

POVRŠINSKI NAPON

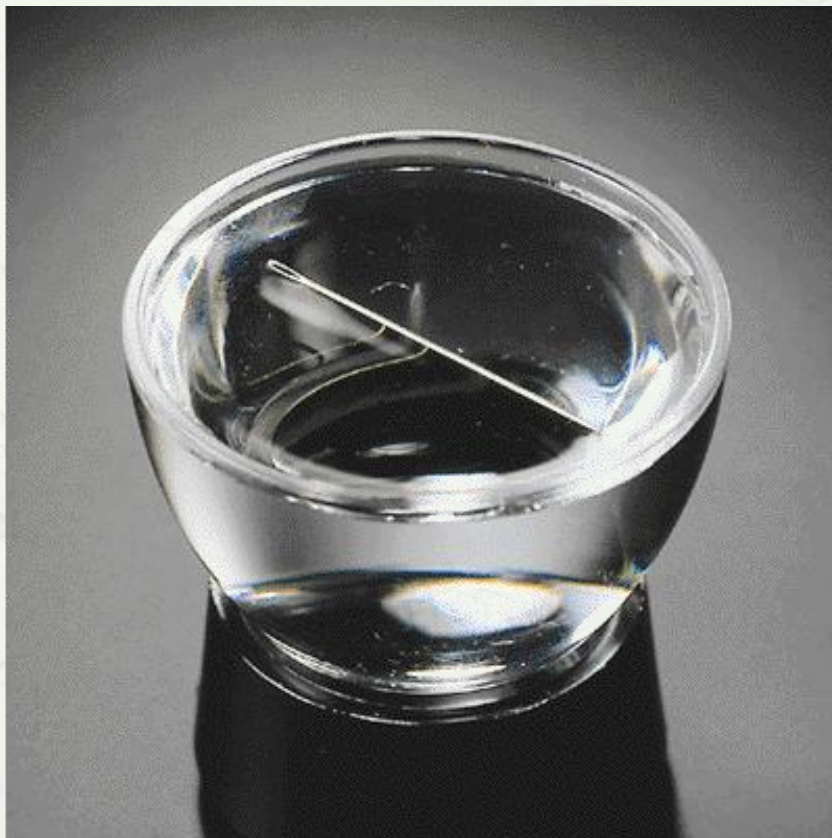
Priroda



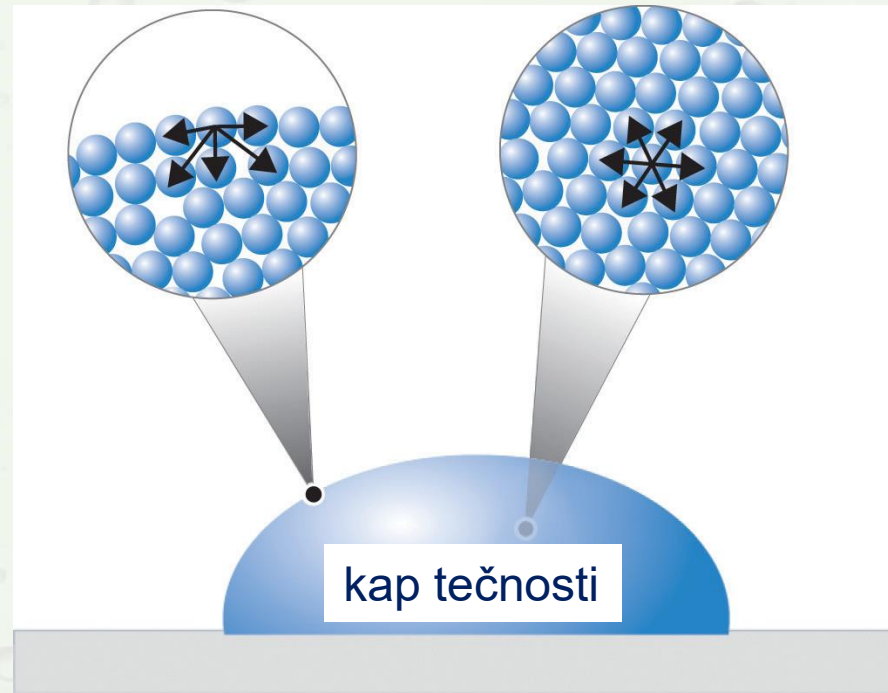
Zašto ovaj insekt može da hoda po površini vode?



Zašto neki mali predmeti plivaju po površini vode?



Površinski napon



jake međumolekulske interakcije



veliki površinski napon

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

Definicija

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

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

γ - površinski napon

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

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

Površinska Gibsova slobodna energija i površinska entalpija

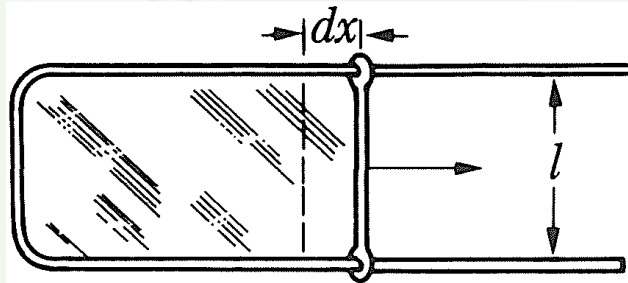
$$\gamma = \left(\frac{\partial G}{\partial \mathcal{A}} \right)_{P,T,n} = G^s$$

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/m²)

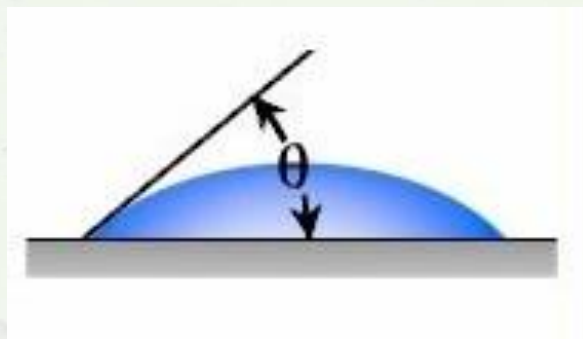
$$|\vec{F}| = \frac{dW}{dx} = \frac{\gamma d\mathcal{A}}{dx} = 2\gamma l$$

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	9070
zlato	1000,0	1070
bakar	1100,0	1130

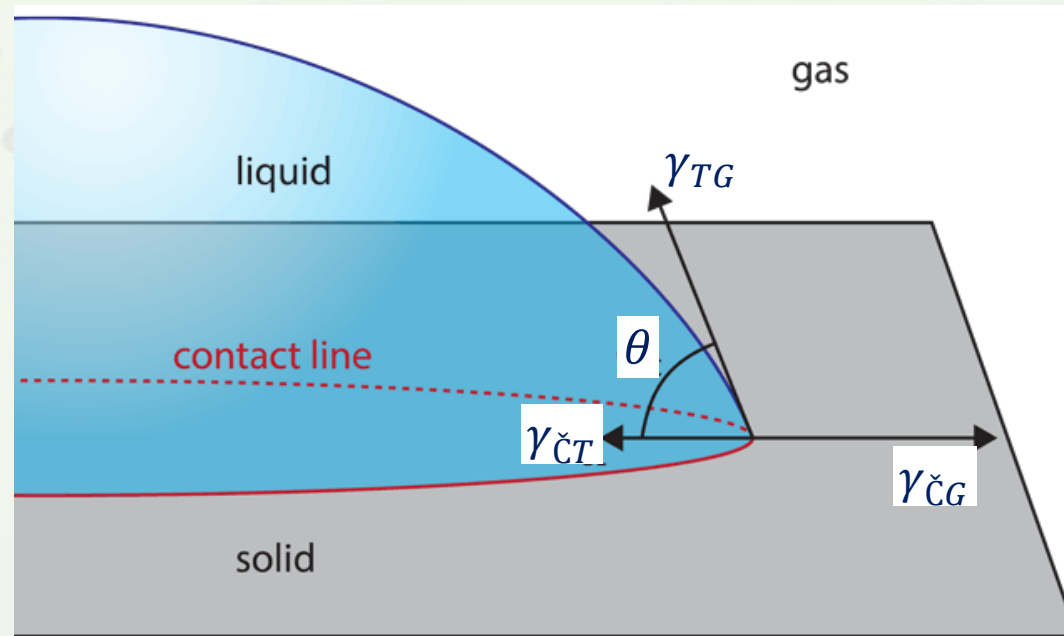
Ugao dodira



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:

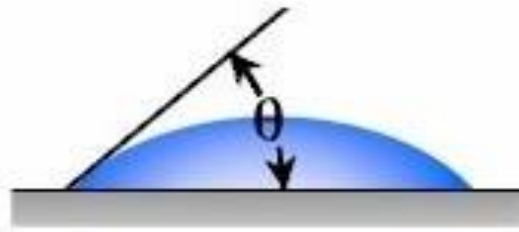


Jangova jednačina:

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

Ugao dodira

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

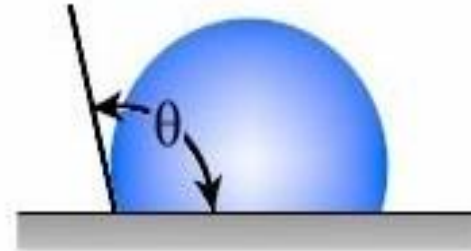


tečnost kvasi površinu

$$\gamma_{\check{C}G} > \gamma_{\check{C}T}$$

$$\cos \theta > 0$$

$$\theta < 90^\circ$$



tečnost ne kvasi površinu

$$\gamma_{\check{C}G} < \gamma_{\check{C}T}$$

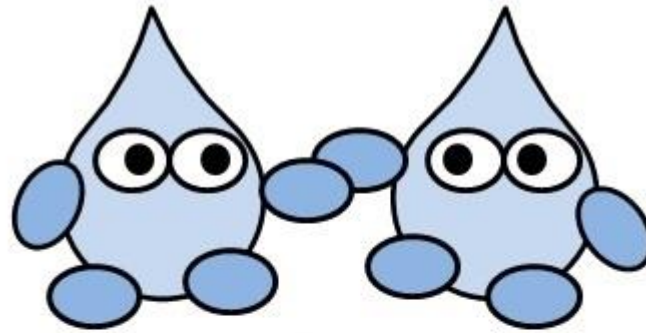
$$\cos \theta < 0$$

$$90^\circ < \theta < 180^\circ$$

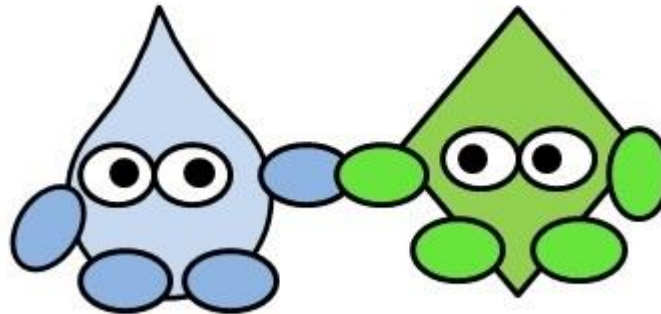
Ugao dodira i kvašenje površine



Kohezija i adhezija

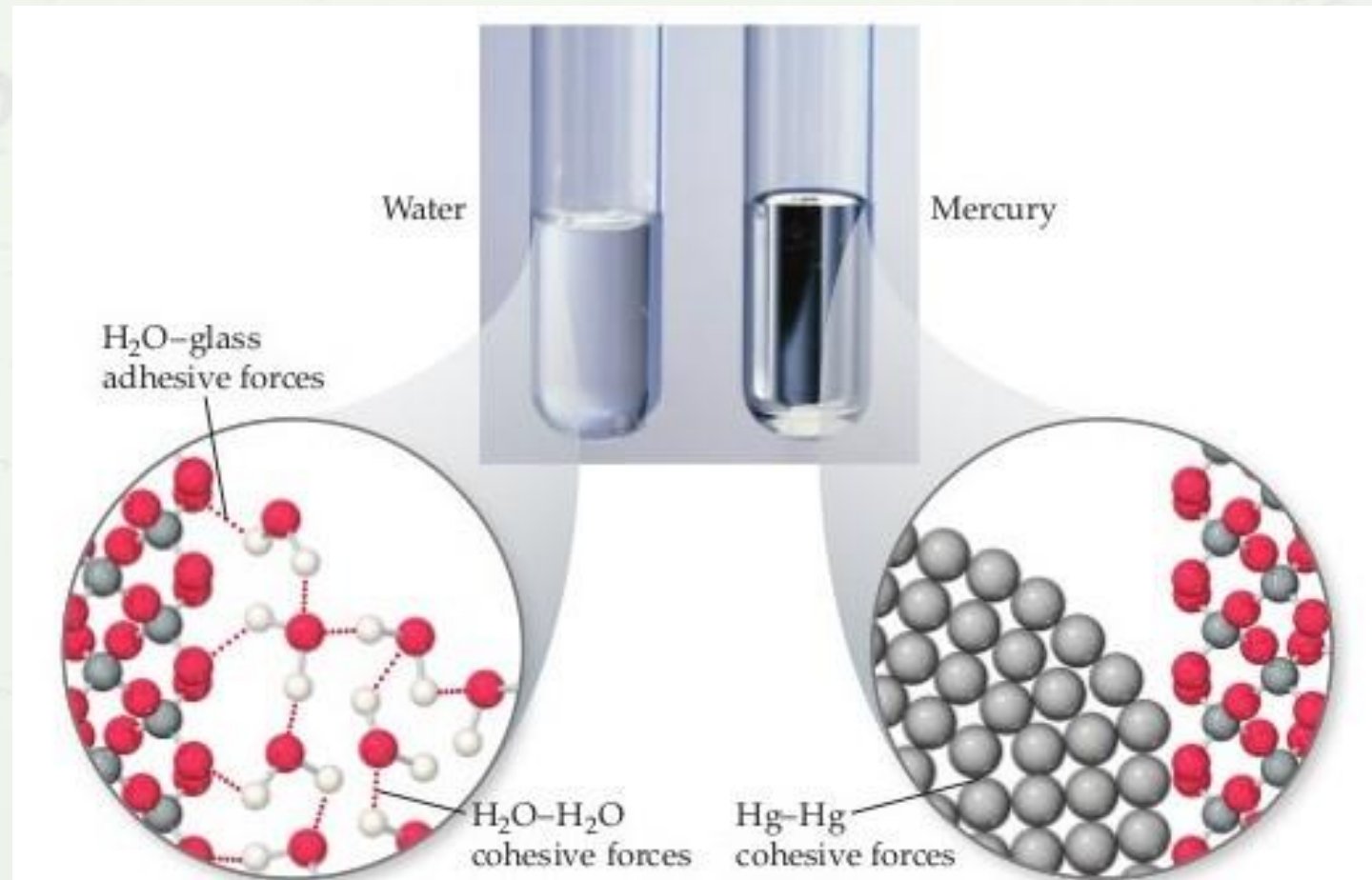


kohezija

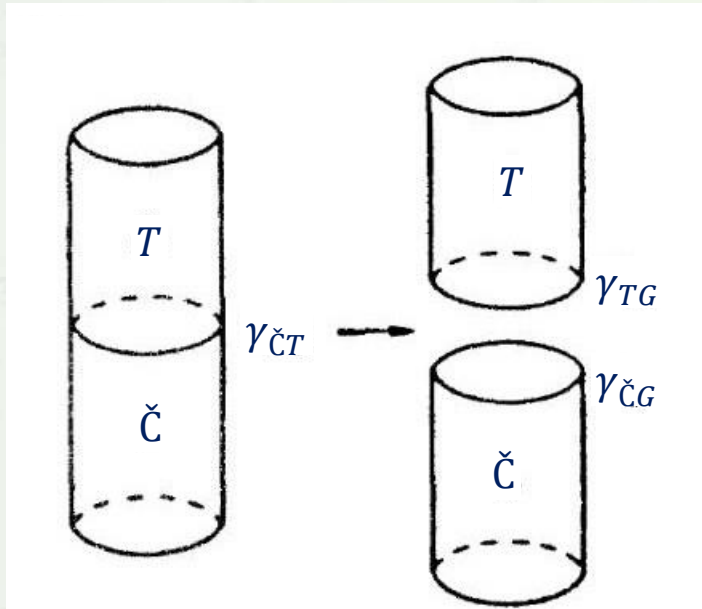


adhezija

Voda – staklo i živa – staklo

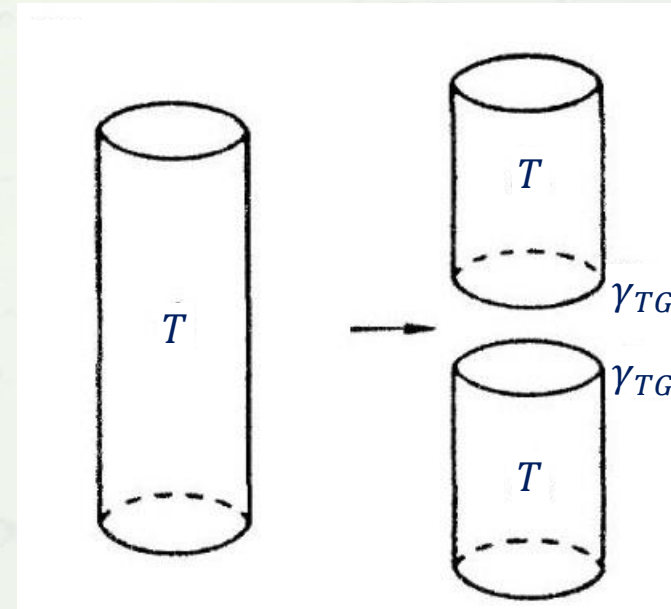


Athezioni i kohezioni rad



Athezioni rad (Dipreova jednačina)

$$w_{\check{C}T} = \gamma_{\check{C}G} + \gamma_{TG} - \gamma_{\check{C}T}$$



Kohezioni rad

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

Ugao dodira

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

tečnost kvasi površinu

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

tečnost ne kvasi površinu

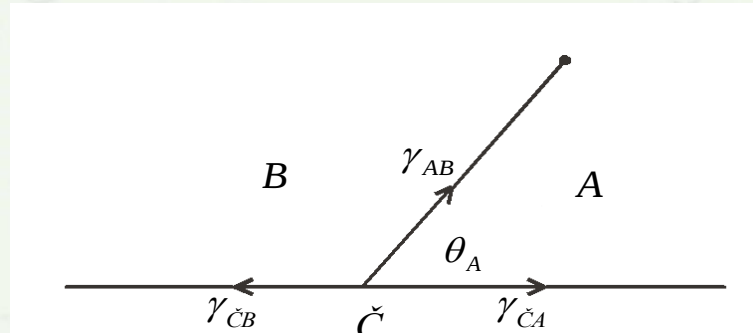
$$90^0 < \theta < 180^0, w_{\check{C}T} < w_{TG}/2$$

Živa na staklu



$$\theta=140^{\circ} \rightarrow w_{\check{C}T} / (w_{TT} / 2) = 0,23$$

Nemešljive tečnosti: razastiranje tečnosti



$$\gamma_{\check{C}B} = \gamma_{\check{C}A} + \gamma_{AB} \cos \theta_A$$



Razastiranje tečnosti

Dve nemešljive tečnosti A i B, tečnost A razastire se spontano po tečnosti B:

$$\gamma_{AB} + \gamma_{AG} - \gamma_{BG} < 0$$

Athezioni rad između A i B: $w_{AB} = \gamma_{AG} + \gamma_{BG} - \gamma_{AB}$

Uslov za razastiranje: $w_{AB} > 2\gamma_{AG}$

Koeficijent razastiranja: $\gamma_{BG} - \gamma_{AG} - \gamma_{AB}$

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.



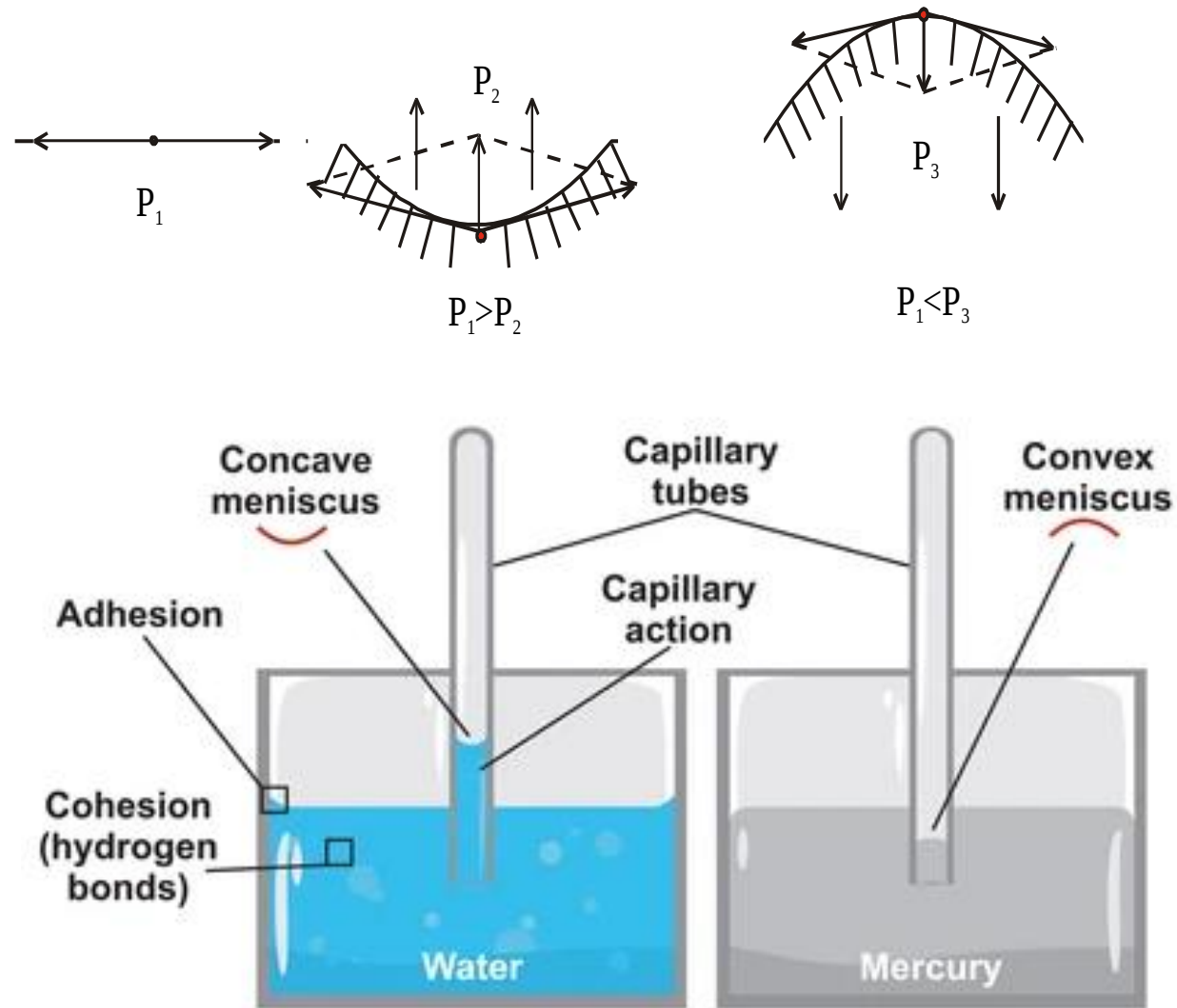
Balon: oblast u kojoj je para zarobljena
tankim filmom koji ima dve površine.



Zakrivljena površina – posledice

- kapilarne pojave
- napon pare zavisi od zakrivljenosti površine

Kapilarne pojave



Kapilarne pojave



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

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

$$dG = dG_1 + dG_2 = 0$$

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

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



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

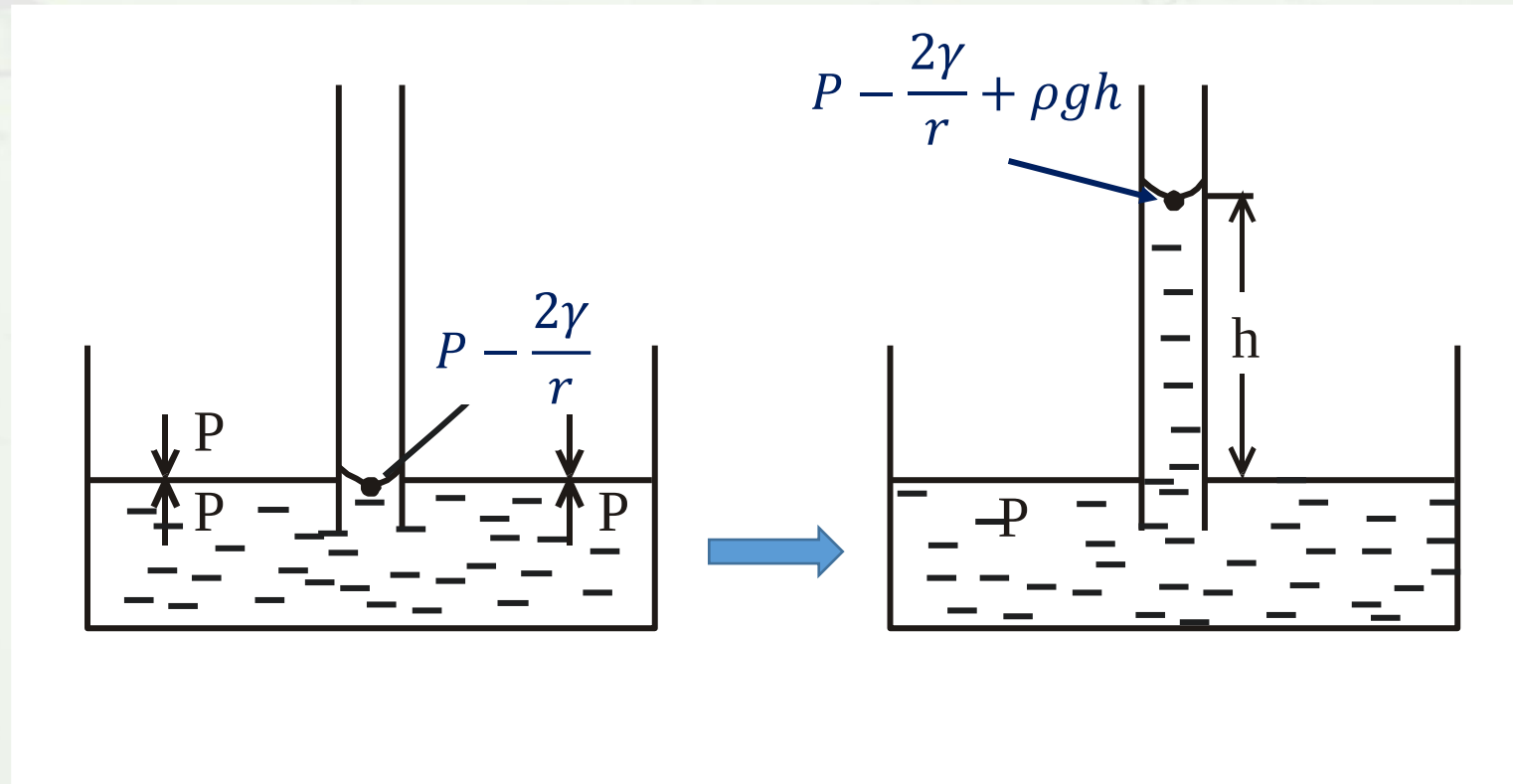
Laplasova jednačina

Primer – mehur u vodi

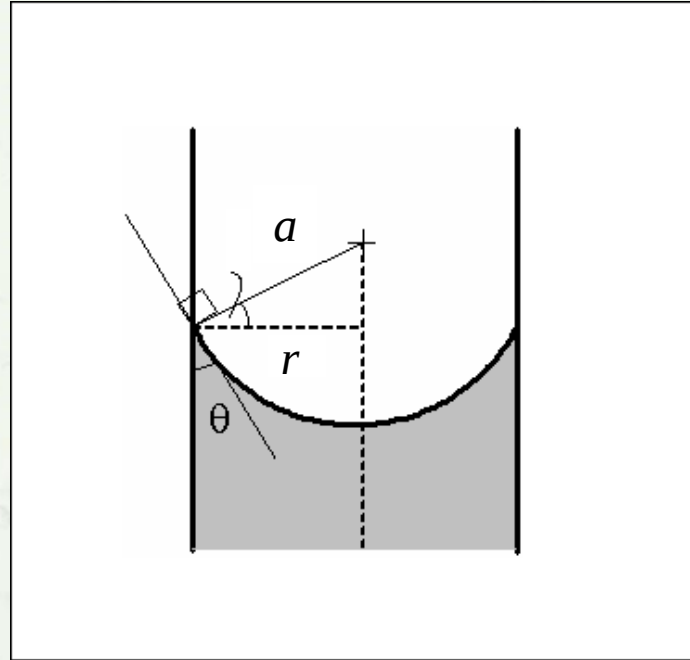
$$T = 298 \text{ K}$$
$$\gamma = 72 \text{ mN/m}$$

$2r / \mu\text{m}$	$\Delta P / \text{Pa (atm)}$
1 000	288 (0,00284)
3,0	96 000 (0,947)
0,3	960 000 (9,474)

Kapilarnost je 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

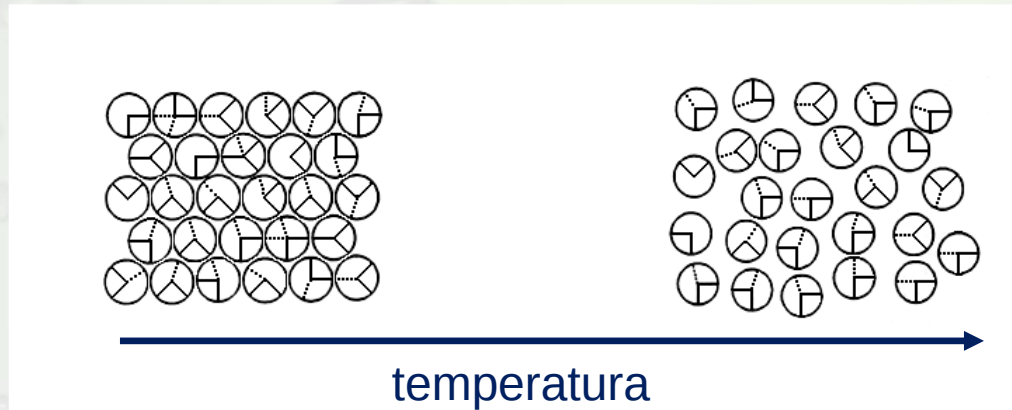
Promena molarne Gibsove slobodne energije pri obrazovanju zakrivljene površine:

$$\left. \begin{aligned} \Delta G_m(t) &= \int_0^{2\gamma/r} V_m^t dP = \frac{2\gamma V_m^t}{r} \\ \Delta G_m(g) &= RT \ln \frac{p}{p^0} \\ \Delta G_m(t) &= \Delta G_m(g) \end{aligned} \right\} \ln \frac{p}{p^0} = \frac{2\gamma V_m^t}{RT r}$$

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

Kelvinova jednačina

Površinski napon i temperatura



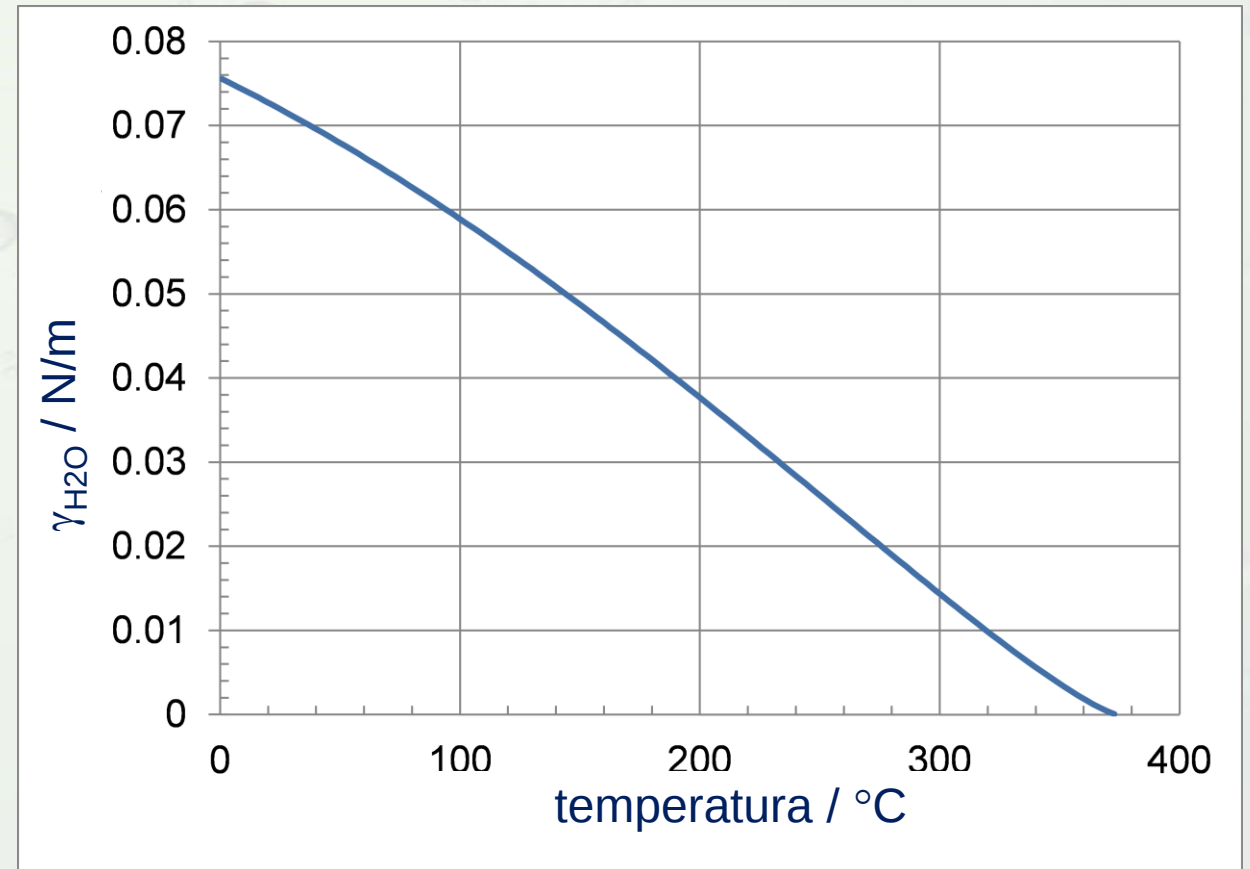
viša temperatura



slabije međumolekulske interakcije



manji γ



Površinski napon odabranih tečnosti (N/m)

t (°C)	H ₂ O	CCl ₄	C ₆ H ₆	C ₆ H ₅ NO ₂	C ₆ H ₅ OH
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:
$$-\frac{d[\gamma V_m^{2/3}]}{dT} = k$$

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

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

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

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

Druge empirijske jednačine:

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

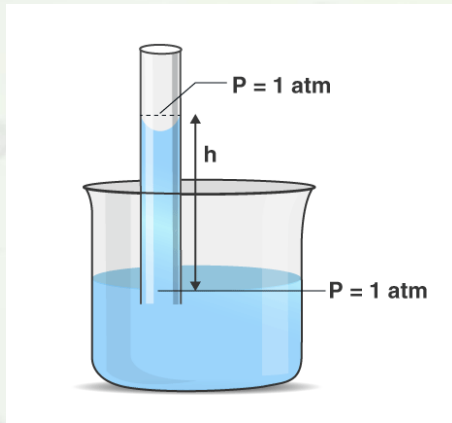
Van der Vals:
$$\gamma = \gamma_0 \left(1 - \frac{T}{T_c}\right)^n$$

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

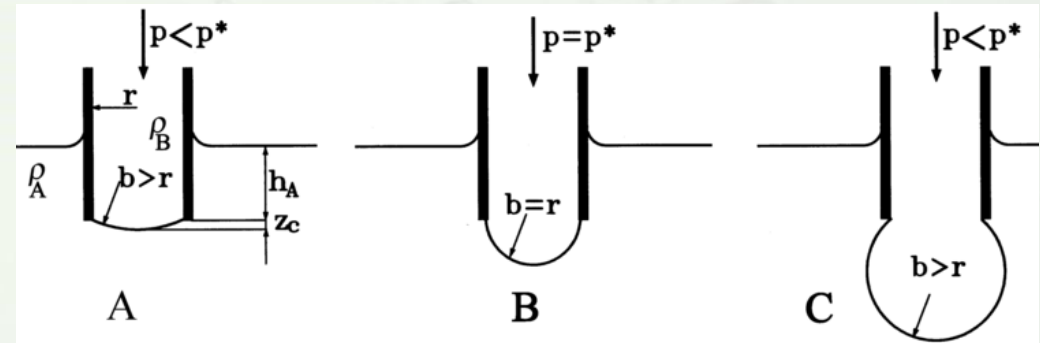
Meklod:
$$\gamma = C(\rho - \rho')^4$$

Merenje koeficijenta površinskog napona

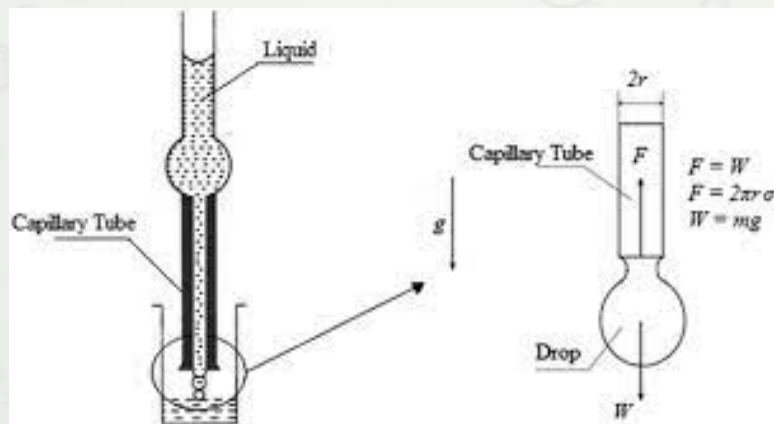
podizanje nivoa tečnosti u kapilari



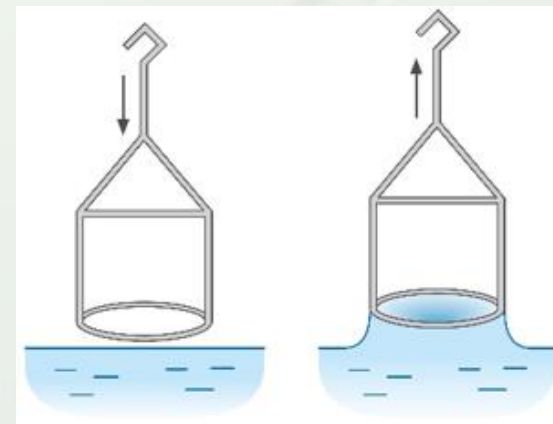
metoda mehura maksimalnog pritiska



stalagmometrijska metoda



tenziometar



Rezime

