7. Clicking fingers

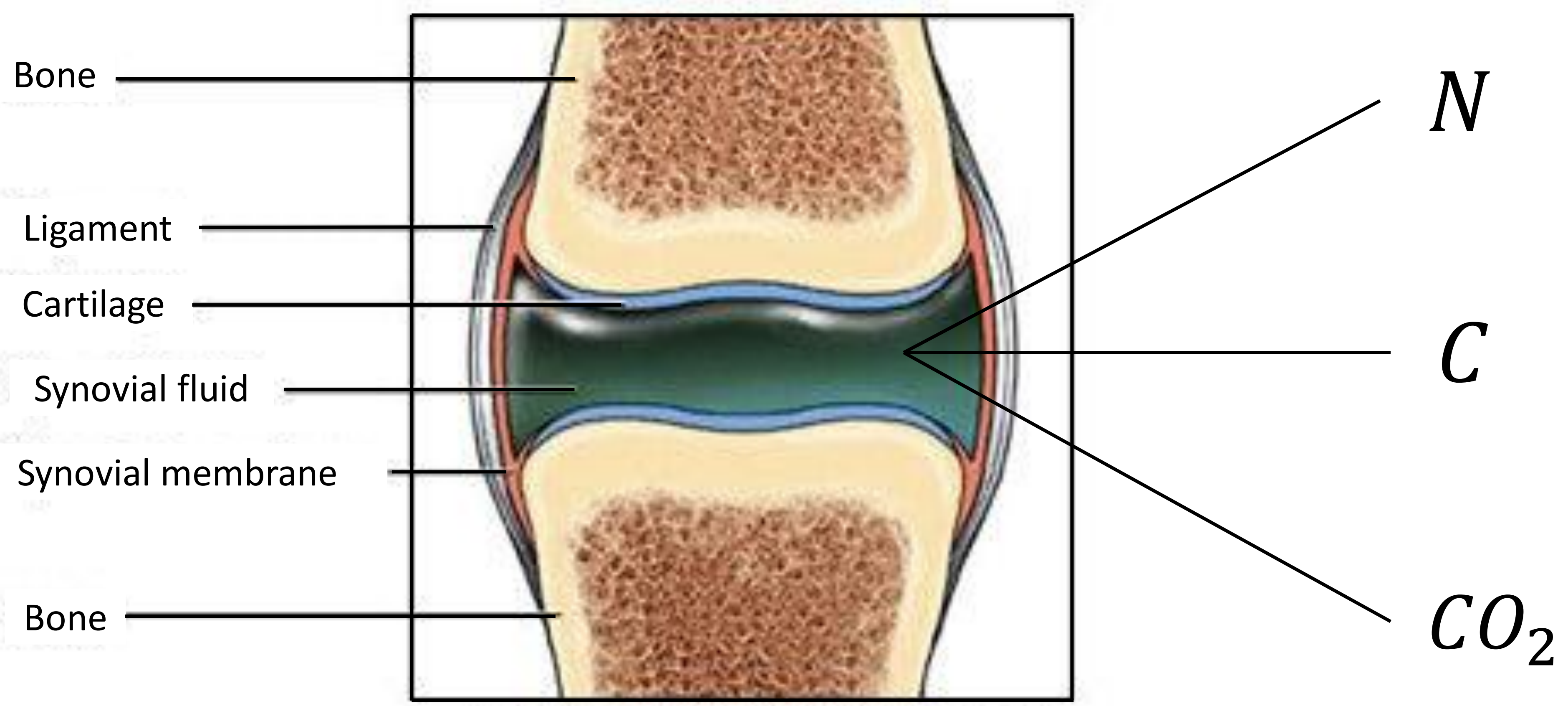
Snapping one's fingers results in a loud popping sound.
Investigate the nature and properties of this sound.

Rep: *Nikoloz Burduli*

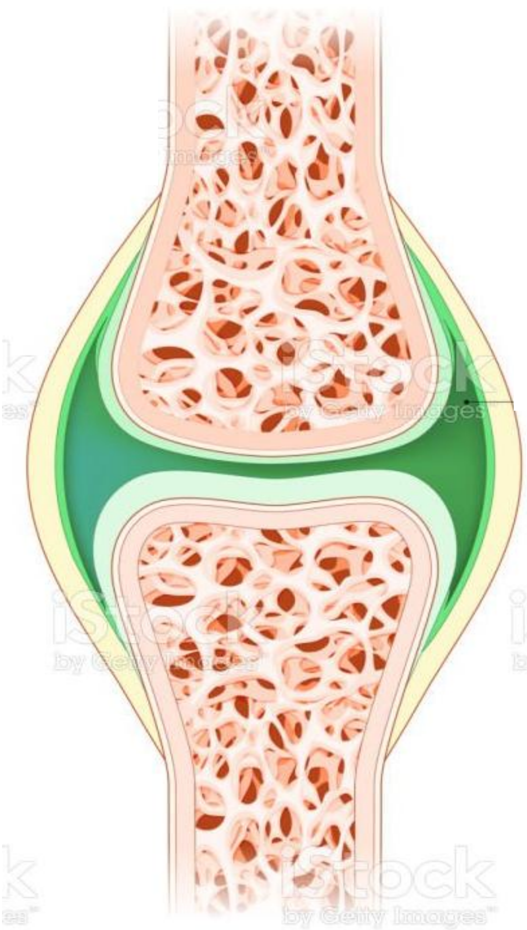
Presentation plan

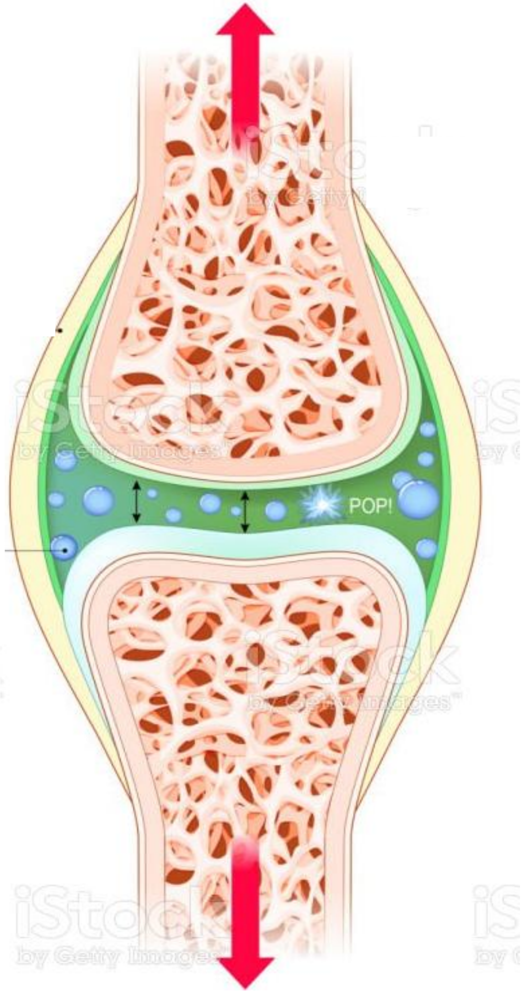
- What is synovial fluid;
- Why is popping sound heard;
- Resonant frequency;
- Theoretical result;
- Experimental result;
- Conclusion.

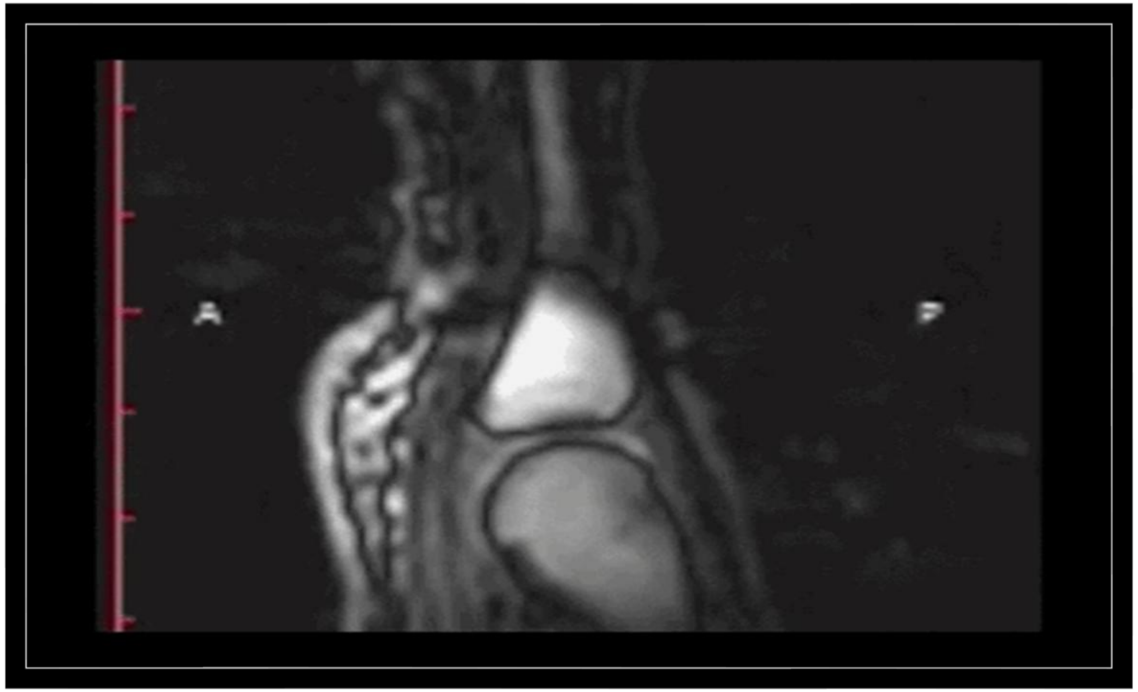
Fluid between the bones



Explanation of the phenomenon

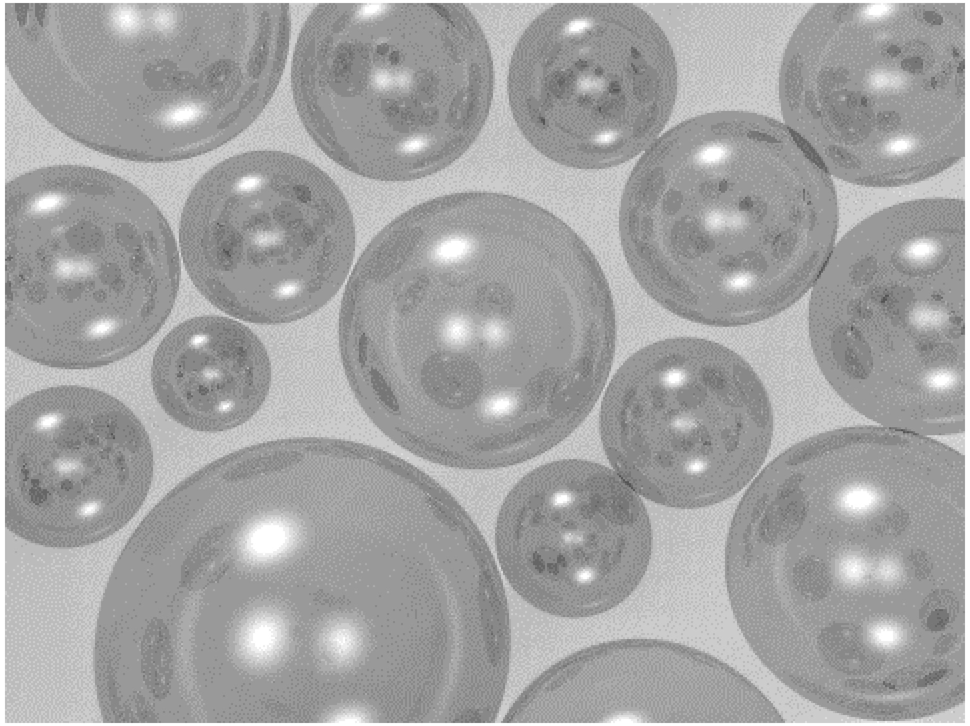




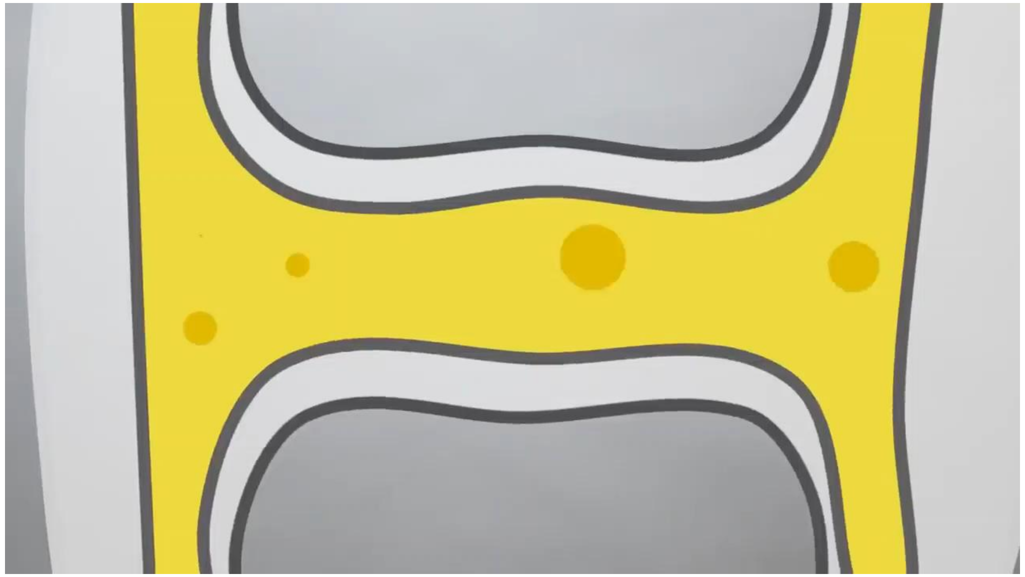


What sound do we hear when a bubble bursts?

Bubble vibration resonance



Bubble bursting



Theoretical model

Harmonic oscillation formula

$$l = l_m \cos wt \qquad \ddot{l} = -w^2 l_m \cos wt$$

$$\sigma l = F = ma = m\ddot{l}$$

$$m = \rho l^3$$

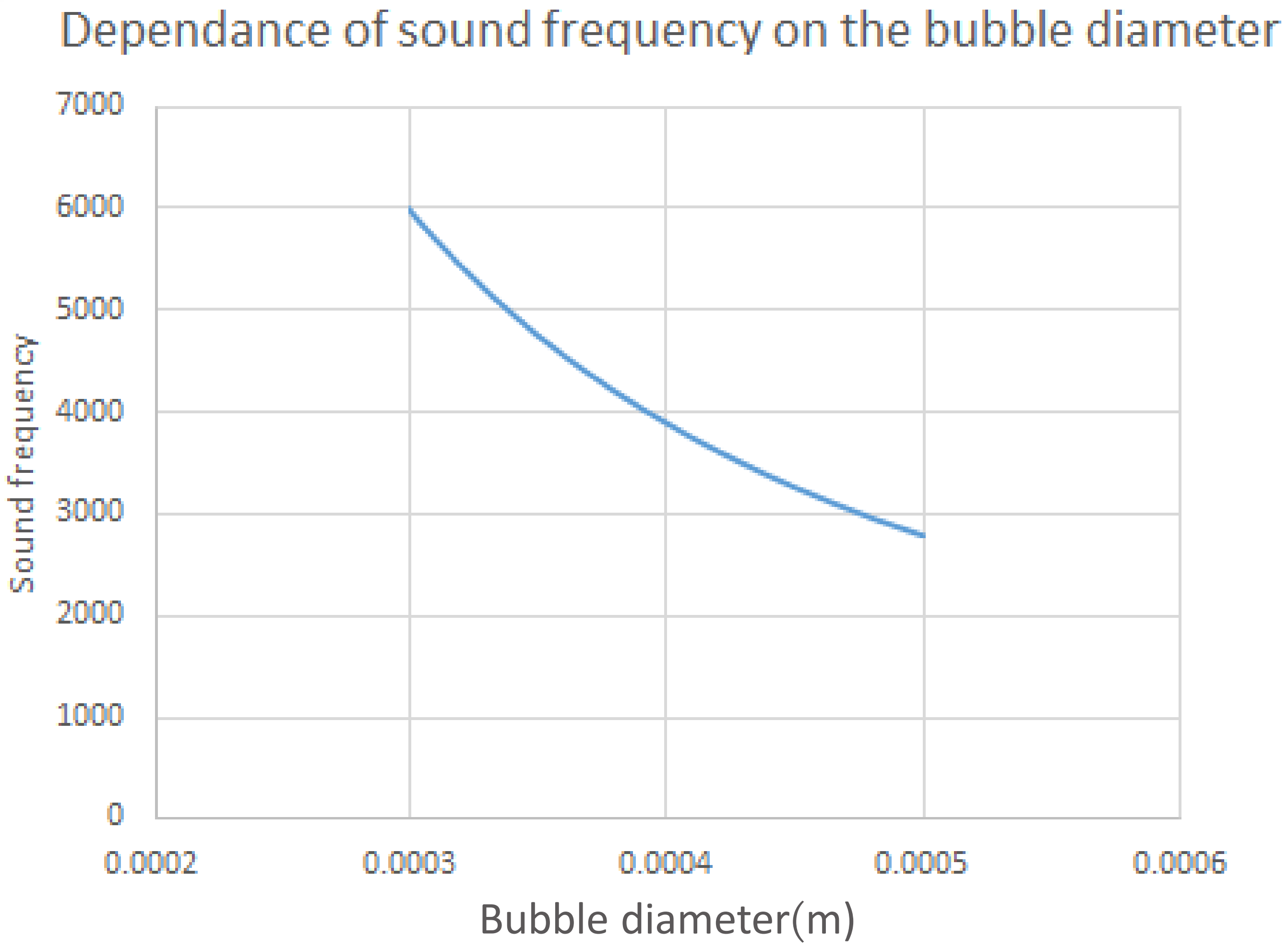
$$\sigma l = \rho l^3 w^2 l$$

l – Bubble diameter
l_m – Oscillation amplitude
w – Circular frequency of oscillation
σ – Surface tension
f – Oscillation frequency
ρ – Bubble density

$$w = \sqrt{\frac{\sigma}{\rho l^3}} \qquad \frac{w}{2\pi} = f$$

$$\boxed{f = \frac{1}{2\pi}\sqrt{\frac{\sigma}{\rho l^3}}}$$

Theoretical graph



$$f = \frac{1}{2\pi}\sqrt{\frac{\sigma}{\rho l^3}}$$

$$\sigma = 0.072\frac{N}{M}$$

$$\rho = 1.87\ kg/m^3$$

Ideal air formula

$$PV = nRT$$

$$PV = \frac{m}{M}RT$$

$$PV = \frac{\rho V}{M}RT$$

$$\rho = \frac{PM}{RT}$$

$$f = \frac{1}{2\pi}\sqrt{\frac{\sigma}{\rho l^3}}$$

$$\boxed{f = \frac{1}{2\pi}\sqrt{\frac{\sigma RT}{PMl^3}}}$$

$$P = \frac{\sigma RT}{4\pi^2 f^2 M l^3}$$

P – pressure

V – bubble volume

n – the number of moles

R – universal gas constant

T – temperature

M – Molar mass

Theoretical graph

$$f = \frac{1}{2\pi}\sqrt{\frac{\sigma RT}{PMl^3}}$$

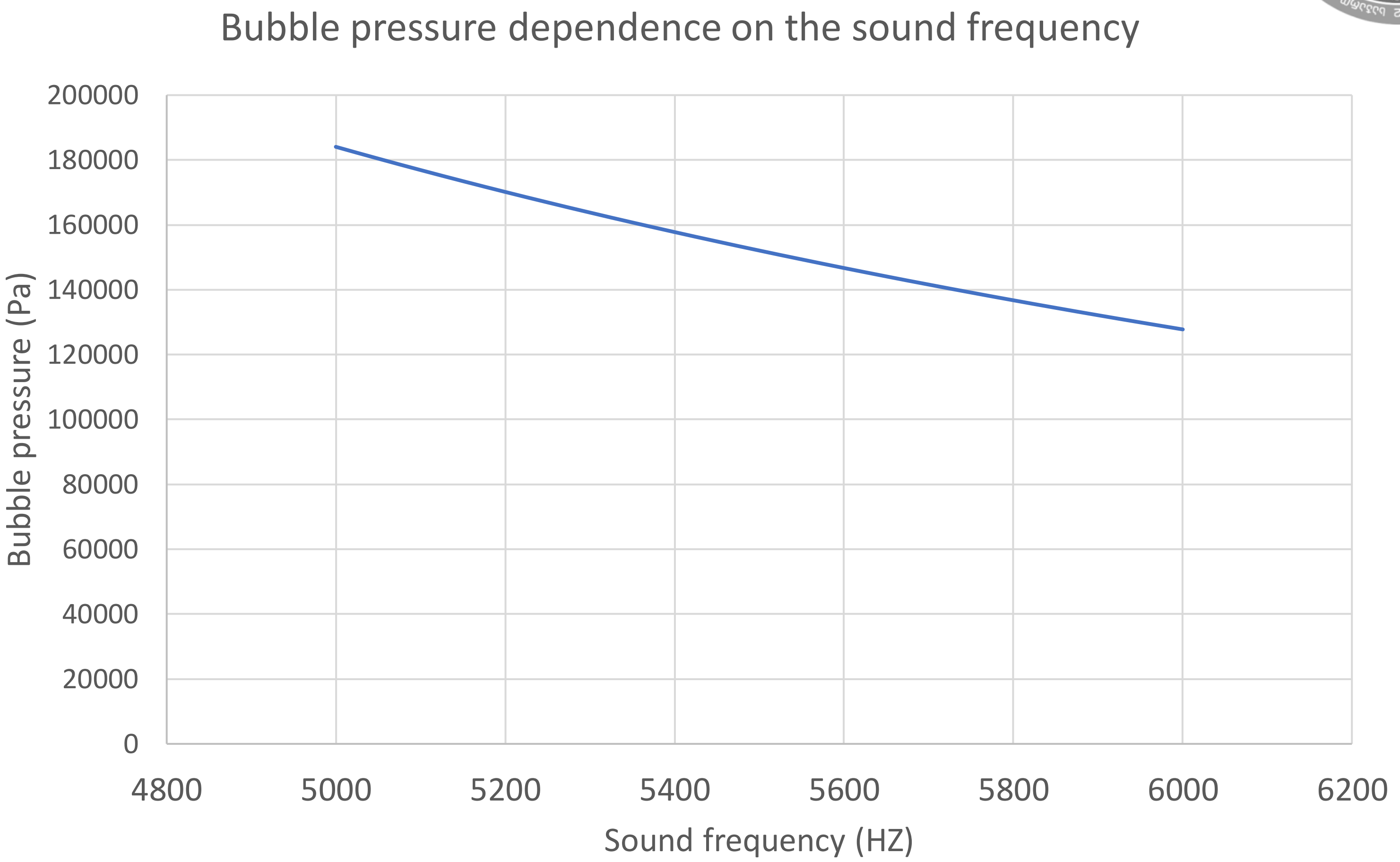
$\sigma = 0.072\,\frac{N}{M}$

$\rho = 1.87\ kg/m^3$

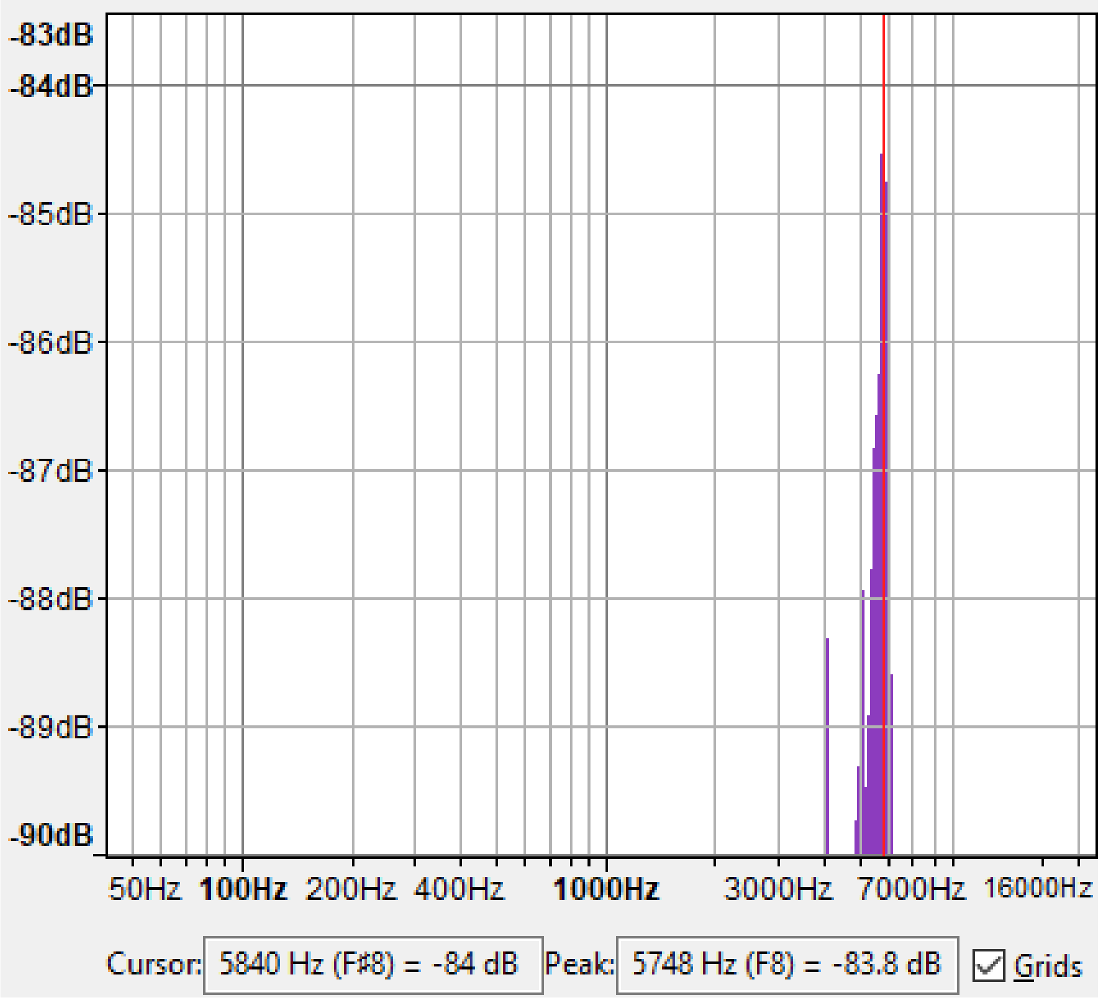
$M = 0.044\ kg/mol$

$l = 0.000313$ m

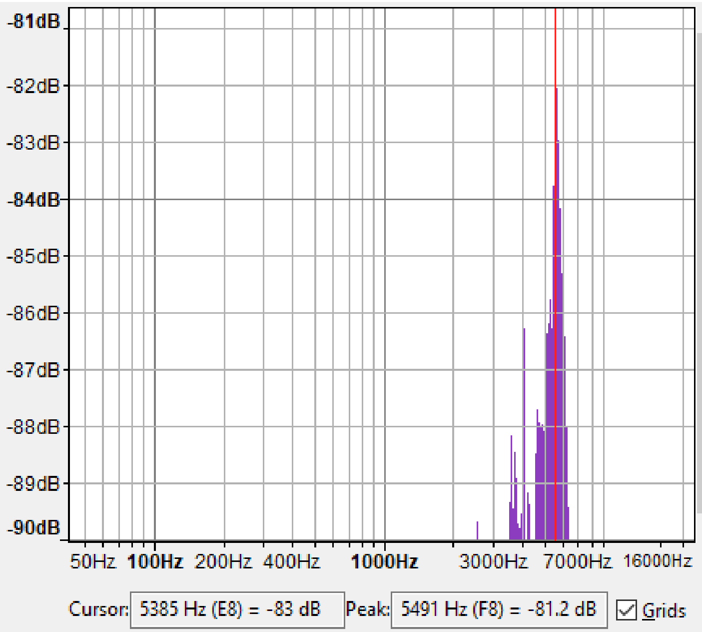
$R = 8.314$ J/mol·K

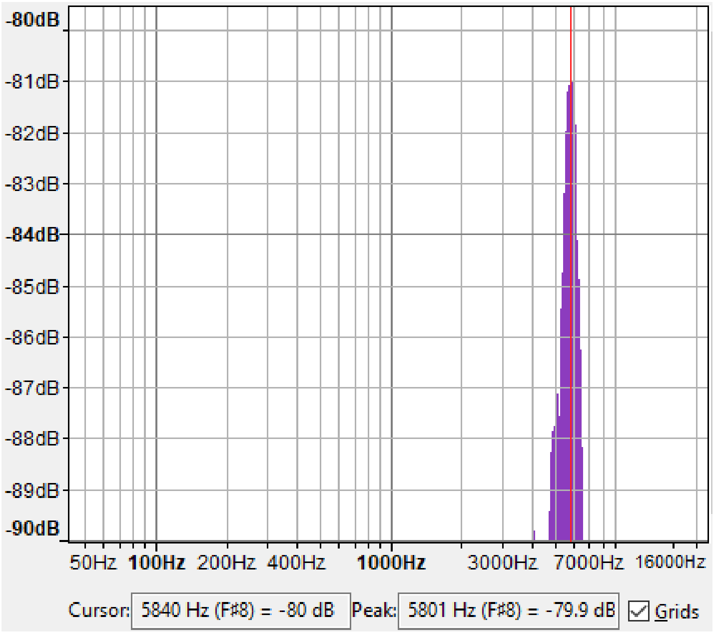


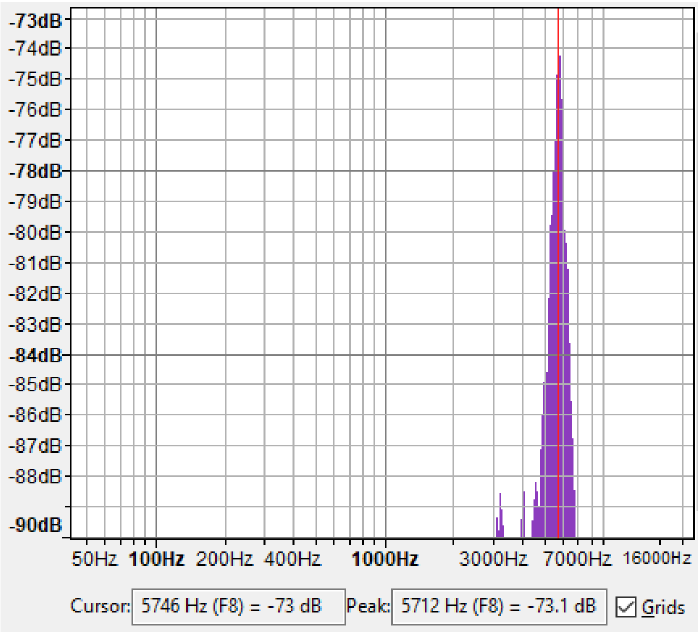
Experiment

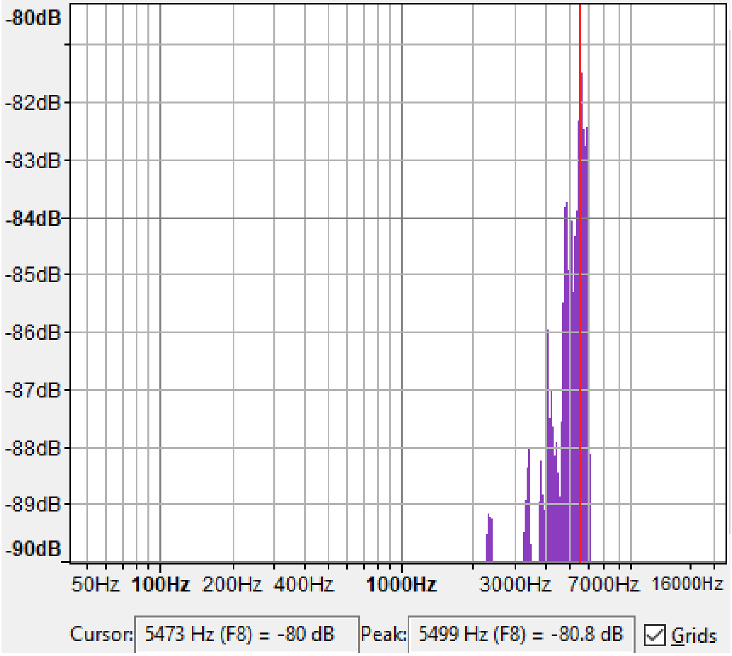


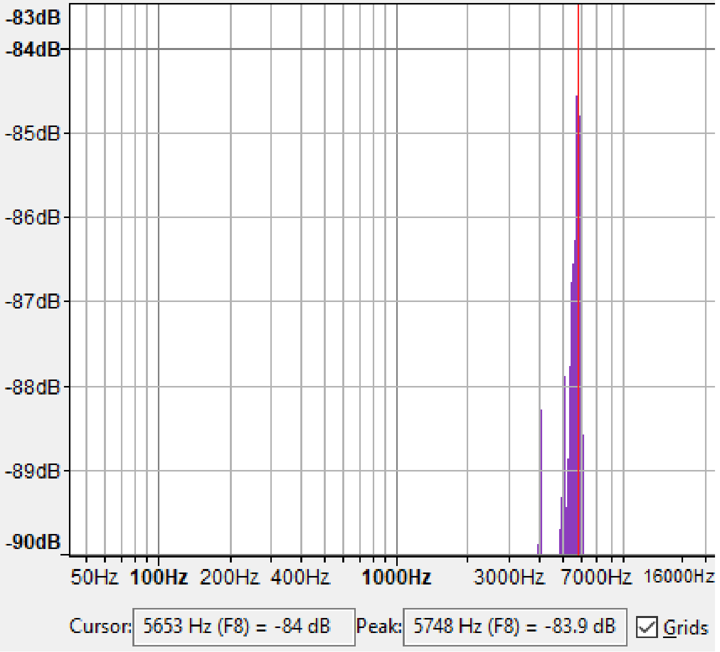
-83dB
-84dB
-85dB
-86dB
-87dB
-88dB
-89dB
-90dB
50Hz 100Hz 200Hz 400Hz 1000Hz 3000Hz 7000Hz 16000Hz
Cursor: 5840 Hz (F#8) = -84 dB
Peak: 5748 Hz (F8) = -83.8 dB
Grids



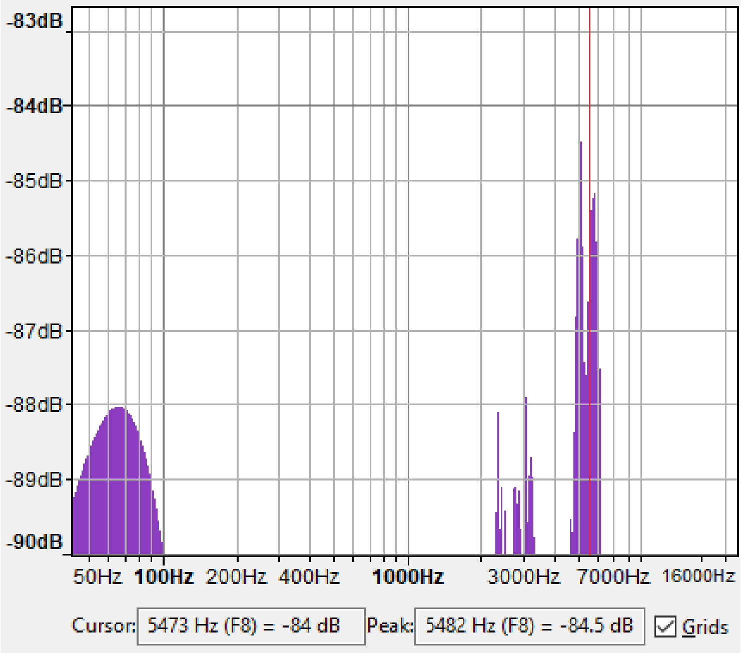


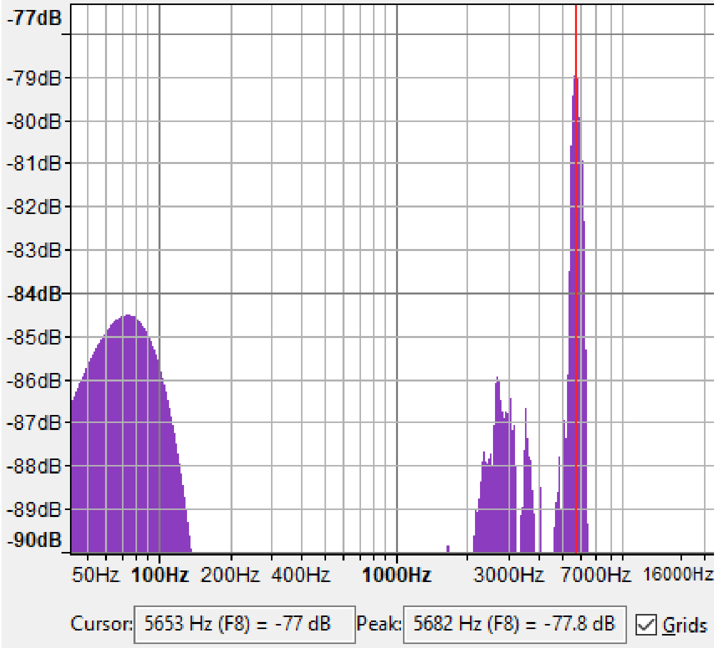


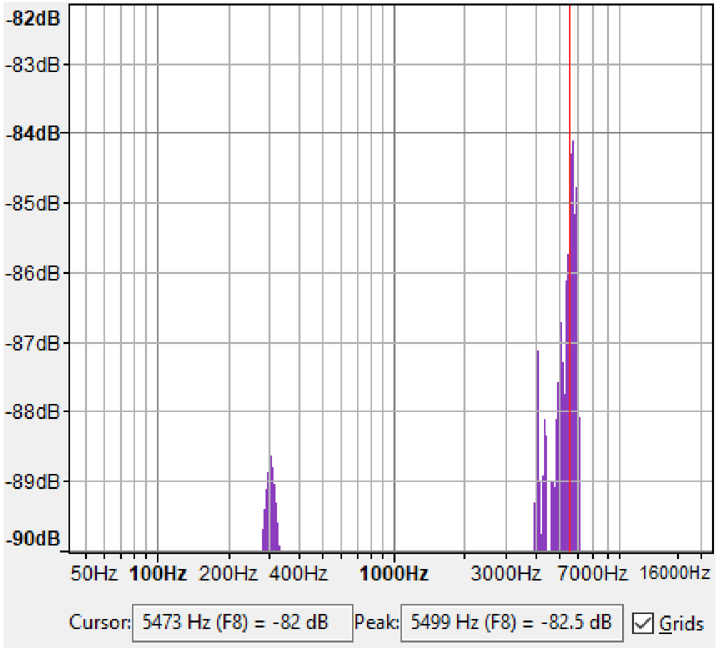


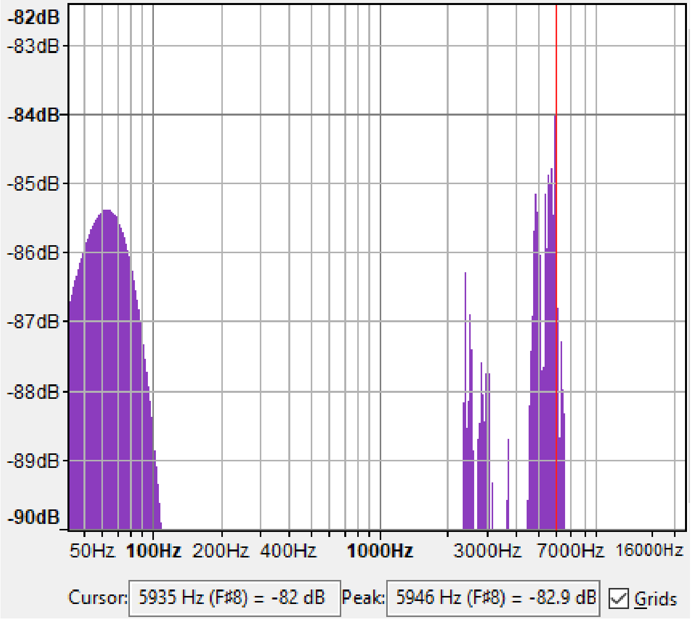


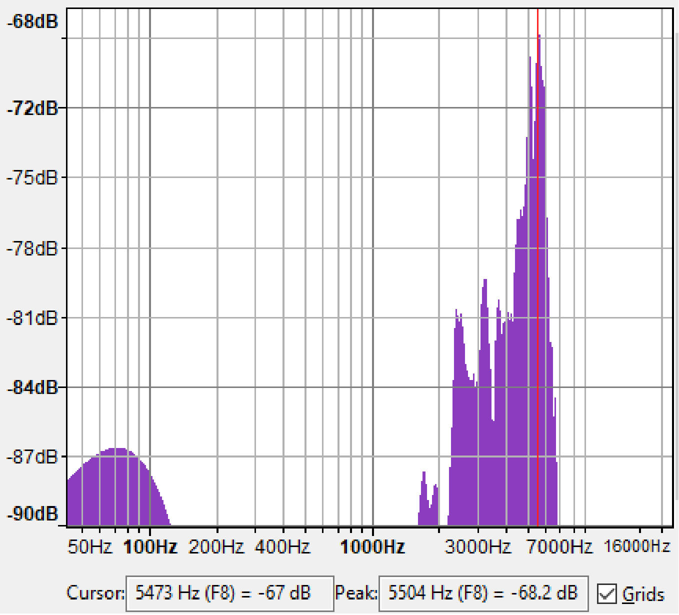
Explanation of the fact | Theoretical model | Experiment | Conclusion


-83dB
-84dB
-85dB
-86dB
-87dB
-88dB
-89dB
-90dB
50Hz 100Hz 200Hz 400Hz 1000Hz 3000Hz 7000Hz 16000Hz
Cursor: 5473 Hz (F8) = -84 dB
Peak: 5482 Hz (F8) = -84.5 dB
Grids


-77dB
-79dB
-80dB
-81dB
-82dB
-83dB
-84dB
-85dB
-86dB
-87dB
-88dB
-89dB
-90dB
50Hz 100Hz 200Hz 400Hz 1000Hz 3000Hz 7000Hz 16000Hz
Cursor: 5653 Hz (F8) = -77 dB
Peak: 5682 Hz (F8) = -77.8 dB
Grids


-82dB
-83dB
-84dB
-85dB
-86dB
-87dB
-88dB
-89dB
-90dB
50Hz 100Hz 200Hz 400Hz 1000Hz 3000Hz 7000Hz 16000Hz
Cursor: 5473 Hz (F8) = -82 dB
Peak: 5499 Hz (F8) = -82.5 dB
Grids


-82dB
-83dB
-84dB
-85dB
-86dB
-87dB
-88dB
-89dB
-90dB
50Hz 100Hz 200Hz 400Hz 1000Hz 3000Hz 7000Hz 16000Hz
Cursor: 5935 Hz (F#8) = -82 dB
Peak: 5946 Hz (F#8) = -82.9 dB
Grids


-68dB
-72dB
-75dB
-78dB
-81dB
-84dB
-87dB
-90dB
50Hz 100Hz 200Hz 400Hz 1000Hz 3000Hz 7000Hz 16000Hz
Cursor: 5473 Hz (F8) = -67 dB
Peak: 5504 Hz (F8) = -68.2 dB
Grids

Conclusion

Experimental frequencies (Hz)

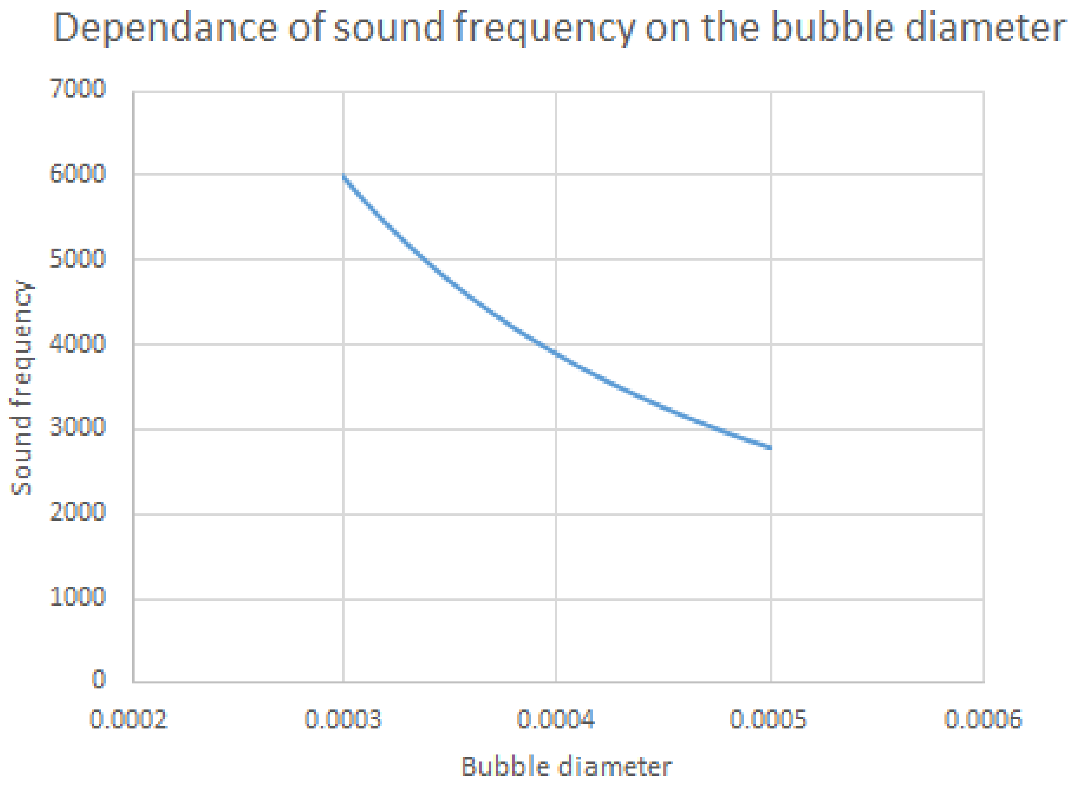
5491
5801
5712
5499
5748

Average frequency
5650.2 Hz

5482
5682
5499
5946
5504

Experimental frequencies (Hz)

Average frequency
5622.6 Hz

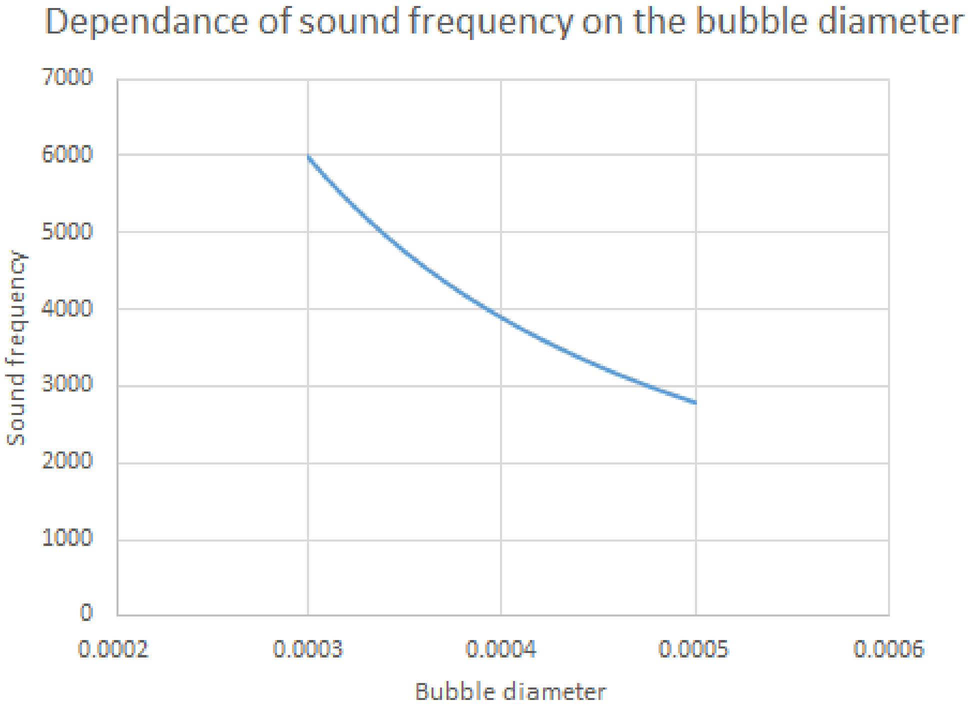


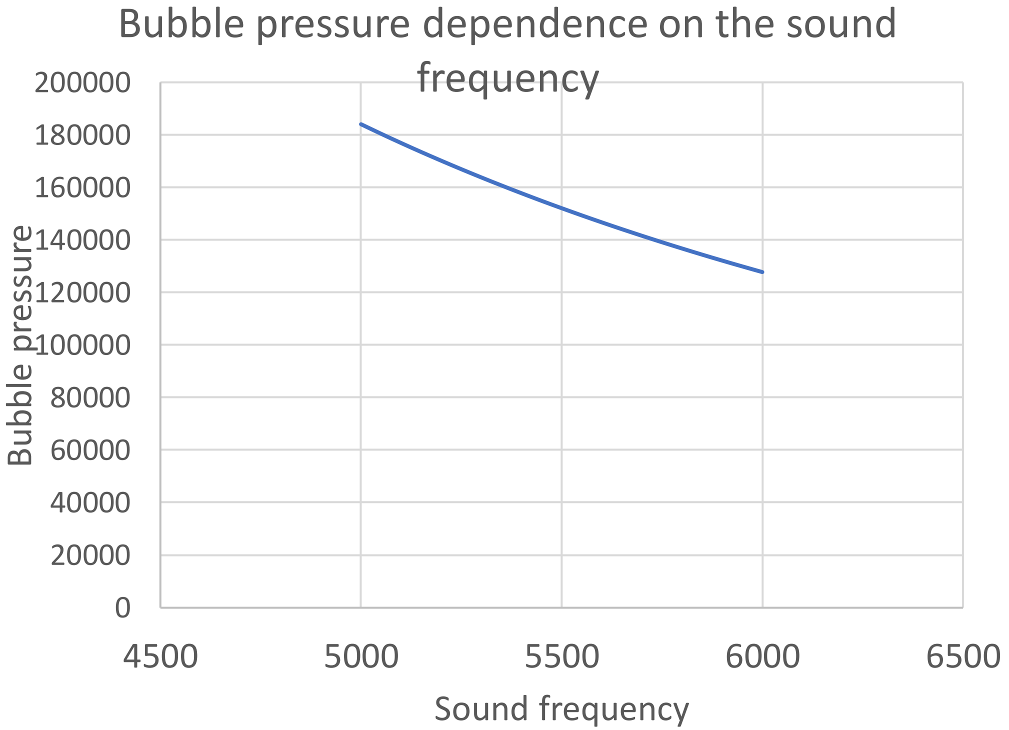
$$0.000313(m) \approx 0.3(mm)$$

Conclusion

$$f = \frac{1}{2\pi}\sqrt{\frac{\sigma}{\rho l^3}}$$

$$f = \frac{1}{2\pi}\sqrt{\frac{\sigma R T}{P M l^3}}$$





81.2
79.9
73.1
80.8
83.9

Experimental sound amplitude (db)

Average sound amplitude 79.78 db

Experimental sound amplitude (db)

84.5
77.8
82.5
82.9
68.2

Average sound amplituden79.18 db

Conclusion

Thanks for your attention!

Theoretical model

$$A = \frac{P}{2\pi V \rho f}$$

$$P = 2\pi f V \rho A$$

$$A \approx R$$

$$\boxed{P \sim 2\pi f V \rho R}$$

f $- Oscillation\ of\ frequency$

V $- Velocity\ of\ wave\ \ in\ medium$

ρ $- Density\ of\ medium$

A $- Diplacement\ amplitude$

Theoretical model

$$f = \frac{1}{2\pi}\sqrt{\frac{\sigma}{\rho l^3}}$$

Ideal air formula

$$PV = nRT$$

$$PV = \frac{m}{M}RT$$

$$PV = \frac{\rho V}{M}RT$$

$$\rho = \frac{PM}{RT}$$

$$\boxed{f = \frac{1}{2\pi}\sqrt{\frac{\sigma RT}{PMl^3}}}$$

P – pressure

V – bubble volume

n – the number of moles

R – universal gas constant

T – temperature

How to convert sound pressure to amplitude

$$A = 20\lg(\mathrm{p}/0.00002)$$