# Effect of $WO_3$ annealing conditions on its electrochemical performance in decoupled water splitting

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To combat the negative aspects of climate change, we must increase our reliance on renewable energy sources such as wind and solar farms. The main problem with these renewables is their intermittency and mismatch in production and consumption cycles. To overcome this problem, we must search for energy storage in the form of batteries or, more likely, hydrogen. Hydrogen can be used as an excellent storage mediator or as syngas to produce carbon-free fuels. Nevertheless, hydrogen production is met with obstacles in the form of membranes, which reduce electrolysis efficiency, and extensive gas equalising systems.

Decoupled electrolysis fixes most of these obstacles by introducing a redox mediator that separates oxygen and hydrogen production in space and time. Better materials must be presented to achieve better performance of decoupled electrolysis via solid-state redox mediator. $WO_3$ has proven to be a reliable and well-established redox mediator for work in acidic electrolytes[1,2]. $WO_3$ nanoparticles with a particle size of 50 nm were produced by the wet-chemical method. Different annealing conditions were analysed, using lyophilised $WO_3$ nanoparticles as the starting material. Produced nanoparticles were analysed using XRD, SEM and XPS measurements. The electrochemical performance was evaluated by preparing high-capacity electrodes and assessing their performance using cyclic voltammetry, electrochemical impedance, and chronopotentiometry.

Lyophilisation and heat treatment lead to an increase in electrode capacity in comparison with sedimented particles. Electrodes showed well-established stability (Figure 1. a) without significant changes in cycle times. Lyophilisation increased the specific capacity of the WO3 electrode more than two times compared to the air-dried sample. Annealing in air showed an increase in specific capacity due to the dehydration of tungstite ($WO_3 \cdot H_2O$) and the formation of monoclinic $WO_3$ (Figure 1. b). Annealing in an inert atmosphere produces crystal defects as detected by XPS and increases the conductivity of $WO_3$ nanoparticles, showing better specific capacity. The combination of lyophilisation and heat treatment in an inert atmosphere increases the specific capacity of $WO_3$ electrodes by four times. Faradaic efficiency for all electrodes reached 98-99%, with an overall efficiency of 34-58% and a hydrogen cycle efficiency of 307-371%.

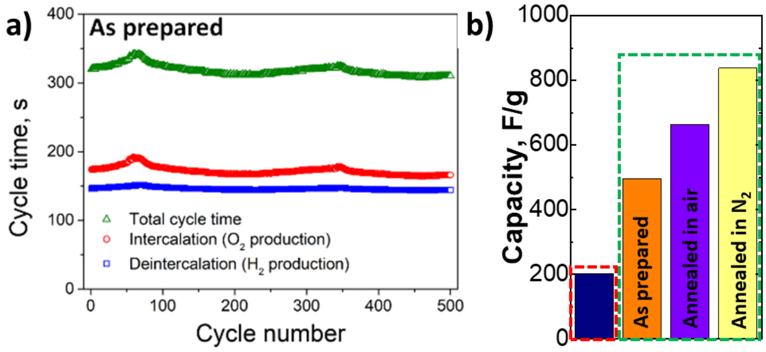


**Figure 1:** Stability measurements of $WO_3$ auxiliary electrode using chronopotentiometry (a) and comparison of specific capacity of $WO_3$ electrodes prepared by different drying and annealing conditions (b).

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**References**

[1]M. Vanags, M. Iesalnieks, L. Jēkabsons, A. Zukuls and A. Šutka, International Journal of Hydrogen Energy, 2023, 48, 20551–20561.

[2]M. Vanags, G. Kulikovskis, J. Kostjukovs, L. Jekabsons, A. Sarakovskis, K. Smits, L. Bikse and A. Šutka, Energy & Environmental Science, 2022, 15, 2021–2028.