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ORIGINAL PAPER

Determination of limiting current density for different electrodialysis modules[‡]

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Limiting current density of ammonium nitrate solution in laboratory-, pilot-, and industrial-scale electrodialysis modules were determined to provide a method for the prediction of the limiting current density of ammonium nitrate solutions at any conditions. The current–voltage curve was measured in each case and the limiting current density was evaluated using the dependence of the derivative, dI/dU, on the electric current, I. The limiting current was determined as a current at which the derivative dI/dU equals zero. The developed method enables not only the prediction of the limiting current density but the limiting cut and limiting flux can be determined concurrently at any linear flow velocity of the diluate and inlet ammonium nitrate concentration. It could help to prevent working in the overlimiting region and to avoid undesirable decrease of current efficiency and pH changes. The limiting cut is the maximal cut that can be obtained at certain linear flow velocity and module geometry irrespective of the inlet ammonium nitrate concentration and it is very useful information when designing a new electrodialysis unit for specific application.

Keywords: desalination, electrodialysis, ion exchange membrane, current–voltage curve, limiting current density

Introduction

Electrodialysis is an electrochemical separation process using ion exchange membranes to separate ions from the solution. Driving force of this process is the electric potential difference. Well-known applications of electrodialysis are: production of potable water and desalination of sea and brackish water/NaCl production (Davis et al., 2001). It is often used for sweet and salty whey desalination (Šímová et al., 2009; Kinčl et al., 2012). Other applications of electrodialysis are: treatment of wastewater from power industry (Marek, 2012), deacidification of fruit juices (Vera et al., 2003), removal of potassium tartrate from wine (Gonçalves et al., 2003), treatment of condensate from ammonium nitrate production (Machuča et al., 2012), etc. In a smaller scale, electrodialysis has been applied also in the separation of organic acids, e.g. oxalic acid (Kaláb & Palatý, 2012) and formic acid from wastewaters (Jaime Ferrer et al., 2006). Basic principle of ion separation has been reviewed by Strathmann (1991). An electrodialysis (ED) module is composed of a membrane stack placed between two electrodes, which consists of alternating cation and anion exchange membranes separated with spacers. Ions are accumulated in concentrate cells and removed from diluate cells. The electrodialysis performance can be influenced by several factors; mainly by the number of cell pairs, length of the solution path in the stack, applied voltage, flow rate and concentration of the feed solution, temperature, etc. The quality of the feed solution is also important because hardness and organic pollution cause membrane scaling and fouling.

The transport rate of ions depends on the value of electric current flowing between electrodes. It is thus desirable to work at high current density. In certain

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