

## CARBOHYDRATES

### DEFINITION, CLASSIFICATION WITH EXAMPLES AND CHEMICAL PROPERTIES

- Carbohydrates are primarily produced by plants and form a very large group of naturally occurring organic compounds.
- Some common examples of carbohydrates are cane sugar, glucose, starch, etc.
- Most of them have a general formula,  $C_x(H_2O)_y$ , and were considered as hydrates of carbon from where the name carbohydrate was derived. For example, the molecular formula of glucose ( $C_6H_{12}O_6$ ) fits into this general formula,  $C_6(H_2O)_6$ .
- But all the compounds which fit into this formula may not be classified as carbohydrates. For example acetic acid ( $CH_3COOH$ ) fits into this general formula,  $C_2(H_2O)_2$  but is not a carbohydrate. Similarly, rhamnose,  $C_6H_{12}O_5$  is a carbohydrate but does not fit in this definition.
- A large number of their reactions have shown that they contain specific functional groups.
- **Definition**  
*“Chemically, the carbohydrates may be defined as optically active polyhydroxy aldehydes or ketones or the compounds which produce such units on hydrolysis.”*
- Some of the carbohydrates, which are sweet in taste, are also called sugars. The most common sugar, used in our homes is named as sucrose whereas the sugar present in milk is known as lactose.
- Carbohydrates are also called saccharides (Greek: *sakcharon* means sugar).

#### ❖ CLASSIFICATION OF CARBOHYDRATES (on the basis of their behaviour on hydrolysis)

##### i) Monosaccharides:

- A carbohydrate that cannot be hydrolysed further to give simpler unit of polyhydroxy aldehyde or ketone is called a monosaccharide.
- About 20 monosaccharides are known to occur in nature.
- Some common examples are glucose, fructose, ribose, etc.

##### ii) Disaccharide-

- When two molecules of a simple sugar (monosaccharide) linked to each other, form a disaccharide, or double sugar.

Or

When a carbohydrates give two monosaccharide on hydrolysis called disaccharide.

- The two monosaccharide units obtained on hydrolysis of a disaccharide may be same or different. For example, one molecule of sucrose (table sugar) on hydrolysis gives one molecule of glucose and one molecule of fructose whereas maltose gives two molecules of only glucose.
- The disaccharide sucrose, or table sugar, consists of one molecule of glucose and one molecule of fructose
- The most familiar sources of sucrose cane sugar.
- Milk sugar (lactose) and maltose are also disaccharides.
- Before the energy in disaccharides can be utilized by living things, the molecules must be broken down into their respective monosaccharides.

##### iii) Oligosaccharides:

- Carbohydrates that yield two to ten monosaccharide units, on hydrolysis, are called oligosaccharides.
- They are further classified as disaccharides, trisaccharides, tetrasaccharides, etc., depending upon the number of monosaccharides, they provide on hydrolysis. Amongst these the most common are disaccharides

##### iv) Polysaccharides:

- Carbohydrates which yield a large number of monosaccharide units on hydrolysis are called polysaccharides.
- Some common examples are starch, cellulose, glycogen, gums, etc.
- Polysaccharides are not sweet in taste, hence they are also called non-sugars.

#### ❖ CLASSIFICATION OF CARBOHYDRATES (on the basis of reducing and non reducing sugar)

The carbohydrates may also be classified as either reducing or nonreducing sugars. All those carbohydrates which reduce Fehling's solution and Tollens' reagent are referred to as reducing sugars. All monosaccharides whether aldose or ketose are *reducing sugars*.

❖ **CLASSIFICATION OF CARBOHYDRATES (on the basis of number of carbon atoms and the functional group present)**

Monosaccharides are further classified on the basis of number of carbon atoms and the functional group present in them. If a monosaccharide contains an aldehyde group, it is known as an aldose and if it contains a keto group, it is known as a ketose. Number of carbon atoms constituting the monosaccharide is also introduced in the name as shown in table

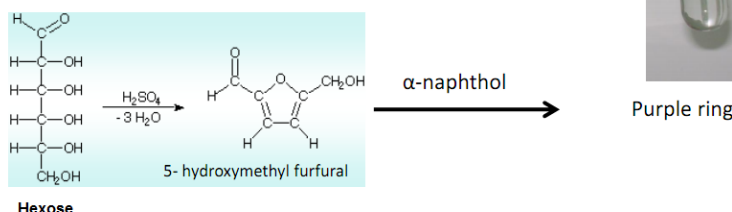
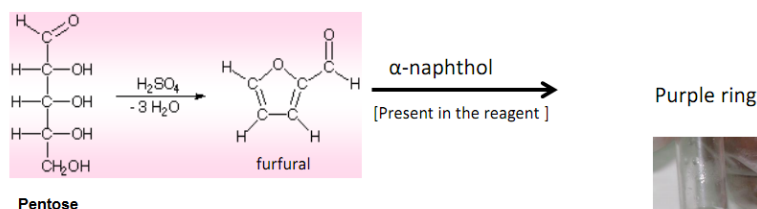
Carbon atoms	General term	Aldehyde	Ketone
3	Triose	Aldotriose	Ketotriose
4	Tetrose	Aldotetrose	Ketotetrose
5	Pentose	Aldopentose	Ketopentose
6	Hexose	Aldohexose	Ketohexose
7	Heptose	Aldoheptose	Ketoheptose

❖ **CHEMICAL PROPERTIES OF CARBOHYDRATES**

The chemical properties of carbohydrates are basically the chemical properties of monosaccharide because monosaccharides are simple sugar and have free functional group

**1. Furfural formation**

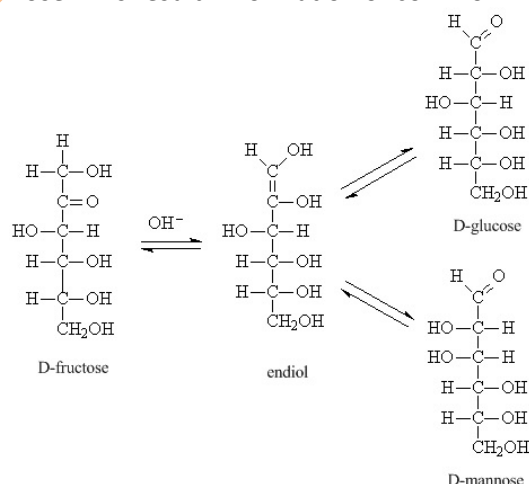
- Sugar when heated with strong mineral acid like Conc. H<sub>2</sub>SO<sub>4</sub>, conc. HCl or conc. HNO<sub>3</sub> undergo dehydration and lose three water molecule to form furfural derivatives



- This is the basis for following reaction
  - Molisch test- identification test for carbohydrates
  - Seliwanoff's test- specific for fructose or test for keto group

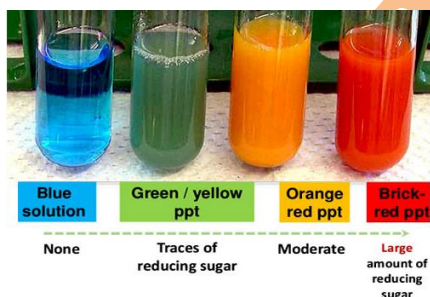
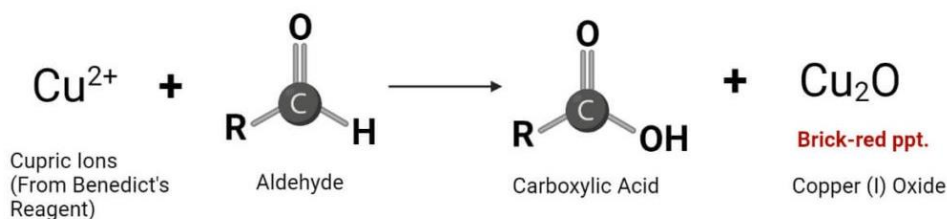
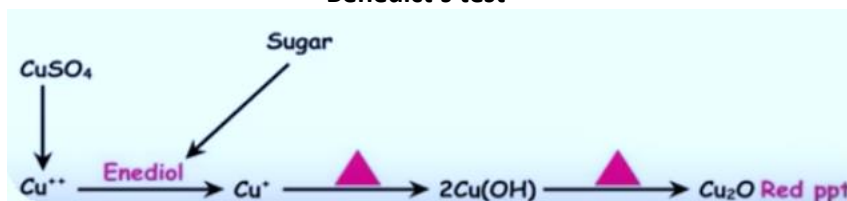
**2. Enolization/Tautomerisation (action of alkali)**

- When glucose is kept in alkaline solution for several hours, it undergoes isomerisation to form D-fructose and D-mannose. This results in formation of common intermediate enediol.



- The process of shifting of hydrogen atom from one carbon atom to another to produce enediols is known as tautomerisation.
- Enediols are good reducing agents and forms the basis for reducing property of sugar.
- Ex-
  - Benedict's test- Benedict's test is a chemical test that can be used **to check for the presence of reducing sugars in a given analyte**. Therefore, simple carbohydrates containing a free ketone or aldehyde functional group can be identified with this test
  - Fehling's test- One of the most popular tests used for the **estimation or detection of reducing sugars and non-reducing sugars** is the Fehling's test

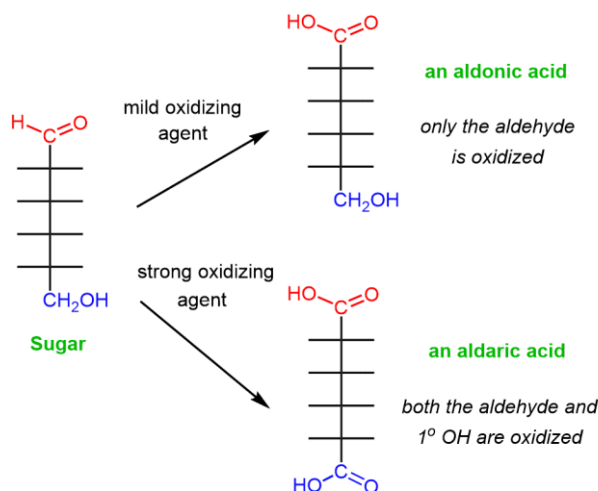
**Benedict's test**



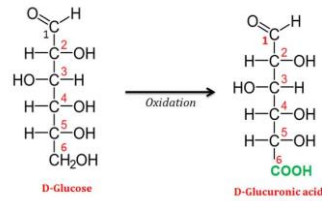
**3. Oxidation of sugars**

When glucose oxidises under proper conditions the sugar may form

- Monobasic Aldonic acid- oxidation with hydrobromous acid
- Dibasic saccharic acids or Alderic Acid- oxidation with nitric acid

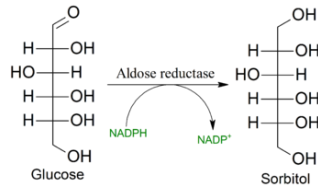


iii) Monobasic Uronic acid – oxidised by specific enzymes



**4. Reduction of sugars**

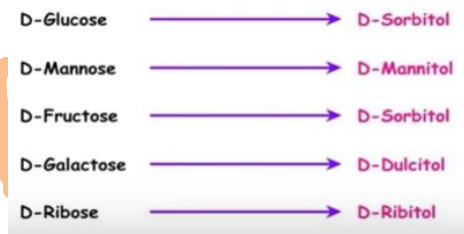
- Both aldoses and ketoses may be reduced by enzymes to the corresponding polyhydroxy alcohol (sugar alcohol)



- The sugar alcohols function mainly as intermediate in the minor pathway of carbohydrate metabolism.

Some of these alcohol are the following

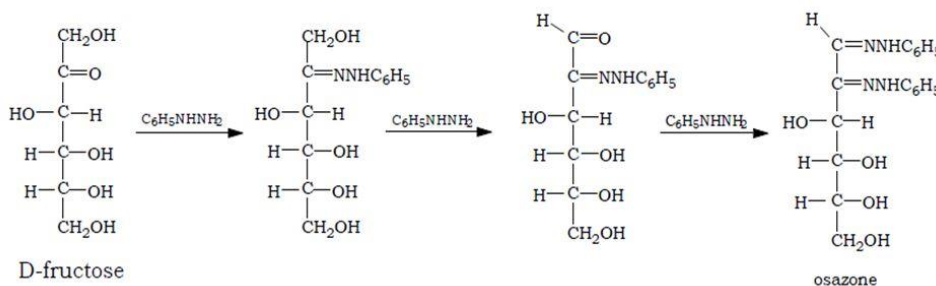
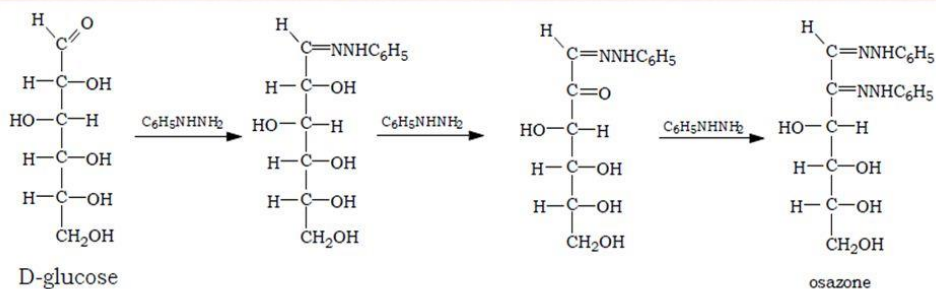
- i) Sorbitol
- ii) Mannitol
- iii) Dulcitol
- iv) Ribitol



**5. OSAZONE FORMATION**

- All reducing sugar gives this test positive
- The presence of free carbonyl group (aldehyde or ketone) in the molecule is essential for the osazone formation.
- Osazone are yellow crystalline derivatives of reducing sugars with phenylhydrazine and have a characteristic crystal structure which can be used for identification and characterisation of different sugars having closely similar properties.
- In osazone formation, only first two carbons are involved in reaction therefore glucose, fructose, and mannose give same type of Osazone as they are identical w.r.t lower four carbon atom

**Osazone formation:**



- Non-reducing sugars like sucrose cannot form osazone due to the absence of a free carbonyl group
- The osazone crystals of some sugars are
  - i) Needle shape- eg: Glucosazone, fructosazone, Mannosazone



- ii) Sunflower petal shape- eg: Maltosazone



- iii) Powder puff of tennis ball shape- eg: Lactosazone

