CAMBRIDGE INTERNATIONAL AS & A LEVEL CHEMISTRY · 9701

CHEMISTRY



EXAM QUESTION PACK

19 NITROGEN COMPOUNDS

SCORE	PERCENTAGE
/	%

STEMUP

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Chapter 19

Nitrogen compounds

19.1 Primary amines

1166. 9701_m21_qp_12 Q: 19

Methylamine, CH_3NH_2, has similar chemical properties to ammonia, NH_3. Methylamine reacts with hydrogen chloride to form a white crystalline salt, methylammonium chloride.

$$CH_3NH_2 + HCl \rightarrow CH_3NH_3^+Cl^-$$

A sample of methylammonium chloride is heated with aqueous sodium hydroxide.

What are the products?

A ammonia, sodium chloride and water

B ammonia, sodium hydrogencarbonate and sodium chloride

C methylamine, hydrogen chloride and water

D methylamine, sodium chloride and water

19.2 Nitriles and hydroxynitriles

1167. 9701_m22_qp_12 Q: 38

Compound Y is heated with a mild oxidising agent. One of the products of the reaction reacts with hydrogen cyanide forming 2-hydroxybutanenitrile.

What is compound Y?

A butan-1-ol

B butan-2-ol

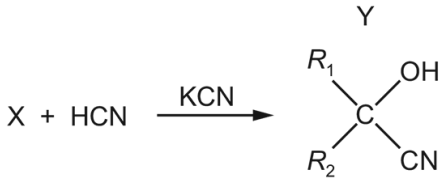
C propan-1-ol

D propan-2-ol

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1168. 9701_m21_qp_12 Q: 26

The diagram shows the formation of compound Y from compound X in a chemical reaction. R_1 and R_2 are alkyl groups.



Which row about this reaction is correct?

	mechanism	compound X
A	electrophilic addition	aldehyde
B	electrophilic addition	ketone
C	nucleophilic addition	ketone
D	nucleophilic addition	aldehyde

1169. 9701_s21_qp_11 Q: 20

Bromoethane reacts with cyanide ions, producing propanenitrile.

Which statement about the S_N2 mechanism of this reaction is correct?

A The lone pair of electrons on C of CN^- attacks the carbon atom of the C–Br bond.

B The lone pair of electrons on C of CN^- attacks the carbocation formed when the C–Br bond breaks.

C The lone pair of electrons on N of CN^- attacks the carbon atom of the C–Br bond.

D The lone pair of electrons on N of CN^- attacks the carbocation formed when the C–Br bond breaks.

1170. 9701_s21_qp_11 Q: 30

Butanoic acid is prepared from 1-bromopropane.

This synthesis requires a sequence of two reactions.

Which compound is prepared in the first stage of the synthesis?

A 1-aminopropane

B propan-1-ol

C butanal

D butanenitrile

1171. 9701_m18_qp_12 Q: 29

Alcohols, aldehydes and nitriles can each be converted into carboxylic acids.

Which descriptions of their conversions into carboxylic acids are correct?

	alcohols	aldehydes	nitriles
A	hydrolysis	hydrolysis	hydrolysis
B	hydrolysis	hydrolysis	oxidation
C	oxidation	oxidation	hydrolysis
D	oxidation	oxidation	oxidation

Organic nitrogen compounds - 2021

1. Nov/2020/Paper_42/No.6f

(f) The amide undergoes the following reaction to produce diethylamine.

$$CH_3CONHC_2H_5 \xrightarrow{\text{reagent } \mathbf{B}} C_2H_5NHC_2H_5$$

diethylamine

(i) Identify reagent **B**.

..... [1]

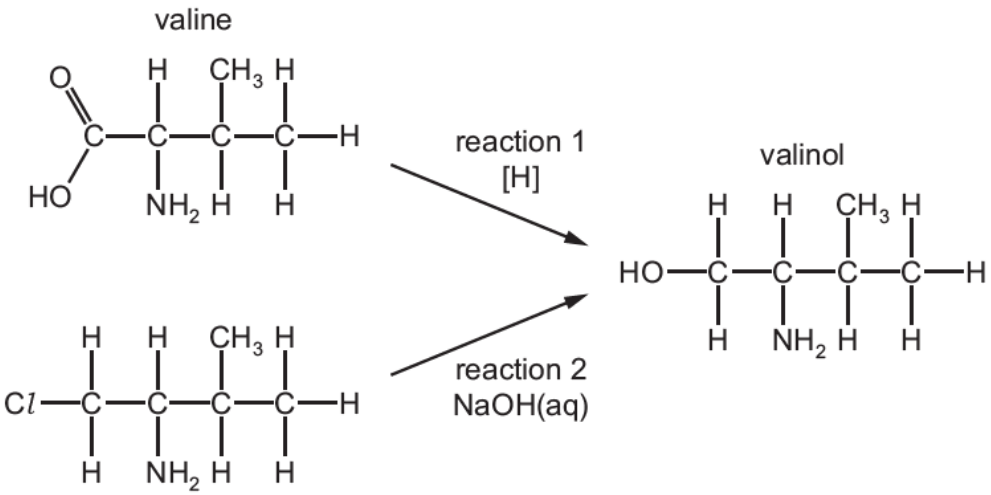
(ii) State the number of different absorptions in the carbon-13 NMR spectrum of diethylamine.

..... [1]

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2. March/2020/Paper_42/No.6

Valinol can be synthesised by the following reactions. Reaction 1 uses valine as the starting material.



(a) (i) Write an equation for reaction 1, using [H] to represent the reducing agent.

..... [1]

(ii) Suggest a suitable reagent for reaction 1.

..... [1]

(iii) Name the mechanism for reaction 2.

..... [1]

(b) Valine and glycine, H_2NCH_2COOH, form the tripeptide Gly–Val–Gly.

Draw the structure of this tripeptide. Show the peptide bonds fully displayed.

[2]

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(c) (i) Valine exists as two stereoisomers.

Draw three-dimensional diagrams to show the two stereoisomers of valine. In your diagrams, the $-CH(CH_3)_2$ group can be represented by –R.

State the type of stereoisomerism shown.

type of stereoisomerism .....

[2]

(ii) Valine is an amino acid.

Draw the zwitterion of valine.

[1]

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(iii) Valinate, Val^-, is the anion of valine. It takes part in a ligand substitution reaction with hexaaquanickel(II) ions. Complex **Z** is formed.

$$[Ni(H_2O)_6]^{2+}(aq) + 2Val^-(aq) \rightleftharpoons^{\mathbf{Z}} [Ni(H_2O)_2(Val)_2](aq) + 4H_2O(l)$$

Write an expression for K_{stab} for this equilibrium.

K_{stab} =

[1]

(iv) At room temperature, the numerical value of K_{stab} is 2.34×10^5.

Explain what this value indicates about the equilibrium and the stability of complex **Z**.

.....

.....

..... [1]

(v) **Z** is an octahedral complex with formula $[Ni(H_2O)_2(Val)_2]$.

Use this information to state the type of ligand that the valinate ion is acting as in this complex.

..... [1]

[Total: 11]

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3. June/2020/Paper_41/No.4

(a) The molecular formulae of three nitrogen-containing compounds are given.

S $C_6H_5CONH_2$

T $C_6H_5NH_2$

U $C_6H_5CH_2NH_2$

Describe and explain the relative basicities of **S**, **T** and **U**.

..... > ..... > .....

most basic least basic

.....

.....

.....

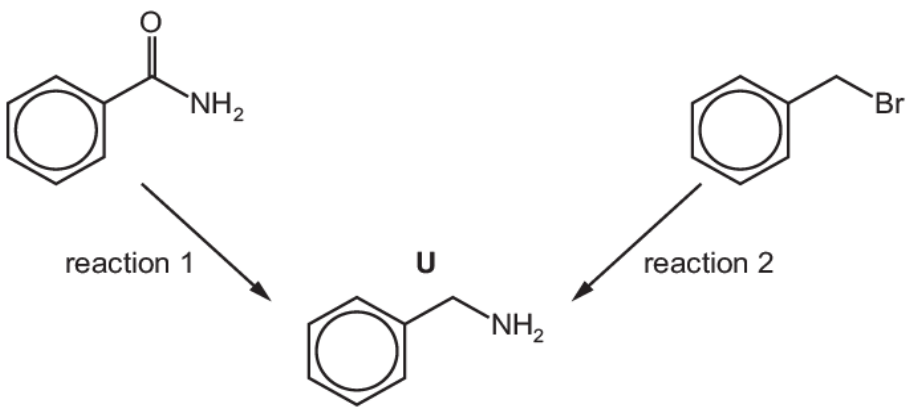
.....

.....

.....

[3]

(b) Compound **U** can be prepared by two different methods as shown.



(i) Suggest reagents and conditions for reaction 1 and for reaction 2.

reaction 1 .....

reaction 2 .....

[2]

(ii) State the type of reaction in reaction 1 and name the mechanism in reaction 2.

type of reaction in reaction 1 .....

mechanism of reaction 2 .....

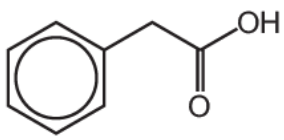
[2]

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Organic nitrogen compounds - 2021

1. Nov/2021/Paper_41/No.7

The structure of phenylethanoic acid is shown.



(a) Give the number of different peaks in the carbon-13 (^{13}C) NMR spectrum of phenylethanoic acid.

number of peaks = ... [1]

(b) Phenylethanoic acid, ethanol and phenol can all behave as acids.

Compare and explain the relative acidities of these three compounds.

..... > ..... > .....

most acidic least acidic

.....

.....

.....

.....

..... [4]

(c) Phenylethanoic acid can be synthesised using benzene as the starting material.

In the first stage of this synthesis, benzene reacts with chloromethane in the presence of an $AlCl_3$ catalyst to form methylbenzene.

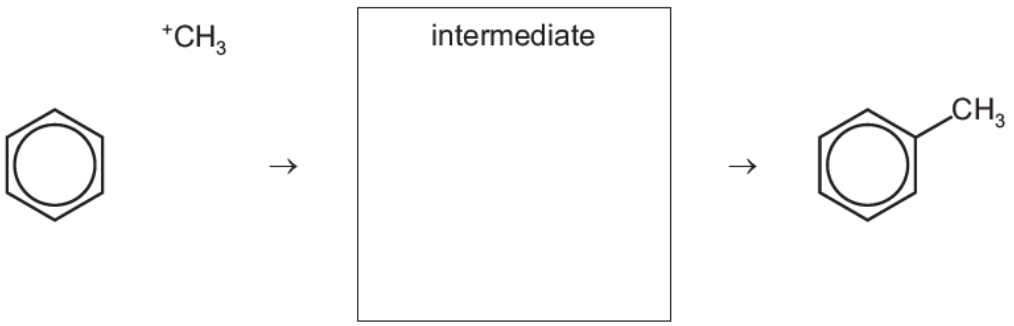
Chloromethane reacts with $AlCl_3$ to form two ions. One of these is the carbocation $^+CH_3$.

(i) Write an equation for the reaction between chloromethane and $AlCl_3$.

..... [1]

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(ii) Draw the mechanism of the reaction between benzene and $^{+}CH_3$. Include all relevant curly arrows, charges and the structure of the intermediate.



[3]

(d) A three-step synthesis of phenylethanoic acid from methylbenzene is shown.



(i) State reagents and conditions for step 1.

..... [1]

(ii) Suggest the structure of compound **Q**.

[1]

(iii) State reagents and conditions for steps 2 and 3.

step 2 .....

step 3 .....

[2]

(iv) Draw the structure of an organic by-product that forms in step 1.

[1]

[Total: 14]

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2. Nov/2021/Paper_41/No.8

Phenylamine, $C_6H_5NH_2$, and ethylamine, $C_2H_5NH_2$, can be distinguished by adding aqueous bromine.

(a) State what is seen when aqueous bromine is added to phenylamine.

.....

..... [2]

(b) Suggest what is seen when aqueous bromine is added to ethylamine.

..... [1]

(c) Draw the structure of the organic product formed when an excess of aqueous bromine is added to phenylamine.

[1]

(d) Name the product you have drawn in **(c)**.

..... [1]

[Total: 5]

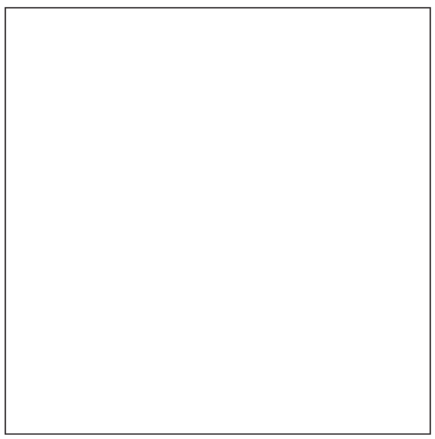
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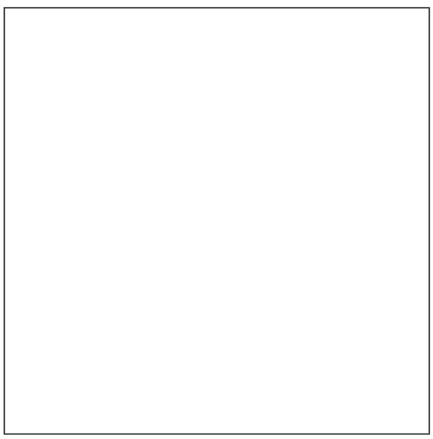
3. Nov/2021/Paper_42/No.8a,8d

Alanine, $H_2NCH(CH_3)CO_2H$, and glutamic acid, $H_2NCH(CH_2CH_2CO_2H)CO_2H$, are two naturally occurring amino acids.

(a) $H_2NCH(CH_3)CO_2H$ exists as two optical isomers.

Draw three-dimensional structures of these two optical isomers.





[2]

(d) At pH 11 alanine exists as $H_2NCH(CH_3)CO_2^-$ ions and glutamic acid exists as $H_2NCH(CH_2CH_2CO_2^-)CO_2^-$ ions. A mixture of alanine and glutamic acid at pH 11 is subjected to electrophoresis.

(i) State how the mixture can be maintained at pH 11 during electrophoresis.

..... [1]

(ii) Draw a fully labelled diagram for the apparatus that would be used to carry out this electrophoresis. Your diagram should include the position of the mixture of alanine and glutamic acid at the start of the electrophoresis experiment.

[2]

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(iii) Identify the electrode that each amino acid travels towards during electrophoresis at pH 11.

alanine .....

glutamic acid .....
[1]

(iv) In a particular electrophoresis experiment at pH 11, the glutamic acid travels 3.4 cm. Alanine travels a shorter distance.

Explain the factors that account for the difference in the distances travelled.

.....

.....

.....

..... [2]

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4. Nov/2021/Paper_42/No.9

Butylamine, $CH_3CH_2CH_2CH_2NH_2$, can be synthesised from different organic compounds by using suitable reagents. Each reaction involves one step.

(a) Complete the table to describe three different syntheses.

- One of the three syntheses should involve a nucleophilic substitution reaction.
- The starting organic compound for each synthesis should contain a different functional group.
- A different reagent should be used for each synthesis.

starting organic compound	reagent and conditions

[6]

(b) Compare and explain the relative basicities of ammonia, butylamine and phenylamine.

..... > ..... > .....

most basic least basic

.....

.....

.....

.....

.....

..... [4]

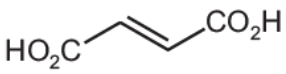
[Total: 10]

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5. March/2021/Paper_42/No.6

Fumaric acid is a naturally occurring dicarboxylic acid.

fumaric acid



(a) Identify the products of the reaction between fumaric acid and an excess of hot, concentrated, acidified manganate(VII).

..... [1]

(b) Fumaric acid can form addition and condensation polymers.

(i) Draw the repeat unit of the addition polymer poly(fumaric acid).

[1]

(ii) Draw the repeat unit of the polyester formed when fumaric acid reacts with ethane-1,2-diol, $(CH_2OH)_2$.

The ester bond should be shown fully displayed.

[2]

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(iii) Explain why polyesters normally biodegrade more readily than polyalkenes.

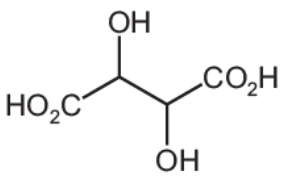
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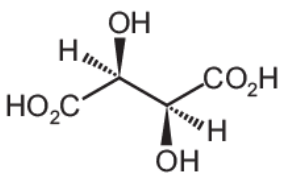
..... [1]

(c) Fumaric acid reacts with cold, dilute, acidified manganate(VII) to form compound **P**.

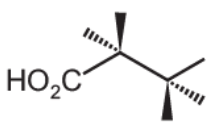
P

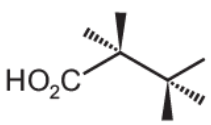


Only three stereoisomers of **P** exist. One of the stereoisomers is shown.



Complete the three-dimensional diagrams in the boxes to show the **other** two stereoisomers of **P**.





[2]

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(d) The enzyme fumarase catalyses the reaction of fumarate ions, $C_4H_2O_4^{2-}$, with water to form malate ions, $C_4H_4O_5^{2-}$.

$$C_4H_2O_4^{2-} + H_2O \rightleftharpoons C_4H_4O_5^{2-}$$

Describe, with the aid of a suitably labelled diagram, how an enzyme such as fumarase can catalyse a reaction.

.....

.....

.....

.....

[3]

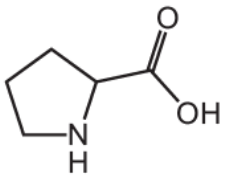
[Total: 10]

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6. March/2021/Paper_42/No.7

Proline (Pro) is a naturally occurring amino acid.

proline



(a) Proline is often found bonded to glycine (Gly) in a protein.

(i) Draw the dipeptide Pro-Gly.

The peptide bond must be shown fully displayed.

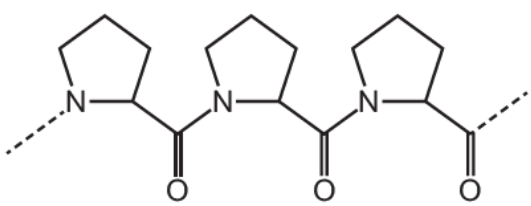
[2]

(ii) Name the type of reaction that forms a dipeptide from two amino acids.

..... [1]

(iii) Proline is able to form a poly(proline) peptide chain.

A section of a poly(proline) chain is shown.



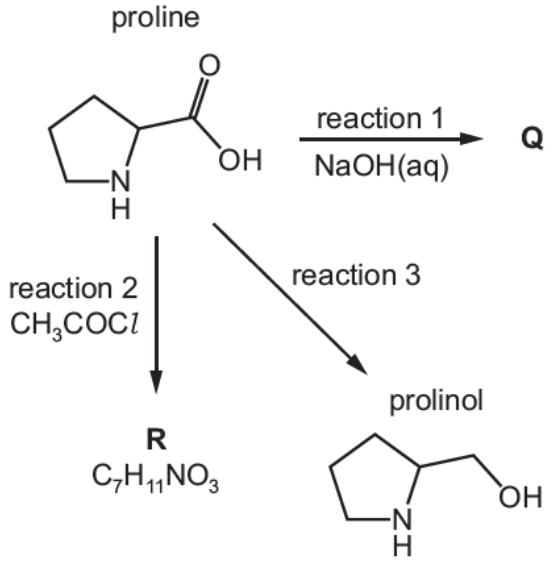
Suggest why the secondary structure of poly(proline) **cannot** be stabilised by hydrogen bonding.

.....

..... [1]

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(b) The reaction scheme shows several reactions of proline.



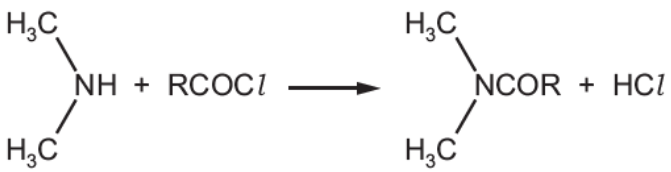
(i) Write an equation for the reaction of proline with NaOH(aq) in reaction 1.

$C_4H_7NHCO_2H$ + ... [1]

(ii) Proline has a secondary amine functional group.

Secondary amines react with acyl chlorides. For example, dimethylamine reacts with RCOC*l* according to the following equation.

dimethylamine



Suggest the skeletal structure of **R**, $C_7H_{11}NO_3$, the product of reaction 2.

[1]

(iii) Suggest the reagent required for reaction 3.

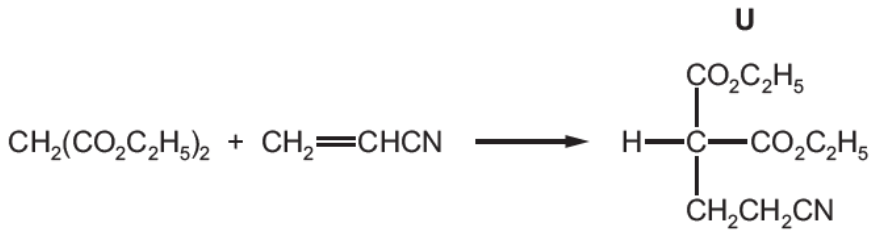
..... [1]

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(c) Proline was first synthesised in the laboratory using a multi-stage synthetic route.

In stage 1, $CH_2(CO_2C_2H_5)_2$ and CH_2=CHCN react to form a single product **U**.

stage 1



(i) Name **all** the functional groups present in the reactants of stage 1.

$CH_2(CO_2C_2H_5)_2$ .....

CH_2=CHCN .....

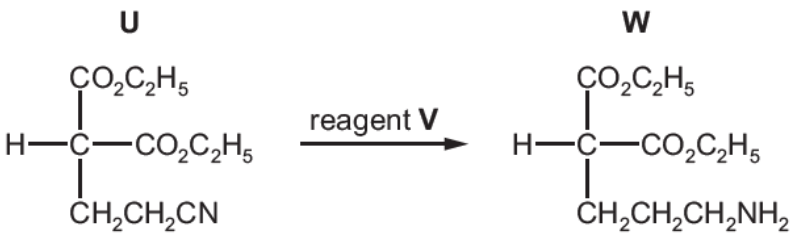
[2]

(ii) Suggest the type of reaction that occurs in stage 1.

..... [1]

In stage 2, **U** reacts with reagent **V** to form **W**.

stage 2



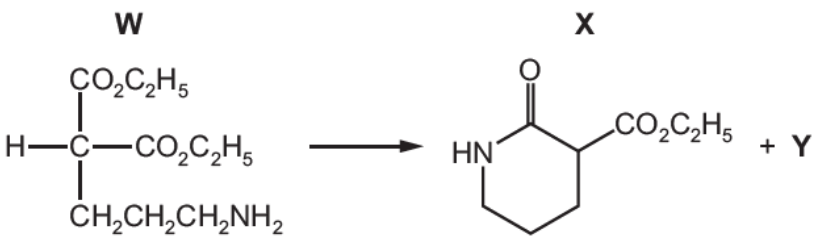
(iii) Suggest a suitable reagent **V**.

..... [1]

Stage 3 takes place in the presence of an acid catalyst.

X and **Y** are the only products of the reaction.

stage 3



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(iv) Suggest the type of reaction that occurs in stage 3.

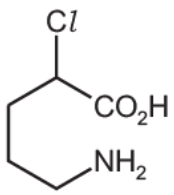
..... [1]

(v) Deduce the identity of **Y**.

..... [1]

After several further stages, **Z** is produced.

Z



In the final stage of the synthesis, **Z** reacts via a nucleophilic substitution mechanism to form proline.

(vi) Complete the diagram to describe the reaction mechanism of the final stage. Draw curly arrows, ions and charges, partial charges and lone pairs of electrons, as appropriate.

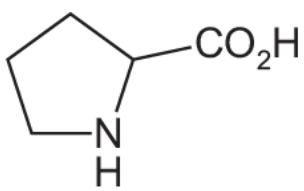
Draw the structure of any organic intermediate ion.

Z proline



[3]

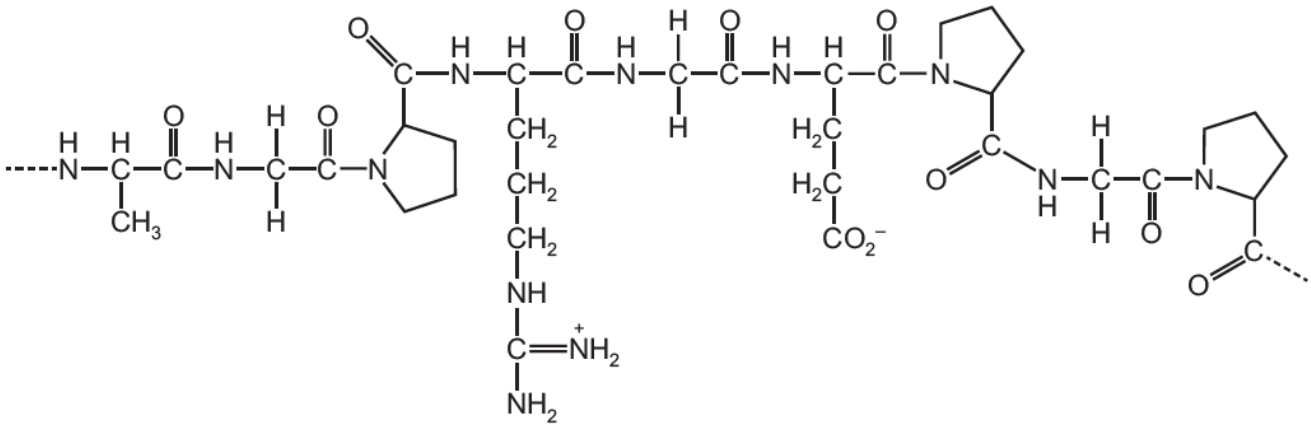
(vii) Identify with an asterisk (*) the chiral centre in proline.



[1]

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(d) Part of the structure of gelatin is shown.



Identify the number of amino acid units in the structure shown.

..... [1]

(e) (i) At pH 6.5, proline exists in aqueous solution as a zwitterion.

Draw the structure of the zwitterion of proline.

Explain how the zwitterion of proline forms.

.....

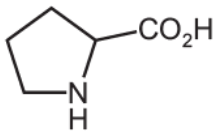
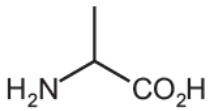
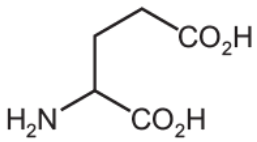
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..... [2]

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(ii) The isoelectric point of an amino acid is the pH at which it exists as a zwitterion.

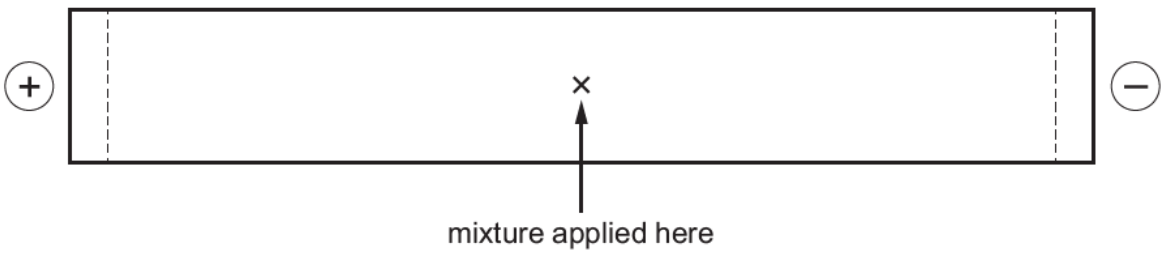
Three of the amino acids in gelatin are proline, alanine and glutamic acid. Their isoelectric points are shown.

amino acid	proline 	alanine 	glutamic acid 
isoelectric point	6.5	6.0	3.1

A mixture of these amino acids was analysed by electrophoresis using a buffer solution at pH 4.0.

Draw and label three spots on the diagram of the electropherogram to indicate the likely position of each of these three species after electrophoresis.

Explain your answer.



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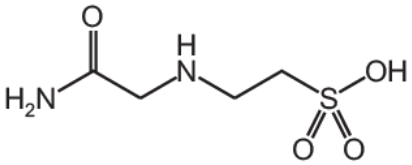
.....

..... [4]

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(f) The weak acid **ACES** is a compound that can be used to make a buffer solution for electrophoresis experiments.

ACES



The anion of the sodium salt of **ACES**, $C_4H_9N_2O_4SNa$, is a strong base.

A buffer solution is prepared by the following steps.

- 3.50 g of $C_4H_9N_2O_4SNa$ is dissolved in 100 cm^3 of distilled water.
- 50.0 cm^3 of 0.200 mol dm^{-3} dilute hydrochloric acid is added to the solution.
- The resulting mixture is transferred to a 250.0 cm^3 volumetric flask, and the solution made up to the mark.

$C_4H_9N_2O_4SNa$ reacts with HCl with a 1 : 1 stoichiometry.

The pK_a of **ACES** is 6.88 at 298 K.

Calculate the pH of the buffer solution formed at 298 K.

[M_r: $C_4H_9N_2O_4SNa$, 204.1]

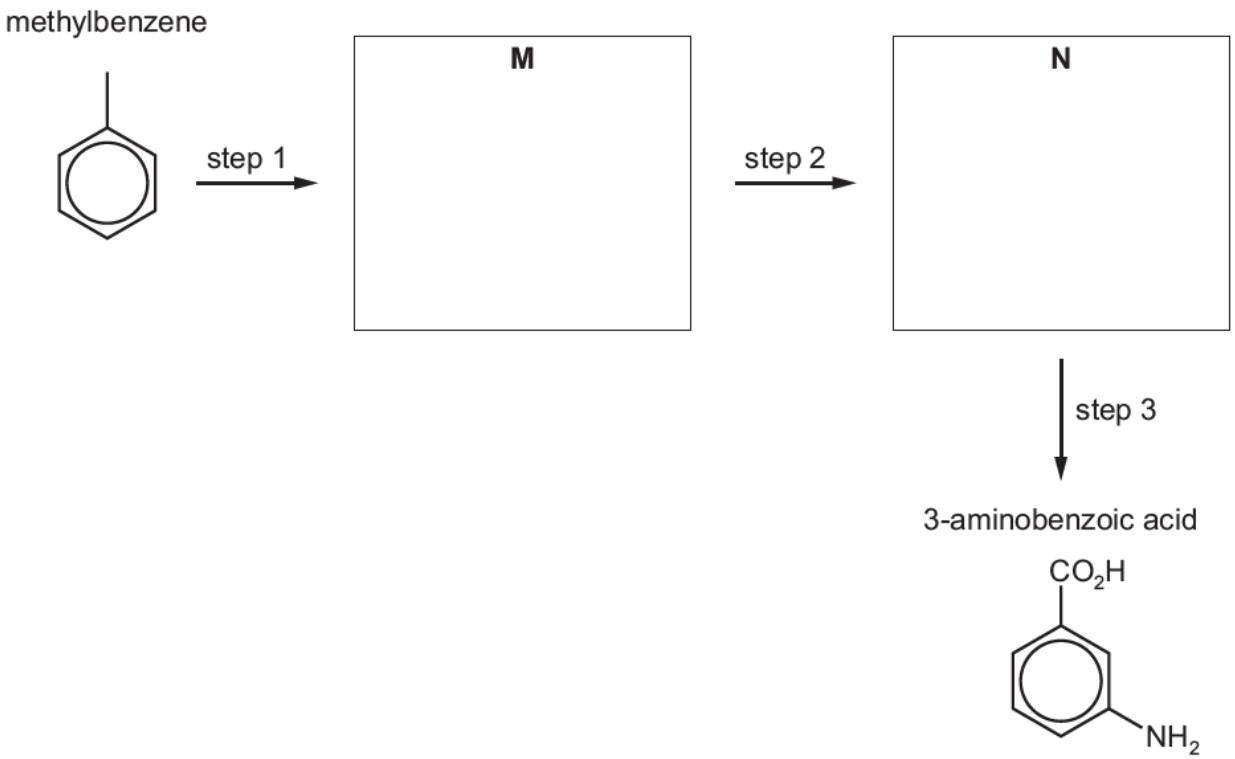
pH = ... [4]

[Total: 28]

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7. June/2021/Paper_41/No.7

(a) 3-aminobenzoic acid can be synthesised from methylbenzene in three steps.



(i) Draw the structures of **M** and **N** in the boxes. [2]

(ii) Suggest reagents and conditions for each step of the synthesis.

step 1 .....

step 2 .....

step 3 .....

[3]

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(b) A mixture of serine, $HOCH_2CH(NH_2)CO_2H$, and lysine, $H_2N(CH_2)_4CH(NH_2)CO_2H$, reacts to form several different products.

(i) Draw the structures of the two structural isomers with the molecular formula $C_6H_{12}N_2O_5$ that could be present in the product mixture.

The functional group formed in each case should be displayed.

[3]

(ii) Predict the number of different structural isomers with the molecular formula $C_9H_{19}N_3O_4$ that could be present in the product mixture.

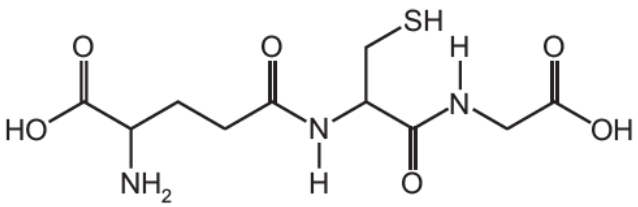
molecular formula	number of structural isomers formed
$C_9H_{19}N_3O_4$	

[1]

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(c) Glutathione is a naturally occurring compound found in plants.

glutathione



(i) On the diagram of glutathione, label each chiral centre with an asterisk (*). [1]

(ii) Draw the structures of the three products formed after complete acid hydrolysis of glutathione. Assume the thiol group, –SH, does not react.

[2]

(iii) Glutathione is soluble in water.

By referring to the structure of glutathione, explain why glutathione is soluble in water.

.....

.....

..... [1]

[Total: 13]

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8. June/2021/Paper_42/No.5

(a) Describe and explain the relative basicities of phenylamine, ethylamine and 4-nitrophenylamine.

..... > ..... > .....

most basic least basic

.....

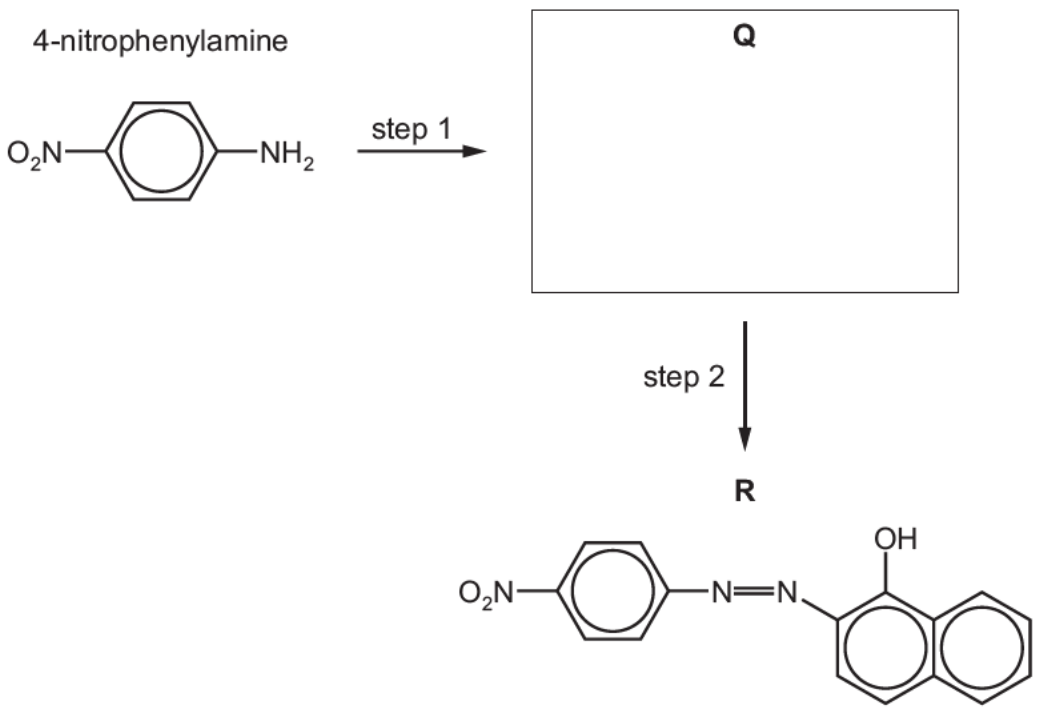
.....

.....

.....

..... [4]

(b) The dye **R** can be synthesised from 4-nitrophenylamine in two steps.



(i) Deduce and draw the structure of the organic salt **Q** in the box. [1]

(ii) Suggest reagents and conditions for step 1 and 2 in **(b)**.

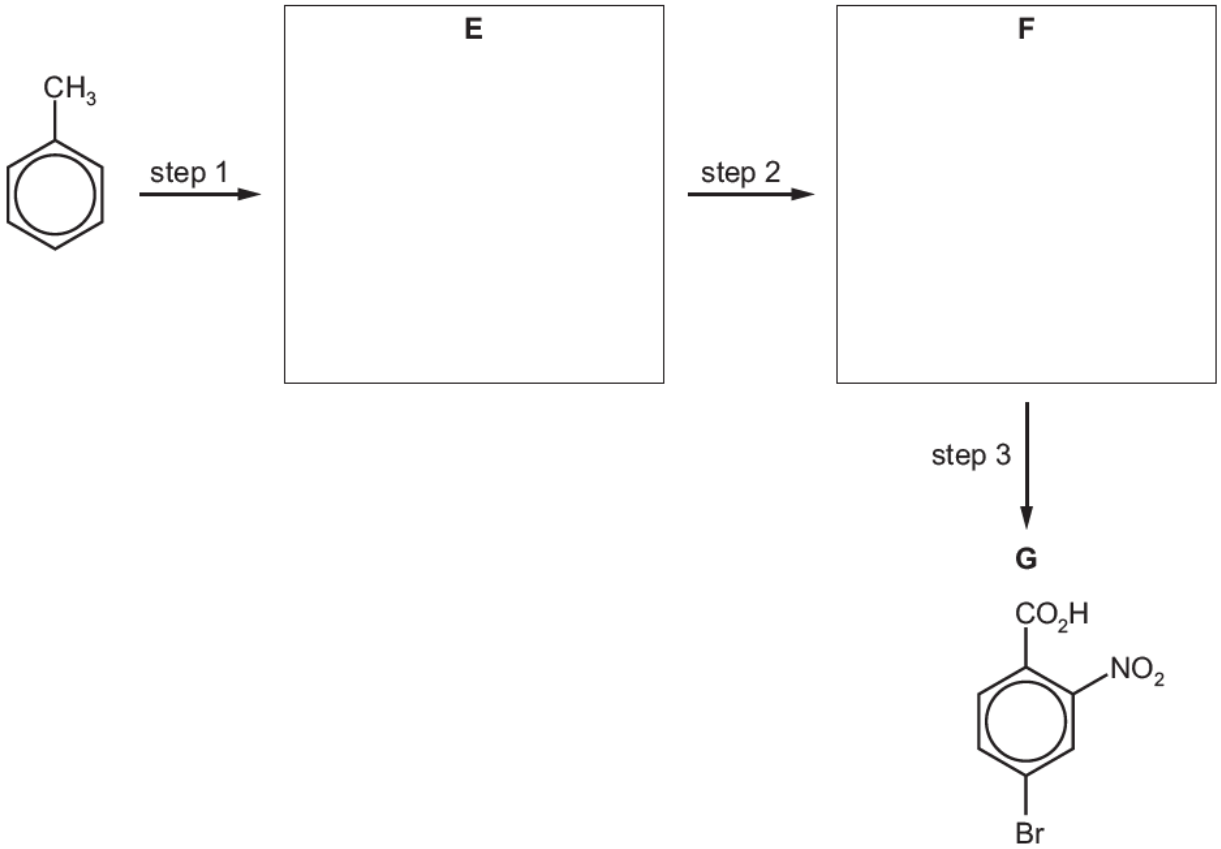
step 1 .....

step 2 .....

[2]

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(c) Compound **G** can be synthesised from methylbenzene in three steps.



(i) Give the systematic name of compound **G**.

..... [1]

(ii) Deduce the identities of **E** and **F** and draw their structures in the boxes. [2]

(iii) Suggest reagents and conditions for each of steps 1 to 3 in **(c)**.

step 1 .....

step 2 .....

step 3 .....

[3]

[Total: 13]

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9. June/2021/Paper_42/No.6

(a) There are four possible structural isomers of C_8H_{10} that contain a benzene ring.

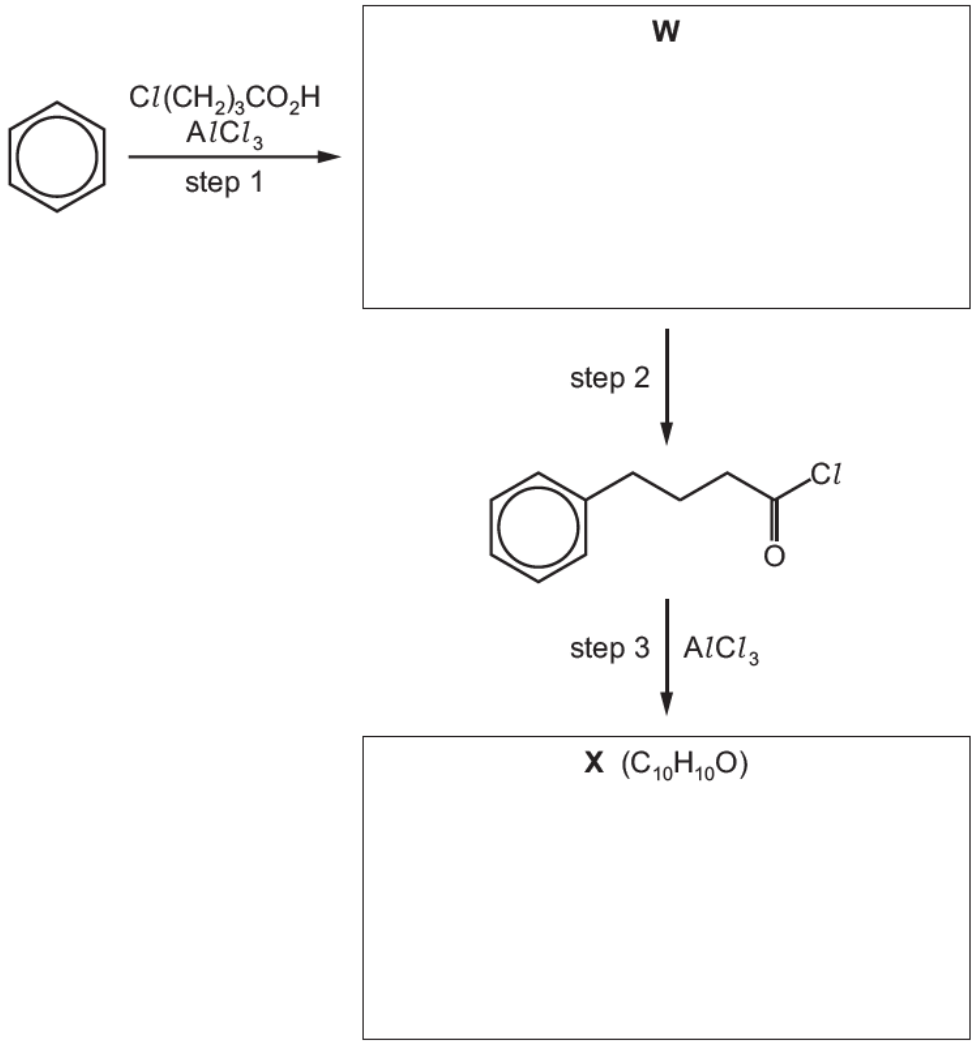
Draw the **skeletal** formulae of the four structural isomers in the appropriate boxes. The number of peaks observed in the carbon-13 (^{13}C) NMR spectrum of each compound is given.

isomer 1 three peaks in ^{13}C NMR	isomer 2 four peaks in ^{13}C NMR
isomer 3 five peaks in ^{13}C NMR	isomer 4 six peaks in ^{13}C NMR

[4]

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(b) A three-step synthesis of **X** ($C_{10}H_{10}O$) from benzene is suggested as shown.



(i) Step 1 is the alkylation of benzene by electrophilic substitution.
Use R–Cl to represent $Cl(CH_2)_3CO_2H$.

Write an equation for the formation of an electrophile from R–Cl and $AlCl_3$.

..... [1]

(ii) Deduce and draw the structures of **W** and **X** in the boxes. [2]

(iii) Suggest the reagents and conditions for step 2.

..... [1]

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(iv) Complete the mechanism for the reaction of benzene with the electrophile formed in **(b)(i)**.

Include all relevant charges and curly arrows showing the movement of electron pairs.

Draw the structure of the intermediate.



[3]

[Total: 11]

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Nitrogen compounds - 2022 June A2 Chemistry 9701

1. June/2022/Paper_41/No.6(a, c, d, e,)

(a) Describe what is meant by a racemic mixture.

.....

..... [1]

(c) The isoelectric point of asparagine, asn, is at pH 5.4.

(i) Describe the meaning of the term isoelectric point.

.....

..... [1]

(ii) Draw the structure of asparagine at pH 1.0.

[1]

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(d) Asparagine can polymerise to form poly(asparagine).

Draw the structure of poly(asparagine), showing **two** repeat units. The peptide linkage should be shown displayed.

[2]

(e) The isoelectric point of lysine, lys, is at pH 9.8.

lysine

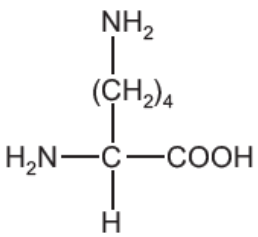


Fig. 6.2

A mixture of the dipeptide lys-asn and its two constituent amino acids, asparagine and lysine, is analysed by electrophoresis using a buffer at pH 5.0. The results obtained are shown in Fig. 6.3.

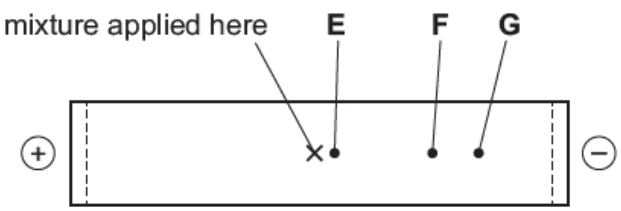


Fig. 6.3

Suggest identities for the species responsible for spots **E**, **F** and **G**. Explain your answers.

spot	identity
E	
F	
G	

.....

.....

.....

[3]

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(d) The azo compound Congo Red is used as an acid–base indicator and can be made by the route shown in Fig. 6.2.

In step 3 of this synthesis, compound **Y** reacts with compound **Z**. Compound **Z** is made from compound **X**. Assume that the $-SO_3^-Na^+$ groups do not react.

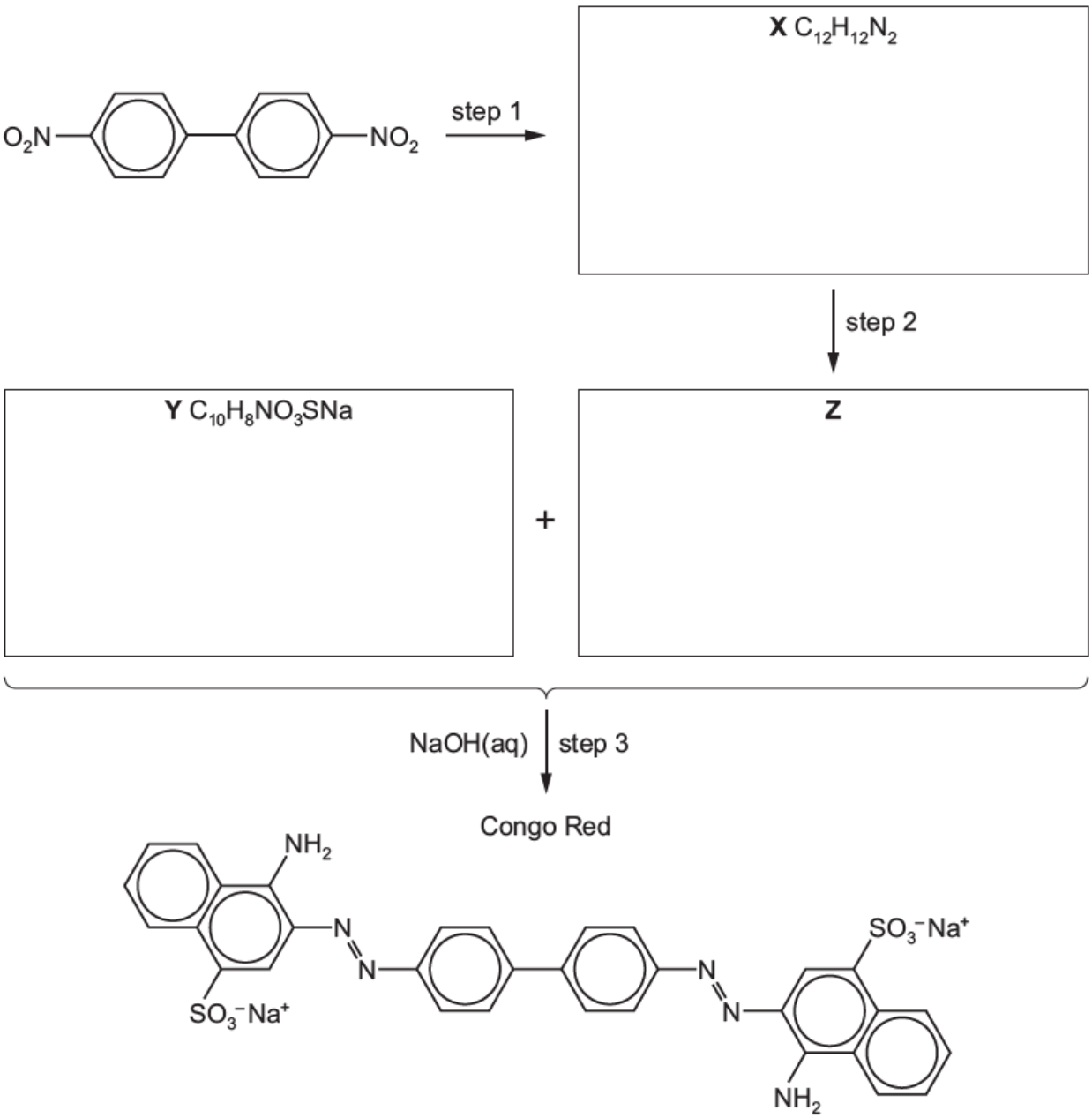


Fig. 6.2

(i) Suggest structures for compounds **X**, **Y** and **Z** and draw them in the boxes in Fig. 6.2. [3]

(ii) Give the reagents and conditions for step 1 and step 2.

step 1 .....

step 2 .....

[3]

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3. June/2022/Paper_42/No.9

The structure of cyclohexylamine is shown in Fig. 9.1.

cyclohexylamine

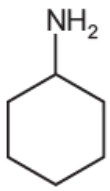


Fig. 9.1

(a) Compare the relative basicities of ammonia, cyclohexylamine and phenylamine. Explain your reasoning.

..... > ..... > .....

most basic least basic

.....

.....

.....

.....

.....

[3]

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(b) Cyclohexylamine reacts with ethanoyl chloride to form the corresponding amide, **L**.

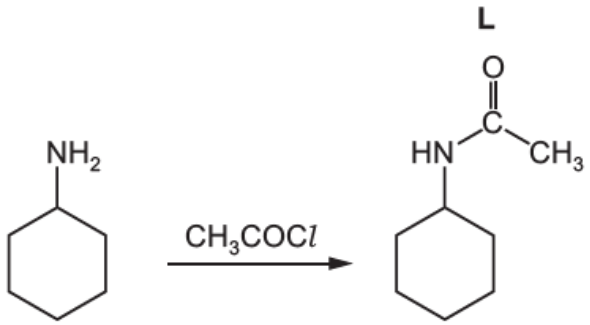


Fig. 9.2

(i) Name the mechanism for the reaction shown in Fig. 9.2.

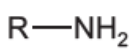
..... [1]

(ii) Complete the mechanism of the reaction between cyclohexylamine and CH_3COCl.

R–NH_2 is used to represent cyclohexylamine.

Include all relevant lone pairs of electrons, curly arrows, charges and partial charges.





[4]

(iii) The reaction between cyclohexylamine and an excess of CH_3COCl forms compound **M**. Compound **M** has the molecular formula $C_{10}H_{17}NO_2$.

Suggest and draw the structure of **M**.

[1]

[Total: 9]

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Nitrogen compounds - 2022 Nov A2 Chemistry 9701

1. Nov/2022/Paper_42/No.9

Tyrosine and lysine, shown in Fig. 9.1, are naturally occurring amino acids found in proteins.

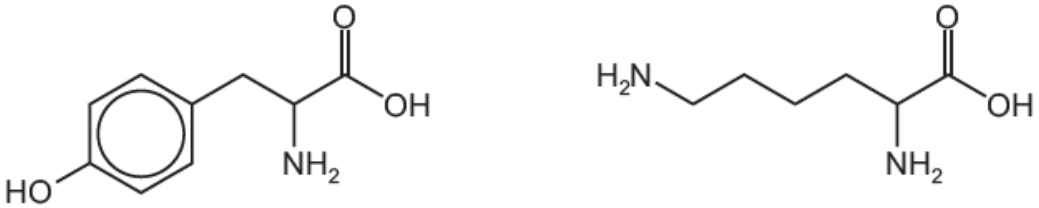


Fig. 9.1

(a) The isoelectric point of lysine is 9.47.

Draw the structure of lysine at the stated pH in the boxes below.

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lysine at pH 7.00	lysine at pH 9.47	lysine at pH 12.00

[2]

(b) When ethanoic acid is treated with PCl_5 product **D** is formed.

When **D** is added to tyrosine two different isomeric products, **E** and **F**, are formed.

E has an ester linkage, **F** does not.

Draw the structures of **D**, **E** and **F** in the boxes below.

D	E	F

[3]

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(c) Complete Table 9.1 by drawing the structure of the organic product formed when tyrosine reacts with each named reagent.

Ignore the directing effect of the $-CH_2CHNH_2COOH$ substituent.

Table 9.1

reagent	structure
an excess of $Br_2(aq)$	
an excess of NaOH(aq)	
an excess of $HNO_3(aq)$	

[3]

(d) A mixture of tyrosine and lysine can be separated by thin-layer chromatography. Under certain conditions the R_f value of lysine is 0.14 and the R_f value of tyrosine is 0.45.

(i) Explain what is meant by R_f value.

.....

..... [1]

(ii) Suggest an explanation for the difference in R_f values.

.....

..... [1]

[Total: 10]

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Nitrogen compounds - 2023 A2 Chemistry 9701

1. Nov/2023/Paper_9701/42/No.9

(a) State the reactants and conditions for two different types of reactions that both produce diethylamine, $CH_3CH_2NHCH_2CH_3$.

reaction one .....

.....

reaction two .....

.....

[4]

(b) Describe the relative basicities of diethylamine, phenylamine and ammonia in aqueous solution.

Explain your answer in terms of structure.

....

least basic most basic

explanation .....

.....

.....

.....

.....

[3]

(c) Phenylamine reacts with $HNO_2(aq)$ at 4°C to form compound **P**. Compound **P** reacts with phenol under alkaline conditions at 4°C. The product of this reaction is acidified, forming azo compound **Q**.

Draw the structure of compound **Q**.

Circle the azo group on your structure.

State one use of an azo compound such as **Q**.

compound **Q**:

An azo compound can be used ..... .

[2]

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(d) $CH_3CH_2NHCH_2CH_3$ reacts with ethanoyl chloride, CH_3COCl, to give the amide N,N-diethylethanamide, $CH_3CON(C_2H_5)_2$.

An incomplete description of the mechanism of this reaction is shown in Fig. 9.1.

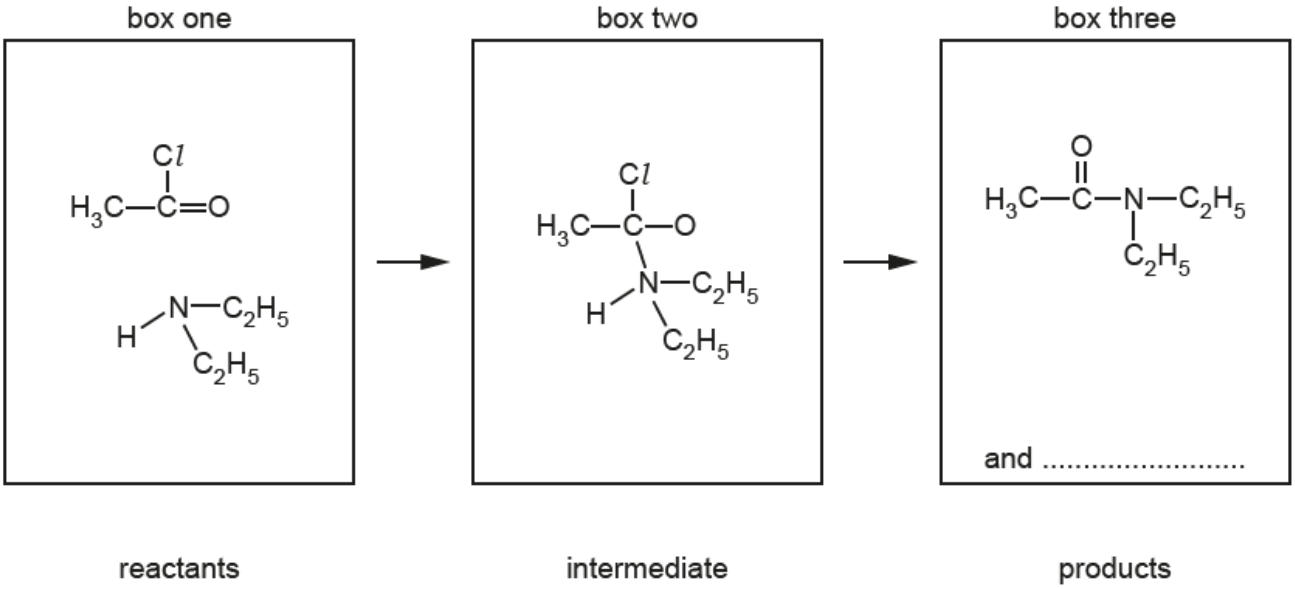


Fig. 9.1

(i) Complete the mechanism in Fig. 9.1. You should include:

- all relevant dipoles (δ+ and δ–) and full electric charges (+ and –) on the species in box one and in box two
- all relevant lone pairs on the species in box one and in box two
- all relevant curly arrows to show the movement of electron pairs in box one and in box two
- the formula of the second product in box three.

[4]

(ii) Name this mechanism.

..... [1]

[Total: 14]

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2. June/2023/Paper_9701/42/No.6

(a) Perindopril is a drug used to treat heart disease.

perindopril

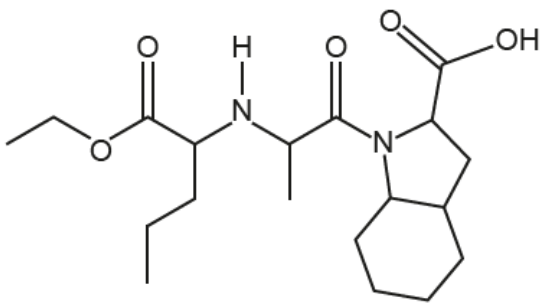


Fig. 6.1

(i) State the number of chiral carbon atoms present in one molecule of perindopril.

..... [1]

(ii) Suggest **one** benefit and **one** disadvantage of producing a drug such as perindopril as a single pure optical isomer.

benefit .....

.....

disadvantage .....

.....

[2]

(b) **(i)** Name all the functional groups in perindopril.

.....

..... [2]

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(ii) A sample of perindopril is hydrolysed with hot aqueous acid.

Draw the structures of the **three** organic products of the **complete** acid hydrolysis of perindopril.

[3]

[Total: 8]

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3. June/2023/Paper_9701/41/No.4(b ,c)

(b) Compound **Z** can be synthesised from benzene in three steps by the route shown in Fig. 4.1.

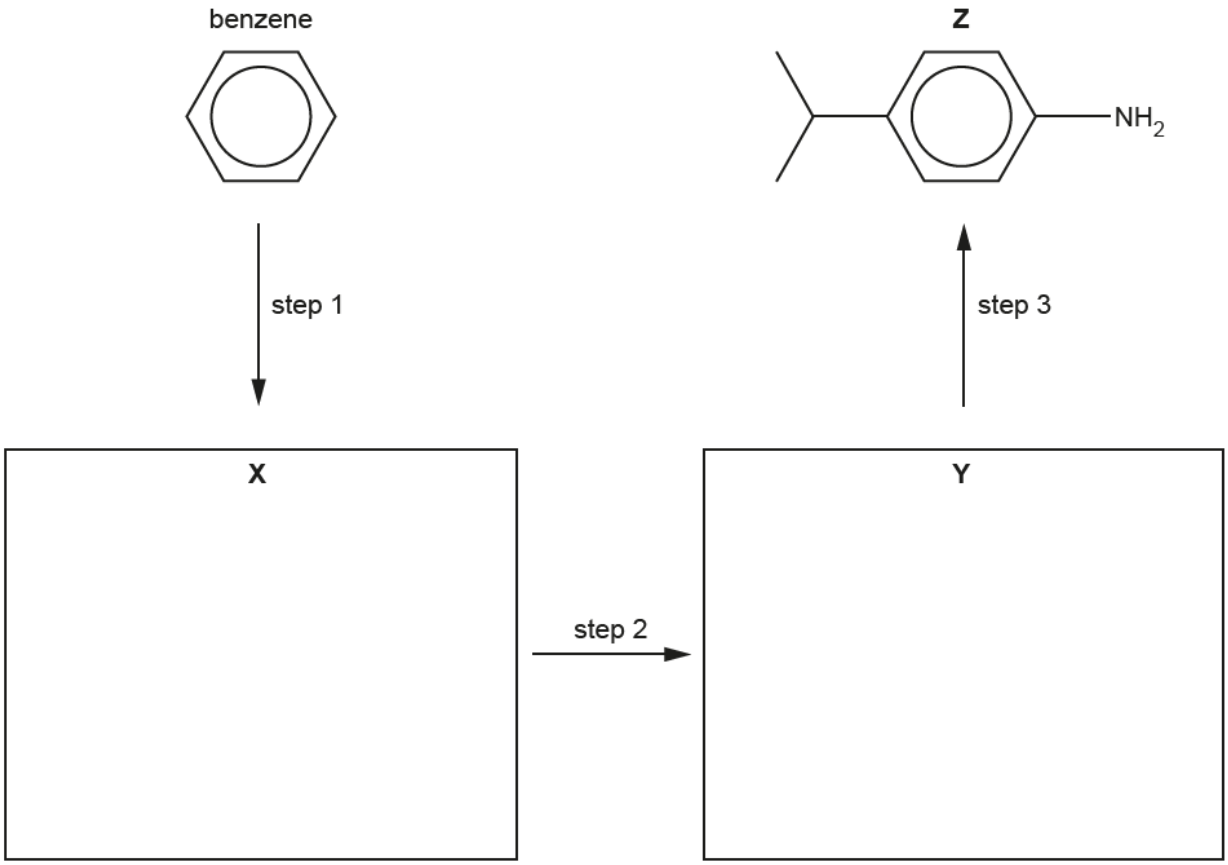


Fig. 4.1

(i) Draw structures for **X** and **Y** in Fig. 4.1. [2]

(ii) Give the reagents and conditions for steps 1, 2 and 3.

step 1 .....

step 2 .....

step 3 .....

[3]

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(c) Compound **W** is an isomer of **Z**.

W

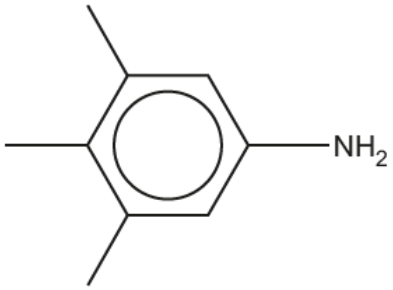


Fig. 4.2

Give the systematic name of **W**.

..... [1]

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4. June/2023/Paper_9701/41/No.7(a _ d)

(a) State the relative basicities of ethanamide, diethylamine and ethylamine in aqueous solution.

Explain your answer.

..... > ..... > .....
most basic least basic

.....

.....

.....

.....

.....
[4]

(b) The amino acid alanine, $H_2NCH(CH_3)COOH$, can act as a buffer.

(i) Define a buffer solution.

.....

.....

..... [2]

(ii) Write **two** equations to show how an aqueous solution of alanine can act as a buffer solution.

.....

..... [2]

(c) Glutamic acid is another amino acid that acts as a buffer.

glutamic acid

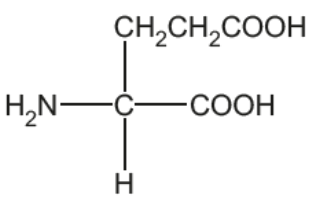


Fig. 7.1

(i) Draw the **skeletal** formula for glutamic acid.

[1]

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(ii) Draw the structure for the dipeptide, ala-glu, formed from one molecule of alanine and one molecule of glutamic acid.

The peptide bond formed should be displayed.

[2]

(d) The isoelectric point of alanine is 6.0 and of glutamic acid is 3.2.

A mixture of the dipeptide, ala-glu, and its two constituent amino acids, alanine and glutamic acid, is analysed by electrophoresis using a buffer at pH 6.0.

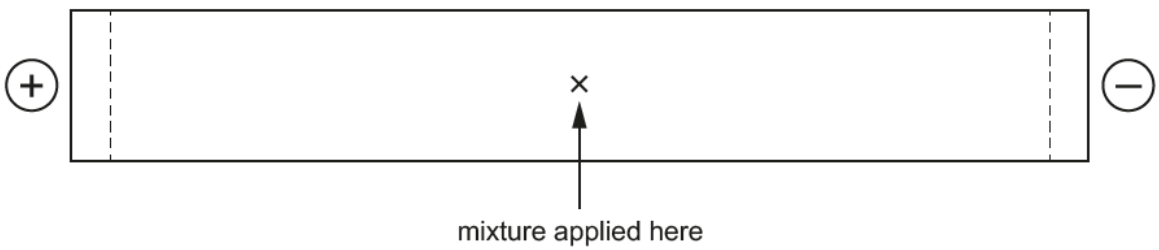


Fig. 7.2

Draw and label **three** spots on Fig. 7.2 to indicate the predicted position of each of these three species after electrophoresis.

Explain your answer.

.....

.....

.....

.....

..... [3]

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5. March/2023/Paper_9701/42/No.4(a_ d)

Ethylamine and phenylamine are primary amines.

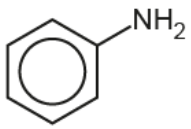
ethylamine	phenylamine
$CH_3CH_2NH_2$	

Fig. 4.1

These two compounds are synthesised by different methods.

(a) Several methods can be used to form ethylamine.

(i) Ethylamine forms when ethanamide, CH_3CONH_2, is reduced by $LiAlH_4$.

Write an equation for this reaction. Use [H] to represent one atom of hydrogen from the reducing agent.

..... [1]

(ii) Ethylamine is a product of the reaction of bromoethane with ammonia.

Name the mechanism of this reaction and state the conditions used.

mechanism .....

conditions .....

[2]

(iii) The reaction in **(a)(ii)** also forms secondary and tertiary amines.

Suggest the identity of a secondary or tertiary amine formed by the reaction in **(a)(ii)**.

..... [1]

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(b) Ethylamine is a weak base.

State the relative basicities of ammonia, ethylamine and phenylamine.

Explain your answer.

..... < ..... < .....
least basic most basic

.....

.....

.....

.....

.....

.....

..... [4]

(c) Pure phenylamine, $C_6H_5NH_2$, can be prepared from benzene in two steps.

Draw the structure of the intermediate compound.

Suggest reagents and conditions for each step.

.....

.....

.....

.....

..... [3]

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(d) Fig. 4.2 shows some reactions of phenylamine.

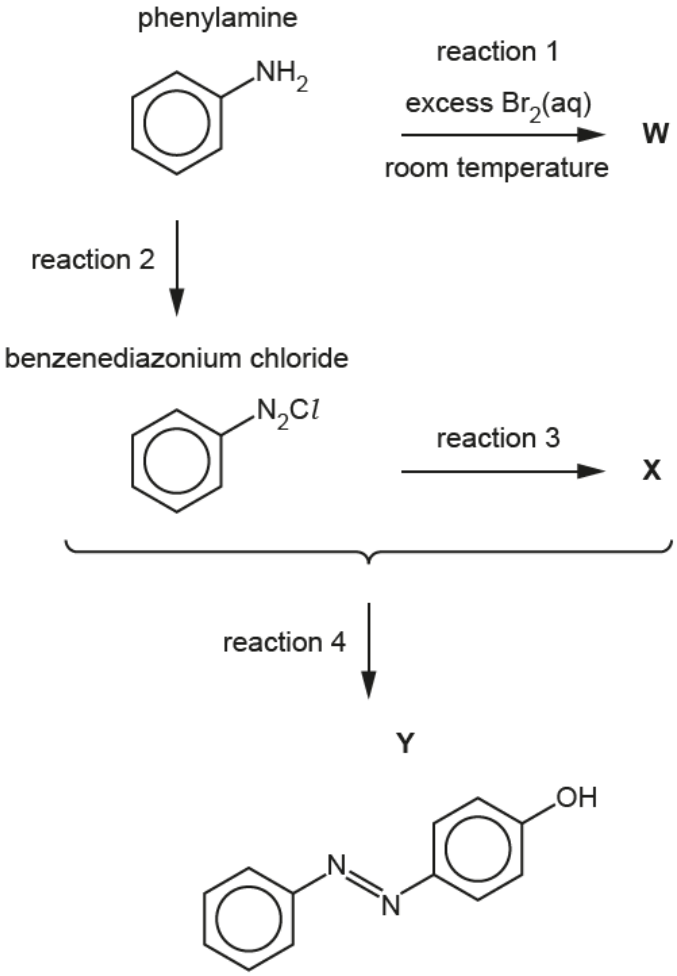


Fig. 4.2

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(i) Draw the structure of **W**, the organic product of reaction 1.

[1]

(ii) State the reagents used in reaction 2.

..... [1]

Benzenediazonium chloride, $C_6H_5N_2Cl$, and **X** react together in reaction 4 to form **Y**, an azo compound.

(iii) Name **X**, the organic product of reaction 3.

..... [1]

(iv) State the necessary conditions for reaction 4 to occur.

..... [1]

(v) Suggest a use for **Y**.

..... [1]

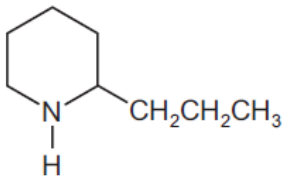
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Organic synthesis – 2022 June AS Chemistry 9701

1. June/2022/Paper_12/No.32

The structure of coniine is shown.

coniine



Coniine can be synthesised by reacting ammonia with a dibromo compound, X.

X

$$NH_3 + C_8H_{16}Br_2 \rightarrow \text{coniine} + 2HBr$$

What is compound X?

A 1,1-dibromo-2-propylcyclopentane

B 1,2-dibromo-2-propylcyclopentane

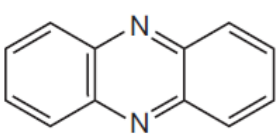
C $Br(CH_2)_3CHBr(CH_2)_3CH_3$

D $Br(CH_2)_4CHBr(CH_2)_2CH_3$

2. June/2022/Paper_13/No.27

The diagram shows the skeletal formula of phenazine.

phenazine



What is the empirical formula of phenazine?

A C_6H_4N **B** C_6H_6N **C** $C_{12}H_8N_2$ **D** $C_{12}H_{12}N_2$

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Nitrogen compounds – 2022 Nov AS Chemistry 9701

1. Nov/2022/Paper_11/No.23

Which statement about ammonia or the ammonium ion is correct?

A Ammonia gas is produced when an aqueous solution containing the ammonium ion is reacted with a strong acid.

B Silver iodide is soluble in a concentrated aqueous solution of ammonia.

C The ammonium ion has the same number of electrons as a methane molecule.

D The square planar ammonium ion contains a dative covalent bond.

2. Nov/2022/Paper_11/No.24

Sulfur dioxide can be catalytically oxidised by an oxide of nitrogen in the atmosphere.

Which reaction shows how the catalyst is reformed?

A $N_2 + 2O_2 \rightleftharpoons 2NO_2$

B $4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$

C $N_2 + O_2 \rightarrow 2NO$

D $NO + \frac{1}{2}O_2 \rightarrow NO_2$

3. Nov/2022/Paper_12/No.23

R is a solid. R fizzes when hydrochloric acid is added.

R reacts with hot aqueous sodium hydroxide, giving off a gas which turns red litmus blue.

What is the formula of R?

A NH_4CO_3 **B** $(NH_4)_2CO_3$ **C** $(NH_4)_2HCO_3$ **D** $(NH_4)_2SO_4$

4. Nov/2022/Paper_12/No.24

Photochemical smog is a type of air pollution produced in urban areas by the effect of sunlight on substances released from vehicle exhausts.

Which mixture of primary pollutants leads to the formation of photochemical smog?

A carbon dioxide and water vapour

B carbon monoxide and unburnt hydrocarbons

C nitrogen oxide and unburnt hydrocarbons

D sulfur dioxide and water vapour

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Nitrogen and Sulfur – 2023 June AS Chemistry 9701

1. Nov/2023/Paper_ 9701/11/No.24

If ammonium cyanate is heated in the absence of air, the only product of the reaction is urea, $CO(NH_2)_2$. No other products are formed in the reaction.

What is the formula of the cyanate ion present in ammonium cyanate?

A CON_2^- **B** CON_2^{2-} **C** OCN^- **D** OCN^{2-}

2. Nov/2023/Paper_ 9701/12/No.26

NaOH(aq) is added to NH_4Cl(aq). The mixture is warmed.

The gas that is produced turns damp red litmus paper blue.

Which row is correct?

	behaviour of the ammonium ion in NH_4Cl	behaviour of the water present on the litmus paper
A	Brønsted–Lowry acid	Brønsted–Lowry base
B	Brønsted–Lowry acid	Brønsted–Lowry acid
C	Brønsted–Lowry base	Brønsted–Lowry acid
D	Brønsted–Lowry base	Brønsted–Lowry base

3. Nov/2023/Paper_ 9701/22/No.2(d, e)

(d) Identify one natural process and one man-made process that cause the formation of atmospheric NO and NO_2.

natural process .....

man-made process .....

[2]

(e) NO_2 is a brown gas that can be used to form nitric acid.

(i) NO_2 is a free radical.

Define free radical.

..... [1]

(ii) NO_2 has a catalytic role in the oxidation of atmospheric sulfur dioxide.

Write equations to show the catalytic role of NO_2 in this oxidation.

.....

..... [2]

(iii) State **one** environmental consequence of the oxidation of atmospheric sulfur dioxide.

..... [1]

4. June/2023/Paper_9701/11/No.20

Which emission from an internal combustion engine contributes to the erosion of marble statues?

A carbon monoxide

B nitrogen

C nitrogen dioxide

D unburnt hydrocarbons

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5. June/2023/Paper_9701/12/No.23

Ammonium sulfate, $(NH_4)_2SO_4$, and ammonium nitrate, NH_4NO_3, are used as fertilisers.

These salts have different percentages by mass of nitrogen. They have the same effect as each other on the pH of wet neutral soil.

Which row is correct?

	higher percentage of nitrogen by mass	effect on pH of soil
A	ammonium nitrate	decrease
B	ammonium nitrate	increase
C	ammonium sulfate	decrease
D	ammonium sulfate	increase

6. June/2023/Paper_9701/12/No.24

The equation shows a reaction that occurs between carbon monoxide and nitrogen monoxide in a catalytic converter.

$$2CO(g) + 2NO(g) \rightarrow 2CO_2(g) + N_2(g)$$

Which statement is correct?

A The catalyst used is finely divided iron.

B The reaction prevents greenhouse gas emissions into the atmosphere.

C The reaction reduces the possibility of the formation of photochemical smog.

D The reaction results in increased ozone depletion.

7. June/2023/Paper_9701/13/No.20

HCN has been detected in interstellar gas. The molecules below have also been detected in interstellar gas.

Which molecule contains the same total number of valence shell (outer shell) electrons as HCN?

A HNO **B** NH_3 **C** NO **D** PN

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8. June/2023/Paper_9701/13/No.26

Which statement about the oxides of nitrogen is correct?

A During lightning storms, atmospheric oxygen and nitrogen combine to form oxides of nitrogen.

B In a catalytic converter, nitrogen monoxide is removed by reaction with carbon dioxide.

C In car engines, the restricted supply of oxygen eliminates the possibility of the formation of oxides of nitrogen.

D In the atmosphere, nitrogen monoxide reacts with sulfur dioxide to produce sulfur trioxide.

9. June/2023/Paper_9701/21/No.5(a , b)

(a) Molecule **M** is present in petrol, a fuel used in cars. **M** is a saturated, non-cyclic hydrocarbon. **M** contains eight carbon atoms.

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

..... [2]

(ii) Describe how the composition of products differs when incomplete combustion of **M** occurs.

.....

..... [2]

(b) When petrol is burned in an internal combustion engine, oxides of nitrogen are released into the atmosphere. Oxides of nitrogen are responsible for the formation of acid rain.

(i) Suggest the conditions required for the production of oxides of nitrogen during combustion of **M** in an internal combustion engine. Use an appropriate equation in your answer.

.....

.....

.....

..... [2]

(ii) Describe how acid rain is formed in the atmosphere in the presence of oxides of nitrogen and SO_2. Identify the role of the oxides of nitrogen in this process. Include **all** relevant equations.

.....

.....

.....

..... [3]

(iii) State **one** other type of air pollution that is caused by the production of oxides of nitrogen in an internal combustion engine.

..... [1]

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10. March/2023/Paper_9701/12/No.1

Four equations representing reactions of nitrogen or one of its compounds are given.

Which equation represents a disproportionation reaction?

A $2HNO_3 + CaCO_3 \rightarrow Ca(NO_3)_2 + CO_2 + H_2O$

B $N_2 + 3H_2 \rightarrow 2NH_3$

C $NH_4Cl + NaOH \rightarrow NH_3 + NaCl + H_2O$

D $2NO_2 + H_2O \rightarrow HNO_3 + HNO_2$

11. March/2023/Paper_9701/12/No.17

Two procedures are described.

1 Sulfur is burned in an excess of oxygen and then NO is added to the product mixture.

2 Sulfur is burned in an excess of oxygen and then NO_2 is added to the product mixture.

Which procedures will produce some sulfur trioxide, SO_3?

A both 1 and 2 **B** 1 only **C** 2 only **D** neither 1 nor 2

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12. March/2023/Paper_9701/22/No.3(a)

Alkenes undergo an addition reaction with a 1:1 mixture of CO and H_2 to form aldehydes.

Fig. 3.1 shows the reaction of propene with a 1:1 mixture of CO and H_2.

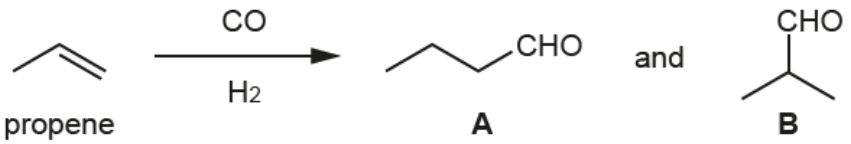


Fig. 3.1

(a) (i) Define addition reaction.

.....

..... [1]

(ii) Aldehydes **A** and **B** are structural isomers.

State the type of structural isomerism shown by **A** and **B**.

..... [1]

(iii) Name **A**.

..... [1]

(iv) The complete reaction of propene with a 1:1 mixture of CO and H_2 produces **A** and **B** only. The product mixture contains 96% **A** and 4% **B**.

Calculate the mass of **A** produced in this reaction when 5.00×10^3 kg of propene is used.

mass of **A** = ... kg [1]

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