ST. LAWRENCE HIGH SCHOOL

A JESUIT CHRISTIAN MINORITY INSTITUTION

STUDY MATERIAL FOR CHEMISTRY (CLASS-12)

TOPIC-BIOMOLECULES (CARBOHYDRATE)

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SET NUMBER-16

DATE: 23.01.2021

Carbohydrates

- They are polyhydroxy-aldehydes or ketones or substances which give these substances on hydrolysis and contain at least one chiral atom.
- They have general formula of $C_x(H_2O)$
- Rhamnose, deoxyribose, rhamnohexose do not obey this formula but are carbohydrates.

Types of carbohydrates

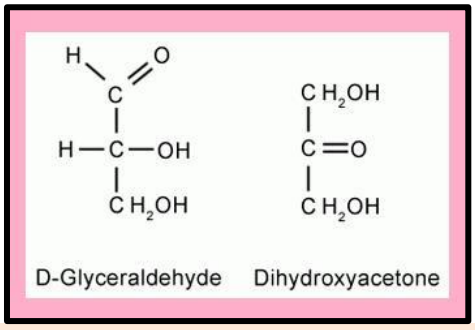
- Monosaccharide
- Oligosaccharide
- Polysaccharide

Monosaccharide

- These are simplest carbohydrate which can't be hydrolyzed further into smaller compounds.
- They are called as aldose or ketose depending upon whether they have aldehyde or ketone group.
- Depending upon the number of carbon atoms present they are called as triose, tetrose etc.
- All monosaccharide's are sweet smelling crystalline, water soluble and are also capable of diffusing through cell membranes.

For example: Glucose is aldohexose while fructose is a ketohexose. Both of them have 6 carbon atoms. The simplest monosaccharide is a triose (n=3).
Example: Glyceraldehyde and Dihydroxyacetone. They have one or more asymmetric carbon and are optically active.

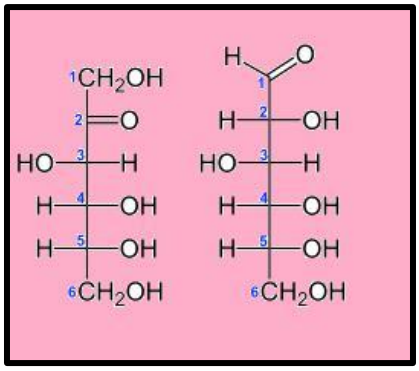
Their structures are:



Configuration

All naturally occurying monosaccharides belong to D—series that is OH group at their penultimate C-atom.

Open chain structures:



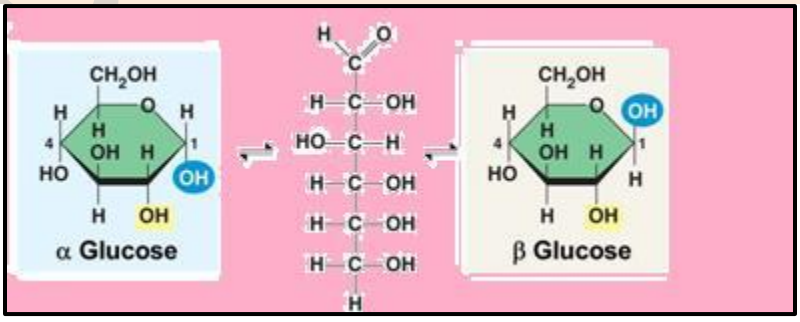
- D-glucose and D-mannose, differ only in configuration at C-2 and are known as epimers.
- Similarly D-glucose and D-galactose, differ in configuration around C-4 atom and are also known as epimers.
- Thus a pair of diastereomers, differing only in configuration around C-2 or any other chiral carbon except C-1 is called epimers.

Close chain structure

- All the pentose's and hexoses exist in cyclic hemiacetal structure.
- In free state, they have generally six membered cyclic structure known as pyranose form and in combined state, some of them have 5 membered cyclic structure called as furanose .

Due to cyclic hemiacetal or hemiketal structure all the pentoses and hexoses exist in two stereoisomeric forms

- Alpha form
- Beta form
- Both alpha and beta form are Anomers.
- Their structure is given below :



Oligosaccharides

These carbohydrates on hydrolysis give 2 to 9 molecules of monosaccharides.

They are further of few types:

- Disaccharides ($C_{12}H_{22}o_{11}$): On hydrolysis, they give 2 molecules of monosaccrides which are held together by Glycosidic linkage

Example: sucrose etc

- Trisaccharides ($C_{18}H_{32}o_{16}$): On hydrolysis, they form three molecules of monosaccharides.

Example: raffinose

- Tetra-saccharides: ($C_{24}H_{42}o_{21}$): Such as stachyose which gives four monosaccrides on hydrolysis.

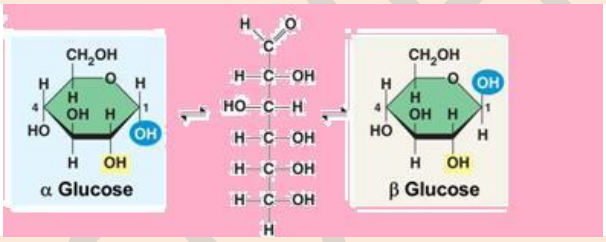
Polysaccharides

These are the carbohydrates which on hydrolysis, yield more than nine monosaccharides molecules.

Example: Starch etc

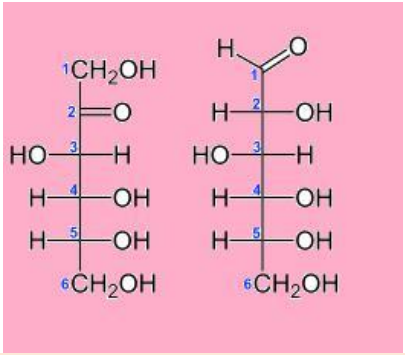
Mutarotation

- Glucose exist in two forms : i.e. alpha –D glucose with specific rotation of 112degree and beta D-glucose with specific rotation of +19 degree.
- However, when either of these two forms is dissolved in water and allowed to stand, it gets converted into same equilibrium mixture of both the alpha and beta forms with a small amount of open chain form having specific rotation of 52.7 degree.
- As a result of this, equilibrium the specific rotation of freshly prepared solution of alpha glucose decreases from +112 degree to 52.7 degree while that for beta glucose increases from +19 to 52.7 degrees.
- The phenomenon of change of change in specific rotation of optically active compounds with time to an equilibrium value is known as Mutarotation.



- The alpha D (+) glucose and beta (+) glucose, differ in configuration at C-1 carbon and the compounds differing in configuration at C-1 are called Anomers.

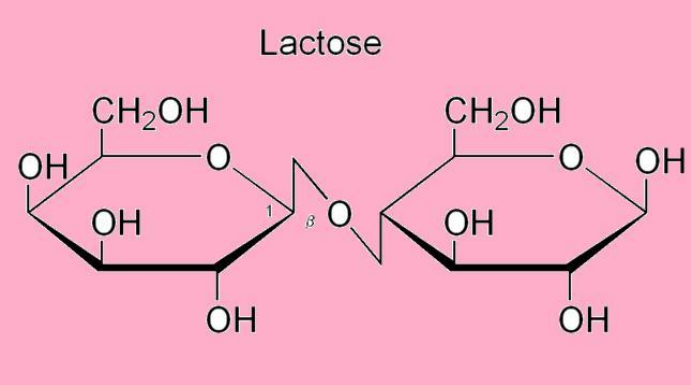
Fructose: It is represented by six membered ring as shown:



Beta –D+(fructose) **furanose structure**

Fructose is assigned furanose structure.

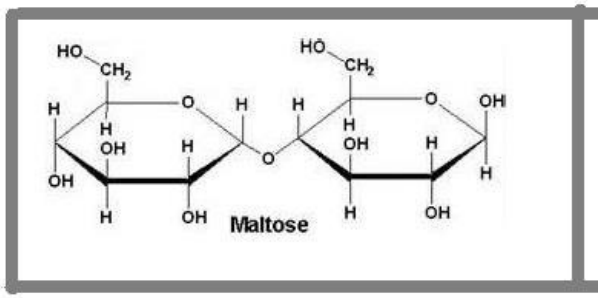
Lactose: It is made up of molecule and a molecule of galactose. The units are linked together.



Lactose

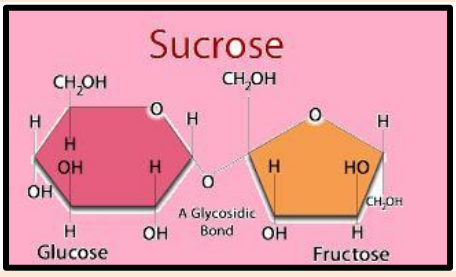
Maltose: It has the structure as shown below

- On treatment, with acid or with enzyme maltose gets hydrolysed to 2 molecules.
- That is alpha D-glucose.
- Since one of the glucose units exist in hemiacetal form it is a reducing sugar.



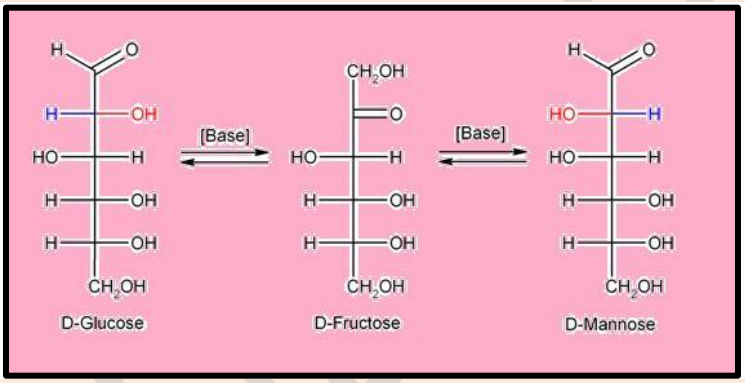
Sucrose: It has a structure shown below

- On hydrolysis, with dilute mineral acid or enzyme invertase sucrose gives glucose and fructose in equal amounts.
- Sucrose and glucose are dextrorotatory while fructose is laevorotatory and has higher value of specific rotation.
- Thus the process is accompanied by inversion of optical activity. The mixture formed is invert sugar. That is sucrose àglucose + fructose



Sweetness of sugars

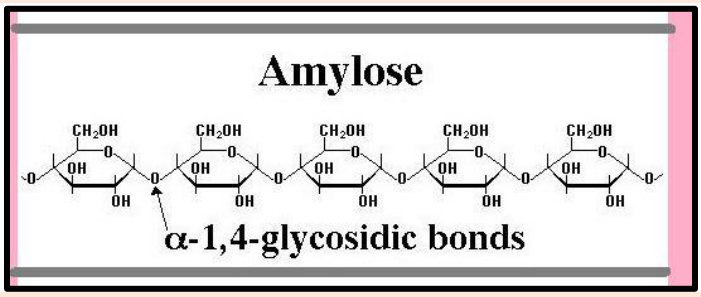
- All the monosaccharide and disaccharides are sweet in taste and hence also known as sugars.
- Sucrose is given sweetness value of 100. The sweetness of other sugars is compared with the value of sucrose.
- The sweetness of fructose -173, invert sugar 130, sucrose 100, glucose 74,glactose 32,maltose 32 and that of lactose is 16.
- All the monosaccharide and disaccharides are reducing agents due to hemiacetal and hemiketal forms which easily change in to aldehydic form in the alkaline medium.
- Although fructose doesn't contain any aldehydic group yet it gives Tollen's reagent test and Fehling's solution test because under the basic conditions of reagent the fructose gets converted into the mixture of glucose and mannose both of which contains aldehydic group.
- This is called Lobry De Bruyn Van Eikensten rearrangement.



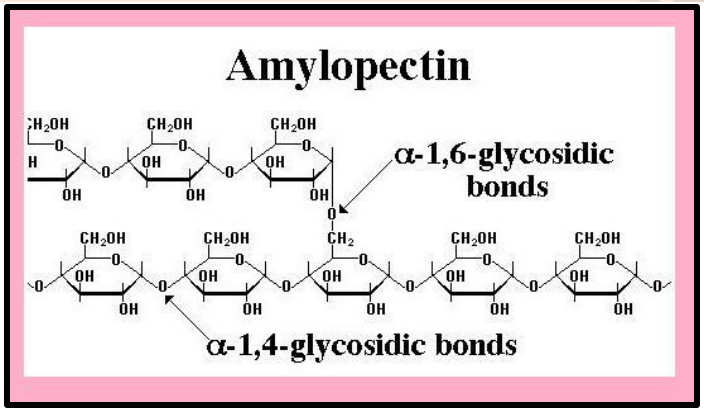
- The alpha and beta glucose reacts with one molecule of ethanol to form the corresponding methyl glucosides.
- When glucose is treated with methanol in presence of HCl the hemiacetal form changes to acetal form.

Starch: It serves as a storage polysaccharide in plants .It consist of two components of alpha glucose.

- **Amylase**
  - It is a linear polymer of glucose and is soluble in water.
  - Its percentage in starch is about 10-20 %.
  - These are linked together by alpha linkage involving C-1 of glucose unit to C-4 of the other.

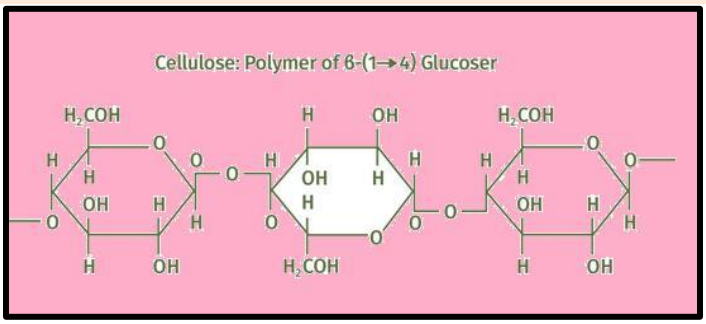


- **Amylopectin**
- It is branched chain polymer of alpha glucose and is insoluble in water.
- There are about 1000 units of glucose.



(c) Cellulose

- It is found in all plants
  - It constitutes 50% of total organic matter in the living beings.
  - Cotton is pure cellulose.
  - Cellulose is linear polymer of beta D-glucose.
  - The chains are arranged to form bundles and linked together by hydrogen bonds between glucose molecules of adjacent organic solvents.
  - When it is treated with concentrated sulphuric acid in cold it slowly passes into solution.
  - This solution when diluted with water gives starch like substance amyloid which is known as parchment paper.
  - On boiling with water it is hydrolyzed into D-glucose.
  - Cellulose gives many useful products when treated with different chemicals like rayon, gum, cotton etc.
  - Cellulose is directly used in making cloth and paper.



Glycogen

- In glycogen there are about 25 glucose units. Its structure is similar to amylopectin and is a condensation polymer of alpha glucose.
- Glycogen in short term food storage in animals.

Tests for carbohydrates

- For this Molisch test is performed.
- In it Molisch reagent is used which is 10%alcoholic solution of alpha naphthol and it is added to aqueous solution of carbohydrate followed by concentrated sulphuric along the sides of tube.

As a result a violet ring is formed at the junction of two layers.

Carbohydrates are the most abundant and diverse class of organic compounds occurring in nature. It played a key role in the establishment and evolution of life on earth by creating a direct link between the sun and chemical energy.

Aim:

To study some simple tests of carbohydrates in the given sample.

Theory:

The word carbohydrate is formed from the words carbon and hydrogen. Carbohydrates are combinations of the chemical elements carbon and hydrogen plus oxygen. In the natural world, carbohydrates are the most common chemical compounds used for food.

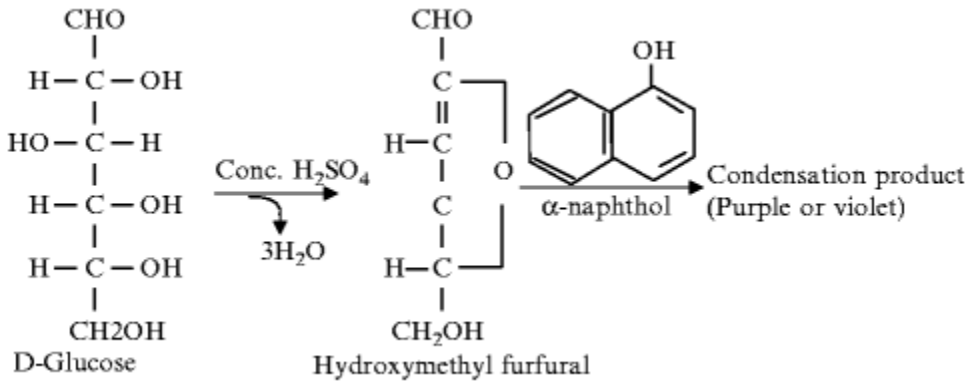
The following are the test to identify the presence of carbohydrates.

1. Molisch's test
2. Fehling's test
3. Benedict's test
4. Tollen's test
5. Iodine test

(a) Molisch's Test:

Molisch's test is a general test for carbohydrates. This test is given by almost all of the carbohydrates. In this test concentrated sulfuric acid converts the given carbohydrate into furfural or its derivatives, which react with α-naphthol to form a purple coloured product.

The chemical reaction is given below.

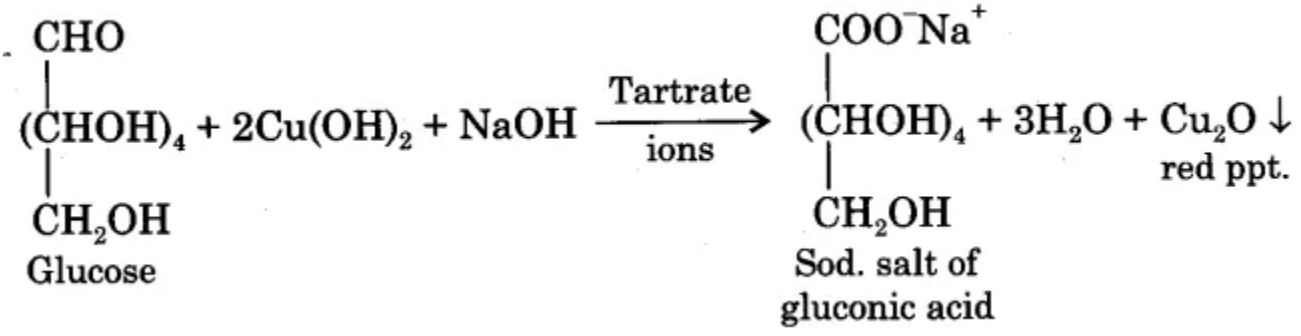


Note: *The appearance of purple or violet ring confirms the presence of carbohydrate.*

(b) Fehling's Test:

This test is given by reducing sugars. To the aqueous solution of carbohydrate fehling's solution is added and heated in water bath. Formation of red precipitate confirms the presence of reducing sugars. The copper ions present in fehling's solution in +3 state is reduced to +2 oxidation state and in alkaline medium it is precipitated as red cuprous oxide.

The chemical reaction is given below.

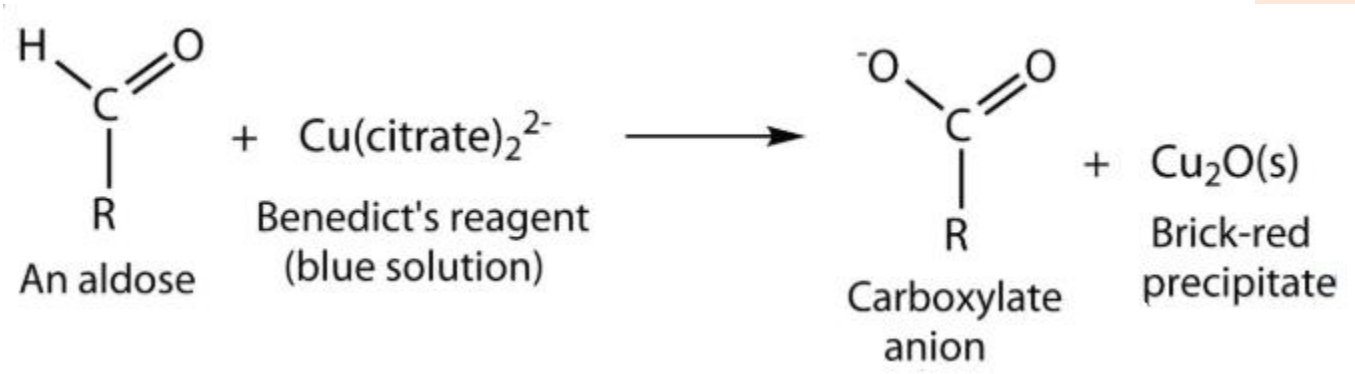


Note: *The appearance of red precipitate confirms the presence of carbohydrates.*

(c) Benedict's Test:

This test is given by reducing sugars. in alkaline medium, sodium carbonate converts glucose to enediol and this enediol reduce cupric to cuprous forming cuprous hydroxide. This solution is kept in sodium citrate and on boiling red precipitate of cuprous oxide is formed.

The chemical reaction is given below.



Note: *The appearance of red precipitate confirms the presence of carbohydrates.*

(d) Tollen's Test:

This test is given by reducing sugars. Carbohydrates reacts with Tollens reagent forms a silver mirror on the inner walls of the test tube. This confirms the presence of reducing sugars. Silver ions are reduced to metallic silver.

The chemical reaction is given below.

$$NH_4OH + AgNO_3 \longrightarrow NH_4NO_3 + Ag(OH)$$

$$2Ag(OH) \longrightarrow Ag_2O + H_2O$$

$$\begin{array}{l} CH_2OH \\ | \\ (CHOH)_4 \\ | \\ CHO \\ \text{Glucose} \end{array} + Ag_2O \longrightarrow \begin{array}{l} CH_2OH \\ | \\ (CHOH)_4 \\ | \\ COOH \end{array} + 2Ag \quad \begin{array}{l} \text{Silver} \\ \text{mirror} \end{array}$$

Note: *The appearance of silver mirror confirms the presence of reducing sugars.*

(e) Iodine Test:

This test is only given by starch. Starch reacts with iodine solution forms complex blue colour solution. On heating the blue colour disappears and on cooling the blue colour reappears.

The chemical reaction is given below.

$$\underset{\text{Dark Blue Complex}}{I_3^-} + \text{Starch} \xrightarrow{\text{Multi-step Process}} \underset{\text{Amber}}{I_2 + I^-}$$

Note: *The appearance of blue colour solution confirms the presence of starch.*

Materials Required:

1. Molisch's reagent
2. Fehling's reagent
3. Benedict's reagent
4. Tollen's reagent
5. Iodine solution
6. Concentrated sulfuric acid
7. Sodium hydroxide solution
8. Test tubes
9. Test tube holder
10. Test tube stand
11. Bunsen burner
12. Water bath
13. Dropper
14. Stirrer

Apparatus Setup:

Procedure:

Preparation of Reagents:

- **Molisch's reagent –** It is prepared by adding α-naphthol in 10% alcoholic solution.
- **Fehling's reagent –** It is a solution of 1ml each Fehling's A and Fehling's B
- **Fehling's solution A –** Dissolve copper sulfate in distilled water and add a few drops of sulfuric acid.
- **Fehling's solution B –** Dissolve sodium potassium tartrate and sodium hydroxide in 150ml of distilled water.
- **Benedict's reagent –** To a solution of sodium citrate 0.25g of anhydrous sodium carbonate in distilled water is added and copper sulfate solution is added to it. Make the total volume up to 125ml by adding distilled water.
- **Tollen's reagent –** Add sodium hydroxide solution to the silver nitrate solution. Then add ammonium hydroxide solution dropwise till the precipitate dissolves. The clear solution is called Tollens reagent.
- **Iodine solution –** Iodine solution is obtained by dissolving iodine in potassium iodide solution.

(a) Molisch's Test:

1. Take 2ml of the given sample solution in a clean test tube.
2. Add 2-3 drops of Molisch reagent slowly.
3. Now add concentrated sulfuric acid along the sides of the test tube.
4. The acid layer forms a layer at the bottom.
5. Note the junction of the two layers.
6. If there is a formation of the violet ring then the presence of carbohydrate is confirmed.

(b) Fehling's Test:

1. Take 2ml of given sample solution in a clean test tube.
2. Add 2 ml of Fehling's solution A and Fehling's solution B to it.
3. Keep the solution in a boiling water bath for about 10 minutes.
4. If there is the formation of red precipitate then the presence of carbohydrate is confirmed.

(c) Benedict's Test:

1. Take the given sample solution to be tested in a clean test tube.
2. Add 5ml of Benedict's reagent to it.
3. Boil the solution for about 2 minutes.
4. Cool the solution and observe the solution.
5. If there is formation of green, red or yellow precipitate then there is presence of reducing sugars.

(d) Tollen's Test:

1. Take the given sample solution in a clean test tube.
2. Add 2-3ml of tollens reagent to it.
3. Keep the test tube in a boiling water bath for 10 minutes.
4. If there is the appearance of shiny silver mirror confirms the presence of reducing sugars.

(e) Iodine Test:

1. Take the sample solution to be tested in a clean test tube.
2. Add 2-3 drops of iodine solution.
3. Observe the change in colour.
4. If there is the appearance of a blue colour then the presence of starch is confirmed.

Observations and Inference:

Test	*Glucose*	*Lactose*	*Sucrose*	*Starch*
Molisch's test	Purple ring	Purple ring	Purple ring	Purple ring
Fehling's test	Red precipitate	Red precipitate	No precipitate	No precipitate
Benedict's test	Red precipitate	Red precipitate	No precipitate	No precipitate
Tollen's test	Appearance of silver mirror.	Appearance of silver mirror.	No silver mirror	No silver mirror
Iodine test	No reaction	No reaction	No reaction	Appearance of blue colour solution.

Results and Discussions:

The given organic compound is a _____ (reducing sugar/starch/carbohydrate) compound.

Precautions:

1. Handle the acids like concentrated sulfuric acid with care.
2. Always use droppers to take reagents from the reagent bottles.
3. While heating the reaction mixture do it carefully.

Also, Check ⇒ Structure & Properties of Maltose

Keep visiting BYJU'S to learn more about class 12 CBSE chemistry practicals.

Frequently Asked Questions on Tests of Carbohydrates

What are carbohydrates?

Carbohydrates are polyhydroxy aldehydes, ketones or compounds that are transformed into one of a large group of organic compounds that occur in foods and living tissues, including sugars, starch and cellulose.

What is Fehling's solution?

Fehling's solution is prepared by mixing two solutions Fehling's A and Fehling's B. Fehling's A contain copper sulfate solution whereas Fehling's B contain potassium hydroxide and potassium sodium tartrate.

If a compound gives a positive test for iodine test, what is the nature of the compound?

If a chemical compound gives positive iodine test then the given organic compound is starch.

What are the most important constituents of food?

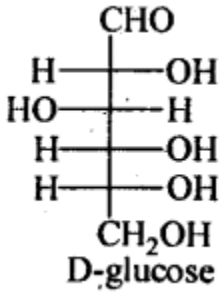
Carbohydrates, proteins and fats are the most important constituents of food.

What are reducing and non-reducing sugars?

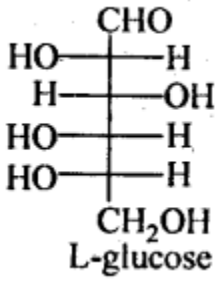
Non-reducing sugars do not have an OH group attached to the anomeric carbon so that other compounds cannot be reduced. Glucose is a reducing sugar. A disaccharide may be a reducing sugar or non-reducing sugar. Maltose is a reducing sugar, while sucrose is a non-reducing sugar.

SOME IMPORTANT POINTS:

1. Carbohydrates is a class of compounds that include polyhydric aldehydes and ketones and large number of other polymeric molecules that yield these on hydrolysis, e.g., sugars, glycogen, cellulose, starch, etc.
2. Depending upon their behaviour on hydrolysis, carbohydrates are further divided into three types: Monosaccharides (e.g., glucose, fructose etc.), disaccharides (e.g., sucrose, maltose etc.) and polysaccharides (e.g., starch, cellulose, etc.)
3. Another classification of carbohydrates is as sugars and non sugars. Sugars are sweet in taste, crystalline, soluble in water, mainly include mono and oligosaccharides. Non Sugars are tasteless, amorphous, water insoluble and mainly include polysaccharides.
4. Carbohydrates can also be classified as reducing and non reducing sugars. Reducing sugars respond to Tollens' and Fehling solution test. All monosaccharides, aldoses and ketoses,fall in this category. Some other oligosaccharides also may be reducing. All polysaccharides are non reducing (starch, cellulose, glycogen etc). Sucrose is a disaccharide and non reducing sugar.
5. The molecular formula of glucose is $C_6H_{12}O_6$. It is prepared by boiling sucrose with dilHCl or dil H_2SO_4 in alcoholic solution or by the hydrolysis of starch with dil H_2SO_4 at 393 K under pressure.
6.The Fisher projection for D-and L-glucose are shown below:



D-glucose



L-glucose

7. A pair of stereoisomeric ring forms of any sugar differing in configuration only at carbon 1 (the anomeric carbon) are called **anomers**.

8. The spontaneous change that takes place in specific rotation of an optically active sugar when dissolved in water is known as **mutarotation.**

9. The cyclic structure of glucose was proposed by R. D. Haworth. The six-membered cyclic structure of glucose is called as **pyranose structure (α or β)**.

10. The hydrolysis of sucrose brings about a change in the sign of rotation, from dextro (+) to laevo (-). Such a change is known as **inversion of sugar**.

11. Starch/Amylum $(C_6H_{10}O_5)_n$ is a polymer of D-glucose and consists of two components amylose and amylopectin. Natural starch consists of approximately 15 – 20% of amylose and 80 -85% of amylopectin.

12. Cellulose $(C_6H_{10}O_5)_n$ is a linear polymer of β-D-glucose in which the β-D- glucose units are joined by β-D-glucosidic linkage.

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