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Master Thesis of X, B.Sc.

Synthesis of Iron-Based Catalysts with Magnesia as Support or Structural Stabilizer via a Modified Benzyl Alcohol Route

Background:
The functional properties of catalysts, such as activity, selectivity, and stability, are linked to material-specific parameters including crystallite size, phase composition, surface area, porosity, metal loading, reducibility, and the nature of metal-support interactions. The synthesis method therefore plays a decisive role in shaping these characteristics. Among the available preparation methods, liquid-phase synthesis techniques have proven suitable for producing metal oxide nanoparticles with well-defined structural and chemical properties. While established aqueous routes, such as co-precipitation and deposition-precipitation, are widely used, they can face limitations in controlling particle morphology, size distribution, and phase composition. To overcome these limitations, nonaqueous synthesis approaches employing organic solvents emerge as an attractive alternative. In these systems, the organic solvent serves not only as the reaction medium but may also participate in precursor conversion and nanoparticle formation, thereby influencing nucleation, crystal growth, and the resulting material properties. Most studies on nonaqueous synthesis have focused on single-component metal oxide nanoparticles, whereas comparatively little attention has been devoted to multicomponent catalyst systems containing both an active metal and a support or structural stabilizer. This work aims to systematically investigate the modified benzyl alcohol synthesis of iron-based catalyst materials with magnesia as support or structural stabilizer.

Tasks and scheduled work:

- Literature review on the synthesis of iron and magnesium oxides in organic solvents, initially focusing on the individual components to establish a fundamental understanding of the influence of synthesis parameters on their structural and physicochemical properties.
- Synthesis of the individual iron and magnesium oxide components via a modified benzyl alcohol route.
- Development of synthesis strategies for combining the active iron phase with magnesia as a support or structural stabilizer.
    - Investigation of synthesis approaches analogous to co-precipitation and deposition-precipitation for the preparation of mixed iron and magnesium oxide precursors via modified benzyl alcohol route.
    - Systematic investigation of key synthesis parameters, including the metal precursors, the base acting as precipitation agent, and the temperature during precursor dissolution and aging as well as the duration of these steps.
- Investigation of the influence of post-synthesis thermal treatment on the structural and textural properties of the synthesized materials.
- Comparison of the synthesized materials with conventionally precipitated reference materials.
- Physicochemical characterization of the synthesized materials using XRD, N_2 physisorption, metal content analysis, H_2-TPR, and, where appropriate, complementary characterization techniques.
- Comprehensive documentation of all experimental work using the digital laboratory notebook eLabFTW, including synthesis procedures, synthesis parameters, and characterization results.
- Optional catalytic testing of selected materials in CO_2 methanation.

The final thesis includes regular presentation and discussion of results as well as research data management, a written report of max. 60 pages excl. references and appendix as well as a final presentation of the thesis (20 min) in the IKFT seminar. The rules of safeguarding good scientific practice of the German Research Foundation (Deutsche Forschungsgemeinschaft, DOI: 10.5281/zenodo.3923601) and the current regulation for the safeguarding of good scientific practice at KIT must be observed.

Start of the thesis: October or November 2026

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