

Brief information about the project

Name of the project	IPH AP25794557 Electrochemical extraction of lithium from lithium-ion battery recycling solutions.
Relevance	The development of effective methods for recycling lithium-ion batteries is of great importance for reducing environmental impact and ensuring sustainable resource use. The implementation of this project will not only improve existing technologies but also make a significant contribution to the development of Kazakhstan's circular economy and reduce dependence on primary material extraction. The project on electrochemical extraction of lithium from lithium-ion battery recycling solutions is relevant and important for the advancement of modern science and technology.
Purpose	The objective of the project is to optimize the method of extracting useful components, particularly lithium, from circulating (model) solutions obtained during lithium-ion battery recycling using electrochemical methods, and to create an affordable and efficient laboratory setup.
Objectives	To achieve the stated objective, the following tasks must be completed: 1. Selection of electrode material. Conducting a search for a stable material capable of selectively extracting lithium ions that is mechanically and chemically resistant in aqueous solutions. Examples of such materials include those used as cathodes for lithium-ion batteries: LiCoO_2 (lithium cobalt oxide), LiMn_2O_4 (lithium manganese spinel), LiFePO_4 (lithium iron phosphate), as well as LiNiMnCoO_2 (NMC) and LiNiCoAlO_2 (NCA). An electrolyte for electrochemical lithium extraction will also be selected and modeled. Model electrolytes containing lithium ions will be used to study the kinetics of lithium intercalation processes and its behavior at the cathode. 2. Optimization of the synthesis process for the selected electrode material. Development of a methodology that will allow the creation of electrodes with improved properties such as high conductivity, stability, selectivity, and durability. 3. Development of the delithiation method (material activation). When using lithium cathode material, oxidizing agents will be used to extract lithium by chemical methods. 4. Fabrication of the electrolyzer. Development of a design that meets the objectives and process requirements. It is important to consider geometry, reaction conditions, and the possibility of subsequent scaling. 5. Optimization of the electrolyzer operating parameters for lithium extraction with the selected intercalation-based

	material. The possibility of adding complexing agents, surfactants, and polymeric substances to minimize contamination of the lithium electrode by transition metals (Fe, Co, Mn) will be considered.
Expected and achieved results	A literature review was conducted. Review and experimental articles on lithium-ion battery recycling were found, specifically on lithium iron phosphate, lithium nickel manganese cobalt, lithium cobalt oxide, as well as LiNiMnCoO₂ (NMC) and LiNiCoAlO₂ (NCA). The lithium-selective electrode "ELIS-142" was selected for measuring lithium ion activity in solutions. Due to funding delays, procurement of necessary components is currently underway: the "ELIS-142" lithium-selective electrode, power supplies (10V, 30A), lithium-containing salts, and a standard for Li determination by AAS. Research was conducted on the selection and optimization of a model solution for lithium determination using a lithium-selective electrode control method. It was determined that the optimal lithium salts are Li₂CO₃ and LiClO₄ (LiOH contains carbonate impurities, LiCl is hygroscopic). The solution pH for measurement should be in the range of 5 to 12. The range of measured concentrations is from 0.1 to 10⁻⁴ M. An aqueous solution of lithium salts Li₂CO₃ will be used to study the kinetics of lithium intercalation processes. Synthesis of LiFePO₄ was carried out using the solid-phase reduction synthesis method. As an initial precursor, FePO₄·H₂O was synthesized from FeCl₃ and H₃PO₄. Li₂CO₃ was used as a lithium source. Stearic acid was used as a reducing agent (T = 600 C, t = 6 h, Ar). Physical and chemical characterization of the material by XRD and SEM methods is currently underway. Synthesis reaction: $\text{FePO}_4 \cdot 2\text{H}_2\text{O} + \text{LiAc} + \text{Red} \rightarrow \text{LiFePO}_4/\text{C} + \text{Ox} + 2\text{H}_2\text{O}$ Red - reducing agent (in our case, stearic acid); Ox - reduction and decomposition products of the oxidizing agent: CO, CO₂. The necessary components were procured: a linear constant voltage source (10V, 30A), lithium-containing salts (lithium carbonate, lithium sulfate, lithium chloride, lithium hydroxide), and a magnetic stirrer bath.
Research team members with their identifiers (Scopus Author ID, Researcher ID, ORCID, if available) and links to relevant profiles	Tazhibayeva Aigerim Shotaevna Master of engineering and technology in chemical technology of inorganic substances PhD candidate H – index 1 Scopus ID: 59168703500 WoS Researcher ID: AFX-1089-2022 ORCID: 0000-0002-4680-5846

	Malchik Fyodor Igorevich Associate Professor, PhD of chemical sciences H-index: 13 Scopus Author ID: 57196147903 Researcher ID: D-5721-2015 ORCID: 0000-0001-6381-0738
Usage	The project results will help apply the methodology in the energy sector, particularly in waste and secondary resource recycling companies, as well as in government environmental programs aimed at implementing strategies to reduce technogenic impact. In addition, mining and metallurgical enterprises can apply this technology to reduce dependence on primary resources.
Priority compared to real-world alternatives	Electrochemical extraction of lithium from recycling solutions, as opposed to lithium extraction by 'wet chemistry' methods.
List of publications with links to them	Aigerim Tazhibayeva, Altynai Tanash, Yaroslav Zhigalenok, Saken Abdimomyn, Kaiyrgali Zhumadil, Fyodor Malchik. Stearic acid induced hydrophobic protection of $\text{NaTi}_2(\text{PO}_4)_3$ for long-term operation in aqueous Na-ion systems // Journal of Electroanalytical Chemistry, 2025, 998, 119550 https://doi.org/10.1016/j.jelechem.2025.119550 Aigerim Tazhibayeva, Altynai Tanash, Yaroslav Zhigalenok, Seiilbek Malik, Kaiyrgali Zhumadil, Sergey Nechipurenko Saken Abdimomyn, Fyodor Malchik. Peroxodisulphuric acid synthesis in a flow electrolyser and its potential utilisation for black mass leaching // RSC Adv., 2025, 15, 42450 https://doi.org/10.1039/D5RA06474K
Patents	None