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Recycling Critical Minerals from Battery Waste – Panel Discussion

Analytical solutions for battery recycling

Simon Nelms
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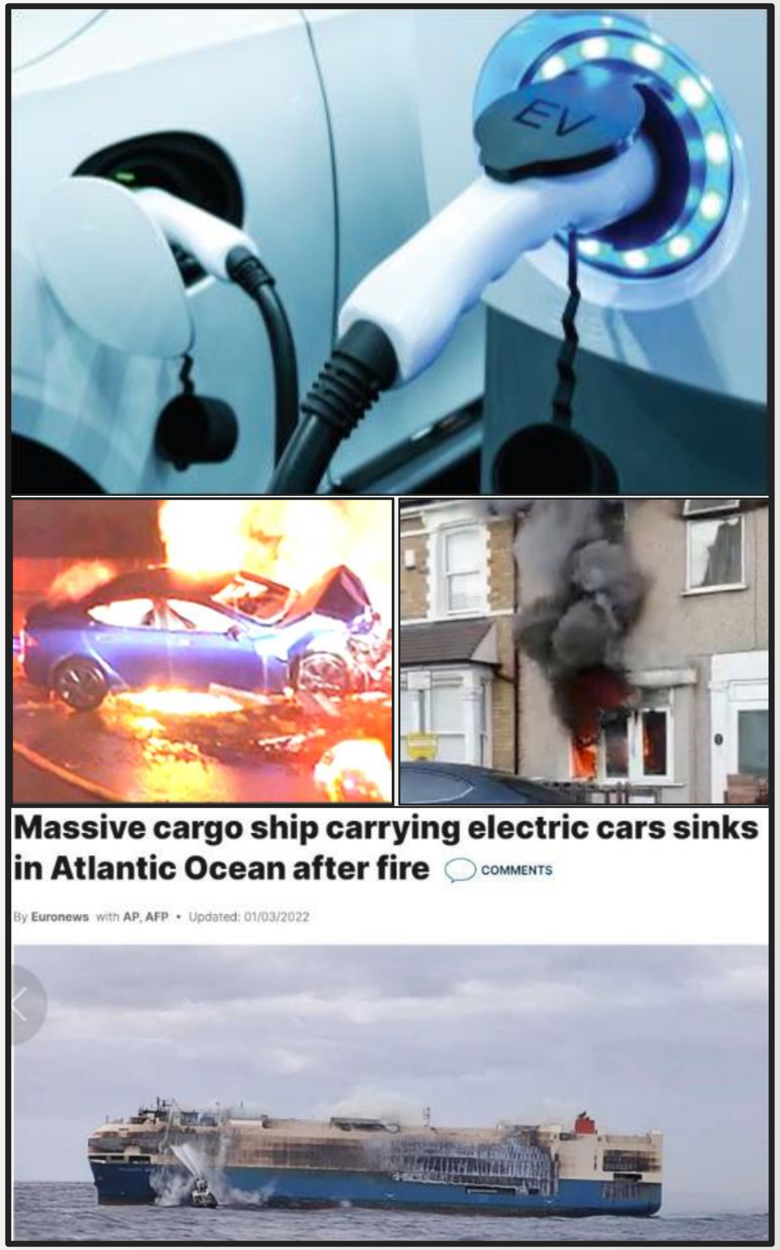
Overview

- Use of elemental analysis in the overall battery supply chain
- Solutions for recycled and raw material elemental analysis
- Recycling and raw material analysis applications
- Other measurement solutions in the battery material supply chain
- Battery technology resources from Thermo Fisher Scientific
- Lab Chemistry Demo Day, June 2nd

Use of elemental analysis in the overall battery supply chain

- Research into higher capacity, faster charging and safer batteries
- Composition and impurity analysis of raw and refined feedstock materials
- Cathode material bulk composition measurement
- Elemental impurity analysis in cathode, anode and electrolyte materials
- Electrolyte / electrode degradation product analysis
- Screening incoming material, verifying final product purity in recycling stage
- Adherence to environmental emission regulations for battery factories



Solutions for recycled and raw material elemental analysis

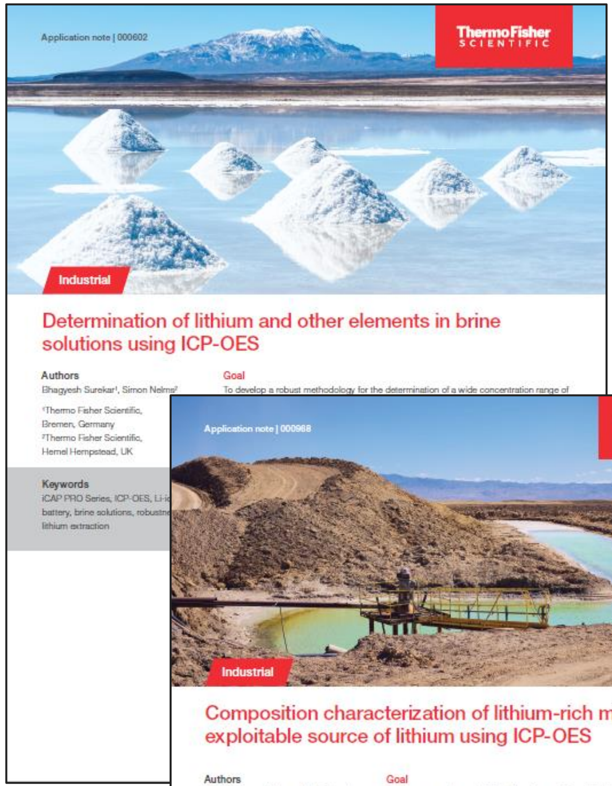
- ICP-OES
  - Robust, accurate and sensitive routine workhorse for QA/QC analysis
  - Low maintenance, straightforward operation
  - Detection limits in the ng/mL range for a wide range of elements
  - Ideal for recycled cathode, anode, electrolyte composition / impurity analysis
- Single quadrupole (SQ) ICP-MS
  - Higher sensitivity, lower detection limits (pg/mL range for many elements)
  - Well suited to high purity product analysis, in R&D and production environments
  - Ability to couple with chromatography techniques for degradation product analysis
- Triple quadrupole (TQ) ICP-MS
  - All the benefits of SQ ICP-MS plus advanced interference removal capability
  - High accuracy for difficult elements (e.g. Si, P, S, As, Se)

Thermo Scientific™ iCAP™ PRO ICP-OES

Thermo Scientific™ iCAP™ RQplus ICP-MS

Thermo Scientific™ iCAP™ TQe ICP-MS

Recycling and raw material analysis applications



Application note | 000602

Industrial

Determination of lithium and other elements in brine solutions using ICP-OES

Authors
Bhagyesh Surekar[1], Simon Nelms[2]
[1]Thermo Fisher Scientific, Bremen, Germany
[2]Thermo Fisher Scientific, Hemel Hempstead, UK

Goal
To develop a robust methodology for the determination of a wide concentration range of

Keywords
iCAP PRO Series, ICP-OES, Li-i
battery, brine solutions, robustne
lithium extraction

Application note | 000968

Industrial

Composition characterization of lithium-rich minerals as an exploitable source of lithium using ICP-OES

Authors
Tomoko Vincent[1], Simon Nelms[2], and Kateryna Omelchuk[3]
[1]Thermo Fisher Scientific, Germany
[2]Thermo Fisher Scientific, United Kingdom
[3]British Lithium, United Kingdom

Keywords
Green energy, high matrix, ICP-OES, lithium-ion battery, lithium mining, quality control

Goal
To demonstrate the suitability of the Thermo Scientific™ iCAP™ PRO X ICP-OES Duo for the elemental analysis of lithium mineral samples

Introduction
The transition to electric vehicles (EVs) is one of the key developments of the green energy revolution, and global demand for these vehicles is soaring. Lithium-ion batteries are one of the most important power storage materials for EVs due to their power density and life cycle performance. The lithium used in the production of electric vehicle batteries and other electronic devices is obtained from sources such as underground brines[1] and lithium-rich minerals and rocks. While brine solutions can be potentially rich, relatively easy-to-access sources of lithium, consideration must be given to the potential impact of the exploitation activities themselves on climate change, related environmental risks, and raw material supply.[2] Mining lithium containing minerals is an alternative source for regions where underground brines are not existing or not possible to exploit, but developing lithium mining sites also requires environmental impact consideration.

Lithium containing minerals differ significantly in their chemical composition, characteristics, and lithium content.[3] To determine whether a given mineral or brine is worth extracting, it is important to obtain quantitative information about certain major and trace components in the mineral/brine (Table 1). Portable X-ray fluorescence (pXRF) is a technique widely used in the mining industry as it is a non-destructive analytical technique that is effective for determining the elemental composition of a sample directly in the field.

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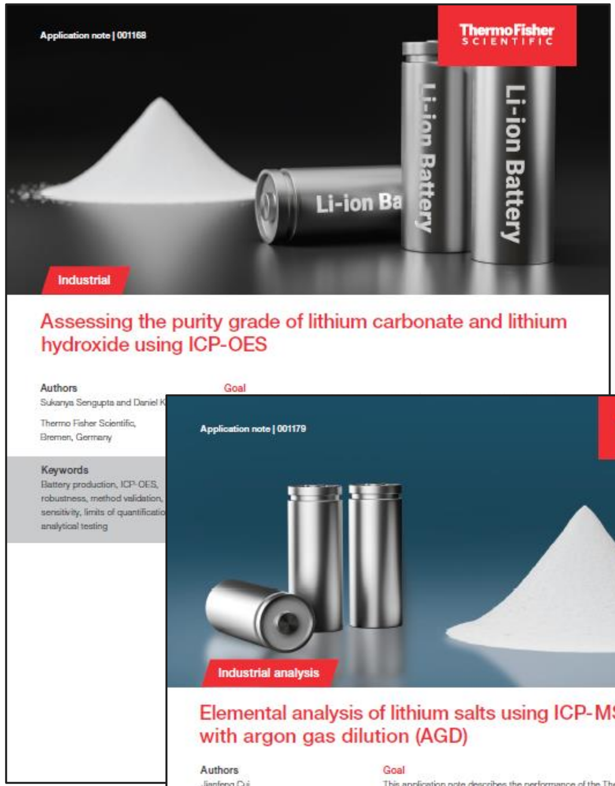


Application note | 001168

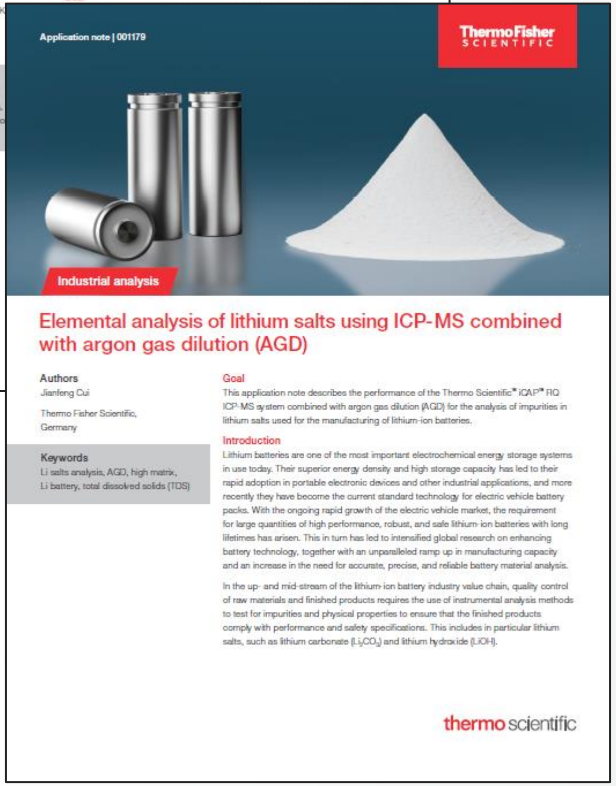
Industrial

Assessing the purity grade of lithium carbonate and lithium hydroxide using ICP-OES

Authors
Sukanya Sengupta and Daniel K
Thermo Fisher Scientific, Bremen, Germany

Goal

Keywords
Battery production, ICP-OES, robustness, method validation, sensitivity, limits of quantificatio
analytical testing



Application note | 001179

Industrial analysis

Elemental analysis of lithium salts using ICP-MS combined with argon gas dilution (AGD)

Authors
Jianfeng Cui
Thermo Fisher Scientific, Germany

Keywords
Li salts analysis, AGD, high matrix, Li battery, total dissolved solids (TDS)

Goal
This application note describes the performance of the Thermo Scientific™ iCAP™ RQ ICP-MS system combined with argon gas dilution (AGD) for the analysis of impurities in lithium salts used for the manufacturing of lithium-ion batteries.

Introduction
Lithium batteries are one of the most important electrochemical energy storage systems in use today. Their superior energy density and high storage capacity has led to their rapid adoption in portable electronic devices and other industrial applications, and more recently they have become the current standard technology for electric vehicle battery packs. With the ongoing rapid growth of the electric vehicle market, the requirement for large quantities of high performance, robust, and safe lithium-ion batteries with long lifetimes has arisen. This in turn has led to intensified global research on enhancing battery technology, together with an unparalleled ramp up in manufacturing capacity and an increase in the need for accurate, precise, and reliable battery material analysis.

In the up- and mid-stream of the lithium-ion battery industry value chain, quality control of raw materials and finished products requires the use of instrumental analysis methods to test for impurities and physical properties to ensure that the finished products comply with performance and safety specifications. This includes in particular lithium salts, such as lithium carbonate (Li_2CO_3) and lithium hydroxide (LiOH).

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Application note | 002085

Energy

Single quadrupole-inductively coupled plasma mass spectrometry (ICP-MS) as a tool for process control in lithium battery recycling

Authors
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Cambridge, United Kingdom
[3]Thermo Fisher Scientific, Hemel Hempstead, United King

Keywords
Anode materials, graphite, argon gas dilution, battery, high
ICP-MS, KED, lithium, recycling

THE BATTERY RECYCLING COMPANY

Application note | 002086

Energy

Managing the challenges of analyzing battery materials using triple quadrupole inductively coupled plasma mass spectrometry (ICP-MS) equipped with Argon Gas Dilution

Authors
Tomoko Vincent[1], Daniel Kutscher[1], Mikael D. Axelsson[2], Ibrija Musfique[3]
[1]Thermo Fisher Scientific, Germany
[2]Thermo Fisher Scientific, Sweden
[3]Northvolt Revolt AB, Sweden

Keywords
Argon Gas Dilution, battery, cathode, high matrix, high resolution, ICP-MS, KED, lithium, recycling, triple quadrupole, TQ-O_2 mode

Goal
To demonstrate the analysis of critical elemental impurities in highly concentrated solutions (up to 5.3% w/w) of cathode materials used in lithium-ion batteries with high sensitivity, accuracy, and robustness using triple quadrupole ICP-MS.

Introduction
The transition to electric vehicles (EVs) is one of the key developments of the green energy revolution, and the resulting demand for these vehicles shows an unprecedented speed in ramping up manufacturing capacity for both the vehicles themselves and the lithium-ion batteries that power them. Lithium-ion batteries are one of the most important power storage materials for EVs due to their power density and life cycle performance. With the high, and increasing, demand for batteries, questions arise around their fate at the end of their lifetime. Key areas of concern are recycling, to recover valuable raw materials and maintain sustainability in the supply chain, and issues surrounding environmental contamination following inappropriate battery disposal.

A typical lithium-ion battery consists of four main parts, namely the cathode, separator, anode, and electrolyte (Figure 1). To meet the required performance criteria (i.e., long battery lifetime and maximum achievable charge capacity), it is important to monitor not only the concentration ratio of the main components (typically nickel, manganese, cobalt, and lithium in nickel manganese cobalt (NMC) batteries, or iron, phosphorus, and lithium in lithium iron phosphate ($LiFePO_4$) batteries and lithium ferrophosphate (LFP) batteries), but also trace impurities in both the precursor materials and the finished products.[1]

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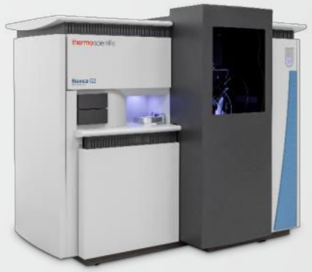
Other measurement solutions in the battery material supply chain

- Ion, gas and liquid chromatography
  - Raw and refined material anion and organic impurity analysis
  - Electrolyte composition and impurity analysis
- XRD and XRF
  - Mineral, cathode and anode crystalline structure examination
- Electron microscopy
  - Material characterization, electrode defect imaging
- X-ray photoelectron spectroscopy (XPS)
  - Electrode surface composition analysis
- FTIR and Raman spectroscopy
  - Battery research, binder and separator analysis

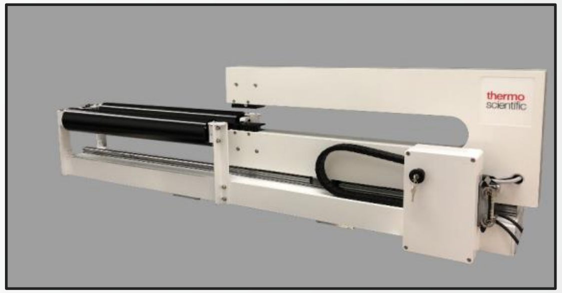




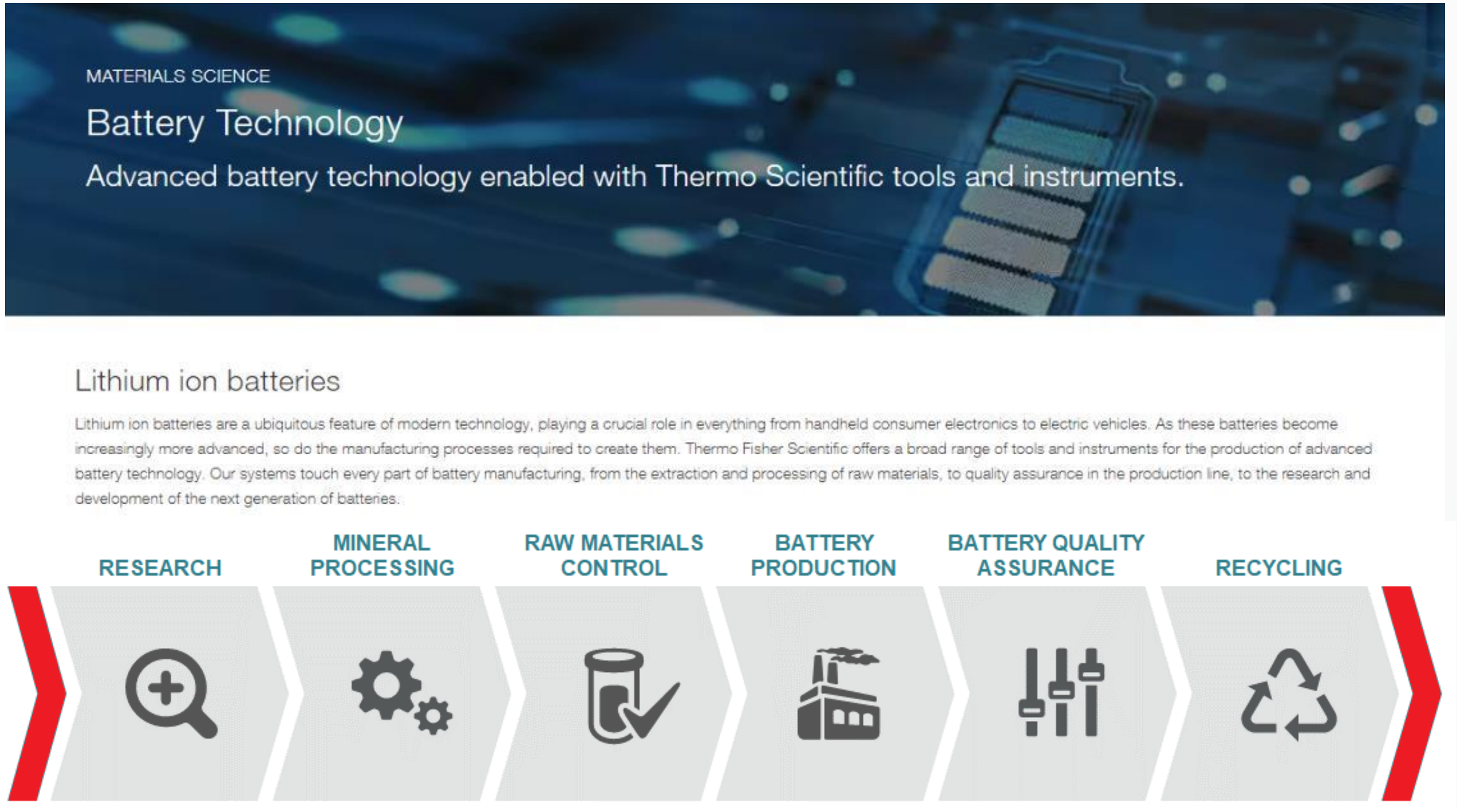


Other measurement solutions in the battery material supply chain

- Extrusion and rheometry
  - Slurry preparation and viscosity measurement
- On-line gauges
  - Electrode coating weight and thickness measurement
- Handheld XRF
  - Rapid mineral identity confirmation and incoming recycled material profiling
- Process mass spectrometry
  - Airborne solvent detection (health and safety)
- Laboratory Information Management Systems
  - Efficient data processing, sharing and report generation



Battery technology resources from Thermo Fisher Scientific



- Advanced Battery Technology web page – scan the QR code to access!
- Follows battery manufacturing process workflow from mining / refining through to recycling
- Single reference source for all our solutions in one convenient location

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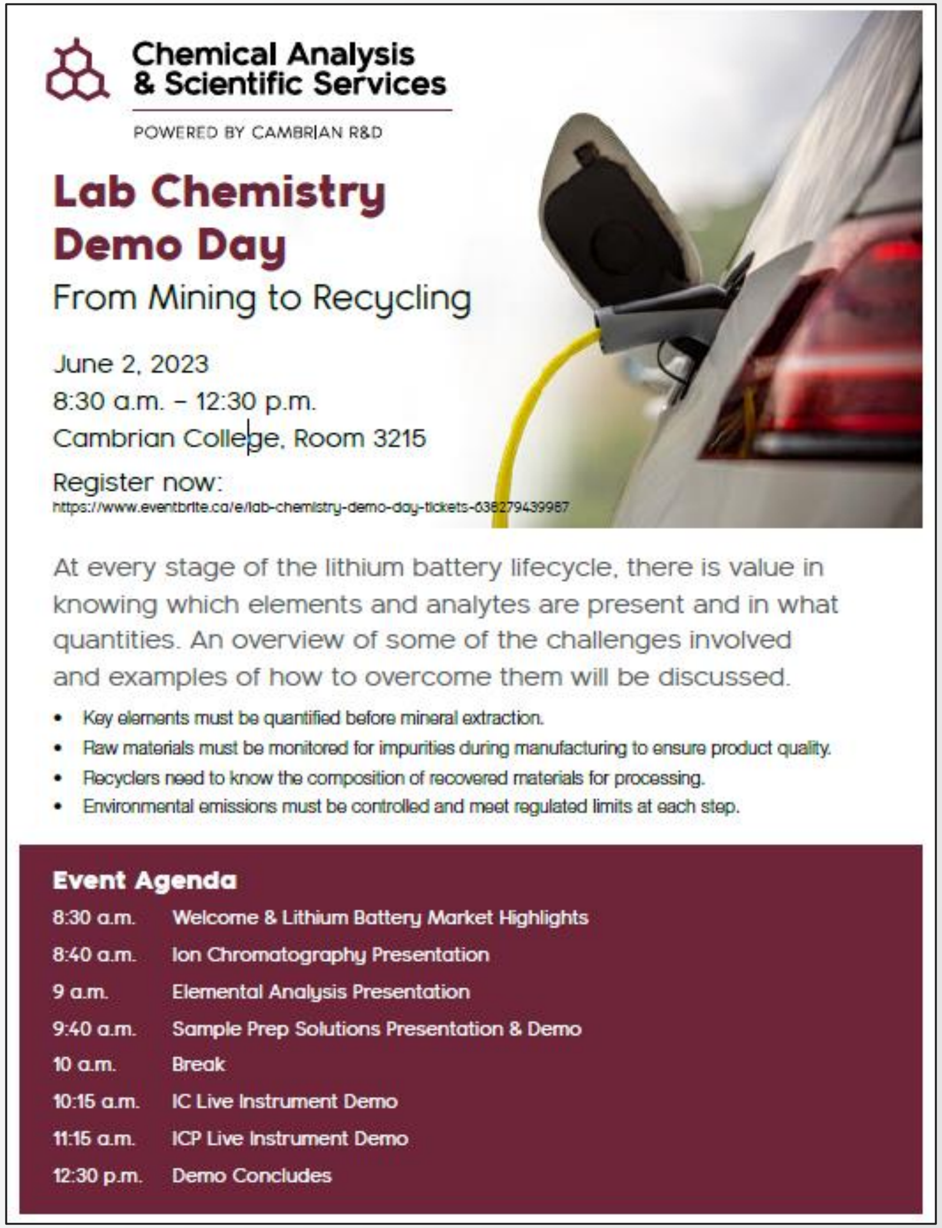
Lab Chemistry Demo Day, June 2nd

- Free half-day educational seminar tomorrow, 8:30 - 12:30
- Talks from experts in trace element analysis and ion chromatography
- Live ICP-OES and ion chromatography demonstrations
- Taking place in the Cambrian College Chemical Analysis and Scientific Services facility – Room 3215
- To attend, register with me after this session



Chemical Analysis & Scientific Services

POWERED BY CAMBRIAN R&D

Lab Chemistry Demo Day

From Mining to Recycling

June 2, 2023
8:30 a.m. – 12:30 p.m.
Cambrian College, Room 3215

Register now:
https://www.eventbrite.ca/e/lab-chemistry-demo-day-tickets-638279439987

At every stage of the lithium battery lifecycle, there is value in knowing which elements and analytes are present and in what quantities. An overview of some of the challenges involved and examples of how to overcome them will be discussed.

- Key elements must be quantified before mineral extraction.
- Raw materials must be monitored for impurities during manufacturing to ensure product quality.
- Recyclers need to know the composition of recovered materials for processing.
- Environmental emissions must be controlled and meet regulated limits at each step.

Event Agenda

8:30 a.m.	Welcome & Lithium Battery Market Highlights
8:40 a.m.	Ion Chromatography Presentation
9 a.m.	Elemental Analysis Presentation
9:40 a.m.	Sample Prep Solutions Presentation & Demo
10 a.m.	Break
10:15 a.m.	IC Live Instrument Demo
11:15 a.m.	ICP Live Instrument Demo
12:30 p.m.	Demo Concludes

Thank you