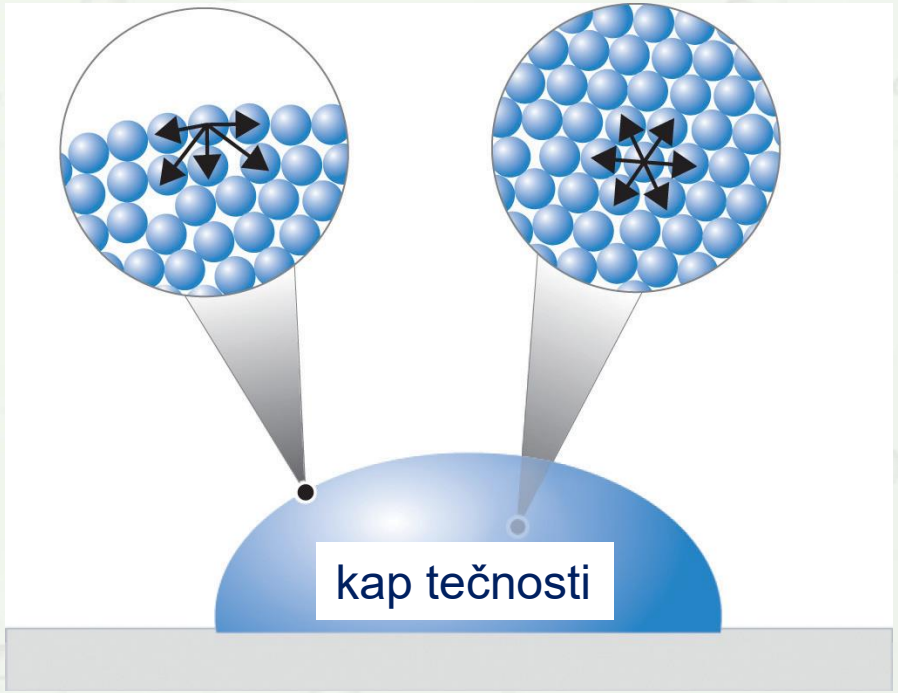
POVRŠINSKI NAPON

Priroda

Zašto ovaj insekt može da hoda po površini vode?

Zašto neki mali predmeti plivaju po površini vode?

Površinski napon



Potrebno je uložiti energiju da se molekul iz unutrašnjosti dovede na površinu.

jake međumolekulske interakcije

↓

veliki površinski napon

Definicija

p = const, T = const , n = const : $dG = \gamma d\mathcal{A}$

V = const, T = const , n = const : $dA = \gamma d\mathcal{A}$

γ - površinski napon

$$\gamma = \left(\frac{\partial G}{\partial \mathcal{A}}\right)_{p,T,n} \qquad \gamma = \left(\frac{\partial A}{\partial \mathcal{A}}\right)_{V,T,n}$$

Površinska Gibsova slobodna energija i površinska entalpija

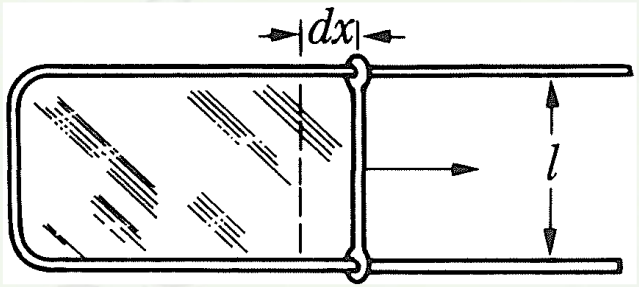
$$\gamma = \left(\frac{\partial G}{\partial \mathcal{A}}\right)_{P,T,n} = G^s$$

površinska Gibsova slobodna energija

$$H^s = \gamma - T\frac{d\gamma}{dT}$$

površinska entalpija

Obrazovanje površine: rad i sila



$$d\mathcal{A} = 2 \cdot l dx$$

$$dW = \gamma d\mathcal{A}$$

γ – površinska energija (J/m^2)

$$\left|\vec{F}\right| = \frac{dW}{dx} = \frac{\gamma d\mathcal{A}}{dx} = 2\gamma l$$

γ – površinski napon (N/m)

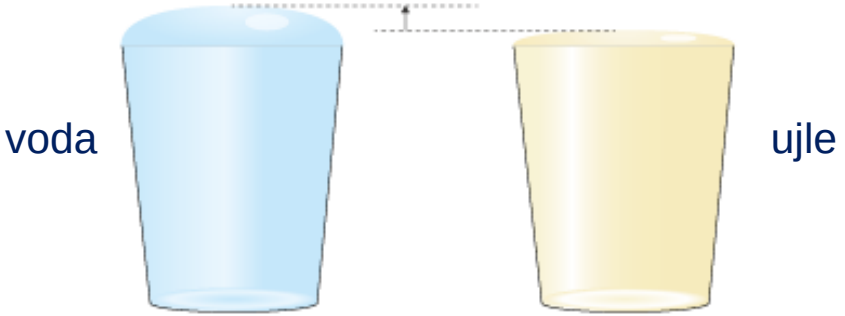
Površinski napon odabranih tečnosti

tečnost	površinski napon (mN/m)	temperatura (°C)
neon	5,2	-247
kiseonik	15,7	-193
etanol	22,3	20
maslinovo ulje	32,0	20
voda	72,8	20
živa	465,0	20
srebro	800,0	970
zlato	1000,0	1070
bakar	1100,0	1130

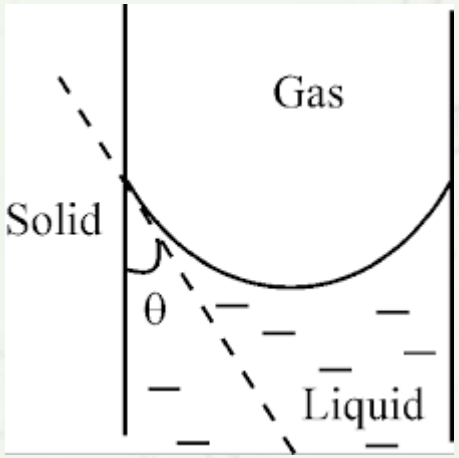
Površinski napon maslinovog ulja i vode

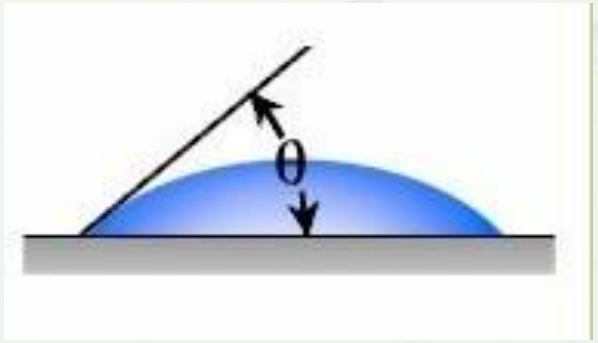
tečnost	površinski napon (mN/m)	temperatura (°C)
maslinovo ulje	32,0	20
voda	72,8	20

površina vode je ispupčenija od površine ulja



Ugao dodira

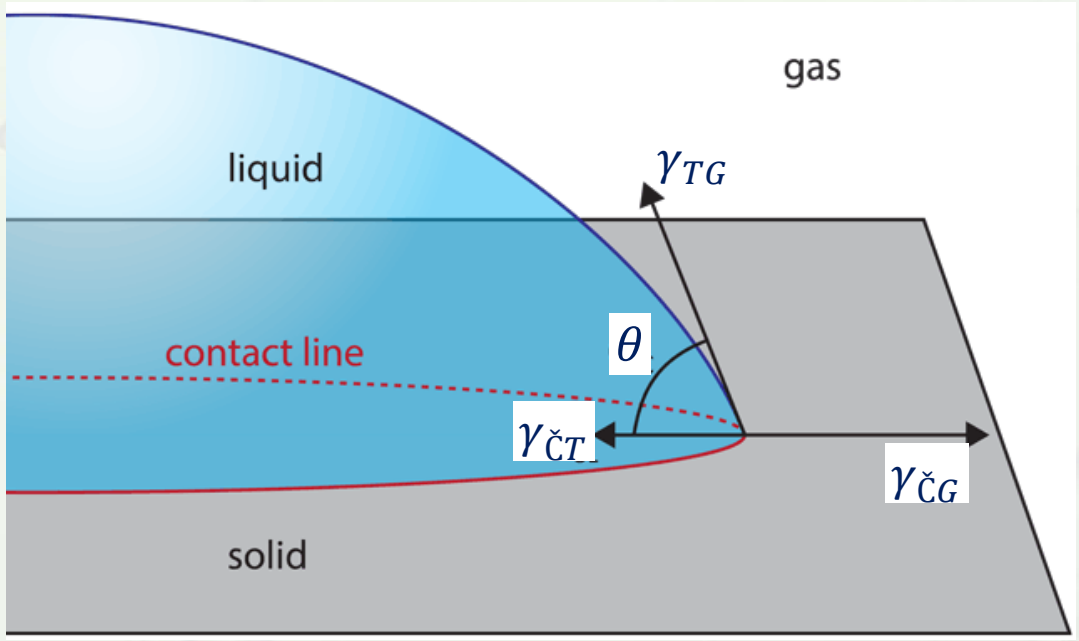




Ugao dodira – ugao između meniska tečnosti i zida suda u kome se tečnost nalazi (meren u tečnosti).

Ugao dodira

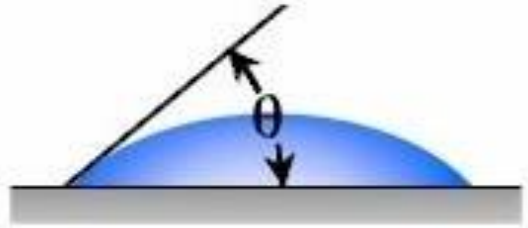
Ugao dodira se definiše iz ravnoteže sila na graničnu liniju između G, T i Č faze u horizontalnoj ravni:



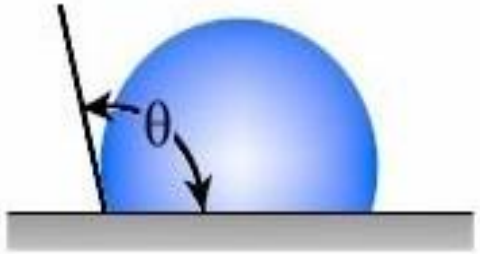
$$\gamma_{\check{C}G} = \gamma_{\check{C}T} + \gamma_{TG}\cos\theta$$

Ugao dodira

$$\gamma_{ČG} = \gamma_{ČT} + \gamma_{TG} \cos\theta$$



tečnost kvasi površinu



tečnost ne kvasi površinu

$\gamma_{ČG} > \gamma_{ČT}$

$\cos\theta > 0$

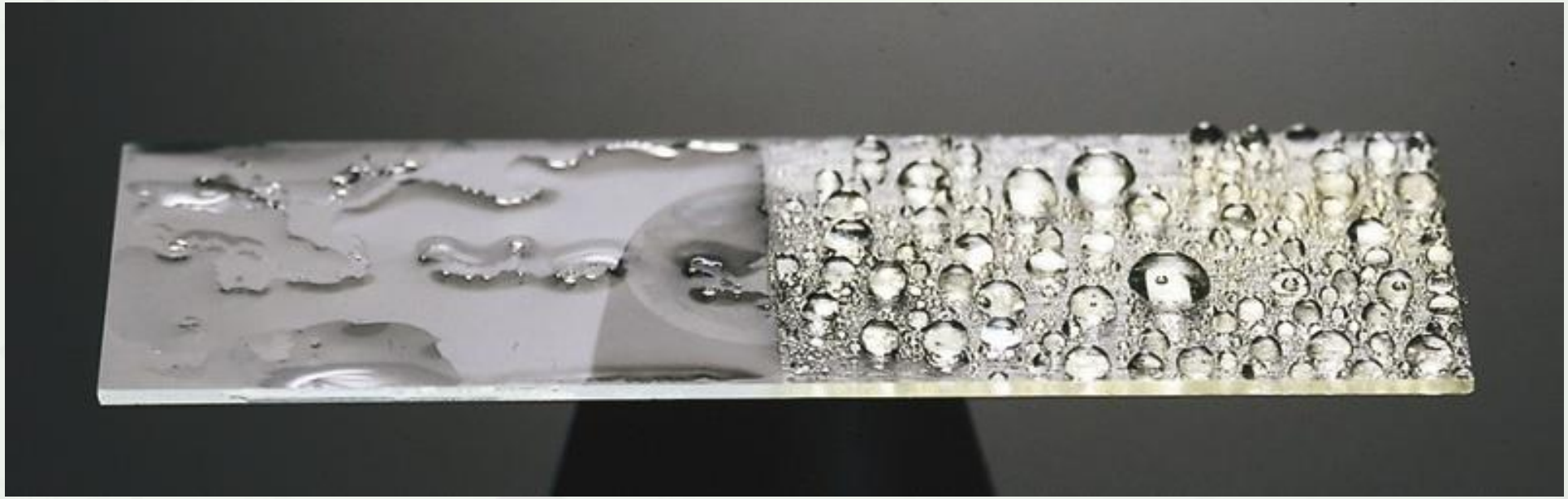
$\theta < 90^0$

$\gamma_{ČG} < \gamma_{ČT}$

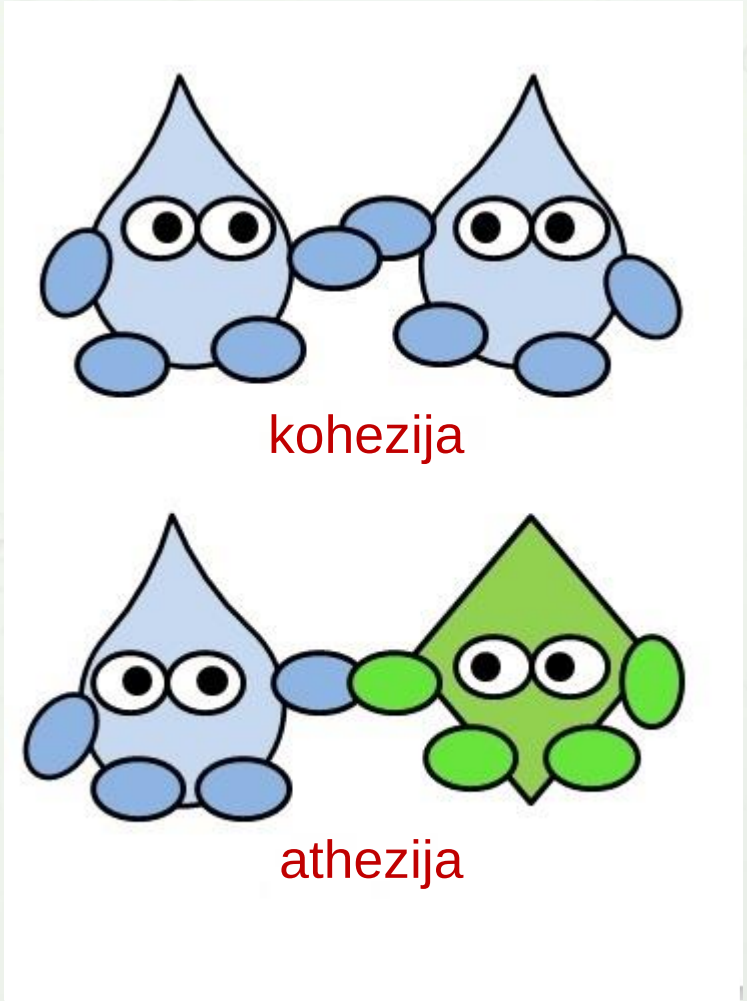
$\cos\theta < 0$

$90^0 < \theta < 180^0$

Ugao dodira i kvašenje površine



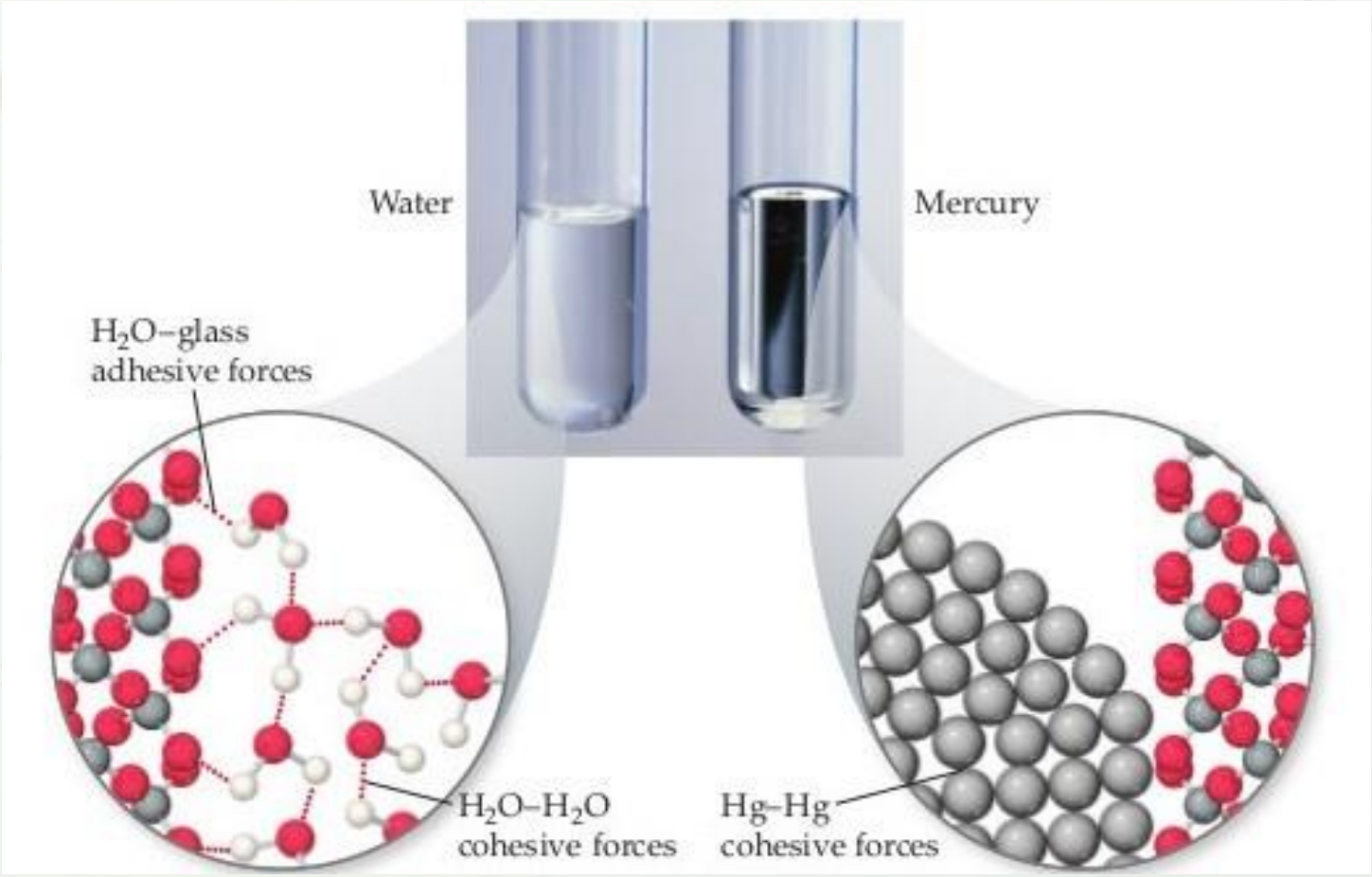
Kohezione i athezione sile



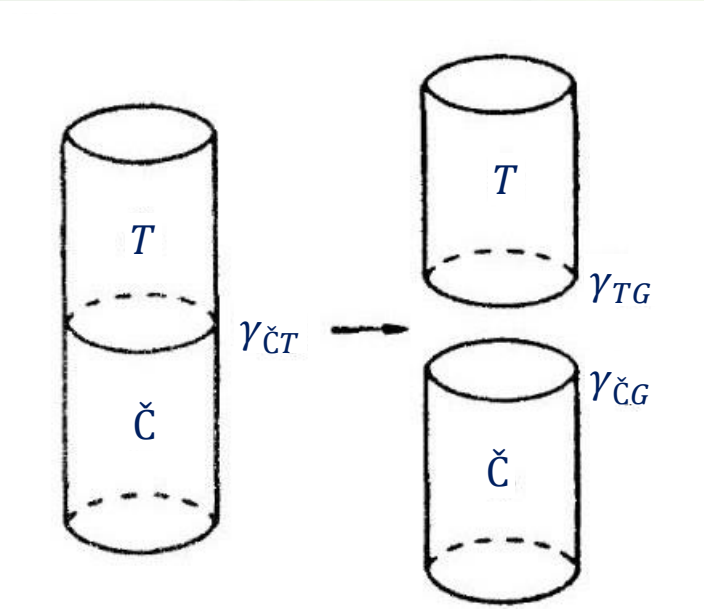
kohezija

athezija

Voda – staklo i živa – staklo

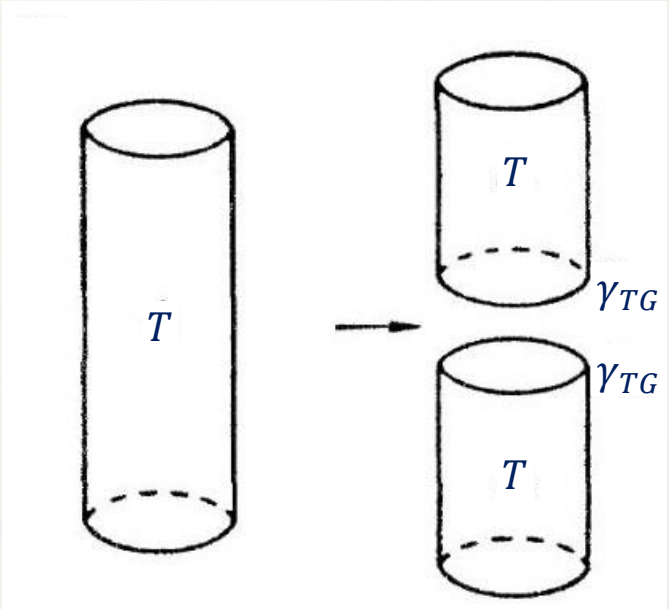


Athezioni i kohezioni rad



Athezioni rad

$$w_{ČT} = \gamma_{ČG} + \gamma_{TG} - \gamma_{ČT}$$



Kohezioni rad

$$w_{TT} = 2\gamma_{TG}$$

Ugao dodira

$$\left.\begin{aligned} \gamma_{\check{C}G} &= \gamma_{\check{C}T} + \gamma_{TG}\cos\theta \\ w_{\check{C}T} &= \gamma_{\check{C}G} + \gamma_{TG} - \gamma_{\check{C}T} \\ w_{TT} &= 2\gamma_{TG} \end{aligned}\right\} \quad \cos\theta = \frac{w_{\check{C}T}}{w_{TT}/2} - 1$$

tečnost kvasi površinu

$$\theta < 90^0, w_{\check{C}T} > w_{TG}/2$$

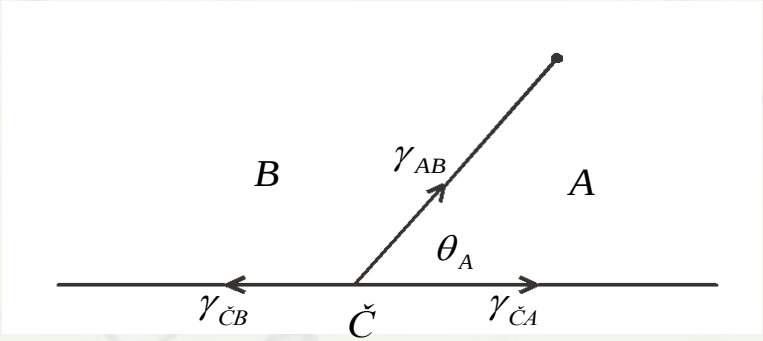
tečnost ne kvasi površinu

$$90^0 < \theta < 180^0, w_{\check{C}T} < w_{TG}/2$$

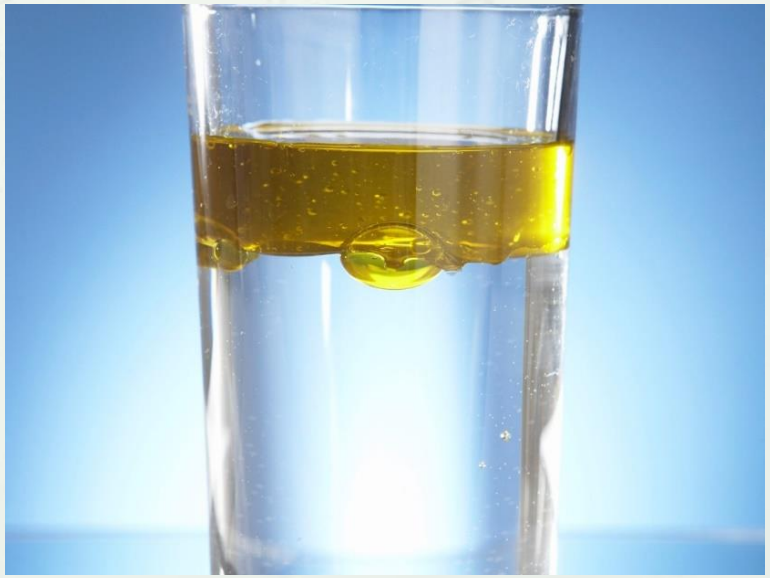
Živa na staklu

$\theta = 140^0 \rightarrow w_{ČT} / (w_{TT} / 2) = 0{,}23$

Nemešljive tečnosti



$$\gamma_{ČB} = \gamma_{ČA} + \gamma_{AB} \cos \theta_A$$



Za datu zapreminu tečnosti površina se može smanjiti formiranjem zakrivljene površine

Kapljica: mala zapremina tečnosti u ravnoteži sa okružujućom parom.

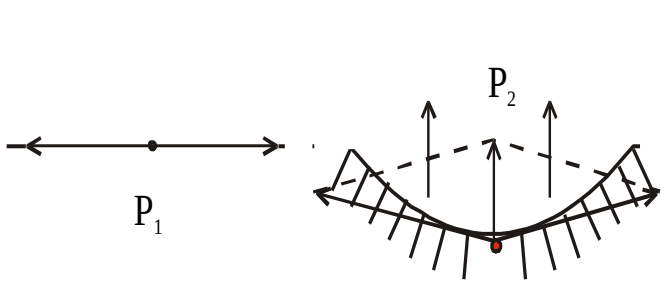
Mehur: šupljina u tečnosti ispunjena parom.

Balon: oblast u kojoj je para zarobljena tankim filmom koji ima dve površine.

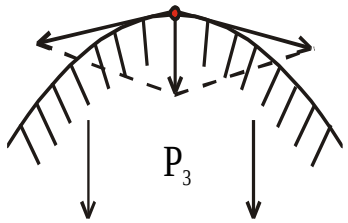
Zakrivljena površina – posledice

- kapilarne pojave
- napon pare zavisi od zakrivljenosti površine

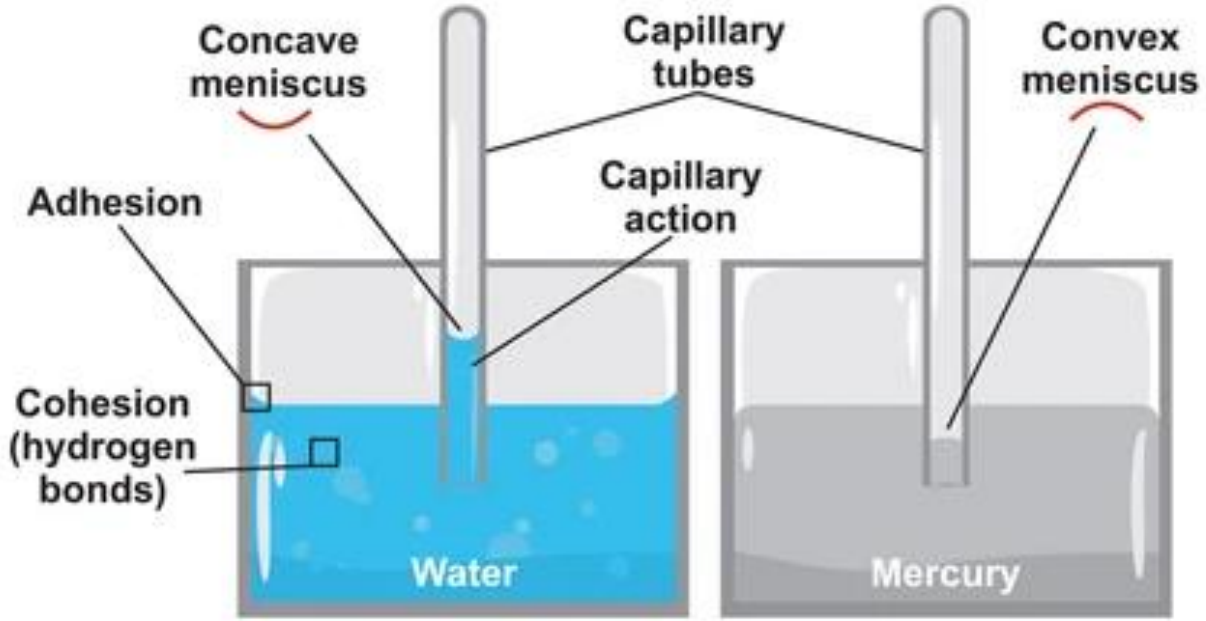
Kapilarne pojave



$P_1 > P_2$



$P_1 < P_3$



Kapilarne pojave

$$dG_1 = -\gamma d(4\pi r^2) = -8\gamma\pi r dr$$

$$dG_2 = \Delta P d\left(\frac{4}{3}\pi r^3\right) = 4\Delta P \pi r^2 dr$$

$$dG = dG_1 + dG_2 = 0$$

$$-8\gamma\pi r dr + 4\Delta P \pi r^2 dr = 0$$

$$\boxed{\Delta P = \frac{2\gamma}{r}}$$

$$\boxed{\Delta P = \gamma\left(\frac{1}{r_1} + \frac{1}{r_2}\right)}$$

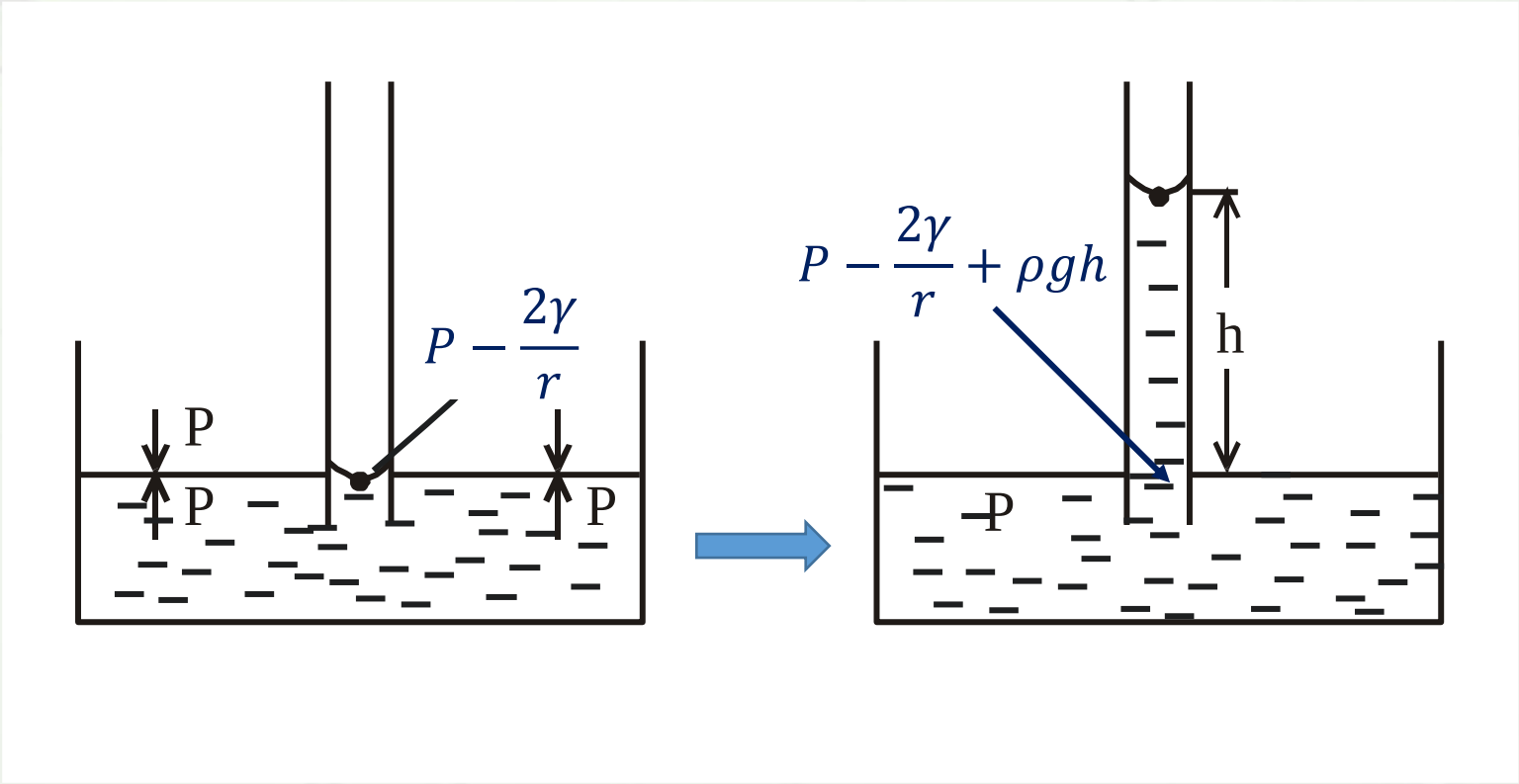
Laplasova jednačina

Primer – mehur u vodi

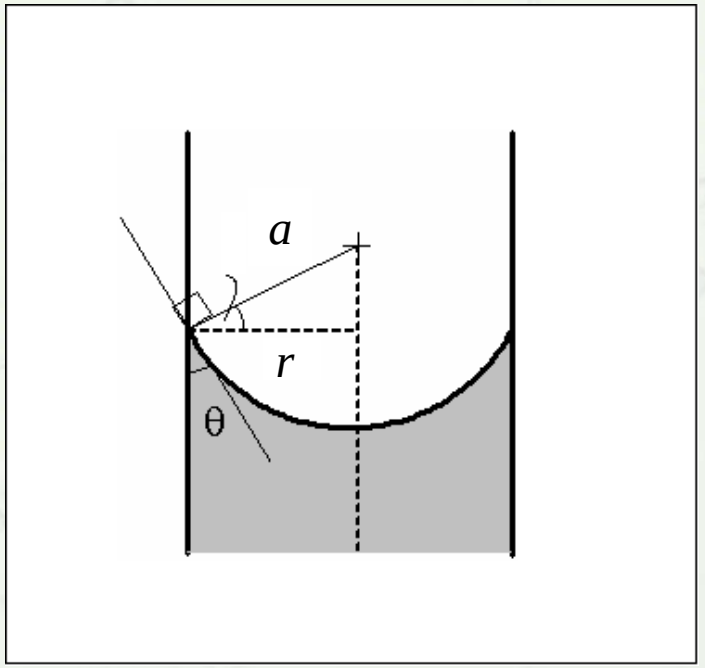
T = 298 K
γ = 72 mN/m

2r / μm	ΔP / Pa (atm)
1 000	288 (0,00284)
3,0	96 000 (0,947)
0,3	960 000 (9,474)

Posledica površinskog napona



Kapilarnost



$$\rho g h = \frac{2\gamma}{a} \longrightarrow \gamma = \frac{1}{2}\rho g h a$$

$$\gamma = \frac{1}{2}\rho g h \frac{r}{\cos\theta}$$

Zakrivljena površina – posledice

- kapilarne pojave
- napon pare zavisi od zakrivljenosti površine

Površinski napon i napon pare

Promena molarne Gibsove slobodne energije pri obrazovanju zakrivljene površine:

$$\Delta G_m(t) = \int_0^{2\gamma/r} V_m^t dP = \frac{2\gamma V_m^t}{r}$$

$$\Delta G_m(g) = RT\ln\frac{p}{p^0}$$

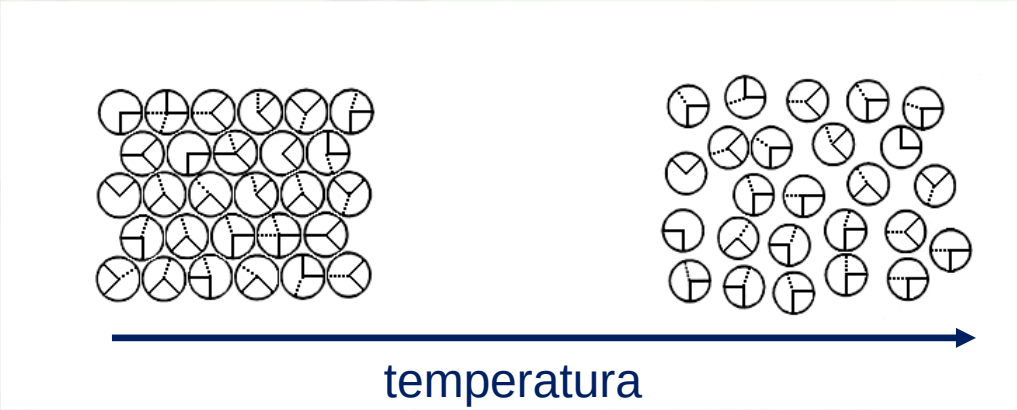
$$\Delta G_m(t) = \Delta G_m\,(g)$$

$$\ln\frac{p}{p^0} = \frac{2\gamma V_m^t}{RTr}$$

$$\boxed{p = p^0 exp\left(\frac{2\gamma V_m^t}{RTr}\right)}$$

Kelvinova jednačina

Površinski napon i temperatura



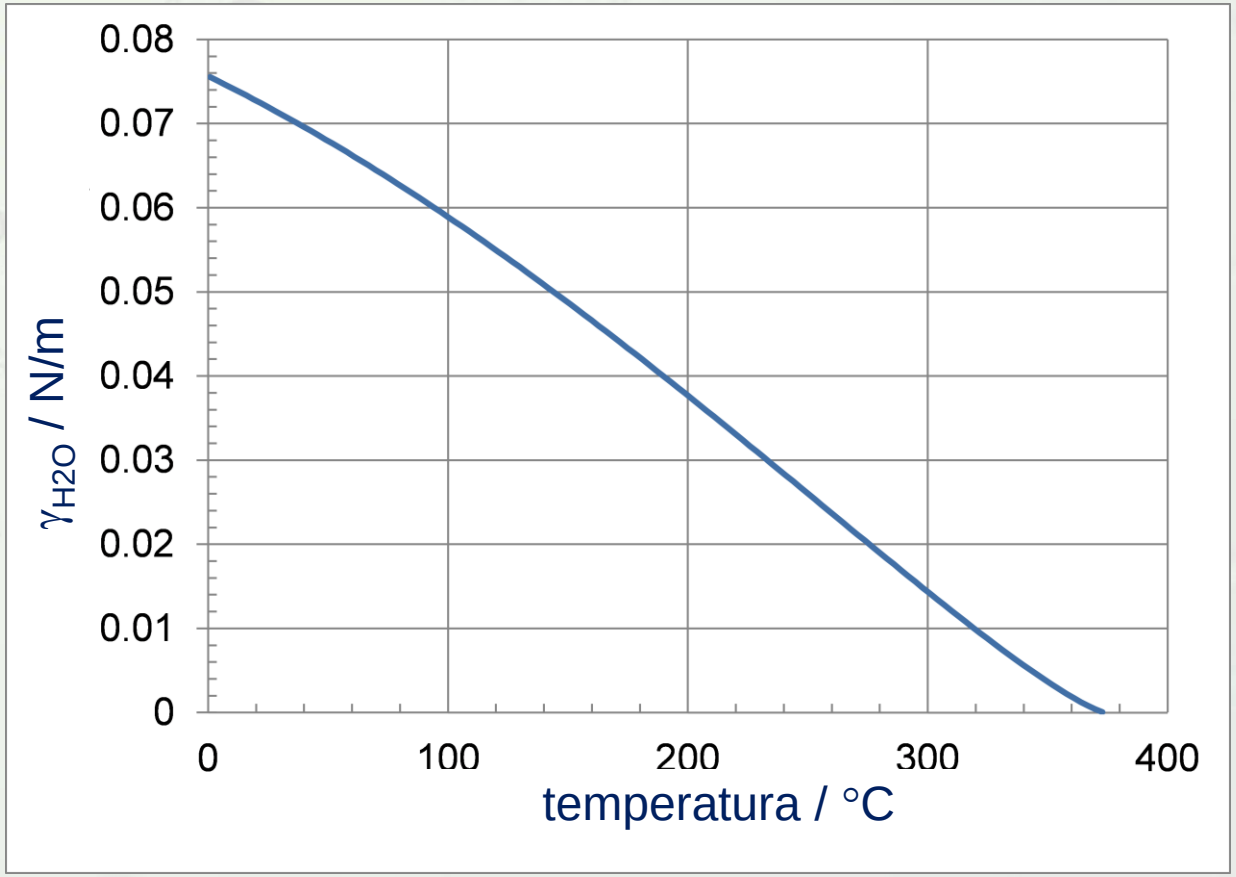
viša temperatura

↓

slabije međumolekulske interakcije

↓

manji γ



Površinski napon odabranih tečnosti (N/m)

t (°C)	H_2O	CCl_4	C_6H_6	$C_6H_5NO_2$	C_6H_5OH
0	0,07564	0,0290	0,0316	0,0464	0,0240
25	0,07197	0,0261	0,0282	0,0432	0,0218
50	0,06791	0,0231	0,0250	0,0402	0,0198
70	0,06350	0,0202	0,0219	0,0373	-

Površinski napon i temperatura

Etveš: $-\frac{d\left[\gamma V_m^{2/3}\right]}{dT} = k$

$$-\int_{\gamma_1 V_{m1}^{2/3}}^{\gamma_2 V_{m2}^{2/3}} d\left[\gamma V_m^{2/3}\right] = k\int_{T_1}^{T_2} dT$$

$$-\frac{\gamma_2 V_{m2}^{2/3} - \gamma_1 V_{m1}^{2/3}}{T_2 - T_1} = k$$

$T_2 = T_c;\ \ \gamma_2 = 0$

$$\boxed{\gamma V_m^{2/3} = k(T_c - T)}$$

Druge empirijske jednačine:

Remzi i Šilds: $\gamma V_m^{2/3} = k(T_c - T - 6)$

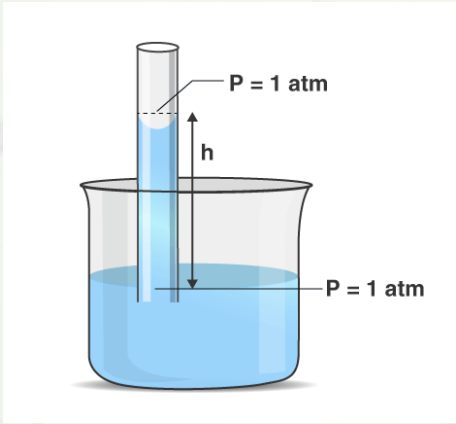
Van der Vals: $\gamma = \gamma_0\left(1 - \frac{T}{T_c}\right)^n$

Katajama: $\gamma\left(\frac{M}{\rho - \rho'}\right)^{\frac{2}{3}} = k(T_c - T)$

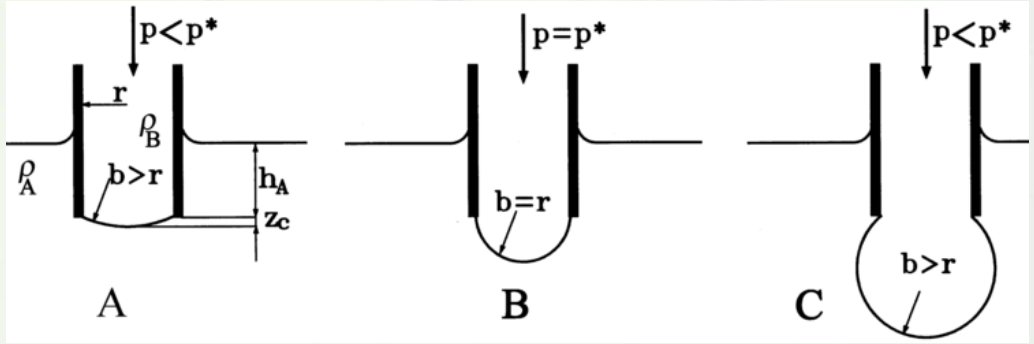
Meklod: $\gamma = C(\rho - \rho')^4$

Merenje koeficijenta površinskog napona

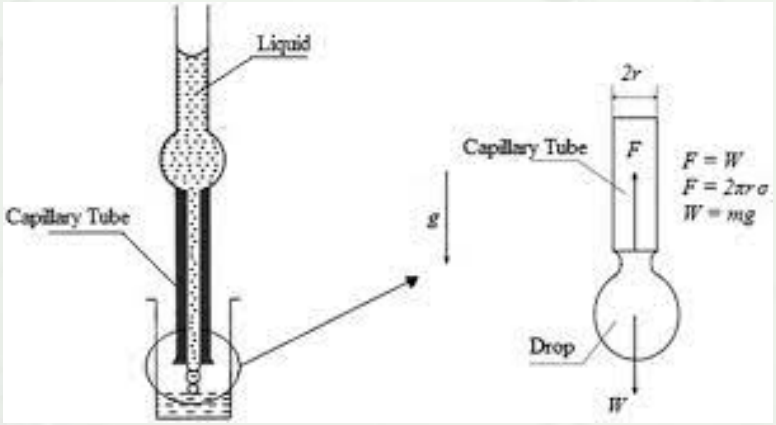
podizanje nivoa tečnosti u kapilari



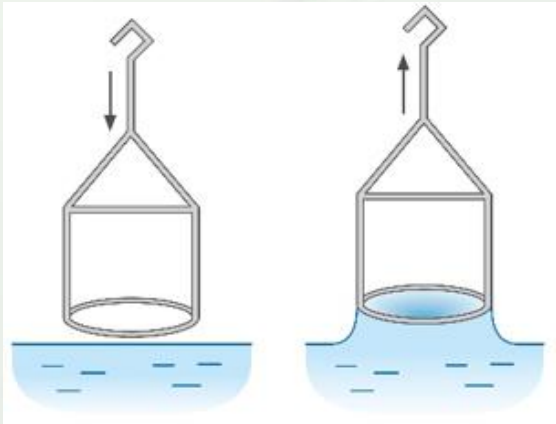
metoda mehura maksimalnog pritiska



stalagmometrijska metoda



tenziometar



Rezime