CO_2 methanation over Ni nanoparticles dispersed on CeO_2 supports: the effect of support synthesis method and the resulting nano-configurations

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Abstract.

CO_2 methanation reaction, also known as Sabatier reaction, is an exothermic process that converts CO_2 into methane using H_2 as a reducing agent ($CO_2 + 4H_2 \rightleftharpoons CH_4 + 2H_2O$, $\Delta H_{298K} = -164$ kJ/mol). Sabatier reaction can be considered an alternative strategy for capturing and recycling emitted CO_2, offering significant potential for reducing fossil fuel dependence and consequently lowering atmospheric CO_2 concentration levels. Additionally, it can serve as a safe and efficient method for storing and transporting H_2, as part of the Power-to-Gas (PtG) process. This approach helps overcome the safety challenges and high costs associated with transporting H_2 produced from renewable energy sources. In present study, the effect of the CeO_2 support synthesis method and the resulting nanostructures was investigated. Two different synthesis approaches were employed to obtain nanorods (CeO_2-NR) and irregular nanostructures (CeO_2-PR): a simplified hydrothermal method and a conventional co-precipitation method. The active Ni phase (10% Ni) was deposited onto the supports using the wet impregnation method. The catalytic performance and stability of the above materials were examined over CO_2 methanation reaction through kinetic experiments conducted over a temperature range of 150–600°C, as well as 12-hour stability tests at 380°C. The experimental conditions were as follows: H_2/CO_2 ratio = 4/1, balanced with Ar, with a total flow rate of F_t = 19 cc/min and a catalyst mass of m_{at} = 60 mg. Additionally, the physicochemical and chemical properties of CeO_2 supports and counterpart catalysts were evaluated using various characterization techniques (BET, XRD, Chem-H_2, H_2-TPR, SEM, and TEM) to establish correlations between their activity and structural features. The supports synthesis method plays a crucial role in the performance of catalytic materials, as it affects the degree of nickel (Ni) dispersion and metal-support interactions. Notably, nanostructured supports like nanorods enhance nickel (Ni) catalysts, achieving up to 90% methane yield, at 355°C. These innovative materials, with specialized nanoconfigurations, offer both exceptional catalytic performance and improved stability, positioning them as promising materials in catalytic technology and methane production processes.

Authors' background

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