Analytical Measurements and Vacuum Solutions for the Lithium-Ion Battery Industry

Partnering for your success

Agilent

Trusted Answers

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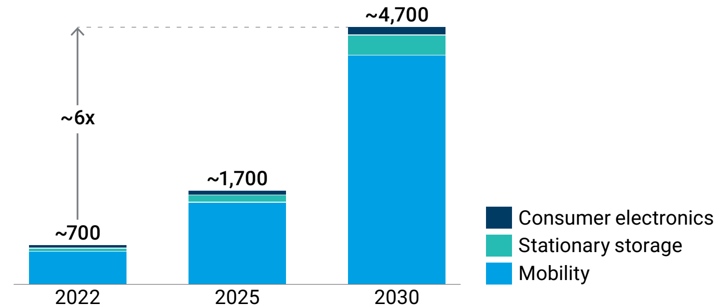
Clean Energy Demand – Driving the Battery Industry

A rapidly growing industry needs a flexible analytical partner with a wide range of products and services

Unprecedented growth in the lithium-ion battery (LIB) market is being driven by demand for electric vehicles (EVs) and renewable energy storage. This growth has led to a surge in demand for analytical services to ensure the quality of battery products, protect the environment and worker health, and deliver circular use of battery materials. Failure to properly characterize starting materials, products, or formulations can result in costly delays, production disruptions, and intensive root cause investigations.

Agilent partners with companies who are supporting the transition to renewable energy. From analytical equipment, to vacuum pumps, to training, method development and technical consulting, through to purchasing finance, lab audits, and asset management. We can help any company, whether you are a start up needing finance and method development support, or a large battery manufacturer needing 24/7 uptime on instruments to meet production targets.

Global Lithium-ion battery demand, GWh, by sector



Electric vehicles are driving the growth in the lithium-ion battery industry.

Source: McKinsey & Company

Global Lithium-ion Market Size (B$)

The lithium-ion battery market will grow to nearly $100 billion by 2025.

Analytical instruments

Reliably meet your analytical testing needs using accurate and reliable chromatography, mass spectrometry, and spectroscopy instruments that are already popular across the battery supply chain.

More information

Vacuum and leak detection equipment

Ensure high standards of quality and efficiency across your operations with our vacuum and leak detection products, including integrated solutions tailored to meet your design, production, assembly, and testing requirements.

More information

Laboratory supplies

Be confident your analytical results are accurate and that you're achieving the optimum performance from your instruments with Agilent's range of spares and consumables, chemical standards, certified reference materials, and sample preparation supplies.

More information

Analytical method development and application consulting

Improve the economics of your testing with the optimum methods, instruments, and protocols.

Method consulting services

Analyst training and support

Improve lab operations and minimize downtime with courses covering troubleshooting, maintenance, sample preparation, and software operations. An active online community provides answers for problems faced by analysts.

Agilent Education

Agilent Community

Product service and maintenance

Reduce downtime, produce accurate, reliable data, and comply with industry regulations with flexible service and maintenance plans.

Instrument service

Asset Performance Management

CrossLab Connect

Pre-owned instruments, instrument buy-back

Certified pre-owned instruments deliver performance and reliability at an affordable price. Our trade-in and buyback program turns assets into income. Products at end-of-life instruments are safely disposed of.

Certified pre-owned instruments

Instrument Buy Back

Software solutions

From data management systems, offering secure, centralized management of your analytical records to asset management systems to ensure you get the best use from your investment.

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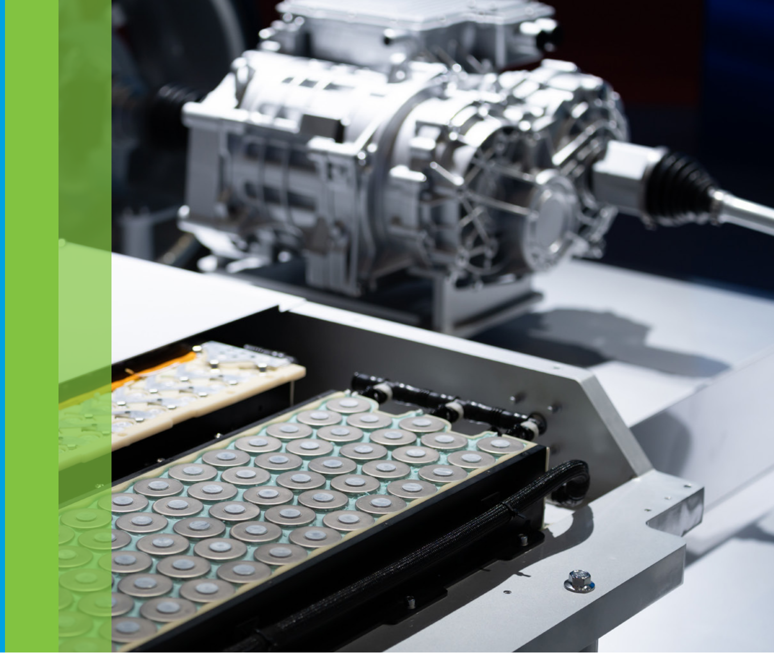
Financial services

Agilent offers flexible payment plans for capital expenditure, instrument subscription services, and bundled services, consumables, and support with a single, predictable monthly payment.

More information

Lithium-ion Battery Value Chain



The beginning of a battery's life – find a high-quality raw material deposit and maximize the yield and purity of extracted material, all while maintaining worker and environmental safety.

The rapidly growing battery recycling industry forms part of the circular economy, reducing energy requirements CO_2 production volumes and raw material shortages.

Manufacture high-specification cathodes, electrolyte, anodes, and separators to create safe, high-performing batteries.

Within battery manufacturing, cell assembly, electrolyte filling, electrode degassing, testing of the anode/cathode/assembled battery, and battery housing leak testing are essential to performance, lifetime, and safety.

Mining and Raw Material Processing

Exploration and extraction

Techniques for exploration for the mineral deposits essential for lithium-ion battery (LiB) production range from aerial spectroscopy to on-ground sampling, and drill cores. While initial exploration can use remote or basic onsite instruments, comprehensive analysis demands extensive sampling and lab tests.

Lithium can be extracted from rock consisting of lithium aluminosilicate (spodumene). Lithium can also come from brine where the lithium is present in salty mineral rich water in an underground reservoir. This water is pumped to the surface for processing. Other minerals, such as nickel, cobalt, manganese, copper, aluminum, iron, phosphate, and graphite are also vital for LiB production. Analytical techniques such as FTIR, Flame AAS, MP-AES, ICP-OES, and ICP-MS are crucial for precise and timely data, aiding geologists and engineers in decision-making.

Mining environments are demanding, requiring sturdy and user-friendly instruments. Modern mines must implement safe, environment-friendly practices. Regular monitoring and analysis are essential for worker safety and production optimization, with diverse instruments needed to analyze various materials. Mining also produces considerable waste, requiring thorough analysis to understand its composition, potential future value, and environmental impact.

Effective and efficient mining demands robust, precise analytical tools that ensure safety, optimal yields, and minimal waste.

Powering the future:

A buyer's guide to elemental analysis instrumentation for unearthing battery minerals

[Download guide](#)

Testing needs

Companies exploring for battery minerals and then extracting them typically need the following analytical tests, conducted either at the mine site or in a commercial lab.

Mine life cycle stage	Testing needs	Instrumentation required	Example applications
Mineral exploration	After geophysical methods have identified a deposit, testing of surface and subsurface rock, or brine samples, is undertaken to confirm and characterize the elements present	X-ray fluorescence (XRF) FTIR, ICP-OES, ICP-MS, AAS	Quantification of Key Elements in Lithium Brines by ICP-OES Ultra-fast determination of base metals in geochemical samples using ICP-OES At Site Rock and Mineral Measurement Using a Handheld Agilent FTIR Analyzer Assay of alkali metals in Pegmatite and Spodumene Ores
Mineral deposit size and quality determination	Mineral assays to determine if the deposit is economically viable and environmentally responsible	X-ray fluorescence (XRF) ICP-OES, ICP-MS, AAS, Ion Chromatography	Analysis of Lithium Content in Pegmatite Ores using AAS Determination of metals in base metal ores using Agilent MP-AES Assay of Alkali Metals in Pegmatite and Spodumene Ores by ICP-OES
Mineral extractability	Metallurgical testing to establish how easily the mineral can be extracted and processed from the ore and to evaluate different extraction methods	X-ray diffraction (XRD), ICP-OES, ICP-MS, AAS, FTIR	Elucidating Rock and Mineral Composition with Handheld Agilent FTIR Analyzers The Measurement of Moisture Content in Mineral Ore Samples (PDF)
Environmental assessments	Examine potential impacts on air, water, and soil quality, as well as the local biodiversity	ICP-MS, ICP-OES, FAAS, gas chromatography/mass spectrometry (GC/MS), and various microbiological assays	Analysis of Environmental Waters by ICP-OES per Standard Method Analysis of Soils, Sediments, and Sludges by ICP-OES per US EPA 6010D
Mine site and refinery EH&S	Monitoring yield and minimizing waste of operations Monitoring of gases and dust to ensure mine worker safety Monitoring of waste streams to ensure environmental compliance and to identify opportunities for further extraction	GC, LC, UV-Vis, FTIR, FAAS, MP-AES, ICP-OES, and ICP-MS	Mine gas analysis using micro GC Multi-Element Analysis of Air-Filters using ICP-OES

Mineral processing

Refining minerals increases their purity and changes them into a useable chemical form. Chemical analysis is needed during the processing stages, to monitor input chemicals to ensure they don't contaminate the process, and to monitor the intermediate products to ensure the process is producing suitable purity and yield. Chemical analysis is also required to ensure the quality and yield of the final product. The complexity of the matrix of the metal concentrates and the intermediate products typically requires skilled lab chemists or spectroscopists to operate the analytical instrumentation.

Lithium extracted from spodumene (lithium aluminosilicate minerals) is refined into lithium salts; lithium carbonate and lithium hydroxide. Processing typically starts with a roasting stage, followed by acid leaching and conversion into lithium carbonate using sodium carbonate. The lithium salt then gets heated, filtered, and dried.

Lithium extracted from brines is concentrated in evaporation ponds, after which unwanted boron and magnesium are removed. It is then treated with sodium carbonate to precipitate lithium carbonate. Again, filtering, washing, and drying are required.

ICP-OES is the technique normally used by a lithium processing plant to test the elemental content of samples. FTIR and UV-Vis can also be used for these measurements. As battery manufacturers demand higher purity materials, more sensitive techniques like ICP-MS are needed.

Global Battery Alliance passport

The Global Battery Alliance has instituted a “battery passport” to achieve transparency about sustainability and circular value chains. The passport reports data on battery origin, chemical make-up, and performance. Sustainability credentials including carbon footprint in production, circularity, and resource efficiency are also reported. Article 65 of the European Union Battery Regulation requires a “battery passport” which contains information for the battery model and the individual battery.

The Chinese government is also adopting a digital battery passport to facilitate trade with the EU, requiring similar data transparency requirements within the battery industry in China.

All companies contributing to the battery value chain will need to understand and comply with the reporting requirements.

Testing needs

Companies processing battery minerals typically need the following analytical testing capabilities.

Mineral processing stage	Testing needs	Instrumentation required	Example applications
Refining	Identification and quantitation of impurity elements present	ICP-OES or ICP-MS, FTIR	Determination of Elemental Impurities in Copper Sulfate using ICP-OES
Final product	Testing purity of final product	ICP-OES or ICP-MS	Determination of Elemental Impurities in Lithium Carbonate Using ICP-OES Quantifying trace-levels of 64 elements in Lithium Ion Battery raw materials using ICP-MS/MS Determination of Elemental Impurities in Lithium Hydroxide Using ICP-OES

Organic raw material processing

Organic polymers and solvents are used across the lithium-ion battery value chain. Materials derived from the refinement and subsequent processing of crude oil include:

- Ethylene and propylene polymers,
- Specialty polymers such as doped polyacetylene polythiophene, coated treated polyester (PET), and polyvinylidene difluoride (PVDF), and
- Various carbonate solvents and specialty additives.

Analytical instruments are required to identify, characterize, and assess the quality of raw materials, in-process streams, and finished products. This testing is typically done according to recognized standards (e.g., ASTM and ISO).

Gas chromatography and gas chromatography/mass spectrometry analyzers quickly provide detailed speciation information about complex hydrocarbon streams. This information helps precisely calculate feedstock value, the purity and quality of processing solvents, polymers and specialty chemicals.

Atomic spectroscopy techniques, such as MP-AES, ICP-OES, and ICP-MS are used to quantify inorganic impurities at various stages of petrochemical processing.

Molecular spectroscopy instrumentation such as UV-Vis and FTIR spectrometry can provide quantitative insights throughout the chemical process. UV-Vis can confirm the quality of organic solvents. FTIR spectroscopy can confirm the identity of organic solvents and polymers, perform degradation studies and quantify polymer ratios, additives, and contaminants.

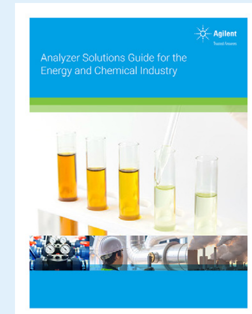
Testing needs

Companies processing organic battery materials typically employ the following analytical testing capabilities.

Testing needs	Instrumentation required	Example applications
Assessment of crude oil before processing	MP-AES, ICP-OES	High-Throughput Multi-Elemental Analysis of Crude Oil Direct multi-elemental analysis of crude oils using the Agilent 4200/4210 Microwave Plasma-Atomic Emission Spectrometer (PDF)
Impurity monitoring in production processes	GC, GC/MS	Trace Analysis of Ammonia in Ethylene by Gas Chromatography and Nitrogen Chemiluminescence Detection Simultaneous Analysis of Trace Oxygenates and Hydrocarbons in Ethylene Feedstocks Using Agilent 7890A GC Capillary Flow Technology Analysis of Arsine and Phosphine in Ethylene and Propylene Using the Agilent Arsine Phosphine GC/MS Analyzer with a High Efficiency Source Trace analysis of permanent gases in ethylene and propylene hydrocarbon products
	MP-AES, ICP-OES, ICP-MS	Determination of iron, nickel, and vanadium in crude oil residues diluted in o-xylene using MP-AES
Plastics material identification and characterization	FTIR	Material Identification of Plastics Throughout Their Life Cycle by FTIR Spectroscopy Polymer Analysis using FTIR Identification of Solvents Used in Lithium-Ion Batteries by FTIR

Analyzer solutions for the energy and chemical industry

This guide summarizes the Agilent portfolio of analyzers serving the energy and chemical industries. Find your specific workflow solution here.

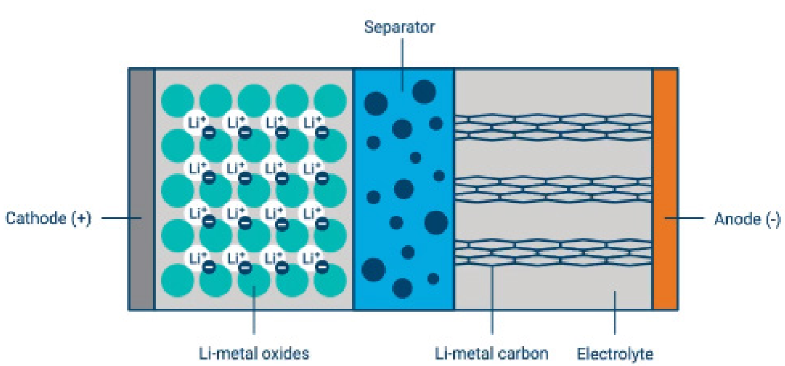


Download guide

Battery Component Manufacturing

Each component in a lithium-ion battery contributes to the battery's performance and lifetime, or, when incorrectly formulated or manufactured, its early failure.

There are four main components in a lithium-ion battery, the cathode, anode, electrolyte, and the separator.



A practical guide to elemental analysis of lithium ion battery materials using ICP-OES

[Download guide]

Cathode

The cathode plays a major role in battery performance. The composition of the precursor cathode active material (pCAM) and mechanical construction of the cathode can impact performance specifications, including energy density, safety, and longevity. Common cathode chemistries include: lithium iron phosphate (LFP); lithium nickel manganese cobalt oxide (NMC); lithium, nickel, cobalt, and aluminum oxide (NCA); and lithium cobalt oxide (LCO).

The cathode is made by applying a pCAM slurry to the cathode substrate (commonly aluminum foil). The slurry is produced from powdered pCAM, with styrene-butadiene rubber (SBR) or polyvinylidene fluoride (PVDF) binder and conducting powder (graphite) in n-methylpyrrolidone (NMP) solvent.

Dispersing the pCAM slurry is often done under vacuum to avoid gas inclusions. Once the slurry is applied to the cathode, chemical testing in situ is no longer possible, so all impurity testing is done before deposition onto the cathode. The foil is then heated and dried to remove the NMP solvent before rolling. The NMP solvent removed during the heating can be recovered for re-use but would need to be tested to ensure it is not introducing impurities.

The cathode is now ready for cutting to size. Before creation of the cell, vacuum heating is applied to the cathode to remove any residual moisture. It is then dry packed under vacuum.

Impurity testing

Metal impurities present in the cathode will have a deleterious effect on battery performance, longevity, and safety. Analytical testing of input chemicals, binder, conducting powder, and slurry solvent, as well as the final pCAM product, before it is applied it to a cathode, ensures quality and purity. Determination of trace impurities in concentrated metal salt solutions can be difficult, requiring analyst expertise and sophisticated instrumentation.

Testing and processing needs

Companies manufacturing battery cathodes typically need the following analytical testing capabilities.

Testing/processing needs	Equipment required	Example applications
Confirming the identity and purity of input chemicals	ICP-OES ICP-MS FTIR	Determination of Trace Metal Impurities in High Purity Aluminum Nitrate using ICP-OES Elemental Analysis of Intermediate Feedstock Chemicals for Li-Ion Batteries (LIBs) by ICP-OES Quick and Easy Material Identification of Salts Used in Lithium-Ion Batteries by FTIR
Impurity monitoring in production processes	ICP-OES ICP-MS FTIR	Analysis of Elemental Impurities in Lithium Iron Phosphate Cathode Materials for LIBs by ICP-OES ICP-MS Analysis of Trace Elements in LIB Cathode Materials
Base material mixing	Rotary vane pumps and roots pumps	Agilent Vacuum and Leak Detection Solutions for e-Mobility
Current collectors coating	Diffusion pumps	
Laminated lithium-ion electrode vacuum drying	Dry scroll pumps	Agilent Vacuum and Leak Detection Solutions for e-Mobility

Save weeks or months of procedure writing

Agilent has a fully developed standard operating procedure (SOP) for impurity analysis in an LFP cathode (as per the GB/T 30835-2014 method). Supplied in Word format, the free SOP is ready to be copied and pasted into your company's template.

A sample of the SOP is available online.

Anode

The anode in a LiB has a relatively simple chemistry and construction, being based on a copper foil coated with graphite. Research to improve energy efficiency and reduce the weight and cost of batteries is continuing. For example, a hybrid graphite-silicon coating offers higher energy density, while copper-plated metals or copper-plated polymers offer potential as cheaper and lighter anode substrates.

Natural or synthetic graphite (NG or SG) is the traditional main component for the anode active material (AAM). Particle size and purity of the graphite are key specifications. NG is mined and ground to achieve the right particle size. SG is made from coke, using high temperatures, which makes the process energy and CO_2 emissions intensive. However, SG can be produced in a controlled process that delivers higher purity, which battery manufacturers prefer.

The production of an anode starts with a slurry of graphite, a conductive material like graphene, styrene butadiene rubber (SBR) or poly vinylidene fluoride (PVDF) as a binder, and a dispersant like sodium hydroxymethyl cellulose (CMC). This slurry is then coated onto the current collector (commonly copper foil). Hydrocarbon-free vacuum pumps are used to remove water by vacuum drying. The resulting coated copper foil is then cut to size. The vacuum drying step is essential to eliminate impurities, residual gas pockets, and oil residues that could otherwise impair the electrical performance of the cell.

Impurity testing

To protect product quality, input materials need to be tested for impurities before anode construction. Input materials include $CuSO_4$ for electrodeposition to manufacture the anode substrate, as well as graphite, PVDF, SBR, and water for coating the copper anode.

Testing and process needs

Companies manufacturing battery anodes typically need the following analytical testing capabilities.

Testing/process needs	Instrumentation required	Example applications
Confirming the identity and purity of input chemicals	ICP-OES ICP-MS	Determination of Elemental impurities in Si-C anode materials via ICP-OES Determination of Elemental Impurities in Copper Sulfate using ICP-OES
Quantifying and identifying impurities in an anode	ICP-OES ICP-MS	Determination of Elemental Impurities in Graphite-based Anodes using ICP-OES Elemental impurity analysis of Lithium Ion Battery anodes using Agilent ICP-MS Determination of Elemental Impurities in Copper Sulfate using ICP-OES
Base material mixing	Rotary vane pumps and roots pumps	Agilent Vacuum and Leak Detection Solutions for e-Mobility
Current collectors coating	Diffusion pumps	
Laminated lithium-ion electrode vacuum drying	Dry scroll pumps	

Save weeks or months of procedure writing

Agilent has a fully developed standard operating procedure (SOP) for impurity analysis graphite and silicon-graphite anode materials (as per the GB/T 24533-2019 method). Supplied in Word format, the free SOP is ready to be copied and pasted into your company's template.

A sample of the SOP is available online.

The uses of vacuum during cathode and anode manufacturing

Vacuum techniques play a pivotal role in the production of electrodes for lithium batteries in three critical stages of manufacturing: base material mixing, coating, and vacuum drying.

During base material mixing, active materials, binders, and conductive agents are blended under vacuum conditions to achieve the necessary uniformity, viscosity, and purity. Vacuum aids in eliminating air bubbles, improving the material purity and overall electrical performance of the electrode.

In the coating phase, precise deposition of active materials onto current collectors is essential for optimal electrochemical performance. Vacuum is crucial to achieve the right process conditions.

Finally, vacuum drying is indispensable for removing moisture from laminated lithium-ion electrodes without compromising their microstructure. Vacuum conditions influence the extraction rates of water mass. Maintaining the right vacuum levels using dry scroll vacuum pumps is essential for ensuring the quality of the electrodes.

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Agilent vacuum and leak detection solutions for e-Mobility

Download this brochure to discover more about our products for the battery industry.

Electrolyte

Optimal battery performance and lifetime require the electrolyte to have the correct balance of lithium salt, organic solvents, and protective and performance-enhancing additives. Poor battery lifetime is often caused by manufacturing process-related issues such as impurities in starting materials or incorrect additive proportions.

Electrolyte testing

Confirming starting material purity, precursor mixtures and electrolyte formulations are important quality control steps, particularly for lithium salts, the costliest component (by weight) of electrolyte slurries. Such tests must be rapid, accurate, and simple to perform, and not introduce production delays. Degradation studies related to production must also be rapid. However, deeper investigation for product development and improvement is also needed.

Lithium hexafluorophosphate is the most commonly used lithium salt for the electrolyte in car batteries. This lithium salt is dissolved in a range of organic carbonate solvents, including organophosphates. Production may also employ proprietary materials for which there are no off-the-shelf reference standards or involve new product/formulation testing using novel materials.

The organic solvent is typically a mixture of cyclic and linear alkyl carbonates. Their role is to efficiently dissolve the lithium salt and promote high ion dissociation. As solvent constitutes the bulk (by weight) component of the slurry, testing and monitoring its purity is important. Additives range in composition and function, e.g., film-forming and high-/low-temperature additives, and are key to improving the performance of electrolyte, even though their content is low. These complex samples require chromatographic separation to fully analyze, but testing must remain rapid and simple to perform.

Consideration of sampling handling requirements is also necessary. For example, to safely test lithium salts, it is recommended to only handle these materials in an oxygen- and moisture-controlled environment, such as a glove box. Instrumentation that can be used inside the glove box to test the lithium salts protects the analyst and makes measurements easy.

Testing and process needs

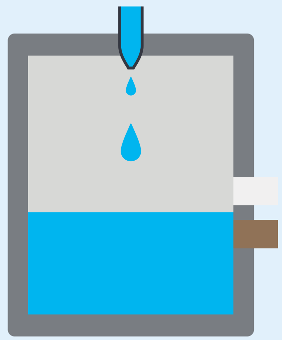
The manufacture of battery electrolyte relies on the following capabilities:

Testing/process needs	Instrumentation required	Example applications
Confirming the identity and purity of input chemicals	ICP-OES and ICP-MS FTIR GC/MS GC/FID	Quick and Easy Material Identification of Salts Used in Lithium-Ion Batteries by FTIR Quick and Easy Material Identification of Solvents Used in Lithium-Ion Batteries by FTIR
Quantifying and identifying impurities in the electrolyte throughout the production process Confirming electrolyte composition	ICP-OES and ICP-MS FTIR GC/MS GC/FID	Rapid Analysis of Elemental Impurities in Battery Electrolyte by ICP-OES Accurate ICP-MS Analysis of Elemental Impurities in Electrolyte Used for Lithium-Ion Batteries Determination of Carbonate Solvents and Additives in Lithium Battery Electrolyte Using GC/MSD Analysis of Carbonate Esters and Additives in Battery Electrolyte Using Agilent 8860 GC
Electrolyte filling process enablement	Rotary Vane Pumps, Roots pumps and Dry Scroll Pumps	Agilent Vacuum and Leak Detection Solutions for e-Mobility

Process control – battery filling

The filling of batteries with electrolyte can impact the battery's efficiency and lifespan. Vacuum technology is used in this process to achieve two key objectives:

- Uniform distribution of the electrolyte within the cell. This is crucial as the electrolyte is the medium that allows lithium ions to move between the electrodes. Nonuniform distribution of the electrolyte can lead to inefficiencies in the battery's performance.
- Guaranteeing electrode wetting and preventing trapped gas bubbles. The electrolyte must thoroughly coat the electrode surface and any residual gas must be removed. This ensures cathode effectiveness and a smooth flow of lithium ions.



Separator

The separator in a LiB electrically isolates the anode from the cathode while allowing a flow of lithium ions between the two electrodes. The design and quality of the separator impacts battery safety, thermal stability, and overall performance. The separator must be porous to allow the transport of ions but demonstrate sufficient rigidity and mechanical performance. Under excessive heat conditions, the separator should also shut down ion transport to prevent thermal runaway. Polypropylene (PP) or polyethylene (PE) are the most commonly used materials in electric vehicle applications; however, other polymer formulations and ceramic additives are being developed. Impurities within the separator materials must be minimized to prevent unwanted and uncontrolled reactions. If ceramics are used, they need to be of ultrahigh purity. Rapid purity and composition testing greatly enhances the manufacturing process. Simple at- or near-line confirmation of material quality with clear go/no-go outcomes are needed for technicians to make informed production decisions. Failed batches delay downstream processes and drive up costs.

Testing needs

Companies manufacturing battery separators typically need the following analytical testing capabilities.

Testing needs	Instrumentation required	Example applications
Studying battery degradation—examining binder and separator materials for chemical bond change during charging and discharging	FTIR	Polymer Analysis using FTIR
Confirming the identity of raw materials and work in progress products during manufacturing, including surface modification and functionalization studies and monitoring additive levels, comonomer content, branching, and tacticity	FTIR	Material Identification of Plastics Throughout Their Life Cycle by FTIR Spectroscopy Polymer Analysis using FTIR Determination of Percent Polyethylene in Polyethylene/Polypropylene Blends Using Cast Film FTIR Techniques

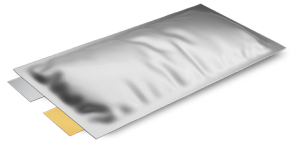
Battery Assembly

In the final stage of battery production, individual cells are combined into battery packs. Production requirements vary, depending on final battery configuration and application. However, as with other stages of production, high quality must be maintained to ensure optimal lifetime, performance, and safety. Leak tightness of both the battery module and final battery assembly are critical.

Battery form factors

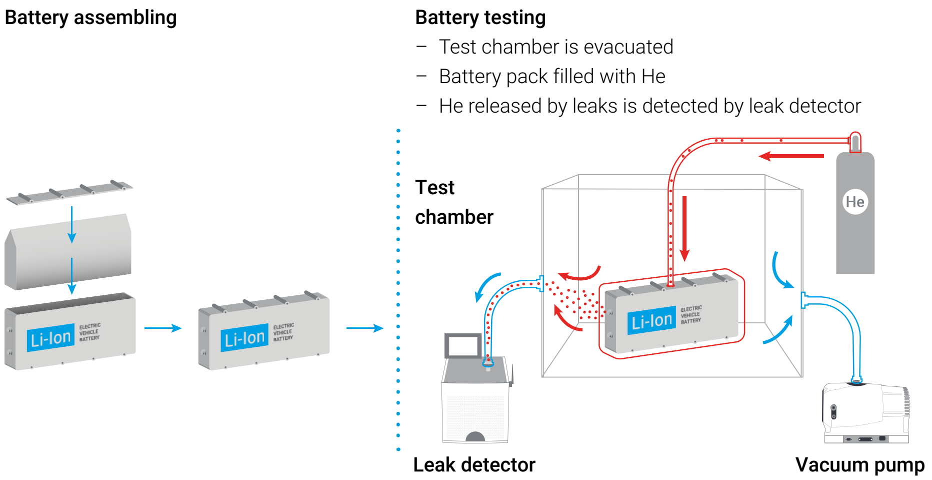
Prismatic lithium battery

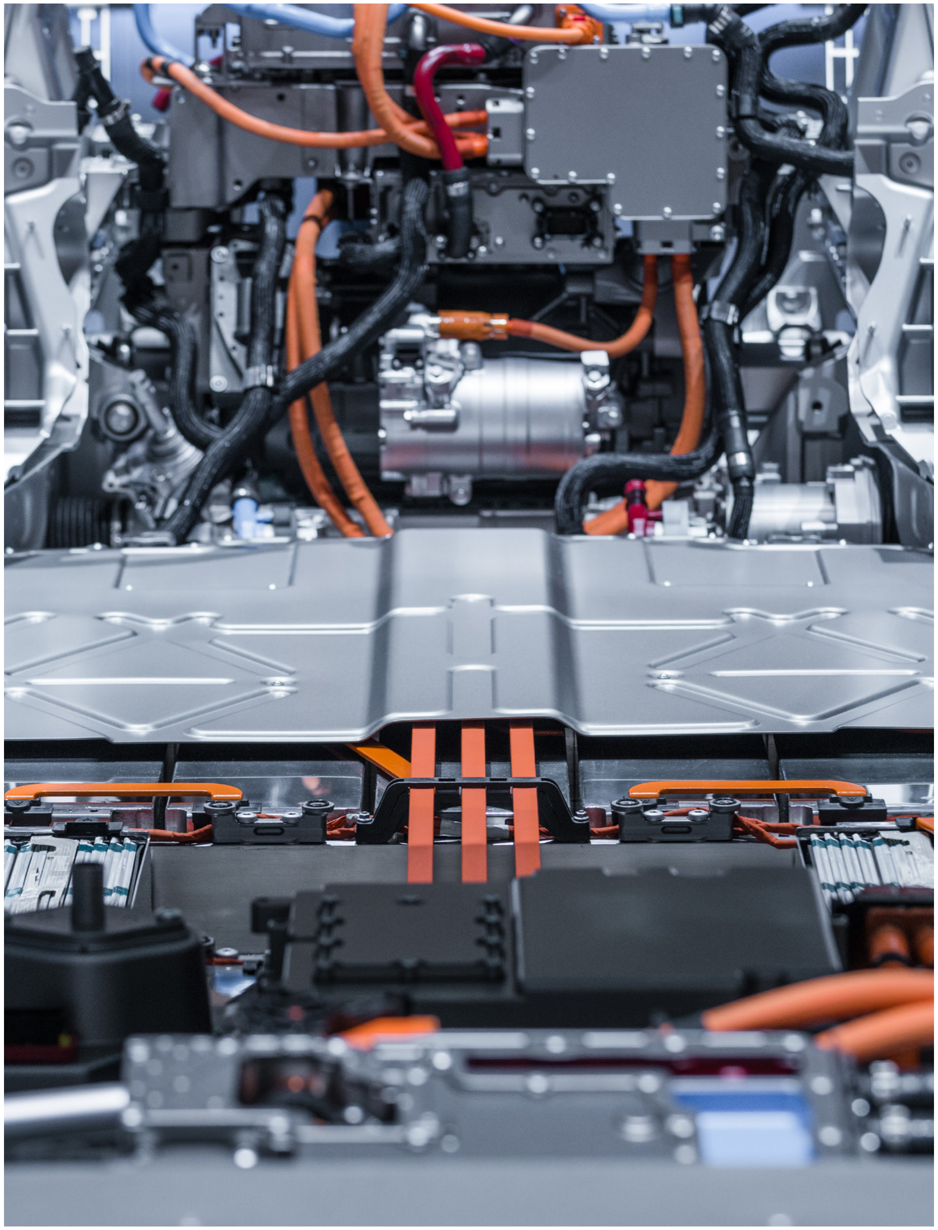
Cylindrical lithium battery



Pouch cell lithium battery

The external battery casing or enclosure houses the battery cells and protects them from damage and environmental factors. These housings must be water and dust-resistant, and provide adequate corrosion resistance, electromagnetic shielding, and efficient cooling. The casing is usually made of a durable material such as aluminum, steel or polymer, and is designed to withstand high temperatures and other harsh conditions. Batteries can also be contained within soft pouches.





Leak testing

A typical leak testing configuration involves evacuating a test chamber using a vacuum pump. A battery pack placed in the chamber is filled with helium, before connecting a helium leak detector to the chamber. This testing can identify any helium emissions resulting from potential leaks or cracks in the battery enclosure.

Accumulation-based leak detection is an alternative method used to identify leaks in batteries when vacuum is not available in the detection system. In this method, a helium leak detector's sniffer probe inlet is attached to an enclosure that surrounds the potential leak source. The enclosure must form a sufficient seal to accumulate helium from any potential leak, leading to an increased helium concentration within the volume. The battery housing is designed to be water- and dust-resistant and requires specific leak detection tests.

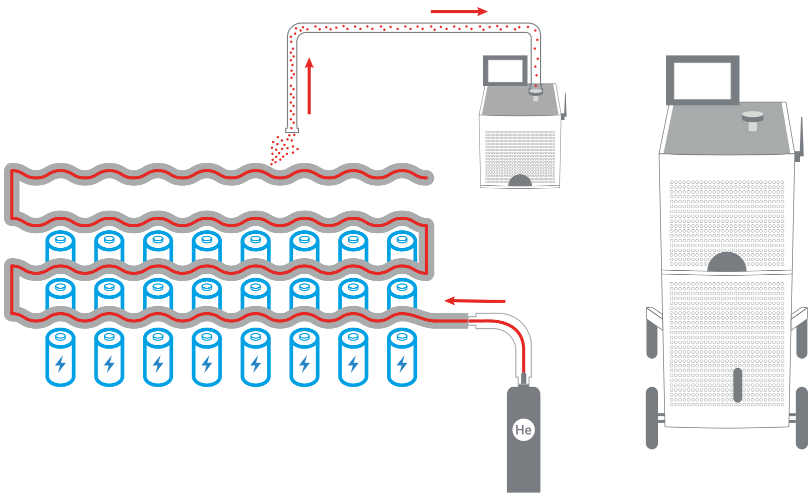
Battery temperature management

The battery housing also contains a temperature management system to control the temperature. Temperature has a profound impact on battery operation, capacity, lifespan, recharging, and safety. Low temperatures can lead to capacity loss, as they cause a slowdown in the chemical reactions within the battery. High temperatures can pose serious hazards, including the risk of fire and explosion. Elevated temperatures also accelerate degradation processes in battery electrodes, affecting, cycle-by-cycle, the maximum storage capacity.

The latest electric vehicle cooling systems circulate fluid to precisely control the temperature of all crucial components, including electronics, motors, cabin, and the battery itself. Potential leakage within a battery cooling system and possible contact with battery elements threatens both battery durability and pack safety. Detecting such leaks promptly and accurately during the cooler production process is crucial.

Cooling system testing

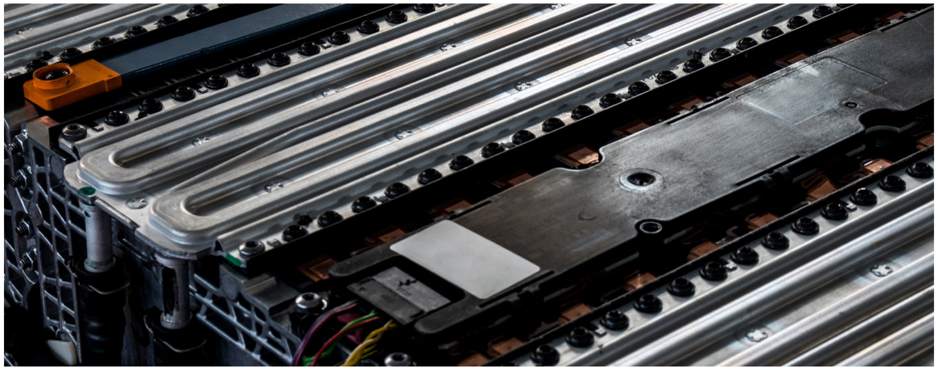
- Test performed in free air
- Cooling serpentine filled with He
- He released by leaks is sniffed and detected by leak detector



A helium leak detection system is used to detect leaks in the battery cooling system during and after production.

Degradation, swelling gas, and aging studies

As batteries age their performance falls, often caused by electrolyte degradation. This degradation creates gasses (called swelling gas) inside the battery, typically permanent gasses, and light hydrocarbons. The composition of the swelling gas can identify production issues and improve battery design. In fact, during development batteries are often artificially aged to promote degradation to enable subsequent analysis and process and formulation optimization. Gas chromatography is an ideal technique for swelling gas analysis as it is simple and provides confident compound identification.



Testing needs

Companies manufacturing battery casings and housings typically need the following testing capabilities.

Testing needs	Instrumentation required	Example applications
Detecting leaks in the battery casing	Helium leak detector GC	The Analysis of Swelling Gas in Lithium-Ion Batteries with a Micro GC
Detecting leaks in the battery housing and cooling system		Battery cooling leak testing – see page 8 HLD helium mass spectrometer leak detectors. Helium Leak Testing Pressurized Components Using the Accumulation Method
Confirming the identity of raw materials and work in progress products during manufacturing	FTIR	Material Identification of Plastics Throughout Their Life Cycle by FTIR Spectroscopy Polymer Analysis with FTIR Determination of Percent Polyethylene in Polyethylene/Polypropylene Blends Using Cast Film FTIR Techniques
Detecting electrolyte degradation and gas generation inside battery cells	GC	The Analysis of Swelling Gas in Lithium-Ion Batteries with a Micro GC

Battery Recycling

Recycling of lithium-ion batteries is essential for environmental protection, waste reduction, and economic sustainability. Recycling is also critical to delivering the environmental and sustainability promise of electric vehicles. The growing popularity of EVs has heightened the potential impact of metals or organic compounds from spent batteries leaching into the environment.

While a battery's performance may degrade over time, the materials (lithium, nickel, cobalt, etc.) remain present and can be retrieved and recycled in a continuous cycle. Solvents like NMP can also be re-used, provided recaptured material is demonstrated to be sufficiently pure.

As the lithium-ion battery market grows, more raw materials will be sourced from battery recycling, rather than from mining.

Establishing and operating a recycling facility, however, is challenging. Batteries are not standardized or designed with recycling in mind. Their chemistry varies from manufacturer to manufacturer, making cost-effective recycling challenging.

In terms of analytical testing, the process of recycling batteries requires similar tests to battery manufacturing. Testing for material identification, impurity analysis, and ensuring materials meet specifications is required. There are few industry standard methods for recycled materials, so it is common to adapt standard quality control analytical methods to test recovered materials.

Waste generated during battery manufacturing

Battery manufacturers also recapture raw material waste to re-introduce into the production chain. These recaptured materials are put through an existing quality control test program.

Testing needs

Companies recycling batteries typically need the following testing capabilities.

Testing needs	Instrumentation required	Example applications
Measuring the elemental content of black mass to optimize recycling processes	ICP-OES ICP-MS	Elemental Analysis of Intermediate Feedstock Chemicals for Li-Ion Batteries by ICP-OES (from recycled batteries Determination of Metals in Recycled Li-ion Battery Samples by ICP-OES
Measuring the elemental content of recycled battery materials to determine material purity	ICP-OES ICP-MS	These measurements are the same as those used during battery manufacturing. See the anode and cathode sections earlier in this document.
Environmental discharge and worker safety monitoring	ICP-OES, UV-Vis, GC, GC/MS, LC, LC/MS	Measuring fluorides in water Fast, Robust Analysis of Various Types of Waters by ICP-OES following Method HJ 776-2015 Multi-element Analysis of Air Filters

Battery recycling process

The battery recycling process consists of:

Hydrometallurgical process:

The fine powdery residue from shredding or the output from the smelting process undergoes a hydrometallurgical treatment. It involves using chemicals to leach out metals from the residue. For example, using an acid leach process, lithium can be extracted as lithium carbonate, which can be further processed and re-used in new batteries.

Pyrometallurgical (smelting) process:

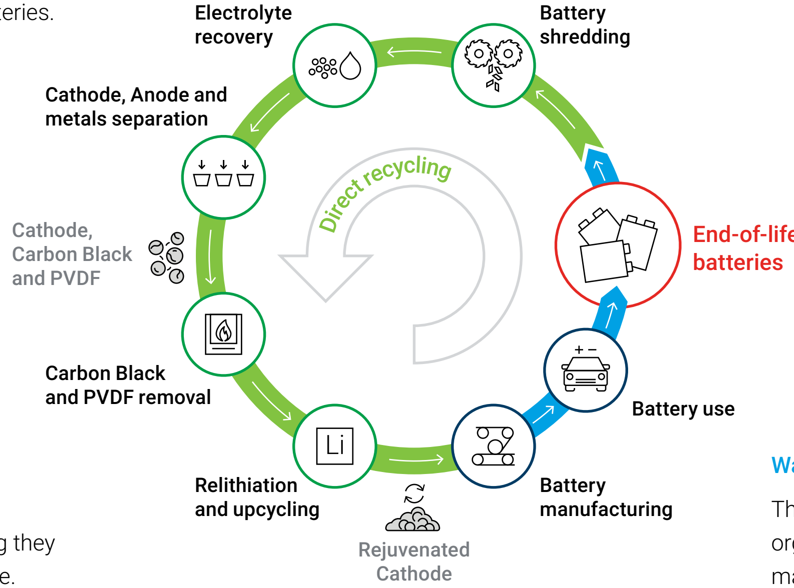
This is a high-temperature process where battery scraps are fed into a furnace. The heat causes the organic components to burn off, and the metals like cobalt, nickel, and copper are recovered in alloy form from the molten slag. This method is efficient for recovering cobalt and other metals but not as effective for lithium.

Reprocessing (shredding or crushing):

The batteries are shredded or crushed into small pieces, producing a mixture of metal content and other materials. This mixture is then sieved to separate larger metallic pieces from finer powdery material, resulting in a 'black mass' material.

Physical separation:

Some advanced recycling methods use physical processes like froth flotation or gravity separation to differentiate and extract materials based on their physical properties.



Purification:

The extracted metals undergo purification processes to remove any impurities, ensuring they meet the quality standards required for re-use.

Material refinement and preparation for re-use:

Once the metals are purified, they are processed into forms suitable for manufacturing, such as metal salts or precursor materials. These materials can then be integrated back into the battery production chain or used in other industries.

Waste treatment:

The leftover material, which includes electrolytes, organic solvents, and other nonrecoverable materials, is treated to neutralize harmful substances. This waste is then managed and disposed of following environmental regulations.

Image reproduced from chemistryworld.com

Battery Research and Development

Research and Development (R&D) within the battery industry drives innovation and enhancement of battery performance, longevity, safety, and cost-effectiveness. R&D explore new materials and chemistries to increase energy density—crucial for extending the range of electric vehicles and the storage capacity of power grids. There is also a focus on improving manufacturing processes to scale production and reduce costs as well as involvement in troubleshooting manufacturing problems. R&D also contributes to sustainability by finding ways to minimize the environmental impact through more efficient recycling techniques and the reduction or elimination of toxic or rare materials.

An R&D group may provide production support, performing the types of analyses described earlier in this primer. More often, R&D scientists need more sensitive and flexible analytical instruments than a quality control lab to investigate new materials, formulations, and performance and degradation studies. An R&D lab must handle a broader range of samples as they test new materials and seek lower levels of impurities. Techniques that incorporate mass spectrometry, such as ICP-MS, UV-Vis, GC/MS, and LC/MS provide the higher sensitivity needed for R&D applications.

Example applications
Investigation and profiling of organic solvent-based lithium Ion Battery electrolytes and composition products using quadrupole time of flight LC/MS
Quantifying trace-levels of 64 elements in lithium carbonate using ICP-MS/MS
Accurate ICP-MS analysis of elemental impurities in electrolyte used for lithium-ion batteries
Quality control of lithium-ion battery electrolytes using LC/MS

Services To Support Setup and Operation

Whether you need finance to buy equipment or help with staff training or technical support, Agilent is your trusted partner. Here are some of the areas that we support.

Financial services

Whether adding capacity, expanding operations to other parts of the value chain, or expanding R&D into new battery formulations and types, your capital budget can be an obstacle to your ambition – but it doesn't need to.

The challenge of being competitive in the face of evolving technology and regulatory requirements means that equipment ownership is a potential risk – especially in the face of shrinking capital budgets and inflation-impacted operational budgets. Agilent Financial Services mean you can acquire critical technology while keeping your budget under control.

Agilent can design flexible payment plans to meet your business and analytical needs. You can adjust your payments based on your budget cycle: step up, step down, or defer payments. Even better, you can bundle services, consumables, and support together in a single, predictable monthly payment. Also, Flexible Spend Plans allow you to manage your operational budgets.

You could even take advantage of an instrument subscription. Agilent is your partner to simplify your sourcing, buying, and budgeting.

[More information]

Agilent Technologies is offering financial solutions to customers through cooperations with preferred financing providers in applicable countries.
Offers are subject to credit approval and completion of all required documentation at the sole discretion of the financing provider.
This information is subject to change without notice.

Strengthen your budget with certified pre-owned instruments.

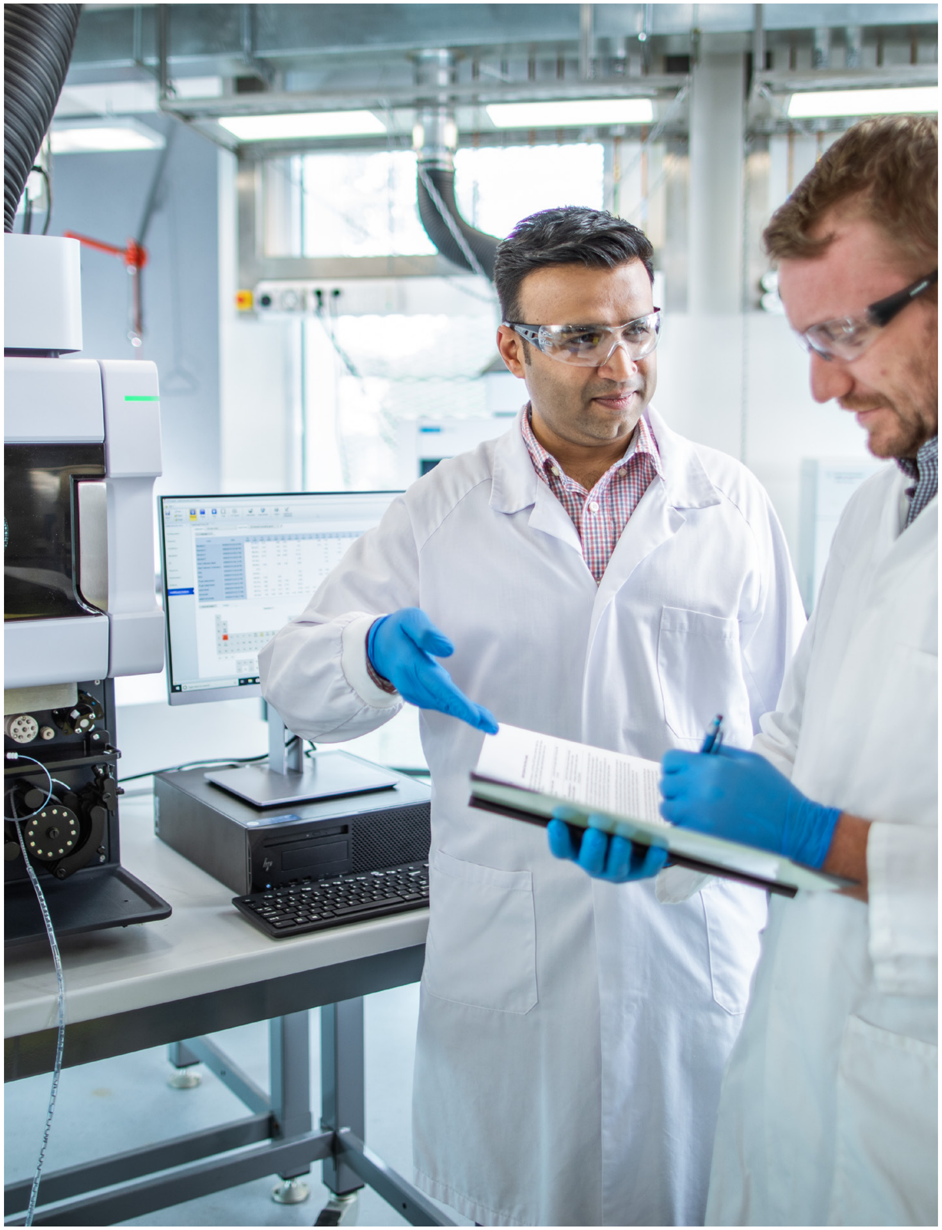
Certified Pre-Owned Instruments deliver performance, reliability, and value to your lab. Used instruments undergo comprehensive refurbishment, testing, and come with a one-year warranty – equivalent to a new instrument. Included are factory updates, consumable parts, start-up kits, and cosmetic refreshment to ensure Agilent quality and performance at a remarkably attractive price. Gain access to innovation at an attractive price with refurbished instruments.

More information

Reduce the cost of the latest technology through instrument buy-back

Agilent also offers trade-in and buyback opportunities on lab assets, allowing you to turn underutilized assets into income. We handle the removal of used instruments at no cost, unlocking the value and simultaneously supporting your sustainability targets on waste reduction, proper disposal of used instrumentation, and support the "end of life" of your lab instrumentation.

More information



Product service and maintenance

When production or your analysis is time critical – you need to know you can trust your equipment. Enable your team to reduce downtime, produce accurate, reliable data, and comply with industry regulations through flexible service and maintenance plans tailored to your specific needs.

Selected service plans also cover preventive maintenance, which is proven to lower repair costs and save days of downtime each year. Options for remote diagnostics can help identify and troubleshoot issues before they become critical. Support and maintenance for both Agilent and non-Agilent equipment is available too.

Instrument Service

Vacuum and Leak Detection Service

Software solutions

If you want to make the most of your analytical instrumentation – Agilent offers data systems for instrument control and data analysis, laboratory informatics and automation software, data and workflow management, and other lab software packages to enhance data visualization and mining.

Commitment to open data is at the heart of delivering solutions your analytical challenges and business demands. Data has to be in the right place at the right time for critical decisions to be made. In an environment of multiple data streams and processes, you need a seamless integration of analytical equipment and informatics. Agilent's commitment to an Instrument Control Framework means you can easily bring our equipment into your existing systems, or you can explore our own tailored solutions.

The Agilent OpenLab Software portfolio is an integrated suite of products that includes sample management, data acquisition, data analysis, data management, lab workflow management. These products easily integrate to work together to cover the analytical workflow from the moment the analytical request is generated until the data are archived. OpenLab software improves lab throughput and the quality of your results and will be an integral part of your data integrity strategy.

Agilent SLIMS workflow management is a solution for streamlining and organizing lab operations. It offers a range of features, including sample tracking, experiment management, and automated result reporting. With an intuitive interface and flexible options, Agilent SLIMS can be tailored to meet the specific needs of your laboratory, regardless of its size, complexity, or quality system.

OpenLab Suite Data management

SLIMS

Analytical method development and application consulting

Method consulting services

Improve the economics of your testing with the optimum methods and protocols to meet your needs. Small changes can have big impacts. Our teams can harness their insights to create methods, or help you maintain the performance of your current methods. They can also move methods from another instrument or site, even across the world, as part of your local installation and verification, to get you productive immediately.

[Method consulting services]

Quality system services

Verification services provide documented evidence of optimal instrument performance, ensuring you meet your quality system needs. Agilent CrossLab Verification Services delivers cost-effective proof of verification for a range of analytical instruments. Verification includes factory-recommended testing of your Agilent systems and provides documented evidence of optimal instrument performance. Metrology-based testing confirms the accuracy and verification of critical instrument functions.

[Verification services]

Analyst training and support

Development and education are critical to building a team who can meet today's demands and prepare for future challenges. Agilent training helps build confident teams through learning the essentials of new techniques and real-world applications with advanced methodologies. You can improve lab operations and minimize downtime with courses covering troubleshooting, maintenance, and sample preparation. Courses on operating software for chromatography, mass spectrometry, and spectroscopy are also available.

[Education services]

CrossLab Connect

Optimizing lab performance is easier with a partner who is competent in lab operations, allowing laboratories to focus on science. In the digital lab era, such partnerships afford a level of unprecedented visibility and asset control, while reducing cost and increasing sustainability. Agilent CrossLab Connect is the digital backbone of a comprehensive asset performance management program for the lab.

By combining aspects of asset management, data analytics and industry expertise, CrossLab Connect allows you to view your entire lab at once. A suite of digital tools, tailored specific for your laboratory, gives critical information, allowing you to meet your analytical commitments efficiently, effectively, and sustainably.

[Asset Performance Management]

[CrossLab Connect]

Select Agilent Products for the Lithium Battery Industry

5800 ICP-OES

7850 ICP-MS

Cary 630 FTIR

Cary 60 UV-Vis

Vacuum pumps and leak detection systems

Revident LC/Q-TOF and 1290 Infinity II HPLC

990 Micro GC

5977C GC/MSD and 8860 GC

Sustainability and Commitment to the Environment

The environmental promise of electric vehicles drives the actions and outcomes for manufacturers. Remanufacturing, cell recycling, and facility environmental and health and safety management are a few ways your environmental and sustainability values are represented daily.

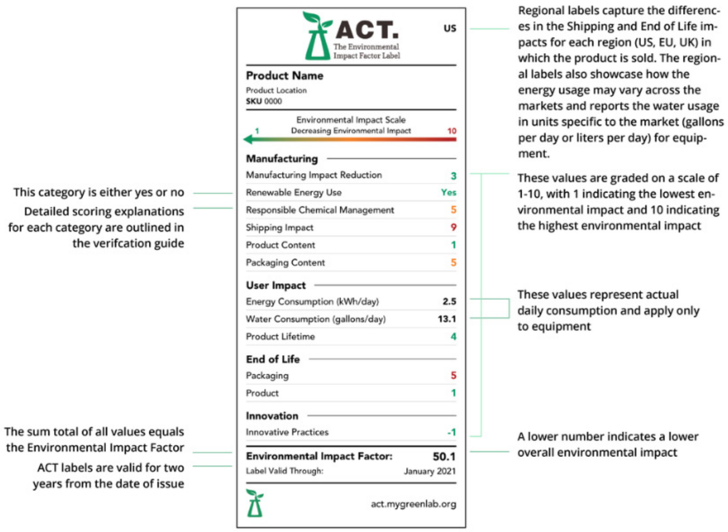
At Agilent, we share those values. We consistently address sustainability issues and [report on our progress](). We are now expanding those efforts by [committing to net-zero greenhouse gas emissions](), with interim targets aligned with the Paris Agreement. Our net-zero commitment includes the products that we make, how we work with customers and suppliers, how we manage our internal operations, and being accountable for achieving our goals.

Many of our efforts are designed specifically to allow our customers to meet their own sustainability goals without compromising business commitments. These efforts include:

- Increasing the number of instruments that have earned the My Green Lab Accountability, Consistency, and Transparency (ACT) label
- Adding "How2Recycle" labeling to product packaging
- Achieving My Green Lab certification for Agilent customer demonstration labs
- Introducing the HydroInert source for GC/MS, which runs on renewable hydrogen as the carrier gas in place of nonrenewable helium
- Offering asset performance management software that can reduce lab energy use.

Our goal is to embed sustainability into all aspects of our job all day and every day through people, products, and processes

[Learn more]() about Agilent's approach to ESG



Through our partnership with MyGreenLab—a nonprofit organization dedicated to building a global culture of sustainability in science—we have third-party guidance and verification processes for implementing sustainable strategies into everyday testing and research; instruments, workflows, even entire laboratories can be certified.

These sponsorships and certifications build upon Agilent's ongoing partnership with My Green Lab, which includes achieving My Green Lab's ACT labels. These labels provide consumers with third-party verified information on the environmental impact of Agilent products and services—making it easier for labs to make sustainable choices.

[ACT labeled products]

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Published in the USA, November 30, 2023
5994-6848EN

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