

Application Note AN-S-372

Analysis of Li-ion battery electrolytes with ion chromatography

In the next decade, our reliance on batteries is predicted to increase five-fold [1]. Lithium-ion (Li-ion) batteries (LIBs) dominate the current market. LIBs operate by moving electrons from an anode to a cathode (discharging) and back (charging). The Li ions from the liquid electrolyte balance this flow [2].

Consequently, the lithium battery electrolyte composition is crucial for the performance and lifetime of the battery [3,4]. Li electrolytes are

mostly composed of lithium hexafluorophosphate (LiPF_6) or lithium difluorophosphate (LiPO_2F_2) dissolved in organic carbonates. The content of LiPF_6 or LiPO_2F_2 significantly influences the ionic conductivity, electrolyte stability, and battery safety. Therefore, it is crucial to determine the LiPF_6 or LiPO_2F_2 content to ensure that Li-ion batteries meet performance, safety, and aging criteria [5,6].

Analysis is challenging for certain techniques due to solvent or salt effects. Ion chromatography provides an accurate, economic solution for battery electrolyte analysis. The **Metrohm intelligent Partial-Loop Technique (MiPT)** simplifies the analysis, improves reproducibility and accuracy, and

decreases costs. This Application Note details an ion chromatographic approach to determine lithium-ion battery electrolyte composition, i.e., the concentration of lithium bis(trifluoromethanesulfonyl)imide (LiTFSI), lithium difluoro(oxalato)borate (LiODFB), LiPF_6 , and LiPO_2F_2 .

SAMPLE AND SAMPLE PREPARATION

Three different samples of Li-ion battery electrolytes were used for this study (Sample 1, Sample 2, and Sample 3, as noted in the Results section). A 500 mg portion of the respective sample material was weighed into a 50 mL volumetric flask and brought up to the correct volume with acetone (HPLC grade, 99.8%).

A mixed standard with a concentration of 40 mg/L LiODFB (lithium difluoro(oxalato)borate), LiPO_2F_2 (lithium difluorophosphate), LiPF_6 (lithium hexafluorophosphate), and LiTFSI (lithium bis(trifluoromethanesulfonyl)imide) was used for the automatic system calibration with MiPT.

EXPERIMENTAL

Sample handling was performed with the 858 Professional Sample Processor and MiPT. MiPT enables the precise generation of a calibration curve out of a single standard. Therefore, the 800 Dosino accurately aspirates a specific volume of the given standard into the injection loop. Samples were injected with a volume of 4 μL .

After injection, the target analytes (ODFB^- ,

PO_2F_2^- , PF_6^- and TFSI^-) were separated using the high-capacity Metrosep A Supp 7 - 250/4.0 column and a mixture of 14.4 mmol/L Na_2CO_3 and 40 vol% acetone as eluent. For accurate conductivity measurement, the background conductivity is reduced via sequential suppression, followed by conductivity detection. The example flow path for this analysis is shown in **Figure 1**.

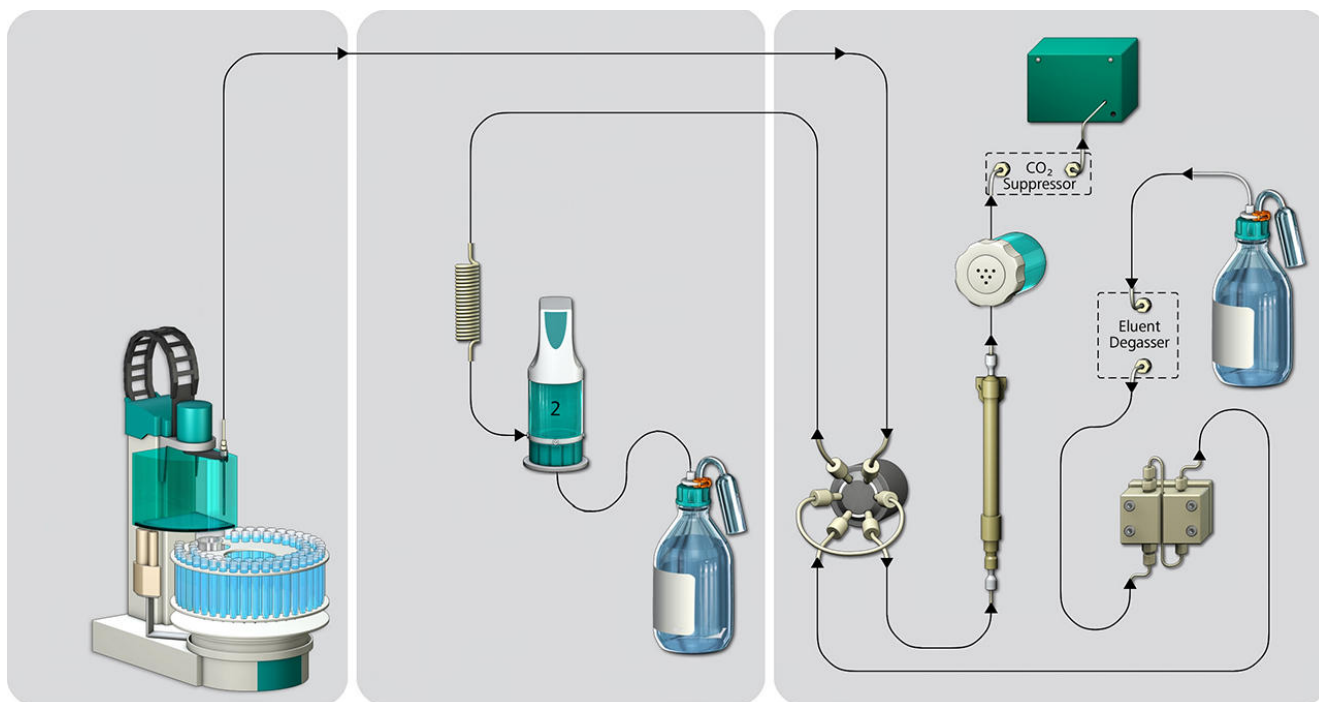


Figure 1. Schematic of an ion chromatographic setup with MiPT.

SAMPLE ANALYSIS

Five standards each of LiODFB, LiPO_2F_2 , LiPF_6 , and LiTFSI were automatically prepared (at concentrations of 40, 80, 200, 400, and 800 mg/L) via MiPT. Due to the precise liquid

handling offered by MiPT, the resulting calibration curve for LiODFB, LiPO_2F_2 , and LiPF_6 had RSD values <2%, and LiTFSI achieved an RSD value of 2.61%.

RESULTS

The target analytes, i.e., LIB electrolyte components (LiODFB , LiPO_2F_2 , LiPF_6 and LiTFSI), are effectively separated in their anionic forms (i.e., ODFB^- , PO_2F_2^- , PF_6^- , and TFSI^-) within 29 minutes (**Figure 2**). The recovery from two-level spike experiments (**Table 1**) ranged from 90–100% and reveals the robustness of the analysis. The sample concentration ranges

covered 0.52–1.1 mg/L for ODFB^- (**Table 2**), 0.28–0.76 mg/L for PO_2F_2^- (**Table 3**), 11.05–14.07 mg/L for PF_6^- (**Table 4**), and 0.45–1.05 mg/L for TFSI^- (**Table 5**). The samples were determined in triplicate and showed average RSD values of 2.8% for ODFB^- , 2.8% for PO_2F_2^- , 1.8% for PF_6^- , and 0.8% for TFSI^- .

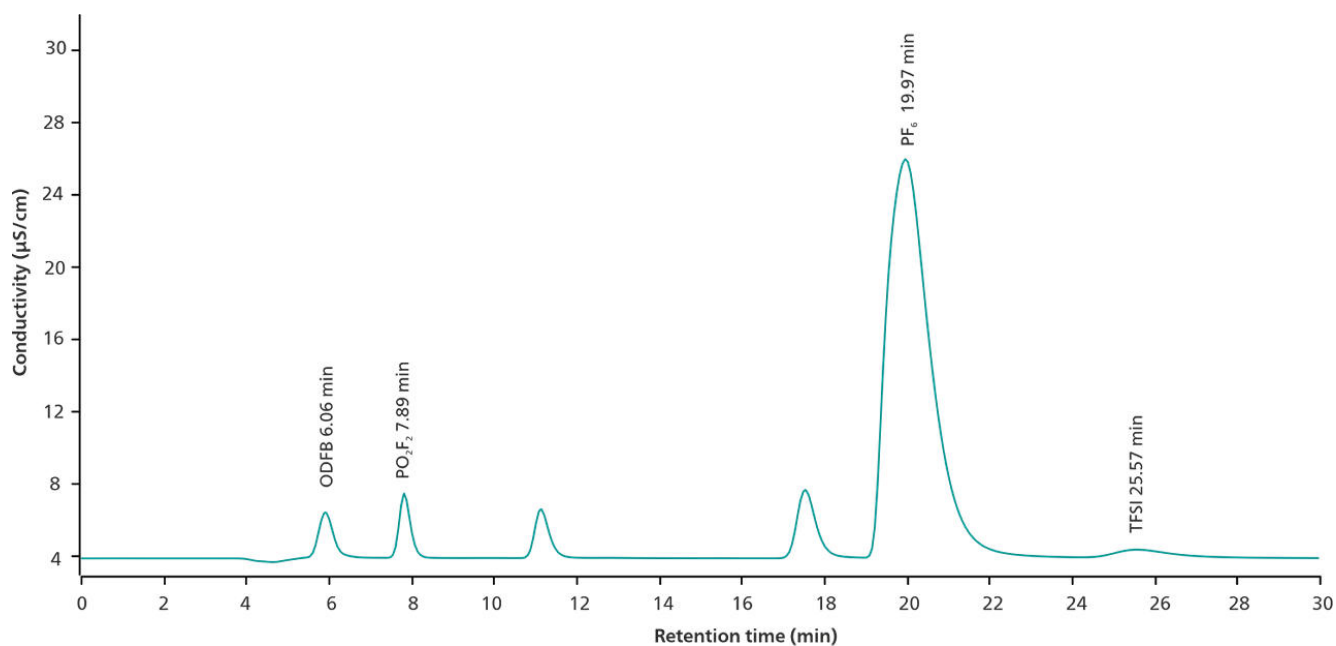


Figure 2. Chromatogram for the determination of lithium difluoro(oxalato)borate, lithium difluorophosphate, lithium hexafluorophosphate, and lithium bis(trifluoromethanesulfonyl)imide with a 930 Compact IC Flex and MiPT. The LiB electrolyte components are determined in their anionic forms and separated on a Metrosep A Supp 17 column.

Table 1. Results for the recovery of the spiked samples. The spike experiments were performed in two levels (added concentration) and the recovery was determined from the target and final concentrations.

Sample, [conc.] (mg/L)	Added conc. (mg/L)	Target conc. (mg/L)	Final conc. (mg/L)	Recovery(%)
ODFB ⁻ , [0.52]	0.20	0.72	0.72	100
	0.40	0.92	0.94	100
PO ₂ F ₂ ⁻ , [0.42]	0.20	0.62	0.60	90
	0.40	0.82	0.79	95
PF ₆ ⁻ , [12.64]	5.58	18.22	18.37	100
	11.42	24.06	23.99	99
TFSI ⁻ , [1.05]	0.79	1.84	1.83	99
	1.58	3.42	2.61	99

Table 2. Results of concentration and %RSD for the analyte ODFB-.

Analyte		Sample 1	Sample 2	Sample 3
ODFB ⁻ (mg/L)	1	0.52	0.68	1.08
	2	0.54	0.68	1.12
	3	0.49	0.66	1.09
	Average	0.52	0.67	1.10
	%RSD	4.9	1.7	1.9

Table 3. Results of concentration and %RSD for the analyte PO₂F₂-.

Analyte		Sample 1	Sample 2	Sample 3
PO ₂ F ₂ ⁻ (mg/L)	1	0.43	0.75	0.29
	2	0.43	0.76	0.28
	3	0.40	0.76	0.27
	Average	0.42	0.76	0.28
	%RSD	4.1	0.8	3.6

Table 4. Results of concentration and %RSD for the analyte PF₆-.

Analyte		Sample 1	Sample 2	Sample 3
PF ₆ ⁻ (mg/L)	1	12.63	14.23	11.15
	2	12.33	13.95	11.18
	3	12.95	14.03	10.81
	Average	12.64	14.07	11.05
	%RSD	2.4	1.0	1.9

Table 5. Results of concentration and %RSD for the analyte TFSI⁻. N.D: Not detectable.

Analyte		Sample 1	Sample 2	Sample 3
TFSI ⁻ (mg/L)	1	1.07	N.D.	0.44
	2	1.09	N.D.	0.46
	3	0.99	N.D.	0.45
	Average	1.05	N.D.	0.45
	%RSD	1.1	—	0.5

CONCLUSION

Ion chromatography with the Metrohm intelligent Partial-Loop Injection technique is an accurate and efficient method to determine the concentration of LIB electrolytes such as LiODFB, LiPO₂F₂, LiPF₆, and LiTFSI.

An advantage of ion chromatography over other analytical methods is that the salts and organic

solvents that are present in LIB samples do not interfere with the analysis, and therefore results are more accurate and reproducible. With the help of spike experiments and replicate measurements, this application example shows that ion chromatography is a reliable method to determine the LIB electrolyte composition.

REFERENCES

1. Zhao, Y.; Pohl, O.; Bhatt, A. I.; et al. A Review on Battery Market Trends, Second-Life Reuse, and Recycling. *Sustainable Chemistry* **2021**, *2* (1), 167–205. DOI:10.3390/suschem2010011
2. Fathi, R. A Guide to Li-Ion Battery Research and Development.
3. Treptow, R. S. Lithium Batteries: A Practical Application of Chemical Principles. *J. Chem. Educ.* **2003**, *80* (9), 1015. DOI:10.1021/ed080p1015
4. Liu, Y.-K.; Zhao, C.-Z.; Du, J.; et al. Research Progresses of Liquid Electrolytes in Lithium-Ion Batteries. *Small* **2023**, *19* (8), 2205315. DOI:10.1002/smll.202205315
5. Palacín, M. R. Understanding Ageing in Li-Ion Batteries: A Chemical Issue. *Chem. Soc. Rev.* **2018**, *47* (13), 4924–4933. DOI:10.1039/C7CS00889A
6. Wang, Q.; Jiang, L.; Yu, Y.; et al. Progress of Enhancing the Safety of Lithium Ion Battery from the Electrolyte Aspect. *Nano Energy* **2019**, *55*, 93–114. DOI:10.1016/j.nanoen.2018.10.035

CONTACT

瑞士万通中国
北京市海淀区上地路1号院
1号楼7702
100085 北京

marketing@metrohm.com.cn

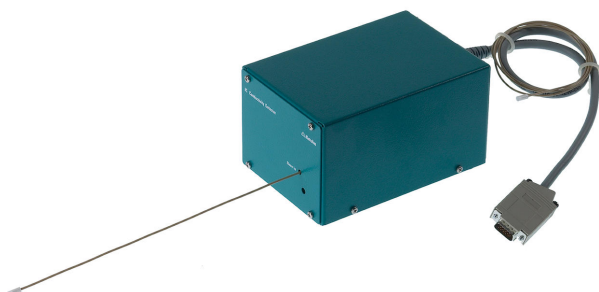
CONFIGURATION



930 Compact IC Flex Oven/SeS/PP/Deg

930 Compact IC Flex Oven/SeS/PP/Deg 是智能型 Compact 子色器,有柱加炉、**序列抑制**和**蠕**用于抑制器再生,以及内置的**脱气装置**。器可使用各分和方法。典型的用范:

- 子或子定,序列抑制法及



IC Conductivity Detector

用于智能型子色的智能型高性能器。不凡的温度定性,受保的器端子板内的整个信号理程以及新一代的 DSP(数字式信号理)均能保量的准性。功于工作范,无需行范更(也不是自行)。



Metrosep A Supp 7 - 250/4.0

水理中的副物(消毒副物)不可能危害健康,甚至可能致癌。因此基化物成多方法及准的目(例如 EPA 300.1 方法 B 部分、EPA 方法 317.0、EPA 方法 326.0)。首先那些用水臭化程中由化物中生的酸。Metrosep A Supp 7 - 250/4.0 是可以同定准子、基化物和二乙酸的高效分柱。借助此柱甚至在低 $\mu\text{g/L}$ 范内也可准可靠地定些子。使用 $5\ \mu\text{m}$ 的聚乙醇聚合物使其到高度指示敏度,其分度高,由此秀的分性能和指示敏度。此外,可通更改温度来特殊用要求整分工作。



Metrosep A Supp 5 Guard/4.0

Metrosep A Supp 5 Guard/4.0 IC 子柱 Metrosep A Supp 5 和 7 行可靠保,使其不受品或淋洗液的染。它含有与 Metrosep A Supp 5 相同的分材料,也同由 PEEK(聚)制成,并直接以几乎无死点容的方式到相分柱上(«On Column Guard System»)。保柱将延分析用柱的使用寿命,且不会影其色分效率。建使用 A Supp 5 Guard/4.0,其价格惠且操作。



858 Professional Sample Processor

858 Professional Sample Processor 可理体在500 μ L 至 500 mL 之的品。行品移,既可以使用 850 Professional IC System 上的蠕、也可通 800 Dosino 来行。



800 Dosino

800 Dosino ,有可用于智能型加液元的/写硬件。固定。



MiPT

用于安装 Dosino 以行局部循的附件。