Nalanda Open University

***Subject- Chemistry***

***Course- B. Sc. Part-2(Honours)***

***Paper-4***

***Topic- Carbohydrates***

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***Carbohydrates***

* Carbohydrates are the sugars, starches and fibers found in fruits, grains, vegetables and milk products.
* They are called carbohydrates because, at the chemical level, they contain carbon, hydrogen and oxygen.
* Carbohydrates are macronutrients, meaning they are one of the three main ways the body obtains energy, or calories," said [Paige Smathers](http://www.paigesmathersrd.com/), a Utah-based registered dietitian. The [American Diabetes Association](http://www.diabetes.org/food-and-fitness/food/what-can-i-eat/understanding-carbohydrates/types-of-carbohydrates.html) notes that carbohydrates are the body's main source of energy.
* There are three macronutrients: carbohydrates, protein and fats. Macronutrients are essential for proper body functioning, and the body requires large amounts of them.
* All macronutrients must be obtained through diet; the body cannot produce macronutrients on its own.

## **Function of carbohydrates**

Carbohydrates provide fuel for the central nervous system and energy for working muscles. They also prevent protein from being used as an energy source and enable fat metabolism, according to Iowa State University.

Also, "carbohydrates are important for brain function. They are an influence on "mood, memory, etc., as well as a quick energy source."

**Classification of Carbohydrates**

Carbohydrates are classified as simple or complex carbohydrates. The difference between the two forms is the chemical structure and how quickly the sugar is absorbed and digested. Generally speaking, simple carbohydrates are more quickly and easily absorbed and digested than complex carbohydrates .

Simple carbohydrates contain just one or two sugars, such as fructose (found in fruits) and galactose (found in milk products).

These single sugars are called monosaccharides. Carbs with two sugars — such as sucrose (table sugar), lactose (from dairy) and maltose (found in beer and some vegetables) — are called disaccharides.

Simple carbs are also in candy, soda and syrups. However, these foods are made with processed and refined sugars and do not have vitamins, minerals or fiber. They are called "empty calories" and can lead to weight gain, according to the NIH.

Complex carbohydrates (polysaccharides) have three or more sugars. They are often referred to as starchy foods and include beans, peas, lentils, peanuts, potatoes, corn, parsnips, whole-grain breads and cereals.

Smathers pointed out that, while all carbohydrates function as relatively quick energy sources, simple carbs cause bursts of energy much more quickly than complex carbs because of the quicker rate at which they are digested and absorbed.

Simple carbs can lead to spikes in blood sugar levels and sugar highs, while complex carbs provide more sustained energy.

**Glucose**

is a simple [sugar](https://en.m.wikipedia.org/wiki/Sugar) with the [molecular formula](https://en.m.wikipedia.org/wiki/Chemical_formula#Molecular_formula) [C](https://en.m.wikipedia.org/wiki/Carbon)6[H](https://en.m.wikipedia.org/wiki/Hydrogen)12[O](https://en.m.wikipedia.org/wiki/Oxygen)6. Glucose is the most abundant [monosaccharide](https://en.m.wikipedia.org/wiki/Monosaccharide),[[3]](https://en.m.wikipedia.org/wiki/Glucose#cite_note-DombKost1998-3) a subcategory of [carbohydrates](https://en.m.wikipedia.org/wiki/Carbohydrates). Glucose is mainly made by [plants](https://en.m.wikipedia.org/wiki/Plants) and most [algae](https://en.m.wikipedia.org/wiki/Algae) during [photosynthesis](https://en.m.wikipedia.org/wiki/Photosynthesis) from water and carbon dioxide, using energy from sunlight, where it is used to make [cellulose](https://en.m.wikipedia.org/wiki/Cellulose) in [cell walls](https://en.m.wikipedia.org/wiki/Cell_wall), which is the most abundant carbohydrate.[[4]](https://en.m.wikipedia.org/wiki/Glucose#cite_note-4) In [energy metabolism](https://en.m.wikipedia.org/wiki/Energy_metabolism), glucose is the most important source of energy in all [organisms](https://en.m.wikipedia.org/wiki/Organism). Glucose for metabolism is partially stored as a [polymer](https://en.m.wikipedia.org/wiki/Polymer), in plants mainly as [starch](https://en.m.wikipedia.org/wiki/Starch) and [amylopectin](https://en.m.wikipedia.org/wiki/Amylopectin) and in animals as [glycogen](https://en.m.wikipedia.org/wiki/Glycogen). Glucose circulates in the blood of animals as [blood sugar](https://en.m.wikipedia.org/wiki/Blood_sugar). The naturally occurring form of glucose is d-glucose, while [l-glucose](https://en.m.wikipedia.org/wiki/L-glucose) is produced synthetically in comparatively small amounts and is of lesser importance. Glucose is a monosaccharide containing six carbon atoms, an aldehyde group and is therefore referred to as an aldohexose. The glucose molecule can exist in an open-chain (acyclic) as well as ring (cyclic) form, the latter being the result of an intramolecular reaction between the aldehyde C atom and the C-5 hydroxyl group to form an intramolecular hemiacetal. In water solution both forms are in equilibrium and at pH 7 the cyclic one is the predominant. It is naturally occurring and is found in fruits and other parts of plants in its free state. In animals glucose arises from the breakdown of glycogen in a process known as glycogenolysis. Glucose, as [intravenous sugar solution](https://en.m.wikipedia.org/wiki/Intravenous_sugar_solution), is on the [World Health Organization's List of Essential Medicines](https://en.m.wikipedia.org/wiki/World_Health_Organization%27s_List_of_Essential_Medicines), the most important medications needed in a basic [health system](https://en.m.wikipedia.org/wiki/Health_system).[[5]](https://en.m.wikipedia.org/wiki/Glucose#cite_note-5) The name glucose derives through the French from the [Greek](https://en.m.wikipedia.org/wiki/Greek_language) γλυκός ('glukos'), which means "sweet", in reference to [must](https://en.m.wikipedia.org/wiki/Must), the sweet, first press of grapes in the making of [wine](https://en.m.wikipedia.org/wiki/Wine).[[6]](https://en.m.wikipedia.org/wiki/Glucose#cite_note-6)[[7]](https://en.m.wikipedia.org/wiki/Glucose#cite_note-7) The suffix "[-ose](https://en.m.wikipedia.org/wiki/-ose)" is a chemical classifier, denoting a sugar.

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| |  | | --- | | **d-Glucose** | | α-d-Glucopyranose ([chair form](https://en.m.wikipedia.org/wiki/Cyclohexane_conformation)) | | [Haworth projection](https://en.m.wikipedia.org/wiki/Haworth_projection) of α-d-glucopyranose | | [Fischer projection](https://en.m.wikipedia.org/wiki/Fischer_projection) of d-glucose | |

## Chemical properties

With six carbon atoms, it is classed as a [hexose](https://en.m.wikipedia.org/wiki/Hexose), a subcategory of the monosaccharides. d-Glucose is one of the sixteen [aldohexose](https://en.m.wikipedia.org/wiki/Aldohexose" \o "Aldohexose) [stereoisomers](https://en.m.wikipedia.org/wiki/Stereoisomer). The d-[isomer](https://en.m.wikipedia.org/wiki/Isomer), d-glucose, also known as dextrose, occurs widely in nature, but the l-isomer, [l-glucose](https://en.m.wikipedia.org/wiki/L-glucose), does not. Glucose can be obtained by [hydrolysis](https://en.m.wikipedia.org/wiki/Hydrolysis) of carbohydrates such as milk sugar ([lactose](https://en.m.wikipedia.org/wiki/Lactose)), cane sugar ([sucrose](https://en.m.wikipedia.org/wiki/Sucrose)), [maltose](https://en.m.wikipedia.org/wiki/Maltose), [cellulose](https://en.m.wikipedia.org/wiki/Cellulose), [glycogen](https://en.m.wikipedia.org/wiki/Glycogen), etc. It is commonly commercially manufactured from cornstarch by hydrolysis via pressurized steaming at controlled [pH](https://en.m.wikipedia.org/wiki/PH) in a jet followed by further enzymatic depolymerization.[[21]](https://en.m.wikipedia.org/wiki/Glucose#cite_note-21) Unbonded glucose is one of the main ingredients of [honey](https://en.m.wikipedia.org/wiki/Honey). All forms of glucose are colorless and easily soluble in water, [acetic acid](https://en.m.wikipedia.org/wiki/Acetic_acid), and several other solvents. They are only sparingly soluble in [methanol](https://en.m.wikipedia.org/wiki/Methanol) and [ethanol](https://en.m.wikipedia.org/wiki/Ethanol).

Structure and nomenclature

Glucose is a monosaccharide with formula C6H12O6 or H−(C=O)−(CHOH)5−H, whose five [hydroxyl](https://en.m.wikipedia.org/wiki/Hydroxyl) (OH) groups are arranged in a specific way along its six-[carbon](https://en.m.wikipedia.org/wiki/Carbon) back. Glucose is usually present in solid form as a [monohydrate](https://en.m.wikipedia.org/wiki/Monohydrate) with a closed [pyran](https://en.m.wikipedia.org/wiki/Pyran" \o "Pyran) ring (dextrose hydrate). In aqueous solution, on the other hand, it is an open-chain to a small extent and is present predominantly as α- or β-[pyranose](https://en.m.wikipedia.org/wiki/Pyranose), which partially mutually merge by [mutarotation](https://en.m.wikipedia.org/wiki/Mutarotation" \o "Mutarotation). From aqueous solutions, the three known forms can be crystallized: α-glucopyranose, β-glucopyranose and β-glucopyranose hydrate.[[22]](https://en.m.wikipedia.org/wiki/Glucose#cite_note-Ullmann-22) Glucose is a building block of the disaccharides [lactose](https://en.m.wikipedia.org/wiki/Lactose) and [sucrose](https://en.m.wikipedia.org/wiki/Sucrose) (cane or beet sugar), of [oligosaccharides](https://en.m.wikipedia.org/wiki/Oligosaccharide) such as [raffinose](https://en.m.wikipedia.org/wiki/Raffinose" \o "Raffinose) and of polysaccharides such as [starch](https://en.m.wikipedia.org/wiki/Starch) and [amylopectin](https://en.m.wikipedia.org/wiki/Amylopectin), [glycogen](https://en.m.wikipedia.org/wiki/Glycogen)

**Open-chain form**

In its fleeting [open-chain](https://en.m.wikipedia.org/wiki/Open-chain) form, the glucose molecule has an open (as opposed to [cyclic](https://en.m.wikipedia.org/wiki/Cyclic_compound)) and unbranched backbone of six carbon atoms, C-1 through C-6; where C-1 is part of an [aldehyde group](https://en.m.wikipedia.org/wiki/Aldehyde_group) H(C=O)−, and each of the other five carbons bears one hydroxyl group −OH. The remaining [bonds](https://en.m.wikipedia.org/wiki/Covalent_bond) of the backbone carbons are satisfied by [hydrogen](https://en.m.wikipedia.org/wiki/Hydrogen) atoms −H. Therefore, glucose is both a [hexose](https://en.m.wikipedia.org/wiki/Hexose) and an [aldose](https://en.m.wikipedia.org/wiki/Aldose), or an [aldohexose](https://en.m.wikipedia.org/wiki/Aldohexose" \o "Aldohexose). The aldehyde group makes glucose a [reducing sugar](https://en.m.wikipedia.org/wiki/Reducing_sugar) giving a positive reaction with the [Fehling test](https://en.m.wikipedia.org/wiki/Fehling_test).

Each of the four carbons C-2 through C-5 is a [stereocenter](https://en.m.wikipedia.org/wiki/Stereocenter" \o "Stereocenter), meaning that its four bonds connect to four different substituents. (Carbon C-2, for example, connects to −(C=O)H, −OH, −H, and −(CHOH)4H.) In d-glucose, these four parts must be in a specific three-dimensional arrangement. Namely, when the molecule is drawn in the [Fischer projection](https://en.m.wikipedia.org/wiki/Fischer_projection), the hydroxyls on C-2, C-4, and C-5 must be on the right side, while that on C-3 must be on the left side.

The positions of those four hydroxyls are exactly reversed in the Fischer diagram of [l-glucose](https://en.m.wikipedia.org/wiki/L-Glucose). d- and l-glucose are two of the 16 possible aldohexoses; the other 14 are [allose](https://en.m.wikipedia.org/wiki/Allose" \o "Allose), [altrose](https://en.m.wikipedia.org/wiki/Altrose" \o "Altrose), [galactose](https://en.m.wikipedia.org/wiki/Galactose), [gulose](https://en.m.wikipedia.org/wiki/Gulose" \o "Gulose), [idose](https://en.m.wikipedia.org/wiki/Idose" \o "Idose), [mannose](https://en.m.wikipedia.org/wiki/Mannose), and [talose](https://en.m.wikipedia.org/wiki/Talose" \o "Talose), each with two [enantiomers](https://en.m.wikipedia.org/wiki/Enantiomer), “d-” and “l-”.

It is important to note that the linear form of glucose makes up less than 0.02% of the glucose molecules in a water solution. The rest is one of two cyclic forms of glucose that are formed when the hydroxyl group on carbon 5 (C5) bonds to the aldehyde carbon 1 (C1).

### Cyclic forms

In solutions, the open-chain form of glucose (either "D-" or "L-") exists in equilibrium with several [cyclic isomers](https://en.m.wikipedia.org/wiki/Carbohydrate#Ring-straight_chain_isomerism), each containing a ring of carbons closed by one oxygen atom. In aqueous solution however, more than 99% of glucose molecules, at any given time, exist as [pyranose](https://en.m.wikipedia.org/wiki/Pyranose) forms. The open-chain form is limited to about 0.25%, and [furanose](https://en.m.wikipedia.org/wiki/Furanose" \o "Furanose) forms exists in negligible amounts. The terms "glucose" and "D-glucose" are generally used for these cyclic forms as well. The ring arises from the open-chain form by an intramolecular [nucleophilic addition](https://en.m.wikipedia.org/wiki/Nucleophilic_addition) reaction between the aldehyde group (at C-1) and either the C-4 or C-5 hydroxyl group, forming a [hemiacetal](https://en.m.wikipedia.org/wiki/Hemiacetal) linkage, −C(OH)H−O−.

The reaction between C-1 and C-5 yields a six-membered [heterocyclic](https://en.m.wikipedia.org/wiki/Heterocycle) system called a pyranose, which is a monosaccharide sugar (hence "-ose") containing a derivatised [pyran](https://en.m.wikipedia.org/wiki/Pyran" \o "Pyran) skeleton. The (much rarer) reaction between C-1 and C-4 yields a five-membered furanose ring, named after the cyclic ether [furan](https://en.m.wikipedia.org/wiki/Furan). In either case, each carbon in the ring has one hydrogen and one hydroxyl attached, except for the last carbon (C-4 or C-5) where the hydroxyl is replaced by the remainder of the open molecule (which is −(C(CH2OH)HOH)−H or −(CHOH)−H respectively).

The ring-closing reaction makes carbon C-1 [chiral](https://en.m.wikipedia.org/wiki/Chirality), too, since its four bonds lead to −H, to −OH, to carbon C-2, and to the ring oxygen. These four parts of the molecule may be arranged around C-1 (the [anomeric carbon](https://en.m.wikipedia.org/wiki/Anomeric_carbon" \o "Anomeric carbon)) in two distinct ways, designated by the prefixes "α-" and "β-". When a glucopyranose molecule is drawn in the [Haworth projection](https://en.m.wikipedia.org/wiki/Haworth_projection), the designation "α-" means that the hydroxyl group attached to C-1 and the −CH2OH group at C-5 lies on opposite sides of the ring's plane (a [*trans*](https://en.m.wikipedia.org/wiki/Cis-trans_isomerism) arrangement), while "β-" means that they are on the same side of the plane (a [*cis*](https://en.m.wikipedia.org/wiki/Cis-trans_isomerism) arrangement). Therefore, the open-chain isomer D-glucose gives rise to four distinct cyclic isomers: α-D-glucopyranose, β-D-glucopyranose, α-D-glucofuranose, and β-D-glucofuranose. These five structures exist in equilibrium and interconvert, and the interconversion is much more rapid with acid [catalysis](https://en.m.wikipedia.org/wiki/Catalysis).

**Sucrose**

Sucrose, commonly known as “table sugar” or “cane sugar”, is a carbohydrate formed from the combination of glucose and fructose. Glucose is the simple carbohydrate formed as a result of [*photosynthesis*](https://biologydictionary.net/photosynthesis/). Fructose is nearly identical, except for the location of a double-bonded oxygen. They are both six-carbon molecules, but fructose has a slightly different configuration. When the two combine, they become sucrose.

Plants use sucrose as a storage [molecule](https://biologydictionary.net/molecule/). For quick energy, cells may store the sugar for later use. If far too much is accumulated, plants may begin to combine the complex sugars like sucrose into even large and denser molecules, like starches. These molecules, and oily lipids, are the main storage chemicals used by plants. In turn, animals eat these sugars and starches, break them back down into glucose, and use the energy within the bonds of glucose to power our cells.

Sucrose has been an important sugar for humans because it is easy extracted from plants such as sugar cane and sugar beets. These plants tend to store an excess of sugar, and from this we produce the majority of the sugar that we use. Even most “natural” sweeteners, which claim to be healthier than sucrose, are simply a different version of glucose combined in a different manner by plants.

In a [plant](https://biologydictionary.net/plant/) creating sucrose, an enzyme comes along to smash these two rings together, and extract a molecule of water. This process is called a condensation reaction, and forms a glycosidic bond between the two molecules. As you can see in the image, the reaction can also go the other way. To dissolve sucrose into fructose and glucose, a molecule of water can be added back in. This is what happens to sucrose as you digest it.

## **Sucrose Uses**

Sucrose is the most common form of carbohydrate used to transport carbon within a plant. Sucrose is able to be dissolved into water, while maintaining a stable structure. Sucrose can then be exported by plant cells into the [*phloem*](https://biologydictionary.net/phloem/), the special [vascular tissue](https://biologydictionary.net/vascular-tissue/) designed to transport sugars. From the cells in which it was produces, the sucrose travels through the intercellular spaces within the [leaf](https://biologydictionary.net/leaf/). It arrives at the vascular bundle, where specialized cells pump it into the phloem. The [*xylem*](https://biologydictionary.net/xylem/), or vascular tube which carries water, adds small amounts of water to the phloem to keep the sugar mixture from solidifying. The sucrose mixture then makes its way down the phloem, arriving at cells in the stem and roots which have no chloroplasts and rely on the leaves for energy.

The sucrose is absorbed into these cells, and enzymes begin breaking the sucrose back into its constituent parts. The six-carbon glucose and fructose can be broken down into 3-carbon molecules, which are imported into the [mitochondria](https://biologydictionary.net/mitochondria/), where they go through the citric acid cycle (AKA the [Krebs Cycle](https://biologydictionary.net/krebs-cycle/)). This process reduces coenzymes, which are then used in [*oxidative phosphorylation*](https://biologydictionary.net/oxidative-phosphorylation/) to create ATP. The energy within the bonds of ATP can power many of the reactions these cells need to complete in order to maintain the stem and roots.

Likewise, all other life on Earth is dependent upon sucrose and other carbs produced by plants. Sucrose was one of the first substances to be extracted from plants on a mass-scale, creating the white table sugar we know today. These sugars are extracted and purified from large crops, including sugar cane and sugar beets. To extract the sugar, the plants are usually boiled or heated, releasing the sugar. “Sugar in the Raw” is sugar which has not been treated further, while white table sugar undergoes more purification.

## Physical and chemical properties

### Structural O-α-D-glucopyranosyl-(1→2)-β-D-fructofuranoside

In sucrose, the monomers glucose and fructose are linked via an ether bond between C1 on the [glucosyl](https://en.m.wikipedia.org/wiki/Glucosyl" \o "Glucosyl) subunit and C2 on the fructosyl unit. The bond is called a [glycosidic linkage](https://en.m.wikipedia.org/wiki/Glycosidic_linkage" \o "Glycosidic linkage). Glucose exists predominantly as a mixture of α and β "pyranose" isomers, but only the α form links to fructose. Fructose itself exists as a mixture of α and β "furanose" isomers, but only the β isomer links to glucose. Unlike most disaccharides, the glycosidic bond in sucrose is formed between the reducing ends of both glucose and fructose, and not between the reducing end of one and the non-reducing end of the other. This linkage inhibits further bonding to other saccharide units, and prevents sucrose from spontaneously reacting with cellular and circulatory macromolecules in the manner that glucose and other reducing sugars do. Since sucrose contains no anomeric hydroxyl groups, it is classified as a non-[reducing sugar](https://en.m.wikipedia.org/wiki/Reducing_sugar).

### Synthesis and biosynthesis of sucrose

The [biosynthesis](https://en.m.wikipedia.org/wiki/Biosynthesis) of sucrose proceeds via the precursors [UDP-glucose](https://en.m.wikipedia.org/wiki/UDP-glucose) and [fructose 6-phosphate](https://en.m.wikipedia.org/wiki/Fructose_6-phosphate), catalyzed by the enzyme [sucrose-6-phosphate synthase](https://en.m.wikipedia.org/wiki/Sucrose-phosphate_synthase). The energy for the reaction is gained by the cleavage of [uridine diphosphate](https://en.m.wikipedia.org/wiki/Uridine_diphosphate) (UDP). Sucrose is formed by plants and cyanobacteria but not by other [organisms](https://en.m.wikipedia.org/wiki/Organism). Sucrose is found naturally in many food plants along with the [monosaccharide](https://en.m.wikipedia.org/wiki/Monosaccharide) [fructose](https://en.m.wikipedia.org/wiki/Fructose). In many fruits, such as [pineapple](https://en.m.wikipedia.org/wiki/Pineapple) and [apricot](https://en.m.wikipedia.org/wiki/Apricot), sucrose is the main sugar. In others, such as [grapes](https://en.m.wikipedia.org/wiki/Grapes) and [pears](https://en.m.wikipedia.org/wiki/Pear), fructose is the main sugar.

**Maltose**

Maltose (malt sugar) is a disacchride formed from two molecules of D-glucose. Maltose is the basic molecule of starch. In foods, it plays only a minor role. However, it accumulates in large amounts in the body during digestion of starch. The enzyme β-amylase cleaves starch to maltose units. Maltose is produced also in the process of germination, thus fresh seedlings contain lots of this sugar. The production of maltose from germinating cereals, such as barley, is an important part of the brewing process. Therefore beers contain maltose, too.

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|  | The disaccharide maltose is a white, crystalline powder, it |
| has the elemental formula C12H22O11. The two glucose molecules are bound to each other in an α-glycosidic bond. Maltose is soluble in water, its taste is sweetish. The sweetening intensity is only 30 to 50% of that of sucrose.  **Usage:** Malt sugar tastes like caramel; it is used for bakeries, soft drinks, sweets, alcoholic drinks, and infant food. | |

## Structure and nomenclature

Maltose is a disaccharide: the carbohydrates are generally divided into [monosaccharides](https://en.m.wikipedia.org/wiki/Monosaccharide), [oligosaccharides](https://en.m.wikipedia.org/wiki/Oligosaccharide), and [polysaccharides](https://en.m.wikipedia.org/wiki/Polysaccharide) depending on the number of sugar subunits. Maltose, with two sugar units, is an oligosaccharide, specifically a disaccharide, because it consists of two glucose molecules. Glucose is a [hexose](https://en.m.wikipedia.org/wiki/Hexose): a monosaccharide containing six carbon atoms. The two glucose units are in the [pyranose](https://en.m.wikipedia.org/wiki/Pyranose) form and are joined by an [O-glycosidic bond](https://en.m.wikipedia.org/wiki/Glycosidic_bond), with the first carbon (C1) of the first [glucose](https://en.m.wikipedia.org/wiki/Glucose) linked to the fourth carbon (C4) of the second [glucose](https://en.m.wikipedia.org/wiki/Glucose), indicated as (1→4). The link is characterized as α because the glycosidic bond to the anomeric carbon (C1) is in the opposite plane from the CH  
2OH [substituent](https://en.m.wikipedia.org/wiki/Substituent) in the same ring (C6 of the first glucose). If the glycosidic bond to the anomeric carbon (C1) were in the same plane as the CH  
2OH substituent, it would be classified as a β(1→4) bond, and the resulting molecule would be [cellobiose](https://en.m.wikipedia.org/wiki/Cellobiose" \o "Cellobiose). The anomeric carbon (C1) of the second glucose molecule, which is not involved in a glycosidic bond, could be either an α- or β-anomer depending on the bond direction of the attached hydroxyl group relative to the CH  
2OH substituent of the same ring, resulting in either α-maltose or β-maltose.

An [isomer](https://en.m.wikipedia.org/wiki/Isomer) of maltose is [isomaltose](https://en.m.wikipedia.org/wiki/Isomaltose" \o "Isomaltose). This is similar to maltose but instead of a bond in the α(1→4) position, it is in the α(1→6) position, the same bond that is found at the branch points of [glycogen](https://en.m.wikipedia.org/wiki/Glycogen) and [amylopectin](https://en.m.wikipedia.org/wiki/Amylopectin).

## Properties

Like glucose, maltose is a [reducing sugar](https://en.m.wikipedia.org/wiki/Reducing_sugar), because the ring of one of the two glucose units can open to present a free [aldehyde](https://en.m.wikipedia.org/wiki/Aldehyde) group; the other one cannot because of the nature of the glycosidic bond. Maltose can be broken down to glucose by the [maltase](https://en.m.wikipedia.org/wiki/Maltase) enzyme, which catalyses the hydrolysis of the glycosidic bond.

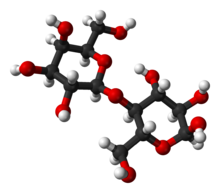
Maltose in aqueous solution exhibits [mutarotation](https://en.m.wikipedia.org/wiki/Mutarotation" \o "Mutarotation), because the α and β isomers that are formed by the different conformations of the anomeric carbon have different [specific rotations](https://en.m.wikipedia.org/wiki/Specific_rotation), and in aqueous solutions, these two forms are in equilibrium. Maltose can easily be detected by the Woehlk test or Fearon's test on methylamine.[[7]](https://en.m.wikipedia.org/wiki/Maltose#cite_note-7)

**Lactose**

**Lactose** is a [disaccharide](https://en.m.wikipedia.org/wiki/Disaccharide). It is a [sugar](https://en.m.wikipedia.org/wiki/Sugar) composed of [galactose](https://en.m.wikipedia.org/wiki/Galactose) and [glucose](https://en.m.wikipedia.org/wiki/Glucose) subunits and has the [molecular formula](https://en.m.wikipedia.org/wiki/Molecular_formula) C12H22O11. Lactose makes up around 2–8% of [milk](https://en.m.wikipedia.org/wiki/Milk) (by weight). The name comes from *lac* (gen. *lactis*), the [Latin](https://en.m.wikipedia.org/wiki/Latin) word for milk, plus the suffix [*-ose*](https://en.m.wikipedia.org/wiki/-ose) used to name sugars. The compound is a white, water-soluble, non-hygroscopic solid with a mildly sweet taste. It is used in the food industry.[[5]](https://en.m.wikipedia.org/wiki/Lactose#cite_note-Ull-5)

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| **Lactose** |
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## Structure and reactions[Edit](https://en.m.wikipedia.org/w/index.php?title=Lactose&action=edit&section=1)

[](https://en.m.wikipedia.org/wiki/File:Alpha-lactose-from-xtal-3D-balls.png)

The molecular structure of α-lactose, as determined by [X-ray crystallography](https://en.m.wikipedia.org/wiki/X-ray_crystallography).

Lactose is a [disaccharide](https://en.m.wikipedia.org/wiki/Disaccharide) derived from the [condensation](https://en.m.wikipedia.org/wiki/Condensation_reaction) of [galactose](https://en.m.wikipedia.org/wiki/Galactose) and [glucose](https://en.m.wikipedia.org/wiki/Glucose), which form a β-1→4 [glycosidic](https://en.m.wikipedia.org/wiki/Glycosidic_bond" \o "Glycosidic bond) linkage. Its systematic name is β-D-galactopyranosyl-(1→4)-D-glucose. The glucose can be in either the α-[pyranose](https://en.m.wikipedia.org/wiki/Pyranose) form or the β-pyranose form, whereas the galactose can only have the β-pyranose form: hence α-lactose and β-lactose refer to the [anomeric](https://en.m.wikipedia.org/wiki/Anomer" \o "Anomer) form of the glucopyranose ring alone. Detection reactions for lactose are the Woehlk-and Fearon's test Both can be easily used in school experiments to visualise the different lactose content of different dairy products such as whole milk, lactose free milk, yoghurt, buttermilk, coffee creamer, sour creme, kefir etc

Lactose is [hydrolysed](https://en.m.wikipedia.org/wiki/Hydrolysation) to glucose and galactose, [isomerised](https://en.m.wikipedia.org/wiki/Isomerisation) in alkaline solution to [lactulose](https://en.m.wikipedia.org/wiki/Lactulose), and [catalytically](https://en.m.wikipedia.org/wiki/Catalysis) hydrogenated to the corresponding [polyhydric alcohol](https://en.m.wikipedia.org/wiki/Polyhydric_alcohol), [lactitol](https://en.m.wikipedia.org/wiki/Lactitol" \o "Lactitol) Lactulose is a commercial product, used for treatment of constipation.

## Occurrence and isolation

Lactose composes about 2–8% of milk by weight. Several million tons are produced annually as a by-product of the [dairy industry](https://en.m.wikipedia.org/wiki/Dairy_industry).

[Whey](https://en.m.wikipedia.org/wiki/Whey) or milk plasma is the liquid remaining after milk is curdled and strained, for example in the production of [cheese](https://en.m.wikipedia.org/wiki/Cheese). Whey is made up of 6.5% solids, of which 4.8% is lactose, which is purified by crystallisation Industrially, lactose is produced from whey permeate – that is whey filtrated for all major [proteins](https://en.m.wikipedia.org/wiki/Protein). The protein fraction is used in [infant nutrition](https://en.m.wikipedia.org/wiki/Infant_nutrition) and [sports nutrition](https://en.m.wikipedia.org/wiki/Sports_nutrition) while the permeate can be evaporated to 60–65% solids and crystallized while cooling crystallisation. Lactose can also be isolated by dilution of whey with [ethanol](https://en.m.wikipedia.org/wiki/Ethanol).

Dairy products such as [yogurt](https://en.m.wikipedia.org/wiki/Yogurt) and [cheese](https://en.m.wikipedia.org/wiki/Cheese) contain very little lactose, as the bacteria used to make them consume lactose during the manufacturing process.

## Applications

Its mild flavor and easy handling properties have led to its use as a carrier and stabiliser of aromas and pharmaceutical products. Lactose is not added directly to many foods, because its solubility is less than that of other sugars commonly used in food. Infant formula is a notable exception, where the addition of lactose is necessary to match the composition of human milk.

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Lactose is not fermented by most [yeast](https://en.m.wikipedia.org/wiki/Yeast) during brewing, which may be used to advantage.[[9]](https://en.m.wikipedia.org/wiki/Lactose#cite_note-Linko1981-9) For example, lactose may be used to sweeten stout beer; the resulting beer is usually called a [milk stout](https://en.m.wikipedia.org/wiki/Milk_stout) or a cream stout