A comparative study of the effect of the active phase (Rh, Ru, Ir, and Ni) and catalyst support on CO_2 methanation reaction.

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Abstract: The rapid increase in atmospheric CO_2 levels, due to our continued dependence on fossil fuels (coal, oil and natural gas) for energy production, which intensifies the greenhouse effect and accelerates climate change, imposes the urgent need to review our energy strategies. The global community is now moving in a coordinated manner towards the so-called "energy transition" and the reduction of CO_2 emissions. The capture and reuse of emitted CO_2, in the sense of recycling it by converting it into fuels (e.g. methane, methanol), is currently receiving significant research and technological interest.

In this work, we study the catalytic performance on CO_2 methanation reaction of the noble metals ruthenium (Ru), rhodium (Rh) and iridium (Ir) compared to that of nickel (Ni). These active metals are supported on various metal oxide supports, namely γ-Al_2O_3 (AL), Al_2O_3-CeO_2-ZrO_2 (ACZ), and CeO_2-ZrO_2 (CZ), which exhibit different values of labile lattice oxygen (oxygen storage capacity, OSC), a factor critical for enhancing redox reactions. Our goal is to comparatively evaluate the effectiveness of the various active metal phases in the reaction, but also how the properties of the various supports used affect the catalytic behavior through metal-support interactions. Our findings revealed a clear ranking in the catalytic performance of the active phases, as Ru > Rh > ~ Ni > Ir, regardless of the supports on which they were dispersed. Furthermore, we observed a significant, but not monotonic, effect of the oxygen storage capacity of the support on the CO_2 methanation performance. Interestingly, supports that possess an intermediate oxygen storage capacity, such as ACZ, demonstrated optimal enhancement of the active phase for CO_2 methanation. These insights emphasize the importance of catalyst support properties in the design of efficient methanation catalysts. By carefully tailoring the OSC of the support, metal-support interactions can be optimized and, consequently, the catalytic performance.

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