# Rectified mass diffusion

When a bubble is placed in an oscillating pressure field, an important nonlinear effect can occur in the mass transfer of dissolved gas between the liquid and the bubble. This effect can cause a bubble to grow in response to the oscillating pressure when it would not otherwise do so. This effect is known as *rectified mass diffusion* (Blake 1949) and is important since it may cause nuclei to grow from a stable size to an unstable size and thus provide a supply of cavitation nuclei. Analytical models of the phenomenon were first put forward by Hsieh and Plesset (1961) and Eller and Flynn (1965), and reviews of the subject can be found in Crum (1980, 1984) and Young (1989).

Consider a gas bubble in a liquid with dissolved gas as described in section **??**. Now, however, we add an oscillation to the ambient pressure. Gas will tend to come out of solution into the bubble during that part of the oscillation cycle when the bubble is larger than the mean because the partial pressure of gas in the bubble is then depressed. Conversely, gas will redissolve during the other half of the cycle when the bubble is smaller than the mean. The linear contributions to the mass of gas in the bubble will, of course, balance so that the average gas content in the bubble will not be affected at this level. However, there are two nonlinear effects that tend to increase the mass of gas in the bubble. The first of these is due to the fact that release of gas by the liquid occurs during that part of the cycle when the surface area is larger, and therefore the influx during that part of the cycle is slightly larger than the efflux during the part of the cycle when the bubble is smaller. Consequently, there is a net flux of gas into the bubble that is quadratic in the perturbation amplitude. Second, the diffusion boundary layer in the liquid tends to be stretched thinner when the bubble is larger, and this also enhances the flux into the bubble during the part of the cycle when the bubble is larger. This effect contributes a second, quadratic term to the net flux of gas into the bubble.

Strasberg (1961) first explored the issue of the conditions under which a bubble would grow due to rectified diffusion. This and later analyses showed that, when an oscillating pressure is applied to a fluid consisting of a subsaturated or saturated liquid and seeded with microbubbles of radius, $R_e$, then there will exist a certain critical or threshold amplitude above which the microbubbles will begin to grow by rectified

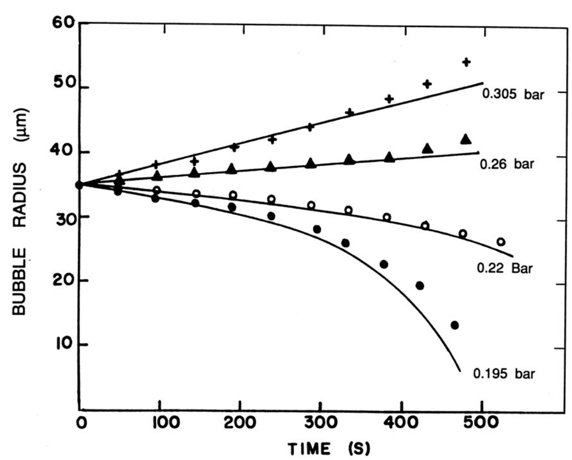


Figure 1: Examples from Crum (1980) of the growth (or shrinkage) of air bubbles in saturated water ($S = 68$ $dynes/cm$) due to rectified diffusion. Data is shown for four pressure amplitudes as shown. The lines are the corresponding theoretical predictions.

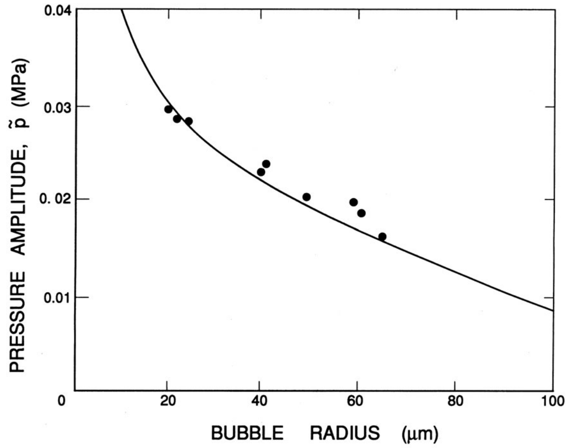


Figure 2: Data from Crum (1984) of the threshold pressure amplitude for rectified diffusion for bubbles in distilled water ($S = 68\ dynes/cm$) saturated with air. The frequency of the sound is $22.1kHz$. The line is the theoretical prediction.

diffusion. The analytical expressions for the rate of growth and for the threshold pressure amplitudes agree quite well with the corresponding experimental measurements for distilled water saturated with air made by Crum (1980, 1984) (see figures 1 and 2).