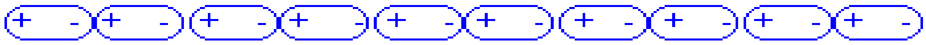
Mpemba Effect

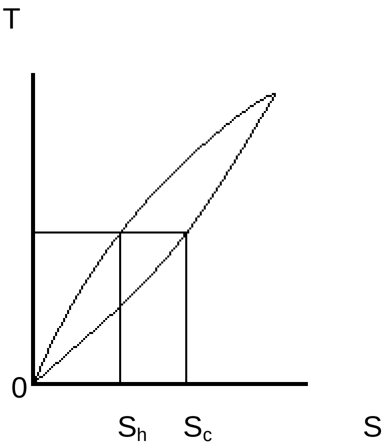
We use natural mineral water pure in salts, so we can assume that the effect of the dissolved ions is negligible. It is known that water molecules are electric dipoles V-shaped. Cold water has a rudimentary "structure" where these dipoles are positioned and oriented next to one another by their opposite charges face to face. They are joined by hydrogen bonds to form straight chains:



The hydrogen bonding percentage may vary till over 80%. When water is heated bonds are broken and molecules are removed from each other and randomly repositioned, so the structure collapses. The H-bonding percentage decreases. This is called increasing entropy (S).The increase of entropy (dS) after water is heated from a lower temperature T_1 to a higher T_2 is:

$$dS=mc\ln(T_2/T_1)\ ,\qquad m=\text{water mass},\quad c=\text{special heat}$$

If after the water is cooled to lower temperature the structure is not reconstructed immediately but it is needed some time in calm to be done. **Sometimes** this time is not available inside a freezer because the cooling process is fast. Inside a fridge when reaches and stabilize at the temperature of the refrigerator (5 ^{o}C) water will find the time to restore its structure. So, when the water is cooled at the initial low temperature its structure is not instantaneously fixed to the initial situation, or in other words, its entropy is not decreased immediately. During the cooling process, water's structure is not momently returns to the neat condition. Hydrogen bonds are not reconnected at once. The entropy reduction curves function of temperature S=f(T) appear retardation (lagging) relative to entropy growth curves. At any temperature point T entropy during heating S_h is less than entropy during cooling S_c.



Thereby now the water, after is heated and recooled at the starting temperature, has more entropy than witch it has before it is heated. Also, the hydrogen bonding percentage is less than before it is heated. At any temperature point T the heat capacity mc=S/lnT during cooling is more than this during heating. Thereby, special heat coefficient c is bigger in the first case.

Suppose that we have two jars contains the same quantity of water at the same temperature (T) but the one (A) has more entropy than the other (B). This means that molecules of both jars have the same energy, but inside A they are moving to all directions whereas inside B thermal motion is more oriented by the structure mentioned above. So, in the case of A random collisions are more possible than in the case of B. The random collisions cause molecules loosing average kinetic energy (E), which means temperature's reduction: E=(3/2)bT, b=Boltzmann constant. Therefore, water A is cooling faster than B.

It is known by Newton's Law of Cooling that during cooling of a material body the rate of temperature decrease is proportional to temperature (T):

$$dT/dt = -kT \Rightarrow T = T_0 e^{-kt}$$

t=time, k=coefficient of temperature change, T_0=initial temperature

half time period (HTP) = ln2/k

Now, let's do an experiment. We simultaneously put in a freezer three bottles of water A, B and Γ with exactly the same quantity in each of them. The temperature of A is at 50 ^oC, B and Γ at 35 ^oC. B was taken at ambient temperature the summer. Γ was heated to 50 ^oC before is cooled down to 35 ^oC. After a time period we observe that A and Γ simultaneously reaches 0 ^oC earlier than B. A and Γ followed the same process. Coefficient k is the same for A and Γ and is bigger than that of B. Halftime period is the same for A and Γ but lower than that of B.

The experiment was conducted in the laboratory of the Argolida regional quality control center. The lab meets the requirements of the standard ISO/IEC 17025:2005 since 2009. Accreditation Body: ESYD S.A., certificate number: 609

I used commercial PET bottles 500 ml filled with 500,00g distilled water. The water Γ was warmed up and left to cool down. Water A was warmed up. Right away after these they were entered the bottles. The bottles then were immediately entered the freezer remaining until water content was cooled down to 2 ^oC. The procedure and results are shown concisely in the table below:

type of samples	average weigh (g)	freezing duration (min)	standard error (min)
Γ	500,006	82	1
B	500,001	90	2
A	500,003	81	3

Number of samples=10 per type (total 30).

If there are many dissolved salts water's structure differs because the ions are hydrated. Consequently chains are smaller and orientation of the molecules is less of pure water. So the phenomenon occurs reduced.

REFERENCES

"The structure of water; from ambient to deeply surercooled"
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