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A thermodinamically consistent reduced model for iron corrosion

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In [1] Christian Bataillon et al. have proposed a DPCM (Poisson Coupled Diffusion Model) to describe the corrosion process that occurs on the surface of steel containers in contact with the claystone formation. The model in question focuses on the development of a dense oxide layer in the region of contact between the metal and the claystone. The system formed by the layer, the metal and the solution involves the exchange and the transport of several species: electrons, iron cations and oxygen vacancies. This model leads to a system of drift-diffusion equations for the transport of charge carriers and a Poisson equation for the electrostatic potential, posed in a domain with moving boundaries. So far, some numerical methods have been proposed for the model, however no existence result has yet been established.
In our project we explore some as minor as possible corrections to make the DPCM free energy diminishing. To this aim we start by studying the model in a simplified case: we only take into account the exchanges of electrons and iron cations in a fixed oxyde layer. Our first goal is to establish a thermodynamically coherent model. To that end, some modifications on the boundary conditions are needed. Then we prove a global existence result by adapting to our needs some techniques of [2]. By cutting off all the non-linearities of the starting problem at a certain level, we obtain a regularized problem. Its solvability is proved by the investigation of systems which result from the regularized problem by a discretization of time. Finally, estimates independent of such level are established making use of the Moser iterations technique (cf. [3]). Consequently, a solution of the regularized problem will be a solution of the initial problem if the cut-off level is chosen sufficiently large.

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Orateur: RAIMONDI, Federica (CNRS - Univ. Lille - Inria)

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