CompPhys2014
Leipzig November 27-29,2014

The stability of foam films: remarks on the concept of disjoining pressure

Introduction

The accepted (DLVO) theory by Derjaguin, Landau, Verwey, Overbeek

Doubts on the key concept of disjoining pressure

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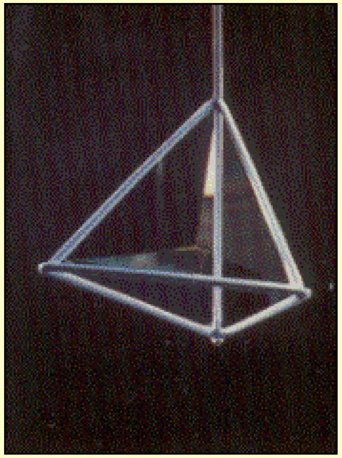
thin liquid soap films:

reflections, refractions, colors of light

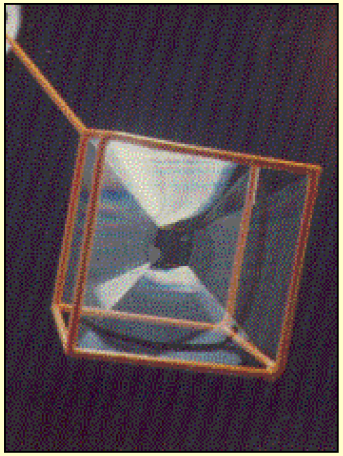
Isaac Newton (1643 – 1727), Robert Hooke (1635 – 1703)

minimal surfaces and their forms

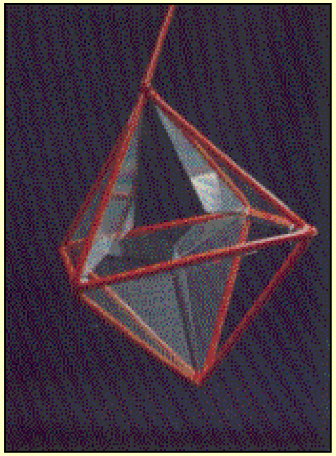
Joseph Antoine Ferdinand Plateau (1801 – 1883) : *Statique experimentale et theorique des liquides soumis aux seules forces moleculaires.* (Gauthiers-Villars, Paris, 1873)



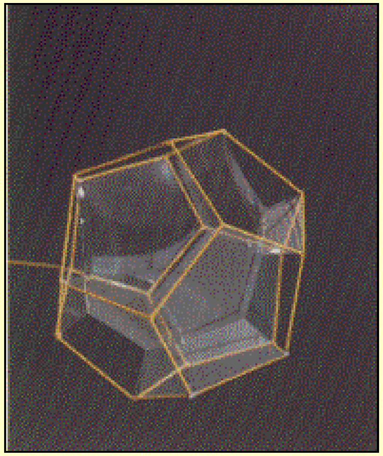
Tetrahedron



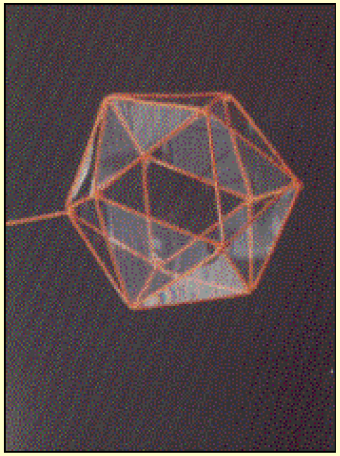
Square



Octahedron



Dodecahedron

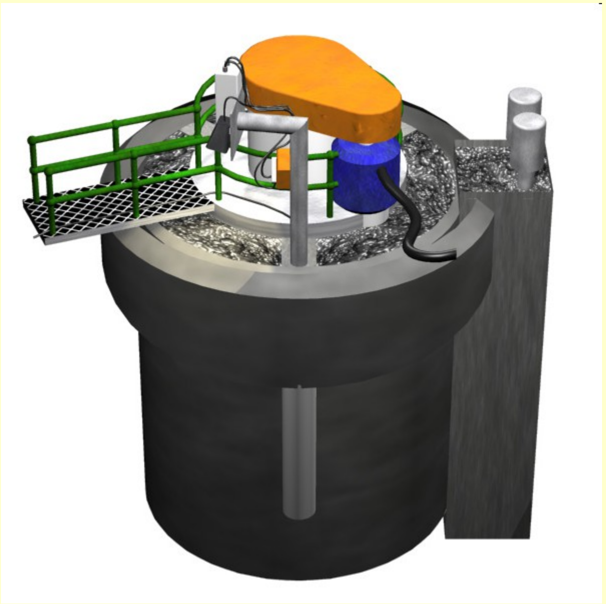


Icosa

froth flotation

selective ore mining

recycling of paper (de-inking)

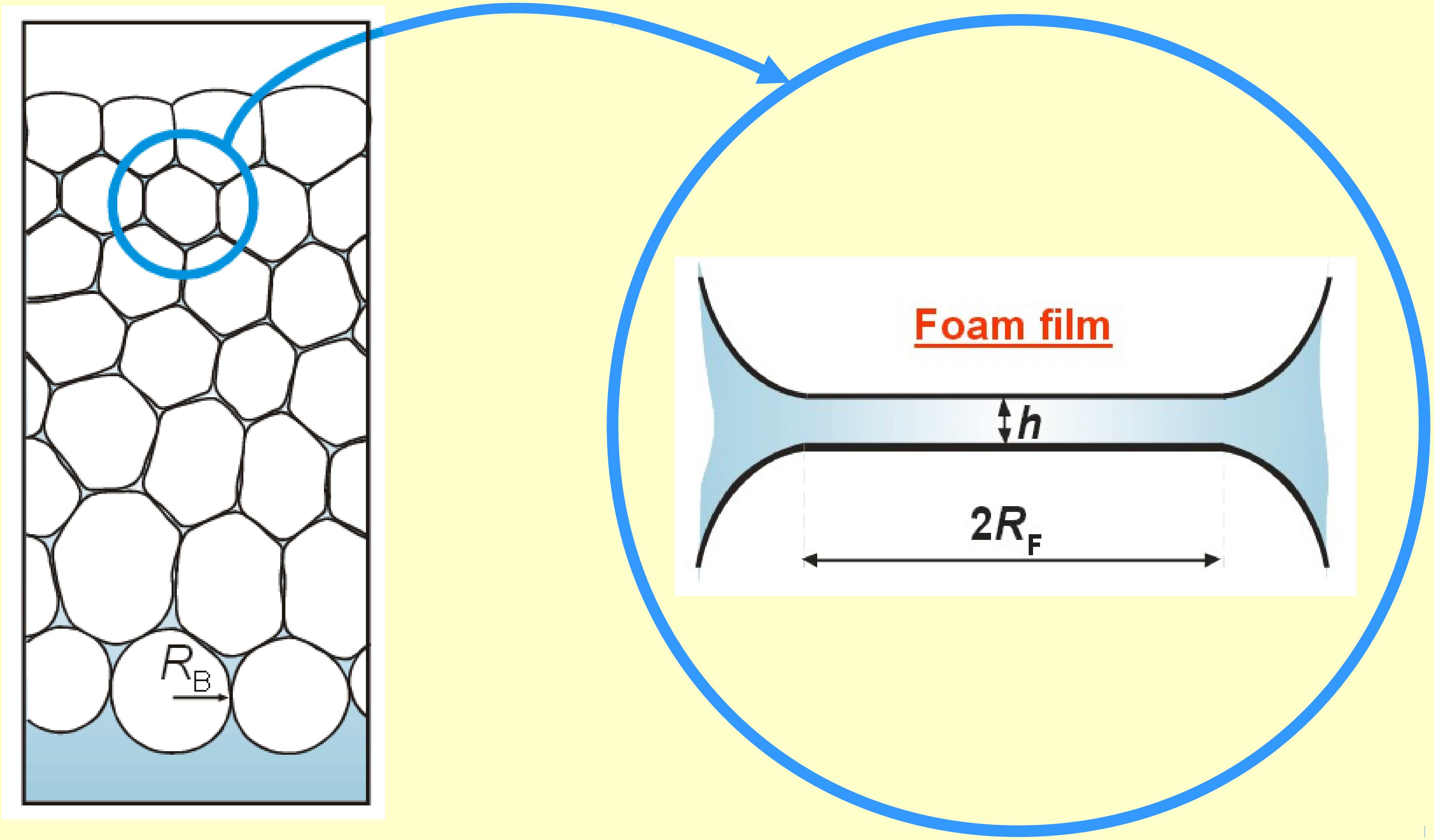


flotation cell

air bubbles loaded with copper sulfide float on the pulp in a flotation cell

The stability of foam films

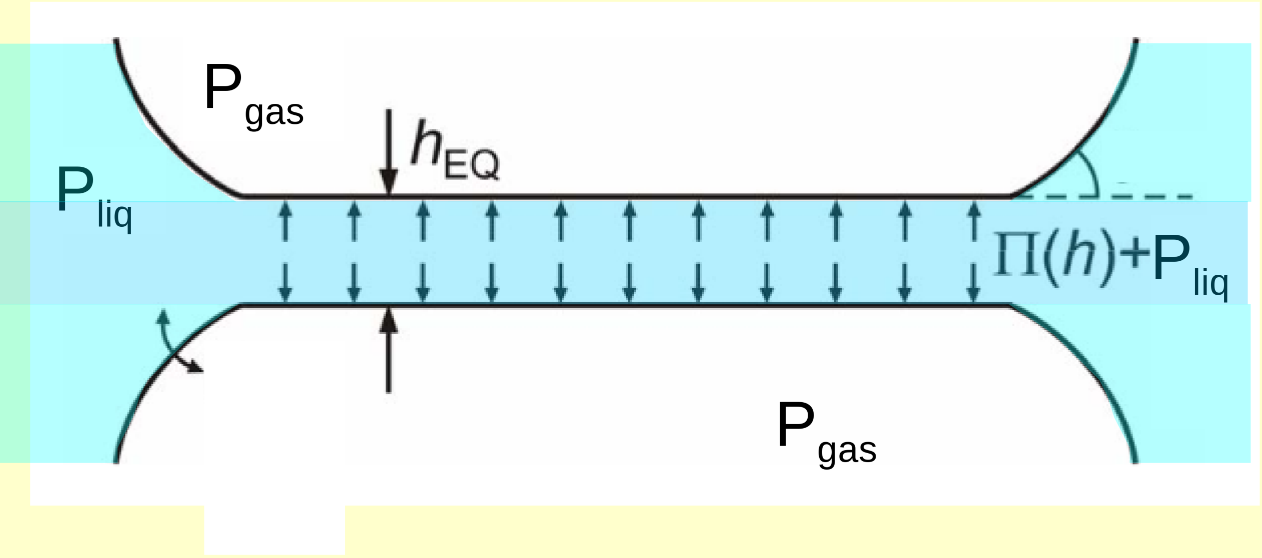
The official Guinnes world record bubble created 2013 by Megan Colby Parker



from:
Foam Films: Properties and Stability
Lecture at Trinity College, Dublin

pressure in gas phase > pressure in liquid phase

difference is called disjoining pressure Π



$P_{gas} > P_{liq}$

disjoining pressure

$\Pi(h) = P_{gas} - P_{liq}$

positive

from:
Foam Films: Properties and Stability
Lecture at Trinity College, Dublin

disjoining pressure

Vance Bergeron,

J.Phys.:Condens. Matter 11, 1999, R215-R238

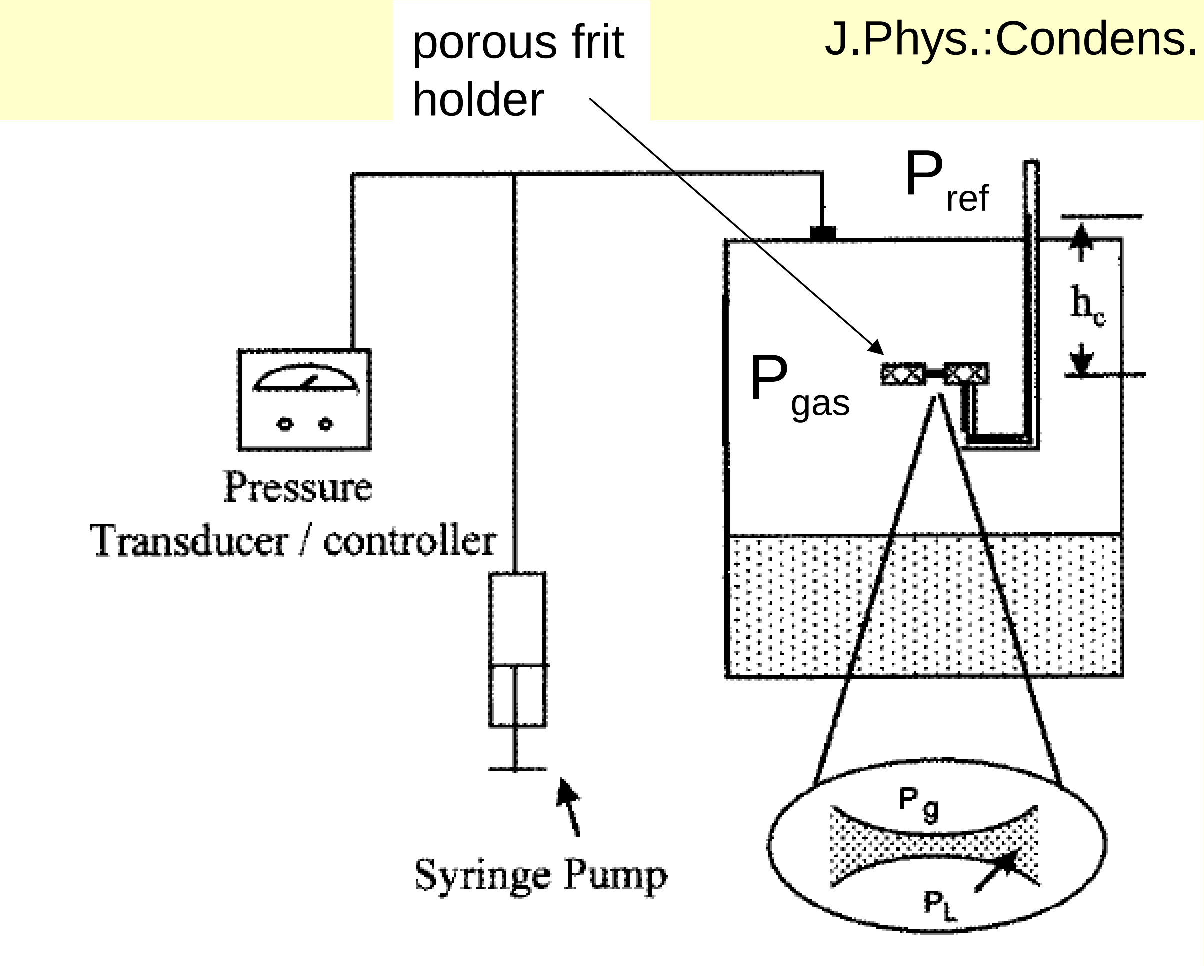


FIG. 4. A schematic diagram showing the principal elements of a typical thin-film balance used to measure disjoining pressure isotherms and monitor thin film drainage

disjoining pressure

$\Pi=$

$=P_{gas}-P_{ref}+2\sigma/r-\Delta\rho g h_c$

positive

disjoining pressure

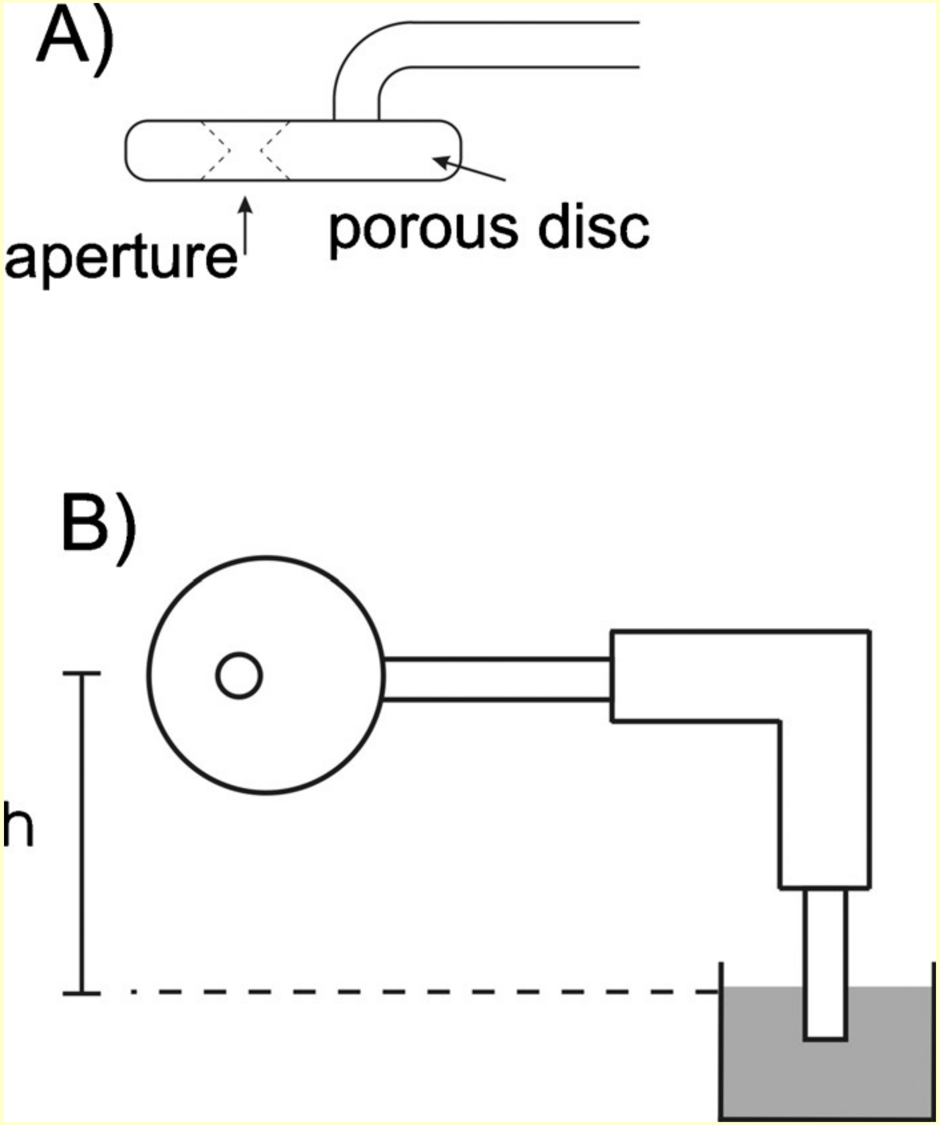


FIG. 2. A) shows the schematic of the film holder viewed from top with the glass capillary fused to the back of the porous disk.

B) is a front view and details the schematic for applying a pressure difference over the film. The filled capillary is connected to a beaker. Both parts of the glass tube are connected via the 90° bend. The difference between the level of solution in the beaker and the height of the film is proportional to the pressure applied.

C.Ridings and G. Andersson,

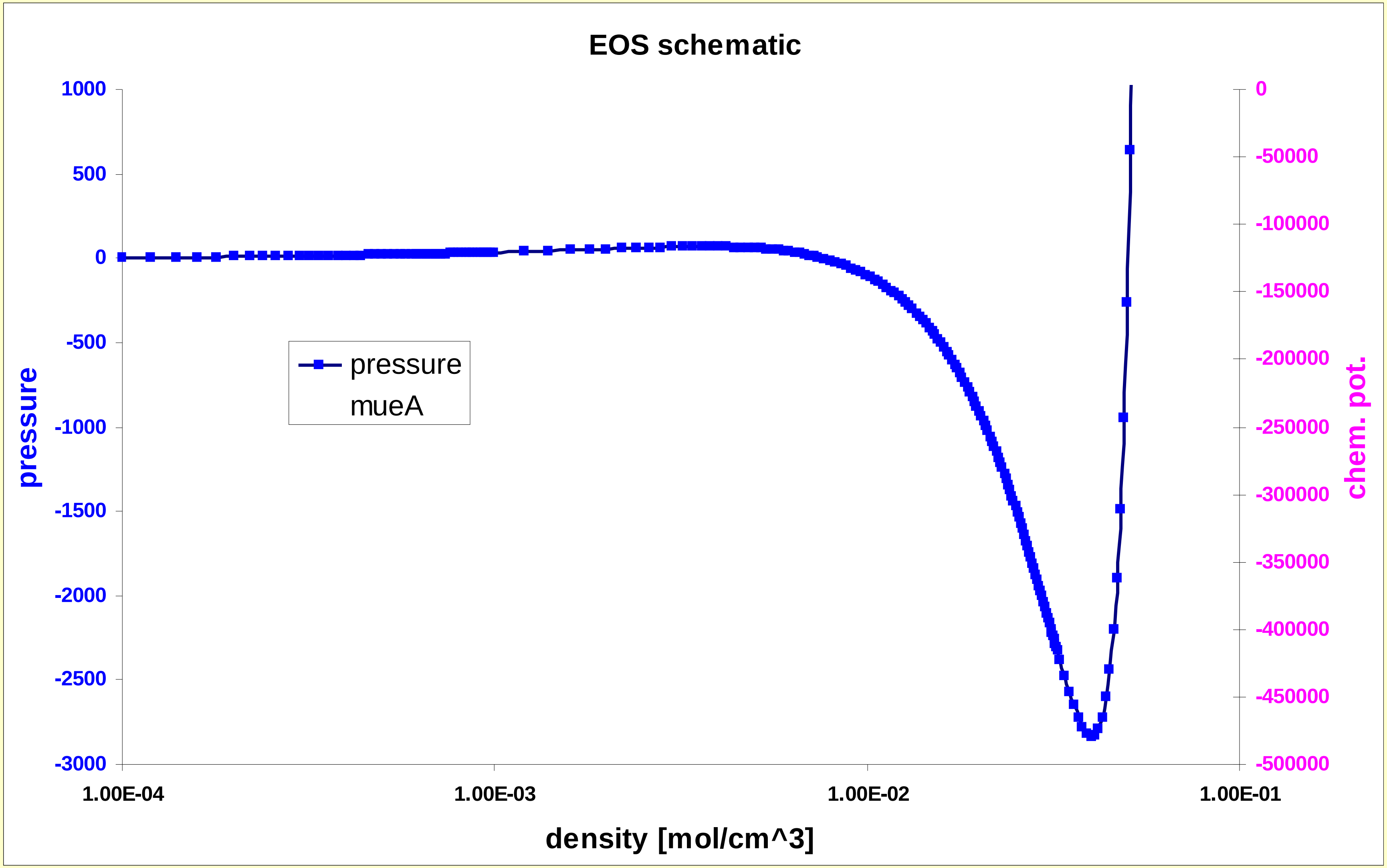
Rev.Sci. Instr. 81, 2010, 113907

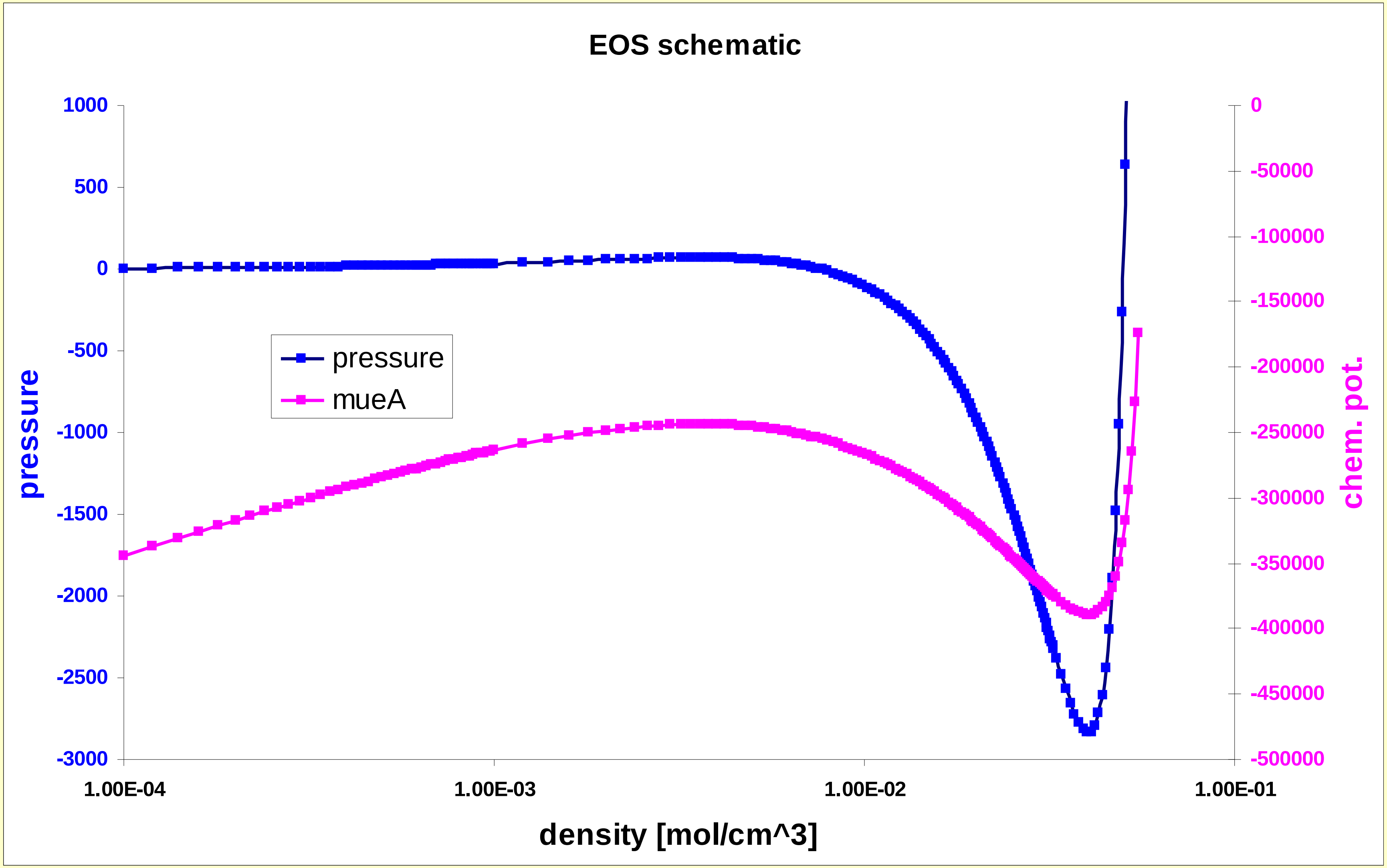
disjoining pressure

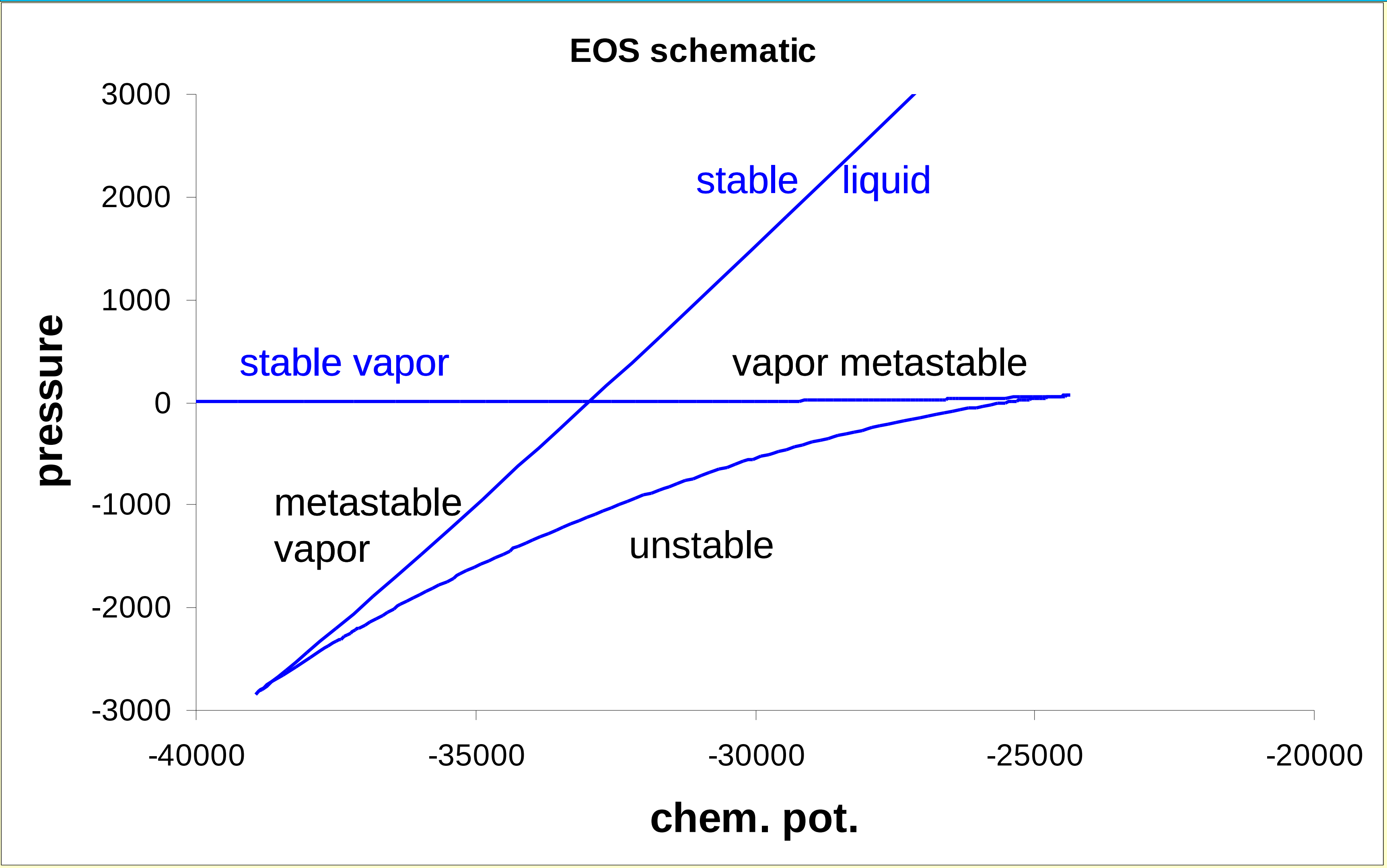
$\Pi = h\rho g$

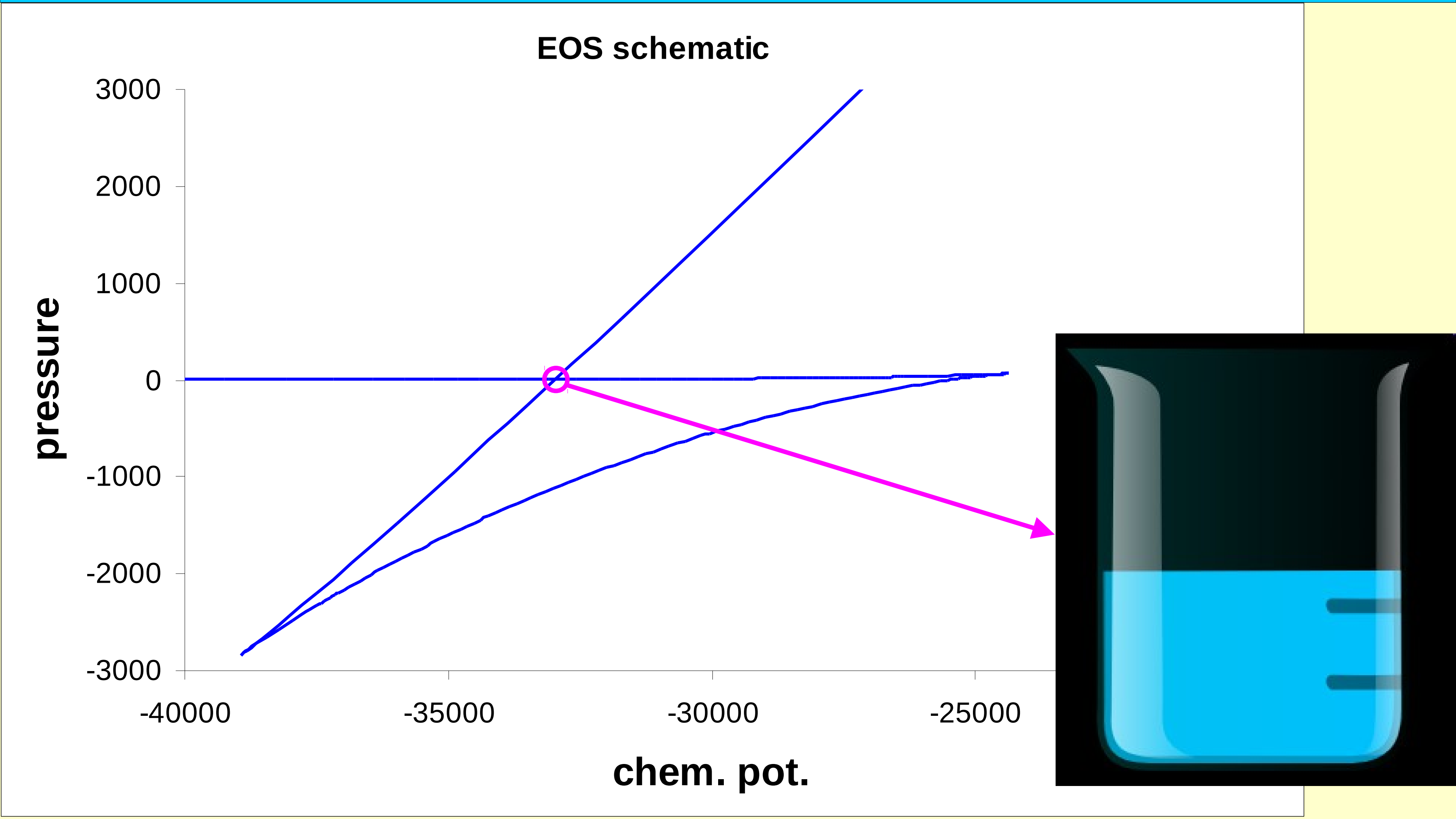
positive

EOS

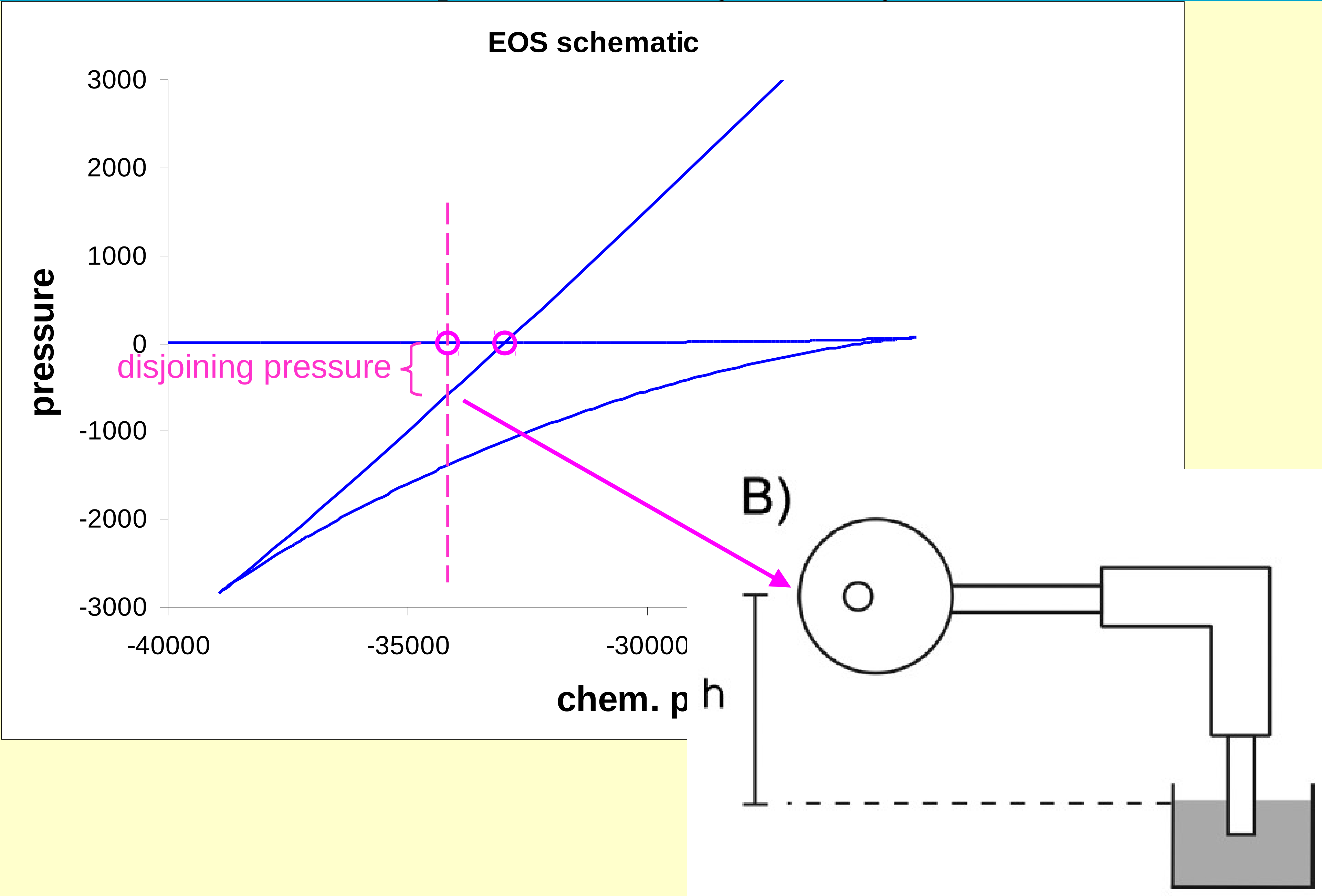

EOS schematic
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
pressure
0
-50000
-100000
-150000
-200000
-250000
-300000
-350000
-400000
-450000
-500000
chem. pot.
pressure
mueA
1.00E-04
1.00E-03
1.00E-02
1.00E-01
density [mol/cm^3]


EOS schematic
pressure
mueA
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
0
-50000
-100000
-150000
-200000
-250000
-300000
-350000
-400000
-450000
-500000
1.00E-04
1.00E-03
1.00E-02
1.00E-01
density [mol/cm^3]
chem. pot.

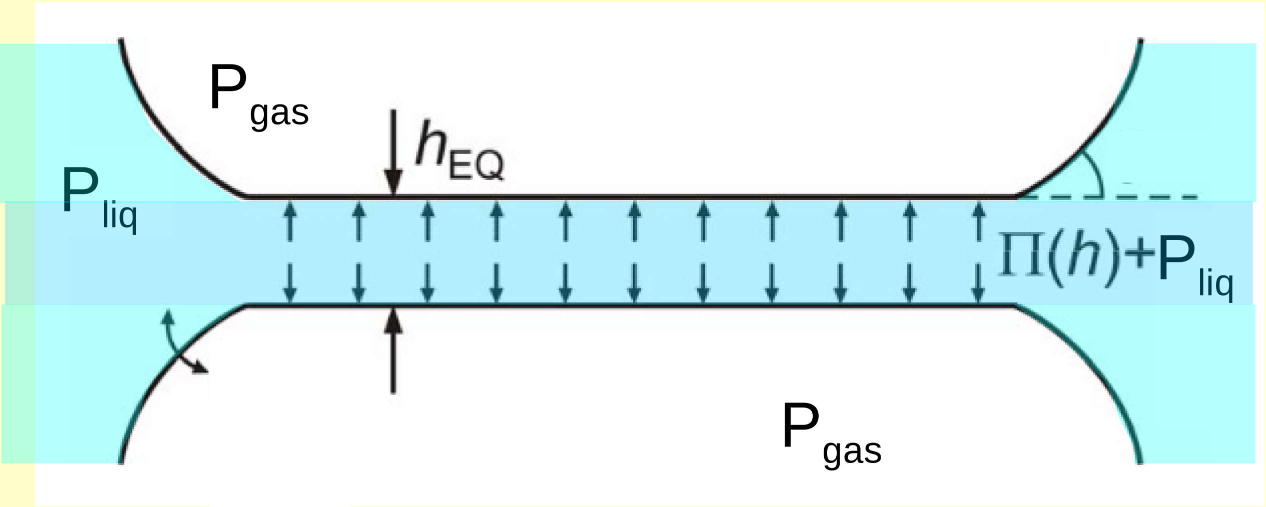

EOS schematic
3000
2000
1000
0
-1000
-2000
-3000
pressure
-40000
-35000
-30000
-25000
-20000
chem. pot.
stable liquid
stable vapor
vapor metastable
metastable vapor
unstable


EOS schematic
3000
2000
1000
0
-1000
-2000
-3000
pressure
-40000
-35000
-30000
-25000
chem. pot.

liquid film viewed by thermodynamics



liquid film viewed as mechanical problem



$P_{gas} > P_{liq}$

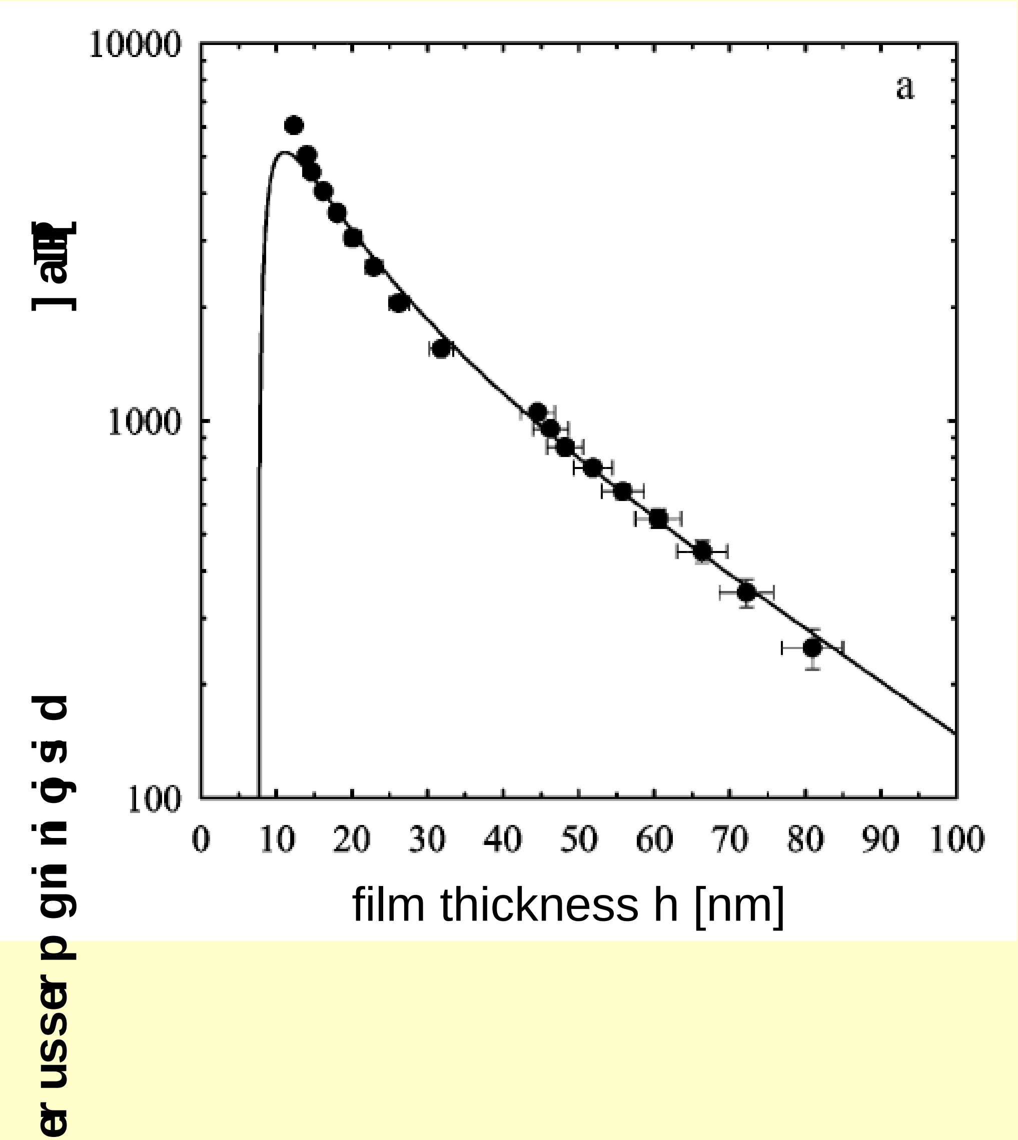
mechanical concept (e.g. Bergeron J.Phys.Condens.Matter 11, 1999,R215):

difference in pressure means non-equilibrium of forces (per unit area)

explanation: the missing force results from the interaction between both interfaces

⇒ disjoining pressure must depend on film thickness h, i.e. **Π=Π(h)**

measurement of disjoining pressure

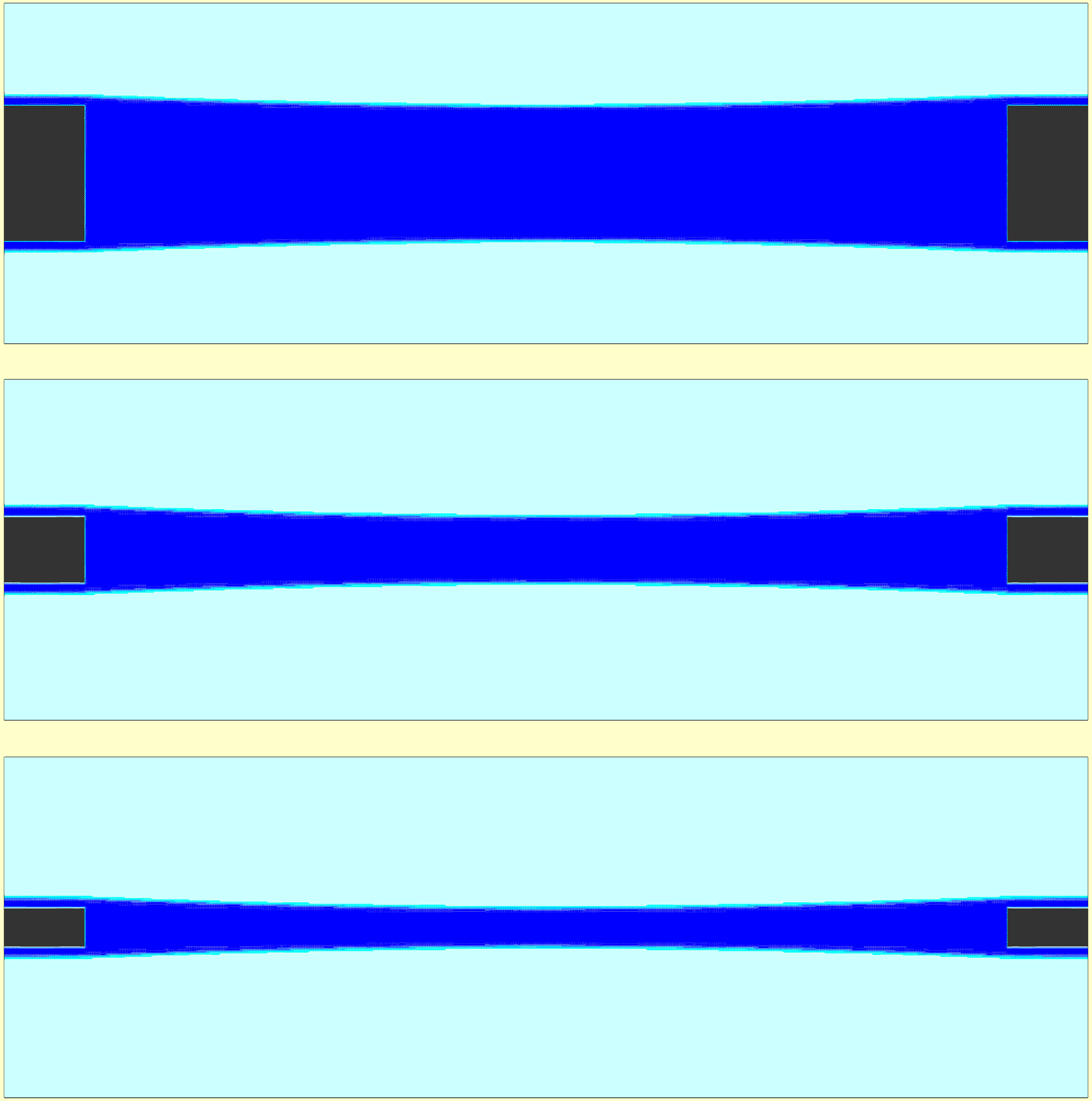


C. Stubenrauch, J. Schlarmann, R.Strey
Phys.Chem.Chem.Phys. 4, 2002, 4504-4513

⇒

experimental observation:

disjoining pressure varies with film thickness h, i.e. **$\Pi = \Pi(h)$**



film thickness varied by varying the thickness of solid frame, all other parameters left constant

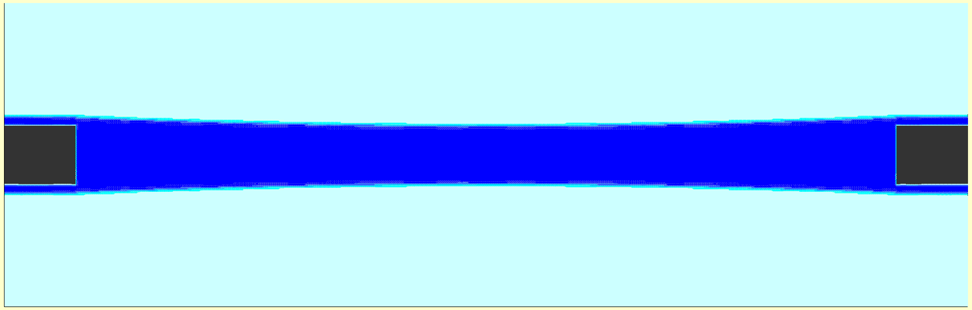
⇒

$\Pi(h)=P_{gas}-P_{liq}$ constant

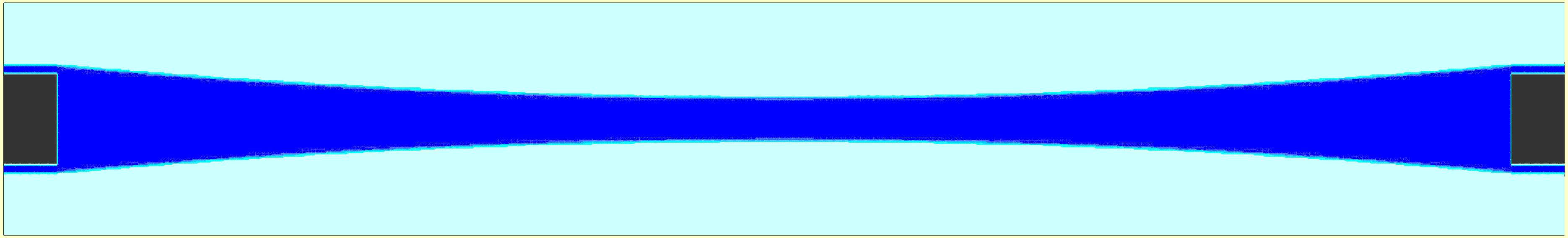
curvature of interface constant

⇒

disjoining pressure does **not** depend **directly** on film thickness h



varying diameter of solid frame, all other parameters left constant



⇒

$\Pi(h)=P_{gas}-P_{liq}$ constant

curvature of interface constant

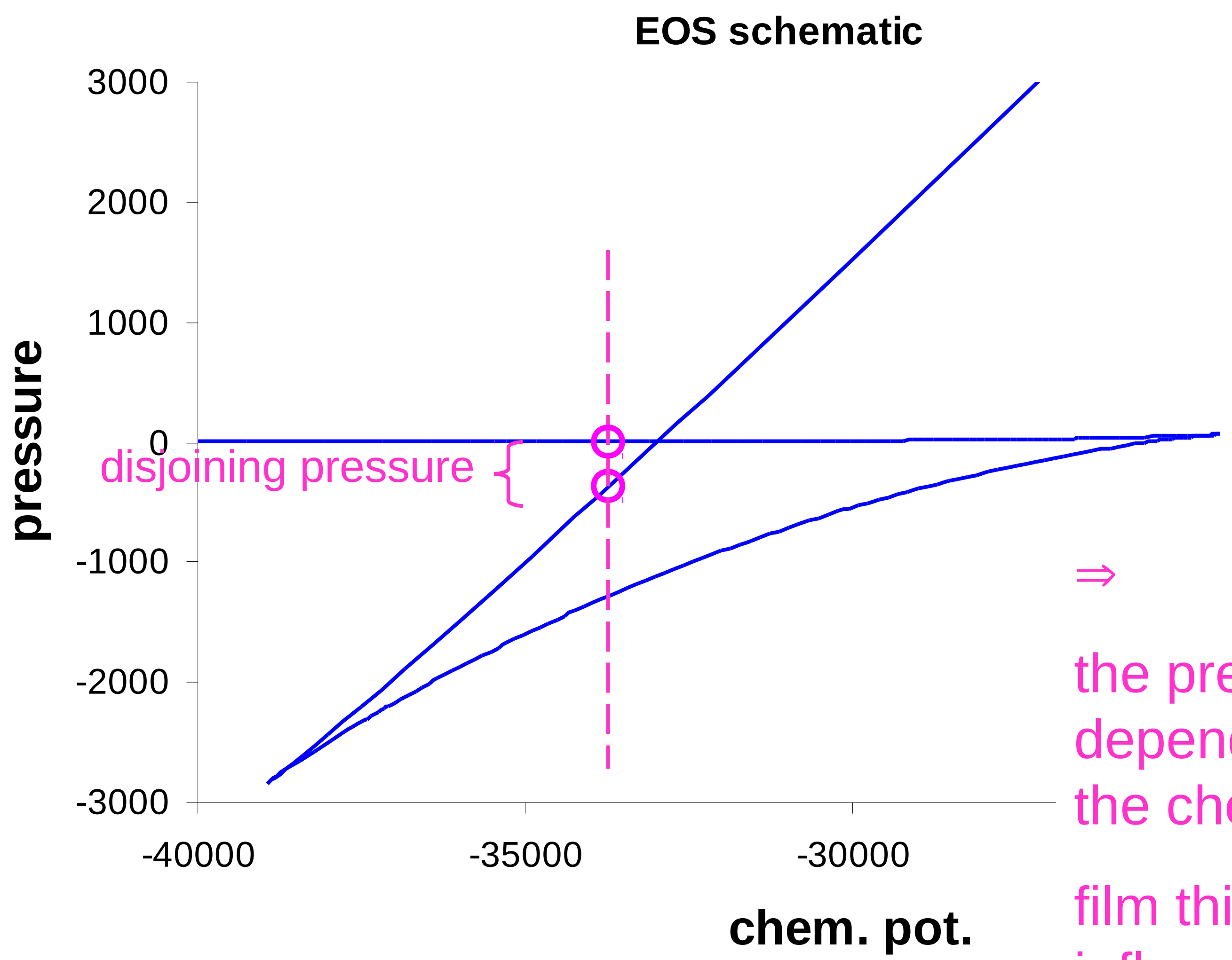
⇒

which key quantity controls the disjoining pressure?

answer:

Π depends on chemical potential

physical meaning of disjoining pressure?

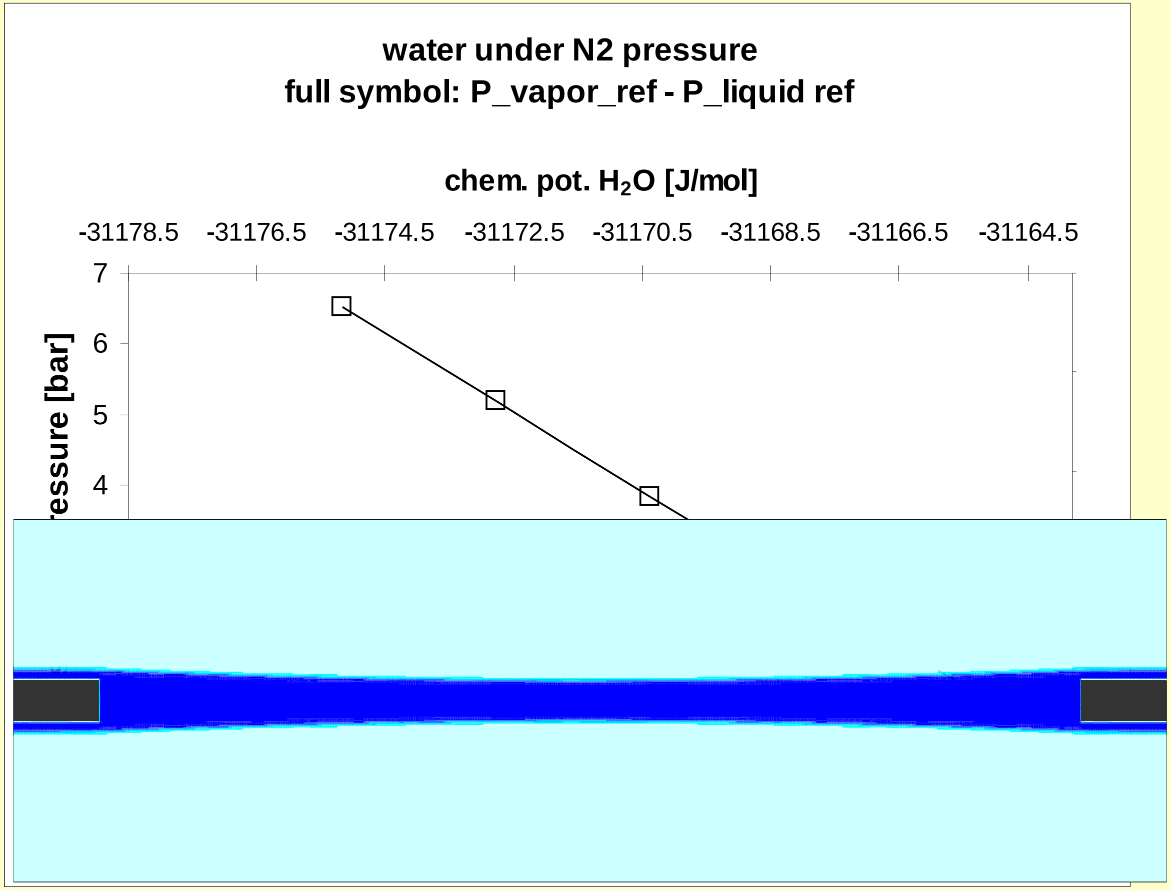


⇒

the pressure difference depends exclusively on the chemical potential

film thickness has no influence

physical meaning of disjoining pressure?



in fact, experiments demonstrate dependence of lamella thickness on chemical potential

disjoining pressure does not correspond to force between interfaces

pressure difference $\Delta P = P_{vap} - P_{liq}$ is counteracted by surface tension of curved interface.

Quantitative agreement with Young-Laplace equation $\Delta P = 2\ \sigma / R$

the mechanical interpretation of $\Delta P = P_{vap} - P_{liq}$ as „disjoining pressure“ lacks justification

Thank you. Critical remarks welcome