

TEACHING OF PHYSICS IN SCHOOLS WITH HELP OF EXPERIMENTS OF FOOD INVESTIGATION

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Abstract. Teaching of physics (and other branches of natural science, like chemistry, biology) in the schools the experiments are of primary importance (Sprott, 2015). The pupils are satisfied if the investigated materials are food samples, wellknown for them. The paper deals with 3 simple experiments of physical type. The following foodstuffs were investigated: sugar, salt, apple, potato, lemon, egg. For teaching the following experiments were prepared and carried out (Szabo et al., 2015), (Bozi et al., 2016), (Szabo, Izsak, 2016):

boiling point measurement in case of sugar and salt (NaCl) solutions for determination of the concentrations

creation of galvanic battery using agricultural products, like lemon, potato or apple

differentiation between raw (crude) fresh egg and boiled (cooked) egg without cracking (breaking) the egg shell

BOILING POINT MEASUREMENT IN CASE OF SUGAR AND SALT SOLUTIONS

The practical aim of such type measurements can be the determination of the concentration. These experiments show not only the energy-demand (boiling is an endotherm process) of state changes, but the fact that the boiling point is a function of concentration of liquids, as well. If the concentration of salt (NaCl)

and sugar ($C_{12}H_{22}O_{11}$) is high enough (over 10 %) , it is possible even with simple ordinary stick thermometer to show the increase of boiling point of solutions in the a volumetric flask in comparison with tap water used for the preparation of the solutions (Picture 1).

Table 1 shows the solubility of sucrose and NaCl as a function of temperature, and table 2 informs about some sugar-type carbohydrates.



Picture 1
 Measuring set for boiling point determination

Table 1: Solubility of NaCl and sucrose

Substance	Solubility g/100 g solvent		
	15 °C	20 °C	25 °C
NaCl	35,9	36,0	36,2
sucrose	66,3	67,1	67,9

Table 2: Some sugar-type carbohydrates (mono- and disaccharides)

name	composition	found in
glucose	$C_6H_{12}O_6$	grape
fructose	$C_6H_{12}O_6$	fruits
sucrose	$C_{12}H_{22}O_{11}$	sugar beet
lactose	$C_{12}H_{22}O_{11}$	milk
maltose	$C_{12}H_{22}O_{11}$	beer

(chemically cane sugar, beet sugar, palm sugar are identical)

The boiling point of the solvent above a solution will be greater than the boiling point of the pure solvent whether the solution contains a non-volatile solute or a volatile solute. However, for simplicity, only non-volatile solutes will be considered here.

Experimentally, we know that the change in boiling point of the solvent above a solution from that of the pure solvent is directly proportional to the molal concentration of the solute:

$$\Delta T = K_b m$$

where:

ΔT is the change in boiling point of the solvent,

K_b is the **molal boiling point elevation constant**, and

m is the molal concentration of the solute in the solution.

Note that the molal boiling point elevation constant, K_b , has a specific value depending on the identity of the solvent.

The graph (Fig. 1) shows the normal boiling point for water (solvent) as a function of molality in several solutions containing sucrose (a non-volatile solute). Note that the normal boiling point of water solution increases as the concentration of sucrose increases.

It is appropriate to point out the following:

1. from point of view of concentration we should differentiate

unsaturated, saturated and oversaturated solutions

2. the rate of dissolution of different materials is different, therefore there is a difference between the concentration of the saturated solutions of salt and sugar substances

3. the temperature of boiling depends on the air pressure, so when the experiment is carried out on altitudes, significantly higher (e.g. the top of the Matra, appr. 1000 m above sea level) the measured boiling point would be definitely lower.

4. the concentrations and the boiling points are well correlated, so using calibration curve (or table data) based on the boiling point measurements the degree of concentration can be calculated

5. the concentration of the solution affects not only the boiling point, but affects the freezing point, as well (the sea water does not freeze at 0 ° C), however the freezing point is not a function of air pressure

6. for determination of concentrations not only the boiling point increase, but also the freezing point decrease is suitable, so using this technique you can detect for example the milk adulteration (application of precision thermometer is necessary)

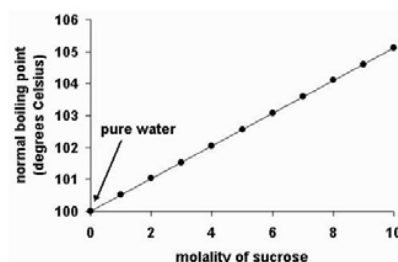
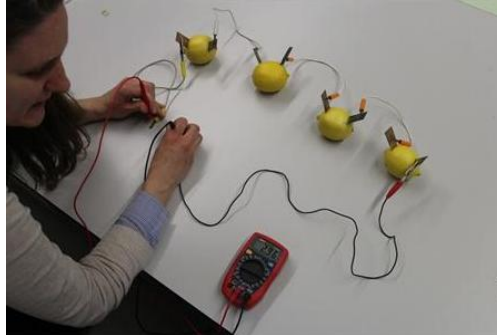


Figure 1
Boiling point as a function of molality



Picture 2
Galvanic battery with lemon

Table 3: Electrode potentials (V)

metals	potentials in Volt
Mg/Mg^{2+}	- 2.38
Al/Al^{3+}	- 1.70
Zn/Zn^{2+}	- 0.76
Fe/Fe^{2+}	- 0.44
Pb/Pb^{2+}	- 0.12
Cu/Cu^{2+}	+0.34
Ag/Ag^+	+0.80
Hg/Hg^{2+}	+0.85
Au/Au^+	+1.50

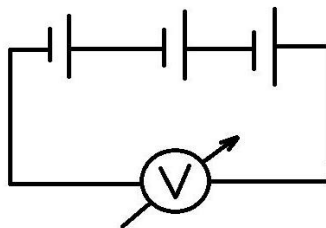


Figure 2
Cascading several galvanic units

CREATION OF GALVANIC BATTERY USING AGRICULTURAL PRODUCTS

Thanks to Italian natural scientists Luigi Galvani (1737-1798) and Alessandro Volta (1745-1827) the so-called galvanic battery is known already more than 200 years, which has become known as an electric power source. The essence of the principle was the recognition that if two different metals are put in alkaline or acidic or salty solution, containing ions, then a voltage difference is created between them. How large is the voltage difference this can be calculated, based on the electrode potentials, shown as the Volta's voltage line. Voltage is about the order of 1 V. The electrode potentials You can see in table 3.

The creation of the test equipment - that is, the galvanic battery - is very simple, we insert into a lemon (or apple or potato) on the opposite sides a copper and zinc plate (the 2 electrodes) and close the circuit! The set is on the picture 2. The produced potential can be measured by a voltmeter, the electricity by an amperometer or to put into the circuit a small flashlight bulb. So even we can enjoy the recognition of enthusiastic pupils that a natural light source has been created. Fig. 2 shows the cascading several galvanic units.

We should call the attention to the following:

- lemons, potatoes, apples represent in this case the electrolyte, that is a solution in which ions (cations and anions) are. Ask the pupils what kind of ions can be expected in foodstuffs! (The clever pupils surely will mention e.g. potassium

and calcium cations and chloride, citrate and phosphate anions)

- The water content of these raw food electrolytes are approx. as follows: 76% potato, 90% apple, 89 % lemon. Mineral content (what is called practically as ash content) is the following: potato – 1.1 %, apple - 0.4%, lemon - 0.6%.
- Ask the question, is the value of the produced voltage affected in what product (food) the electrodes were inserted?, That is to say, does it change the voltage e.g. in the case if instead of apple or lemon pears or oranges are used?
- If we have time to carry out the experiment also with other metals (e.g. iron, silver, aluminum), we should point out the difference between the electrode potentials, hence the differences between the developed voltages.
- Be sure to mention that cascading several galvanic units (batteries connected in line) the voltage can be increased

DIFFERENTIATION BETWEEN RAW (CRUDE) FRESH EGG AND BOILED (COOKED) EGG WITHOUT CRACKING (BREAKING) THE EGGSHELL

If for some reasons you accidentally mixed the raw and the cooked eggs, it is rather easy to distinguish between them with a simple physical method. Try to spin the eggs (with about the same weight) appr. with the same power on the table or other flat surface. The spin is performed holding the eggs between the

index finger and thumb bringing the eggs successively into motion. Picture 3 shows the spinning of eggs, using for measurement a chronometer.



Picture 3
Spinning of fresh and boiled eggs

It can be measured well, that cooked eggs will spin for a longer time, however in case of raw eggs the spin time is significantly shorter. Eg. 20 seconds in the first case and only 12 seconds in the second one. Let's try to interpret the cause of the difference!

The difference is due to the situation, that boiled eggs - physically - behave as a rigid body, where the positions of each mass points are fixed. The time of rotation depends on the spin strength, egg weight and the friction between egg and table, however the drag (air resistance) is negligible. On the other side the raw egg considered as a system in which the white and the yolk (as viscous fluids) do not rotate together with the eggshell, and strong enough friction occurs between the fluid and the solid shell. This friction slows down the rotation, that is, outside of

the friction between the table and egg shell acts further a braking force of friction between the liquid part of the egg and the egg shell.

Finally let us mention that the energy of rotation is a function of the geometric parameters of the objects, with mass m and angular velocity ω . The energy of rotation:

$$E_r = \frac{1}{2} J \omega^2$$

where:

J – inertia momentum

$$J = \sum_{i=1}^n m_i \cdot r_i^2$$

Data for the J inertia momentum as a function of geometry of the objects are shown in table 4.

Table 4: Inertia momentum as a function of geometry

geometry	inertia momentum
globe	$m r^2$
cylinder	$m R^2$
pipe	$m (m R^2 + r^2)$

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REFERENCES

J. Bozi, A.S. Szabo, M. Izsak, E. Tisza-Kosa, G.L.Szabo: Teaching chemistry, biology and physics with the help of food analytical experiments. *J. Food Investigation*, 62(1), 990-995, 2016.

L.O. Figura, A. A. Teixeira: Food physics, Physical properties, Measurement and applications. Springer Verlag, 2007, p. 550.

Cl. Sprott: Physics experiments that you can do at home. The wonders of physics. University of Wisconsin, Madison, <http://sprott.physics.wisc.edu./wop.htm>

N. Svyetlova, A.S. Szabo, P. Laszlo: Physical methods for investigation of plants and foodstuffs of plant origin. *J. Food Physics*, XI-XII., 63-68, 1998-1999.

A. S. Szabo, P. Laszlo, P. Tolnay: Importance of food physics, to fulfill the expectations of modern food technologies. *J.Food Science Eng.*, 3(4), 169-175, 2013, serial number 21.

A. S. Szabo, M. Izsak, J. Bozi: Teaching of chemistry and physics in elementary and high schools with help of food science experiments. *J. Food Investigation*, 61(2), 647-656, 2015.

A.S. Szabo, M. Izsak: Teaching of physics in schools with help of experiments of food investigation. XIIth Int. Conf. of Food Physicists, 6-8 July, 2016, Debrecen, University of Debrecen, Program and abstract book, ed. P. Sipos, I. Fekete, p.27.