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Title: ***Sugars and Inversion – a simple explanation***

Basic Chemistry

There are many different sugars. Sugar molecules are made up of three elements: carbon, oxygen and hydrogen. They therefore belong to the wider chemical group called carbohydrate. The more correct, chemical term for a sugar is saccharide. There are hundreds of different types of saccharide (sugar) molecule; common ones are sucrose, glucose and fructose. Less common examples are mannose, sorbitol.

Sugars are formed in nature by the chemical combination of carbon dioxide and water in a complex variety of permutations. Sugars are classified according to their physical (molecular) structure. Their basic structure is formed by carbon and oxygen atoms joined in three, four, five or six-membered rings (=triose, tetrose, pentose, hexose etc). These rings can themselves be joined together in a daisy chain-like fashion to give the following classification:

Classification	***Structure***	***Example(s)***
Monosaccharides	Single ring	Glucose, Fructose
Disaccharides	Two rings	Sucrose
Oligosaccharides	Several rings	No obvious, common names
Polysaccharides	Very large number of rings	Cellulose, Starch, Gums

A further complication of sugar molecules is that they are invariably ‘optically active’. This means that the same chemical (number of atoms) can co-exist in two or more physical forms (eg non-superimposable structures). Hence the additional classification: D-, L- forms. This prefix denotes the direction in which polarised light is rotated: D = dextrorotatory (right hand or clockwise); L = Levorotatory (left hand or counterclockwise).

(In the old-fashioned terminology, D-Glucose was called Dextrose and L-Fructose was called Levulose.)

It’s complicated, isn’t it? – and this is the simple version!

Inversion

Sucrose is chemically unstable when dissolved in water. The disaccharide molecule breaks in half to form two monosaccharide units: one molecule of glucose and one molecule of fructose. One molecule of water is ‘consumed’ in this reaction as follows:

$$C_{12}H_{22}O_{11} + H_20 \rightarrow C_6H_{12}O_6 + C_6H_{12}O_6$$

Sucrose **Glucose** **Fructose**

The resulting 1:1 mixture of glucose and fructose is called *invert sugar* and the chemical reaction is called *inversion*. In water the reaction is very slow (takes weeks). At higher temperatures and in the presence of acid(s) the reaction speeds up considerably. Thus when cola drinks are made from sucrose, the dissolved sugar inverts quite quickly because the recipe contains phosphoric acid. Similarly, drinks containing citric acid or ascorbic acid (vitamin C) will also invert quite quickly.

Looking at the above chemical reaction, the weight of dissolved sugar increases (by one water molecule) as the reaction proceeds. At 100% inversion, there is an increase of about 5.3% in the weight of dissolved solids. This accounts mainly for the change (increase) in both density and refractive index of the solution (drink) when inversion takes place. There is an additional effect: the intrinsic 'refractivity' of invert sugar is different from that of sucrose and so the observed change is not simply a linear amount based on the change in weight of dissolved solids. Similarly, the density also does not change in a linear fashion.

Inversion is accompanied by a change in optical rotation. Each of the three sugars has a different specific rotation:

Sugar	***Specific Rotation***
Sucrose	+66.5°
Fructose	-92°
Glucose	+52.5°

Inversion is accompanied by a swing from positive to net negative rotation because of the overriding negative rotation from the fructose. Because of this effect, polarimetry is a very convenient way to measure the rate of inversion or the degree of inversion in partially inverted solutions.