

Non-Equilibrium Thermodynamics – A Tool for Fuel Cell Design

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The fuel cell produces electric work and heat, as water is formed by the electrochemical reaction of hydrogen with oxygen. In each of the five layers of a cell; the membrane, the electrocatalytic layers and the porous transport layers next to the membrane, there are large interactions (coupling) between the fluxes of heat, mass and charge. We show how the theory of non-equilibrium thermodynamics can be used to describe these interactions in a systematic manner and how the theory can be used to design more energy efficient cells. Taking the polymer electrolyte fuel cell as an example, we find the local heat production at each electrode using results from calorimetry [1], Seebeck coefficient measurements, thermal osmosis and Soret equilibrium conditions. The measurements, which directly address the coupling with the heat flux, are central for an understanding of transport phenomena in the cell. By optimal cell efficiency, we mean the efficiency with minimum entropy production in the whole cell. We hypothesize that this efficiency is obtained with uniform supply of reactants on a micrometer scale, and calculate that less catalyst material is needed in this situation [2]. Some first experimental efforts are reported which realize this mode of operation.

[1] O. Burheim, S. Kjelstrup, J.G. Pharoah, P. J.S. Vie, S. Møller-Holst, *Electrochim. Acta* **56** (2011) 3248–3257.

[2] S. Kjelstrup, M-O Coppens, J. G. Pharoah, P. Pfeifer, *Energy & Fuels*, **24** (2010) 5097-5108.