Solvometallurgical recovery of cobalt from lithium-ion battery cathode material using deep-eutectic solvents

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Electronic Supplementary Information (ESI)

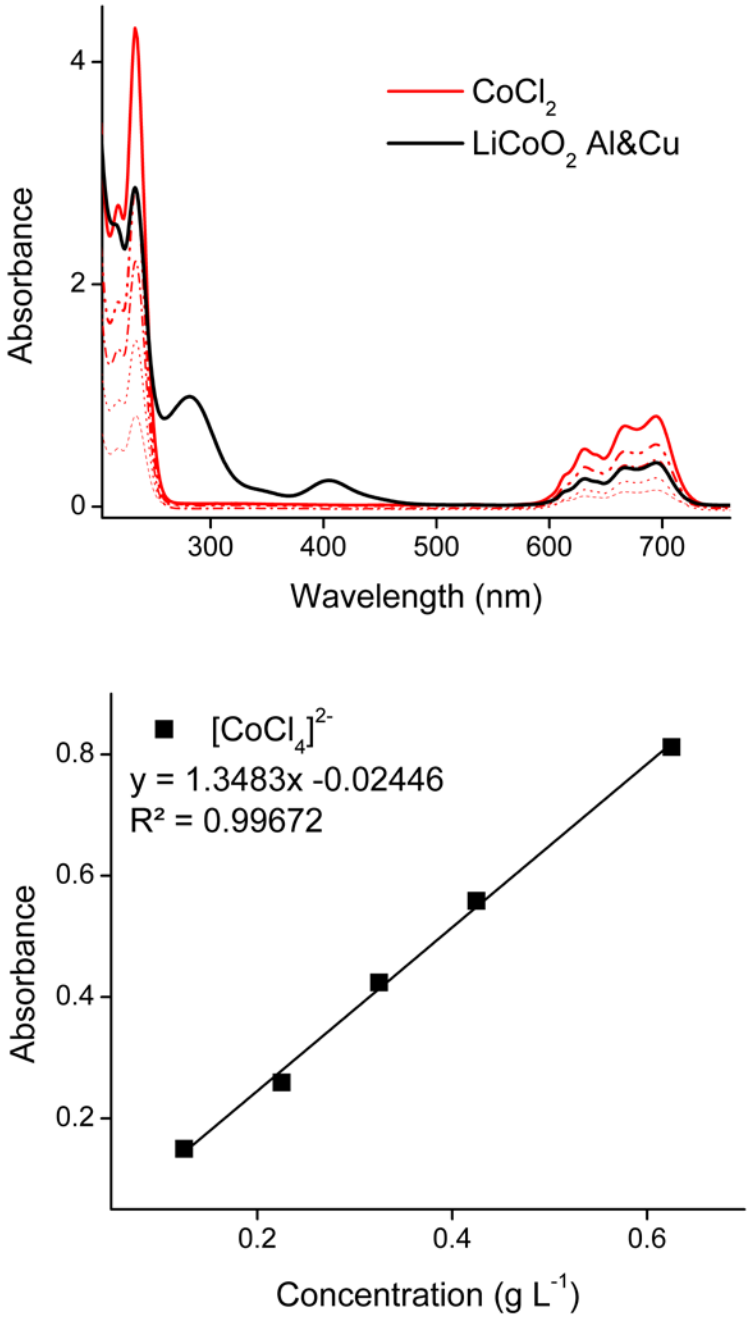

Figure S1: Quantification of the $[CoCl_4]^{2-}$ complex in the pregnant leach solution (PLS) by UV-VIS spectroscopy. Top: spectra at different $CoCl_2$ concentrations and in the PLS. Bottom: calibration curve constructed by use of the absorption band at 694 nm. The calibration curve was recorded by dissolving $CoCl_2$ in 35 wt% H_2O diluted choline chloride solution (choline chloride concentration of ca. 10 mol L^{-1}) at concentrations between 0.125 and 0.625 g L^{-1}. The PLS (ChCl:CA 2 : 1 + 35 wt% H_2O loaded with Al(III), Co(II), Cu(II) and Li(I)) was diluted 40 times.

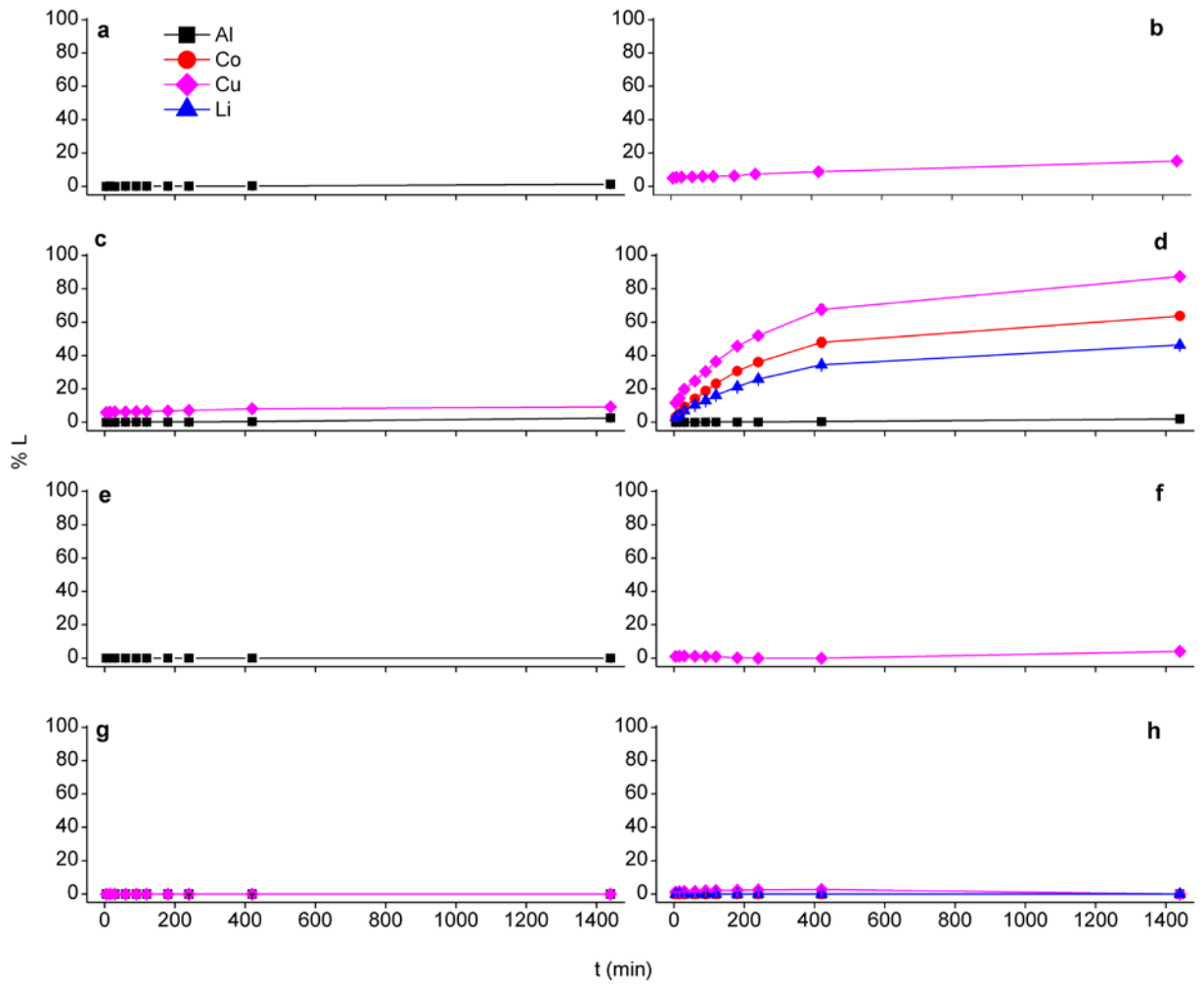

Figure S2: Comparison of leaching of $LiCoO_2$ by citric acid land choline chloride, as a function of time. Leaching parameters: S:L = 20 g L^{-1} , 40 °C, Al:$LiCoO_2$ = 12 wt%, Cu:$LiCoO_2$ = 24 wt% at a stirring speed of 900 rpm. Conditions: (a) Al leaching by 2.8 mol L^{-1} citric acid, (b) Cu leaching by 2.8 mol L^{-1} citric acid , (c) Al + Cu leaching by 2.8 mol L^{-1} citric acid (d) $LiCoO_2$ with Al + Cu leaching by 2.8 mol L^{-1} citric acid (e).Al leaching by choline chloride 35 wt% H_2O, (f) Cu by choline chloride 35 wt% H_2O; (g)Al + Cu leaching by choline chloride 35 wt% H_2O, (h) $LiCoO_2$ with Al + Cu leaching by choline chloride 35 wt% H_2O. The citric acid concentration of 2.8 mol L^{-1} was selected because it represents the maximum solubility in water. The citric acid concentration in the DES is ca. 3.6 mol L^{-1}.

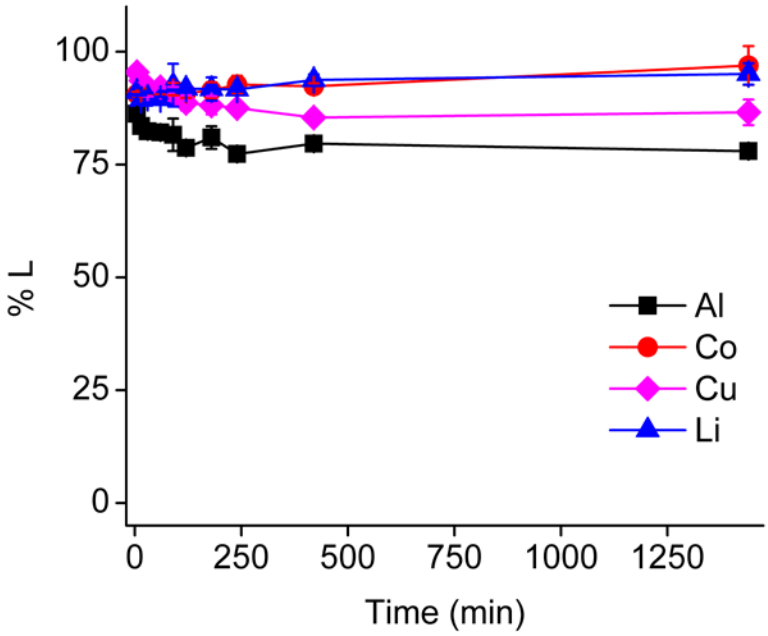

Figure S3: Leaching of $LiCoO_2$ by 3.6 mol L^{-1} HCl solution, in the presence of Al and Cu metal. Leaching parameters: S:L = 20 g L^{-1}, 40 °C, Al:$LiCoO_2$ = 12 wt%, Cu:$LiCoO_2$ = 24 wt% at a stirring rate of 900 rpm.

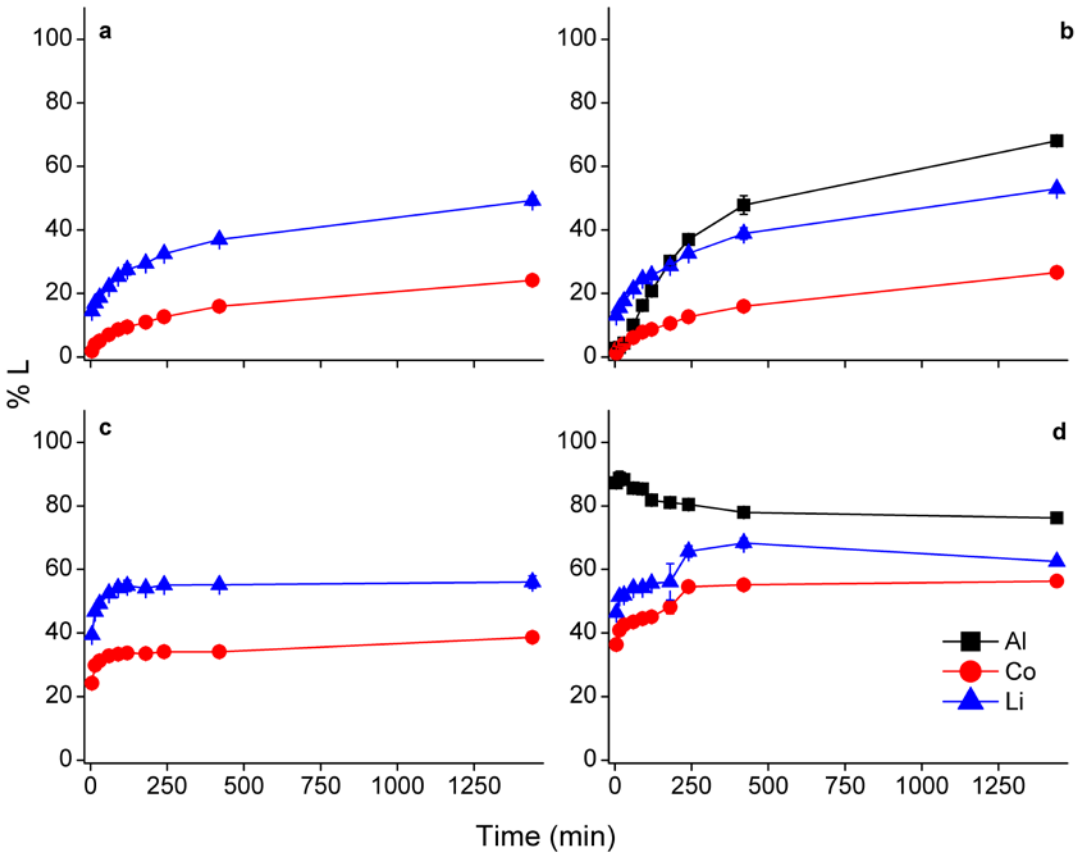

Figure S4: Comparison of leaching of $LiCoO_2$ by DES (top, a and b) and hydrochloric acid solution (bottom, c and d). Leaching parameters: S:L = 20 g L^{-1}, 40 °C, Al:$LiCoO_2$ = 12 wt%, at a stirring rate of 900 rpm. Conditions: $LiCoO_2$ leaching by DES (a, right above), $LiCoO_2$ and Al leaching by DES (b, left above), $LiCoO_2$ leaching by HCl (c, right below), $LiCoO_2$ and Al leaching by HCl (d, left below). DES: (ChCl:CA (2 : 1 + 35 wt% H_2O), concentration HCl = 1 mol L^{-1}.

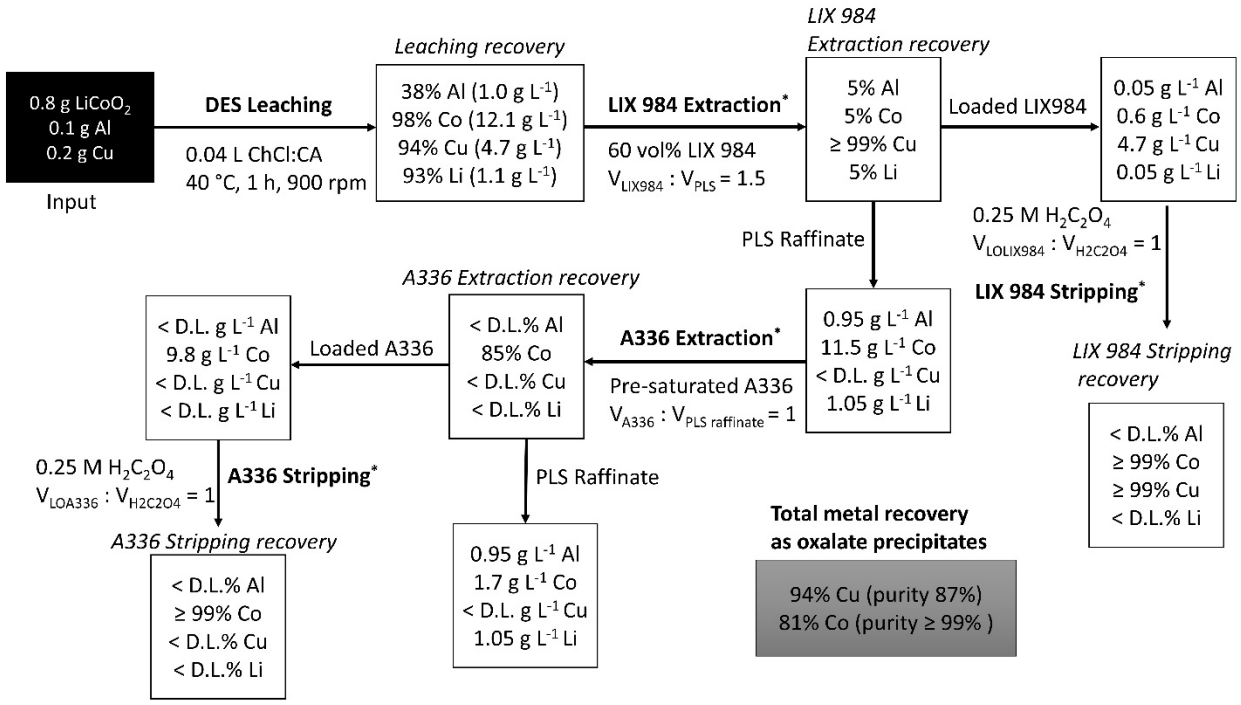

Figure S5: Overview of metal recovery during the entire process. *All experiments were executed at RT, 2250 rpm for 0.5 h