AQA A-LEVEL CHEMISTRY · 7405

CHEMISTRY



EXAM QUESTION PACK

3.3.14 ORGANIC SYNTHESIS

SCORE	PERCENTAGE
/194	%

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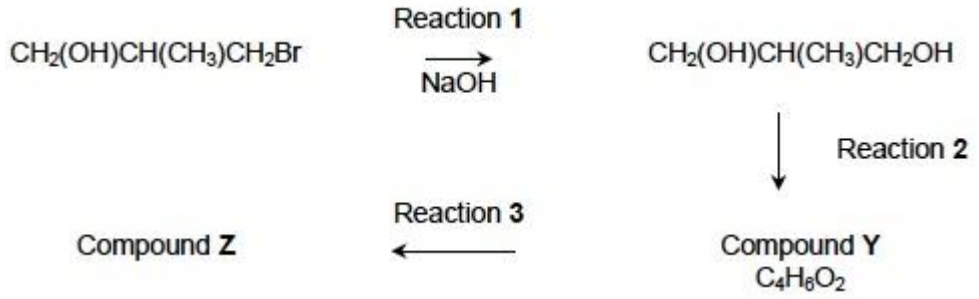
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Q1.

Halogenoalkanes are useful compounds in synthesis. A reaction pathway is shown.



(a) Give the IUPAC name for $CH_2(OH)CH(CH_3)CH_2Br$

_____

(1)

(b) Reaction **1** occurs via a nucleophilic substitution mechanism.

Explain why the halogenoalkane is attacked by the nucleophile in this reaction.

_____

_____

_____

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_____

(3)

(c) The infrared spectrum of Compound **Y** shows a significant absorption in the range 1680–1750 cm^{-1}

Draw the displayed formula of Compound **Y**.

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(1)

(d) Compound **Z** has the empirical formula C_3H_4NO

Give the structure of Compound **Z**.

Suggest the reagent for Reaction **3**.

Structure

Reagent for Reaction **3** _____

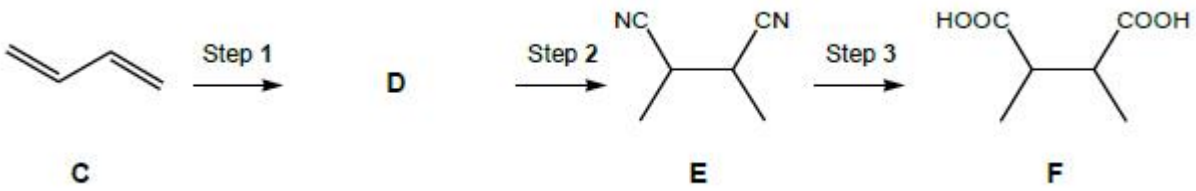
(2)

(Total 7 marks)

Q2.

Chemists design synthetic routes to convert one organic compound into another.

Buta-1,3-diene, **C**, is converted into compound **F** as shown in the diagram below.



(a) State the IUPAC name of compound **F**.

_____

(1)

(b) Deduce the structure of compound **D**.

For each of the conversions in steps **1** and **2**, suggest a reagent for the conversion and name the mechanism.

Suggest the type of reaction occurring in step **3**.

Structure of **D**

Step **1** _____

_____

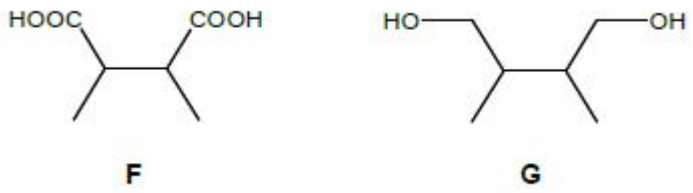
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Step **2** _____

Type of reaction in Step **3** _____

(6)

(c) Compound **F** can also be made from compound **G**.



F **G**

State a reagent (or combination of reagents) that can be used in a test-tube reaction to distinguish between F and G.

Describe what you would observe when the reagent is added to each compound and the test tube is shaken.

Reagent(s) _____

Observation with **F** _____

Observation with **G** _____

(3)

(d) Compounds **F** and **G** react to form a polymer.

Draw the repeating unit of the polymer.

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(2)

(e) In an experiment, 0.930 kg of purified **F** were obtained from 1.11 dm^3 of **G** (density 1.04 g cm^{-3}).

Calculate the percentage yield.

Give your answer to the appropriate number of significant figures.

Percentage yield _____ %

(4)

(f) One reason for a yield of less than 100% in part **(e)** is that **G** reacts to form a number of other compounds.

The other compounds are all liquids at room temperature.

Name the technique that should be used to separate and collect each of these other compounds from the reaction mixture.

Include in your answer a description of the apparatus.

Your description of the apparatus can be either a description in words or a labelled sketch.

Name of technique _____

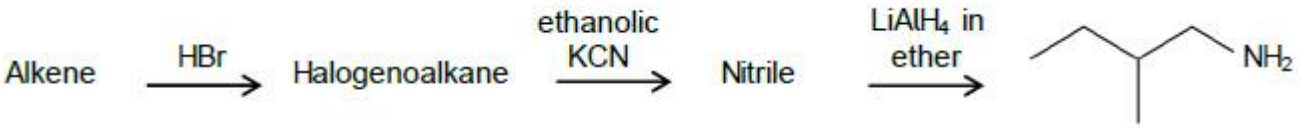
Apparatus

(4)

(Total 20 marks)

Q3.

2-Methylbutylamine can be synthesised from an alkene.



What is the identity of the alkene?

A But-2-ene ⬭

B Methylpropene ⬭

C 2-Methylbut-1-ene ⬭

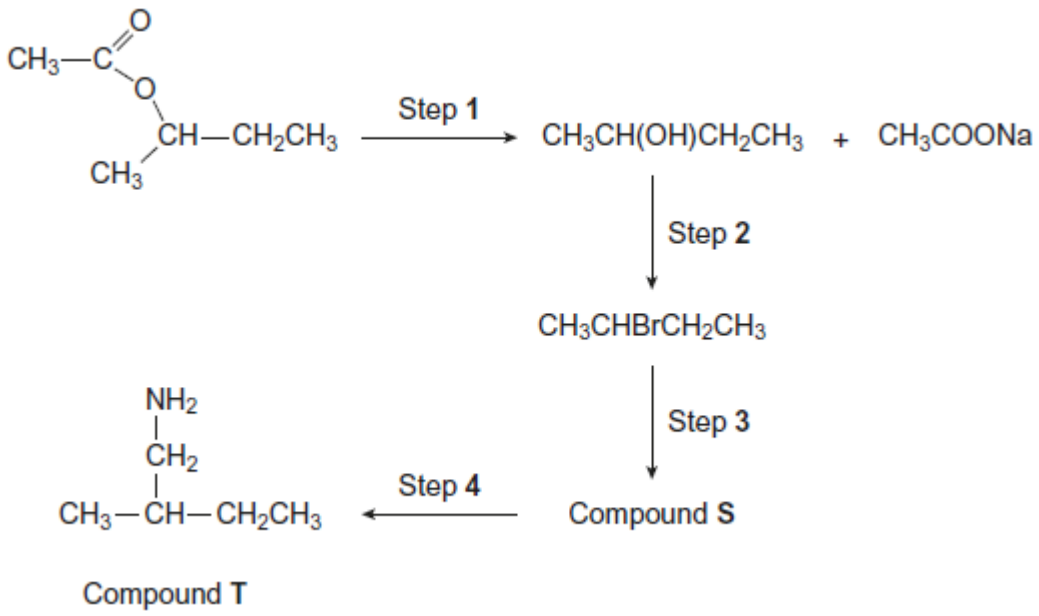
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D 2-Methylbut-2-ene ⬭

(Total 1 mark)

Q4.

A four-step synthesis of compound **T** is shown.



(a) Give the reagent and conditions for Step **1**.
State how you could obtain a sample of the alcohol from the reaction mixture formed in Step **1**.

_____

_____

_____

_____

_____

(3)

(b) Draw the structure of compound **S**.
For each of Steps **3** and **4**, give a reagent and one condition, other than heat.

(5)

(Total 8 marks)

Q5.

The N-substituted amide $C_6H_{13}NO$ can be formed from but−2−ene in a three-step synthesis.

$$H_3CCH{=}CHCH_3 \xrightarrow{\text{Reaction 1}} C_4H_9Br \xrightarrow{\text{Reaction 2}} C_4H_{11}N \xrightarrow{\text{Reaction 3}} C_6H_{13}NO$$

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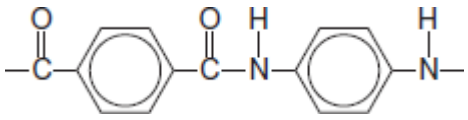
For each reaction
- state a reagent
- give the structure of the product
- name the mechanism of the reaction.

Detailed mechanisms are **not** required.

(Total 9 marks)

Q6.

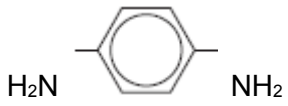
Kevlar is a polymer used in protective clothing.
The repeating unit within the polymer chains of Kevlar is shown.



(a) Name the strongest type of interaction between polymer chains of Kevlar.

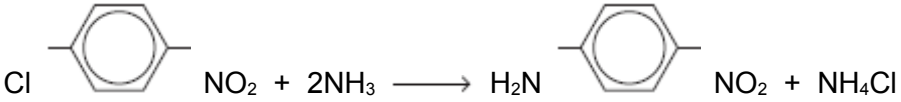
(1)

(b) One of the monomers used in the synthesis of Kevlar is



An industrial synthesis of this monomer uses the following two-stage process starting from compound **X**.

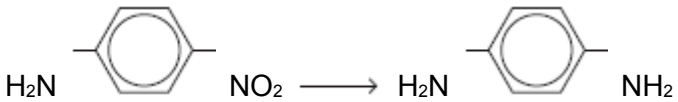
Stage **1**



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X

Stage **2**



(i) Suggest why the reaction of ammonia with **X** in Stage **1** might be considered unexpected.

_____

_____

_____

_____

(2)

(ii) Suggest a combination of reagents for the reaction in Stage **2**.

_____

(1)

(iii) Compound **X** can be produced by nitration of chlorobenzene.

Give the combination of reagents for this nitration of chlorobenzene.
Write an equation or equations to show the formation of a reactive intermediate from these reagents.

Reagents _____

_____

Equation(s) _____

_____

(3)

(iv) Name and outline a mechanism for the formation of **X** from chlorobenzene and the reactive intermediate in part (iii).

Name of mechanism _____

Mechanism

(4)

(Total 11 marks)

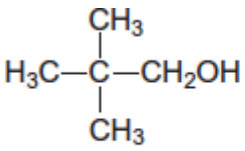
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Q7.

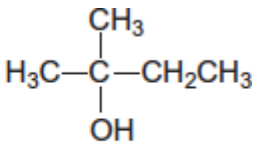
Describe how you could distinguish between the compounds in the following pairs using **one** simple test-tube reaction in each case.

For each pair, identify a reagent and state what you would observe when both compounds are tested separately with this reagent.

(a)



R



S

Reagent _____

Observation with **R** _____

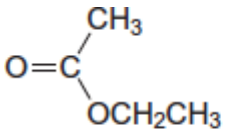
_____

Observation with **S** _____

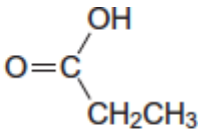
_____

(3)

(b)



T



U

Reagent _____

Observation with **T** _____

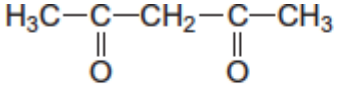
_____

Observation with **U** _____

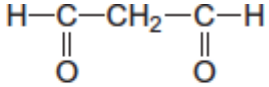
_____

(3)

(c)



V



W

Reagent _____

Observation with **V** _____

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_____

Observation with **W** _____

_____

(3)

(Total 9 marks)

Q8.

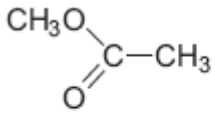
Organic chemists use a variety of methods to distinguish between compounds. These methods include analytical and spectroscopic techniques.

(a) The following compounds can be distinguished by observing what happens in test-tube reactions.

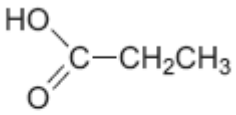
For each pair, suggest a suitable reagent or reagents that could be added separately to each compound in order to distinguish them.

Describe what you would observe with each compound.

(i)



E



F

_____

_____

_____

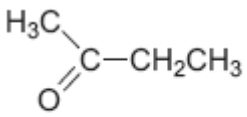
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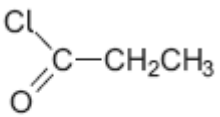
_____

(3)

(ii)



G



H

_____

_____

_____

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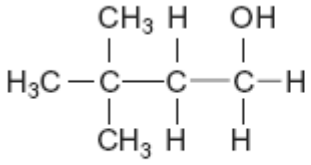
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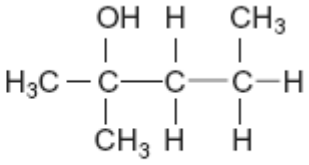
_____

(3)

(iii)



J



K

_____

_____

_____

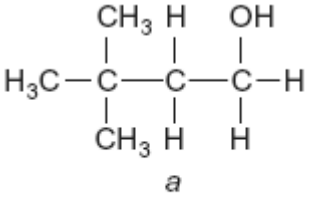
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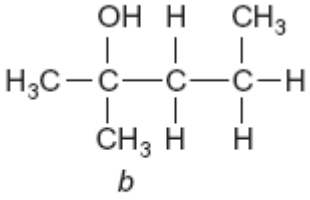
(3)

(b) Compounds **J** and **K** can also be distinguished using spectroscopic techniques such as ^{1}H n.m.r.



a

J



b

K

(i) Name compound **J**.

Give the total number of peaks in the ^{1}H n.m.r. spectrum of **J**.

State the splitting pattern, if any, of the peak for the protons labelled *a*.

_____

_____

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_____

(3)

(ii) Name compound **K**.

Give the total number of peaks in the ^{1}H n.m.r. spectrum of **K**.

State the splitting pattern, if any, of the peak for the protons labelled *b*.

_____

_____

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(3)

(Total 15 marks)

Q9.

A chemist has discovered that the labels have fallen off four bottles each of which contains a different organic liquid. These liquids are known to be propan-2-ol, propanal, hexene and 1-bromopropane.

Suggest a series of test-tube reactions which a chemist could use to confirm the identities of the four compounds. State the reagents used and the observations expected.

_____

_____

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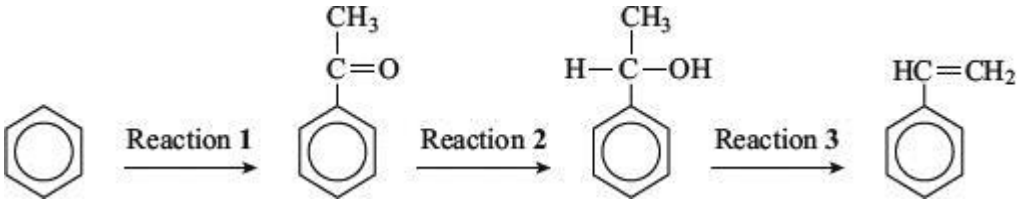
_____

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(Total 10 marks)

Q10.

A possible synthesis of phenylethene *(styrene)* is outlined below.



(a) In Reaction **1**, ethanoyl chloride and aluminium chloride are used to form a reactive species which then reacts with benzene.
Write an equation to show the formation of the reactive species.
Name and outline the mechanism by which this reactive species reacts with benzene.

_____

_____

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_____

(6)

(b) $NaBH_4$ is a possible reagent for Reaction **2**.

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Name and outline the mechanism for the reaction with $NaBH_4$ in Reaction **2**.
Name the product of Reaction **2**.

(6)

(c) Name the type of reaction involved in Reaction **3** and give a reagent for the reaction.

(2)

(Total 14 marks)

Q11.

Which one of the following pairs of reagents reacts to form an organic product that shows only 2 peaks in its proton n.m.r. spectrum?

A butan-2-ol and acidified potassium dichromate(VI)

B ethanoyl chloride and methanol

C propanoic acid and ethanol in the presence of concentrated sulphuric acid

D ethene and hydrogen in the presence of nickel

(Total 1 mark)

Q12.

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Which one of the following pairs reacts to form an organic product with only 2 singlets in its proton n.m.r. spectrum?

A ethene and bromine

B propan-2-ol and acidified potassium dichromate(VI)

C ethanol and concentrated sulphuric acid

D epoxyethane and water in the presence of dilute sulphuric acid

(Total 1 mark)

Q13.

(a) Describe how propanal, CH_3CH_2CHO, and propanone, CH_3COCH_3, can be distinguished using

(i) a chemical test and

_____

_____

_____

_____

_____

_____

(3)

(ii) the number of peaks in their proton n.m.r. spectra.

_____

_____

_____

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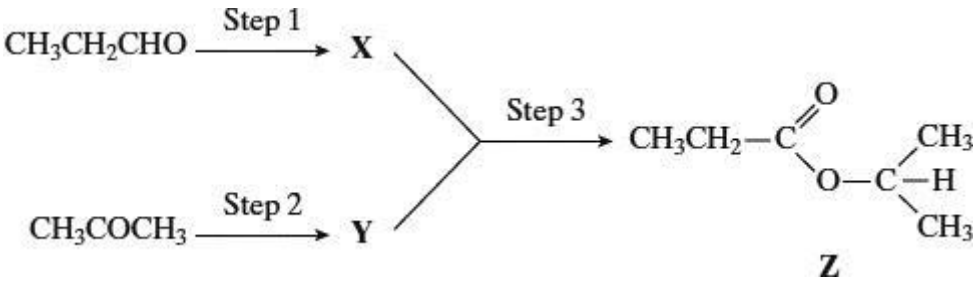
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(2)

(b) Compound **Z** can be produced by the reaction of compound **X** with compound **Y** as shown in the synthesis outlined below.

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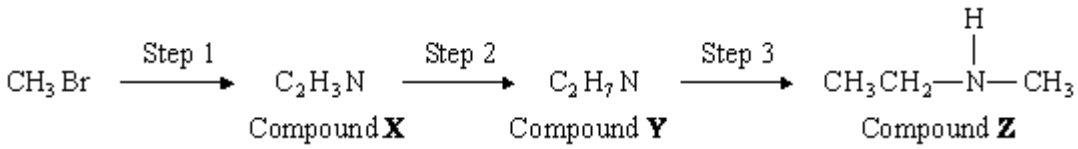
Identify compounds **X** and **Y**.
For each of the three steps in the synthesis, name the type of reaction involved and give reagents and conditions. Equations are **not** required.

(10)
(Total 15 marks)

Q14.

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Compound **Z** can be formed via compounds **X** and **Y** in the three step synthesis shown below.



Identify compounds **X** and **Y** and give reagents and conditions for Steps 1 and 2.

State the **type** of compound of which **Z** is an example.

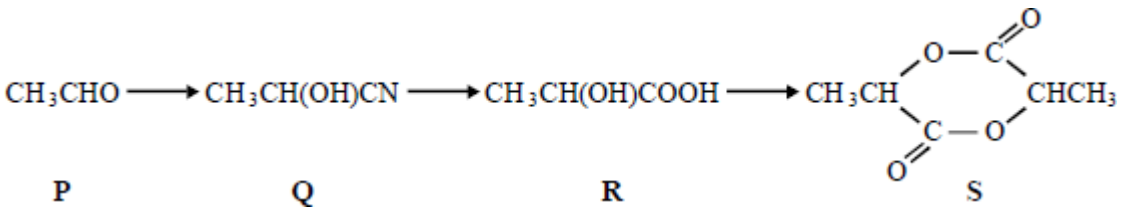
Compound **Z** reacts with a large excess of bromomethane to form a solid product. Draw the structure of this product and name the type of mechanism for this reaction.

(Total 9 marks)

Q15.

This question refers to the reaction sequence below.

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P Q R S

Which one of the following is **not** involved in the reaction sequence?

A esterification

B hydrolysis

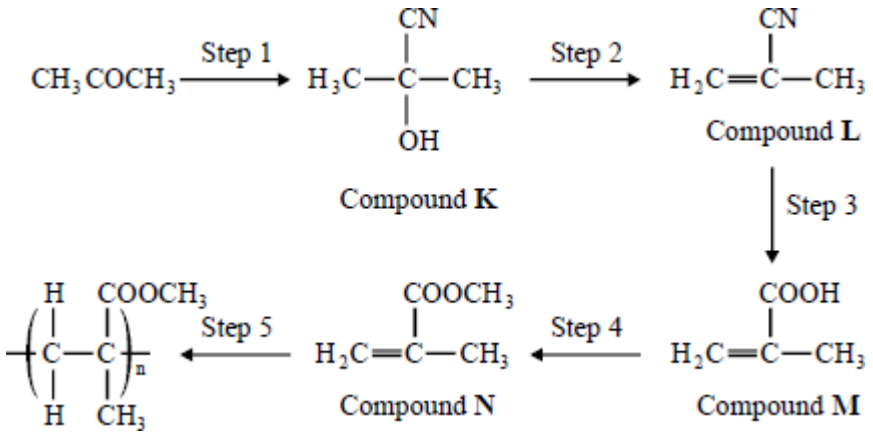
C nucleophilic addition

D reduction

(Total 1 mark)

Q16.

This question concerns the preparation of the plastic poly(methyl 2-methylpropenoate) (*Perspex*), starting from propanone.



Which one of the following sets of reagents is **not** suitable for the step indicated?

A Step 1 HCN (NaCN then dilute HCl)

B Step 2 hot ethanolic KOH

C Step 3 warm aqueous H_2SO_4

D Step 4 CH_3OH with an acid catalyst

(Total 1 mark)

Q17.

Use the data given on the back of the Periodic Table (PT) to help you answer this question.

Compounds **A** to **G** are all isomers with the molecular formula $C_6H_{12}O_2$

(a) Isomer **A**, $C_6H_{12}O_2$, is a neutral compound and is formed by the reaction between compounds **X** and **Y** in the presence of a small amount of concentrated sulphuric acid.

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X and **Y** can both be formed from propanal by different redox reactions.
X has an absorption in its infra-red spectrum at 1750 cm^{-1}.
Deduce the structural formulae of **A**, **X** and **Y**. Give suitable reagents, in each case, for the formation of **X** and **Y** from propanal and state the role of concentrated sulphuric acid in the formation of **A**.

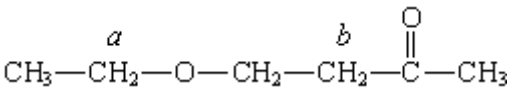
(7)

(b) Isomers **B**, **C**, **D** and **E** all react with aqueous sodium carbonate to produce carbon dioxide.
Deduce the structural formulae of the three isomers that contain an asymmetric carbon atom.
The fourth isomer has only three singlet peaks in its proton n.m.r. spectrum. Deduce the structural formula of this isomer and label it **E**.

(4)

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(c) Isomer **F**, $C_6H_{12}O_2$, has the structural formula shown below, on which some of the protons have been labelled.



A proton n.m.r. spectrum is obtained for **F**. Using Table 1 at the back of the Periodic Table (PT), predict a value of δ for the protons labelled *a* and also for those labelled *b*. State and account for the splitting patterns of the peaks assigned to the protons *a* and *b*.

(6)

(d) Isomer **G**, $C_6H_{12}O_2$, contains six carbon atoms in a ring. It has an absorption in its infra-red spectrum at 3270 cm^{-1} and shows only three different proton environments in its proton n.m.r. spectrum. Deduce a structural formula for **G**.

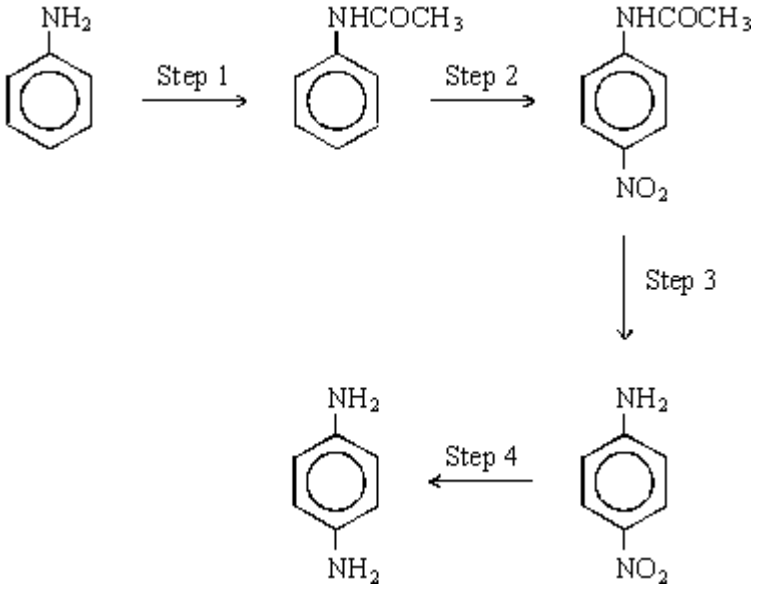
(2)

(Total 19 marks)

Q18.

A possible synthesis of 1,4-diaminobenzene is shown below.

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(a) Identify a suitable reagent or combination of reagents for Step 1. Name and outline a mechanism for the reaction.

(6)

(b) Identify a suitable reagent or combination of reagents for Step 2. Name and outline a mechanism for the reaction.

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(6)

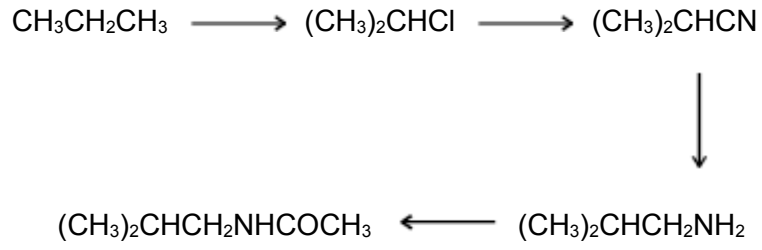
(c) Identify a suitable reagent or combination of reagents for Step 4. Draw the repeating unit of the polymer formed by reaction of 1,4-diaminobenzene with pentanedioic acid.

(3)

(Total 15 marks)

Q19.

Which one of the following types of reaction is **not** involved in the above sequence?



A halogenation

B acylation

C reduction

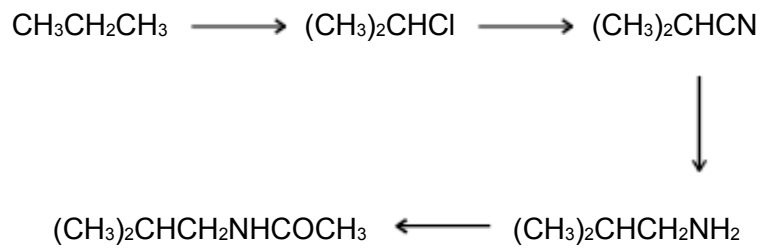
D oxidation

(Total 1 mark)

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Q20.

Which one of the following types of reaction mechanism is **not** involved in the above sequence?



A free-radical substitution

B nucleophilic substitution

C elimination

D nucleophilic addition-elimination

(Total 1 mark)

Q21.

(a) **P**, **Q** and **R** have the molecular formula C_6H_{12}

All three are branched-chain molecules and none is cyclic.
P can represent a pair of optical isomers.
Q can represent a pair of geometrical isomers.
R can represent another pair of geometrical isomers different from **Q**.

Draw one possible structure for one of the isomers of each of **P**, **Q** and **R**.

*Structure of **P***

*Structure of **Q***

*Structure of **R***

(3)

(b) Butanone reacts with reagent **S** to form compound **T** which exists as a racemic mixture. Dehydration of **T** forms **U**, C_5H_7N, which can represent a pair of geometrical isomers.

(i) State the meaning of the term *racemic mixture* and suggest why such a mixture is formed in this reaction.

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Racemic mixture _____

_____

Explanation _____

_____

_____

(ii) Identify reagent **S**, and draw a structural formula for each of **T** and **U**.

*Reagent **S*** _____

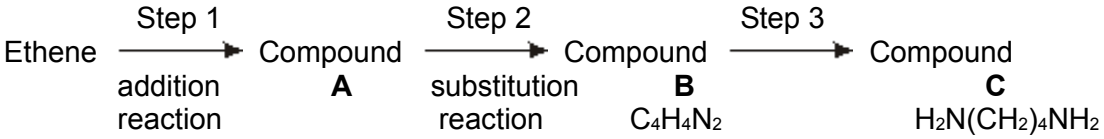
*Compound **T***

*Compound **U***

(6)
(Total 9 marks)

Q22.

(a) Compound **C**, $H_2N(CH_2)_4NH_2$, can be synthesised from ethene in three steps as shown below.



Name compound **C** and draw a structure for each of compounds **A** and **B**.
State the reagent(s) required for each step and name the type of reaction involved in the conversion of **B** into **C**.

_____

_____

_____

_____

_____

_____

_____

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(7)

(b) Draw the repeating unit of the polyamide formed when **C** reacts with hexanedioic acid. Discuss the interactions between the chains of the polyamide.

(4)

(c) Explain why polyamides are degraded by sodium hydroxide whereas polymers such as poly(ethene) are not.

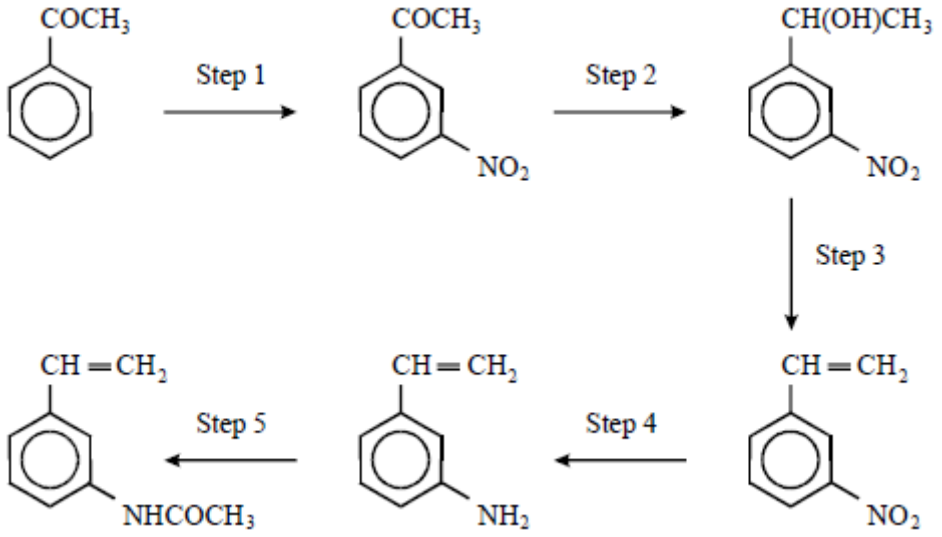
(3)

(Total 14 marks)

Q23.

Refer to the following reaction sequence:

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Which one of the following types of reaction is **not** involved in the above sequence?

A acylation

B oxidation

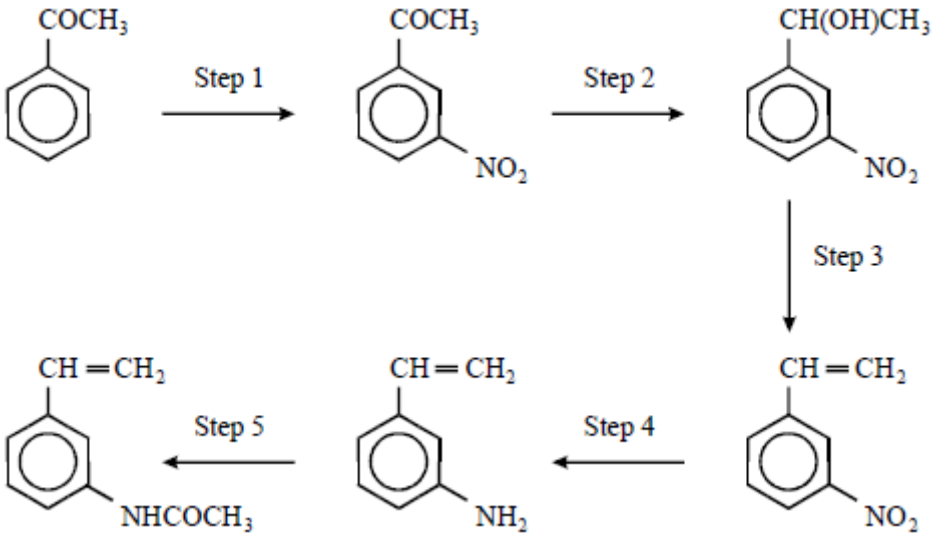
C reduction

D dehydration

(Total 1 mark)

Q24.

Refer to the following reaction sequence:



Which one of the following types of reaction mechanism is **not** involved in the above sequence?

A electrophilic addition

B electrophilic substitution

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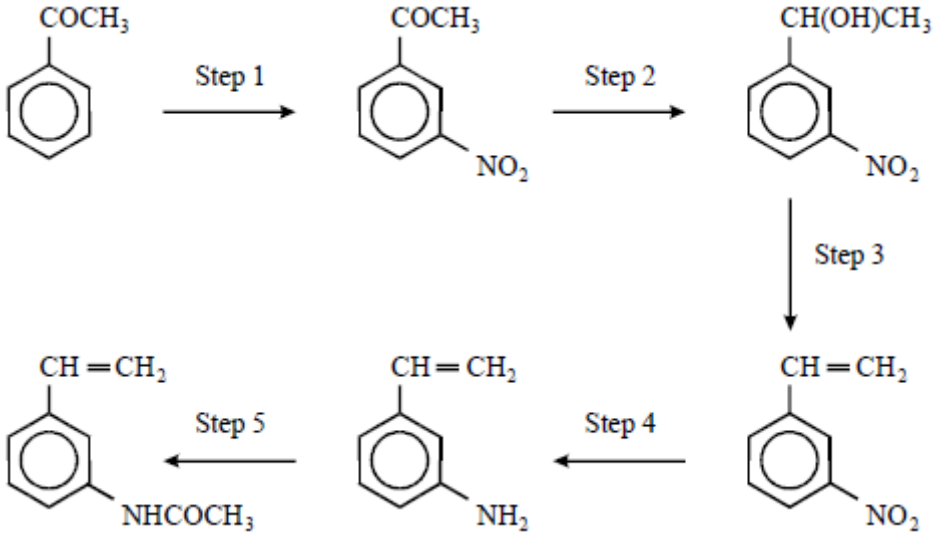
C addition−elimination

D elimination

(Total 1 mark)

Q25.

Refer to the following reaction sequence:



Which one of the following would be the most appropriate to carry out Step 2?

A H_2 / Ni

B Sn / HCl

C $NaBH_4$

D Fe / HCl

(Total 1 mark)

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