Electromigration and Shrinking-core Process in Regenerating Ion Exchange Resins

For more than 60 years ion exchange technology is used in industrial water treatment. Regenerating of exhausted resin is an important unit operation and can cause high consumption of chemicals and investment costs.

Due to theoretical considerations Helfferich postulated 1965 the occurance of core-shell behaviour in ion exchanger pellets, where a sharp interface separates a product shell and an unreacted core. This phenomenon appears for instance in ion exchange with succeeding fast irreversible chemical reaction, which was shown experimentally later on.

The influence of electromotoric forces on mass transfer (so-called electromigration) is well known in ionic systems. This leads to coupling of transport equations and complicates numerical treatment. So far mathematical modeling is based on Fickian diffusion.

Present work investigates the influence of electromotoric forces on core-shell behaviour and regeneration process in weak acid cation exchanger pellets.

For this purpose mathematical modeling is performed with and without electromigration. Based on a novel mathematical approach an efficient numerical technique is developed to calculate the free boundary as an explicit variable which is important in model validation. Sensitivity analysis yields in a so-called hindrance-factor as significant model parameter. It rules inhibition of mass transport of species inside pellet matrix. Unknown parameter is determined by experimental measurement of reaction front in single regenerating copper-loaded ion exchanger pellets of type Amberlite IRC-86.

Numerical calculation of bulk concentrations of released copper ions with both mathematical models incorporating estimated parameter shows different behaviour. Model validation with measured copper concentrations in bulk phase during regeneration process agrees with model considering electromigration. Therefore correct mathematical modeling of such heterogeneous ionic processes has to take into account electromotoric forces.