Q1.

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?

.....

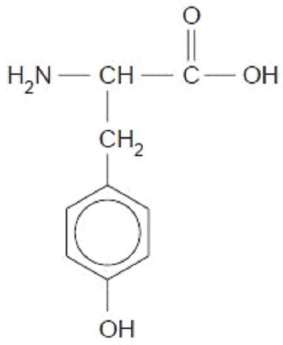
(iii) Write a balanced equation showing the formation of an ester containing five carbon atoms from the acyl chloride you drew in part **(i)**.

.....[3]

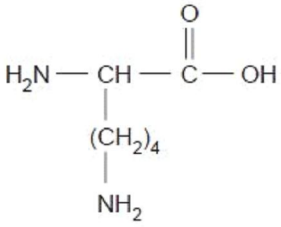
[Total: 7]

Q2.

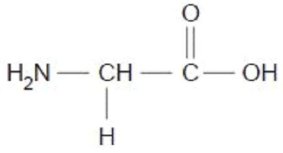
4 The amino acids tyrosine, lysine and glycine are constituents of many proteins.



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 $HCl(aq)$

.....

(iv) tyrosine + excess $Br_2(aq)$

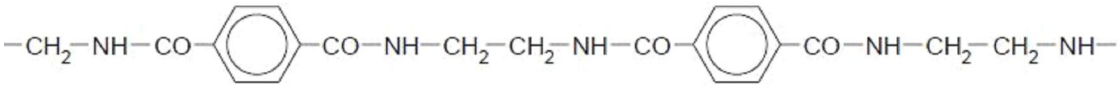
.....

[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]

Q3.

Use

8 **(a)** Electrophoresis can be used to separate amino acids which are produced by the hydrolysis of a polypeptide.

Using glycine as an example, explain why the result of electrophoresis depends on pH.

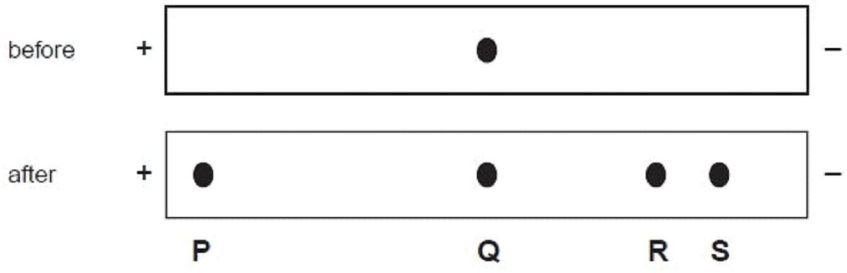
.....

.....

.....

.....[3]

(b) The diagram below shows the results of electrophoresis in neutral solution. At the start of the experiment a spot of a solution containing a mixture of amino acids **P**, **Q**, **R** and **S** was placed in the middle of the plate. Following electrophoresis the amino acids had moved to the positions shown in the lower diagram.



(i) Which amino acid existed mainly as a zwitterion in the buffer solution? Explain your answer.

.....

.....

(ii) Assuming amino acids **R** and **S** carry the same charge when in this buffer solution, which is likely to be the larger molecule? Explain your answer.

.....

.....

[2]

(c) Amino acids may also be separated by using two-dimensional paper chromatography. This involves putting a spot of the mixture on the corner of a piece of chromatography paper and allowing a solvent to soak up the paper. The paper is then dried, turned through 90° and placed in a second solvent. This method gives better separation than a one solvent method.

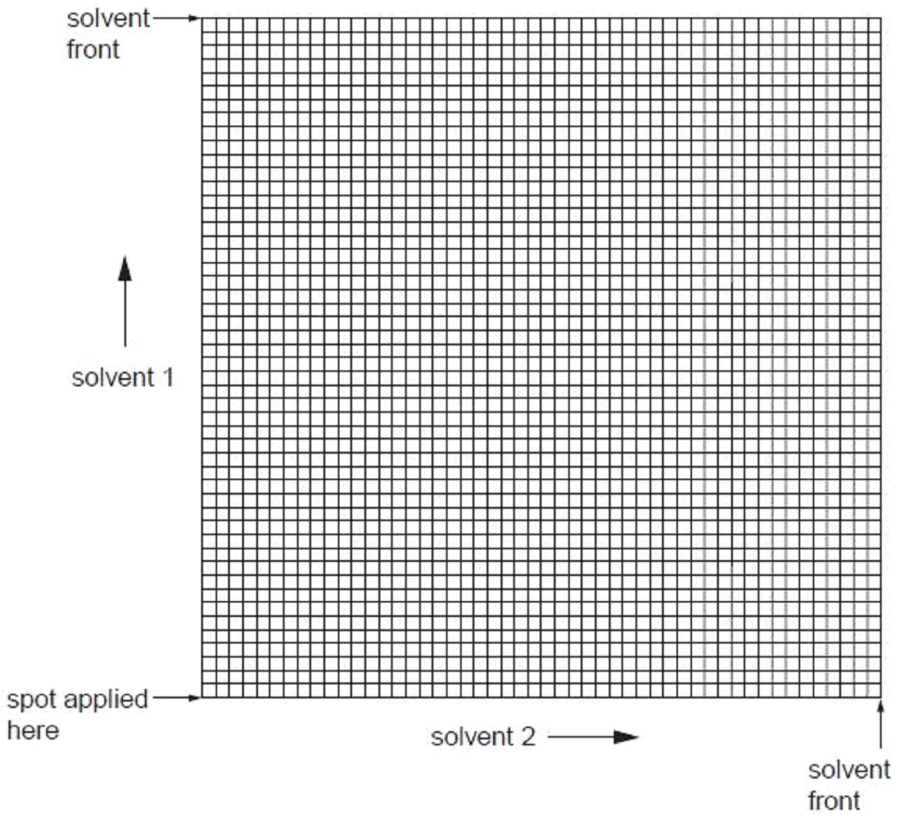
(i) Paper chromatography relies on partition between the solvent applied and another phase.

What is this second phase? .....

(ii) The table below shows the R_f values for some amino acids in two different solvents.

amino acid	R_f solvent 1	R_f solvent 2
A	0.1	0.2
B	0.0	0.4
C	0.3	0.0
D	0.8	0.9
E	0.6	0.5

Use the grid below to plot the positions of the amino acids after two-dimensional paper chromatography using solvent 1 followed by solvent 2.



(iii) Which amino acid travelled fastest in **both** solvents? .....

(iv) Which amino acid did not move at all in solvent 2? .....

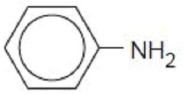
[5]

[Total: 10]

Q4.

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.

For Examiner Use

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.

.....

.....

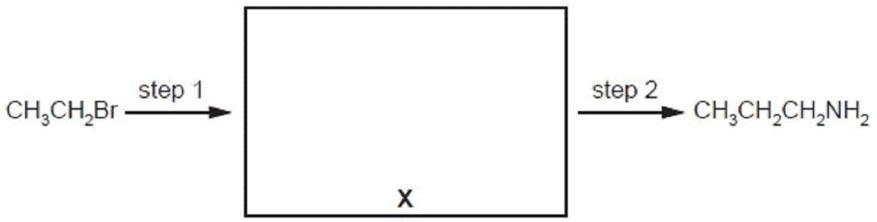
.....[2]

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

.....[1]

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

For Examiner's Use



(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]

Q5.

For Examine Use

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.

.....

.....

.....

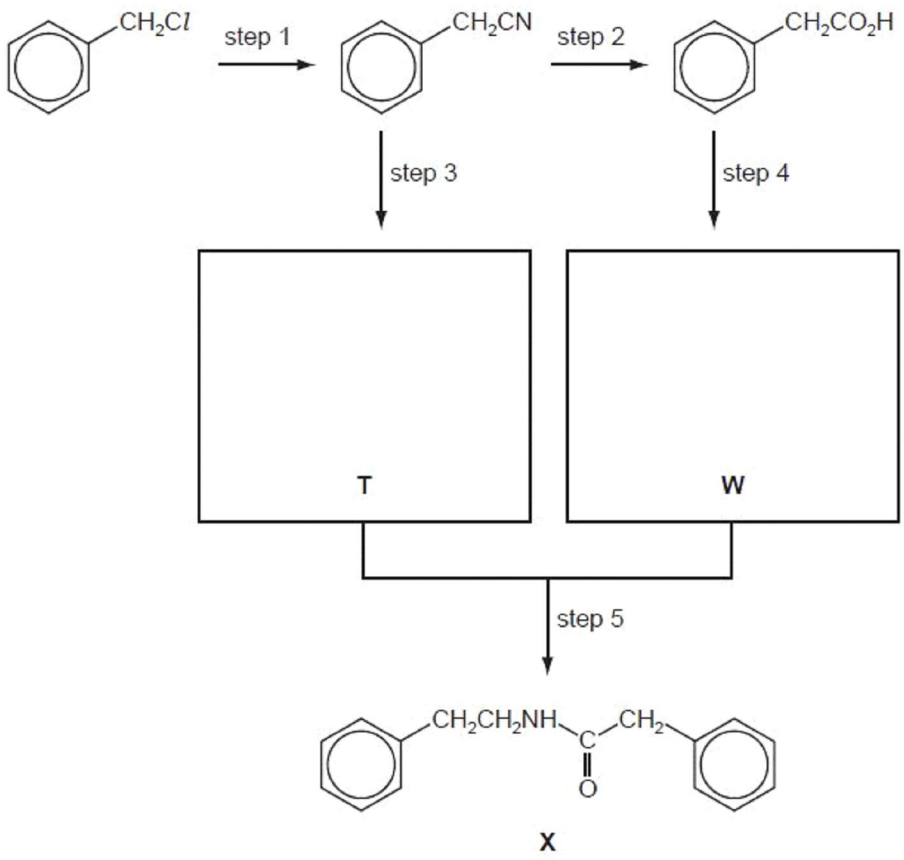
.....

.....

[4]

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

For Examiner Use



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.

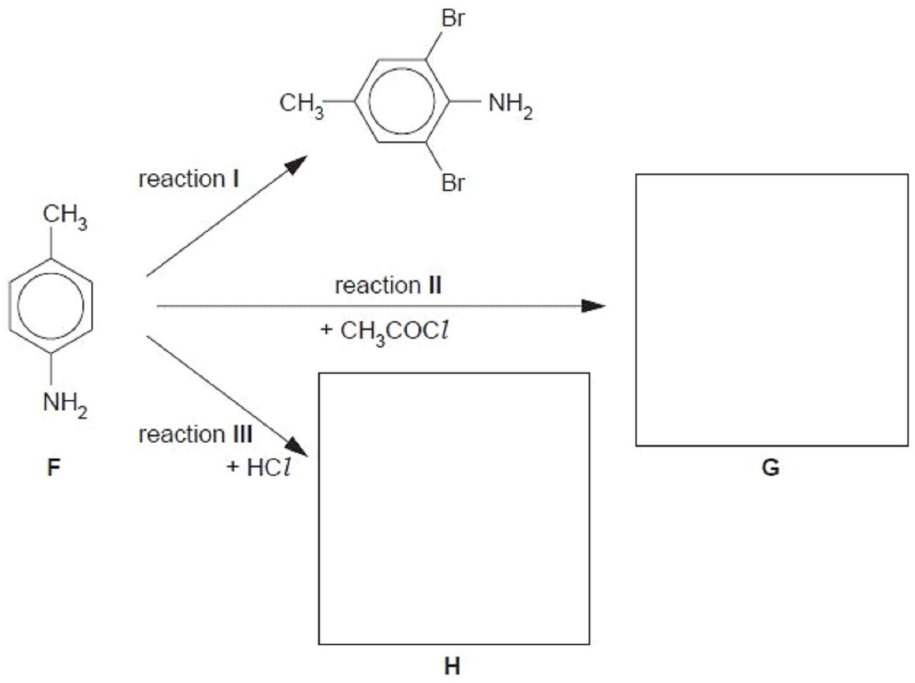
[6]

[Total: 15]

Q6.

Use

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.

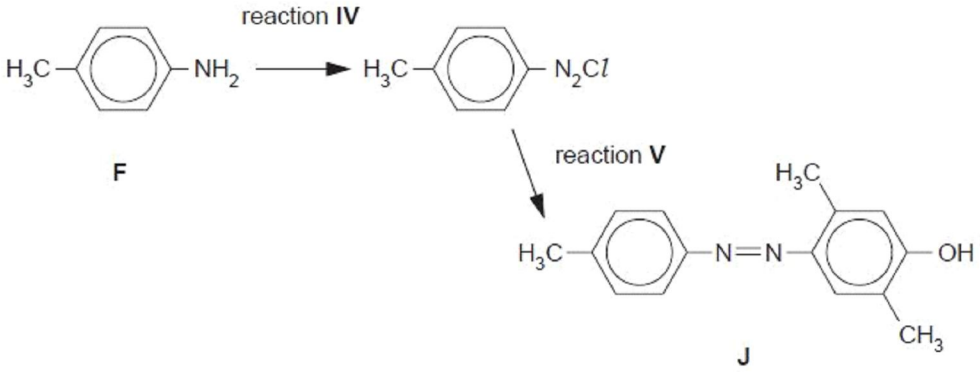
(iii) Name the functional group you have drawn in compound **G.**

.....

[4]

Use

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



Suggest reagents and conditions for

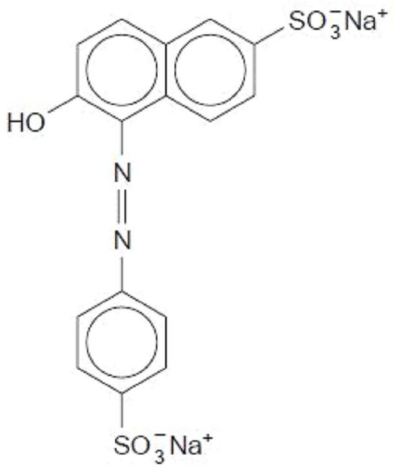
(i) reaction **IV**, ...

(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]

Q7.

(c) A good way of making synthetic amino acids uses chloro-acids as intermediates.

$$CH_3CH_2CO_2H \xrightarrow[\text{I}]{Cl_2 + \text{trace of P}} CH_3CHClCO_2H \xrightarrow[\text{II}]{NH_3(\text{excess})} \underset{\text{alanine}}{CH_3CH(NH_2)CO_2H}$$

(i) Suggest the role that the trace of phosphorus plays in reaction I.

.....

(ii) Write a fully balanced equation for reaction I.

.....

(iii) State the *type of mechanism* of reaction II.

.....

(iv) When 10.0 g of propanoic acid was used in this 2-stage synthesis, a yield of 9.5 g of alanine was obtained.
Calculate the overall percentage yield.

.....

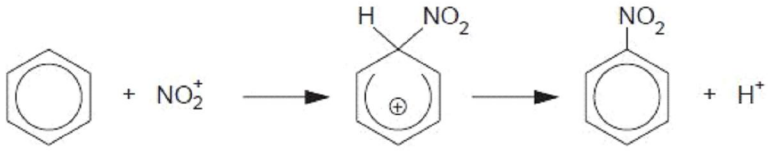
[5]

(d) In the solid state and in aqueous solutions, alanine exists as a zwitterion.
Draw the structural formula of this zwitterion.

[2]

Q8.

7 The nitration of benzene occurs in the following steps.



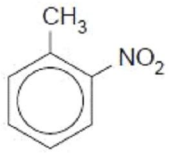
(a) What reagents and conditions are needed for this reaction?

.....[2]

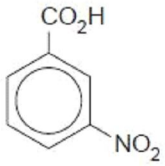
(b) Write an equation showing how the electrophile NO_2^+ is formed from the reagents.

.....[1]

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

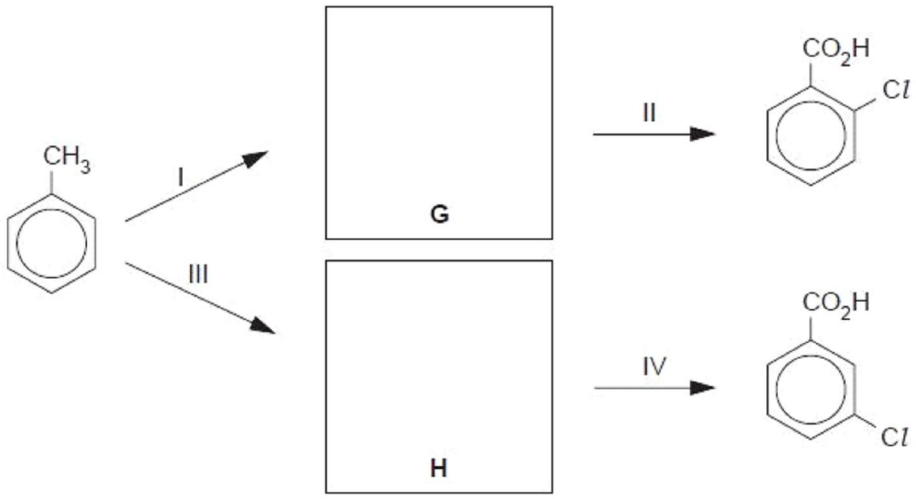


2-nitromethylbenzene



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]

Q9.

7 **(a)** Explain briefly what is meant by the word *protein*.

.....

..... [1]

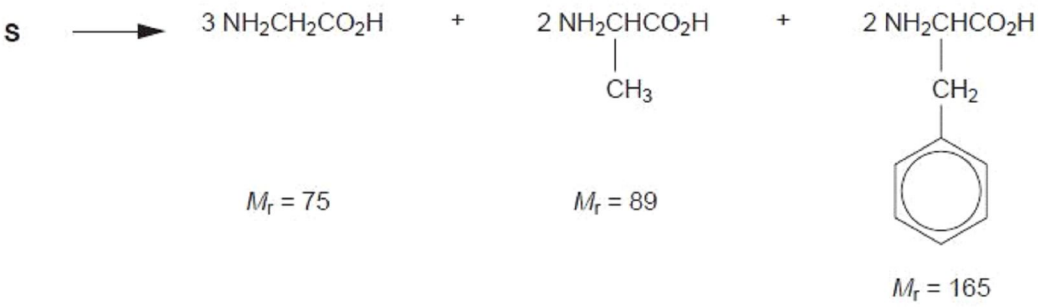
(b) Describe how peptide bonds are formed between amino acids during the formation of a tripeptide. Include diagrams and displayed formulae in your answer.

..... [3]

(c) Describe how proteins can be broken down into amino acids in the laboratory **without** the aid of enzymes.

..... [2]

(d) When a small polypeptide **S** was broken down in this way, three different amino acids were produced according to the following reaction.



(i) How many peptide bonds were broken during this reaction?

.....

(ii) Calculate the M_r of the polypeptide **S**.

M_r = ...

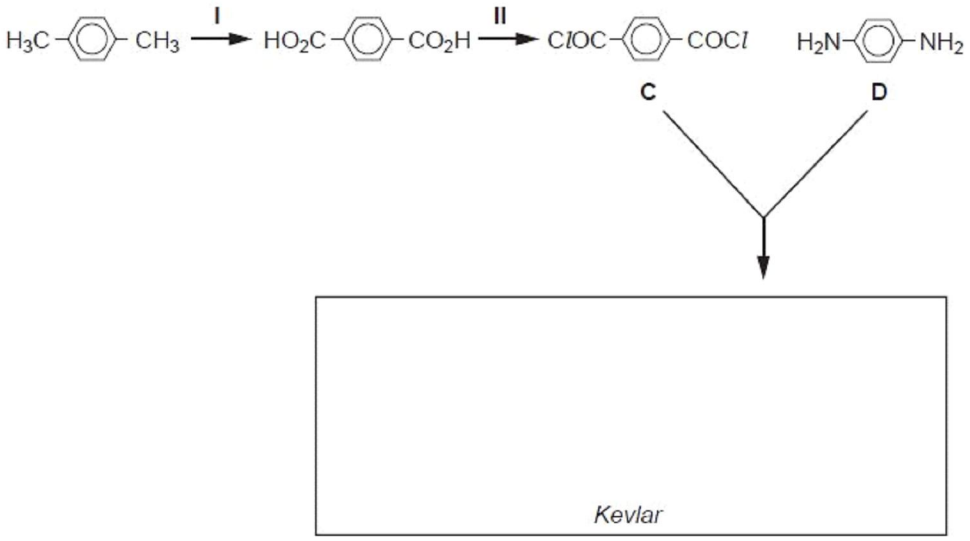
[3]

[Total: 9]

Q10.

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

For Examiner's Use



(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

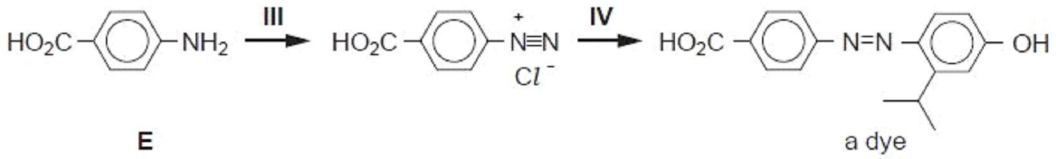
For Examiner's Use

(i) $HCl(aq)$,

(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]

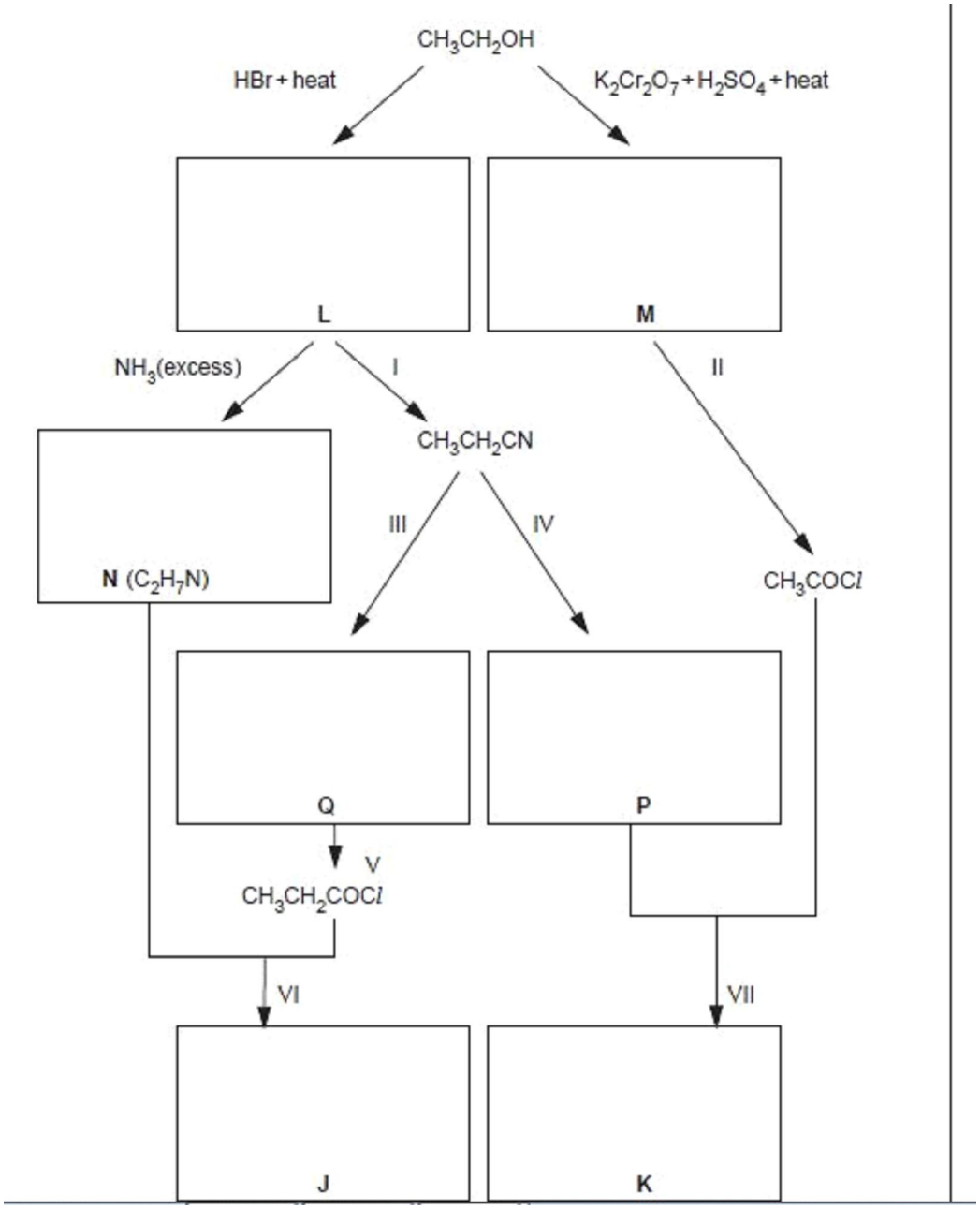
[Total: 16]

Q11.

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.

For Examiner's Use



(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.

For Examiner's Use

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**.

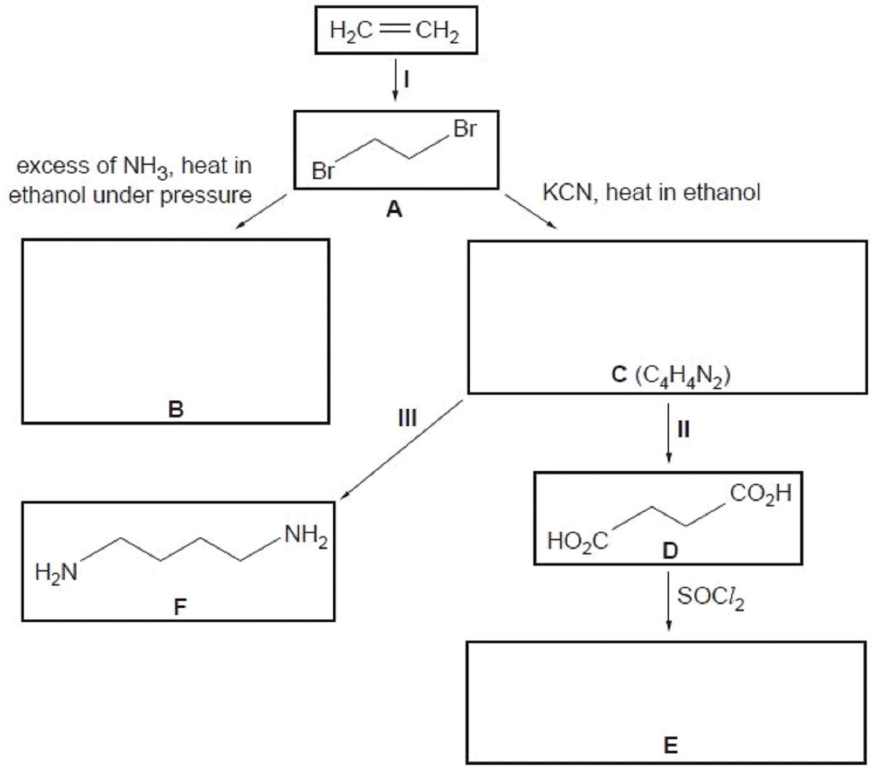
.....[2]

[Total: 14]

Q12.

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

For Examiner's Use



(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]

For Examiner's Use

(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**.

.....

.....

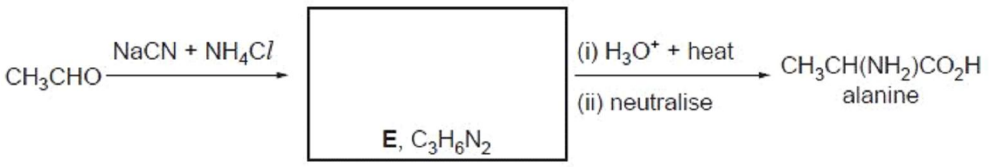
[2]

[Total: 13]

Q13.

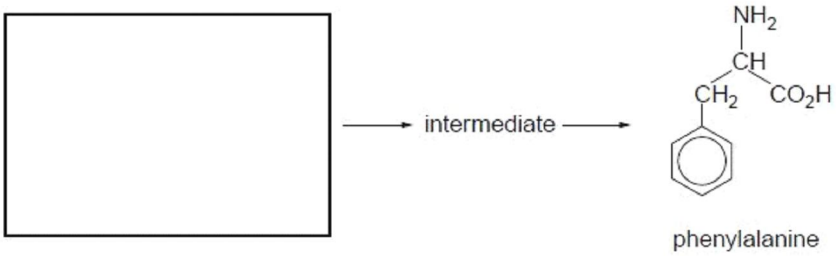
For Examiner's Use

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.



phenylalanine

[2]

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

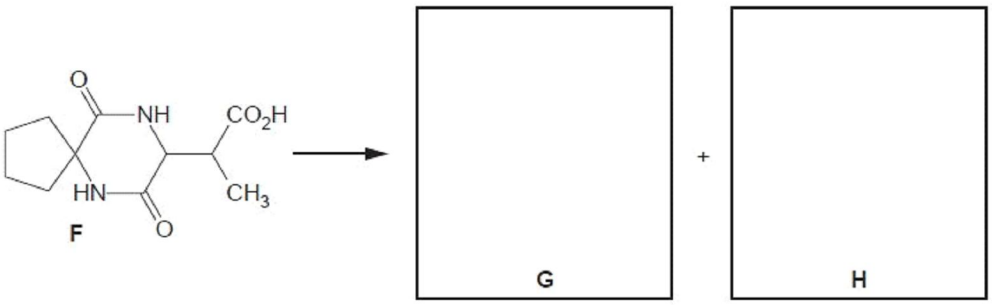
.....

(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**.

For Examiner's Use



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

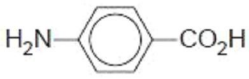
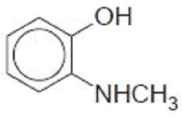
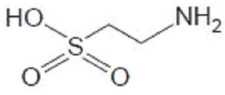
.....

(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]

(e) Solutions of amino acids are good buffers.

For Examiner's Use

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

.....

(ii) Write an equation to show how a solution of alanine, $CH_3CH(NH_2)CO_2H$, behaves as a buffer in the presence of an acid such as HCl(aq).

.....

(iii) Briefly describe how the pH of blood is controlled.

.....

.....

.....

(iv) Calculate the pH of the buffer formed when $10.0\,cm^3$ of $0.100\,mol\,dm^{-3}$ NaOH is added to $10.0\,cm^3$ of $0.250\,mol\,dm^{-3}$ CH_3CO_2H, whose $pK_a = 4.76$.

pH = ...

[7]

[Total: 19]

Q14.

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?

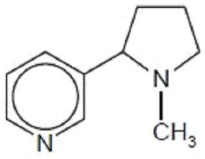
.....

.....

.....

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

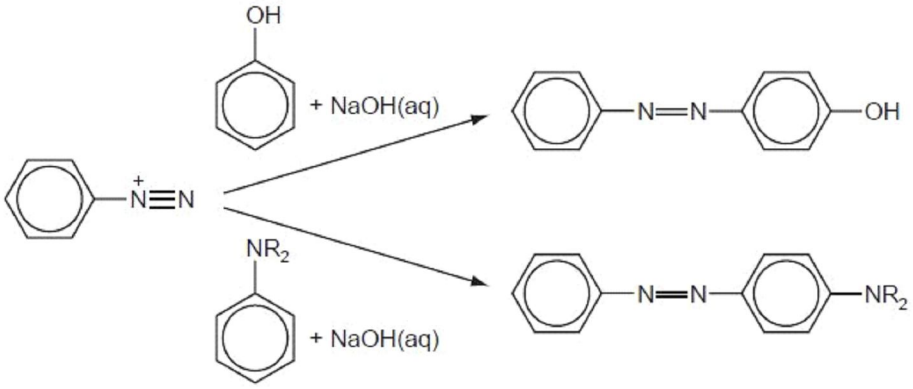
[6]

(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.

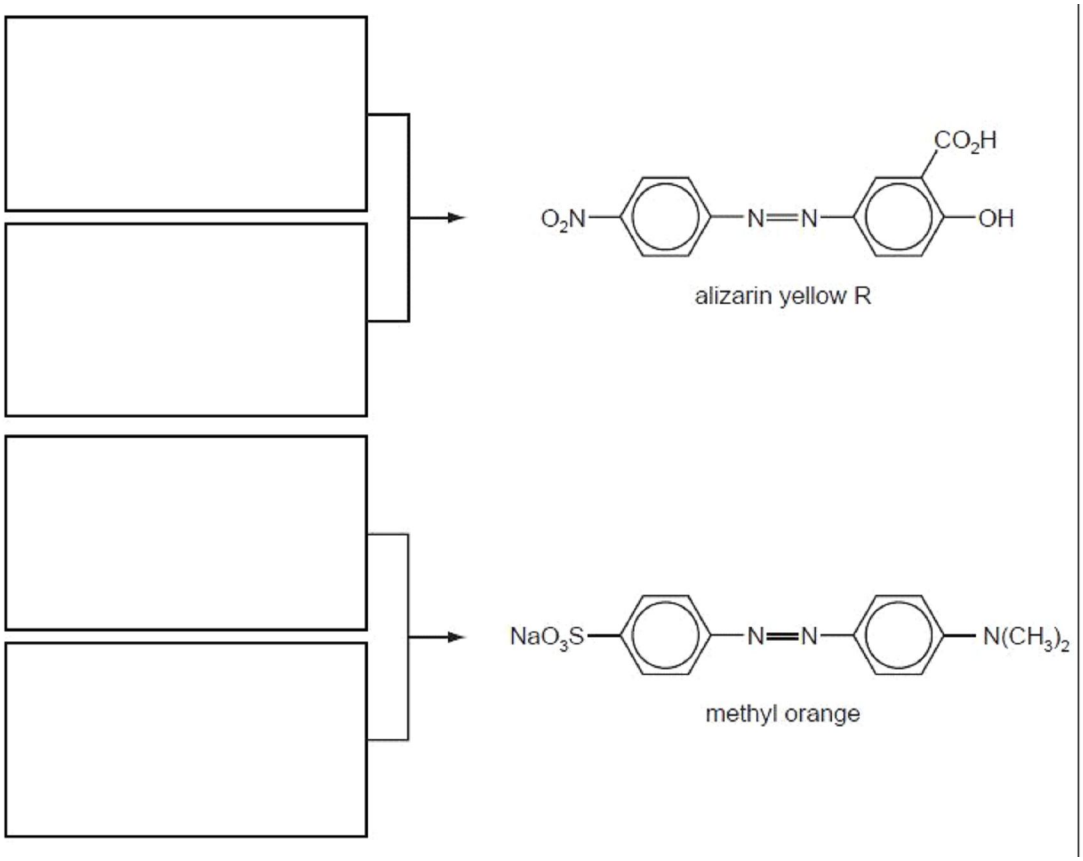
(i) State the reagents and conditions necessary for this reaction.

.....

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]

Q15.

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	$HOCH_2-$

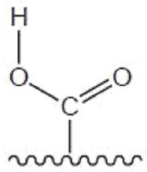
(a) What is the Brønsted-Lowry definition of an acid?

.....

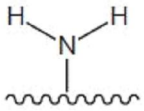
.....

[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.

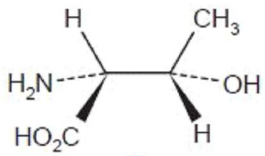
(i) Define the term *stereoisomerism*.

.....

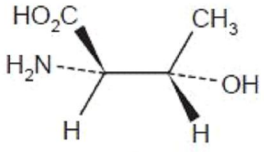
.....

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

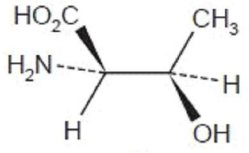
Some of these optical isomers are drawn below.



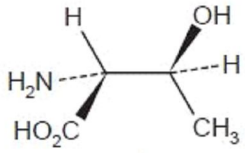
F



G



H



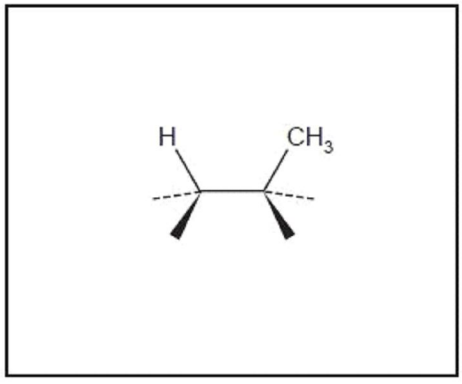
J

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]