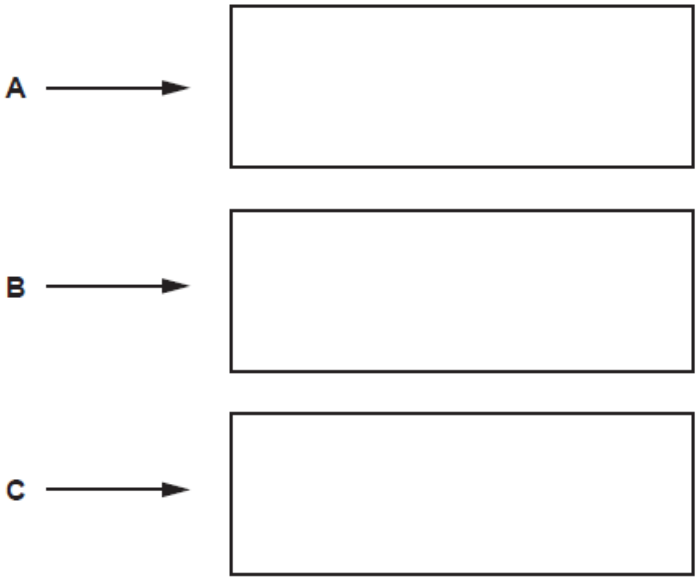
(ii) Describe the observation you would make during this reaction.

.....

(iii) Draw the structural formulae of the products of this reaction.

[4]

(d) Draw the structural formula of the product obtained when **each** of the alcohols **A**, **B** and **C** is heated with an excess of acidified $K_2Cr_2O_7(aq)$.



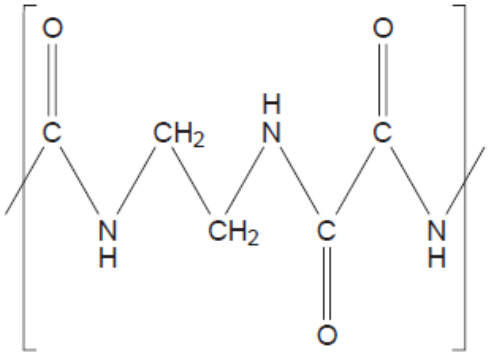
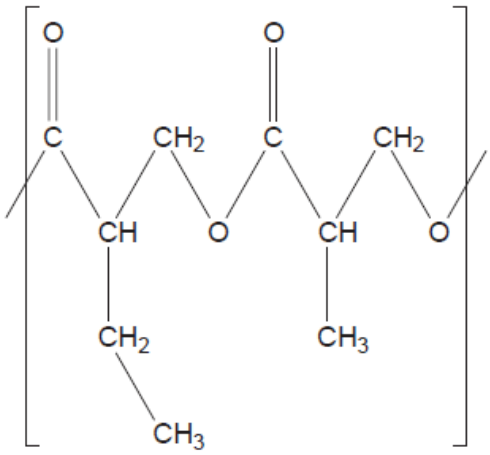
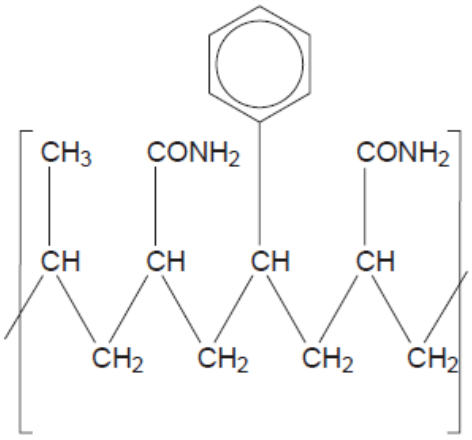
[3]

s/09/qp4

7 Each of the following structures is an 8-atom segment of the chain of a commercial polymer.

For each structure,

- decide whether it is part of a condensation or an addition polymer, and
- draw the structural formulae of the monomer(s) from which the polymer is made.

polymer	addition or condensation?	formulae of monomers
		
		
		

[8]

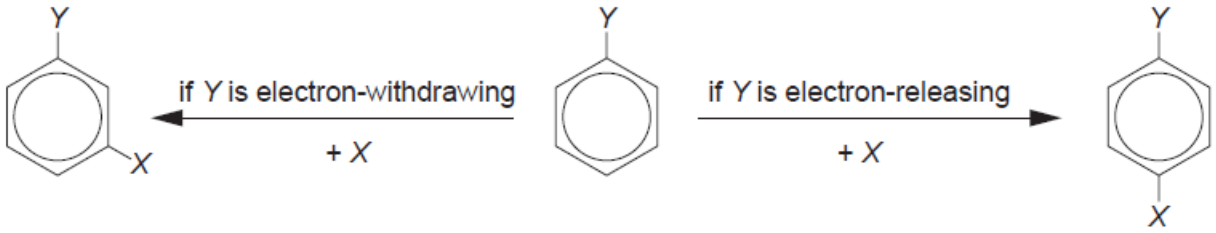
[Total: 8]

s/08/qp4

6 The substituted benzene compound 

can be further substituted.

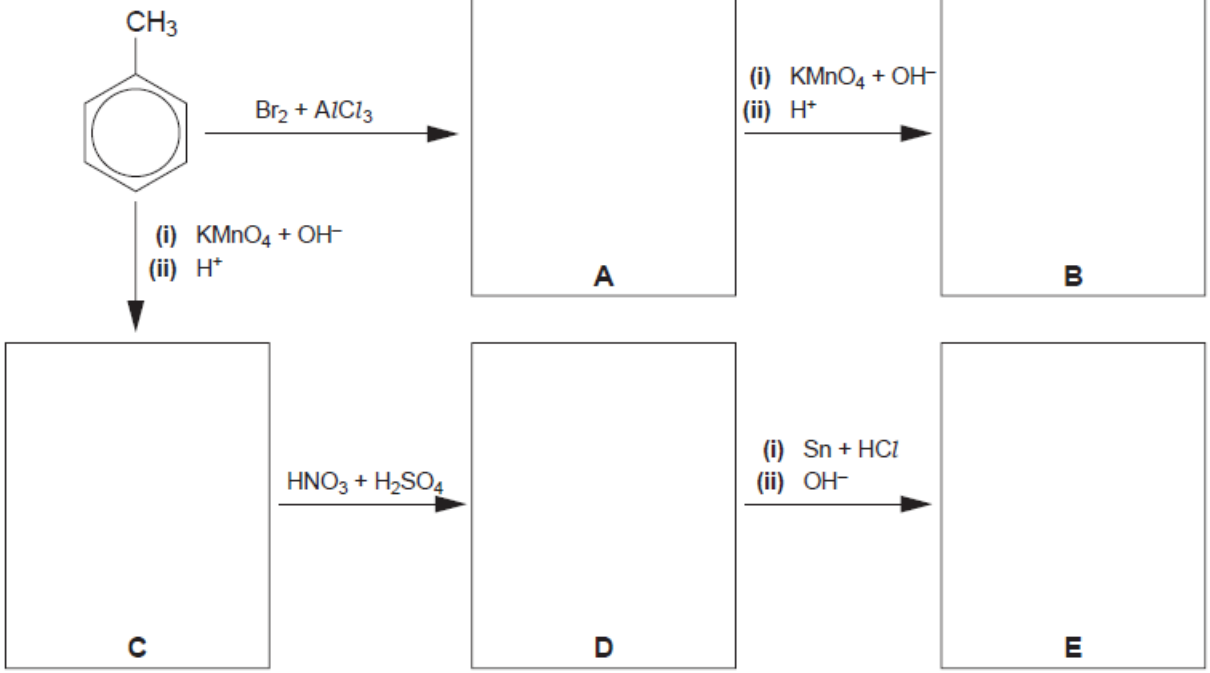
If *Y* is an electron-withdrawing group, the next substitution will be in position 3.
If *Y* is an electron-releasing group, the next substitution will be mostly in position 4.



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

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

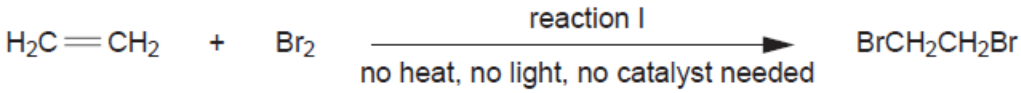
Use the above information to draw relevant structural formulae in the boxes in the schemes below.

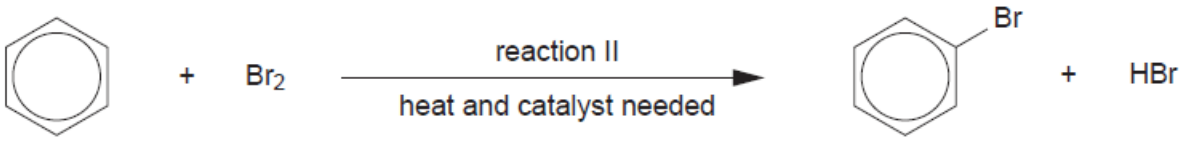


[5]

[Total: 5]

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





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

reaction I

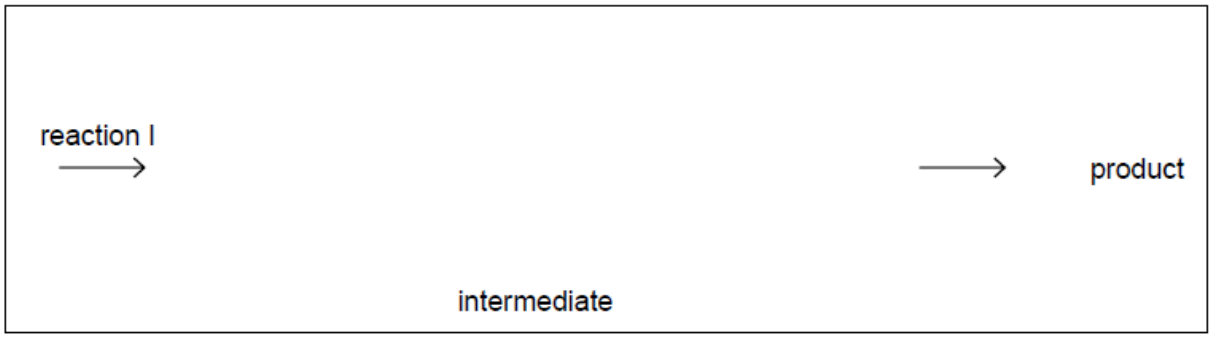
.....

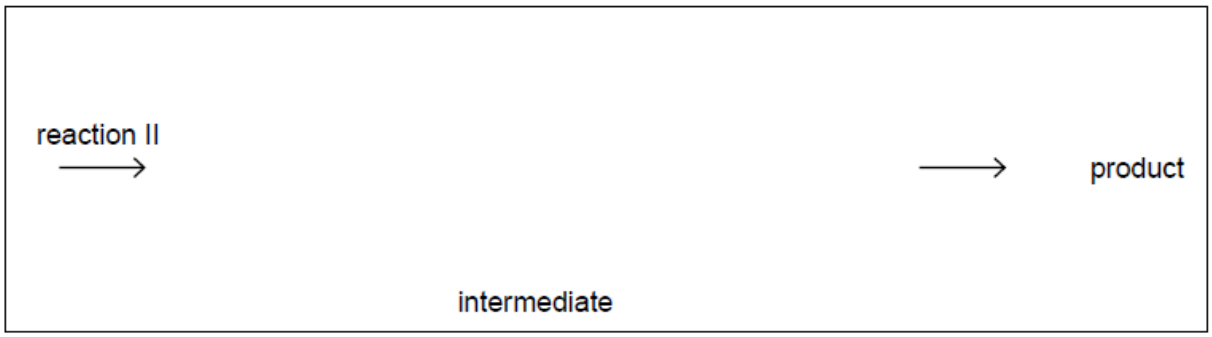
reaction II

.....

[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.





[4]

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

.....

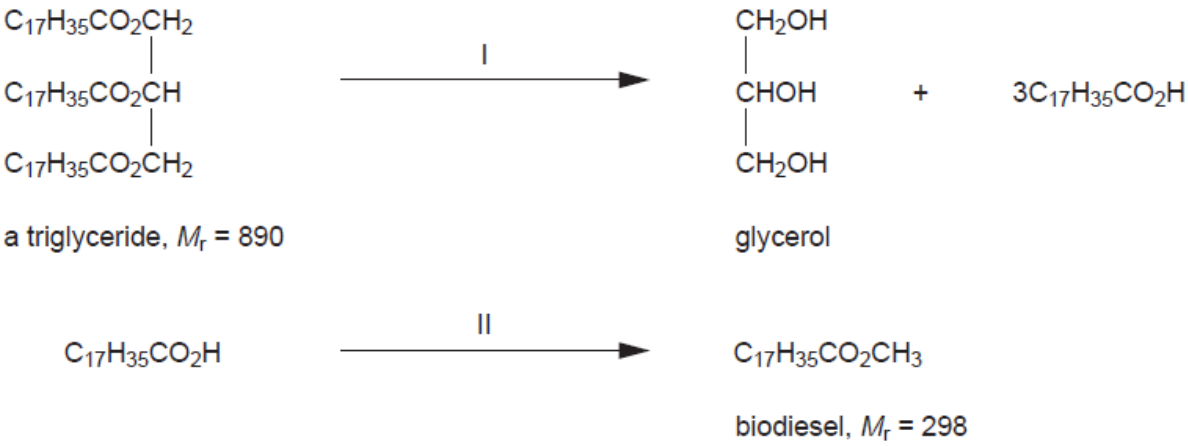
..... [1]

[Total: 7]

s/08/qp4

4 Recently much interest has been shown in the production of the fuel *biodiesel* from algae. Up to 55% of the mass of the dried algae is composed of lipids, the majority of which are triglycerides.

To convert triglycerides into biodiesel, the following processes are carried out.



(a) Name the functional group present in triglycerides.

..... [1]

(b) Suggest reactants and conditions for

reaction I,

.....

reaction II.

.....

[4]

(c) Suggest the structural formula of the compound formed when glycerol is reacted with

(i) an excess of HBr(aq),

.....

(ii) an excess of hot acidified $K_2Cr_2O_7$(aq).

.....

[2]

(d) Calculate the mass of biodiesel that can be produced from 1000 kg of dried algae, assuming that 50% of the algal mass is triglycerides.

mass = ... kg [2]

(e) **(i)** Construct an equation for the complete combustion of biodiesel.

.....

(ii) Use your equation to calculate the mass of CO_2 produced when 10 kg of biodiesel is burned.

.....

.....

[3]

(f) The production of biodiesel is at present an expensive process.

Suggest a reason why the development of biodiesel as an alternative to fossil fuels is important.

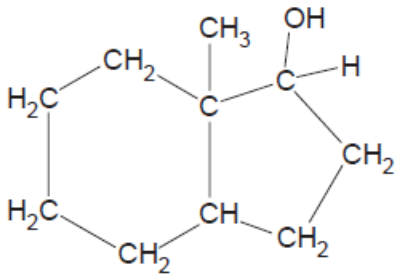
.....

..... [1]

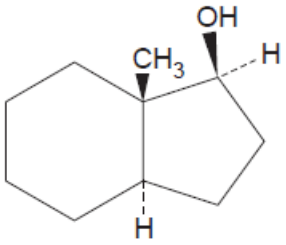
[Total: 13]

s/08/qp4

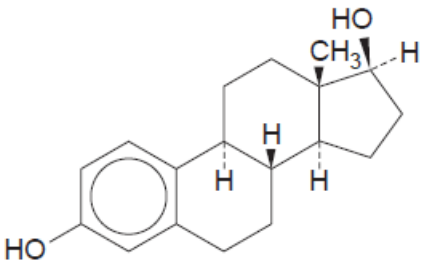
6 Chemists use skeletal or partial-skeletal formulae to represent larger structures. For example the structure



may also be represented as follows.



Oestradiol is one of the hormones that controls the reproductive cycle in female mammals.



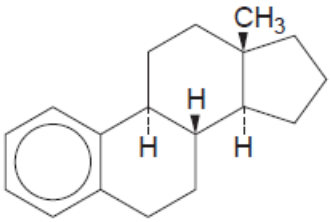
oestradiol

(a) **(i)** On the above structure of oestradiol, circle **one** chiral centre.

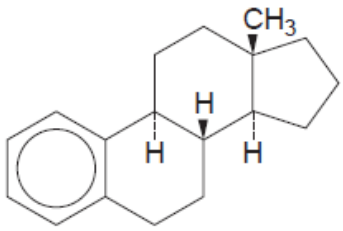
(ii) What is the total number of chiral centres in the oestradiol molecule? .....
[2]

(b) Complete the following part-structures (which have the -OH groups removed) to show the products obtained when oestradiol (above) is reacted with the stated reagents.

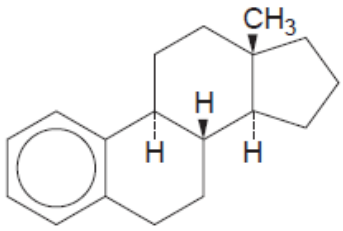
(i) sodium metal



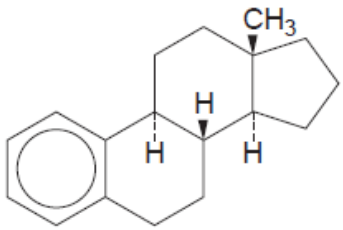
(ii) $Br_2(aq)$



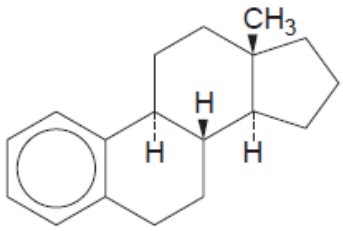
(iii) NaOH(aq)



(iv) CH_3COCl



(v) hot acidified $K_2Cr_2O_7$

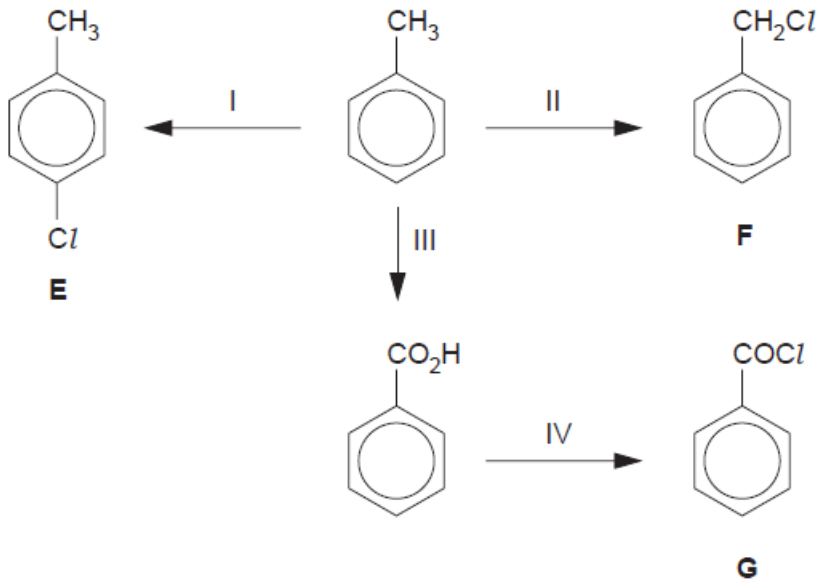


[7]

[Total: 9]

s/07/qp4

5 The following scheme shows some reactions of methylbenzene.



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

I .....

II .....

III .....

IV .....

[4]

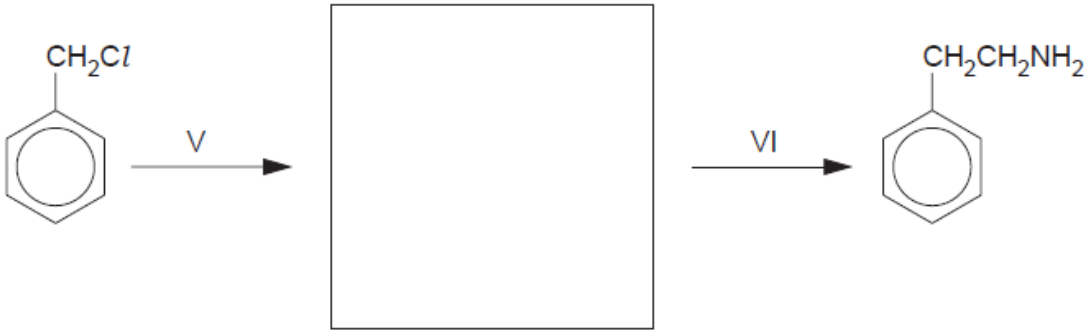
(b) What *type of reaction* is each of the following?

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.

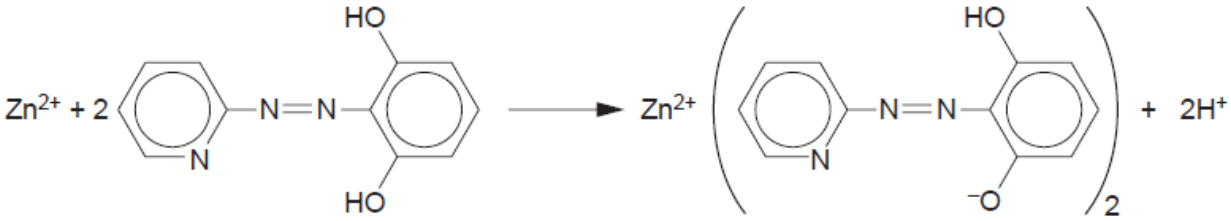
compound	reagent	
	cold water	hot NaOH(aq)
E		
F		
G		

[6]

[Total: 16]

(d) Zinc is an essential element for plant and animal life. It is often administered in the form of a chelate, which is a complex between a metal ion and a polydentate ligand.

The rate of the reaction between zinc ions and the ligand 4-(2-pyridylazo)resorcinol, PAR, has been studied.



PAR Zn-PAR

(ii) Describe a reaction you could carry out to show that PAR is a phenol.

.....

.....