4. PROBLEM № 9: SOUND IN THE GLASS

4.1.SOLUTION OF NEW ZEALAND

Problem № 9: Sound in the Glass
/.Power point Presentation/

The problem

●*Fill a glass with water. Put a tea-spoon of salt into the water and stir it. Explain the change of the sound produced by the clicking of the glass with the tea-spoon during the dissolving process.*

Key definitions

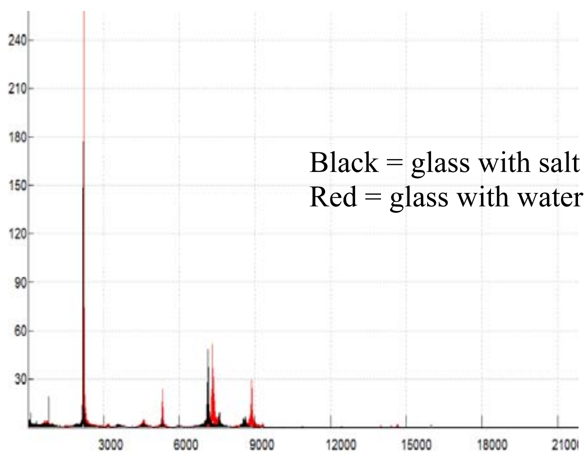
●***Glass***
–Approx cylindrical container of rigid glass
•***Tea-spoon of salt***
–≈ 10 g of standard table salt. Can vary
•***Change of sound***
–***Any variation observed in average frequency, amplitude and overall timbre of the clicking***

The Change in sound

Please listen!!

–1. Water in glass only 2. Same glass during dissolution of 1 teaspoon of salt

Amplitude

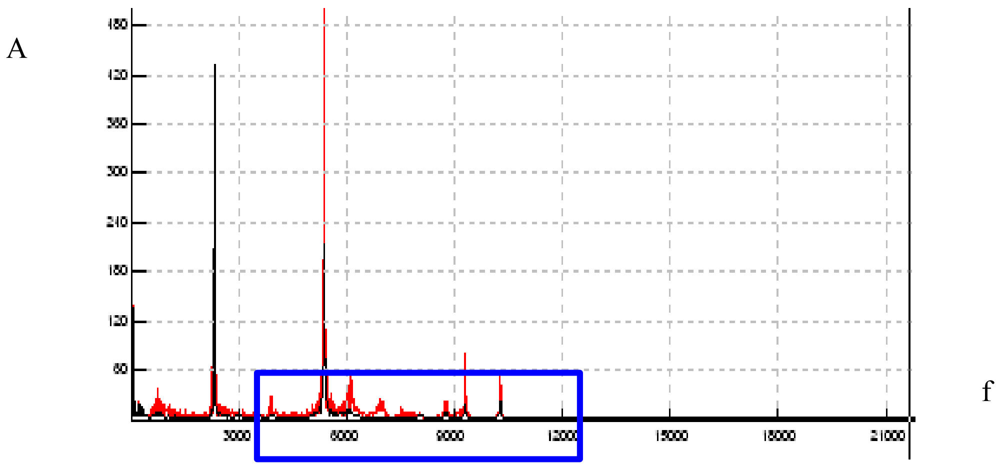


Frequency

Not very clear, is it??

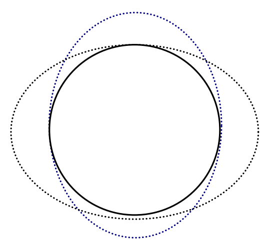
●"Sound" from glass
à Mixture of different sound components
–Cup and water vibrating
–Vibrations of spoon.**Not all components change!!**

Compare...metal vs rubber



Sounds produced in "clicking"

On impact...
–Glass wall flexes
–Produce vibrations
●Produce pressure variations in surrounding media
à SOUND



Clicking Mechanism.

Clicking inside = Clicking outside !
•Clicking outside is easier to regulate

Overview of problem

●Dissolving the salt...
–STEP A : Air bubbles released from powder
–STEP B: Salt disperses into suspension
–STEP C: Salt gradually dissolves (MAIN EFFECT)

●Changes...
–Density
–Bulk Modulus (small change)
–Attenuation

Bulk Modulus ???Reciprocal of *compressibility (κ)*

●*Waves = rarefactions/compressions in medium!*
–*Travel of sound waves in medium will be affected*

PRELIMINARY THEORY

What defines a sound

●Chief sound characteristics governed by:
●Change in one parameter = change in others
–STRING VIBRATION ANALOGY
•Wavelength determined by *physical constraints of system*
●*Frequency determined by medium properties*
–Therefore, wavelength doesn't change

$$c^2 = \frac{\beta_T}{\rho_0}$$

Speed of sound 'c' in liquids

•c = speed of sound in liquids (m/s)
●β_T = Bulk modulus (Pa)
●ρ_o = density of medium (kg/m^3)

STEP A

Air bubbles released from powder:

Air bubbles…?Salt crystals not perfectly even–Air between gaps in particles
●Air escapes as bubbles
–Negligible solubility (N_2, O_2, CO_2 etc.)
●During bubble transition
–Density/bulk mod of medium changes

Equation for sound speed change

$$c_{new} \approx \sqrt{\frac{1}{(1-\varepsilon)\varepsilon\rho_w\kappa_a}}$$

- w = in/of water
- κ = adiabatic compressibility (Pa^{-1})
- ε = fraction of air in water

Consequences

Assume, for example, 1% vol of air in water?

- κ for air = 7.04 x 10^{-6} Pa^{-1}

–Speed of sound in cup of water

- Approx 120 m/s, less than in air!!!
- Unreasonable...1% is very liberal
- c has decreased à f has decreased

Problems with practical investigation

- VERY short time span
- Effect of aeration...use aerator??

–Any aerator will introduce NOISE

–Air concentration will be very different

- Doesn't always occur

–Depends on “click” during air-escape process

STEP B

Salt dispersal & attenuation

Salt suspension

- Before dissolution

–Salt “disperses” into suspension

–Observable during process

- Suspension

–Attenuates sound wave within water medium

–Slight timbre change, amplitude change

–More salt = more attenuation

Attenuation due to solid suspension

$$Att \propto freq^2$$

•Higher attenuation at higher frequencies
●Combined effect of
–Scattering
–Absorption

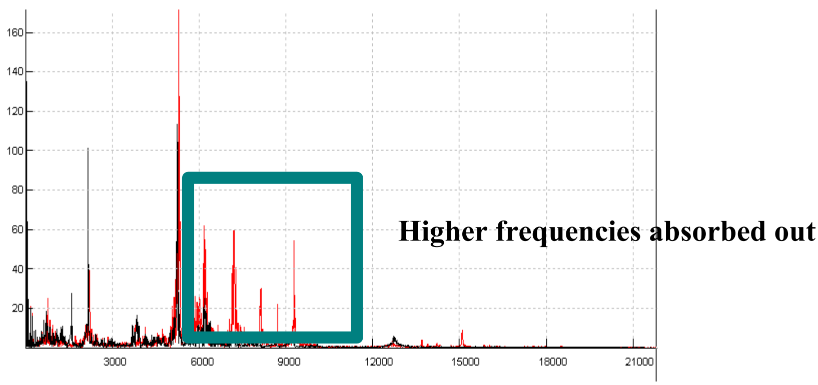
Practical investigation

1Use *large* quantities of salt–Clearer demonstration of effect
–Record clicking spectrum before and after suspension is achieved

Comparison of spectrum

General disturbance of spectrum – "scattering"

•Red line – clicking sound before agitation
•Black line – clicking sound after suspension forms



Other things to note

•As salt dissolves, attenuation dissipates
●Effect on c??
–Minimal
–Bulk mod/density remain approx constant
●Very small fraction of solid in suspension
●Quantitative measurements
–Unreliable with available equipment and such a small scale

STEP C

Density change

Bulk modulus variation with salinity

●Increase in salinity = increase in bulk mod.
●Non-linear variation
●Increments become less with greater salinity
●Linear extrapolation can be made

Theory: c change in water column

$$c^2 = \frac{\beta_T}{\rho_0}$$

•Density increase
Speed decreases – DOMINANT EFFECT
Bulk modulus increase
Speed increases

Overall effect?

Recall
•If c decreases
–Wavelength remains constant
–Frequency decreases
•Negative frequency shift observed in spectrum
•More salt = greater shift

Analogy

•Water not only acts as resonating column
–Vibrates itself, with vessel providing restorative force
–Approximated to a spring
–Natural frequency relationships determined by

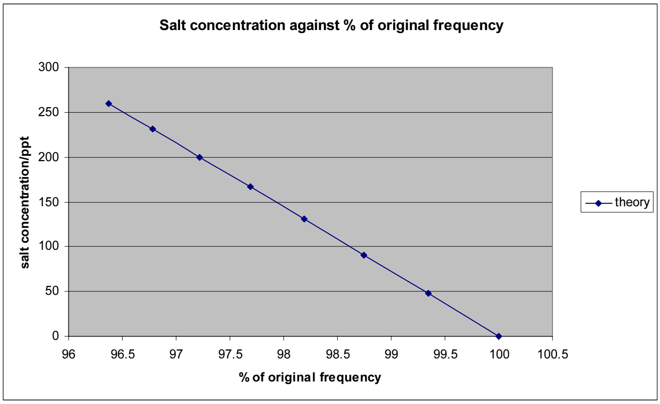
$$f \propto \sqrt{\frac{k}{m}}$$

••As salt is added, mass increases
•Therefore, negative frequency shift
•N.B. k & B, m & ρ

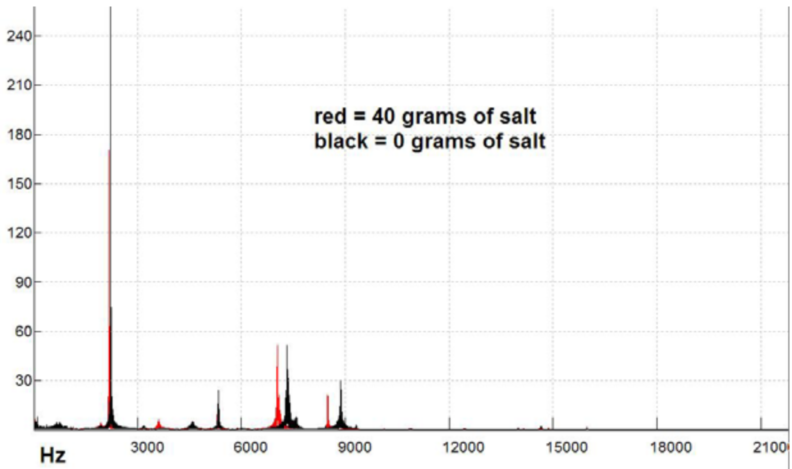
Practical investigation 2

- Dissolve salt in water
- Record clicking spectrum
- Repeat for different amounts

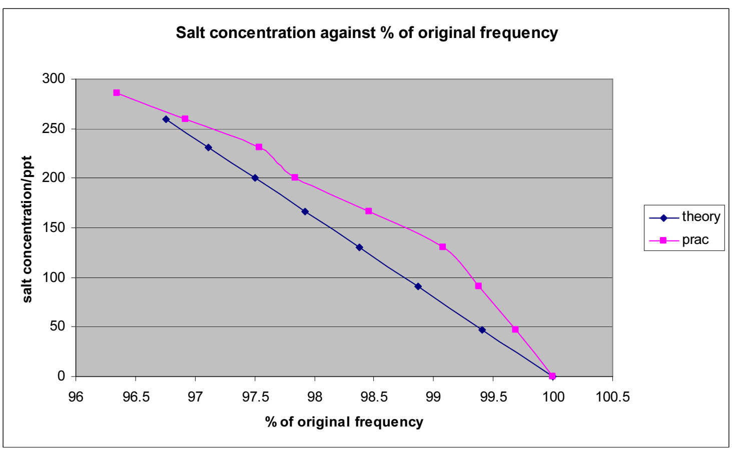
Predicted Spectrum shift



No salt vs. 40 grams of salt



Spectrum shift



Reason for variation in results

Linear extrapolation of bulk modulus used in theory

Conclusion

Question asks: “CHANGE in sound”... “DURING dissolving process”

●Amplitude drops

–Due to attenuation, *while salt in suspension*

●Frequency drops

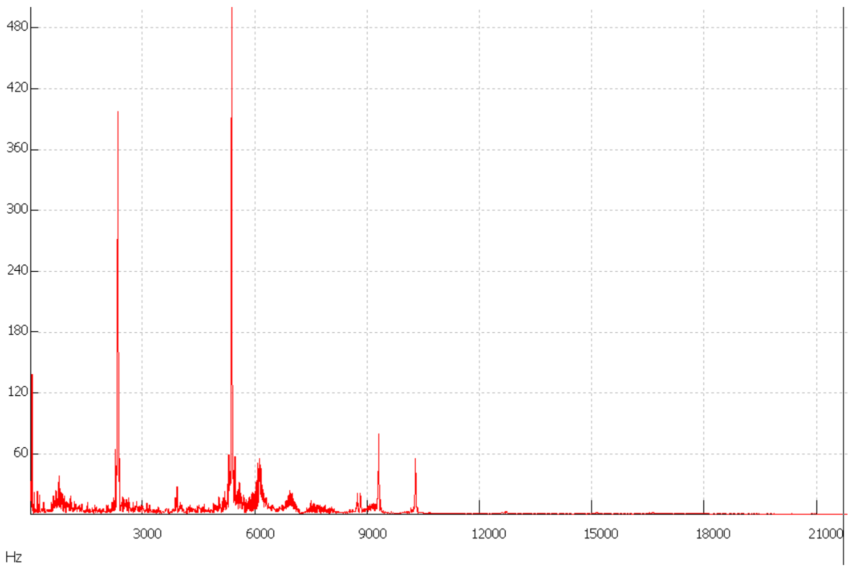
–Due to change in c, change in density (and bulk modulus)

–Lower frequencies more noticeable – due to attenuation

●(Possible large frequency drop

–Due to release of air from solid, very short time span)

Example – Empty cup & spoon



Thank you to our sponsors:

Royal Society of New Zealand