6. PROBLEM № 13: HARD STARCH

SOLUTION OF CZECH REPUBLIC

Problem № 13: Hard Starch

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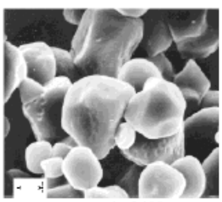
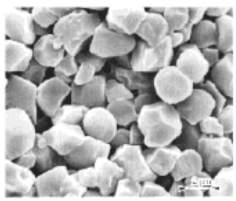
The problem

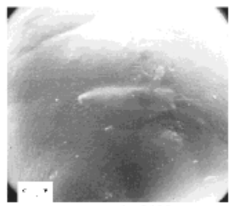
A mixture of starch (e.g. corn flour or cornstarch) and a little water has some interesting properties. Investigate how its "viscosity" changes when stirred and account for this effect.
Do any other common substances demonstrate this effect?

Starch has been used for production of papyrus and glue since 3500 B.C. In 1525 it was used for solidification of shirt's collars. There are many sources of starch in nature –bulbs and roots (potatoes, manioca), seeds (grain), fruits (chestnut, pulses). Content of starch is very different, e.g. rice 70-75 %, potatoes 12-20%.

The mixture of starch and a little water is made of small insoluble particles in liquid, which means that it is a suspension.


corn starch, 2400x


rice starch, 3000x


potato starch, 2400x

corn starch, 2400x rice starch, 3000x potato starch, 2400x

The interesting property of the mixture of starch and a little water is the fact, that during stirring (force application) the liquid mixture starts to behave as a solid material, but just for the duration of the force application..

After ending the force application the solid becomes liquid again and we can observe how the "solid" is melting back to liquid.

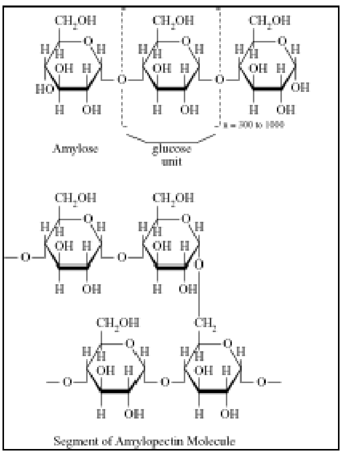
Another remarkable property to be mentioned; immerse your finger into the glass with the mixture very quickly and you will find out that it's simply impossible, because you bump into the hard upper level of the mixture. On the other hand, if you immerse your finger slowly, you can easily reach the bottom of the glass.

Account for this effect?

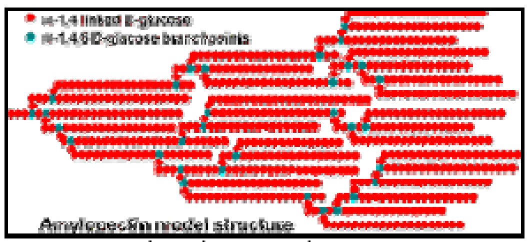
Water penetrates into the molecules of starch and creates hydrogen bonds with free hydroxides. Although this suspension has a high viscosity, it is possible to immerse objects with high density into it. But how is it possible that the mixture seems to be solid for a while? We can say that the starch corns in the mixture of starch and water are freely floating surrounded by water. If we apply mechanical force, the water iscrushed out, the starch corns join and create an impression of a solid material. But if themechanical force is small, the corns can freely move and the water acts as a lubricant.

It is easier to explain this effect on the microscopic structure of starch. Starch consists of two different polymeric polysaccharides – amylose (30%) and amylopectin (70%).

While amylose is linear and is made of few thousands of monomers, the structure of amylopectin isbranched and can be made of millions monomers. Molecules of water which are between the chains of amylose and amylopectin are during the force application crushed out and the chainswedge. The hydrogen links are forming and the structure of amylopectin is misshaped.   It results in growth of the viscosity – this happens just for the duration of the force application.After ending the force application, the solid becomes liquid again. The bigger force we apply, the bigger viscosity and more solid properties we get



structure of amylose and amylopectin



amylopectin structure in space

This property is called **rheopecticity**. The suspension owing to the movement (stirring, crumpling, shaking) becomes solid but at ease it becomes liquid again.

The better known property is **thixotrophy** – which is the opposite effect to rheopecticity. All of us know ketchup – at ease it's solid, you can't get it out of the bottle but after shaking it becomes liquid.

This means that the viscosity of starch during stirring increases so much that the mixture seams to behave as a solid material.

What is the definition of viscosity and rheopecticity? **Viscosity** is a measure of the resistance of a fluid to deformation under shear stress. It is commonly perceived as"thickness", or resistance to pouring. Viscosity describes a fluid's internal resistance to flowand may be thought of as a measure of fluid friction.

Rheopectic fluids are a type of non-Newtonian fluids. Rheopecticity shows a time dependant change in viscosity; the longer the fluid undergoes shear, the higher its viscosity. Rheopectic fluids are a rare type of fluids, in which shaking for time causes solidification.

How to measure viscosity using different force and intensity of the mechanical force in order to prove the increase of the viscosity?

The best how to do it is to use Stokes's figure for resistance force acting on the ball during drawing through the liquid.

$$F = 6 \pi \eta R v$$

We measured viscosity using drawing an iron ball in a mixture of starch and a little water with a constant force application, which we kept with a help of dynamometer.

Because we drew the ball in a volumetric cylinder, instead of **v**
into the figure we had to institute

$$vl = vm (1 + 2,4 R/RT)$$

where vl is the velocity of drawing after Landerburg's correction and
vm is the measured velocity.

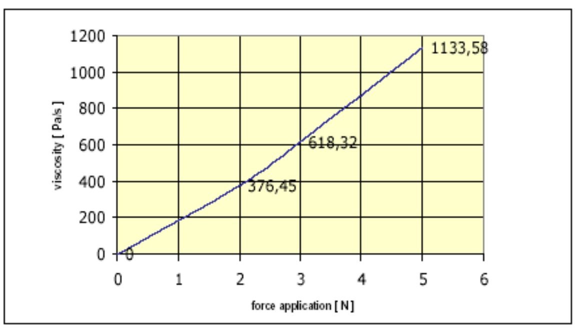
In our case::

At first we measured the velocity of starch during the force application of 2N. Average time of this measurement was t = 9, 13 s, we used this data for a calculation of the viscosity.

After calculating vl and institution into the figure for viscosity we got a viscosity 376, 45Pa/s.

During the force application of 3N and t = 10s calculated viscosity was 618, 32 Pa/s.

During the force application of 5N and t = 11s calculated viscosity was 1133, 58 Pa/s.



viscosity dependence on the force application

This experiment proved that during stirring (=force application) the viscosity of starch is increased. The bigger force we apply, the bigger viscosity we get.

Other values we used for the calculation:

RT= 0,045 m

s = 0, 13 m

r = 0,012 m

For our experiment we used a suspension of water and potato starch in weigh ratio 1: 1.

Other interesting property is that this effect occurs when the proportion of the amount of water and starch is 1: 1. If using more water for the mixture, this surplus water separates from the mixture on the bottom of the glass after some time. The arisen mixture has perfect rheopectic properties.

The same effect doesn't occur only during stirring but it also appears while shaking or crumpling. Other common substances that demonstrate this effect are all rheopectic substances, for example asphalt, gum arabic, mud or gypsum.

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