ULTRASONIC CHEMISTRY

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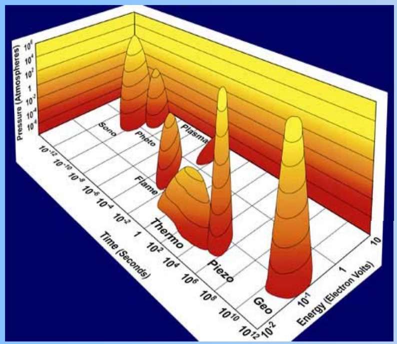
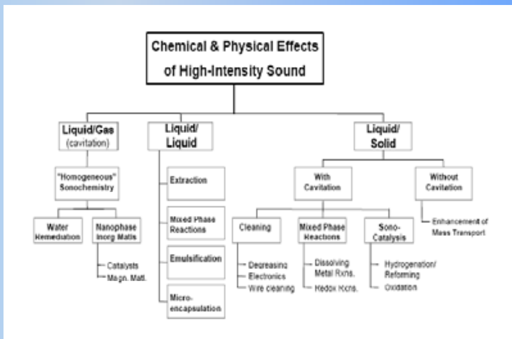
Frequency range Hz	Description	Example
0 - 20	Infrasound	Earth quake
20 - 20.000	Audible sound	Speech, music
> 20.000	Ultrasound	Bat, Quartz crystal

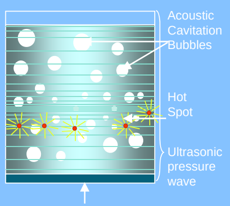
Spectrum of sound





Sonochemistry vs. other forms of chemistry

Glass Beaker with water

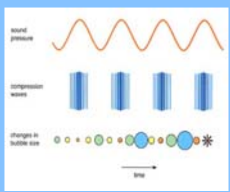


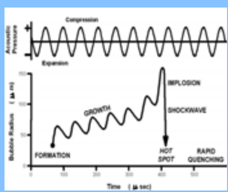
Ultrasonic Transducer

- Sonochemistry: chemical effects of ultrasound on aqueous and non-aqueous solutions. The effects are due to Acoustic Cavitation: the nucleation, growth and violent collapse of gas/vapor filled microbubbles in a liquid.
- The widely accepted Hot Spot Theory proposes that collapse of these microbubbles is an almost adiabatic process.
- This results in the creation of very high temperatures (thousands of Kelvin) and pressures (hundreds of atmospheres) in extremely small and transient regions in the liquid (Hot Spots).
- The collapse of bubbles is accompanied by the simultaneous emission of light (Sonoluminescence).

Characteristics of the Ultrasonic Wave:

Ultrasound travels through a liquid as a longitudinal wave, i.e., the molecules of the liquid oscillate about their equilibrium positions in the direction of the motion of the wave. Therefore, the effective pressure in any given region of liquid is determined by the equation, $P_t = P_h + P_a$, where P_t = the total pressure in a specific region in the liquid, P_h = the hydrostatic pressure and P_a = the acoustic pressure in a particular region and time.





Nucleation, Growth and Collapse of Microbubbles:

- Pockets of gas are trapped on microscopic impurities (e.g., dust particles), inherently present in any liquid, or in imperfections on the wall of the vessel.
- The gas nuclei expand under the influence of the ultrasonic wave and form free bubbles in the liquid. The bubbles continue to adsorb energy from the wave and grow isothermally.
- When the microbubbles reach a critical size (approximately 2 to 3 times the resonance radius), they implode violently. Assuming adiabatic collapse, the temperature of the hot spot can be estimated using the equation below. This equation demonstrates the importance of g in determining the collapse temperature (note, the collapse is not completely adiabatic, so the thermal conductivity will effect T_f in a real system).

$$T_f = T_i \left(\frac{R_{max}}{R_{min}}\right)^{3(g-1)}$$

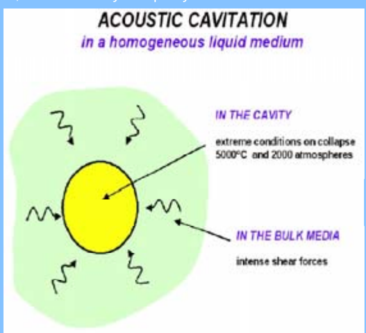
Where, T_f is the temperature of the core, T_i is ambient temperature, R_{max} and R_{min} are the maximum and minimum bubble radius and γ is the ratio of specific heats (C_p/C_v) of the gas inside the bubble. $\gamma = 1.67$ for monoatomic gases and 1.40 for diatomic gases.

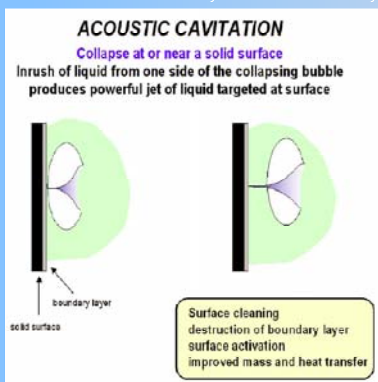
Sonochemical reactions can occur in three different regions.

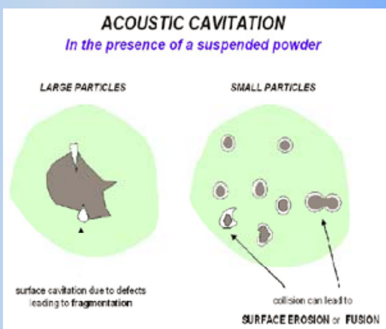
Region 1: Interior of collapsing gas bubbles (i.e., the core) in which very high temperatures and pressures exist. Under these conditions the solvent vapor inside the bubble undergoes pyrolysis reactions.

Region 2: Interface between the collapsing bubble and the bulk solvent, where high temperature and pressure gradients exist. In aqueous solutions, the relative efficiency of non-volatile solutes to decompose thermally or to scavenge radicals formed in the hot spot depends on their ability to accumulate at the gas/solution interface of the growing microbubble.

Region 3: Bulk solution at ambient temperature. Free radicals formed in the hot regions may diffuse to the bulk solution and react to yield products similar to those found in aqueous radiation chemistry. Thus, sonochemistry can partly be understood in terms of a combination of combustion chemistry and radiation chemistry.







Anatomy of an ultrasonic system

Transducer

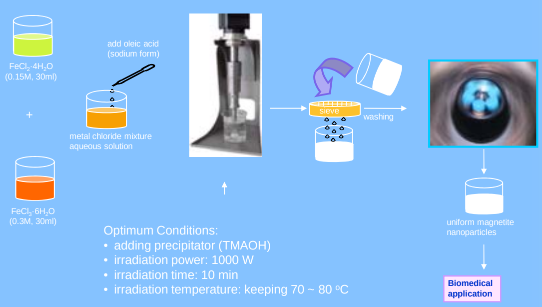
The transducer (or converter) converts electrical power to mechanical - as vibrations. It is a tuned system, resonant at the operating frequency.

Booster

Optionally, a "booster" or interstage may be fitted between the transducer and the ultrasonic tool. This is also resonant at the operating frequency. It modifies (usually increases) the vibration amplitude and may also be used to mount all the mechanical parts of the ultrasonic system. Material is titanium or high-strength aluminium alloy.

Sonotrode

The sonotrode is the only part of the system which is unique to each process. They come in all shapes and sizes, according to the application, but like other components should be resonant at the operating frequency. The material used is a compromise between the needs of the ultrasonics and the application - titanium alloys, steel, stainless steel or ceramics might be used.



Optimum Conditions:
- adding precipitator (TMAOH)
- irradiation power: 1000 W
- irradiation time: 10 min
- irradiation temperature: keeping 70 ~ 80 °C

Synthesis of Fe_3O_4

TEM images of Fe_3O_4 | *TEM images of silver nanoparticles* | *TEM images of copper* | *TEM images of cobalt-oxide*