CAMBRIDGE
OCR

For issue on or after 13 March 2026

A Level Chemistry B (Salters)

H433/02 Scientific literacy in chemistry

Advance Notice Article

To prepare candidates for the examination taken on Tuesday 9 June 2026 – Morning

INSTRUCTIONS
- Before the exam, read this article carefully and study the content of the learning outcomes for A Level Chemistry B (Salters).
- You can ask your teacher for advice and discuss this article with others in your class.
- You can investigate the topic of this article yourself using any resources available to you.
- Do **not** take this copy of the article or any notes into the exam.

INFORMATION
- In the exam you will answer questions on this article. The questions are worth 20–25 marks.
- A clean copy of this article will be given to you with the question paper.
- This document has **4** pages.

ADVICE
- In the exam you won't have time to read this article in full but you should refer to it in your answers.

Understanding the Maillard Reaction

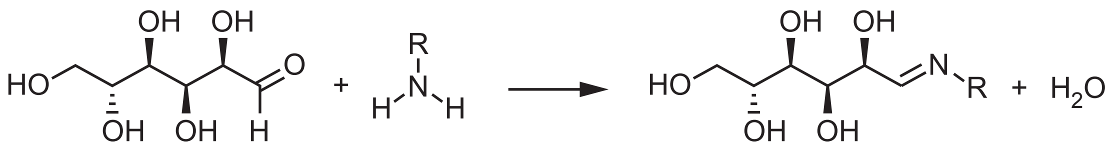
Adapted from ‘Understanding the Maillard Reaction’ in ‘Future Learn – Exploring Everyday Chemistry’ from the University of York.

The Maillard reaction is a very important flavour-producing reaction, as illustrated when sugar forms brown nutty-flavoured caramel, in a process called non-enzymatic browning. It is also an important reaction in developing the flavour compounds in tea and coffee. Before coffee beans are roasted, they lack the aroma of roasted coffee beans, and the Maillard reaction is very important in providing the characteristic flavour of a brew. The reaction was first described by French chemist Louis-Camille Maillard in 1912.

The Maillard Reaction Process

Stage 1: Making a glycosylamine

The first step of the Maillard reaction is a reaction to form an *N*-substituted glycosylamine. The carbonyl group on the glucose sugar reacts with a protein or amino acid in the food to form an imine bond in the *N*-substituted glycosylamine, together with water. Notice that the sugar (glucose) reacts when it is in an open-chain form (you may remember that for most of the time, glucose exists in a cyclic form).



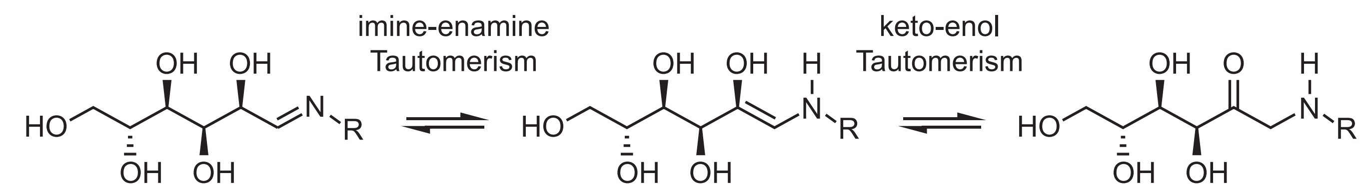
Sugar (Glucose)
aldehyde

N-Substituted Glycosylamine
imine

The mechanism for the first stage of the Maillard reaction involves the nitrogen lone pair from the NH_2 group attacking the electrophilic carbon atom on the aldehyde carbonyl (C=O). Electrons are pushed from the double bond onto the oxygen atom giving it a negative charge. A proton is then transferred from the positively charged nitrogen to the negatively charged oxygen atom forming a hemiaminal intermediate. Final electron rearrangement occurs to give the *N*-substituted glycosylamine and water.

Stage 2: The Amadori rearrangement

The second step in the Maillard reaction is the Amadori rearrangement, a spontaneous reaction even at temperatures as low as 25 °C. The Amadori rearrangement is an isomerisation reaction (the *N*-substituted glycosylamine, 1,2-enaminol and the Amadori compound all have the same chemical formula, with the atoms arranged in different ways, and so they are isomers of each other) that results in the formation of a ketosamine called the Amadori compound – this contains both a ketose (a sugar bearing a ketone) and an amine.

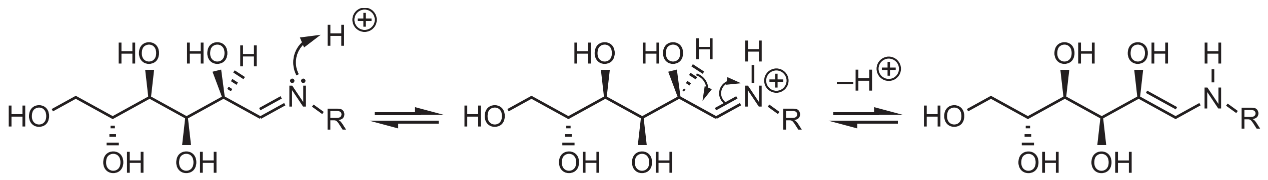


N-Substituted Glycosylamine

1,2-Enaminol
an enol is C=C−OH

Amadori Compound

The isomerisation reaction (called an imine-enamine tautomerism) that occurs between the *N*-substituted glycosylamine and 1,2-enaminol is reversible. The nitrogen atom in *N*-substituted glycosylamine donates a lone pair of electrons to a proton, forming a new N–H covalent bond; following this, the two electrons in the C–H bond are donated to form a new carbon-carbon double bond, pushing the electrons in the C=N double bond onto the positively charged nitrogen atom.



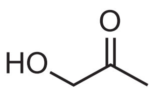
N-Substituted Glycosylamine Intermediate 1,2-Enaminol

The second reversible isomerisation reaction occurs between the 1,2-enaminol and the Amadori compound, and is an example of keto-enol tautomerism. In the forward reaction, two electrons from the O–H oxygen (in the 1,2-enaminol) are donated to a proton, through the C=C double bond, and this is followed by deprotonation.

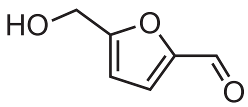
Stage 3: Further reactions

The Amadori compound can then react to form several different products, including hydroxypropanone ($C_3H_6O_2$), all of which can react again to form even more products. The products that are formed depend on whether the reaction mixture is alkaline or acidic (e.g. hydroxymethylfurfural, $C_6H_6O_3$), so, this is a complicated process.

Alkaline Conditions Acidic Conditions



Hydroxypropanone



Hydroxymethylfurfural

Melanoidins are a class of brown polymers with high molecular weights, and one of the potential end products of the Maillard reaction; melanoidins are the species that give cooked food its colour. The analysis of melanoidins is challenging, meaning that it is hard to assign the structures to the end products of the Maillard reaction; this difficulty stems from the vast numbers of Maillard reaction products and the difficulty in purifying and identifying individual products.

Maillard Reaction Mysteries

So, there is still a lot about the Maillard reaction that remains unclear, however, its responsibility for the flavour development of cooked or roasted foods is recognised as being very important.

Does the Maillard Reaction Cause Cancer?

Perhaps you remember the ruling made by a California judge in 2018, that coffee companies must serve the drink with a cancer warning? It arose from the presence of acrylamide ($H_2C{=}CH{-}C({=}O)NH_2$) in coffee, which is formed from a Maillard reaction involving the amino acid asparagine ($HO_2CCH(NH_2)CH_2C({=}O)NH_2$) from proteins in the coffee. This reacts with sugars from the coffee and the breakdown of the subsequent Amadori compound gives acrylamide. Evidence has shown that acrylamide is a likely carcinogen (a cancer-causing substance).
However, each 150 mL cup contains only a trace amount of acrylamide, 0.9–2.4 micrograms – one estimate suggests an 80 kg adult would need to consume over 208 micrograms of acrylamide (at least 87 cups) per day to have an increased risk of cancer. Interestingly, the same scientists who classified acrylamide as a carcinogen also found no conclusive evidence that drinking coffee caused cancer (and in 2016, the World Health Organisation took coffee off its list of possible carcinogens).

END OF ADVANCE NOTICE ARTICLE