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Advanced Lithium Recovery from Brine: 2D-Based Ion Selectivity Membranes

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Abstract : Abstract—The advancement of lithium extraction methods from water sources, particularly saltwater brine, is gaining prominence in the lithium recovery industry due to its cost-effectiveness. Traditional techniques like recrystallization, chemical precipitation, and solvent extraction for metal recovery from seawater or brine are energy-intensive and exhibit low efficiency. Moreover, the extensive use of organic solvents poses environmental concerns. As a result, there's a growing demand for environmentally friendly lithium recovery methods. Membrane-based separation technology has emerged as a promising alternative, offering high energy efficiency and ease of continuous operation. In our study, we explored the potential of lithium-selective sieve channels constructed from layers of 2D graphene oxide and MXene (transition metal carbides and nitrides), integrated with surface – SO_{3-} groups. The arrangement of these 2D sheets creates interplanar spacing ranging from 0.3 to 0.8 nm, which forms a barrier against multivalent ions while facilitating lithium-ion movement through nano capillaries. The introduction of the sulfonate group provides an effective pathway for Li^+ ions, with a calculated binding energy of Li^+ – SO^{3-} at – 0.77 eV, the lowest among monovalent species. These modified membranes demonstrated remarkably rapid transport of Li^+ ions, efficiently distinguishing them from other monovalent and divalent species. This selectivity is achieved through a combination of size exclusion and varying binding affinities. The graphene oxide channels in these membranes showed exceptional inter-cation selectivity, with a Li^+/Mg^{2+} selectivity ratio exceeding 104, surpassing commercial membranes. Additionally, these membranes achieved over 94% rejection of $MgCl_2$.

Keywords : ion permeation, lithium extraction, membrane-based separation, nanotechnology
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