A Magnetic-Suspension Balance for Measurements of Hydrogen at Temperatures Down to 77 K with Pressures up to 15 MPa

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As the demand for a clean energy future grows, hydrogen has emerged as a viable solution for transporting, storing, and utilizing carbon-free energy. Accurate knowledge of hydrogen's thermophysical properties is crucial to understanding its behavior under the varying conditions along the value chain. In this context, not only the low-temperature regime of liquefied hydrogen (below 20 K) or very high pressures are of interest, but also the temperature range between 77 K and 200 K in which sorption effects show great potential to be utilized for hydrogen storage technologies. Here, we report adsorption measurements of hydrogen on readily available adsorbents with simultaneous density measurements at low temperatures (e.g., 77 K) utilizing a commercial cryogenic gravimetric sorption analyzer based on a magnetic-suspension balance (MSB). Minor, yet essential, modifications were applied to the measuring system to ensure adequate temperature control during the measurement process. However, one key consideration when studying hydrogen is that hydrogen molecules exhibit different nuclear spin symmetries, leading to division into ortho- and para-hydrogen. The ratio of these isomers is temperature-dependent and can significantly influence the behavior of hydrogen, especially at low temperatures [1]. Therefore, monitoring the ortho-para ratio of hydrogen is essential alongside measuring thermophysical properties [2, 3]. To achieve this, the MSB has been expanded to include an optical view cell and a non-invasive Raman system to monitor the present composition of the hydrogen. As natural conversion between the hydrogen isomers is usually very slow, an additional hydrogen reactor incorporating catalyst material is used to enhance the conversion rate and adjust the composition of the hydrogen sample [1]. The capabilities of the apparatus will be highlighted by presenting selected adsorption isotherms and results of density measurements with comparisons to the few available literature data. Additionally, we address the uncertainty associated with the measured data and offer insights into potential future developments. The data generated in this study can be instrumental in advancing hydrogen thermophysical property models.

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