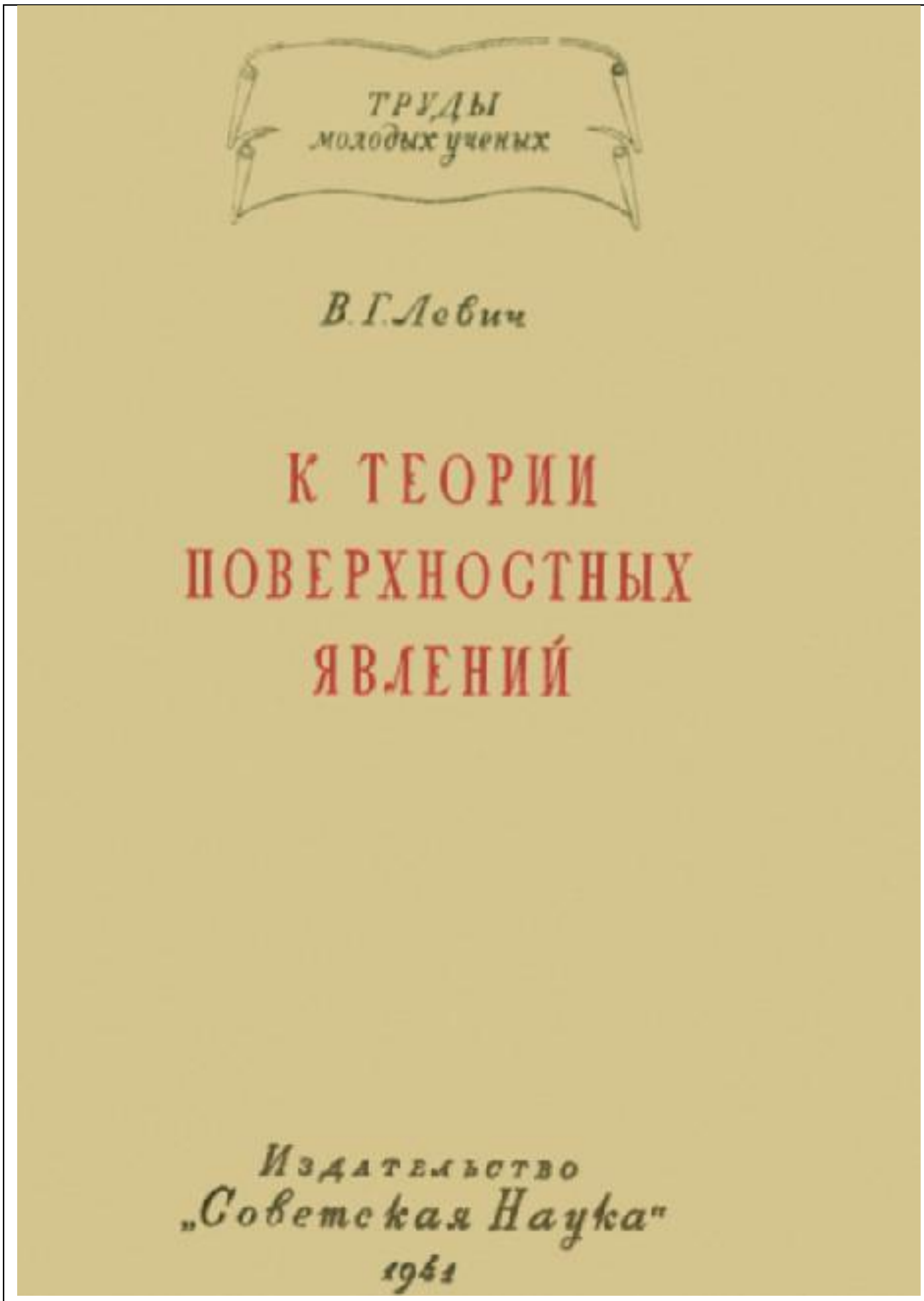
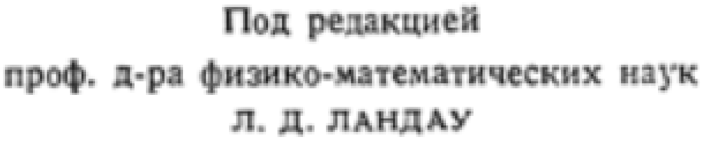
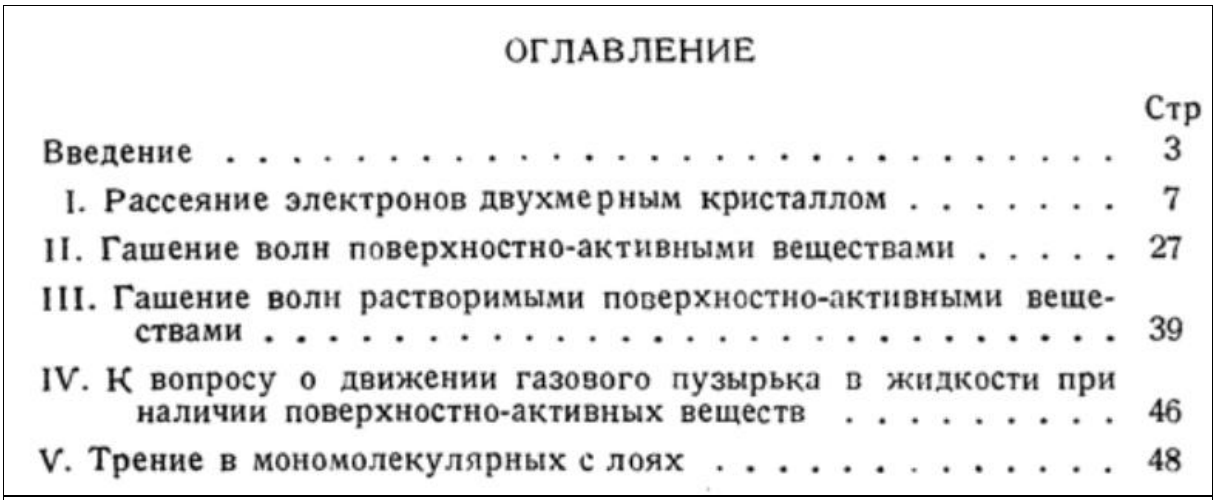
Full text in Russian containing all Eqs is available at

http://heritage.jscc.ru/Book/10077564

 ТРУДЫ молодых ученых В. Г. Левич К ТЕОРИИ ПОВЕРХНОСТНЫХ ЯВЛЕНИЙ Издательство „Советская Наука“ 1941	*Works of young scientists* *V.G. Levich* On the theory of interfacial phenomena *Soviet Science Publ.* *1941*
 Под редакцией проф. д-ра физико-математических наук Л. Д. ЛАНДАУ	Editor Prof Dr of Physics and Math L.D. Landau

A number of results presented in this book are published in two early Levich's articles (1940, 1941) and later in his "Physico-chemical hydrodynamics" book, mostly in Chapter IX.



ОГЛАВЛЕНИЕ

CONTENT

Introduction

As it follows from the title, this work is devoted to some issues of the theory of interfacial phenomena. Namely, some properties of surfactant films deposited at the surface of liquid are considered.

The studies of Rayleigh, Langmuir, and a number of other authors [1] demonstrated that such films present the specific peculiar state of the substance. Interfacial films are formed when organic substances are put to the surface of water, which are the molecules having a long hydrocarbon chain and also active groups (COOH in acids, and OH in alcohols). Due to attraction between water and active groups, the latter find themselves in the liquid. Contrary, hydrocarbon chaines linked to active groups tend not to dissolve, and are standing upright above the surface. By these means, surfactant molecules for a monomolecular film at the surface of water, and all the molecules have the same orientation, forming a sort of palisade consisting of long molecules with their one end submerged in water.

The substance in two-dimensional state, i.e. in monomolecular film, as well as in three-dimensional state, can find itself in various phases. The state of the most diluted films is the same as gaseous state of usual substances. For more dense films, three states are typically distinguished: solid condensed state, liquid condensed state, and stratched (expanded film). One can observe phase transitions between these states of the films, when the properties of films undergo abrupt changes. The expanded state of the film should be probably considered as a liquid state.

The condensed state of the film having the highest density are of major interest.

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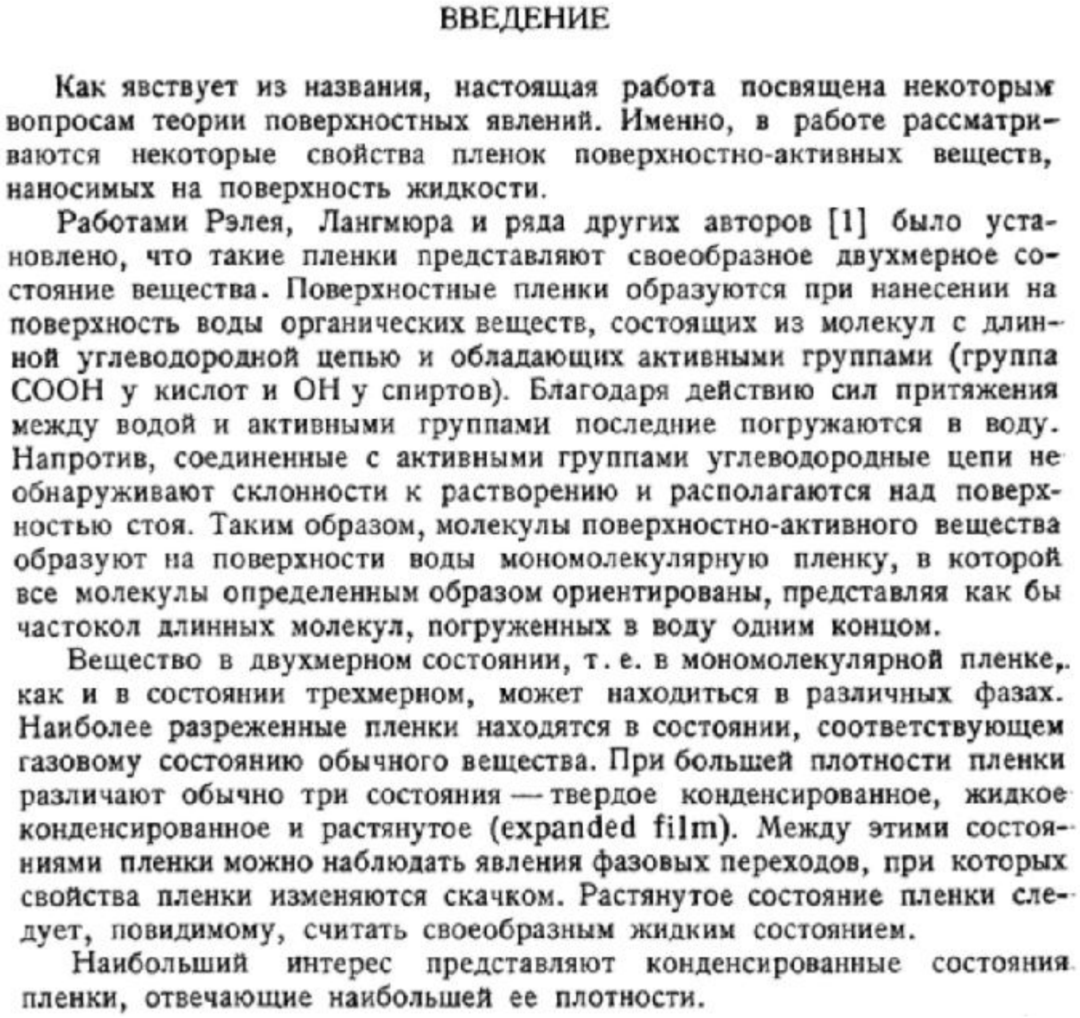


ВВЕДЕНИЕ

Как явствует из названия, настоящая работа посвящена некоторым вопросам теории поверхностных явлений. Именно, в работе рассматриваются некоторые свойства пленок поверхностно-активных веществ, наносимых на поверхность жидкости.

Работами Рэлея, Лангмюра и ряда других авторов [1] было установлено, что такие пленки представляют своеобразное двухмерное состояние вещества. Поверхностные пленки образуются при нанесении на поверхность воды органических веществ, состоящих из молекул с длинной углеводородной цепью и обладающих активными группами (группа $COOH$ у кислот и OH у спиртов). Благодаря действию сил притяжения между водой и активными группами последние погружаются в воду. Напротив, соединенные с активными группами углеводородные цепи не обнаруживают склонности к растворению и располагаются над поверхностью стоя. Таким образом, молекулы поверхностно-активного вещества образуют на поверхности воды мономолекулярную пленку, в которой все молекулы определенным образом ориентированы, представляя как бы частокол длинных молекул, погруженных в воду одним концом.

Вещество в двухмерном состоянии, т. е. в мономолекулярной пленке, как и в состоянии трехмерном, может находиться в различных фазах. Наиболее разреженные пленки находятся в состоянии, соответствующем газовому состоянию обычного вещества. При большей плотности пленки различают обычно три состояния — твердое конденсированное, жидкое конденсированное и растянутое (expanded film). Между этими состояниями пленки можно наблюдать явления фазовых переходов, при которых свойства пленки изменяются скачком. Растянутое состояние пленки следует, повидимому, считать своеобразным жидким состоянием.

Наибольший интерес представляют конденсированные состояния пленки, отвечающие наибольшей ее плотности.

Introduction is continued by discussion of the difference between 2D and 3D crystals, as related to thermal fluctuations effect on the long-range order. This discussion is based on the works of Peierls, 1936, and Landau, 1937 (both cited as [2]). This concept was later reconsidered in 1971-1972 articles of Vadim L. Berezinskii (1935-1980), and slightly later articles of D.J. Thouless and J.M. Kosterlitz, who were finally awarded 2016 Nobel prize in pjysics.

I. Electron scattering in two-dimensional crystal

§ 1. Scattering intensity

Elastic scattering from the motionless atoms is first addressed in terms of Bragg reflections. In addition, elastic and inelastic scattering from the liquid and horizontal displacements of atoms induced by the capillary waves are considered.

§ 2. Averaging

The averaging of scattering intensity over all possible film configurations is presented for the temperatures far exceeding Debye temperature of the crystal.

§ 3. Calculation of intensity

The intensity as a function of deviation from the centrum of Bragg reflection is calculated.

§ 4. The effect of capillary waves

Vertical displacements induced by the capillary waves are considered in addition.

§ 5. Discussion of results and their applicability limits

Reflection width and its integral intensity are discussed in frames of involved approximations. It is stated that the results are valid for scattering of electrons of not too high energy.

§ 6. Scattering by polycrystal

Reflection shape is considered for the film consisting of single crystalline regions of various orientations, for the case of beam cross-section being much larger than the size of such regions. Corresponding experimental pattern is predicted.

II. Waves suppression by surfactants

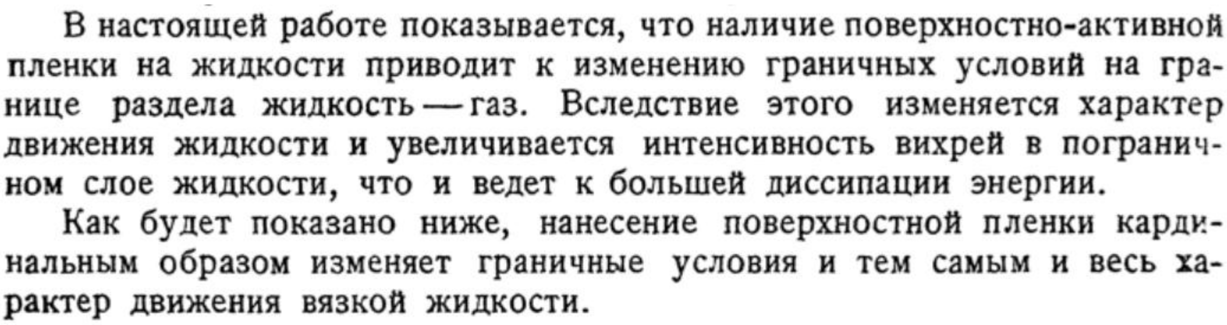
§ 7. Formulation of the problem

First, it is stated that 2D crystals, like their 3D analogues, demonstrate elasticity and shear resistance. 'Calming effect' of surfactants on the capillary waves, as observed experimentally in many studies [12], was previously explained either by irreversible energu loss in monomolecular film [13], or by the changes of the movements of liquid itself, due to high loss of energy for tension in the bulk [14].

This work demonstrates that the presence of surface-active film at the surface of liquid induces the change of boundary conditiona at liquid-gas interface. This results in the changes of liquid motion, with increase of vortices intensity in the liquid layer near the interface, which leads to stronger energy dissipation.

As will be shown below, deposition of interfacial film affects the boundary conditions crucially, and by this means affects all the character of viscous liquid motion.

This is the formulation of the final part of research statement, translated above:



В настоящей работе показывается, что наличие поверхностно-активной пленки на жидкости приводит к изменению граничных условий на границе раздела жидкость — газ. Вследствие этого изменяется характер движения жидкости и увеличивается интенсивность вихрей в пограничном слое жидкости, что и ведет к большей диссипации энергии.

Как будет показано ниже, нанесение поверхностной пленки кардинальным образом изменяет граничные условия и тем самым и весь характер движения вязкой жидкости.

§ 8. Liquid motion

General equation for incompressible liquid describing strain tensor and liquid horizontal and vertical velocities are obtained.

§ 9. Boundary conditions

Insoluble surfactant is considered (film deformation is not accompanied by the changes of the number of moleciules). The force acting on the film is defined via surface tension and film compressibility.

§ 10. Attenuation coefficient

The difference of boundary conditions in the absence and in presence of film is considered for attenuation of the capillary, capillary-gravitational, and gravitational waves. In the former case, film elasticity does not play any role. Suppression of waves is less pronounced for higher wave length.

III. Waves supression by soluble surfactants

§ 11. The case of soluble substance

This case is treated in terms of two coexisting solutions: highly concentrated surfactant solution near the surface (film), and diluted solution in liquid bulk. Equilibria between these solutions result in the transfer of molecules from the bulk to the surface when the film is expanded, and from the film to solution bulk when the *film is compressed. The results differ from presented above in case of short enough waves and low enough bulk surfactant concentrations.*

IV On the motion of gas bubble in the liquid in presence of surfactants

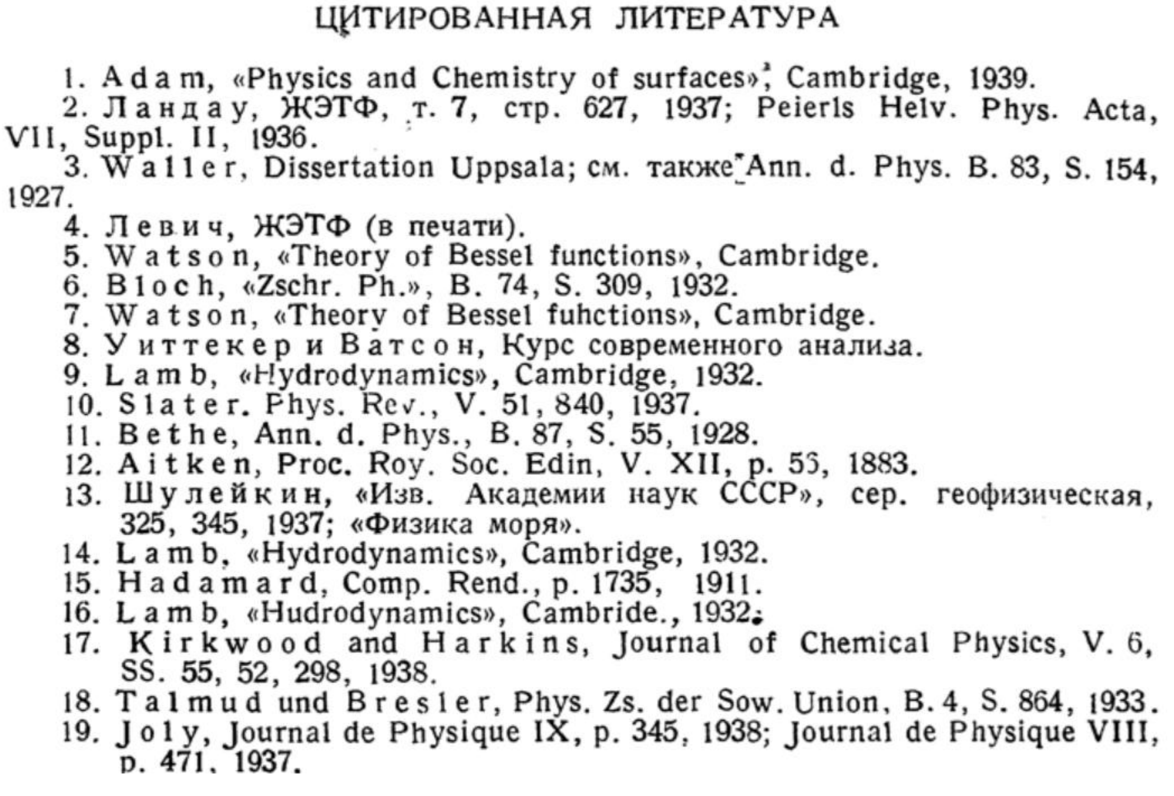
§ 12. Motion of bubble

The starting point is Hadamard's solution [15] for moving bubble. Final answer is as follows: the bubble covered by surfactant moves like a solid sphere.

V Tension in monomolecular layers

§ 13. The flow through two-dimensional capillary

Experiments on determination of 2D films viscosity are considered. Two-dimensional capillary refers to the narrow gap in the bar separating Langmuir bath, in which one of the sections contains pure liquid, and another one contains liquid with the film. Kirkwood's treatment [17] in terms of anomalously high viscosity of the film is mentioned as less realistic. The alternative is energy dissipation in the liquid carried away jointly with the film. The obtained Eqs are verified by comparison with experiments of Joly [19].



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