Ultrasonic Chemistry
(Sonochemistry)

Summary of Some Articles

1 – "Effect of Ultrasound on Chemical Reaction Rate", by J.W. Chen and Walter M. Kalback,

The effect of ultra sound on hydrolysis of methyl acetate using hydrochloric acid as a catalyst was studied in a batch reactor under isothermal condition. The reaction rate increased with increasing sonic amplitude. Varying frequency had only negligible effect. Arrhenius plots showed that ultrasonic vibration increased the frequency factor of the rate and that there was no effect on activation energy. Mechanical agitation and concentration of acid catalyst were also studied. There was no evidence that extra hydrogen ions were produced by ultrasonic vibration.

2 – "New Way to Drive Chemical Reactions: Collision of Liquids at High Speed", University of Illinois at Urbana-Champaign October 10, 1997, ScienceDaily

When a liquid moves fast enough, gas bubbles will form and collapse. This process – called cavitation – is responsible for the pleasant bubbling sound of streams and rivers, and for the stealth-defying sound of propellers on submarines. Chemists at the University of Illinois have discovered that in addition to making noise, high-velocity liquids also can drive chemical reactions.


Ultrasound can produce temperatures as high as those on the surface of the sun and pressure as great as those at the bottom of the ocean. In some cases, it can also increase chemical reactivities by nearly a million fold. Acoustic cavitations result in an enormous concentration of energy. If the energy density in an acoustic field that produce
Cavitation is compared with that in the collapsed cavitation bubble, there is an amplification of almost one trillion. The enormous local temperature and pressure of cavitation result in sonochemistry and sonoluminescence. Cavitation produces an unusual method for fundamental studies of chemistry and physics under extreme conditions, and sonochemistry provides a unique interaction of energy and matter.

In addition, ultrasound is well suited to industrial applications. Since the reaction liquid itself carries the sound, there is no barrier to its use with large volumes. In fact, ultrasound is already heavily used industrially for the physical processing of liquids, such as emulsification, solvent degassing, solid dispersion and sol formation. It is also extremely important in solids processing, including cutting, welding, cleaning and precipitation.

The extension of ultrasound to the chemical processing of liquids is underway. The future uses of ultrasound to drive chemical reactions will be diverse. It is becoming a common tool in nearly any case where a liquid and a solid must react. In the synthesis of pharmaceuticals, for example, ultrasound may permit improved yields and facilitate reactions run on large scale. In the development and use of catalysts, ultrasound also has potential applications. Its ability to create highly reactive surface and thereby increase their catalytic activity has only just now been established. Ultrasound can produce materials with unusual properties. The extraordinary temperatures and pressures reached during cavitation collapse, combined with the exceptionally high rates of cooling, may allow researchers to synthesize novel solid phases difficult to prepare in other ways. One may be optimistic that the unusual reactivities caused by ultrasound will find important industrial application in the years to come.


The reaction of 5H,5Cl-dibenzo{a,d} cycloplatriene with nitrobenzene was investigated under both thermal (210 oC) and ultrasonic (50 oC, 40 kHz) activation. The reaction products of both procedures are similar, but their amounts depend on the activation source. To account for the products a common electron transfer reaction is postulated though the dibenzotropylium cation. The differences between the thermal and ultrasonic process is thought to arise from the role of nitrobenzene as oxidant. Under thermal conditions this occurs throughout the mixture but under sonication it occurs only in the cavitation bubble and in its immediate vicinity.

5 – “Ultrasoncation boosts heterogeneous reactions”, Published in Engineer Live-Chemical-Engineer/material, September, 2005.
Chemical reactions require the interaction of the reactant molecules. For heterogeneous or multi-phase reactions and catalysis, the interaction is limited to the contact surface of the dispersed reactant. Therefore, the phase boundary is a rate determination factor.

Ultrasonic cavitation is an effective means to increase the exposure of the reactants without the need to increase their concentration. Cavitation generates high shear force that reduce the particle size of the reactants resulting in higher specific surface area and increased exposure. Finally, when reagents react at a phase boundary, the products of the chemical reaction accumulate at the contact surface and block other reagent molecules from interacting. Cavitation and acoustical streaming results in turbulent flow that transport material from and to the reactant surface. In the case of droplets, the ultrasonication leads to coalescence and subsequent formation of new droplets. As the chemical reaction progresses over time, a repeated sonication, e.g. two-stage or recirculation, may be required to maximize the exposure of the reagents.

Ultrasonic cavitation is a unique way to put energy into chemical reactions. A combination of high speed liquid jets, high pressure (>1000 atm) and high temperature (>5000K), enormous heating and cooling rates (>109Ks-1) occur locally concentrated during the implosive compression of cavitational bubbles. For many chemical reactions, this increases reaction rates or changes the reaction pathway significantly.

Hielscher Ultrasonics produces ultrasonic devices for the application at any scale from small test tubes to commercial production. For initial studies, a UP400S (400 watts) is very suitable. The UIP1000hd (1000 watts) is the more sophisticated research tool, as it allows for the sonication at wide range of process parameters, such as amplitude, pressure or temperature. This device can be used either for batch sonication or for inline processing using flow cell reactors.

Hielscher offers extensive technical support during application development, e.g. in their process laboratory.

6 – "Ultrasonic activation of chemical processes. Sonochemistry", Ultrasonic Technique- INLAB

Intensification of chemical reactions rate in liquid medium is one of the principal chemistry problem. Customary as a rule this is achieved by increasing of reagents concentration, increasing of temperature or pressure, by applying of expensive catalysts.

Ultrasonic activation is one of the modern ways of chemical reactions accelerating. It is significant that applying of ultrasound not only
allows to increase rate of chemical reaction, but also increases percent of reacted substances. Liquid medium is being exposed to ultrasonic cavitation, one can obtain chemical reactions which are impossible in other cases.

Emulsification and dispersion of reagents inside ultrasonic reactor increases significantly surface of chemical reaction processing.

Applying of ultrasonic activation is possible in two-phase system; in additive reactions substitution reactions, in metal-organic chemistry; in petrochemistry; in catalysis; in polymer chemistry; in different chemical technologies.

INLAB Co. develops and manufactures ultrasonic chemical reactors for various applications. Range of operating temperature and pressure, design, material of reactor and ultrasonic emitter can be different and are determined by accommodation with Customer.

Power of ultrasonic generator and transducer are determined by necessary consumption of reagents, volume of reacting medium.

Development and manufacturing of ultrasonic activator into existing equipment of Customer is possible.

7 – "Sonochemical Reaction and Synthesis", published by Hielscher Ultrasonic GmbH, 14513 Teltow, Germany.(Email- info@hielscher.com)

Sonochemistry is the application of ultrasound to chemical reaction and processes. The mechanism causing sonochemical effects in liquids is the phenomenon of acoustic cavitation.

Hielscher ultrasonic laboratory and industrial devices are used in a wide range of sonochemical processes.

Sonochemical Reactions

The following sonochemical effects can be observed in chemical reactions and processes:

- increase in reaction speed
- increase in reaction output
- more efficient energy usage
- sonochemical methods for switching of reaction pathway
- performance improvement of phase transfer catalysts
- avoidance of phase transfer catalysts
- use of crude or technical reagents
- activation of metals and solids
- increase in the reactivity of reagents or catalysts
- improvement of particle synthesis
- coating of nanoparticles