Republic of Belarus

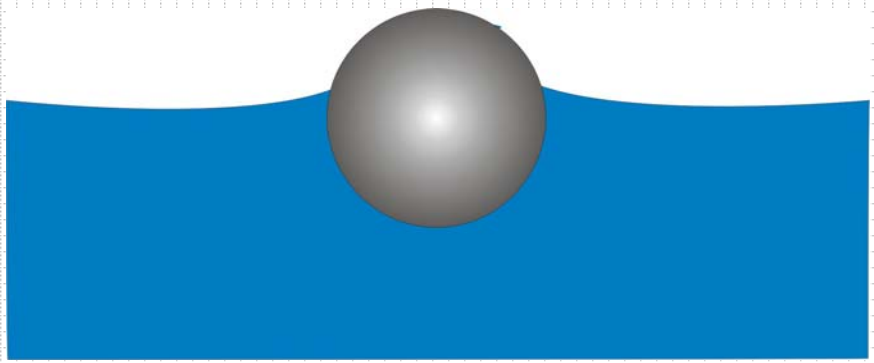
Dusty Blot

Task

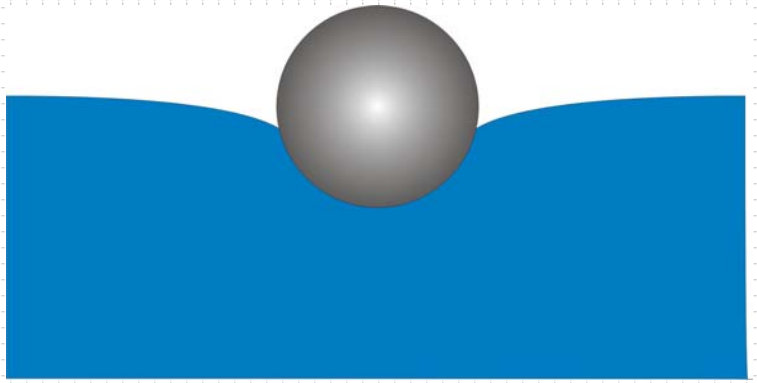
Dusty Blot

Describe and explain the dynamics of the pattern you observe when some dry dust (e.g. coffee powder or flour) is poured onto a water surface. Study the dependence of the observed phenomena on the relevant parameters.

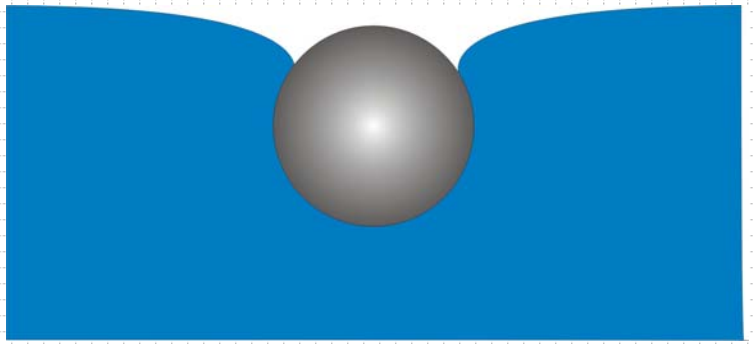
Floating



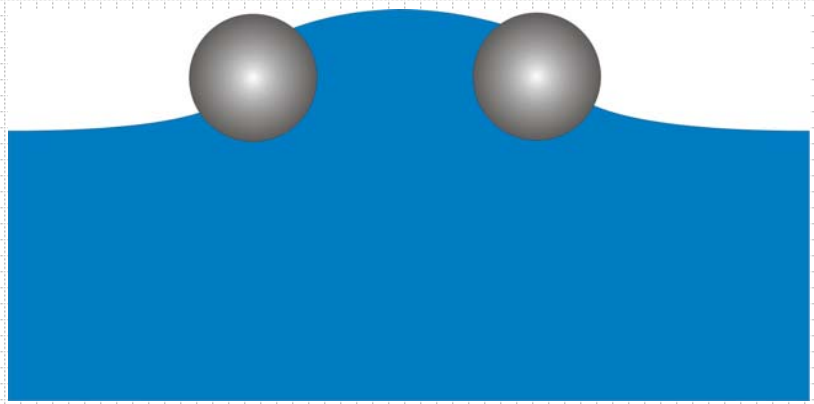
Wettable speck



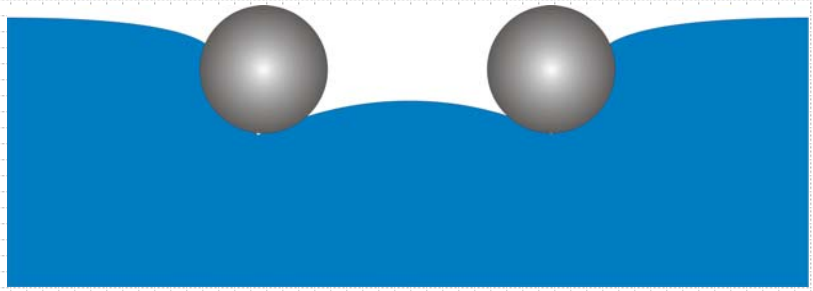
Unwettable speck



capillary effect

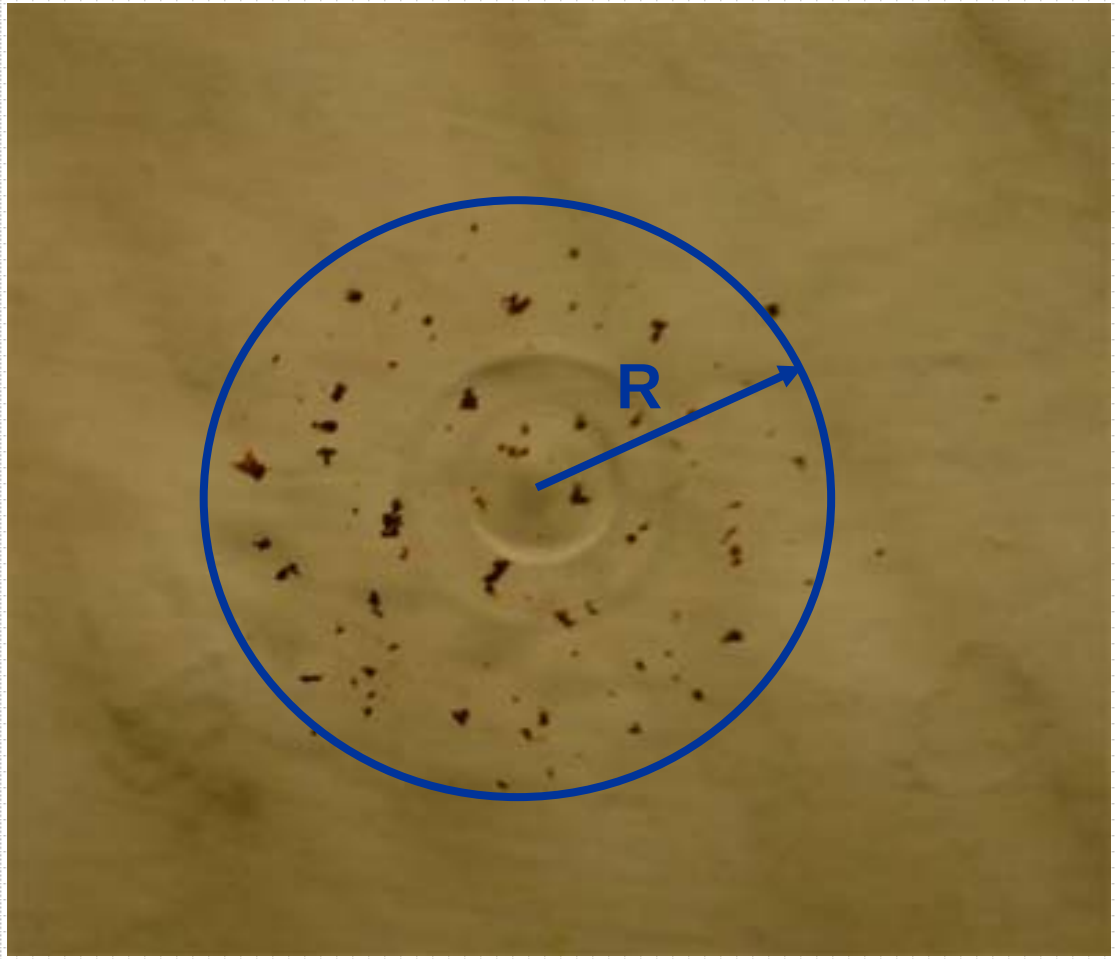


Two wettable specks



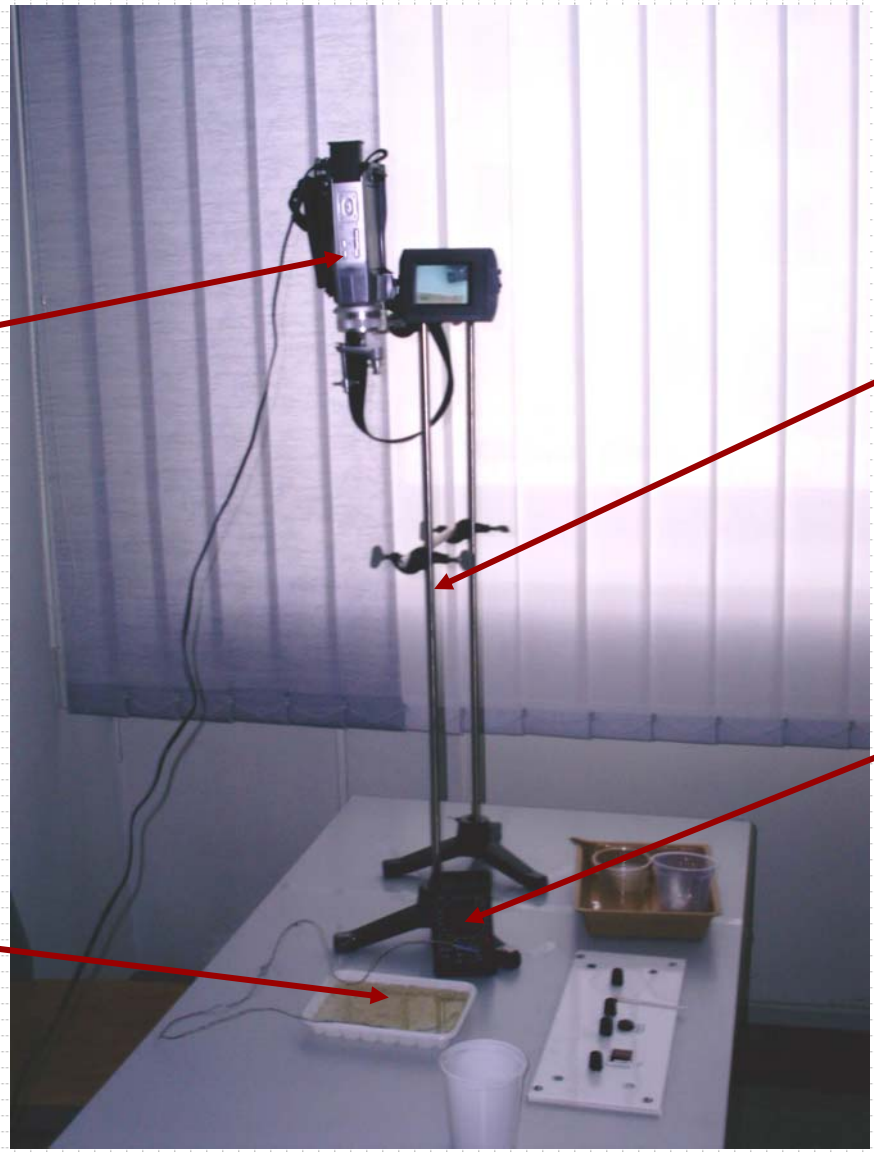
Two unwettable specks

The blot

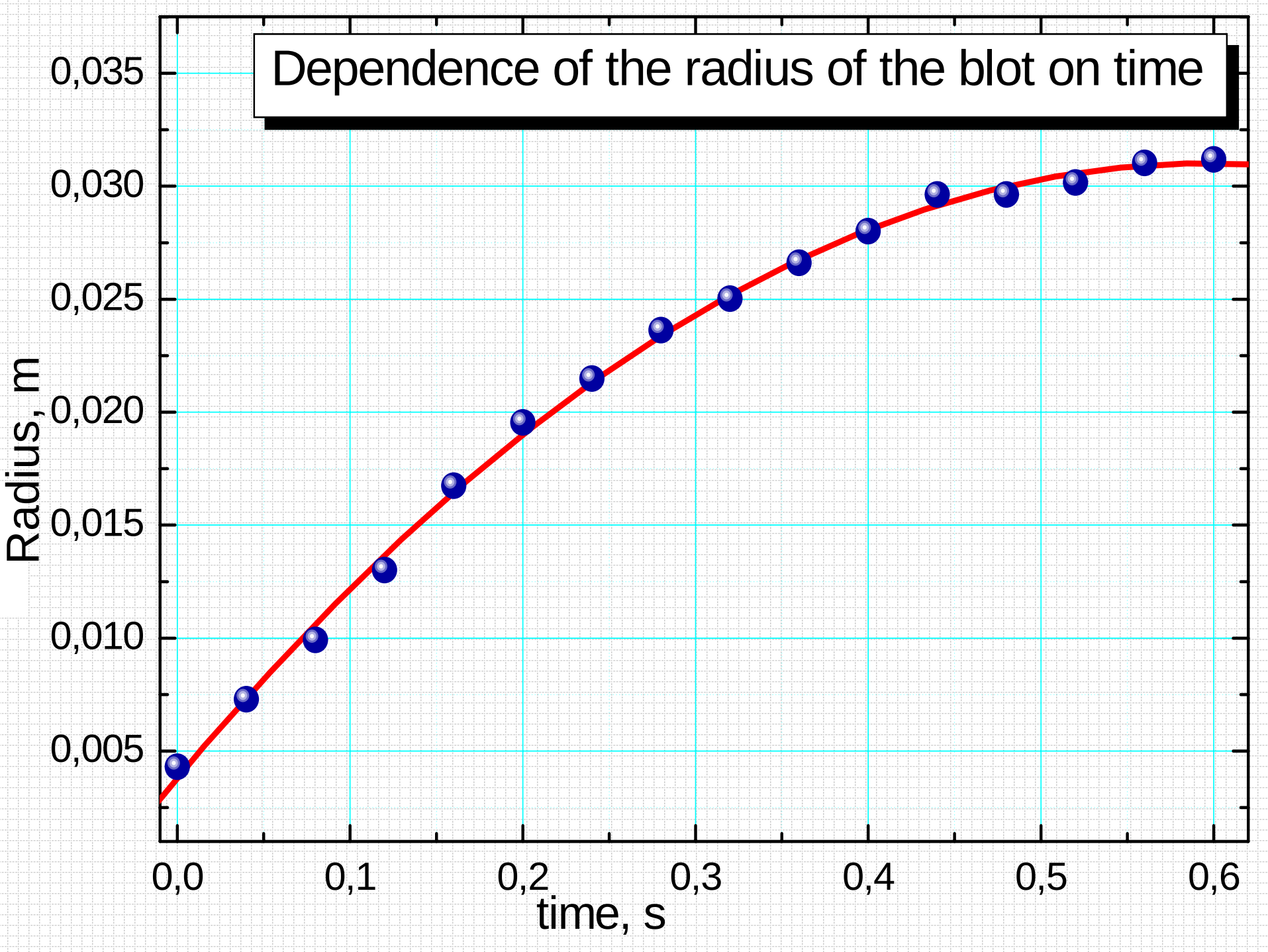


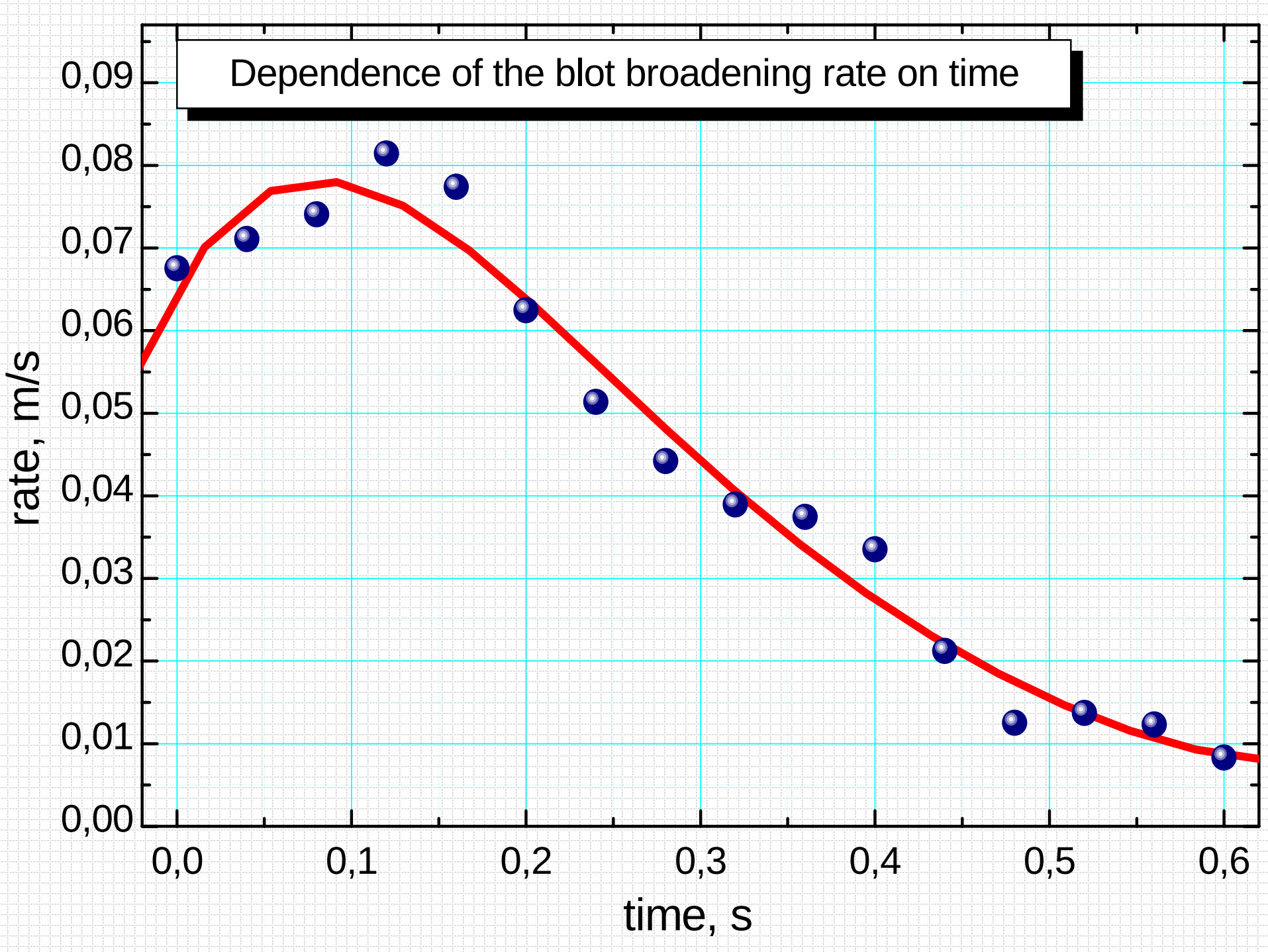
Some substances, having been poured by a pitch, disperse on the surface and form a round blot

experiment

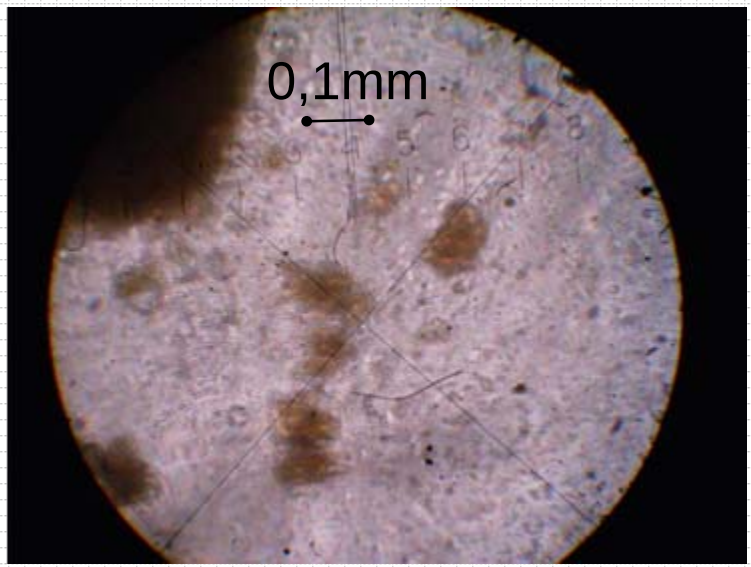


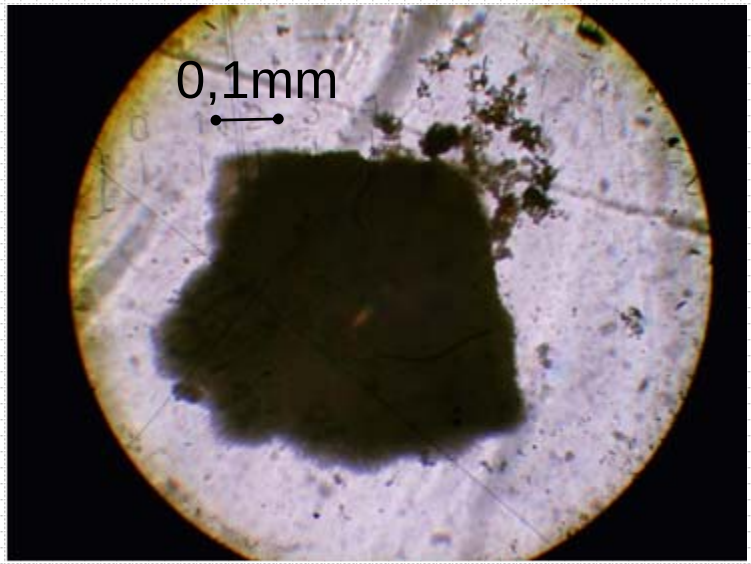
VIDEO

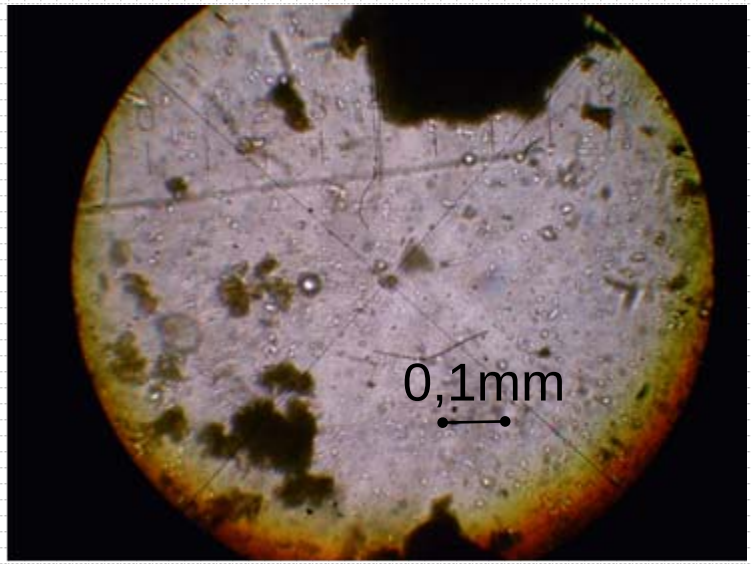

Dependence of the radius of the blot on time
Radius, m
0,035
0,030
0,025
0,020
0,015
0,010
0,005
0,0
0,1
0,2
0,3
0,4
0,5
0,6
time, s


Dependence of the blot broadening rate on time
rate, m/s
time, s
0,00
0,01
0,02
0,03
0,04
0,05
0,06
0,07
0,08
0,09
0,0
0,1
0,2
0,3
0,4
0,5
0,6

complex compound







complex compound

Black pepper

- piperinum
- piperidinum
- ether and fat oils
- starch
- albumen
- vitamins
- steroid saponina
- alkaloid capsaicinum

Coffee

fats, albumens, carbohydrates

- mono- и disaccharides
- food fibers
- organic acids
- ash
- iron
- potassium
- calcium
- magnesium
- sodium
- phosphorus

theory

Main assumptions:

1. **The blot is round and plain (the only spatial coordinate is *radius*);**
2. **The dependence of surface tension on SAS concentration is linear (and decreasing):**

$$\sigma = \sigma_0 \left(1 - \alpha\gamma\right) \qquad (1)$$

where σ_0 – surface tension of pure water (with no SAS);
γ – SAS concentration on the surface (mol/m^2);
α – some constant coefficient .

theory

Main assumptions (continues):

3. **The force affecting a speck is proportional to the gradient of surface tension, to speck's area and is directed against the gradient**

$$F_s = -S \frac{\partial \sigma}{\partial r}$$

theory

Main assumptions (continues):

4. **The viscous friction force is proportional to the velocity (Stoke's law):**

$$F_{fr} = -\beta v \qquad (3)$$

5. **We use a quazi-static estimation:**

$$F_{fr} = F_s \Rightarrow \beta v = -S\alpha\sigma_0 \frac{\partial \gamma}{\partial r} \qquad (4)$$

theory

Main assumptions (continues):

6. The dissolution:

$$\frac{\partial \gamma}{\partial t} = Cn\left(\gamma_{\lim} - \gamma\right) \qquad (5)$$

where n – specks' concentration on the surface ($1/m^2$);
γ_{lim} – limiting SAS concentration on the surface (mol/m^2);
γ – current SAS concentration;
C – some constant coefficient .

theory

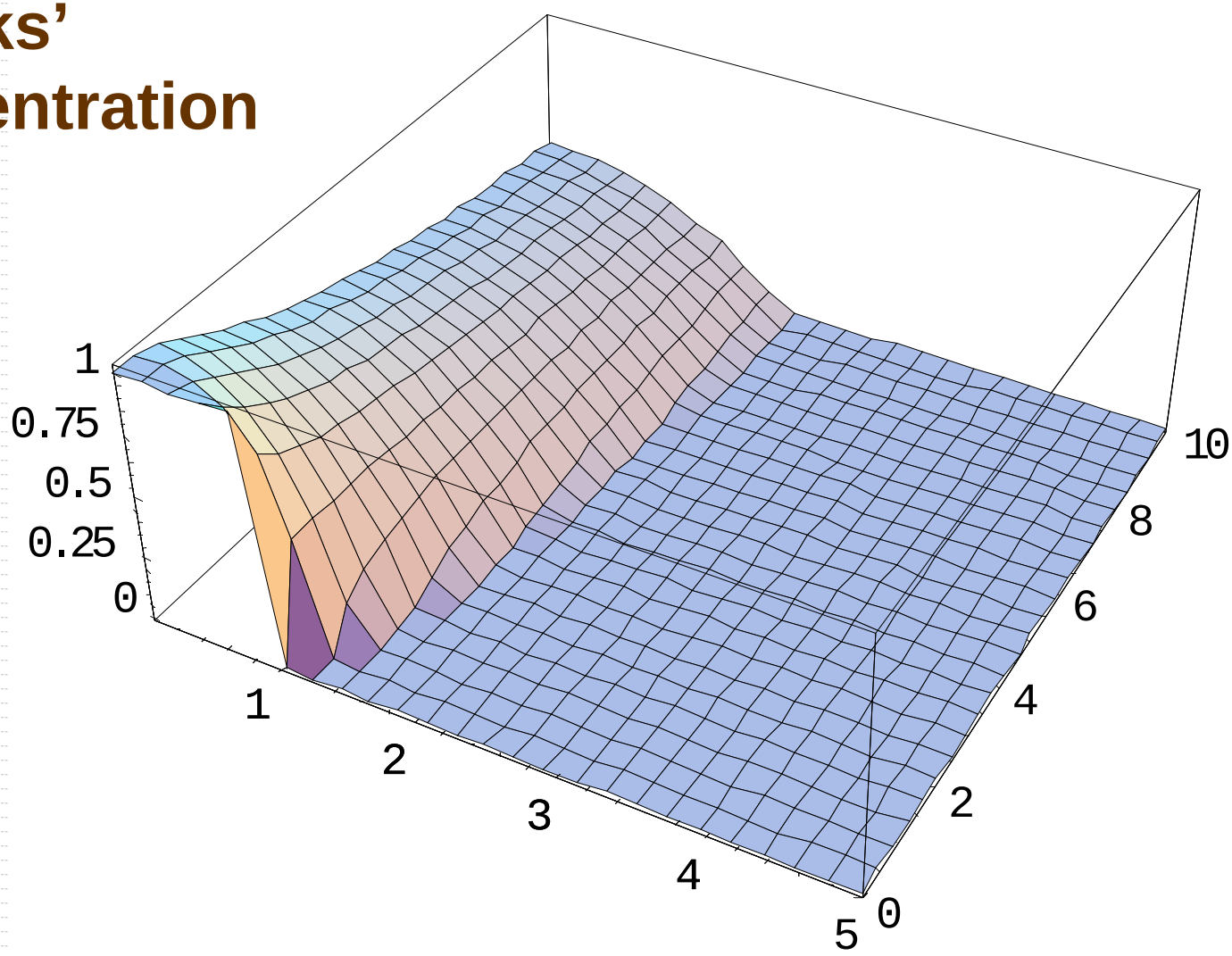
Resulting system of equations:

$$\begin{cases} \dfrac{\partial n}{\partial t} = \dfrac{\mu}{r}\dfrac{\partial}{\partial r}\left(nr\dfrac{\partial \gamma}{\partial r} \right) \\ \dfrac{\partial \gamma}{\partial t} = Cn\left(\gamma_{\lim} - \gamma \right) \end{cases} \qquad (6)$$

This system is non-linear and has to be solved numerically!

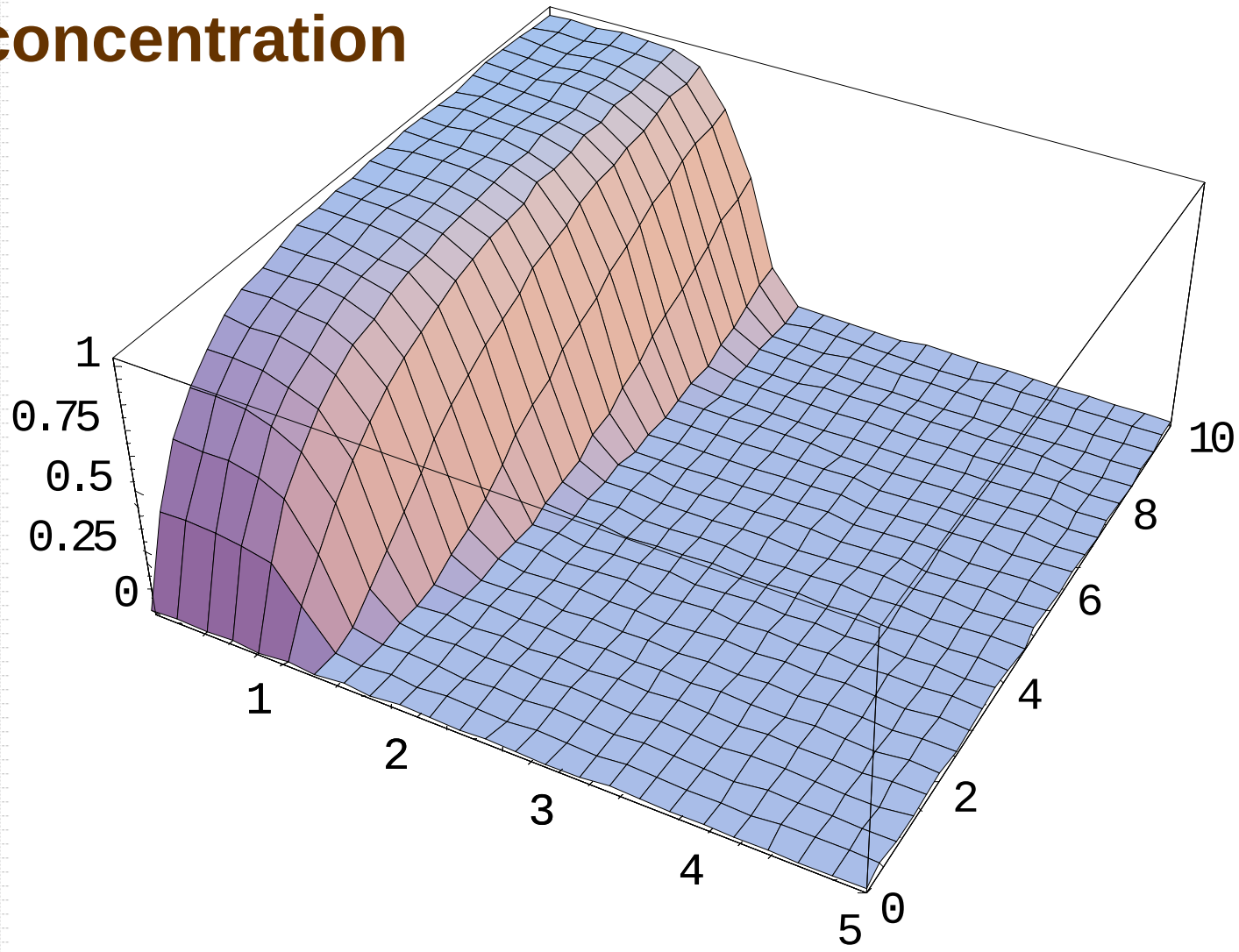
numerical solution

Specks' concentration



numerical solution

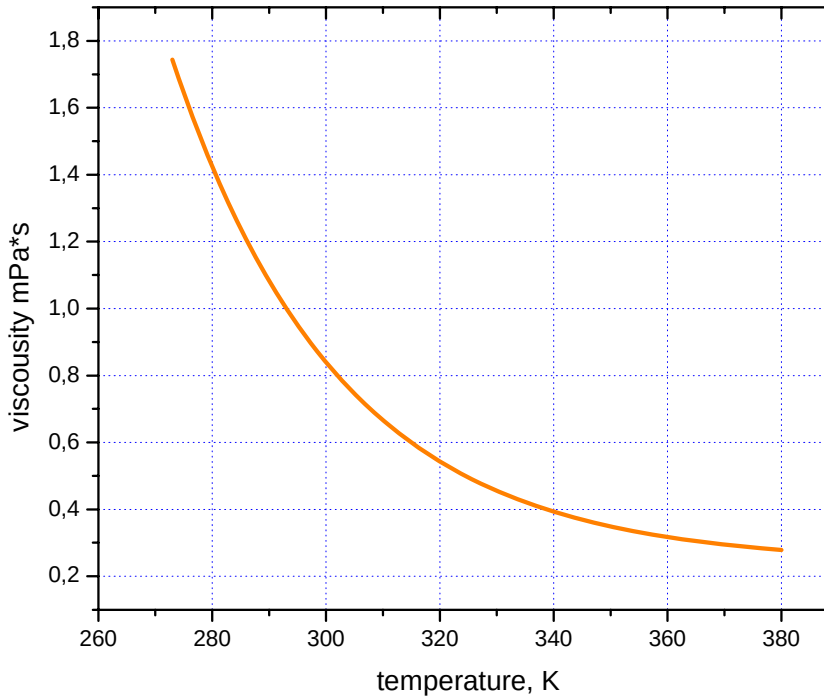
SAS concentration

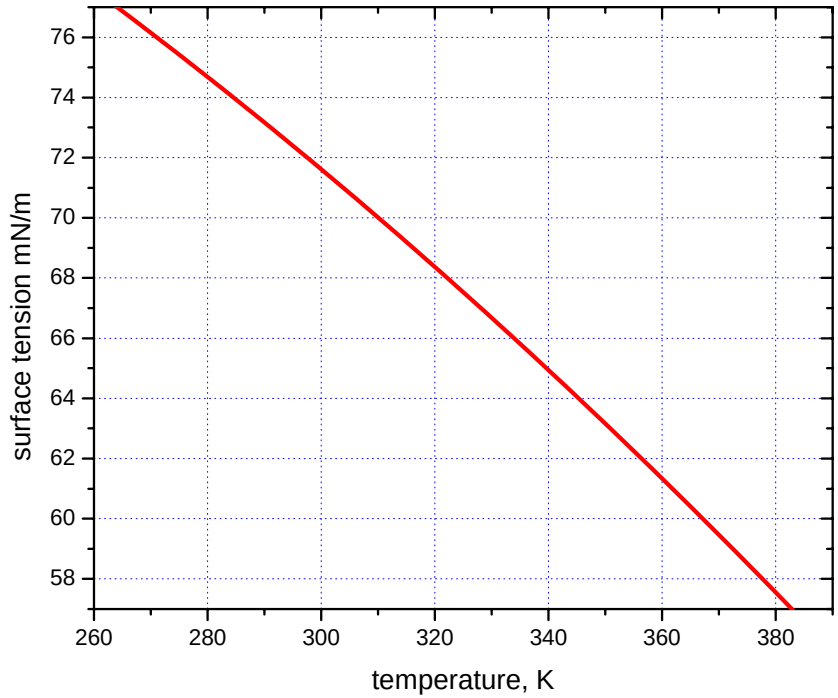


some observations

- ✓**Many substances stop dispersing in soap water and oil.**
- ✓**Insoluble substances do not disperse.**
- ✓**Heating can fasten the process.**

temperature dependence



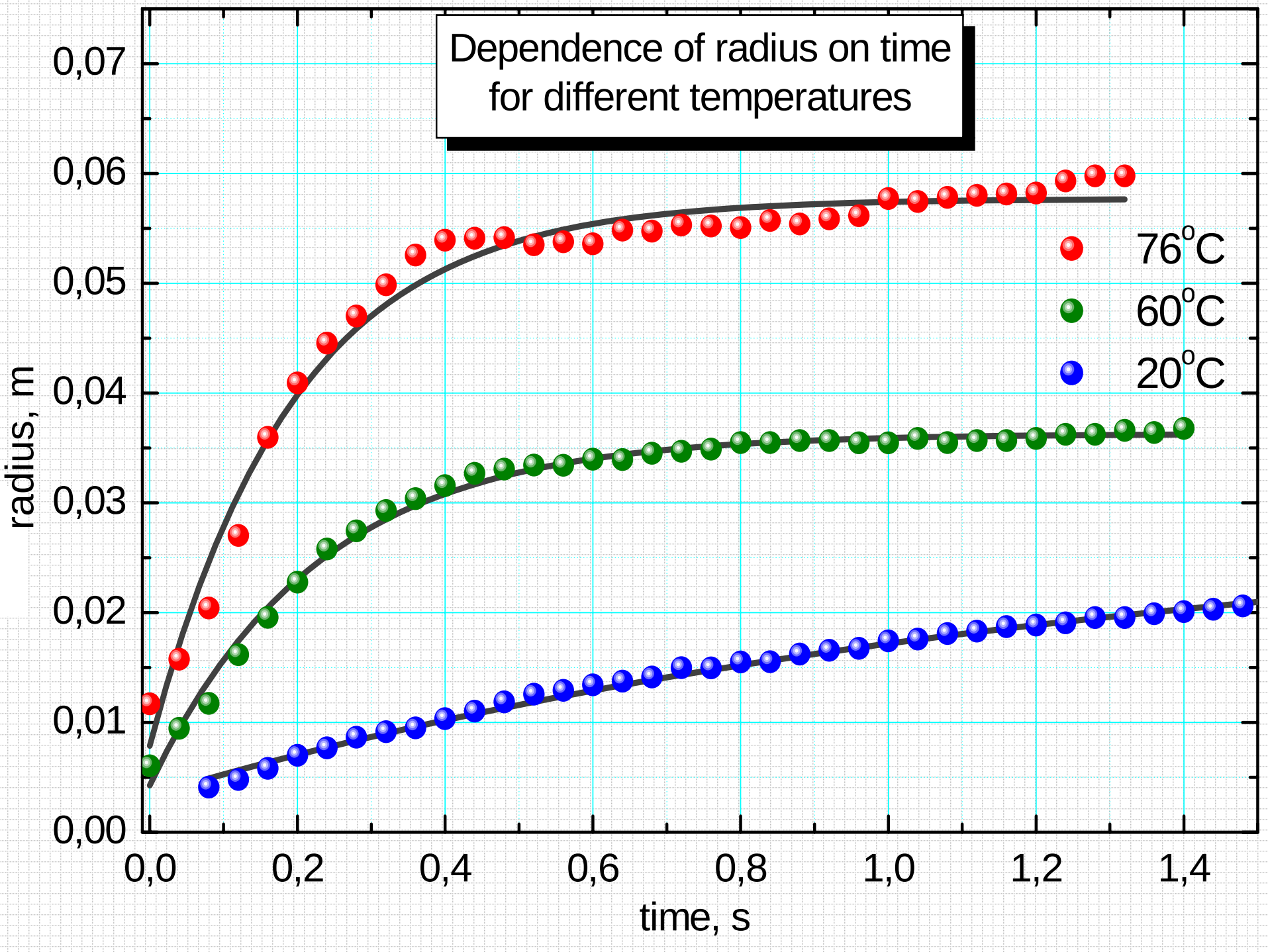


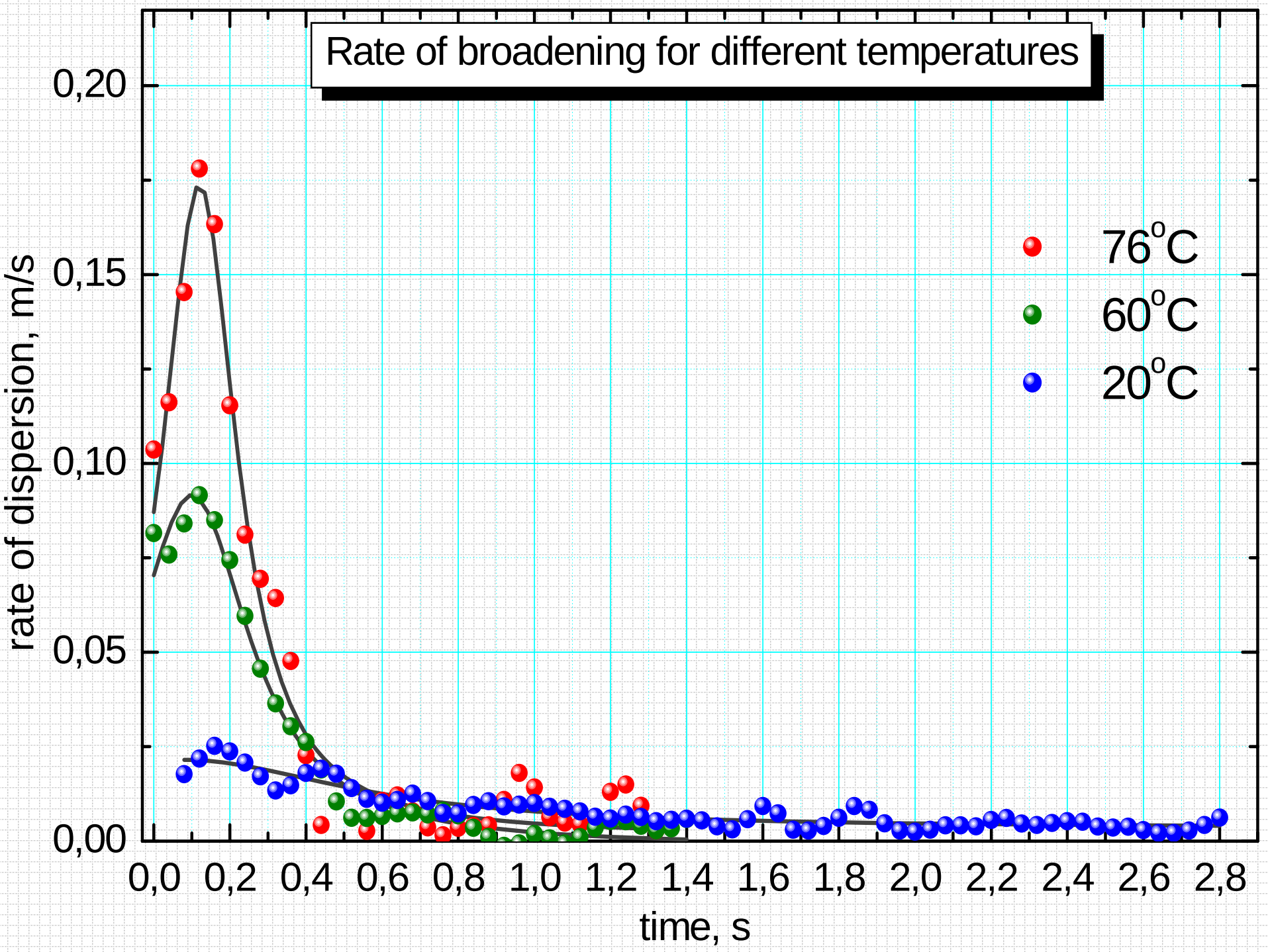
Alteration of *β* is 48%

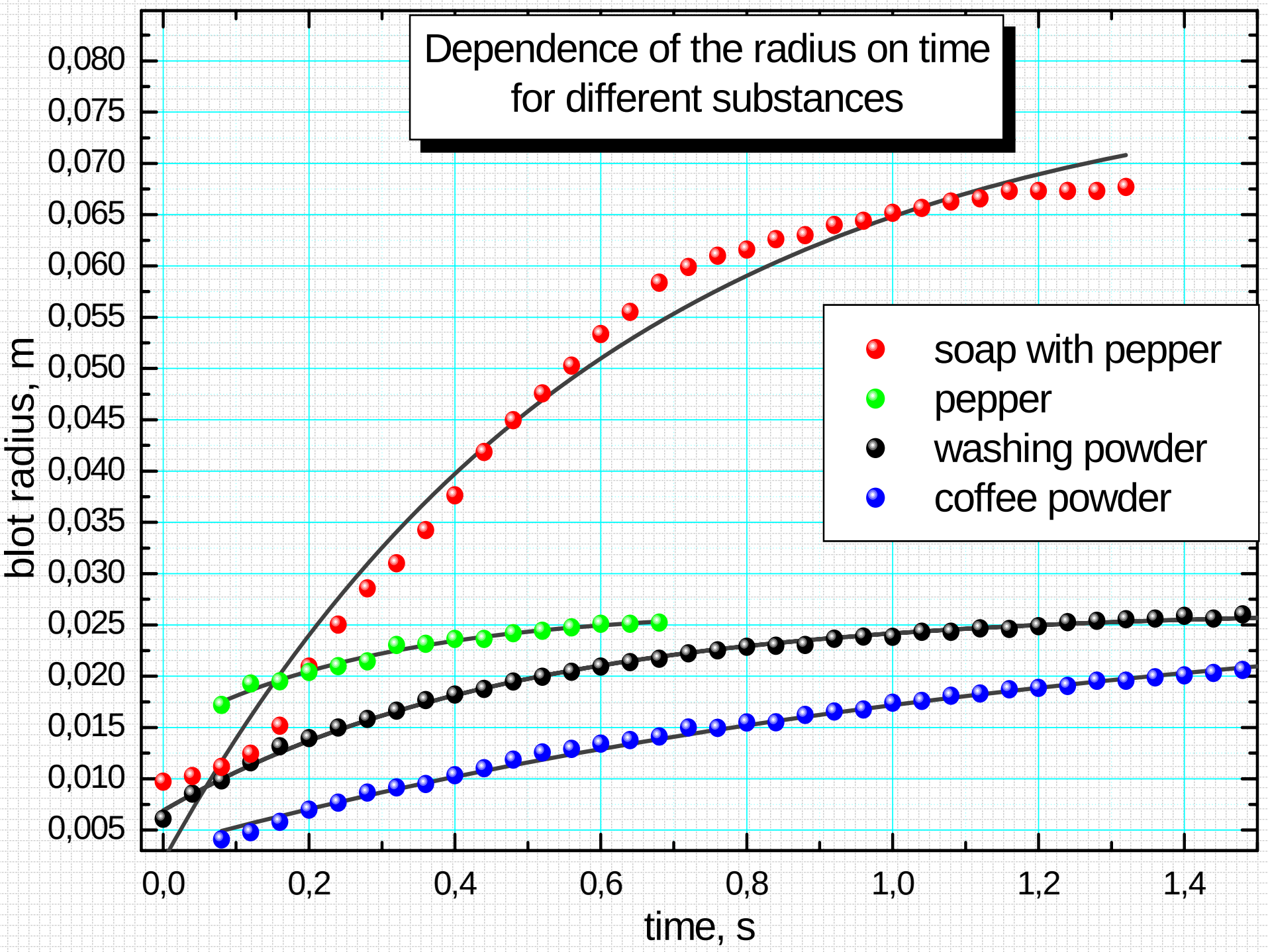
T_1=20°C

Alteration of *σ* is 13%

T_2=80°C


Dependence of radius on time
for different temperatures
76°C
60°C
20°C
radius, m
time, s
0,00
0,01
0,02
0,03
0,04
0,05
0,06
0,07
0,0
0,2
0,4
0,6
0,8
1,0
1,2
1,4


Rate of broadening for different temperatures
rate of dispersion, m/s
0,20
0,15
0,10
0,05
0,00
0,0 0,2 0,4 0,6 0,8 1,0 1,2 1,4 1,6 1,8 2,0 2,2 2,4 2,6 2,8
time, s
76°C
60°C
20°C


Dependence of the radius on time for different substances
soap with pepper
pepper
washing powder
coffee powder
blot radius, m
0,080
0,075
0,070
0,065
0,060
0,055
0,050
0,045
0,040
0,035
0,030
0,025
0,020
0,015
0,010
0,005
0,0
0,2
0,4
0,6
0,8
1,0
1,2
1,4
time, s

conclusions

The specks can held at the surface by the surface tension forces.

✓The movement of the specks is caused by surface distortions, changes in surface tension and flows in liquid.

✓The most important parameters are: specks' compound, surface tension and viscosity of liquid

reckon up the work

WE:

- ✓**Gave the explanation to the dust behavior on the surface of water;**
- ✓**Carried out several series of experiments;**
- ✓**Gave a clear mathematical description of the phenomena observed;**
- ✓**Plotted some theoretical graphs;**
- ✓**Compared the theory and the practice;**
- ✓**Investigated some additional dependences.**

Thanks a lot

for your attention!