Ministry of Health of Ukraine
Ukrainian Medical Stomatological Academy

It is approved
on meeting of department of
medical informatics, medical and biological physics
27 August 2020
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Head of department _____ O.V.Silkova

Methodical instructions
for students' self-preparation work at preparation for a practical lesson
at home and at the classroom

Subject matter	**Medical and biological physics**
The unit	1. Fundamentals of higher mathematics and biological physics
Theme of lecture:	**Surface phenomena. Determination of a surface tension coefficient of a fluid. A gas embolism.**
Year	1
Faculty	Medical
Speciality	Medicine

Poltava - 2020

The topic significance:
Surface tension coefficient is one of manifestations of atoms and molecules interactions. It is very important for future doctors in their professional activity, positively influences the students in their attitude to the future profession, forms professional skills and experience as well as taking as a principle the knowledge of the subject learnt.

Specific targets:
1. To have general knowledge of the topic studied;
2. To understand, to remember and to use the knowledge received;
3. To form the professional experience by reviewing, training and authorizing it;
4. To be able to carry out laboratory and experimental work, measurement of the surface tension coefficient of solutions.

Basic knowledge, experience, skills necessary for studying the topic in connection with other subjects:

Disciplines	Obtainable skills
Previous (providing disciplines): physics	To know basic concepts of: atoms and molecules interactions. To describe them. To describe electrokinetic appearances, membrane's pumps work, membrane's permeability
The subsequent disciplines: Normal physiology	To know physical bases of ***surface tension, watering, nonwettabillity,*** capillary phenomena, surface-active materials action, embolism. To explain mechanism of medical appearances based on atoms and molecules interactions. To name and explain meaning of methods of the surface tension coefficient measurement.

	To explain relationship between the weight of the drops and the surface tension.

List of main term, parameters, characteristics, which student have to learn at preparation to class:

Term	Definition
Surface tension	Effect on a fluid surface, which behaves like an elastic membrane which wraps and compresses the below liquid.
Watering	Appearances on the border of three phases (liquid, solid, gas). The watering (dampening, damping, wetting) is watched, when the attractive forces between molecules of a fluid and molecules of a solid surface are more than attractive forces between molecules of a fluid.
Nonwettabillity	Nonwettabillity is inverse effect to watering.
Capillary phenomena	Results of wetting and nonwettabillity in thin pipes.
Meniscus	The curved surface of a fluid at the border of three phases.

Theoretical questions to class:

1. Meaning of surface tension.
2. Coefficient of surface tension.
3. Methods of the surface tension coefficient measurement.
4. Methods of the falling drop for measurement surface tension coefficient.

Practice work executed at class:

Measurement of the surface tension coefficient of alcohol solutions by method of falling drop.

Recommendations

1. Close the burette tap. Fill burette [dropping glass] with water.
2. Unclose the tap with care. Remove air which has accumulated in tip of dry burette under a layer of instilled fluid. The fluid should stream enough slowly, that you had time to count falling drops.

Calculate how many drops of water in 1 cm^3.

3. Repeat experiment 3 times.
4. Fill capillary with alcohol solution.

Preferably to utilize the dry pure pipette. Layer of solution remain on walls of the pipette. It is immixed with an added new solution and varies its composition and concentration. The cause is the effect of watering [damping, dampening, wetting]. Wash off the pipette by a new added solution to minimize effect of interfusing before every measurement.

5. Calculate how many drops of alcohol in 1 cm^3.
6. Repeat experiment 3 times.
7. Put data on the table:

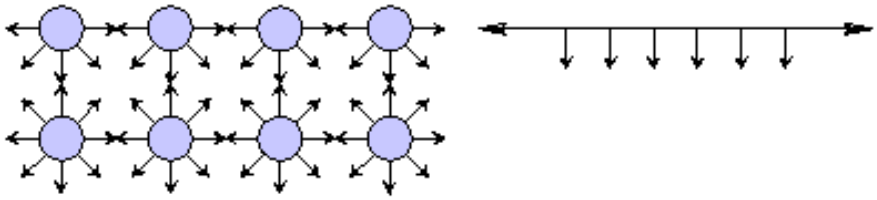
N	Amount of drops			Density, kg/m^3			Surface tension coefficient, N/m		
	water, n_1	alcohol solution		water, ρ_1	alcohol solution		water, σ_1	alcohol solution	
		n_2 (60%)	**n_3 (80%)**		**ρ_2 (60%)**	**ρ_3 (80%)**		**σ_2 (60%)**	**σ_3 (80%)**
1									
2									
3									
Mean									

Contens of the topic.

On the interface of two phases (liquid and it's saturated steam, liquid and solid, liquid and gas, two immiscible liquids) a force directed to one of phases is discloses. It is resultant of interatomic forces of both substances.

Any solid or fluid material maintains the volume due to equilibrium between forces of an interatomic attraction and repulsion. Thus with magnification of interatomic distance of attractive forces accrue faster, than repulsion forces, and at approach of atoms - on the contrary. It provides maintenance of integrity of volume of material, and in solid bodies where attractive forces provide smaller, than in fluids, interatomic distances, - and maintenance of the shape. In gases of force of a repulsion prevail above attractive forces. With increase of temperature velocity thermal motion of atoms increase too, that gives relative impairment of effect of attractive forces, magnification of volume of material, phase transitions a solid body – a fluid – gas.

A molecule of a liquid attracts the molecules which surround it and in its turn it is attracted by them (fig. 1). For the molecules which are inside a liquid, the resultant of all these forces is neutral and all they are in equilibrium by reacting with each other. When these molecules are on the surface, they are attracted by the molecules below and by the lateral ones, but not toward the outside (toward the gas molecules). The resultant is a force directed inside the liquid. In its turn, the cohesion among the molecules supplies a force tangential to the surface. So, a fluid surface behaves like an elastic membrane which wraps and compresses the below liquid. The ***surface tension*** expresses the force with which the surface molecules attract each other. A way to see the surface tension in action is to observe the efforts of a bug to climb out of the water. On the contrary, other insects, like the marsh treaders and the water striders, exploit the surface tension to skate on the water without sinking.



The surface tension coefficient σ of the liquid can be determined from the energy expended for creation of some liquid surface to area of this surface: $\sigma = A/S$.

If to analyse force that influences onto the some contour of restricted part of liquid surface, the surface tension coefficient σ of the liquid will be given by the detachment force F divided by contour length l: $\sigma = F/l$.

The surface tension descends with temperature increase.

Here are some simple experiments using surface tension:

The floating needle. Carefully place a needle on the surface of a glass of water (fig. 2). If the water does not completely wet it, you will see the needle float. To avoid your fingers disturbing the surface as you place the needle, you can make a small cradle from wire to hold the needle as you lower it gently on to the surface of the water. Another way to make it easier to float an object heavier than water using only the surface tension is to first float a strip of tissue paper and lay the needle on it. Slowly, the water will soak the strip, which will eventually sink, while the needle will remain on the surface.

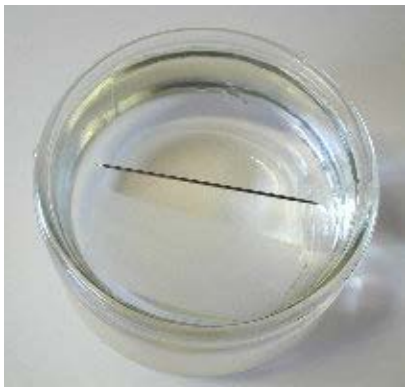


Fig.2. The floating needle

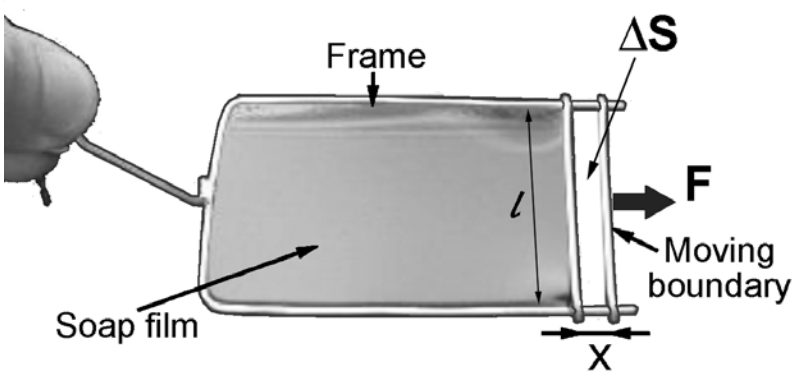


Fig.3. Soap film.

The strength of the soap films. With some iron wire, make a "U" frame and a slider, as shown by the fig. 3. Plunge the frame in soapy water. When you extract it, you will see that the slider will be drawn toward the bottom of the frame by the surface tension of the soap membrane. By holding the slider still with your fingers, you can feel the force of the membrane. In this case, moving work (and surface energy accumulated in added surface owing to this work) is A=F•x, increase of area is ΔS=2x•l, and surface tension coefficient σ=A/(2•ΔS), or, as in previous formula, σ=F/(2l). Index 2 signifies that in this experiment two surfaces of both sides of soap film form surface tension forces.

For example, at t=20°C for water σ=0,0725 N/m^2, for blood serum σ=0,06 N/m^2, for mercury σ=0,47 N/m^2.

Appearances on the border of three phases (liquid, solid, gas) have general name ***watering***. Free surface of liquid nearby solid surface is distorted. The curved surface of a fluid is termed a ***meniscus***. Watering effect is characterized by limiting wetting angle ϑ (fig.4).

The ***watering (dampening, damping, wetting)*** is watched, when the attractive forces between molecules of a fluid and molecules of a solid surface are more than attractive forces between molecules of a fluid. In this case $\vartheta<\pi/2$. Solid surface is named hydrophilic (in relation to water – carbonates, quartz).

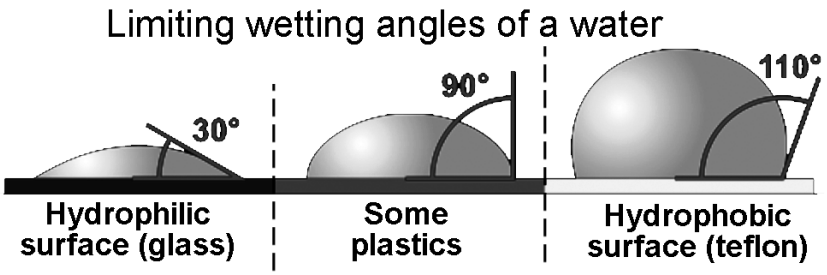


Fig.4. Limiting wetting angles at different substances.

Nonwettabillity is inverse effect. It is observed, for example, when you drip water on fatty surface or drip oil on teflon frying pan. At that drops roll into small balls, which are slightly flat as a result of influence of gravity. Drops of nonwetting liquid don't spread on the surface. Drops of wetting liquid spread on the surface and cover it by continuous layer. In this case $\vartheta>\pi/2$. Solid surface is named hydrophobic (in relation to water – clear metals, graphite).

Surface-active materials are named detergent also. In water solution the surface-active materials provide for magnification of effect of watering, promote separation of dirt molecules from cleaned object thanks to magnification of interaction forces between them and detergent solution. Soap is surface-active substance.

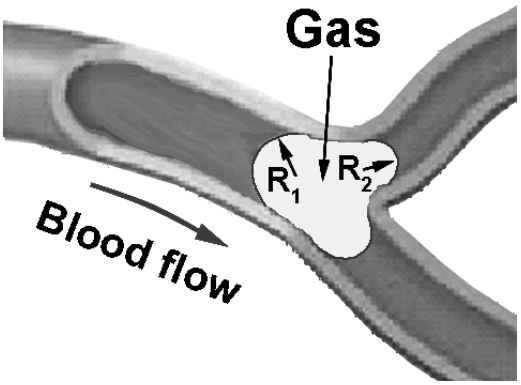


Fig.5. Gas embolism.

The curved surface of a fluid is termed a ***meniscus***.

Capillary phenomena are results of wetting and nonwettabillity.

Capillary phenomena are observed in tubes of small diameter in which limiting wetting angles

are comparable to radius of a tube. Limiting wetting angle θ can be deternined under the formula which takes into account forces of interaction fluid - gas (σ_{12}), fluid - solid material (σ_{13}) and solid material - gas (σ_{23}): $\cos\theta = (\sigma_{13} - \sigma_{23})/ \sigma_{12}$.

The fluid in the capillar can rise (at wetting) or to sink (at an unwettability). The height of a raising (sinking) of the fluid is determined under the formula:

$h = 2\sigma_{l\text{-}g}\cos\theta/(R\rho g)$, where R - radius of the capillar, ρ - density of a fluid, g - a free fall acceleration.

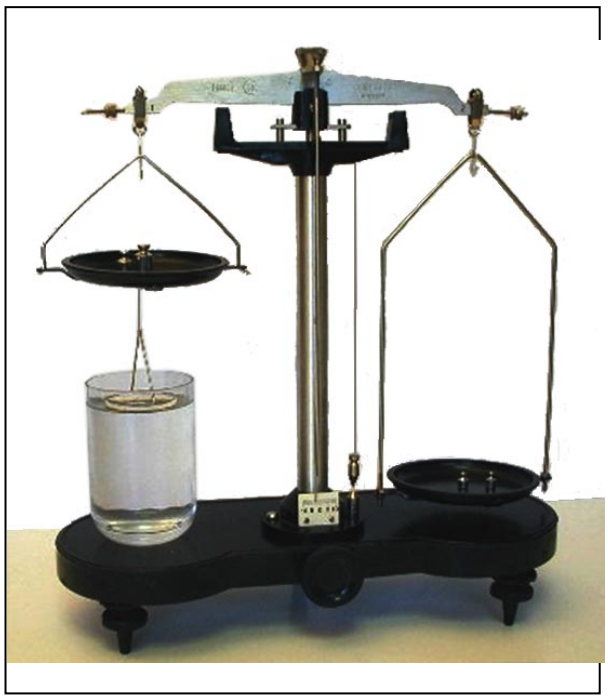
Contortion of surface layer carryes to appearance additional pressure onto the liquid, which depend on surface tension coefficient σ and curvature of surface. If menisc is spherical surface $P = 2\sigma/R$; in bubble with radius R: $P = 4\sigma/R$.

Capillary phenomena are observed when bandage absorbs liquid, plants absorb water with solutes from ground.

Dangerous phenomenon is formation of gas or fat bubbles in blood vessels, that is named embolism. Embolus can cork up small vessel and to hinder from blood supply of some organ or, if amount of emboli is large, to make worse oxygenation and metabolism in whole organism. Embolus can be formed of air (after incorrect injections), fat (incorrect injections, bone marrow penetrated into blood after trauma), nitrogen (decompression or caisson sickness) made bubbles at fast raising of diver and so forth. Nitrogen has low solubility in water and blood at low pressure and high solubility at high pressure. It is dissolved during sinking and turn into gas during raising. If raising is fast, lungs have not time to evolve nitrogen into outer air. Emboli can hamper or completely stop blood flow in the vessel. In places of vessel division radii of two parts of embolus diminish; pressure $P = 2\sigma/R_2$ from the side of smaller vessels is more, than from the side big vessel $P = 2\sigma/R_1$. If it is more, tham sum of blood ans big surface pressures, blood movement is stopped. If it is in big vessel - infarction of the tissue or insult is result.

Method of ring detachment. To measure the surface tension of liquids, you can use a metal wire ring of the diameter comprised between 3 and 4 cm. Ring wire diameter should be of 1–2 mm. In this case an analytical balance should be used.

Dip the ring just under the surface of the examined liquid, which surface tension will be determined. Level the balance in these conditions. Add some masses on the opposite arm until the ring detaches from the liquid. The surface tension (***σ***) of the liquid will be given by the detachment force (***F***) you have measured divided by two times the mean circumference of the ring:



$$\sigma = \frac{F}{2 \cdot 2\pi r}$$

This index 2 takes into account the two surfaces of liquid: the internal one and the external one to the ring (figure 5). For reasons of clarity, in the figure the ring has been drawn with the diameter greater than the actual diameter.

Relationship between the weight of the drops and the surface tension. This method uses in medicine. By a dropper, slowly drop some water and determine the mass of drop. When drop fall its weight is equal to force of surface tension:

$F = P$, $P = mg$, $2\pi r\sigma = mg$, therefore

$$\sigma = \frac{mg}{2\pi r}.$$

If $\sigma_1 = \frac{m_1 g}{2\pi r}$ – surface tension coefficient for water; $\sigma_2 = \frac{m_2 g}{2\pi r}$ – surface tension coefficient of alcohol, then:

$$\frac{\sigma_1}{\sigma_2} = \frac{m_1 g}{m_2 g} = \frac{V\rho_1 g n_2}{V\rho_2 g n_1} = \frac{\rho_1 n_2}{\rho_2 n_1},$$

where m_1 – mass of water drop, m_2 – mass of alcohol drop, ρ_1 – density of water, ρ_2 – density of alcohol, n_1 – number of water drops in volume V, n_2 – number of alcohol drops in volume V.

Therefore surface tension coefficient of alcohol is equal to:

$$\sigma_2 = \frac{\sigma_1 \rho_2 n_1}{\rho_1 n_2}.$$

Self-control material:

A. Questions and statements to be answered:

1. Drop size in moment of it's separation from capillary do not depend on...
2. Drop weight in moment of it's separation from capillary do not depend on...
3. How a surface tension index depends on a temperature?
4. How surface–active materials are influence on surface tension index?
5. How to calculate the surface tension index (σ) of the liquid by the detachment force (F) in method of the ring detachment ?
6. In methods of falling drops the surface tension coefficient of examined liquid is calculated by formula:
7. In moment of the drop separation in time of surface tension index measuring …
8. Liquid surface tension is increased after adding of:
9. Method of ring detachment consists in…
10. Physical value equal to a surface tension accounts for an unit of the liquid free surface is
11. Physical value equal to force, which act on unit of surface contour length, is…
12. What is a cause of a surface tension?
13. What is a cause of capillary phenomena?
14. What is a cause of dampening?
15. What is a measure of a watering?
16. What is a meniscus?
17. What is a name of the curved surface of a fluid in capillary?
18. What is a name of vessel corking (stopping up) by gas bubble or insoluble liquid drop?
19. What is additional pressure onto the liquid due to spherical meniscus with radius R?
20. What is additional pressure onto the liquid in bubble with radius R ?
21. What is the formula of determination of limiting wetting angle θ (here forces of interaction σ_{12} – fluid - gas, σ_{13} – fluid - solid material and σ_{23} – solid material - gas)?
22. What is the formula of determination of the height of a raising (sinking) of the fluid in the capillary (here R – radius of the capillary, ρ – density of a fluid, g – a free fall acceleration, $\sigma_{l\text{-}g}$ – fluid – gas surface tension coefficient)?
23. What is unit of surface tension index?
24. What is unit of surface tension index?
25. What is value of a limiting wetting angle ϑ at a nonwettabillity?
26. What is value of a limiting wetting angle ϑ at a watering?
27. What is value of a surface tension index at t=20°C for blood serum ?
28. What is value of a surface tension index at t=20°C for water?
29. What material does not form embolus in blood vessel?
30. When drop fall its weight is equal to force of surface tension calculated by formula:
31. Why a liquid drop gets spherical shape in zero gravity?
32. Why free surface of liquid nearby solid surface is distorted?

33. Why Nitrogen can call caisson sickness?
34. What of parameters influence on liquid surface tension coefficient?
35. What of sicknesses is result of surface tension effects?
36. In which appearances surface phenomena are not represented? Are represented?

B. Tasks to be done

Liquid surface tension is increased after adding of:

1. surface–active material
2. NaCl
3. electrolyte
4. sugar
5. soap

In moment of the drop separation in time of surface tension index measuring …

1. Drop weight is equal to surface tension force
2. Drop weight is equal to zero
3. Drop weight is less then surface tension force
4. Drop weight is more then surface tension force
5. Drop mass is equal to zero

Drop size in moment of it's separation from capillary do not depend on...

1. surface tension index
2. liquid density
3. viscosity index
4. capillary diameter
5. gravitational acceleration

Drop weight in moment of it's separation from capillary do not depend on...

1. liquid nature
2. viscosity index
3. surface tension index
4. capillary diameter
5. gravitational acceleration

Why a liquid drop gets spherical shape in zero gravity?

1. That a sphere has minimal volume
2. That surface tension is absent in zero gravity
3. That pressure is absent in zero gravity
4. That weight is absent in zero gravity
5. That a sphere has minimal surface

What is a name of vessel corking (stopping up) by gas bubble or insoluble liquid drop?

1. entropy
2. emaciation
3. plugism
4. embolism
5. floatism

Choose correct name of effect: attractive forces between molecules of a fluid and molecules of a solid surface are less than attractive forces between molecules of a fluid:

1. Nonwettabillity
2. Watering
3. Dampening
4. Wetting
5. Damping

Literature recommended

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Methodical elaboration have prepared by senior lecturer, PhD Biol.Sc. Korovina L.D.