Cryogenic Speeds of Sound of Gaseous Mixtures of Hydrogen for the Hydrogen Liquefaction Process

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Technologies that enable cost-effective hydrogen storage and distribution will be critical to developing domestic and global hydrogen supply chains. In this regard, liquid hydrogen (LH2) has emerged as a viable option that offers advantages in certain contexts, particularly when extremely high purities are required in end-use applications such as fuel cells, and demonstrations of LH2 production and shipping from Australia to Japan have recently been completed. The current liquefaction process, however, faces numerous technical hurdles, primarily the high energy consumption, between (11.9 and 15.0) kWh/kg_{LH2}, and the high liquefaction cost, between (2.5 and 3.0) US$/$kg_{LH2}$. Alternative mixed refrigerants, consisting of blends of hydrogen, helium, neon, and/or nitrogen, offer a promising avenue for reducing costs and energy consumption in hydrogen liquefaction processes. Nonetheless, the development of efficient refrigeration systems using these mixed refrigerants is impeded by a lack of comprehensive thermophysical property data and reliable models, particularly at cryogenic temperatures.

To address this critical gap, this research focuses on measuring the speeds of sound in binary mixtures of H_2 and He, as well as H_2 and Ne, under cryogenic conditions (down to less than 20 K) across a wide range of pressures with standard uncertainties of less than 0.1%. A modified cryostatic chamber will house a cylindrical acoustic resonator, enabling the precise determination of experimental sound speeds. The chamber is cooled using an Advanced Research Systems (ARS) cryocooler consisting of an expander (DE-210) that operates on the Gifford-McMahon refrigeration cycle and a water-cooled helium compressor (ARS-10HW). Temperature is monitored using Cernox thin film resistance cryogenic sensors and controlled using a Lakeshore Cryotenics Model 336 temperature controller.

The measurement of sound speeds will also facilitate the derivation of other thermodynamic properties of these mixtures through thermodynamic integration. These novel experimental sound speeds and derived thermodynamic data will contribute to the development of a new class of refrigerants tailored for cryogenic applications. This research has the potential to lead to significant reductions in energy consumption and costs in the hydrogen liquefaction process, paving the way for a more sustainable and cost-effective hydrogen economy.