WJEC Chemistry A-level

4.7: Amino Acids, Peptides and Proteins

Practice Questions

Wales Specification

1.

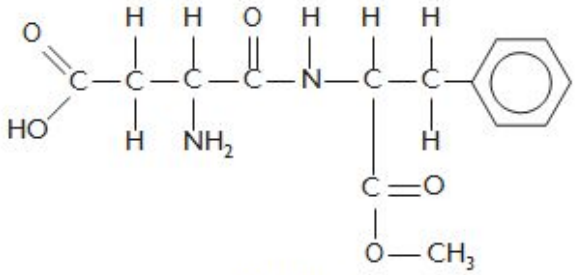
Read the passage below and then answer the questions in the spaces provided.

Tastes in food

The sensation of taste can be categorized into five basic tastes: sweet, bitter, sour, salty and umami. Humans receive tastes through sensory organs called taste buds concentrated on the top of the tongue. Pungency also helps us to describe the tastes that we encounter in food. Some of these tastes are described below.

Sweetness

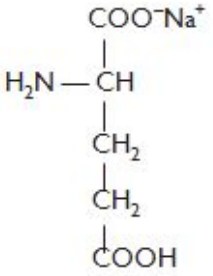
One theory in the 1960s proposed that to be sweet, a compound must contain a hydrogen bond donor (AH) and a hydrogen bond accepter (B).
Human taste buds are much more sensitive to synthetic sweeteners than to naturally-occurring sugars. For example, aspartame is 200 times sweeter than sucrose.



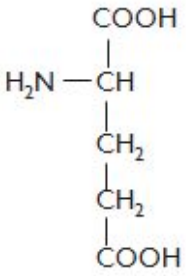
aspartame

Umami

Umami is a Japanese word meaning 'good flavour' or 'good taste' and is described as a savoury or meaty taste. Monosodium glutamate (MSG), the monosodium salt of glutamic acid, was developed as a food additive in 1908 by a Japanese scientist and produces a strong umami taste.



MSG

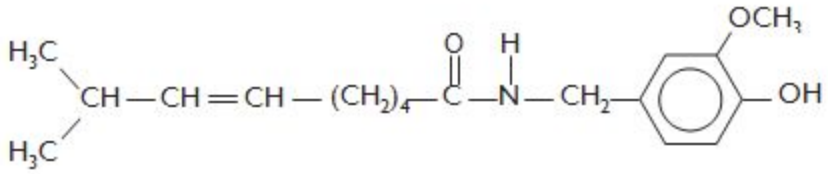


glutamic acid

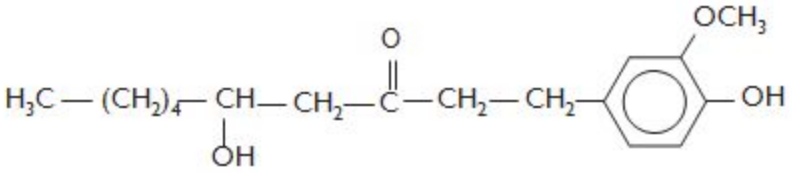
Other foods that have always been popular as flavourings are now known to be rich in umami substances. These include seaweeds, fish, mushrooms and tomatoes.
Like other basic tastes, MSG improves pleasantness only in the right concentration. An excess of MSG quickly ruins the taste of a dish e.g. in clear soup the 'pleasantness score' rapidly falls with 1 g or more of MSG per 100 cm^3.

Pungency

One group of compounds that produce a sensation of pungency or heat contain an aromatic ring system carrying two oxygen atoms. This seems to be the key structure responsible for their
25 interaction with the taste buds. Two examples are shown below.



capsaicin (chilli peppers)



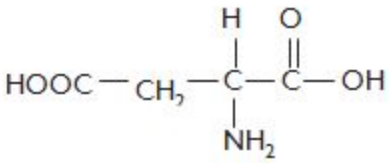
gingerol (ginger)

– End of passage –

(a) Describe what is meant by hydrogen bonding, using an example of your choice.

[3] QWC [1]

(b) Aspartame *(line 10)* is a methyl ester of a dipeptide formed from two α-amino acids. The structure of one of the acids is as shown below.

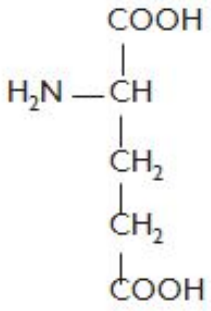


Draw the structure of the other α-amino acid. [1]

(c) Glutamic acid *(line 16)* is amphoteric. Explain the meaning of the term *amphoteric* and why glutamic acid exhibits amphoteric behaviour.

[2]

(d) Draw the **skeletal** formula of glutamic acid. [1]



glutamic acid

(e) Calculate the minimum concentration of MSG, in mol dm-³, which if added to clear soup makes its 'pleasantness score' rapidly fall *(lines 20-21).*

[2]

.

Minimum concentration = **.....** mol dm-³

(f) Giving the reagent(s) and an observation, state a chemical test that gives a positive result with both capsaicin and gingerol *(lines 26-27).*

[2]

Reagent(s)

Observation

(g) Giving the reagent(s) and an observation, state a chemical test that gives a positive result with gingerol but **not** with capsaicin.

2

Reagent(s)

Observation

(Total 14)

2. (a) From the information given, draw the displayed formula of each compound.In parts (i)-(iii) the compounds consist of molecules that have **three** carbon In part (iv) the compound has **four** carbon atoms.

(i) A compound that is oxidised to a ketone

[1]

(ii) A neutral sweet-smelling compound

[1]

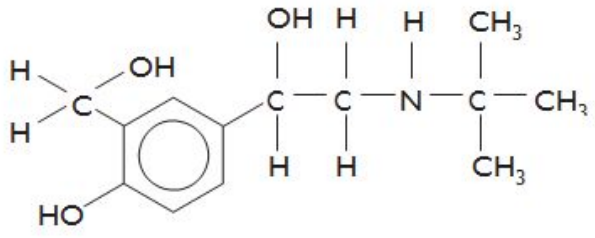
(iii) An α-amino acid

[1]

(iv) A hydrocarbon that exhibits E-Z isomerism

[1]

(b) The active compound in Ventolin® inhalers used by asthma sufferers is salbutamol, which shows optical isomerism.



salbutamol

(i) Indicate a chiral centre in this molecule by labelling it with an asterisk (*). [1]

(ii) State how the optical isomers of salbutamol could be distinguished from each other. [1]

(iii) Suggest a reason why only one optical isomer of salbutamol is used as a pharmaceutical. [1]

(iv) Draw the displayed formula of the likely organic product formed when salbutamol is refluxed with acidified $K_2Cr_2O_7$. [2]

(c) (i) Arrange the following molecules in order of **increasing** acidity

[1]

ethanoic acid *ethanol* *ethylamine* *phenol*

least acidic..... most acidic

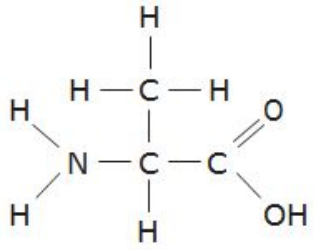
(ii) Explain the difference in acid-base properties of ethylamine and phenol.

[4]

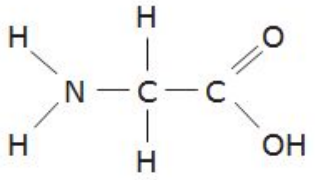
(Total 14)

3. Proteins and polypeptides are natural polyamides built up from α-amino acids.

(a) Two naturally-occurring α-amino acids are alanine and glycine.

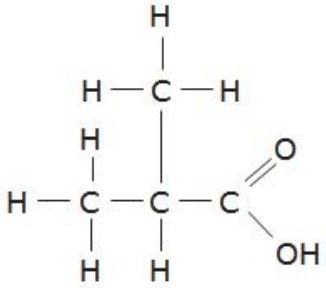


alanine
(2-aminopropanoic acid)



glycine
(2-aminoethanoic acid)

(i) Alanine *(2-aminopropanoic acid)* has a melting temperature of 258 °C whereas the similar compound 2-methylpropanoic acid melts at –46 °C.



2-methylpropanoic acid

Explain why the value for alanine is so much higher than that of 2-methylpropanoic acid. [2]

(ii) Draw the **two** possible dipeptides that can form when one molecule of glycine combines with one molecule of alanine.

[2]

(iii) Circle the peptide linkage in **one** of your dipeptides

[1]

(b) Give **one** use of proteins or polypeptides in biological systems

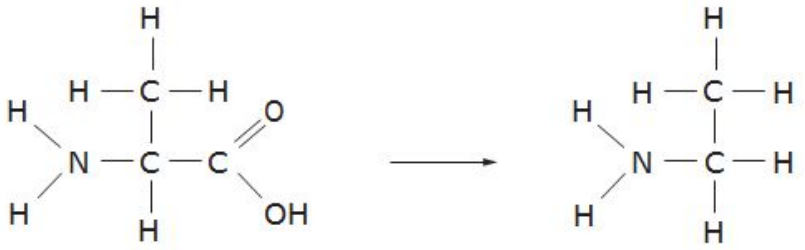
[1]

(c) One laboratory synthesis of amino acids involves the reaction between an aldehyde and hydrogen cyanide, HCN, as the first step before the amino group is introduced into the molecule.

For a general aldehyde, R-CHO, draw the mechanism of the reaction that occurs between this molecule and HCN.

[3]

(d) Amino acids can be converted to amines in a one-step process, as shown below.



Name the reagent required for this reaction. [1]

Total [10]

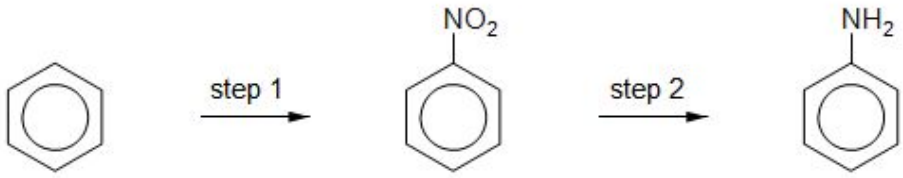
4. This question focuses on molecules that contain the $-NH_2$ group.

(a) Phenylamine and propylamine are both bases, with phenylamine being a weaker base than propylamine.

(i) Explain why both propylamine and phenylamine can act as bases. [2]

(ii) Give a reason why phenylamine is a weaker base than propylamine. [2]

(iii) Phenylamine can be prepared from benzene in a two-step process.



I. Step 1 uses a mixture of concentrated nitric and sulfuric acids to produce NO_2^+ during the reaction. Draw the mechanism of the reaction between NO_2^+ and benzene. [3]

II. During step 1, some dinitrobenzene is produced. Suggest a method of separating the different compounds in the product mixture. [1]

III. Give the reagent(s) required to produce phenylamine from nitrobenzene in step 2. [2]

(b) 1,6-diaminohexane is used to make Nylon-6,6, which is a polyamide.

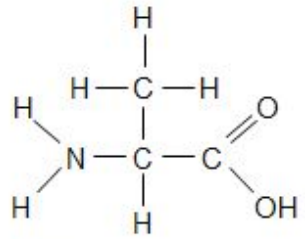
(i) Draw the **skeletal** formula for the molecule that would be combined with 1,6-diaminohexane to make Nylon-6,6

[1]

(ii) Nylon is an example of a condensation polymer. Give **two** differences between condensation polymerisation and addition polymerisation.

[2]

(c) Amino acids contain both $-NH_2$ and $-COOH$ groups, such as in the molecule below.



alanine *(2-aminopropanoic acid)*

(i) Alanine dissolves in strong acid. Draw the carbon-containing species that would be present in this solution.

[1]

(ii) When two molecules of alanine react together they make a dipeptide. Draw the structure of this dipeptide, circling the peptide link.

[2]

(iii) Alanine has a melting temperature of 258 °C. This is much higher than compounds with molecules of a similar size such as butanoic acid, which has a melting temperature of −8 °C. Explain why the melting temperatures of these two compounds are so different.

[2]

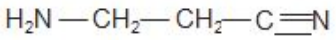
(iv) Alanine can undergo decarboxylation. Give the reagent(s) required for this reaction and identify the organic product formed.

[2]

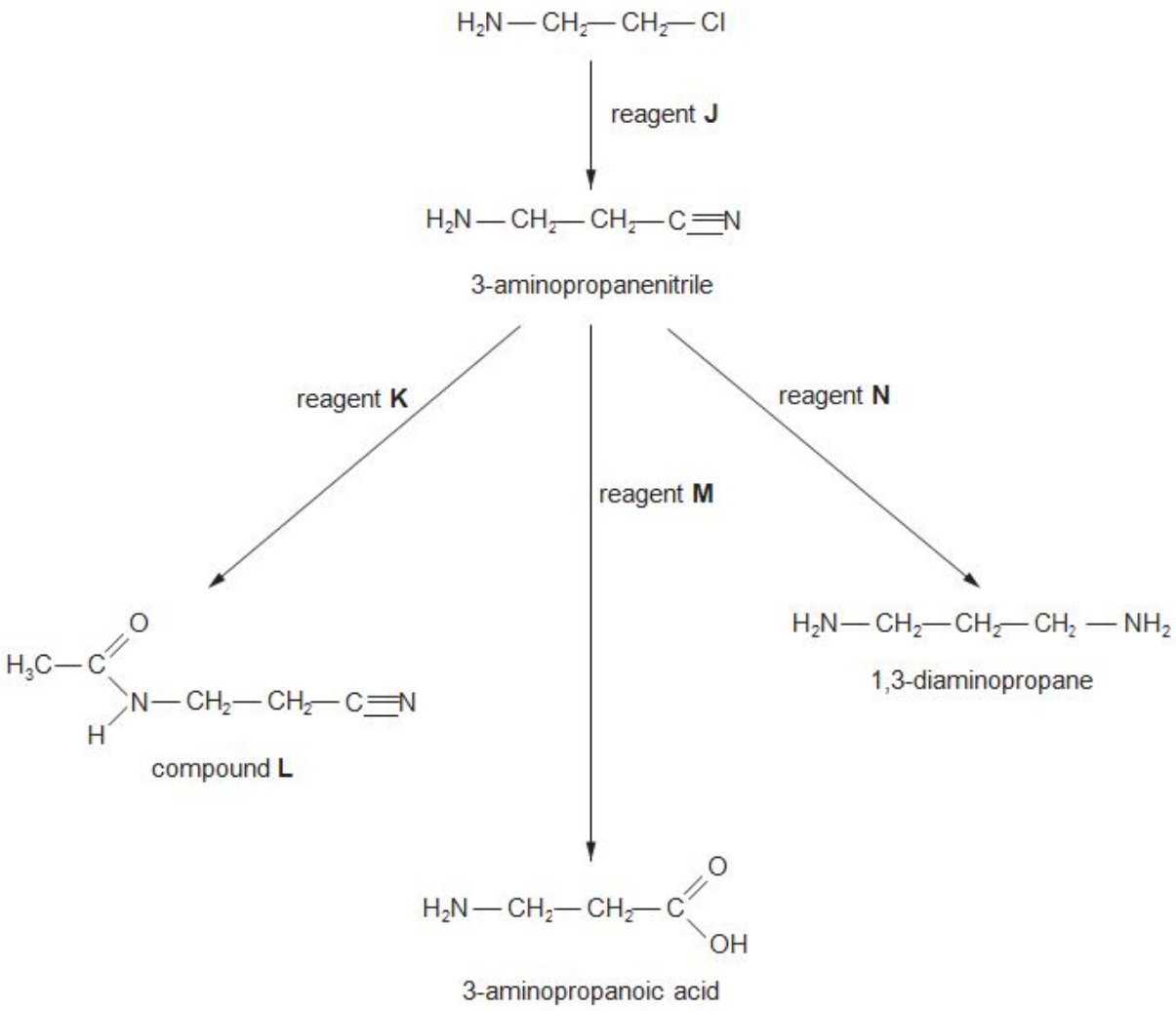
(Total 20)

5.

(a) Seeds of the sweet pea plant contain 3-aminopropanenitrile.



One method of preparation of this compound and some of its reactions are outlined below.



(i) State the name of reagent **J.**

[1]

(ii) Give the displayed formula of reagent **K** that is used to produce compound **L** from 3-aminopropanenitrile.

[1]

(iii) State the name of reagent **M**, which is used in aqueous solution.

[1]

(iv) Although 3-aminopropanoic acid is not an α-amino acid, it exists as a zwitterion in a similar way to an a-amino acid.

Give the displayed formula of the zwitterion form of 3-aminopropanoic acid.

[1]

(v) 3-Aminopropanoic acid and compound **X** are isomers of formula $C_3H_7NO_2$. However, only compound **X** produces a silver mirror when reacted with Tollens' reagent. Suggest a displayed formula for compound **X**. [1]

(vi) State the formula of reagent **N.**

[1]

(vii) State why amines such as 1,3-diaminopropane are able to act as bases.

[1]

(b) Care has to be taken when collecting fungi for consumption as many of them contain poisonous compounds. An Asian mushroom contains a very toxic compound **G**. Some information about compound **G** is given below.

- It is an alicyclic compound (a **ring** compound of carbon atoms that is not aromatic)
- Its empirical formula is C_2H_2O
- It is an unsaturated compound
- It contains one carboxylic acid group, whose carbon atom is not part of the ring structure
- All the oxygen atoms present are in the carboxylic acid group
- The proton NMR spectrum shows 3 peaks whose relative peak areas are 1:1:2

Answer the questions below, which lead you through the information to help you find the displayed formula for compound **G**.

(i) Give the molecular formula for compound **G**.

[1]

(ii) Since one of the carbon atoms present is not part of the ring structure, the number of carbon atoms in the ring is...

[1]

(iii) Compound **G** is an unsaturated compound and therefore the ring must contain the functional group...

[1]

(iv) The peak areas in the NMR spectrum are 1:1:2. The carboxylic acid group proton is responsible for a peak area 1.

The remaining peak area ratio 1:2 suggests that…

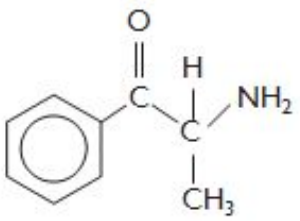
[1]

(v) Use the information from parts (i) to (iv) to suggest the displayed formula for compound **G**.

[1]

(Total 12)

6. *(a)* Cathinone, $C_9H_{11}NO$, is a naturally-occurring psycho-active drug.



(i) Explain why this molecule can act as a base. [1]

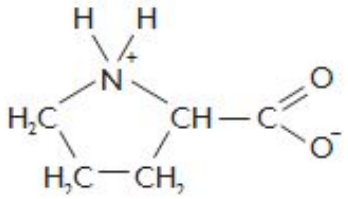
(ii) You are provided with some information about an **isomer** of cathinone, compound **L**.

- It contains a peptide linkage.
- It can be hydrolysed by aqueous sodium hydroxide giving primary aromatic amine **M** as one of the products.
- Primary aromatic amine **M** reacts with nitric(III) acid (nitrous acid) to give a phenol with the molecular formula C_7H_8O.

Use **all** this information to suggest a **structural** formula for compound **L**, giving your reasons throughout. [6]

QWC [1]

(b) Proline is a cyclic α-amino acid. In an aqueous solution of pH 6.3, proline exists largely as its zwitterion form.



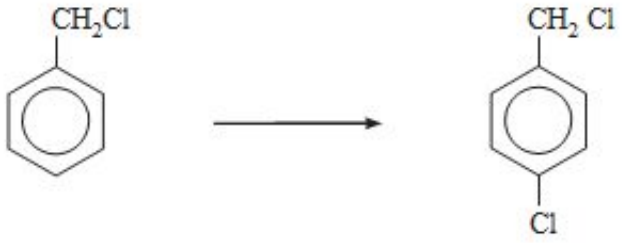
(i) Write the structural formula of proline in its non-zwitterion form.

[1]

(ii) Proline forms two different dipeptides when it reacts with aminoethanoic acid. Give the structural formula of **one** of these dipeptides.

[1]

(c) (i) (Chloromethyl)benzene, $C_6H_5CH_2Cl$, reacts with chlorine in the presence of a catalyst to produce a mixture of isomers, **one** of which is 1-(chloromethyl)-4-chlorobenzene.

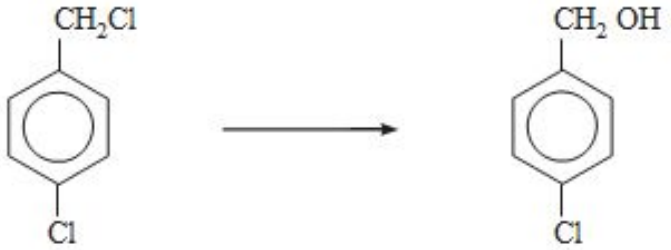


The mechanism of this electrophilic substitution reaction is similar to the reaction of benzene with chlorine. Give the mechanism for the reaction to produce the 4-isomer.

Your mechanism should show any necessary polarisation, curly arrows, the structure of the intermediate and how the catalyst is regenerated so that it can be used again.

[4]

(ii) A student made (4-chlorophenyl)methanol by refluxing 1-(chloromethyl)-4-chlorobenzene (shown in (i)) with aqueous sodium hydroxide.
He obtained a 72 % yield.



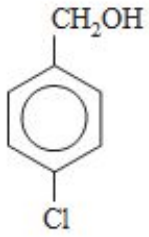
He wrote an outline of his method as follows.

- Place 0.1 mol of the chloro-compound in a flask and add some sodium hydroxide solution of concentration 2 mol dm^{-3}.
- Reflux this mixture using an electrical heater.

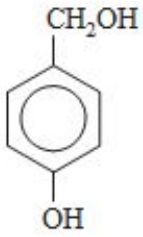
Suggest **two** other details that you would need to know before you could test the reliability and validity of his method.

[2]

(iii) Explain why the product of the reaction in (ii) is (4-chlorophenyl)methanol and not (4-hydroxyphenyl)methanol. [2]

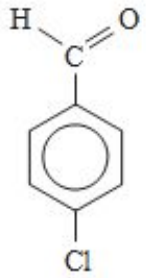


(4-chlorophenyl)methanol



(4-hydroxyphenyl)methanol

(iv) (4-Chlorophenyl)methanol was oxidised to give (4-chlorophenyl)methanal.



The mass spectrum of the product of this reaction showed traces of another compound with molecular ions, m/z, of 156 and 158 in a ratio of 3:1.
Suggest a structural formula for this compound and state why it has these two molecular ions. [2]

Total [20]