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A Henry's Law Method for Generating Bulk Nanobubbles

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Bulk nanobubbles are a novel revolutionary class of bubbles. They pose many challenges to our understanding of bubble physics and behaviour, yet a wide range of industrial applications have already been suggested including surface cleaning, drug delivery, ultrasound imaging, tissue preservation and food flavour retention. Based on Epstein-Plesset theory, the lifetime of bulk nanobubbles should be of the order of microseconds, but we experimentally report here that these nanobubbles display long term stability. A new technique for generating bulk nanobubble suspensions has been developed based on Henry's law which states that the amount of dissolved gas in a liquid is proportional to its partial pressure above the liquid. This principle which forms the basis of vacuum degasification has been exploited here to produce large concentrations of stable bulk nanobubbles in excess of 10^9 bubble.mL^{-1} in pure water, through successive expansion/compression strokes inside a sealed syringe. We prove that the observed nano-entities must be air-filled nanobubbles by showing that: (i) they cannot be attributed to organic or inorganic impurities; (ii) they disappear gradually over time whilst their mean size remains unchanged; (iii) their number density depends on the concentration of dissolved gas in water and its solubility; and (iv) added sparging of gas enhances process yield. We study the properties of these nanobubbles including the effects of type of dissolved gas, water pH and the presence of different valance salts on their number density and stability.