Is sonochemistry a viable alternative to the Haber-Bosch process?

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Ammonia plays a vital and important role in the globalized economy. As a primary commodity for nitrogen fertilizers, the existence of modern agriculture depends heavily on a reliable source of ammonia. In fact, 70% of the produced ammonia is used as fertilizers. It is the most energy and emission-intensive chemical industry. The global average energy intensity is about 46.2 GJ/t (the best available technology is approximately 28 GJ/t), and the emission intensity is nearly 2.4 t CO2/t. In comparison, the corresponding values for steel and cement production are 19.4 GJ/t, 2.4 GJ/t, and 1.4 t CO2/t, 0.6 t CO2/t, respectively. The magnitude of the ammonia industry can also be quantified by its natural gas consumption: more than 20% of the unearthed methane is used for feedstock (methane steam reforming for hydrogen). Thus, any serious policy that attempts to reach net-zero emission by 2050 needs to address the issue of "Green Ammonia". Today, ammonia is produced by the more than a hundred-year-old technology called the Haber-Bosch process. It requires high temperature (500 °C) and pressure (400 bar), which makes the process and the necessary equipment expensive and dangerous. The present paper investigates the energy efficiency of ammonia production by a freely oscillating microbubble placed in an infinite domain of liquid. The spherical bubble initially contains a mixture of nitrogen and hydrogen. The bubble is expanded from its equilibrium size to a specific maximum radius via an isothermal expansion. The work needed to expand the bubble is its potential energy calculated by the sum of the work done by the internal gas, the work needed to displace the mass of the surrounding liquid, and the work needed to increase the area of the bubble against the surface tension. The chemical yield is computed by solving a set of ordinary differential equations describing the radial dynamics of the bubble, the temporal evolution of the internal temperature, and the concentration of the chemical species (reaction mechanism). In the best-case scenario, the energy requirement is only 88.66 GJ/t [1] which is orders of magnitude lower than the reported 882353 GJ/t value in the literature [2]. This have serious consequences. First, sonochemistry became a possible alternative to the Haber-Bosch process upon further optimisation. Second, there is an inherent energy inefficiency in the experiment. The potential causes of the latter issue are also discussed.

Keywords
ammonia, Haber-Bosch process, microbubbles

References

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