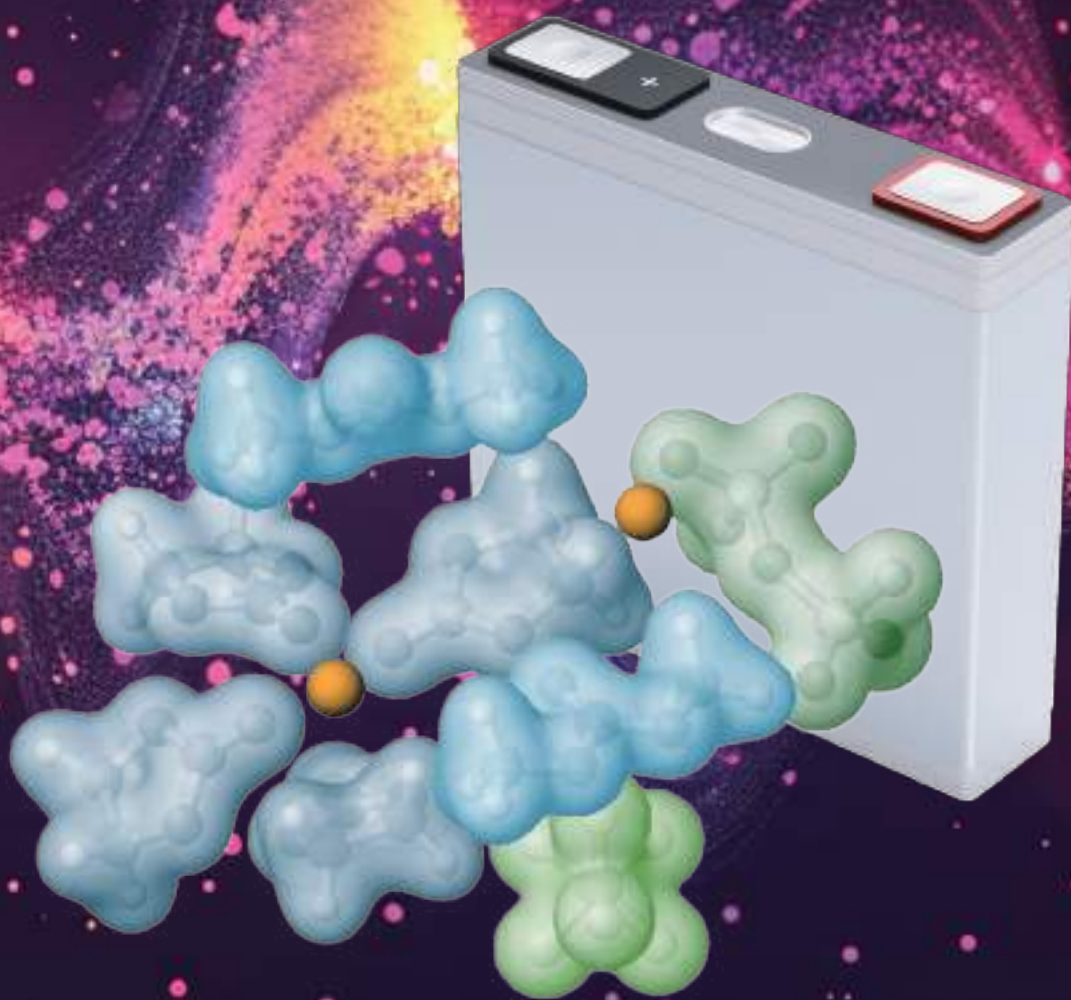


# BATTERY MATERIALS

Battery Research Materials Catalog [ ver.5.0 ]



Kishida Chemical Co., Ltd.

# Aiming to be a partner with a solution for every customer.

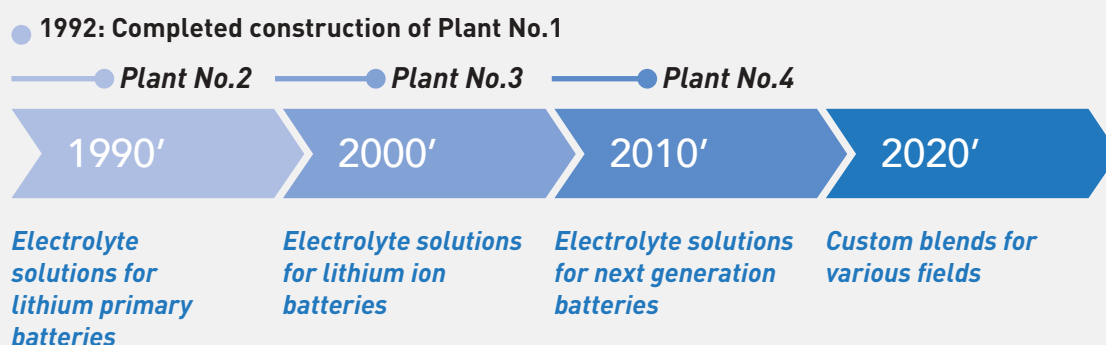
## Introduction

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Thank you very much for your continued use of our products.

We are pleased to announce the publication of our Battery Research Materials Catalog, ver. 5.0.

Since opening our first plant to produce materials for non-aqueous batteries in 1992, we have been working to serve everyone active in the energy field.

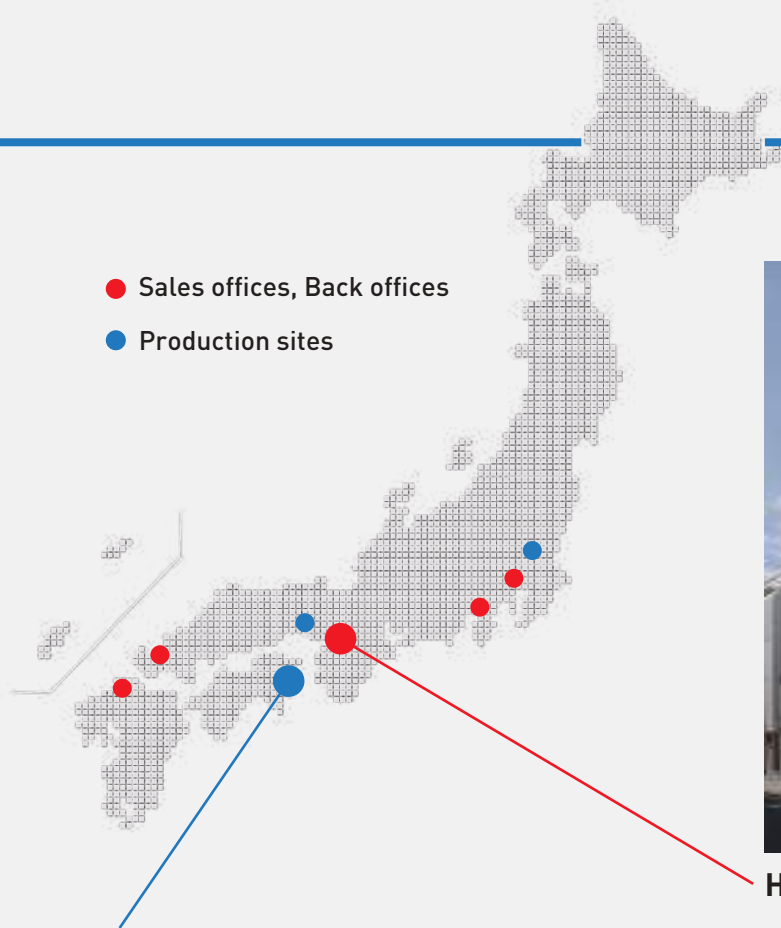


For more than 30 years, we have developed our business focused on low-moisture solvents, and our products have been widely used, from the research reagents business at our founding to mass-produced products for commercial battery production.

Currently, customers in any field where low-moisture solvents are key are using our products, and we are always ready to respond to custom orders for products not listed in our catalog.

We look forward to working with you as a partner to help solve your problems.

Kishida Chemical Co., Ltd.



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# LITHIUM BATTERY GRADE

KISHIDA CHEMICAL

## LITHIUM BATTERY GRADE

[ For research and development ]

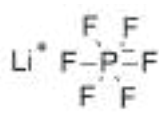
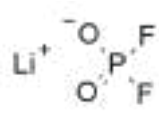
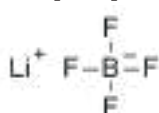
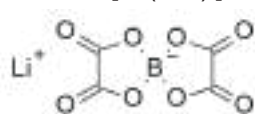
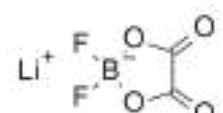
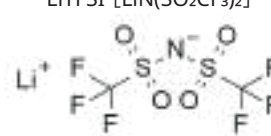
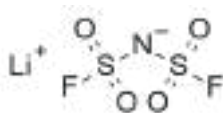
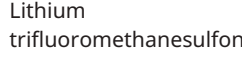
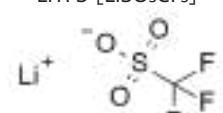
Since the publication of the Battery Materials Catalog ver. 1.0, we have updated our reagent lineup to meet changing demand.

In addition to our catalog lineup, we also offer custom blends of mixed solvents, electrolyte solutions, and binder solutions using materials of your choice for research into various types of devices.

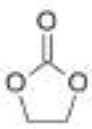
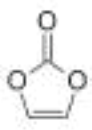
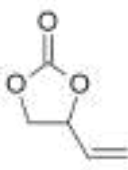
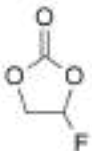
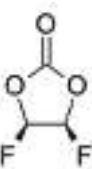
We will strive to expand our products and services, targeting not only batteries for which markets have already been established, but also those now under development for future introduction into society.



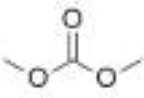
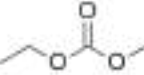
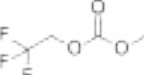
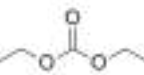
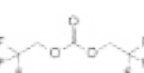
## L-Solve™ - Lithium Battery Grade — Electrolytes

| Product name                                                                                                                             | Abbreviation [Formula]<br>Structure                                                                                                                 | Molecular<br>weight<br>(g/mol) | Specification     |               | Container             | Contents  | Product code |
|------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|-------------------|---------------|-----------------------|-----------|--------------|
|                                                                                                                                          | CAS No.                                                                                                                                             |                                | Moisture<br>(ppm) | Purity<br>(%) |                       |           |              |
| Lithium hexafluorophosphate<br>                          | [LiPF <sub>6</sub> ]<br>                                           | 151.91                         | ≤50               | ≥99.9         | PE                    | 50g       | LBG-45864    |
|                                                                                                                                          | 100g                                                                                                                                                |                                |                   |               |                       | LBG-45860 |              |
|                                                                                                                                          | 250g                                                                                                                                                |                                |                   |               |                       | LBG-45861 |              |
|                                                                                                                                          | 500g                                                                                                                                                |                                |                   |               |                       | LBG-45865 |              |
|                                                                                                                                          | 21324-40-3                                                                                                                                          | 1kg                            | LBG-45863         |               |                       |           |              |
| Lithium difluorophosphate<br>                            | LiDFP [LiPO <sub>2</sub> F <sub>2</sub> ]<br>                      | 107.91                         | ≤150              | ≥99           | PE                    | 25g       | LBG-45532    |
|                                                                                                                                          | 100g                                                                                                                                                |                                |                   |               |                       | LBG-45533 |              |
|                                                                                                                                          | 24389-25-1                                                                                                                                          |                                |                   |               |                       |           |              |
| Lithium tetrafluoroborate<br>                            | [LiBF <sub>4</sub> ]<br>                                           | 93.75                          | ≤100              | ≥99.9         | PE                    | 25g       | LBG-44852    |
|                                                                                                                                          | 50g                                                                                                                                                 |                                |                   |               |                       | LBG-44854 |              |
|                                                                                                                                          | 100g                                                                                                                                                |                                |                   |               |                       | LBG-44850 |              |
|                                                                                                                                          | 250g                                                                                                                                                |                                |                   |               |                       | LBG-44851 |              |
|                                                                                                                                          | 14283-07-9                                                                                                                                          | 500g                           | LBG-44855         |               |                       |           |              |
| Lithium bis(oxalato)borate<br>                         | LiBOB [LiB(C <sub>2</sub> O <sub>4</sub> ) <sub>2</sub> ]<br>    | 193.79                         | —                 | ≥97           | PE                    | 25g       | LBG-44382    |
|                                                                                                                                          | 244761-29-3                                                                                                                                         |                                |                   |               |                       |           |              |
| Lithium difluoro(oxalato)borate<br>                    | LiDFOB [LiBF <sub>2</sub> C <sub>2</sub> O <sub>4</sub> ]<br>    | 143.77                         | ≤0.05%            | ≥99.5         | PE                    | 25g       | LBG-45352    |
|                                                                                                                                          | 100g                                                                                                                                                |                                |                   |               |                       | LBG-45351 |              |
|                                                                                                                                          | 409071-16-5                                                                                                                                         |                                |                   |               |                       |           |              |
| Lithium bis<br>(trifluoromethanesulfonyl)<br>imide<br> | LiTFSI [LiN(SO <sub>2</sub> CF <sub>3</sub> ) <sub>2</sub> ]<br> | 287.11                         | ≤100              | ≥99.9         | Amber<br>glass bottle | 10g       | LBG-43513    |
|                                                                                                                                          | 25g                                                                                                                                                 |                                |                   |               |                       | LBG-43512 |              |
|                                                                                                                                          | 50g                                                                                                                                                 |                                |                   |               |                       | LBG-43514 |              |
|                                                                                                                                          | 100g                                                                                                                                                |                                |                   |               |                       | LBG-43511 |              |
|                                                                                                                                          | 90076-65-6                                                                                                                                          | 500g                           | LBG-43515         |               |                       |           |              |
| Lithium<br>bis(fluorosulfonyl)imide<br>                | LiFSI [LiN(SO <sub>2</sub> F) <sub>2</sub> ]<br>                 | 187.07                         | ≤200              | ≥99           | Amber<br>glass bottle | 25g       | LBG-45282    |
|                                                                                                                                          | 100g                                                                                                                                                |                                |                   |               |                       | LBG-45281 |              |
|                                                                                                                                          | 171611-11-3                                                                                                                                         |                                |                   |               |                       |           |              |
| Lithium<br>trifluoromethanesulfonate<br>               | LiTFS [LiSO <sub>3</sub> CF <sub>3</sub> ]<br>                   | 156.02                         | ≤100              | ≥99           | Amber<br>glass bottle | 25g       | LBG-45672    |
|                                                                                                                                          | 50g                                                                                                                                                 |                                |                   |               |                       | LBG-45674 |              |
|                                                                                                                                          | 100g                                                                                                                                                |                                |                   |               |                       | LBG-45671 |              |
|                                                                                                                                          | 500g                                                                                                                                                |                                |                   |               |                       | LBG-45675 |              |
| 33454-82-9                                                                                                                               |                                                                                                                                                     |                                |                   |               |                       |           |              |

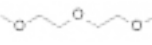
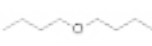
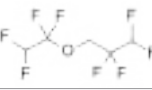
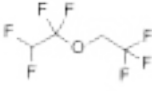
## L-Solve™ - Lithium Battery Grade — Solvents

| Product name                                                                                                                                                                     | Abbreviation Structure                                                                                 | Molecular weight (g/mol)                                                                | Density (g/ml) | Melting point (°C)    | Boiling point (°C) | Flash point (°C) | LUMO    | HOMO     | Dipole moment | Specification              | Contents     | Product code |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|----------------|-----------------------|--------------------|------------------|---------|----------|---------------|----------------------------|--------------|--------------|
|                                                                                                                                                                                  | CAS No.                                                                                                |                                                                                         |                |                       |                    |                  |         |          |               | Moisture(ppm)<br>Purity(%) |              |              |
| Cyclic carbonate esters                                                                                                                                                          |                                                                                                        |                                                                                         |                |                       |                    |                  |         |          |               |                            |              |              |
| Propylene carbonate<br>                                                                          | PC<br>                | 102.09                                                                                  | 1.20           | -49                   | 242                | 132              | 1.3118  | -11.903  | 5.264         | ≤30<br>≥99.5               | 500g         | LBG-64955    |
|                                                                                                                                                                                  | 108-32-7                                                                                               |                                                                                         |                |                       |                    |                  |         |          |               |                            | 1kg          | LBG-64951    |
|                                                                                                                                                                                  | Ethylene carbonate<br> | EC<br> | 88.06          | 1.32<br>(40°C)        | 38                 | 244              | 152     | 1.2416   | -11.906       | 5.068                      | ≤30<br>≥99.5 | 500g         |
|                                                                                                                                                                                  | 96-49-1                                                                                                | 1kg                                                                                     |                |                       |                    |                  |         |          |               |                            |              | LBG-29011    |
| Vinylene carbonate<br>                                                                         | VC<br>              | 86.05                                                                                   | 1.37           | 22                    | 162                | 72               | 0.0151  | -10.336  | 4.473         | ≤100<br>≥99.5              | 25g          | LBG-84922    |
|                                                                                                                                                                                  |                                                                                                        |                                                                                         |                |                       |                    |                  |         |          |               |                            | 100g         | LBG-84923    |
|                                                                                                                                                                                  |                                                                                                        |                                                                                         |                |                       |                    |                  |         |          |               |                            | 250g         | LBG-84920    |
|                                                                                                                                                                                  |                                                                                                        |                                                                                         |                |                       |                    |                  |         |          |               |                            | 500g         | LBG-84925    |
|                                                                                                                                                                                  |                                                                                                        |                                                                                         |                |                       |                    |                  |         |          |               |                            | 1kg          | LBG-84921    |
|                                                                                                                                                                                  |                                                                                                        | 872-36-6                                                                                |                |                       |                    |                  |         |          |               |                            |              |              |
| Vinyl ethylene carbonate<br>                                                                   | VEC<br>             | 114.1                                                                                   | 1.19           | —<br>237<br>(97.7KPA) | 96.7               | 0.456            | -10.982 | 5.268    | ≤500<br>≥98.5 | 25g                        | LBG-84532    |              |
|                                                                                                                                                                                  |                                                                                                        |                                                                                         |                |                       |                    |                  |         |          |               | 100g                       | LBG-84531    |              |
|                                                                                                                                                                                  |                                                                                                        |                                                                                         |                |                       |                    |                  |         |          |               | 250g                       | LBG-84534    |              |
|                                                                                                                                                                                  |                                                                                                        |                                                                                         |                |                       |                    |                  |         |          |               | 500g                       | LBG-84535    |              |
|                                                                                                                                                                                  |                                                                                                        |                                                                                         |                |                       |                    |                  |         |          |               | 1kg                        | LBG-84533    |              |
|                                                                                                                                                                                  | 4427-96-7                                                                                              |                                                                                         |                |                       |                    |                  |         |          |               |                            |              |              |
| Fluoro ethylene carbonate<br>                                                                  | FEC<br>             | 106.05                                                                                  | 1.50           | 17.3                  | 210                | 122              | 0.9829  | -12.335  | 4.703         | ≤50<br>≥99.5               | 25g          | LBG-32052    |
|                                                                                                                                                                                  |                                                                                                        |                                                                                         |                |                       |                    |                  |         |          |               |                            | 50g          | LBG-32054    |
|                                                                                                                                                                                  |                                                                                                        |                                                                                         |                |                       |                    |                  |         |          |               |                            | 100g         | LBG-32051    |
|                                                                                                                                                                                  | 114435-02-8                                                                                            |                                                                                         |                |                       |                    |                  |         |          |               |                            |              |              |
| cis-Difluoro ethylene carbonate<br><br>Test sales product.<br>Contains polymerized substances. | cis-DFEC<br>        | 124.04                                                                                  | —              | —                     | —                  | —                | 0.7116  | -12.5806 | 4.560         | —<br>—                     | 25g          | 060-Q0482    |
|                                                                                                                                                                                  |                                                                                                        |                                                                                         |                |                       |                    |                  |         |          |               |                            |              |              |

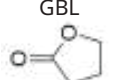
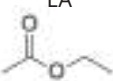
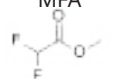
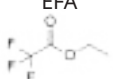
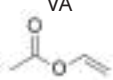
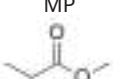
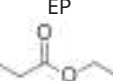
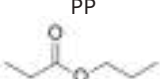
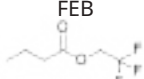
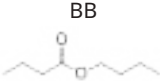
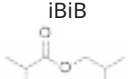
## L-Solve™ - Lithium Battery Grade — Solvents

| Product name                                                                                                                | Abbreviation Structure                                                                                     | Molecular weight (g/mol)                                                                    | Density (g/ml) | Melting point (°C) | Boiling point (°C) | Flash point (°C) | LUMO   | HOMO    | Dipole moment | Specification              | Contents     | Product code |
|-----------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|----------------|--------------------|--------------------|------------------|--------|---------|---------------|----------------------------|--------------|--------------|
|                                                                                                                             | CAS No.                                                                                                    |                                                                                             |                |                    |                    |                  |        |         |               | Moisture(ppm)<br>Purity(%) |              |              |
| Chain carbonate esters                                                                                                      |                                                                                                            |                                                                                             |                |                    |                    |                  |        |         |               |                            |              |              |
| Dimethyl carbonate<br>                      | DMC<br>                   | 90.08                                                                                       | 1.07           | 4                  | 90                 | 17               | 1.1369 | -11.624 | 0.304         | ≤30<br>≥99.5               | 500g         | LBG-24835    |
|                                                                                                                             | 616-38-6                                                                                                   |                                                                                             |                |                    |                    |                  |        |         |               |                            | 1kg          | LBG-24831    |
|                                                                                                                             | Ethyl methyl carbonate<br> | EMC<br>    | 104.1          | 1.02               | -55                | 107              | 23     | 1.1309  | -11.543       | 0.52                       | ≤30<br>≥99.5 | 500g         |
| 623-53-0                                                                                                                    |                                                                                                            | 1kg                                                                                         |                |                    |                    |                  |        |         |               |                            |              | LBG-31381    |
| Methyl 2,2,2-trifluoroethyl carbonate<br> |                                                                                                            | FEMC<br> | 158.08         | 1.33               | -110               | 105              | 35     | 0.3888  | -12.2133      | 2.664                      | ≤30<br>≥99   | 25g          |
|                                                                                                                             | 156783-95-8                                                                                                | 100g                                                                                        |                |                    |                    |                  |        |         |               |                            |              | LBG-80493    |
|                                                                                                                             | Diethyl carbonate<br>    | DEC<br>  | 118.13         | 0.98               | -43                | 126              | 25     | 1.1216  | -11.453       | 0.568                      | ≤30<br>≥99.5 | 500g         |
| 105-58-8                                                                                                                    |                                                                                                            | 1kg                                                                                         |                |                    |                    |                  |        |         |               |                            |              | LBG-23601    |
| Bis (2,2,2-trifluoroethyl) carbonate<br>  |                                                                                                            | TFEC<br> | 226.07         | 1.50               | -100               | 118              | —      | -0.2374 | -12.555       | 4.117                      | ≤30<br>≥99   | 25g          |
|                                                                                                                             | 1513-87-7                                                                                                  | 100g                                                                                        |                |                    |                    |                  |        |         |               |                            |              | LBG-99793    |

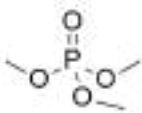
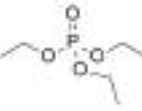
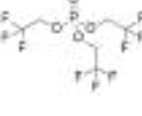
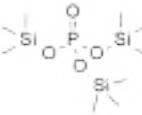
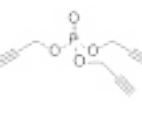
## L-Solve™ - Lithium Battery Grade — Solvents

| Product name                                                                                                                              | Abbreviation<br>Structure                                                                             | Molecular<br>weight<br>(g/mol) | Density<br>(g/ml) | Melting<br>point<br>(°C) | Boiling<br>point<br>(°C) | Flash<br>point<br>(°C) | LUMO   | HOMO     | Dipole<br>moment | Specification              | Contents | Product code |
|-------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|--------------------------------|-------------------|--------------------------|--------------------------|------------------------|--------|----------|------------------|----------------------------|----------|--------------|
|                                                                                                                                           | CAS No.                                                                                               |                                |                   |                          |                          |                        |        |          |                  | Moisture(ppm)<br>Purity(%) |          |              |
| Ethers                                                                                                                                    |                                                                                                       |                                |                   |                          |                          |                        |        |          |                  |                            |          |              |
| 1,2-Dimethoxyethane<br>                                   | DME<br>              | 90.12                          | 0.87              | -58                      | 85                       | 0                      | 2.5256 | -10.506  | 0.042            | $\leq 30$<br>$\geq 99.5$   | 500ml    | LBG-29385    |
|                                                                                                                                           | 110-71-4                                                                                              |                                |                   |                          |                          |                        |        |          |                  |                            | 1L       | LBG-29381    |
| 1,2-Diethoxyethane<br>                                    | DEE<br>              | 118.17                         | 0.84              | -74                      | 121                      | 35                     | 2.436  | -10.408  | 0.036            | $\leq 50$<br>$\geq 97$     | 500ml    | LBG-29365    |
|                                                                                                                                           | 629-14-1                                                                                              |                                |                   |                          |                          |                        |        |          |                  |                            |          |              |
| Diethylene glycol dimethyl ether<br>                      | Diglyme, G2<br>      | 134.18                         | 0.95              | -64                      | 162                      | 56                     | 2.1992 | -10.499  | 1.426            | $\leq 30$<br>$\geq 99$     | 25ml     | LBG-23662    |
|                                                                                                                                           | 111-96-6                                                                                              |                                |                   |                          |                          |                        |        |          |                  |                            |          |              |
| Triethylene glycol dimethyl ether<br>                   | Triglyme, G3<br>   | 178.18                         | 0.99              | -45                      | 216                      | 113                    | 2.0191 | -10.511  | 0.162            | $\leq 30$<br>$\geq 98$     | 25ml     | LBG-80212    |
|                                                                                                                                           | 112-49-2                                                                                              |                                |                   |                          |                          |                        |        |          |                  |                            |          |              |
| Tetraethylene glycol dimethyl ether<br>                 | Tetraglyme, G4<br> | 222.28                         | 1.01              | -30                      | 275                      | 141                    | 1.9117 | -10.522  | 1.424            | $\leq 30$<br>$\geq 98$     | 25ml     | LBG-76792    |
|                                                                                                                                           | 143-24-8                                                                                              |                                |                   |                          |                          |                        |        |          |                  |                            |          |              |
| Di-n-butyl ether<br>                                    |                    | 130.23                         | 0.77              | -95                      | 142                      | 25                     | 2.9864 | -10.3576 | 1.105            | $\leq 30$<br>$\geq 99.5$   | 500ml    | LBG-22305    |
|                                                                                                                                           | 142-96-1                                                                                              |                                |                   |                          |                          |                        |        |          |                  |                            |          |              |
| Anisole<br>                                             |                    | 108.14                         | 0.99              | -37                      | 155                      | 52                     | 0.4835 | -9.0041  | 1.249            | $\leq 30$<br>$\geq 99$     | 500g     | LBG-05115    |
|                                                                                                                                           | 100-66-3                                                                                              |                                |                   |                          |                          |                        |        |          |                  |                            |          |              |
| 1,1,2,2-Tetrafluoroethyl 2,2,3,3-tetrafluoropropyl ether                                                                                  | TTE<br>            | 232.07                         | 1.53              | —                        | 93.2                     | —                      | 0.1773 | -11.9809 | 1.454            | $\leq 30$<br>$\geq 99$     | 25g      | LBG-80652    |
|                                                                                                                                           | 16627-68-2                                                                                            |                                |                   |                          |                          |                        |        |          |                  |                            | 100g     | LBG-80653    |
| 1,1,2,2-Tetrafluoroethyl-2,2,2-trifluoroethyl ether<br> | HFE-347pc-f<br>    | 200.05                         | 1.48              | -94                      | 56                       | —                      | 0.2167 | -12.2006 | 1.051            | $\leq 30$<br>$\geq 99.5$   | 100g     | LBG-80743    |
|                                                                                                                                           |                                                                                                       |                                |                   |                          |                          |                        |        |          |                  |                            | 500g     | LBG-80745    |
|                                                                                                                                           | 406-78-0                                                                                              |                                |                   |                          |                          |                        |        |          |                  |                            | 1kg      | LBG-80741    |

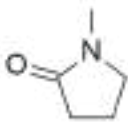
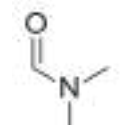
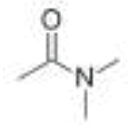
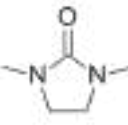
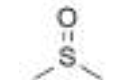
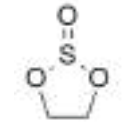
## L-Solve™ - Lithium Battery Grade — Solvents

| Product name                                                                                                                           | Abbreviation<br>Structure                                                                   | Molecular<br>weight<br>(g/mol) | Density<br>(g/ml) | Melting<br>point<br>(°C) | Boiling<br>point<br>(°C) | Flash<br>point<br>(°C) | LUMO   | HOMO     | Dipole<br>moment | Specification              | Contents | Product code |
|----------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|--------------------------------|-------------------|--------------------------|--------------------------|------------------------|--------|----------|------------------|----------------------------|----------|--------------|
|                                                                                                                                        | CAS No.                                                                                     |                                |                   |                          |                          |                        |        |          |                  | Moisture(ppm)<br>Purity(%) |          |              |
| Esters                                                                                                                                 |                                                                                             |                                |                   |                          |                          |                        |        |          |                  |                            |          |              |
| <div>γ-Butyrolactone</div> <div></div>                 | GBL<br>    | 86.09                          | 1.13              | -44                      | 204                      | 101                    | 1.1039 | -11.237  | 4.556            | ≤30<br>≥99.5               | 500g     | LBG-11785    |
|                                                                                                                                        | 96-48-0                                                                                     |                                |                   |                          |                          |                        |        |          |                  |                            | 1kg      | LBG-11781    |
| <div>Methyl acetate</div> <div></div>                  | MA<br>     | 74.08                          | 0.932             | -98                      | 57                       | -9                     | 1.0965 | -11.411  | 1.692            | ≤30<br>≥99.5               | 100ml    | LBG-48574    |
|                                                                                                                                        | 79-20-9                                                                                     |                                |                   |                          |                          |                        |        |          |                  |                            | 500ml    | LBG-48575    |
| <div>Ethyl acetate</div> <div></div>                   | EA<br>     | 88.11                          | 0.902             | -83                      | 77                       | -4.4                   | 1.1482 | -11.246  | 1.732            | ≤30<br>≥99.5               | 100ml    | LBG-28514    |
|                                                                                                                                        | 141-78-6                                                                                    |                                |                   |                          |                          |                        |        |          |                  |                            | 500ml    | LBG-28515    |
| <div>Methyl difluoroacetate</div> <div></div>          | MFA<br>    | 110.06                         | 1.272             | —                        | 85                       | 24                     | 0.3779 | -11.722  | 2.639            | ≤30<br>≥99                 | 50g      | LBG-47844    |
|                                                                                                                                        | 433-53-4                                                                                    |                                |                   |                          |                          |                        |        |          |                  |                            |          |              |
| <div>Ethyl trifluoroacetate</div> <div></div>        | EFA<br>  | 142.08                         | 1.194             | —                        | 61                       | -1                     | 0.0539 | -11.987  | 2.947            | ≤30<br>≥99                 | 50g      | LBG-30144    |
|                                                                                                                                        | 383-63-1                                                                                    |                                |                   |                          |                          |                        |        |          |                  |                            |          |              |
| <div>Vinyl acetate</div> <div></div>                 | VA<br>   | 86.09                          | 0.934             | -93                      | 73                       | -8                     | 0.6546 | -9.907   | 1.729            | ≤30<br>≥99                 | 100g     | LBG-84421    |
|                                                                                                                                        | 108-05-4                                                                                    |                                |                   |                          |                          |                        |        |          |                  |                            |          |              |
| <div>Methyl propionate</div> <div></div>             | MP<br>   | 88.11                          | 0.915             | -88                      | 79                       | 6                      | 1.1495 | -11.283  | 1.687            | ≤30<br>≥98                 | 100ml    | LBG-50424    |
|                                                                                                                                        | 554-12-1                                                                                    |                                |                   |                          |                          |                        |        |          |                  |                            | 500ml    | LBG-50425    |
| <div>Ethyl propionate</div> <div></div>              | EP<br>   | 102.13                         | 0.89              | -73                      | 99                       | 12                     | 1.1969 | -11.221  | 1.769            | ≤30<br>≥98                 | 100ml    | LBG-29964    |
|                                                                                                                                        | 105-37-3                                                                                    |                                |                   |                          |                          |                        |        |          |                  |                            | 500ml    | LBG-29965    |
| <div>Propyl propionate</div> <div></div>             | PP<br>   | 116.16                         | 0.88              | -76                      | 122                      | 27                     | 1.1884 | -11.136  | 1.766            | ≤30<br>≥98                 | 25ml     | LBG-65152    |
|                                                                                                                                        | 106-36-5                                                                                    |                                |                   |                          |                          |                        |        |          |                  |                            |          |              |
| <div>2,2,2-Trifluoroethyl butyrate</div> <div></div> | FEB<br>  | 170.13                         | 1.13              | —                        | 113                      | 24                     | 0.5657 | -11.8366 | 3.187            | ≤30<br>≥99.5               | 25g      | LBG-80672    |
|                                                                                                                                        | 371-27-7                                                                                    |                                |                   |                          |                          |                        |        |          |                  |                            | 100g     | LBG-80673    |
| <div>n-Butyl n-butyrate</div> <div></div>            | BB<br>   | 144.21                         | 0.87              | —                        | 165                      | 55.5                   | 1.2035 | -11.1666 | 1.818            | ≤30<br>≥99                 | 500ml    | LBG-11155    |
|                                                                                                                                        | 109-21-7                                                                                    |                                |                   |                          |                          |                        |        |          |                  |                            |          |              |
| <div>Isobutyl isobutyrate</div> <div></div>          | iBiB<br> | 144.21                         | 0.86              | -81                      | 148                      | 41                     | 1.2568 | -11.0492 | 1.76             | ≤30<br>≥98                 | 500ml    | LBG-40345    |
|                                                                                                                                        | 97-85-8                                                                                     |                                |                   |                          |                          |                        |        |          |                  |                            |          |              |

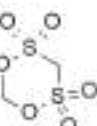
## L-Solve™ - Lithium Battery Grade — Solvents

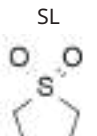
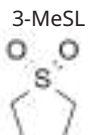
| Product name                                                                                                               | Abbreviation Structure                                                                                                    | Molecular weight (g/mol)                                                                     | Density (g/ml) | Melting point (°C) | Boiling point (°C) | Flash point (°C) | LUMO    | HOMO     | Dipole moment | Specification              | Contents   | Product code |
|----------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|----------------|--------------------|--------------------|------------------|---------|----------|---------------|----------------------------|------------|--------------|
|                                                                                                                            | CAS No.                                                                                                                   |                                                                                              |                |                    |                    |                  |         |          |               | Moisture(ppm)<br>Purity(%) |            |              |
| Phosphate esters                                                                                                           |                                                                                                                           |                                                                                              |                |                    |                    |                  |         |          |               |                            |            |              |
| Trimethyl phosphate<br>                    | TMP<br>                                  | 140.08                                                                                       | 1.197          | -46                | 197                | 107              | 0.661   | -11.512  | 2.025         | ≤30<br>≥99                 | 25ml       | LBG-80702    |
|                                                                                                                            | 512-56-1                                                                                                                  |                                                                                              |                |                    |                    |                  |         |          |               |                            | 500ml      | LBG-80705    |
|                                                                                                                            | Triethyl phosphate<br>                    | TEP<br>     | 182.16         | 1.071              | -56                | 215              | 111     | 0.7227   | -11.346       | 1.198                      | ≤30<br>≥99 | 25ml         |
| 78-40-0                                                                                                                    | 500ml                                                                                                                     | LBG-80265                                                                                    |                |                    |                    |                  |         |          |               |                            |            |              |
| Trioctyl phosphate<br>                   | TOP<br>                                | 434.63                                                                                       | 0.93           | -70                | 220<br>(7hPa)      | 204              | 0.7256  | -10.9    | 1.42          | ≤30<br>≥98                 | 250g       | LBG-77771    |
|                                                                                                                            | 78-42-2                                                                                                                   |                                                                                              |                |                    |                    |                  |         |          |               |                            |            |              |
| Tris(2,2,2-trifluoroethyl) phosphate<br> | TFEP<br>                               | 344.07                                                                                       | 1.59           | -20                | 73<br>(1.1kPa)     | —                | -0.5809 | -12.5212 | 1.918         | ≤30<br>≥99.5               | 25g        | LBG-79832    |
|                                                                                                                            | 358-63-4                                                                                                                  |                                                                                              |                |                    |                    |                  |         |          |               |                            | 100g       | LBG-79831    |
|                                                                                                                            | Tris (trimethylsilyl) phosphate 99%<br> | TMSPa<br> | 314.54         | 0.96               | —                  | 236              | 24      | 0.3958   | -9.4346       | 4.287                      | ≤300<br>—  | 25g          |
| 10497-05-9                                                                                                                 |                                                                                                                           |                                                                                              |                |                    |                    |                  |         |          |               |                            |            |              |
| Tripropargyl phosphate 98%<br>           | TPP<br>                                | 212.14                                                                                       | 1.2            | —                  | 124<br>(0.1kPa)    | 127              | -0.1102 | -10.7798 | 3.342         | ≤100<br>—                  | 25g        | 060-80792    |
|                                                                                                                            | 1779-34-6                                                                                                                 |                                                                                              |                |                    |                    |                  |         |          |               |                            |            |              |

## L-Solve™ - Lithium Battery Grade — Solvents

| Product name                                                                                                         | Abbreviation<br>Structure                                                                   | Molecular weight<br>(g/mol) | Density<br>(g/ml) | Melting point<br>(°C) | Boiling point<br>(°C) | Flash point<br>(°C) | LUMO   | HOMO    | Dipole moment | Specification              | Contents | Product code |
|----------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|-----------------------------|-------------------|-----------------------|-----------------------|---------------------|--------|---------|---------------|----------------------------|----------|--------------|
|                                                                                                                      | CAS No.                                                                                     |                             |                   |                       |                       |                     |        |         |               | Moisture(ppm)<br>Purity(%) |          |              |
| Amides                                                                                                               |                                                                                             |                             |                   |                       |                       |                     |        |         |               |                            |          |              |
| N-Methyl-2-pyrrolidone<br>           | NMP<br>    | 99.13                       | 1.03              | -23                   | 204                   | 99                  | 1.4726 | -9.9517 | 3.594         | ≤100<br>≥99.5              | 1kg      | LBG-50481    |
|                                                                                                                      | 872-50-4                                                                                    |                             |                   |                       |                       |                     |        |         |               |                            |          |              |
| N,N-Dimethylformamide<br>            | DMF<br>    | 73.09                       | 0.95              | -62                   | 153                   | 60                  | 1.4925 | -9.667  | 3.555         | ≤30<br>≥99.5               | 1L       | LBG-24931    |
|                                                                                                                      | 68-12-2                                                                                     |                             |                   |                       |                       |                     |        |         |               |                            |          |              |
| N,N-Dimethylacetamide<br>          | DMAc<br> | 87.12                       | 0.94              | -20                   | 165                   | 66                  | 1.4402 | -9.553  | 3.556         | ≤30<br>≥99                 | 1L       | LBG-24541    |
|                                                                                                                      | 127-19-5                                                                                    |                             |                   |                       |                       |                     |        |         |               |                            |          |              |
| 1,3-Dimethyl-2-imidazolidinone<br> | DMI<br>  | 114.15                      | 1.04              | 8.2                   | 226                   | 93                  | 1.3764 | -9.47   | 4.157         | ≤100<br>≥99                | 500g     | LBG-27385    |
|                                                                                                                      | 80-73-9                                                                                     |                             |                   |                       |                       |                     |        |         |               |                            |          |              |
| Sulfoxides                                                                                                           |                                                                                             |                             |                   |                       |                       |                     |        |         |               |                            |          |              |
| Dimethyl sulfoxide<br>             | DMSO<br> | 78.14                       | 1.10              | 18                    | 189                   | 95                  | 0.817  | -9.5287 | 3.958         | ≤30<br>≥99                 | 500g     | LBG-25425    |
|                                                                                                                      |                                                                                             |                             |                   |                       |                       |                     |        |         |               |                            | 1kg      | LBG-25423    |
|                                                                                                                      | 67-68-5                                                                                     |                             |                   |                       |                       |                     |        |         |               |                            |          |              |
| Sulfite esters                                                                                                       |                                                                                             |                             |                   |                       |                       |                     |        |         |               |                            |          |              |
| Ethylene sulfite<br>              | ES                                                                                          | 108.12                      | 1.43              | —                     | 159                   | 79                  | 0.0263 | -10.471 | 2.434         | —<br>≥98                   | 25g      | LBG-28252    |
|                                                                                                                      | 3741-38-6                                                                                   |                             |                   |                       |                       |                     |        |         |               |                            |          |              |

## L-Solve™ - Lithium Battery Grade — Solvents

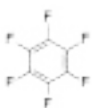
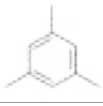
| Product name                                                                                                                       | Abbreviation Structure                                                                     | Molecular weight (g/mol) | Density (g/ml) | Melting point (°C) | Boiling point (°C) | Flash point (°C) | LUMO    | HOMO     | Dipole moment | Specification              | Contents | Product code |
|------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|--------------------------|----------------|--------------------|--------------------|------------------|---------|----------|---------------|----------------------------|----------|--------------|
|                                                                                                                                    | CAS No.                                                                                    |                          |                |                    |                    |                  |         |          |               | Moisture(ppm)<br>Purity(%) |          |              |
| Sulfonate esters                                                                                                                   |                                                                                            |                          |                |                    |                    |                  |         |          |               |                            |          |              |
| 1,3-Propane sultone<br>                            | PS<br>    | 122.14                   | 1.40<br>(30°C) | 32                 | 180<br>(30mmHg)    | 158              | -0.7093 | -11.741  | 4.88          | —<br>≥99                   | 100g     | LBG-60431    |
|                                                                                                                                    | 1120-71-4                                                                                  |                          |                |                    |                    |                  |         |          |               |                            |          |              |
| 1-Propene 1,3-sultone 99%<br>                      | PRS<br>   | 120.12                   | 1.508          | 83                 | —                  | —                | -0.7727 | -11.6064 | 5.325         | ≤100<br>—                  | 25g      | LBG-64442    |
|                                                                                                                                    | 21806-61-1                                                                                 |                          |                |                    |                    |                  |         |          |               |                            |          |              |
| 1,5,2,4-Dioxadithiane-2,2,4,4-tetraoxide 99%<br> | MMDS<br> | 188.17                   | —              | 152                | —                  | —                | -1.7112 | -12.0187 | 0.526         | ≤200<br>—                  | 25g      | LBG-24332    |
|                                                                                                                                    | 99591-74-9                                                                                 |                          |                |                    |                    |                  |         |          |               |                            |          |              |

| Product name                                                                                    | Abbreviation Structure                                                                        | Molecular weight (g/mol) | Density (g/ml) | Melting point (°C) | Boiling point (°C) | Flash point (°C) | LUMO    | HOMO    | Dipole moment | Specification              | Contents | Product code |
|-------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|--------------------------|----------------|--------------------|--------------------|------------------|---------|---------|---------------|----------------------------|----------|--------------|
|                                                                                                 | CAS No.                                                                                       |                          |                |                    |                    |                  |         |         |               | Moisture(ppm)<br>Purity(%) |          |              |
| Sulfones                                                                                        |                                                                                               |                          |                |                    |                    |                  |         |         |               |                            |          |              |
| Sulfolane<br> | SL<br>     | 120.17                   | 1.26<br>(30°C) | 28                 | 285                | 165              | -0.6081 | -11.893 | 4.25          | ≤50<br>≥99.5               | 500ml    | LBG-74315    |
|                                                                                                 | 126-33-0                                                                                      |                          |                |                    |                    |                  |         |         |               |                            |          |              |
| 3-Methyl sulfolane                                                                              | 3-MeSL<br> | 134.2                    | 1.18           | 0                  | 274                | 163              | -0.5616 | -11.701 | 4.363         | ≤30<br>≥98                 | 25g      | LBG-48922    |
|                                                                                                 | 872-93-5                                                                                      |                          |                |                    |                    |                  |         |         |               |                            |          |              |

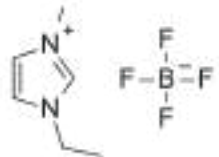
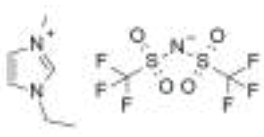
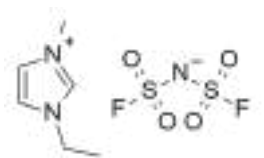
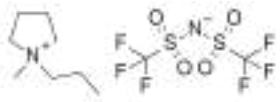
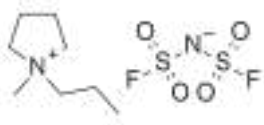
## L-Solve™ - Lithium Battery Grade — Solvents

| Product name                                                                                                                       | Abbreviation Structure                        | Molecular weight (g/mol) | Density (g/ml) | Melting point (°C) | Boiling point (°C) | Flash point (°C) | LUMO   | HOMO     | Dipole moment | Specification           | Contents | Product code |
|------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------|--------------------------|----------------|--------------------|--------------------|------------------|--------|----------|---------------|-------------------------|----------|--------------|
|                                                                                                                                    | CAS No.                                       |                          |                |                    |                    |                  |        |          |               | Moisture(ppm) Purity(%) |          |              |
| Nitriles                                                                                                                           |                                               |                          |                |                    |                    |                  |        |          |               |                         |          |              |
| Acetonitrile<br>                                   | AN<br><br><chem>CC#N</chem>                   | 41.05                    | 0.78           | -45                | 82                 | 2                | 1.6651 | -12.465  | 2.894         | ≤30<br>≥99.5            | 1L       | LBG-00401    |
|                                                                                                                                    | 75-05-8                                       |                          |                |                    |                    |                  |        |          |               |                         |          |              |
| Adiponitrile<br>                                   | ADN<br><br><chem>N#CCCCC#N</chem>             | 108.14                   | 0.96           | 1                  | 295                | 93               | 1.43   | -11.943  | 0.009         | ≤30<br>≥99              | 100ml    | LBG-01583    |
|                                                                                                                                    | 111-69-3                                      |                          |                |                    |                    |                  |        |          |               |                         |          |              |
| n-Valeronitrile<br>                              | VN<br><br><chem>CCCC#N</chem>                 | 83.13                    | 0.8            | -96                | 140                | 40               | 1.7032 | -11.605  | 3.026         | ≤30<br>≥99.5            | 25ml     | LBG-84072    |
|                                                                                                                                    | 110-59-8                                      |                          |                |                    |                    |                  |        |          |               |                         |          |              |
| Glutaronitrile<br>                               | GN<br><br><chem>N#CCCC#N</chem>               | 94.12                    | 0.989          | -26                | 286                | 109              | 1.2373 | -12.128  | 2.937         | ≤30<br>≥99              | 200ml    | LBG-34422    |
|                                                                                                                                    | 544-13-8                                      |                          |                |                    |                    |                  |        |          |               |                         |          |              |
| Succinonitrile<br>                               | SCN<br><br><chem>N#CCC#N</chem>               | 80.09                    | 1.02           | 56                 | 267                | 158              | 1.0264 | -12.318  | 0.054         | —<br>≥99                | 25g      | LBG-74142    |
|                                                                                                                                    | 110-61-2                                      |                          |                |                    |                    |                  |        |          |               |                         |          |              |
| 1,3,6-Hexanetricarbonyl nitrile 99%<br>          | HTCN<br><br><chem>N#CCCCC#N</chem>            | 161.2                    | 1.04           | —                  | 200<br>(0.2mmHg)   | 85               | 1.2892 | -11.9945 | 2.264         | ≤100<br>—               | 25g      | LBG-38192    |
|                                                                                                                                    | 1772-25-4                                     |                          |                |                    |                    |                  |        |          |               |                         |          |              |
| Ethylene glycol bis(propionitrile) ether 97%<br> | EGBE<br><br><chem>CCOC(=O)CCOCC(=O)C#N</chem> | 168.19                   | 1.07           | —                  | 165<br>(0.7kPa)    | 154              | 1.5879 | -10.8184 | 1.156         | ≤30<br>—                | 25g      | 060-30352    |
|                                                                                                                                    | 3386-87-6                                     |                          |                |                    |                    |                  |        |          |               |                         |          |              |

## L-Solve™ - Lithium Battery Grade — Solvents

| Product name                                                                                                  | Abbreviation Structure                                                                            | Molecular weight (g/mol) | Density (g/ml) | Melting point (°C) | Boiling point (°C) | Flash point (°C) | LUMO    | HOMO     | Dipole moment | Specification              | Contents | Product code |
|---------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|--------------------------|----------------|--------------------|--------------------|------------------|---------|----------|---------------|----------------------------|----------|--------------|
|                                                                                                               | CAS No.                                                                                           |                          |                |                    |                    |                  |         |          |               | Moisture(ppm)<br>Purity(%) |          |              |
| Others                                                                                                        |                                                                                                   |                          |                |                    |                    |                  |         |          |               |                            |          |              |
| Biphenyl<br>                  | BP<br>           | 154.21                   | 1.04           | 70                 | 255                | 110              | -0.2402 | -8.788   | 0.001         | ≤30<br>≥99                 | 25g      | LBG-08852    |
|                                                                                                               | 92-52-4                                                                                           |                          |                |                    |                    |                  |         |          |               |                            |          |              |
| Cyclohexyl benzene<br>        | CHB<br>          | 160.26                   | 0.95           | 5                  | 238-240            | 98               | -0.8397 | -8.123   | 0.001         | ≤30<br>≥98                 | 25ml     | LBG-19412    |
|                                                                                                               | 827-52-1                                                                                          |                          |                |                    |                    |                  |         |          |               |                            |          |              |
| Thiophene<br>                |                  | 84.14                    | 1.06           | -38                | 84                 | -9               | 0.2388  | -9.426   | 3.653         | ≤30<br>≥98                 | 25g      | LBG-77802    |
|                                                                                                               | 110-02-1                                                                                          |                          |                |                    |                    |                  |         |          |               |                            |          |              |
| Toluene<br>                 |                | 92.14                    | 0.874          | -95                | 110                | 4                | 0.52    | -9.331   | 0.263         | ≤30<br>≥99.5               | 500ml    | LBG-79025    |
|                                                                                                               | 108-88-3                                                                                          |                          |                |                    |                    |                  |         |          |               |                            |          |              |
| Fluorobenzene<br>           | FB<br>         | 96.1                     | 1.03           | -40                | 85                 | -13              | 0.1635  | -9.5451  | 1.576         | ≤30<br>≥99                 | 500g     | LBG-32475    |
|                                                                                                               | 462-06-6                                                                                          |                          |                |                    |                    |                  |         |          |               |                            |          |              |
| Hexafluoro benzene<br>      | HFB<br>        | 186.05                   | 1.61           | 3.9                | 81                 | 10               | -1.4799 | -10.368  | 0.001         | ≤30<br>≥99                 | 25g      | LBG-36592    |
|                                                                                                               | 392-56-3                                                                                          |                          |                |                    |                    |                  |         |          |               |                            |          |              |
| 1,3,5-Trimethyl benzene<br> | Mesitylene<br> | 120.19                   | 0.86           | -45                | 165                | 50               | 0.5655  | -9.1527  | 0.056         | ≤30<br>≥98                 | 500ml    | LBG-80545    |
|                                                                                                               | 108-67-8                                                                                          |                          |                |                    |                    |                  |         |          |               |                            |          |              |
| n-Heptane<br>               |                | 100.2                    | 0.68           | -91                | 98                 | -5               | 3.6817  | -11.0722 | 0.007         | ≤30<br>≥99                 | 500ml    | LBG-36230    |
|                                                                                                               | 142-82-5                                                                                          |                          |                |                    |                    |                  |         |          |               |                            |          |              |

## Ionic Liquids

| Product name                                                                                                                                                   | Abbreviation<br>Structure                                                                        | Molecular<br>weight<br>(g/mol) | Density<br>(g/ml) | Melting<br>point<br>(°C) | Specification     |               | Contents | Product code |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|--------------------------------|-------------------|--------------------------|-------------------|---------------|----------|--------------|
|                                                                                                                                                                | CAS No.                                                                                          |                                |                   |                          | Moisture<br>(ppm) | Purity<br>(%) |          |              |
| 1-Ethyl-3-methylimidazolium<br>tetrafluoroborate<br>                           | EMI-BF4<br>     | 197.97                         | 1.34              | 15                       | —                 | —             | 25g      | ILD-28622    |
|                                                                                                                                                                | 143314-16-3                                                                                      |                                |                   |                          |                   |               |          |              |
| 1-Butyl-3-methylimidazolium<br>tetrafluoroborate                                                                                                               | BMI-BF4<br>     | 226.02                         | 1.21              | -71                      | —                 | —             | 25g      | ILD-12722    |
|                                                                                                                                                                | 174501-65-6                                                                                      |                                |                   |                          |                   |               |          |              |
| 1-Ethyl-3-methylimidazolium<br>bis(trifluoromethanesulfonyl)<br>imide                                                                                          | EMI-TFSI<br>   | 391.31                         | 1.53              | -15                      | ≤50               | —             | 25g      | ILD-28292    |
|                                                                                                                                                                |                                                                                                  |                                |                   |                          |                   |               | 50g      | ILD-28294    |
|                                                                                                                                                                |                                                                                                  |                                |                   |                          |                   |               | 100g     | ILD-28291    |
|                                                                                                                                                                | 174899-82-2                                                                                      |                                |                   |                          |                   |               | 500g     | ILD-28295    |
| 1-Ethyl-3-methylimidazolium<br>bis(fluorosulfonyl)imide                                                                                                        | EMI-FSI<br>   | 291.32                         | 1.44              | -13                      | —                 | —             | 25g      | ILD-30292    |
|                                                                                                                                                                | 235789-75-0                                                                                      |                                |                   |                          |                   |               | 100g     | ILD-30291    |
| 1-Methyl-1-<br>propylpyrrolidinium bis<br>(trifluoromethylsulfonyl)imide<br> | Mppy-TFSI<br> | 408.38                         | 1.44              | 12                       | —                 | —             | 25g      | ILD-49312    |
|                                                                                                                                                                | 223437-05-6                                                                                      |                                |                   |                          |                   |               |          |              |
| 1-Methyl-1-<br>propylpyrrolidinium bis<br>(fluorosulfonyl)imide                                                                                                | MPPy-FSI<br>  | 308.37                         | 1.34              | -18                      | —                 | —             | 25g      | ILD-49732    |
|                                                                                                                                                                | 852620-97-4                                                                                      |                                |                   |                          |                   |               | 100g     | ILD-49731    |

## Custom Blends

| Electrolytes          | Solvents            | Additives           | Analysis examples     | Contents           |
|-----------------------|---------------------|---------------------|-----------------------|--------------------|
| Desired concentration | Desired composition | Desired composition | Moisture<br>Free acid | 100g / PE, Al      |
|                       |                     |                     |                       | 500g / SUS, Al, PE |
|                       |                     |                     |                       | 1kg / SUS, Al, PE  |

SUS = stainless steel

## L-Solve™ - Lithium Battery Grade — Mixed Solvents – Examples

| Product name            | GHS                                                                                                                                                                     | Contents | Container | Product code |
|-------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|-----------|--------------|
| EC:DMC (1:1 v/v%)       |       | 1kg      | Glass     | LBG-00044    |
| EC:DMC (1:2 v/v%)       |       | 1kg      | Glass     | LBG-00092    |
| EC:DMC (3:7 v/v%)       |     | 1kg      | Glass     | LBG-00873    |
| EC:EMC (1:1 v/v%)       |   | 1kg      | Glass     | LBG-00112    |
| EC:EMC (1:2 v/v%)       |   | 1kg      | Glass     | LBG-00073    |
| EC:EMC (3:7 v/v%)       |   | 1kg      | Glass     | LBG-00796    |
| EC:DEC (1:1 v/v%)       |   | 1kg      | Glass     | LBG-00043    |
| EC:DEC (1:2 v/v%)       |   | 1kg      | Glass     | LBG-00791    |
| EC:DEC (3:7 v/v%)       |   | 1kg      | Glass     | LBG-00792    |
| EC:PC (1:1 v/v%)        |                                                                                      | 1kg      | Glass     | LBG-00798    |
| EC:DMC:EMC (1:1:1 v/v%) |   | 1kg      | Glass     | LBG-01270    |
| EC:DMC:EMC (3:4:3 v/v%) |   | 500g     | Glass     | LBG-02489    |
| EC:DMC:DEC (1:1:1 v/v%) |                                                                                      | 1kg      | Glass     | LBG-00793    |

**L-Solve™ - Lithium Battery Grade — LiPF<sub>6</sub>-based Electrolyte Solutions - Examples**

| Product name                                     | Contents | Container | Product code |
|--------------------------------------------------|----------|-----------|--------------|
| 1mol/L LiPF <sub>6</sub> DMC                     | 500g     | SUS       | LBG-00341    |
|                                                  | 1kg      | SUS       | LBG-00920    |
| 1mol/L LiPF <sub>6</sub> EMC                     | 500g     | SUS       | LBG-00342    |
|                                                  | 1kg      | SUS       | LBG-00905    |
| 2mol/L LiPF <sub>6</sub> EMC                     | 500g     | SUS       | LBG-03333    |
|                                                  | 1kg      | SUS       | LBG-01596    |
| 1mol/L LiPF <sub>6</sub> DEC                     | 500g     | SUS       | LBG-00942    |
|                                                  | 1kg      | SUS       | LBG-00903    |
| 1mol/L LiPF <sub>6</sub> PC                      | 500g     | SUS       | LBG-00089    |
|                                                  | 1kg      | SUS       | LBG-00067    |
| 3mol/L LiPF <sub>6</sub> PC                      | 500g     | SUS       | LBG-02868    |
| 3.5mol/L LiPF <sub>6</sub> PC                    | 500g     | SUS       | LBG-02593    |
| 1mol/L LiPF <sub>6</sub> EC:DMC (1:1 v/v%)       | 500g     | SUS       | LBG-00758    |
|                                                  | 1kg      | SUS       | LBG-00022    |
| 1mol/L LiPF <sub>6</sub> EC:DMC (3:7 v/v%)       | 500g     | SUS       | LBG-01298    |
|                                                  | 1kg      | SUS       | LBG-00027    |
| 1mol/L LiPF <sub>6</sub> EC:EMC (1:1 v/v%)       | 1kg      | SUS       | LBG-00024    |
| 1mol/L LiPF <sub>6</sub> EC:EMC (3:7 v/v%)       | 500g     | SUS       | LBG-00933    |
|                                                  | 1kg      | SUS       | LBG-94893    |
| 1mol/L LiPF <sub>6</sub> EC:DEC (1:1 v/v%)       | 500g     | SUS       | LBG-01759    |
|                                                  | 1kg      | SUS       | LBG-96533    |
| 1mol/L LiPF <sub>6</sub> EC:DEC (3:7 v/v%)       | 500g     | SUS       | LBG-00935    |
|                                                  | 1kg      | SUS       | LBG-94913    |
| 1mol/L LiPF <sub>6</sub> EC:PC (1:2 v/v%)        | 500g     | SUS       | LBG-03461    |
| 1mol/L LiPF <sub>6</sub> EC:PC (3:7 v/v%)        | 500g     | SUS       | LBG-00488    |
| 1mol/L LiPF <sub>6</sub> EC:DMC:DEC (1:1:1 v/v%) | 500g     | SUS       | LBG-01666    |
| 1mol/L LiPF <sub>6</sub> EC:DMC:EMC (3:4:3 v/v%) | 500g     | SUS       | LBG-02344    |
| 1mol/L LiPF <sub>6</sub> EC:EMC:DEC (3:5:2 v/v%) | 500g     | SUS       | LBG-00392    |
| 1mol/L LiPF <sub>6</sub> EC:EP (3:7 v/v%)        | 500g     | SUS       | LBG-02565    |
| 1mol/L LiPF <sub>6</sub> EC:PP (3:7 v/v%)        | 500g     | SUS       | LBG-02566    |
| 1mol/L LiPF <sub>6</sub> FEC:FEMC (3:7 v/v%)     | 500g     | SUS       | LBG-03495    |

SUS = stainless steel

## L-Solve™ - Lithium Battery Grade — LiBF<sub>4</sub>-based Electrolyte Solutions – Examples

| Product name                                 | Contents | Container | Product code |
|----------------------------------------------|----------|-----------|--------------|
| 1mol/L LiBF <sub>4</sub> PC                  | 500g     | PE        | LBG-00865    |
|                                              | 1kg      | PE        | LBG-00038    |
| 1mol/L LiBF <sub>4</sub> EC:PC (1:1 wt/wt%)  | 500g     | PE        | LBG-03063    |
|                                              | 1kg      | PE        | LBG-00037    |
| 1mol/L LiBF <sub>4</sub> GBL                 | 500g     | PE        | LBG-00187    |
| 1.5mol/L LiBF <sub>4</sub> GBL               | 500g     | PE        | LBG-03267    |
| 1.5mol/L LiBF <sub>4</sub> EC:GBL (1:3 v/v%) | 1kg      | PE        | LBG-00057    |
| 1mol/L LiBF <sub>4</sub> PC:DMC (1:1 v/v%)   | 1kg      | PE        | LBG-00242    |
| 1mol/L LiBF <sub>4</sub> EC:DMC (3:7 v/v%)   | 1kg      | PE        | LBG-00128    |
| 1mol/L LiBF <sub>4</sub> EC:EMC (3:7 v/v%)   | 1kg      | PE        | LBG-00860    |
| 1mol/L LiBF <sub>4</sub> EC:DEC (1:1 v/v%)   | 1kg      | PE        | LBG-00041    |

## L-Solve™ - Lithium Battery Grade — LiTFSI-based Electrolyte Solutions –Examples

| Product name                                                   | Contents | Container | Product code |
|----------------------------------------------------------------|----------|-----------|--------------|
| 1mol/L LiN (SO <sub>2</sub> CF <sub>3</sub> ) <sub>2</sub> PC  | 500g     | PE        | LBG-01097    |
| 1mol/L LiN (SO <sub>2</sub> CF <sub>3</sub> ) <sub>2</sub> DME | 1kg      | PE        | LBG-01416    |
| 3mol/L LiN (SO <sub>2</sub> CF <sub>3</sub> ) <sub>2</sub> DME | 500g     | PE        | LBG-03443    |
| LiTFSI:Tetraglyme (1:1 mol ratio)                              | 100g     | PE        | LBG-02292    |

**L-Solve™ - Lithium Battery Grade — LiFSI-based Electrolyte Solutions – Examples**

| Product name                         | Contents | Container | Product code |
|--------------------------------------|----------|-----------|--------------|
| 1mol/L LiFSI DME                     | 500g     | SUS       | LBG-02696    |
| 3mol/L LiFSI DME                     | 500g     | SUS       | LBG-02759    |
| 4mol/L LiFSI DME                     | 100g     | PE        | LBG-02838    |
|                                      | 500g     | SUS       | LBG-02724    |
| LiFSI:Triglyme (1:1mol ratio)        | 100g     | PE        | LBG-03458    |
| 1mol/L LiFSI Tetraglyme              | 500g     | SUS       | LBG-02289    |
| LiFSI:Tetraglyme (1:1mol ratio)      | 100g     | PE        | LBG-03459    |
|                                      | 500g     | SUS       | LBG-02824    |
| 1mol/L LiFSI EC:PC (1:1 v/v%)        | 500g     | SUS       | LBG-03436    |
| 2mol/L LiFSI EC:PC (1:1 v/v%)        | 500g     | SUS       | LBG-02992    |
| 4mol/L LiFSI DMC                     | 500g     | SUS       | LBG-02935    |
| 1mol/L LiFSI EMC                     | 1kg      | SUS       | LBG-03335    |
| 1.5mol/L LiFSI EMC                   | 1kg      | SUS       | LBG-03334    |
| 1mol/L LiFSI EC:DMC:EMC (1:1:1 v/v%) | 500g     | SUS       | LBG-03431    |
| 1.5mol/L LiFSI EC:DMC (3:7 v/v%)     | 500g     | SUS       | LBG-03488    |
| 2mol/L LiFSI EC:EMC (3:7 v/v%)       | 100g     | PE        | LBG-03270    |
| 1mol/L LiFSI EMI-FSI                 | 100g     | PE        | LBG-02315    |
|                                      | 500g     | SUS       | LBG-02316    |
| 1mol/L LiFSI Mppy-FSI                | 100g     | PE        | LBG-02317    |
|                                      | 500g     | SUS       | LBG-02318    |

SUS = stainless steel

## Characteristics of Li salts

|                                                | LiPF <sub>6</sub> | LiBF <sub>4</sub> | LiTFS | LiTFSI | LiClO <sub>4</sub> (*) | LiBOB | LiFAP(*) | LiTCB(*) |
|------------------------------------------------|-------------------|-------------------|-------|--------|------------------------|-------|----------|----------|
| Solvent solubility                             | ◎                 | ○                 | ○     | ◎      | ◎                      | △     | ○        | ○        |
| Ionic conductivity                             | ◎                 | ○                 | △     | ◎      | ○                      | △     | ○        | ◎        |
| Low temperature characteristics (conductivity) | ○                 | △                 | △     | ○      | ○                      | △     | ○        | ○        |
| High temperature stability                     | ×                 | △                 | ○     | ◎      | ×                      | ◎     | ○        | ◎        |
| Material compatibility                         |                   |                   |       |        |                        |       |          |          |
| Cathode current collector(Al)                  | ○                 | ○                 | ×     | ×      | ○                      | ○     | ○        | ○        |
| Anode current collector(Cu)                    | ○                 | ○                 | ○     | ○      | ○                      | ○     | ○        | ○        |

## Physicochemical properties of Li salts

| Lithium salt                                                                   | Ionic radius r- [nm] | Limiting molar conductivity $\Lambda_0$ (PC)[S·cm <sup>2</sup> ·mol <sup>-1</sup> ] | Electrical conductivity* $\kappa$ [mS·cm <sup>-1</sup> ] | Degree of ionic dissociation* $\gamma$ [%] | Oxidation potential* $E_{ox}$ [V vs Li/Li <sup>+</sup> ] | Melting point [°C] | Decomposition temperature [°C] | Characteristics                        |
|--------------------------------------------------------------------------------|----------------------|-------------------------------------------------------------------------------------|----------------------------------------------------------|--------------------------------------------|----------------------------------------------------------|--------------------|--------------------------------|----------------------------------------|
| LiPF <sub>6</sub>                                                              | 0.255                | 26.3                                                                                | 5.8 (11.4)                                               | 22                                         | 6.3                                                      | 67<                | 175                            | Thermal decomposition, hydrolysis      |
| LiBF <sub>4</sub>                                                              | 0.227                | 28.9                                                                                | 3.4 (4.9)                                                | 12                                         | 6.2                                                      | 91<                | 200                            | Weak hydrolysis                        |
| (*) LiClO <sub>4</sub>                                                         | 0.234                | 27.4                                                                                | 5.6 (8.4)                                                | 20                                         | 6                                                        | 236                | 430                            | Explosive, non-fluorinated             |
| LiCF <sub>3</sub> SO <sub>3</sub><br>LiTFS                                     | 0.268                | 25.3                                                                                | 1.7 (3.2)                                                | 7                                          | 5.9                                                      | 423                | 420                            | Corrosive to Al current collectors     |
| LiN(SO <sub>2</sub> CF <sub>3</sub> ) <sub>2</sub><br>LiTFSI                   | 0.328                | 22.8                                                                                | 5.1 (9.3)                                                | 22                                         | 6.1                                                      | 230                | 380                            | Corrosive to Al current collectors     |
| (*) LiN(SO <sub>2</sub> C <sub>2</sub> F <sub>5</sub> ) <sub>2</sub><br>LiBETI | 0.362                | 20.2                                                                                | 3.9                                                      | 19                                         | 6.1                                                      | —                  | >350                           | Not corrosive to Al current collectors |
| LiN(SO <sub>2</sub> F) <sub>2</sub><br>LiFSI                                   | 0.283                | 24.2                                                                                | 6.4                                                      | 26                                         | 5.7                                                      | 140                | >300                           | Corrosive to Al current collectors     |
| LiB(C <sub>2</sub> O <sub>4</sub> ) <sub>2</sub><br>LiBOB                      | 0.305                | 22.9                                                                                | —                                                        | 14                                         | 6                                                        | >400               | 290                            | Non-fluorinated                        |
| (*) LiC(SO <sub>2</sub> CF <sub>3</sub> ) <sub>3</sub>                         | 0.372                | 20.2                                                                                | 3.8 (7.1)                                                | 19                                         | 6.1                                                      | —                  | —                              | —                                      |
| (*) LiPF <sub>3</sub> (C <sub>2</sub> F <sub>5</sub> ) <sub>3</sub><br>LiFAP   | 0.377                | 19.6                                                                                | —(8.2)                                                   | —                                          | 6                                                        | —                  | —                              | Hydrolysis resistance                  |

\* : 1mol/L Li salt in PC or EC:DMC (1:1v%), Pt, 25°C, 5mVs<sup>-1</sup>, 0. 32mA·cm<sup>-2</sup>

(\*) : not for sale

## Decomposition behavior of fluorinated electrolytes

### LiPF<sub>6</sub>

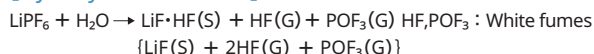
LiPF<sub>6</sub> is highly unstable to heat and moisture.

#### 【Thermal decomposition mechanism】

TG-DTA data shows that it starts to gradually decompose above 150°C and decomposition is complete at 240°C. LiF remains after the decomposition, and an endothermic peak due to the melting of LiF appears around 840°C.

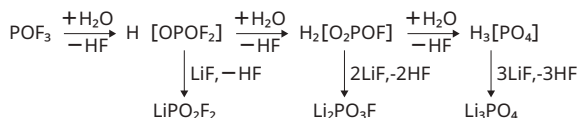


#### 【Hydrolysis mechanism】



POF<sub>3</sub> is further hydrolyzed by humidity to finally produce orthophosphoric acid via oxy-fluoro intermediates, in a process analogous to the hydrolysis of HPF<sub>6</sub>.

Color change: white → light peach → light brown → brown



### LiBF<sub>4</sub>

#### 【Thermal decomposition mechanism】

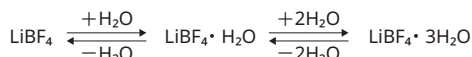
The thermal decomposition of LiBF<sub>4</sub> begins at around 200°C and is complete at around 320°C.

As is the case for LiPF<sub>6</sub>, LiF remains after the decomposition, and an endothermic peak due to the melting of LiF appears around 840°C.

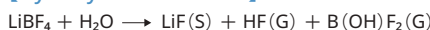


Stable hydrous salts of LiBF<sub>4</sub>, such as LiBF<sub>4</sub>·H<sub>2</sub>O (tetragonal) and LiBF<sub>4</sub>·3H<sub>2</sub>O (hexagonal), are known to exist.

These compounds are altered when they absorb moisture or dry.



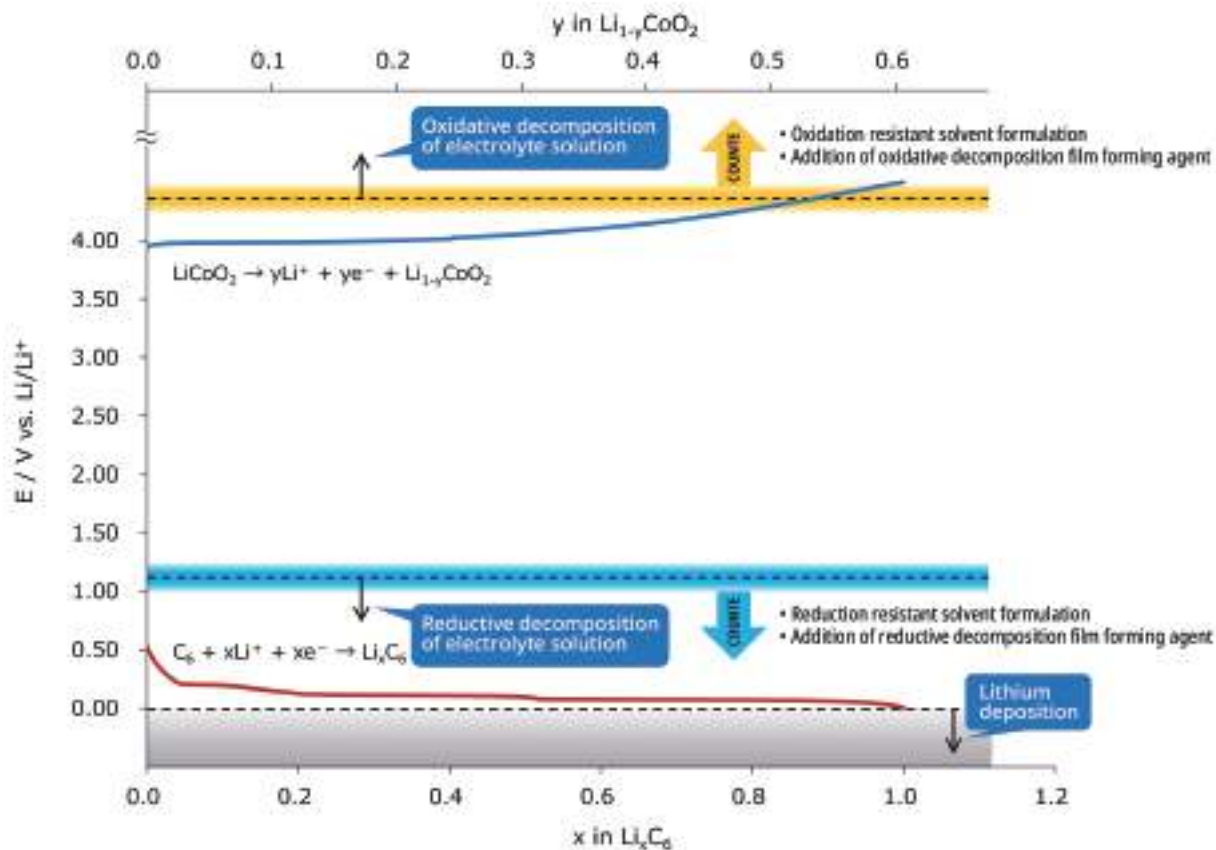
#### 【Hydrolysis mechanism】



## Parameters that determine the physical properties of organic solvents

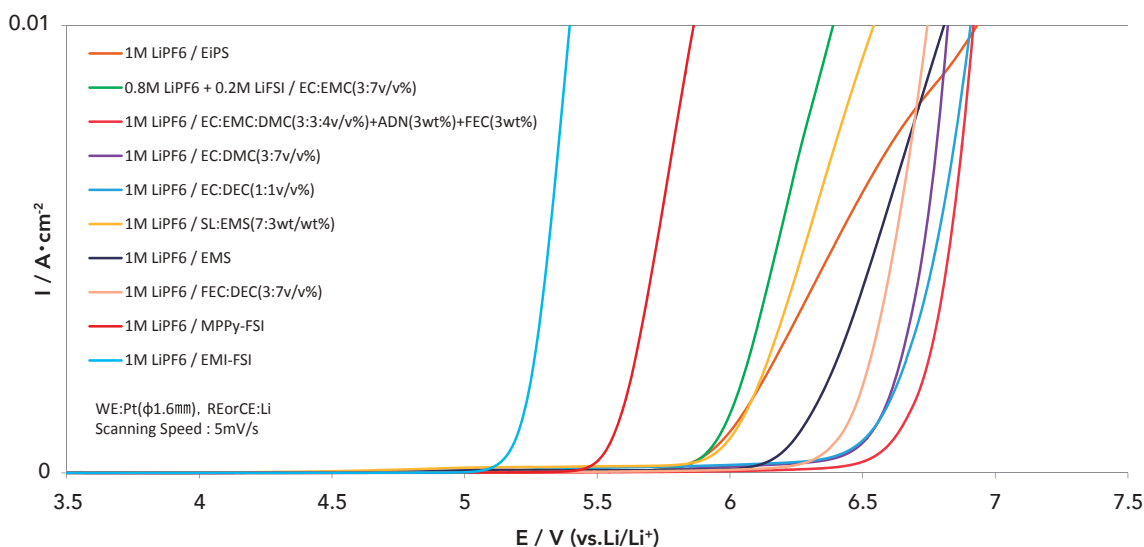
| Property                                        | Characteristics                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|-------------------------------------------------|---------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Boiling point<br>Melting point                  | Physical property related to battery operating temperature range                | These parameters also reflect the physical chemistry of the solvent molecules, such as molecular structure and intermolecular interactions. <b>Solvents with high boiling points and low melting points are ideal.</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| Permittivity<br>(Dielectric constant)           | Physical property closely associated with the dissociation of electrolyte salts | <p>The <b>solvation free energy</b> <math>\Delta G_s</math> for an electrolyte dissolving in a solvent is given by the following equation, based on the <b>solvation energy</b> <math>\Delta G_{sv}</math> and the <b>lattice energy</b> <math>\Delta G_{lat}</math>:</p> $\Delta G_s^\circ = \Delta G_{sv}^\circ - \Delta G_{lat}^\circ$ <p>Furthermore, the electrostatic interaction energy <math>\Delta G_{el}</math>, expressed by the Born equation, accounts for a major portion of the solvation free energy <math>\Delta G_{sv}</math>. In other words, the stabilization of an ion due to its dispersion in a dielectric solvent—quantified by <math>\Delta G_{el}</math>—constitutes the dominant contribution to the overall solvation energy.</p> $\Delta G_{el}^\circ = -\frac{N_A z^2 e^2}{4 \pi \epsilon_0 \cdot 2r} \left(1 - \frac{1}{\epsilon_r}\right) = -\frac{69.4 z^2}{r} \left(1 - \frac{1}{\epsilon_r}\right)$ <p>(z: ionic charge, e: elementary charge, r: ionic radius (nm), N<sub>A</sub>: Avogadro constant)</p> <p><b>By using a solvent with a high relative permittivity, electrolyte salts can be effectively dissolved to yield an ionically dissociated electrolyte solution.</b> Such solvents weaken the electrostatic attraction between ions, thereby promoting dissociation and enabling the preparation of highly conductive electrolyte systems.</p> |
| Viscosity                                       |                                                                                 | The viscosity influences the rate of mass transfer in the solvent, and therefore affects the conductivity of electrolyte solutions. Ion mobility can be improved by employing solvents with lower viscosity, as reduced resistance facilitates ionic transport.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Dipole moment                                   |                                                                                 | Most solvents consist of molecules with intrinsic dipoles and permanent dipole moments. Solvents with high dipole moments are classified as dipolar solvents, whereas those with low dipole moments are referred to as apolar or nonpolar solvents. Many solvents with high relative permittivity also have high dipole moment values.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| Donor number<br>(DN)<br>Acceptor number<br>(AN) |                                                                                 | The acidity and basicity of solvents significantly influence chemical reactions and equilibria in solution. In particular, variations in reactions and equilibria among solvents with high dielectric constants are often attributed to differences in their acidity and/or basicity. To quantify these properties, various empirical parameters have been proposed. Among them, the DN and AN are the most popular in the field of electrochemistry. Solvent basicity tends to increase with higher DN values, while solvent acidity increases with higher AN values.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |

## Relationship between LIB electrode potential and electrolyte solution potential window



## LiPF<sub>6</sub> electrolyte solution decomposition potential

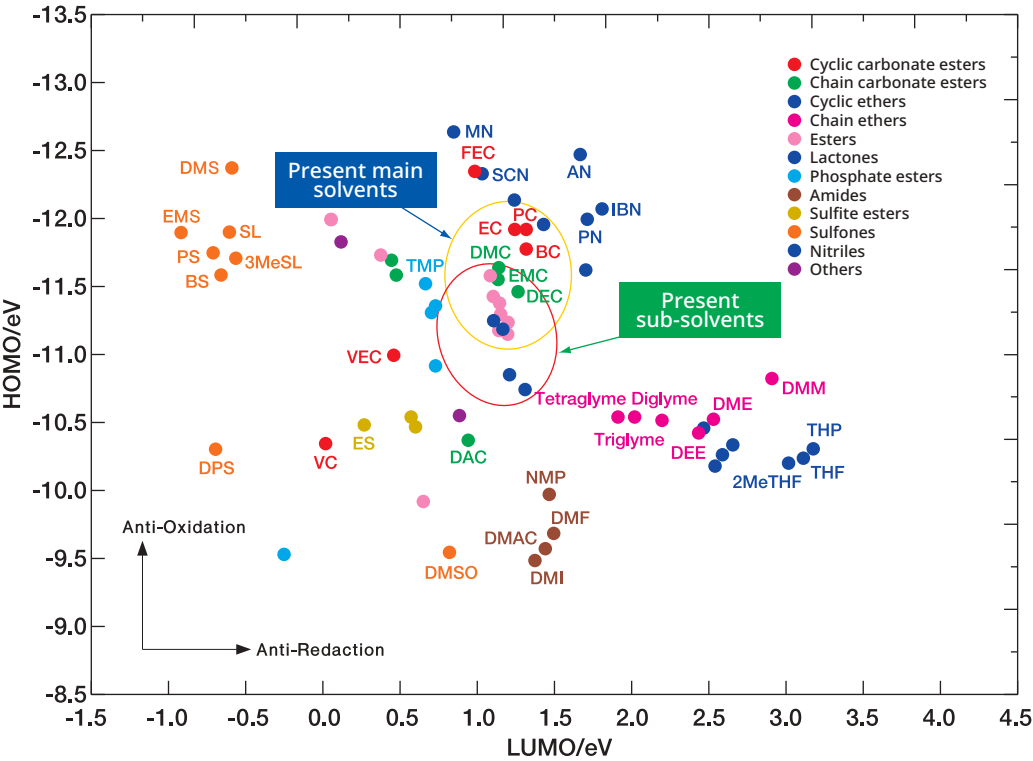
### Oxidative stability (LSV)



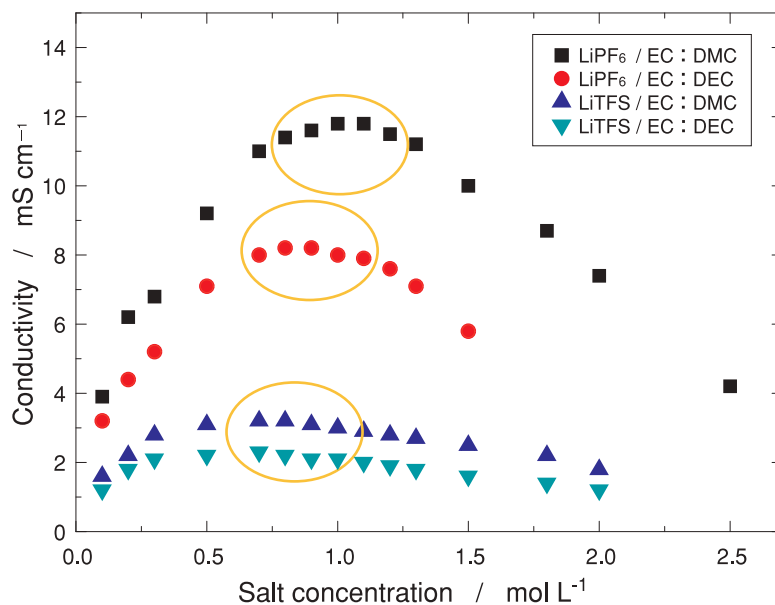
Physical properties of solvents for lithium-ion batteries

| Solvent    | Melting point<br>(°C,1atm) | Boiling point<br>(°C,1atm) | Relative<br>permittivity | Viscosity<br>(cP) | Dipole moment<br>(Debye) | Donor<br>number | Acceptor number |
|------------|----------------------------|----------------------------|--------------------------|-------------------|--------------------------|-----------------|-----------------|
| Carbonates |                            |                            |                          |                   |                          |                 |                 |
| PC         | -49                        | 242                        | 64.4                     | 2.53              | 5.26                     | 15.1            | 18.3            |
| EC         | 38                         | 244                        | 89.6 (40°C)              | 1.86 (40°C)       | 5.07                     | 16.4            | —               |
| FEC        | 17.3                       | 210                        | 105.7                    | 4.00              | —                        | —               | —               |
| DMC        | 4                          | 90                         | 3.1                      | 0.59              | 0.30                     | —               | —               |
| EMC        | -55                        | 107                        | 3.0                      | 0.65              | 0.52                     | —               | —               |
| DEC        | -43                        | 126                        | 2.82                     | 0.75              | 0.57                     | —               | —               |
| Esters     |                            |                            |                          |                   |                          |                 |                 |
| MF         | -100                       | 34                         | 8.5 (20°C)               | 0.33              | 1.51                     | —               | —               |
| Sulfones   |                            |                            |                          |                   |                          |                 |                 |
| SL         | 28                         | 285                        | 42.5 (30°C)              | 9.87 (30°C)       | 4.30                     | 14.8            | 19.3            |
| DMSO       | 18                         | 189                        | 46.45                    | 1.99              | 3.96                     | 29.8            | 19.3            |
| Nitriles   |                            |                            |                          |                   |                          |                 |                 |
| AN         | -45                        | 82                         | 36.0                     | 0.35              | 2.89                     | 14.1            | 18.9            |
| Lactones   |                            |                            |                          |                   |                          |                 |                 |
| GBL        | -44                        | 204                        | 39.1                     | 1.75              | 4.56                     | —               | —               |

HOMO and LUMO energy levels of organic solvents



## Ionic conductivities of electrolytes: salt concentration and solvent



Ionic conductivity varies depending on the electrolyte and solvent type. Each electrolyte solution has a point of maximum conductivity depending on the electrolyte concentration. Therefore, the electrolyte solution concentration at this maximum point is selected.

| Li salt/concentration | Solvent type 25°C (unit: mS/cm) |   |                 |   |                 |   |
|-----------------------|---------------------------------|---|-----------------|---|-----------------|---|
| 1mol/L                | PC                              |   | PC:EMC(1:1v/v%) |   | PC:DME(1:1v/v%) |   |
| LiPF <sub>6</sub>     | 6.0                             | 1 | 8.9             | 1 | 16.1            | 1 |
| LiBF <sub>4</sub>     | 3.5                             | 4 | 3.6             | 4 | 9.8             | 4 |
| LiTFS                 | 1.8                             | 5 | 1.9             | 5 | 6.5             | 5 |
| LiTFSI                | 5.2                             | 3 | 7.3             | 2 | 13.3            | 3 |
| (*)LiClO <sub>4</sub> | 5.7                             | 2 | 6.0             | 3 | 14.0            | 2 |

| Li salt/concentration | Solvent type 25°C (unit: mS/cm) |   |                 |   |                 |  |
|-----------------------|---------------------------------|---|-----------------|---|-----------------|--|
| 1mol/L                | EC:DEC(1:1v/v%)                 |   | EC:DMC(1:1v/v%) |   | EC:DME(1:1v/v%) |  |
| LiPF <sub>6</sub>     | 8.1                             | 1 | 11.4            | 1 | 16.7            |  |
| LiBF <sub>4</sub>     | —                               | — | —               | — | —               |  |
| LiTFS                 | 2.2                             | 3 | 3.2             | 3 | 8.5             |  |
| LiTFSI                | 6.5                             | 2 | 9.3             | 2 | 13.3            |  |

(\*): not for sale

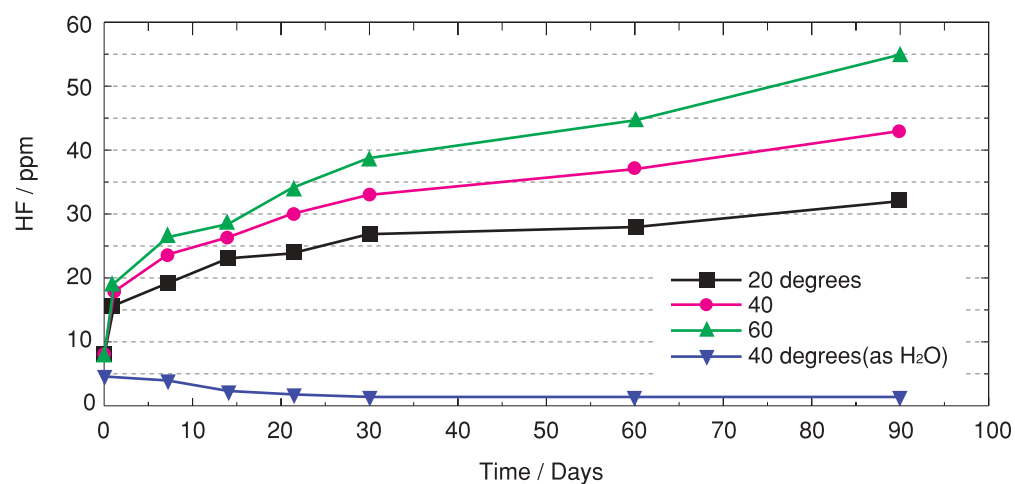
## HF formation in LiPF<sub>6</sub> based electrolyte at different temperatures

Sample: 1 mol/L LiPF<sub>6</sub> / EC: DEC (1:1 vol%)

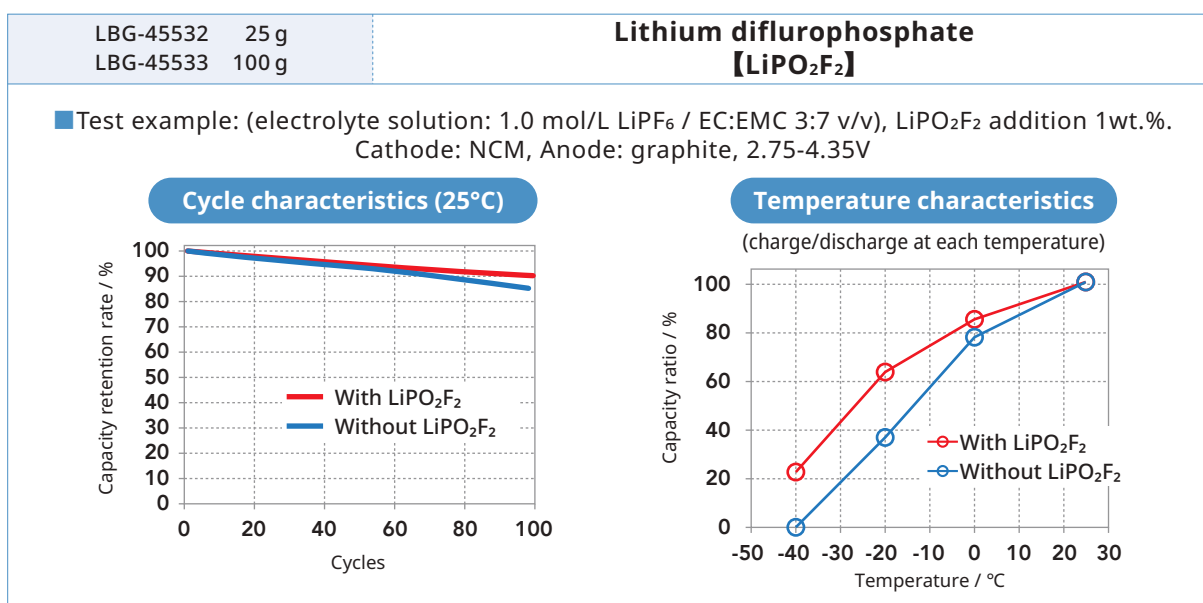
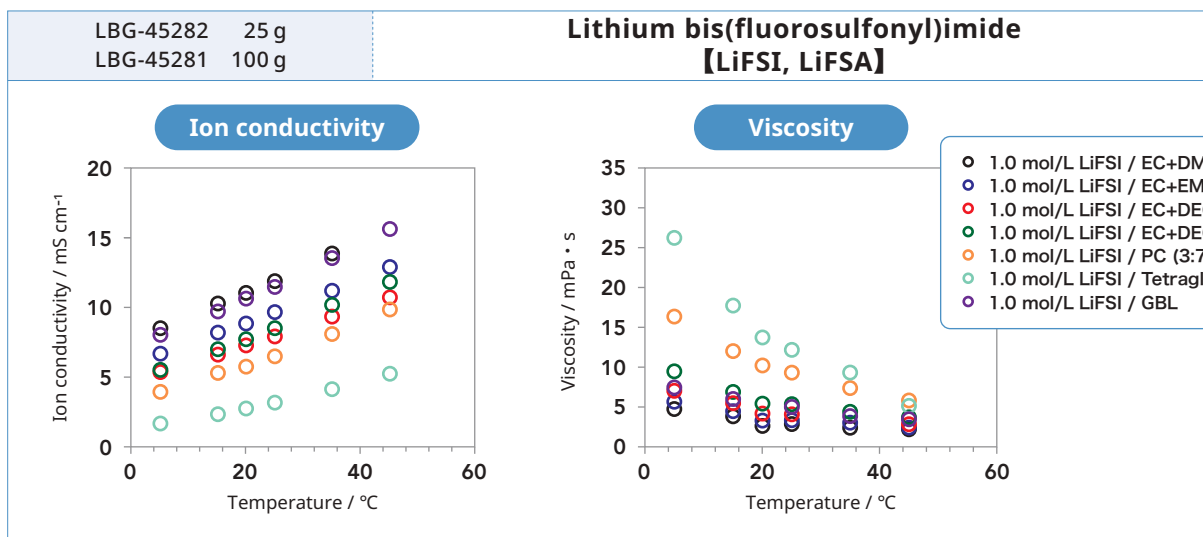
Storage container: SUS (stainless steel)

Storage: In a constant-temperature dryer, without laminated wrapping, in air

Measurement: Ion chromatography

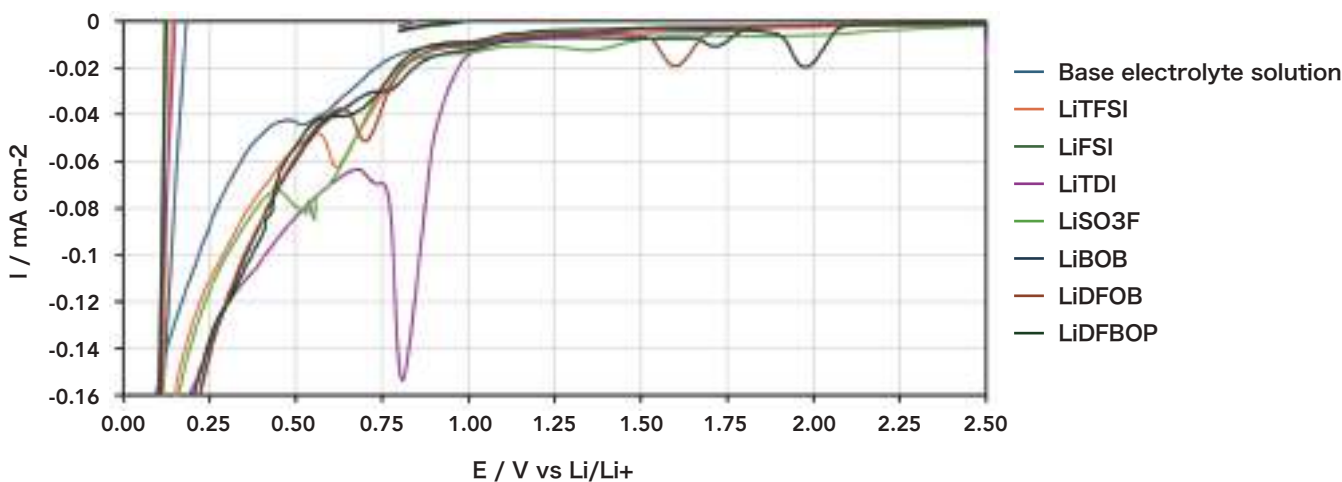


## Lithium salt: Electrolyte Characteristics and Electrochemical properties

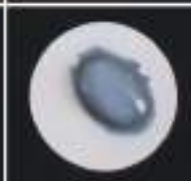
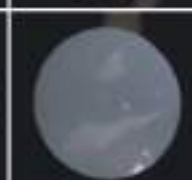


### Cyclic voltammetry

Working electrode: graphite, Counter electrode: lithium metal, Scan rate: 0.05 mV/sec, Electrolyte composition: 1.0 mol/L LiPF<sub>6</sub> / EC:EMC 3:7 v/v% + additives.



## Lithium salts: Separator Wettability

| 1.0 mol/L Salt                            | LiPF <sub>6</sub>                                                                 | LiBF <sub>4</sub>                                                                 | LiTFSI                                                                             | LiFSI                                                                               |
|-------------------------------------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| Solvent                                   | PC                                                                                | PC                                                                                | PC                                                                                 | PC                                                                                  |
| PP                                        |  |  |  |  |
| PE                                        |  |  |  |  |
| Al <sub>2</sub> O <sub>3</sub> -coated PE |  |  |  |  |

## Fluorinated solvent: Electrolyte properties and battery performance

## ■ Electrolyte solution composition

1.0 mol/L LiPF<sub>6</sub> / FEC:FEMC (3:7 v/v%)  
 1.0 mol/L LiPF<sub>6</sub> / FEC:FEMC (1:1 v/v%)  
 1.0 mol/L LiPF<sub>6</sub> / FEC:TFEC (1:1 v/v%)  
 1.0 mol/L LiPF<sub>6</sub> / EC:EMC:FEB (3:5:2 v/v%)

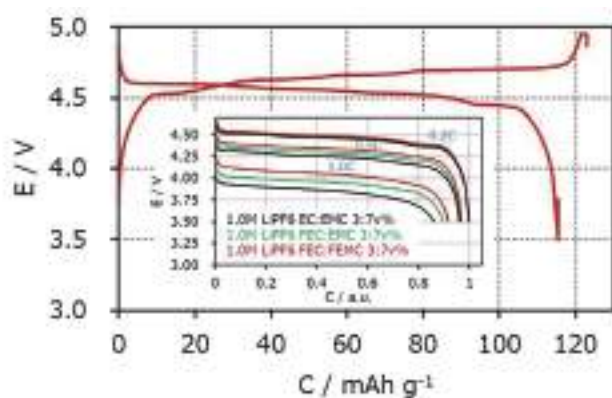
## ■ Ionic conductivity (25°C)

4.4 mS/cm  
 5.5 mS/cm  
 3.4 mS/cm  
 7.4 mS/cm

## ■ Test example

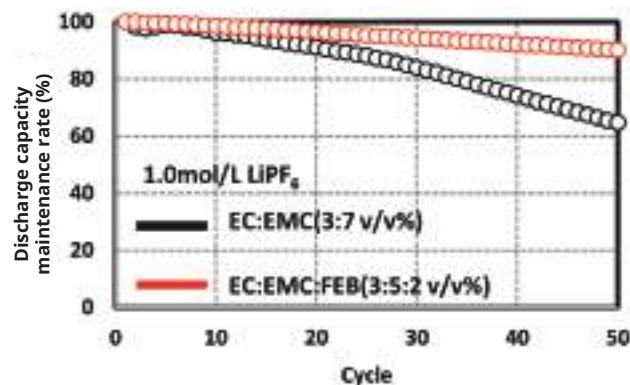
## Charge/discharge characteristics

Cathode: LiNi<sub>0.5</sub>Mn<sub>1.5</sub>O<sub>2</sub>, Anode: graphite  
 3.5 - 4.95V, 25°C  
 FEMC-containing electrolyte



## Cycle characteristics

Cathode: NCM523, Anode: graphite  
 2.75 - 4.5V, 1C, 25°C  
 FEB-containing electrolyte



## Fluorinated solvent: Electrolyte properties and battery performance

LBG-79832 25 g  
LBG-79831 100 g

### TFEP

#### Electrolyte composition

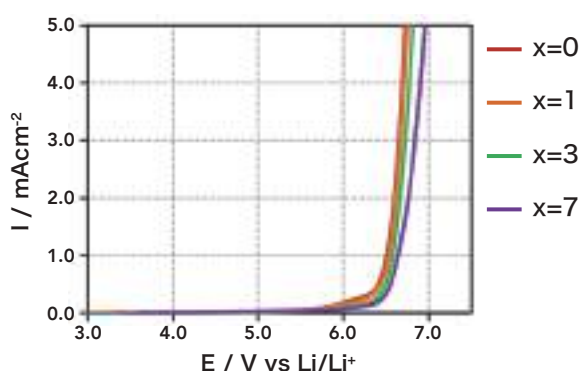
1.0 mol/L  $\text{LiPF}_6$  / EC:EMC (3:7 v/v%)  
1.0 mol/L  $\text{LiPF}_6$  / EC:EMC:TFEP (3:6:1 v/v%)  
1.0 mol/L  $\text{LiPF}_6$  / EC:EMC:TFEP (3:4:3 v/v%)  
1.0 mol/L  $\text{LiPF}_6$  / EC:TFEP (3:7 v/v%)

#### Ionic conductivity (25°C)

8.8 mS/cm  
7.7 mS/cm  
5.7 mS/cm  
2.7 mS/cm

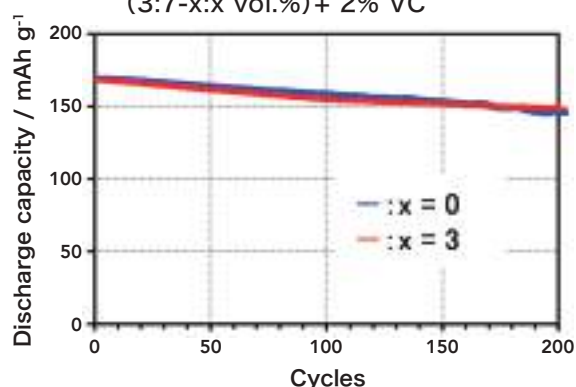
#### Oxidation resistance (Pt/Li/Li)

1.0 mol/L  $\text{LiPF}_6$  / EC+EMC+TFEP  
(3:7-x:x vol.%)



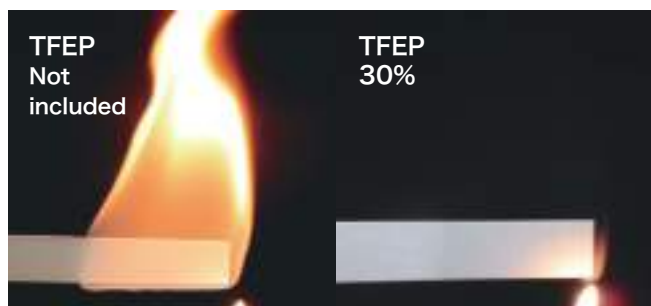
#### Charge/discharge cycle (NCM/C)

2.75-4.35V, 0.5C  
1.0 mol/L  $\text{LiPF}_6$  / EC+EMC+TFEP  
(3:7-x:x vol.%) + 2% VC

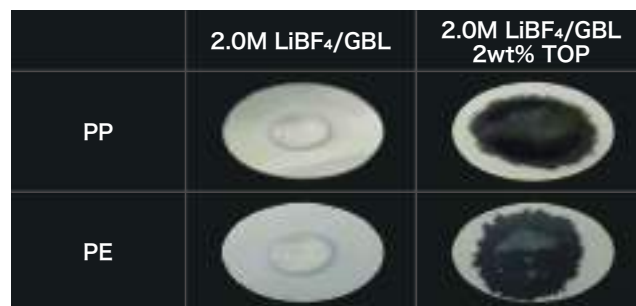


## Phosphate ester properties: Electrolyte properties and battery performance

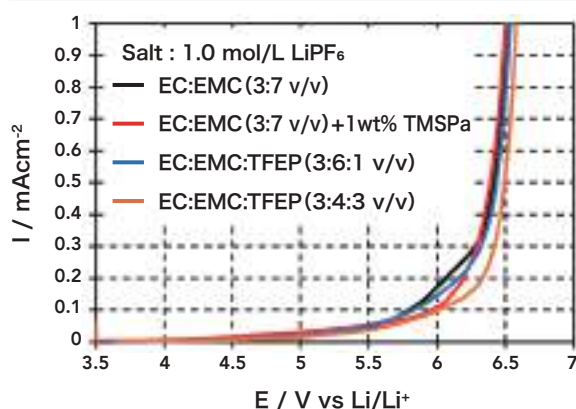
#### Combustibility



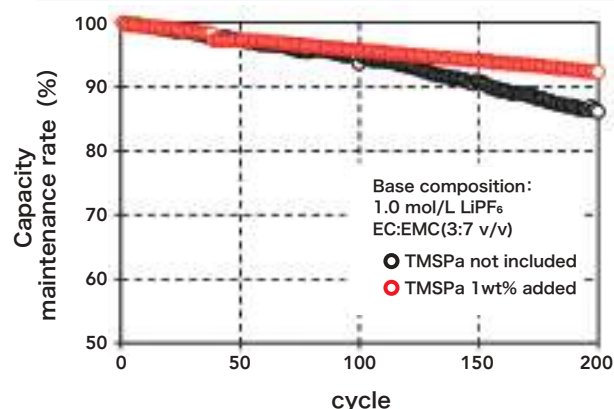
#### Improvement of separator wettability



#### Oxidation resistance (Pt, Scan rate 5.0mV/sec)



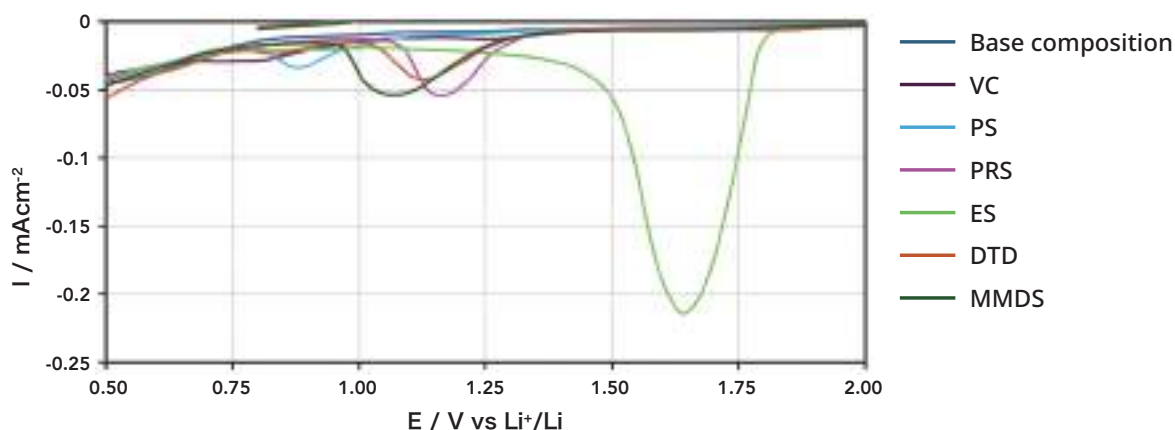
#### Cycle characteristics (NCM523/graphite 2.75-4.35V 1C)



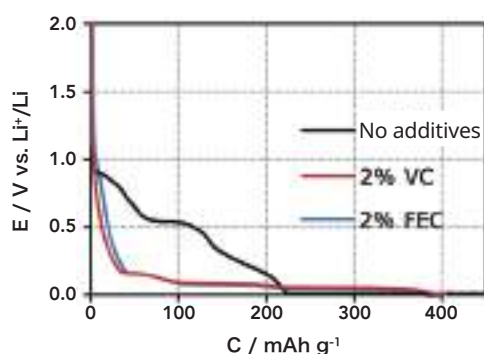
## Organosulfur compound: Electrochemical properties

### Reduction behavior

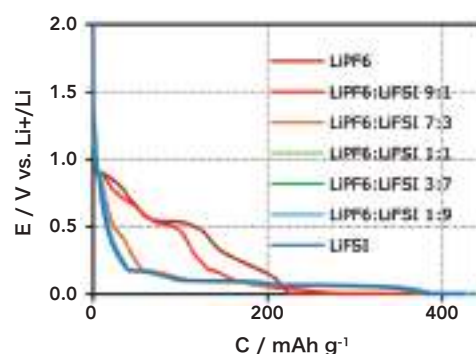
Cyclic voltammetry Working electrode: artificial graphite, Counter electrode: metallic lithium,  
Base composition: 1.0 mol/L  $\text{LiPF}_6$ /EC:EMC(3:7 v/v%)  
Additive : 1wt% Scan rate: 0.1 mV/sec



Anode half-cell, initial charge curve  
Anode: pitch-coated natural graphite  
Rate: 0.1C  
Electrolyte solution: 1.0 mol/L  $\text{LiPF}_6$  /  
SL:EMS (7:3wt.%)

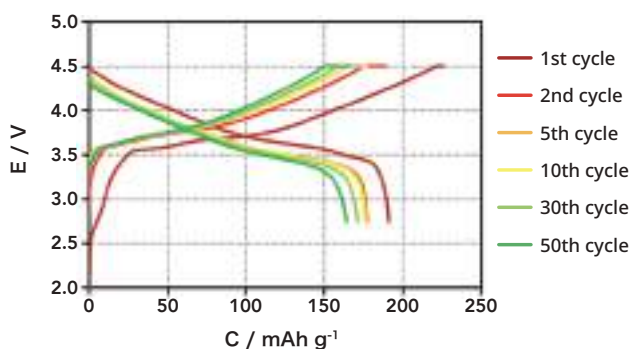


Anode half-cell, initial charge curve  
Anode: pitch-coated natural graphite  
Rate: 0.1C  
Electrolyte solution: 1.0 mol/L Li Salt /  
SL:EMS (7:3wt.%)



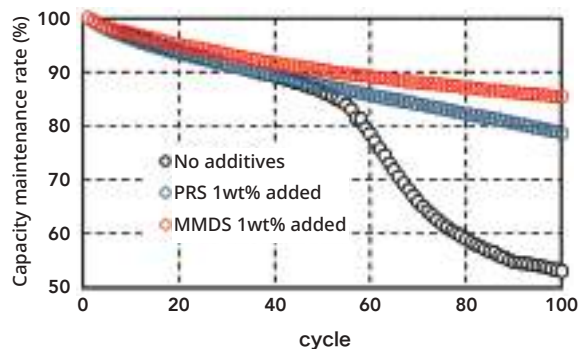
### Cycle characteristics

Cathode: NCM523, Anode: natural graphite  
Electrolyte solution: 1.0 mol/L  $\text{LiPF}_6$  / SL:EMS (7:3wt.%)  
Additive: 1wt% FEC  
Charge/discharge: CCCV charge 4.5V, CC discharge 2.75V  
Rate: 1st cycle 0.1C, 2nd cycle to 1C



### Cycle characteristics

Cathode: Lithium cobaltate, Anode: artificial graphite  
Electrolyte solution: 1.0 mol/L  $\text{LiPF}_6$ /EC:DMC:EMC (3:4:3 v/v%)  
Additive 1wt.%  
CCCV charge 4.45V, CC discharge 2.75V  
Charge/discharge rate 0.2C

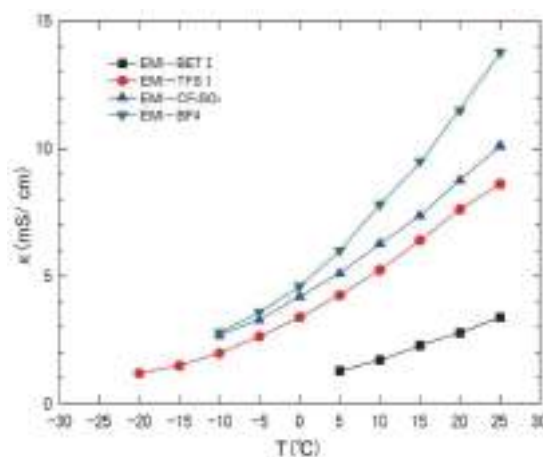
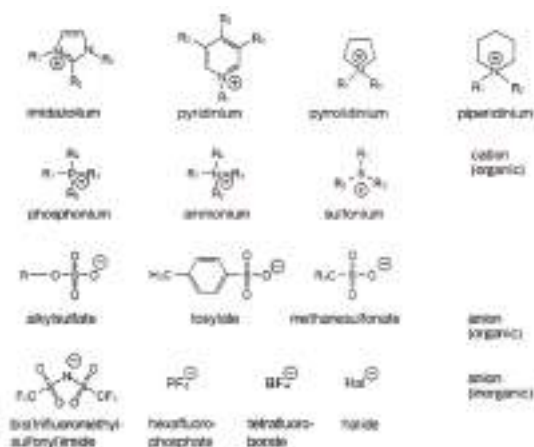


## Ionic Liquids

Physical and electrochemical properties of imidazolium (EMI) based ILs (25°C)

| Ionic Liquid                           | mp(°C) | d(g/cm <sup>3</sup> ) | $\eta$ (cP) | $\kappa$ (mS/cm) | Voltage window* |         |
|----------------------------------------|--------|-----------------------|-------------|------------------|-----------------|---------|
|                                        |        |                       |             |                  | E red(V)        | E ox(V) |
| EMI-BF <sub>4</sub>                    | 15     | 1.29                  | 34          | 13.8             | 1               | 5.5     |
| EMI-CF <sub>3</sub> SO <sub>3</sub>    | -10    | 1.39                  | 43          | 9.3              | 1               | 5.3     |
| EMI-TFSI                               | -15    | 1.51                  | 28          | 8.6              | 1               | 5.7     |
| EMI-BETI                               | -1     | ND                    | 61          | 3.4              | 0.9             | 5.8     |
| EMI-(HF) <sub>2</sub> , <sub>3</sub> F | -90    | 1.14                  | 5           | 100              | 1.5             | 5.3     |

\* WE:GC,RE:Li,CE:Li(1mA/cm<sup>2</sup>,20mV/s)



### Flammability (EMI-TFSI)



### Wetting of PP microporous membrane

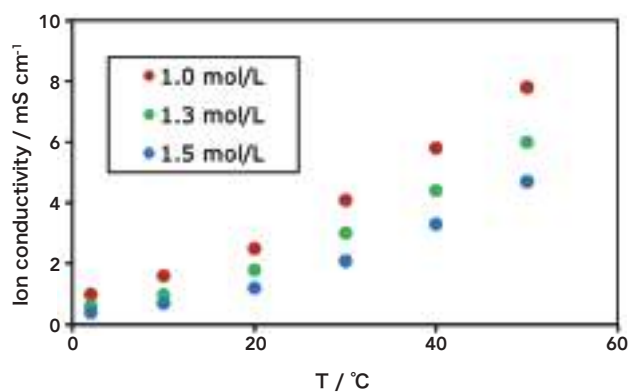
1.0 mol/L LiTFSI in EMI-TFSI:HFE-347pc-f

10:0      9:1      7:3      5:5wt. %



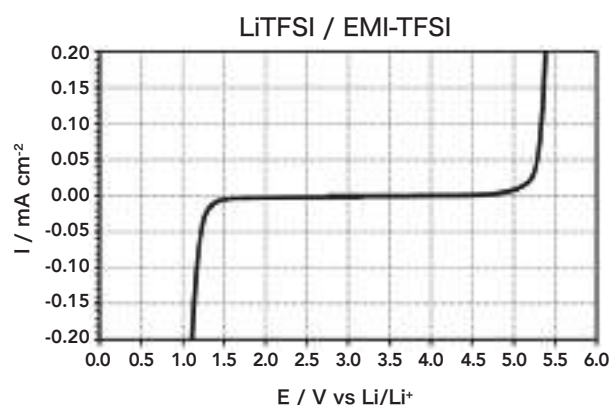
### Ion conductivity

LiTFSI / EMI-TFSI



### LSV

Working electrode: Pt, Counter electrode: Li,  
Reference electrode: Li  
Scan rate: 5 mV/sec



## Characteristics of FSI-based ionic liquids

## FSI-based ionic liquids

(Manufacturer: Daiichi Kogyo Seiyaku Co., Ltd.)

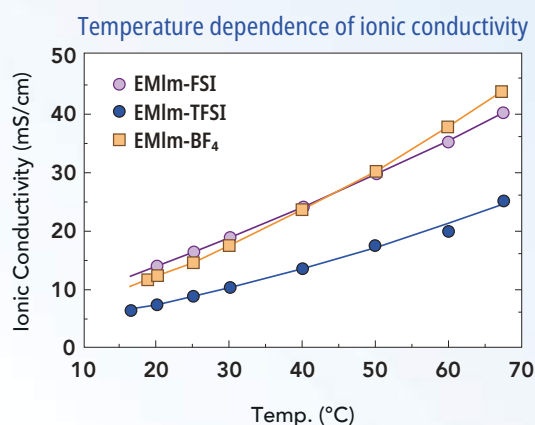
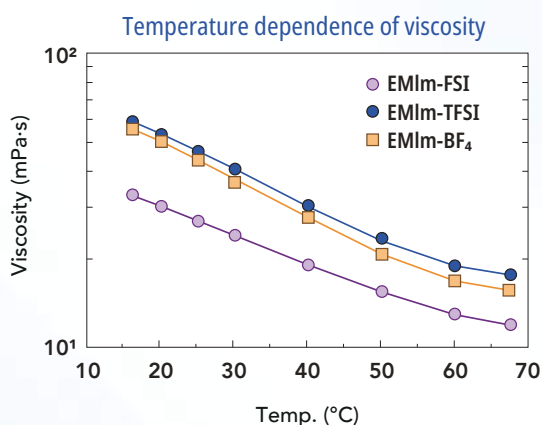
Bis (fluorosulfonyl) imide-based ionic liquids

KISHIDA CHEMICAL

Low viscosity

High ionic conductivity

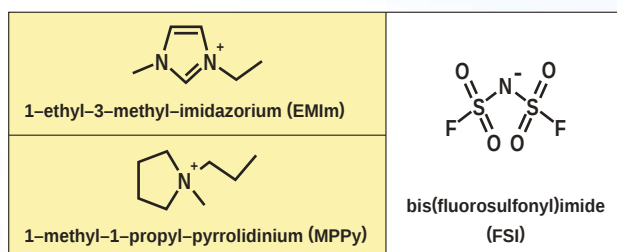
Hydrophobic

Low viscosity and high ionic conductivity compared to TFSI and BF<sub>4</sub> types

For rechargeable batteries, electric double-layer capacitors,  
and dye-sensitized solar cell devices

| Trade name                | EMIIm-FSI | MPPy-FSI |
|---------------------------|-----------|----------|
| Density (g/ml)*           | 1.44      | 1.34     |
| Melting point (°C)*       | -12.9     | -17.5    |
| Viscosity (mPa·s)*        | 17.0      | 39.3     |
| Ion conductivity (mS/cm)* | 16.5      | 8.3      |
| Thermal stability (TG 5%) | 225       | 219      |

\*25°C



Packaging size: 25g, 100g Please contact us for bulk sales

FSI-based ionic liquids are attracting attention for various energy device applications

## Characteristics of FSI-based ionic liquids

The combination of LiTFSI/LiFSI and FSI-based ionic liquids suppresses the interface resistance with the electrode and brings out the cycle characteristics

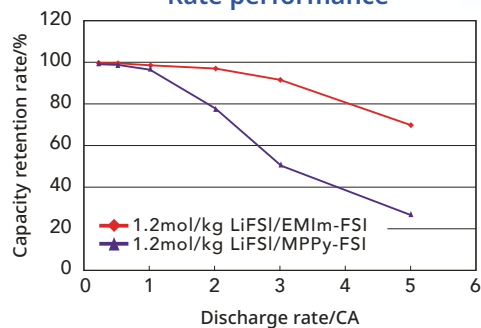
### Battery configuration

Stacked laminated cells  
Cathode: three-dimensional LNMC Ni:Co:Mn=1:1:1  
Anode: surface modified natural graphite  
Electrolyte solution: 1.2 mol/kg LiFSI/EMIm-FSI and MPPy-FSI

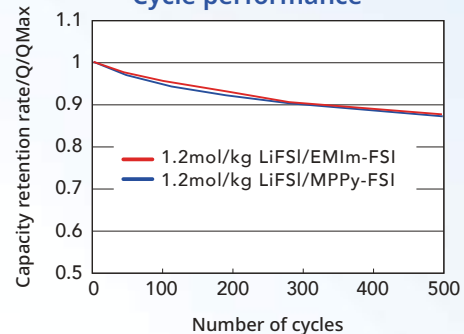
### Trial conditions

25°C 1C, CC-CV 4.2 charge, 2.7V discharge

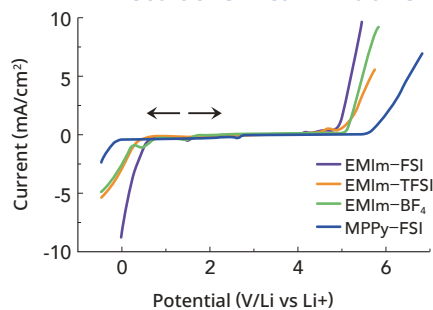
### Rate performance



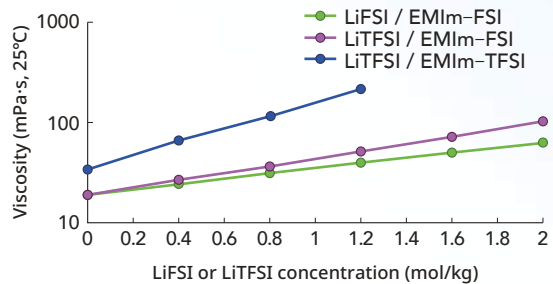
### Cycle performance



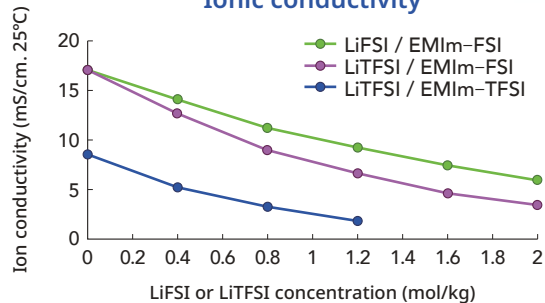
### Electrochemical windows



### Viscosity

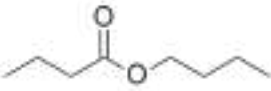
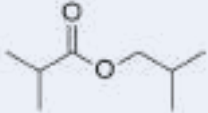
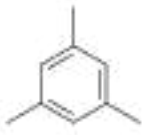
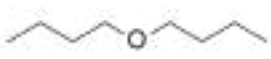


### Ionic conductivity



## Solvents for wet coating of all-solid-state batteries

## Moisture-controlled solvent with low reactivity against sulfide-based solid electrolytes

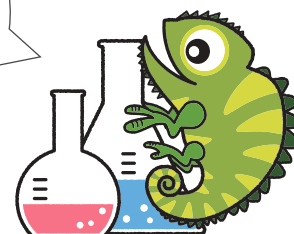
| Product range                      |                                                                                     |          |             |          |              |
|------------------------------------|-------------------------------------------------------------------------------------|----------|-------------|----------|--------------|
| Product name                       | Structure                                                                           | Moisture | Purity (GC) | Contents | Product code |
|                                    | CAS No.                                                                             |          |             |          |              |
| <i>n</i> -Butyl <i>n</i> -butyrate |    | ≤30ppm   | ≥99.0%      | 500ml    | LBG-11155    |
|                                    | 109-21-7                                                                            |          |             |          |              |
| Isobutyl isobutyrate               |    | ≤30ppm   | ≥98.0%      | 500ml    | LBG-40345    |
|                                    | 97-85-8                                                                             |          |             |          |              |
| Mesitylene                         |   | ≤30ppm   | ≥98.0%      | 500ml    | LBG-80545    |
|                                    | 108-67-8                                                                            |          |             |          |              |
| Anisole                            |  | ≤30ppm   | ≥99.0%      | 500g     | LBG-05115    |
|                                    | 100-66-3                                                                            |          |             |          |              |
| Di- <i>n</i> -butyl ether          |  | ≤30ppm   | ≥99.5%      | 500ml    | LBG-22305    |
|                                    | 142-96-1                                                                            |          |             |          |              |
| <i>n</i> -heptane                  |  | ≤30ppm   | ≥99.0%      | 500ml    | LBG-36230    |
|                                    | 142-82-5                                                                            |          |             |          |              |

## Metal impurities: reference values

|    |        |    |        |
|----|--------|----|--------|
| K  | ≤1 ppm | Cu | ≤1 ppm |
| Na | ≤1 ppm | Al | ≤1 ppm |
| Mg | ≤1 ppm | Ni | ≤1 ppm |
| Ca | ≤1 ppm | Mn | ≤1 ppm |
| Fe | ≤1 ppm | Pb | ≤1 ppm |

Actual values, not guaranteed values

We are  
working to  
expand our  
product range!



# LITHIUM BATTERY GRADE

KISHIDA CHEMICAL

## LITHIUM BATTERY GRADE

[ For production ]

Production is carried out in a factory certified to the international standards ISO 9001 (quality) and ISO 14001 (environment).

In response to the growing and diversifying demand for lithium-ion batteries in expanding markets, we have established a system to supply our customers with materials for use in their development and production lines.

We are striving to improve the quality of our products and services and contribute to your production activities by responding to requests for specification documents, audits, and long-term storage of records.

*We can produce the solvents of your choice with low-moisture specifications.*



### L-Solve™ — Solvents — Examples

| Product      | Purity/% | Moisture/ppm | Contents | Container     | Liquid side plug | Gas side plug |
|--------------|----------|--------------|----------|---------------|------------------|---------------|
| EC           | ≥99.5    | ≤30          | 18kg     | 18L canister  | SUS 304 2P       | SUS 304 1P    |
| DMC          | ≥99.5    | ≤30          | 18kg     | 18L canister  | SUS 304 2P       | SUS 304 1P    |
| DMC          | ≥99.5    | ≤30          | 200kg    | 18L canister  | SUS 304 2P       | SUS 304 1P    |
| EMC          | ≥99.5    | ≤30          | 18kg     | 18L canister  | SUS 304 2P       | SUS 304 1P    |
| EMC          | ≥99.5    | ≤30          | 200kg    | 200L canister | SUS 304 4P       | SUS 304 2P    |
| DEC          | ≥99.5    | ≤30          | 18kg     | 18L canister  | SUS 304 2P       | SUS 304 1P    |
| DEC          | ≥99.5    | ≤30          | 200kg    | 200L canister | SUS 304 4P       | SUS 304 2P    |
| Acetonitrile | ≥99.5    | ≤30          | 18L      | 18L canister  | SUS 304 2P       | SUS 304 1P    |
| Acetonitrile | ≥99.5    | ≤30          | 200L     | 200L canister | SUS 304 4P       | SUS 304 2P    |
| NMP          | ≥99.5    | ≤100         | 18kg     | 18L canister  | SUS 304 2P       | SUS 304 1P    |

SUS = stainless steel

#### 18L canister (Specification 1)



#### 20L canister



#### 18L canister (Specification 2)



#### 200L canister



## L-Solve™ — Electrolyte Solutions — Examples

| Electrolyte       | Concentration | Solvent           |
|-------------------|---------------|-------------------|
| LiPF <sub>6</sub> | ~35%          | Chain carbonate   |
| LiPF <sub>6</sub> | ~15%          | Carbonate mixture |
| LiTFSI            | ~20%          | Carbonate, ether  |
| and more...       |               |                   |

| Container specification | Filled gas           | Liquid side plug | Gas side plug |
|-------------------------|----------------------|------------------|---------------|
| 18L container           | Ar or N <sub>2</sub> | SUS 304 2P       | SUS 304 1P    |
| 20L container           | Ar or N <sub>2</sub> | SUS 304 2P       | SUS 304 1P    |
| 200L container          | N <sub>2</sub>       | SUS 304 2P       | SUS 304 1P    |

SUS = stainless steel

### Analysis items - examples

Moisture

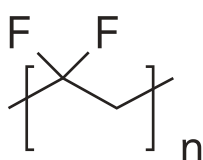
Free acid

Color (APHA)

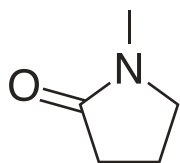
Metal impurities

## L-Solve™ — Binders — Examples

### PVDF/NMP solution



PVDF



NMP



| Polymer             | Concentration | Moisture   | Contents | Container     |
|---------------------|---------------|------------|----------|---------------|
| Your requested item | 5-8%          | Negotiable | 20kg     | PE jerrycan   |
|                     |               |            | 200kg    | Chemi Drum    |
|                     |               |            | 1000kg   | SUS Container |

SUS = stainless steel



PE jerrycan



Chemi Drum

# CAPACITOR GRADE

KISHIDA CHEMICAL

## CAPACITOR

**For research and development**

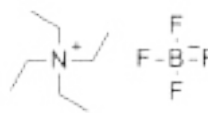
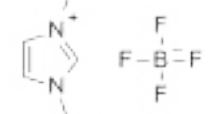
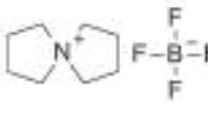
We offer a range of reagents for electric double layer capacitor (EDLC) applications.

EDLCs have higher capacitance than laminated ceramic capacitors and aluminum electrolytic capacitors, and better characteristics than lithium-ion batteries in terms of rapid charge-discharge, long-term reliability, and safety, so they continue to be used even now, a quarter of a century after their commercialization.

We will continue to provide EDLC materials.



## Capacitor Grade — Electrolytes

| Product name                                                                                                                               | Abbreviation [Formula]<br>Structure                                                                                                                                           | Molecular<br>weight<br>(g/mol) | Specification     |               | Contents | Product code |
|--------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|-------------------|---------------|----------|--------------|
|                                                                                                                                            | CAS RN®                                                                                                                                                                       |                                | Moisture<br>(ppm) | Purity<br>(%) |          |              |
| Tetraethylammonium<br>tetrafluoroborate<br><br>           | TEABF <sub>4</sub> [(CH <sub>3</sub> CH <sub>2</sub> ) <sub>4</sub> NBF <sub>4</sub> ]<br>   | 217.1                          | ≤50               | ≥99.9         | 500g     | CPG-92435    |
|                                                                                                                                            | 429-06-1                                                                                                                                                                      |                                |                   |               |          |              |
| 1-Ethyl-3-methylimidazolium<br>tetrafluoroborate<br><br>  | EMI-BF <sub>4</sub> [(CH <sub>3</sub> CH <sub>2</sub> ) <sub>4</sub> NBF <sub>4</sub> ]<br>  | 197.97                         | —                 | —             | 25g      | ILD-28622    |
|                                                                                                                                            | 143314-16-3                                                                                                                                                                   |                                |                   |               |          |              |
| 1-Butyl-3-methylimidazolium<br>tetrafluoroborate<br><br> | BMI-BF <sub>4</sub> [(CH <sub>3</sub> CH <sub>2</sub> ) <sub>4</sub> NBF <sub>4</sub> ]<br> | 226.02                         | —                 | —             | 25g      | ILD-12722    |
|                                                                                                                                            | 174501-65-6                                                                                                                                                                   |                                |                   |               |          |              |
| 5-Azoniaspiro[4.4]nonane<br>tetrafluoroborate<br><br>   | SBP-BF <sub>4</sub> [(C <sub>4</sub> H <sub>8</sub> ) <sub>2</sub> NBF <sub>4</sub> ]<br>  | 213.02                         | —                 | —             | 25g      | CPG-75422    |
|                                                                                                                                            | 129211-47-8                                                                                                                                                                   |                                |                   |               |          |              |

## Capacitor Grade — Electrolyte Solutions

| Product name                                                                   | Contents | Code      | Container |
|--------------------------------------------------------------------------------|----------|-----------|-----------|
| 1 mol/L [(CH <sub>3</sub> CH <sub>2</sub> ) <sub>4</sub> NBF <sub>4</sub> ] PC | 1kg      | CPG-00005 | PE        |
| 1 mol/L [(CH <sub>3</sub> CH <sub>2</sub> ) <sub>4</sub> NBF <sub>4</sub> ] AN | 1L       | CPG-00101 | PE        |
| 1 mol/L EMI-BF <sub>4</sub> PC                                                 | 1kg      | ILD-00007 | PE        |
| 1 mol/L SPB-BF <sub>4</sub> AN                                                 | 1L       | CPG-00197 | SUS       |
| 1.5 mol/L SPB-BF <sub>4</sub> AN                                               | 1L       | CPG-00198 | SUS       |
| 1.5 mol/L SPB-BF <sub>4</sub> PC                                               | 1kg      | CPG-00199 | SUS       |

SUS = stainless steel

## Current Collector and Electrolyte Solution

### Current collector

In EDLCs, **aluminum (Al) foil** is used in both the cathode and anode. The Al current collector is **etched** by anodic oxidation to increase its surface area and improve current collection efficiency. The quality of the contact between the current-collecting Al foil and the activated carbon layer largely governs the internal resistance of the entire electrode. Another method to increase current collection efficiency is to apply a thin layer of conductive paste (called **primer**) to the Al current collection foil and crimp activated carbon at high temperature to ensure high conductivity.

### Electrolyte Solution

Electrolytes for EDLC must exhibit high dissociation and high solubility in solvents.

LIBs have Li<sup>+</sup> on either the cathode or anode, and the electrolyte solution corresponds to the path taken, but in EDLCs the electrolyte solution itself is the ion source rather than the electrode. Therefore, it is necessary to increase the number and carrier density of ions as much as possible. In other words, high dissociation and solubility are required.

To improve dissociation and solubility, a lower ion charge density is desirable.

- ① The ionic radius must be increased to some extent. [Typical examples] **Et<sub>4</sub>NBF<sub>4</sub>**, **Et<sub>4</sub>NN(SO<sub>2</sub>CF<sub>3</sub>)<sub>2</sub>**

However, if the ionic radius is larger than necessary, the inter-ion distance cannot be kept, and the degree of dissociation is reduced.

The activated carbon used in EDLC electrodes has a narrow pore distribution targeting specific adsorption ions, so the use of ions slightly larger than the optimal ion diameter for the electrode can result in a significant drop in capacity.

- ② Another key point for ionic structure is asymmetry. Introducing asymmetry in the ionic structure can result in a decrease in crystallization enthalpy and therefore higher solubility. [Typical examples] **Et<sub>3</sub>MeNBF<sub>4</sub>**, **Et<sub>3</sub>MeN(SO<sub>2</sub>CF<sub>3</sub>)<sub>2</sub>**
- ③ Spiro compounds also have high solubility, dissociation, and mobility. In particular, **SBP** with two five-membered rings shows high conductivity.

Spiro compounds have a more compact structure than acyclic compounds with the same number of carbon atoms, and therefore tend to have higher mobility and solubility.

## Higher energy density due to higher withstand voltage

A high-voltage approach is essential for high energy density in EDLCs. The current EDLC withstand voltage limit of 2.7V is largely due to the decomposition of the solvent on the activated carbon surface, so a solvent with a higher withstand voltage than the conventional PC solvent is required.

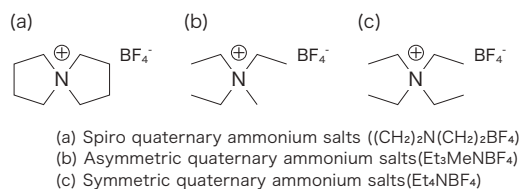
Sulfone compounds such as SL have been proposed to meet these requirements, and electrolyte solutions using SL have reached withstand voltages of 3.3V or higher and have been industrialized.

However, since this solvent is somewhat poor for electrolyte solubility, only asymmetric quaternary ammonium salt (TEMA-BF<sub>4</sub>) or spiro quaternary ammonium salt (SBP-BF<sub>4</sub>) systems have been reported. On the other hand, the use of ionic liquids as electrolytes for EDLCs is also being considered. Ionic liquids are liquids in which cations and anions exist in a bonded state, and have various characteristics such as flame resistance, non-volatility, and high ionic conductivity.

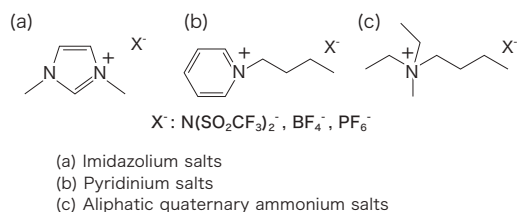
Imidazolium salts, pyridinium salts, and aliphatic quaternary ammonium salts are commonly used as cation components, while typical anion components include inorganic ions such as BF<sub>4</sub><sup>-</sup> and PF<sub>6</sub><sup>-</sup> and fluorine-containing organic anions such as CF<sub>3</sub>SO<sub>3</sub><sup>-</sup> and (CF<sub>3</sub>SSO<sub>2</sub>)<sub>2</sub>N<sup>-</sup>. Since ionic liquids have a wide potential window, using them as electrolyte solutions for EDLCs will broaden the working voltage.

The potential window of the ionic liquid announced by Nisshinbo is about 6.0V (-3.0 to +3.0 vs. Ag/AgCl), enabling EDLC rated working voltage to be widened from 2.5V to 3.0V, and the internal resistance has also been suppressed, achieving an energy density of 10.7Wh/L and output density of 10.8kW/L.

### Electrolytes for capacitors



### Ionic liquid electrolyte solutions for capacitors



## Increased energy density for next generation capacitors

$$\text{Energy Density } E = 1/2 \times \text{Capacitance } C \times (\text{Operating Voltage } V)^2$$

Current electrode capacity : 100 ~ 140 F/g

Higher capacity

### Next-generation nanocarbons (electrode materials)

◆ CNT  
◆ MPC  
◆ ACMFC

60~283 F/g

### Metal oxides (electrode materials)

◆ Ruthenium (IV) oxide ( $\text{RuO}_2$ )  
◆ Manganese (II) oxide ( $\text{MnO}_2$ )  
◆ Nickel (II) oxide ( $\text{NiO}$ )

300~1,220 F/g

### Conductive polymers (electrode materials)

◆ Polyaniline  
◆ 1,5-Diaminoanthraquinone  
◆ Cyclic indole trimer  
◆ Poly (3-methylthiophene)

135~250 F/g

Current operating voltage : 2.5 ~ 2.7 V

Higher working voltage

### Ionic liquids (electrolyte solutions)

■ Imidazolium salts  
■ Pyridinium salts  
■ Aliphatic quaternary ammonium salts

~3.0 V

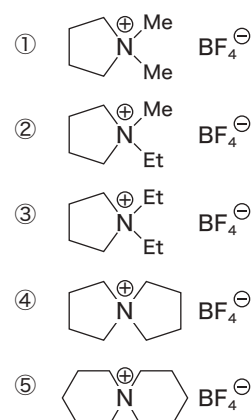
### Asymmetric electrode hybridization (cell configuration)

● Activated carbon cathode vs. graphite anode  
● Activated carbon cathode vs. amorphous carbon anode  
● Activated carbon cathode vs. lithium titanate anode ( $\text{Li}_4\text{Ti}_5\text{O}_{12}$ )  
● Polythiophene cathode vs. activated carbon anode

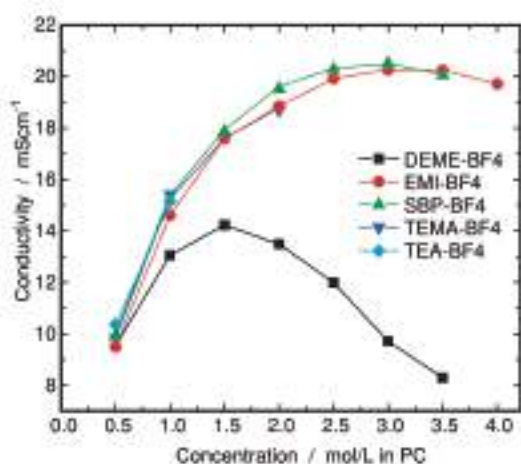
~4.2V

## Solubility of quaternary ammonium salts

| Electrolyte                                      | Solvent type mol/L (at 30°C) |     |     |     |
|--------------------------------------------------|------------------------------|-----|-----|-----|
|                                                  | EC                           | PC  | SL  | GBL |
| Me <sub>3</sub> EtNBF <sub>4</sub>               | —                            | 1.2 | —   | —   |
| Me <sub>2</sub> Et <sub>2</sub> NBF <sub>4</sub> | —                            | 2.9 | —   | —   |
| MeEt <sub>3</sub> NBF <sub>4</sub>               | 2.8 (40°C)                   | 2.1 | 1.9 | 2.7 |
| Et <sub>4</sub> NBF <sub>4</sub>                 | 1.6 (40°C)                   | 1.1 | 0.7 | 1.2 |
| MeEt <sub>3</sub> NPF <sub>6</sub>               | 2.4 (40°C)                   | 2.1 | 1.8 | 2.4 |
| Et <sub>4</sub> NPF <sub>6</sub>                 | 1.7 (40°C)                   | 1.4 | 1.2 | 1.5 |
| ① Pyrrolidinium type                             | —                            | 2.7 | —   | —   |
| ② As above                                       | —                            | 3.6 | —   | —   |
| ③ As above                                       | —                            | 2.6 | —   | —   |
| ④ Spiro bipyrrrolidinium type                    | 3.4 (40°C)                   | 3.6 | 3.7 | 4.0 |
| ⑤ Spiro biperidinium type                        | —                            | 2.6 | —   | —   |



## Relationship between molar concentration and electrical conductivity



### Example

TEMA-BF<sub>4</sub> : MW 203.07, mp 294°C (dec),  
2.1 mol/L (PC) - conductivity 18 mS/cm  
Eox +3.65V vs SCE  
Ered -3.00V vs SCE

### Comparison

- TEA-BF<sub>4</sub>  
1.1 mol/L (PC)-conductivity 15 mS/cm, 0.7 mol/L (SL)
- EMI-BF<sub>4</sub>  
6.6 mol/L (PC)-conductivity 15 mS/cm
- DEME-BF<sub>4</sub>  
5.1 mol/L (PC)-conductivity 15 mS/cm, 3.7 mol/L (SL)
- SBP-BF<sub>4</sub> Spiro- (1,1')-bipyrrolidinium-tetrafluoroborate  
3.6 mol/L (PC)

## EDLC constituents (mainly electrolyte solutions)

### Electrolytes

Quaternary ammonium salts (TEA-BF<sub>4</sub>, TEMA-BF<sub>4</sub>) have been the mainstream, but spiro salts have recently attracted attention. Spiro salts have high dissociation, high conductivity, and excellent low-temperature operating characteristics.

### Solvents

Basically consider in the same way as for LIB. EC is not necessary because the formation of SEI (Solid Electrolyte Interphase) needed for LIB is not necessary, but it is effective for inducing ion dissociation.

### Ionic liquids

Quaternary ammonium salts (TPMA-TFSI, DEME-BF<sub>4</sub>) and imidazolium salts (EMI), etc. Features: High solubility, high dissociation, disadvantageous when used as is due to high rate characteristics.

### Electrolyte Solution

Since EDLC operation at 3V is equivalent to operation of LIB at 4V or higher, electrolytes and solvents with excellent oxidation resistance are required for operation at **higher voltages**.

### Separator

Cellulose types are common. For durability and high temperature drying, glass fiber systems are also promising. Aramids are also promising due to their good compatibility with electrolyte solutions (the key is how to control the moisture content).

# NEXT GENERATION BATTERY

KISHIDA CHEMICAL

## NEXT-GENERATION STORAGE BATTERY

For research and development

Electrolyte solutions for lithium-based next-generation batteries utilize the same material composition as lithium-ion batteries, but the electrolyte must be changed if the charge carrier is changed.

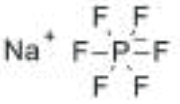
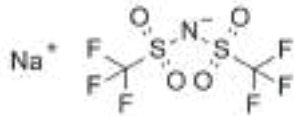
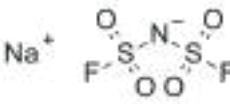
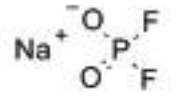
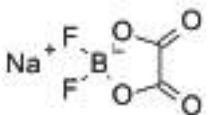
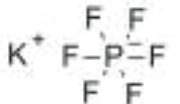
We offer a range of high quality electrolytes for batteries of various metal types and can assist your research with custom blending of electrolyte solutions.

We currently offer materials for sodium, potassium, magnesium, and calcium, and will continue to expand our lineup and improve



# NEXT-GENERATION STORAGE BATTERIES [ For research and development ]

## Next Generation Battery — Electrolytes

| Product name                                                                                                                                                                                                            | Abbreviation [Formula]<br>Structure<br>CAS No.                                                                                                                                     | Molecular<br>weight<br>(g/mol) | Specification     |               | Contents | Product code |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|-------------------|---------------|----------|--------------|
|                                                                                                                                                                                                                         |                                                                                                                                                                                    |                                | Moisture<br>(ppm) | Purity<br>(%) |          |              |
| Sodium<br>hexafluorophosphate<br>                     | [NaPF <sub>6</sub> ]<br>                                                                          | 167.95                         | ≤50               | ≥99.0         | 100g     | MBG-75191    |
|                                                                                                                                                                                                                         | 21324-39-0                                                                                                                                                                         |                                |                   |               |          |              |
| Sodium<br>bis(trifluoromethanesulfonyl)imide<br>      | NaTFSI [NaN(SO <sub>2</sub> CF <sub>3</sub> ) <sub>2</sub> ]<br>                                  | 304.14                         | ≤0.1%             | ≥99.5         | 25g      | MBG-53222    |
|                                                                                                                                                                                                                         | 91742-21-1                                                                                                                                                                         |                                |                   |               |          |              |
| Sodium<br>bis(fluorosulfonyl)imide<br>              | NaFSI [NaN(SO <sub>2</sub> F) <sub>2</sub> ]<br>                                                 | 203.12                         | ≤0.05%            | ≥99.0         | 100g     | MBG-75671    |
|                                                                                                                                                                                                                         | 100669-96-3                                                                                                                                                                        |                                |                   |               |          |              |
| Sodium<br>difluorophosphate<br><br><i>Test sales product. Contains insoluble matter.</i>                                                                                                                                | NaDFP [NaPO <sub>2</sub> F <sub>2</sub> ]<br>                                                   | 123.96                         | —                 | —             | 25g      | 060-Q0466    |
|                                                                                                                                                                                                                         | 15587-24-3                                                                                                                                                                         |                                |                   |               |          |              |
| Sodium<br>difluoro(oxalato)borate<br><br><i>Test sales product. Contains insoluble matter.</i>                                                                                                                          | NaDFOB [NaBF <sub>2</sub> C <sub>2</sub> O <sub>4</sub> ]<br>                                   | 159.82                         | —                 | —             | 25g      | 060-Q0464    |
|                                                                                                                                                                                                                         | 1016545-84-8                                                                                                                                                                       |                                |                   |               |          |              |
| Potassium<br>hexafluorophosphate<br>                                                                                                 | [KPF <sub>6</sub> ]<br>                                                                         | 184.06                         | ≤100              | ≥95.0         | 25g      | MBG-61652    |
|                                                                                                                                                                                                                         | 17084-13-8                                                                                                                                                                         |                                |                   |               |          |              |
| Magnesium<br>bis(trifluoromethylsulfonyl)imide                                                                                                                                                                          | Mg(TFSI) <sub>2</sub> [Mg[N(SO <sub>2</sub> CF <sub>3</sub> ) <sub>2</sub> ] <sub>2</sub> ]<br> | 584.6                          | ≤0.1%             | —             | 100g     | MBG-48591    |
|                                                                                                                                                                                                                         | 133395-16-1                                                                                                                                                                        |                                |                   |               |          |              |
| Calcium<br>bis(trifluoromethylsulfonyl)imide<br>  | Ca(TFSI) <sub>2</sub> [Ca[N(SO <sub>2</sub> CF <sub>3</sub> ) <sub>2</sub> ] <sub>2</sub> ]<br> | 600.37                         | ≤0.1%             | —             | 25g      | MBG-14732    |
|                                                                                                                                                                                                                         | 165324-09-4                                                                                                                                                                        |                                |                   |               |          |              |

## Next Generation Battery — Electrolyte solutions

| Product name                                     | Contents | Container | Product code |
|--------------------------------------------------|----------|-----------|--------------|
| 1 mol/L NaPF <sub>6</sub> PC                     | 100g     | PE        | MBG-00074    |
|                                                  | 500g     | SUS       | MBG-00073    |
| 1 mol/L NaPF <sub>6</sub> + 0.2 mol/L NaFSI / PC | 100g     | PE        | MBG-00219    |
| 1 mol/L NaPF <sub>6</sub> PC:DMC (1:1 v/v%)      | 100g     | PE        | MBG-00103    |
| 1 mol/L NaPF <sub>6</sub> EC:PC (1:1 v/v%)       | 100g     | PE        | MBG-00144    |
|                                                  | 500g     | SUS       | MBG-00272    |
| 1 mol/L NaPF <sub>6</sub> EC:DEC (1:1 v/v%)      | 100g     | PE        | MBG-00079    |
|                                                  | 500g     | SUS       | MBG-00070    |
| 1 mol/L NaTFSI PC                                | 500g     | PE        | MBG-00049    |
| 1 mol/L NaTFSI AN                                | 500g     | PE        | MBG-00051    |
| 1 mol/L NaFSI DME                                | 100g     | PE        | MBG-00287    |
| 5 mol/L NaFSI DME                                | 100g     | PE        | MBG-00273    |
| 0.7 mol/L KPF <sub>6</sub> EC:DEC (1:1 v/v%)     | 1kg      | SUS       | MBG-00268    |
| 0.5 mol/L Mg(TFSI) <sub>2</sub> DME              | 100mL    | PE        | MBG-00160    |
| 0.5 mol/L Ca(TFSI) <sub>2</sub> AN               | 100mL    | PE        | MBG-00055    |

SUS = stainless steel

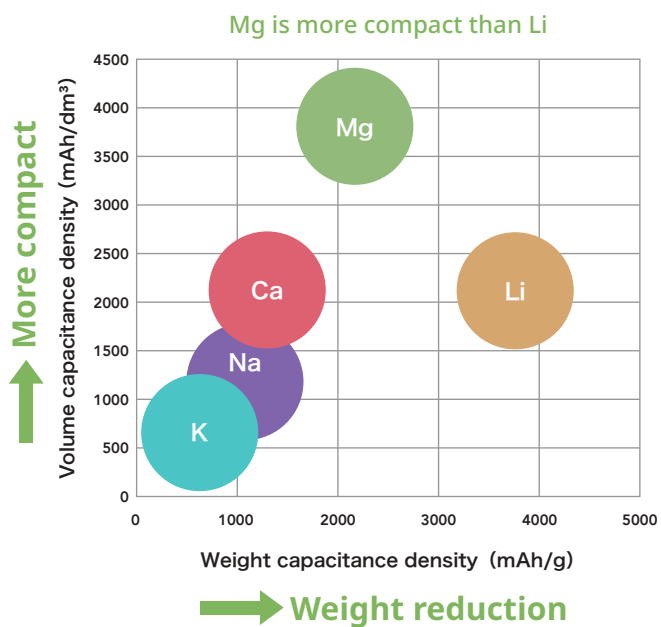
## Metal cation characteristics

Characteristics of metal ions used as driving ions

|    | Valence | Battery voltage (predicted) /V | Ionic radius Å | Reserves |
|----|---------|--------------------------------|----------------|----------|
| Li | 1       | $\geq 3$                       | 0.60           | 20ppm    |
| Ca | 2       | 2 — 3                          | 0.99           | 4.15%    |
| Mg | 2       | 1 — 2                          | 0.65           | 2.33%    |

Standard electrode potential (25°C)  
 $E_0$ : Oxidation-reduction potential

| Greater ionization tendency ↑ | Electrode                    | Electrode reaction                                          | $E_0$ (V) |
|-------------------------------|------------------------------|-------------------------------------------------------------|-----------|
|                               | $\text{Li}^+   \text{Li}$    | $\text{Li}^+ + \text{e}^- \rightleftharpoons \text{Li}$     | - 3.045   |
|                               | $\text{Ca}^{2+}   \text{Ca}$ | $\text{Ca}^{2+} + 2\text{e}^- \rightleftharpoons \text{Ca}$ | - 2.840   |
|                               | $\text{Na}^+   \text{Na}$    | $\text{Na}^+ + \text{e}^- \rightleftharpoons \text{Na}$     | - 2.714   |
|                               | $\text{Mg}^{2+}   \text{Mg}$ | $\text{Mg}^{2+} + 2\text{e}^- \rightleftharpoons \text{Mg}$ | - 2.363   |

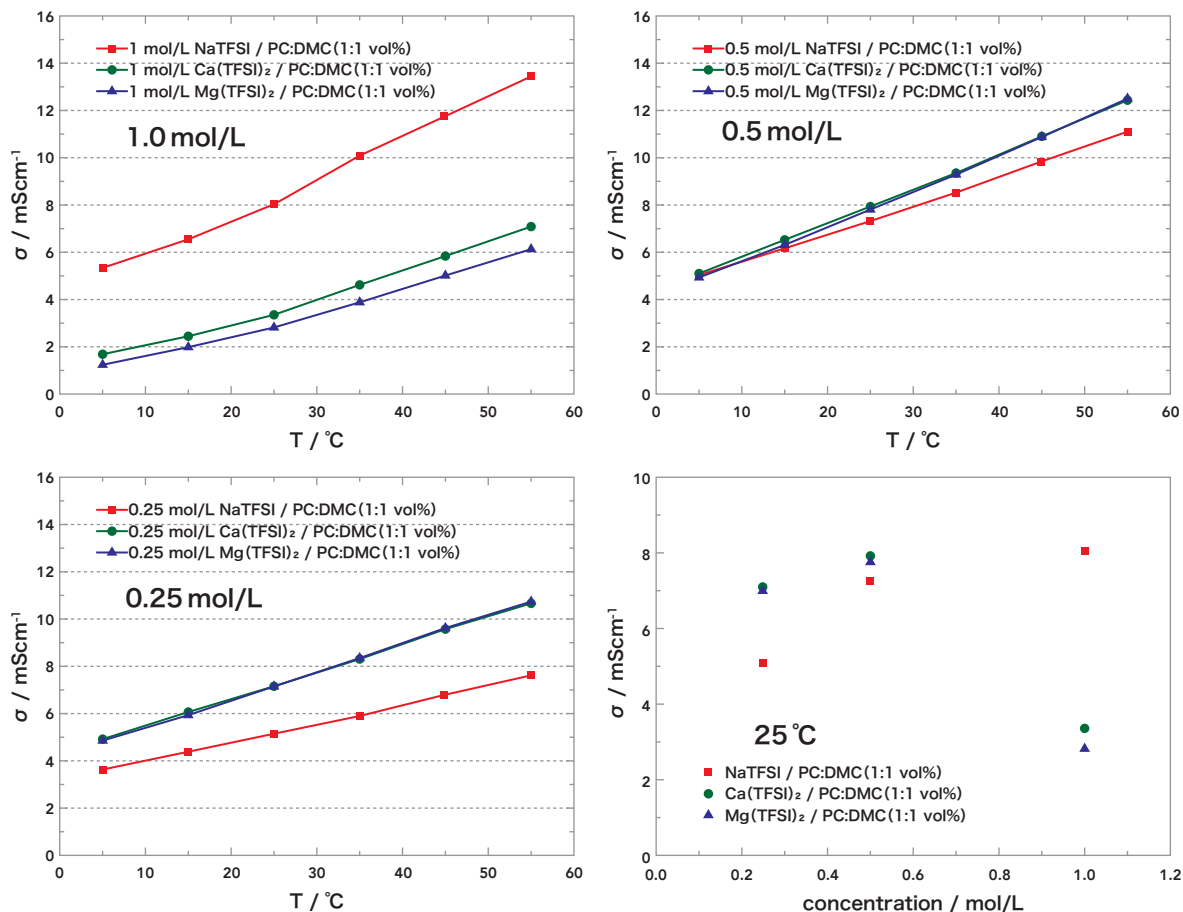


## Solubility in solvents (as electrolyte solution)

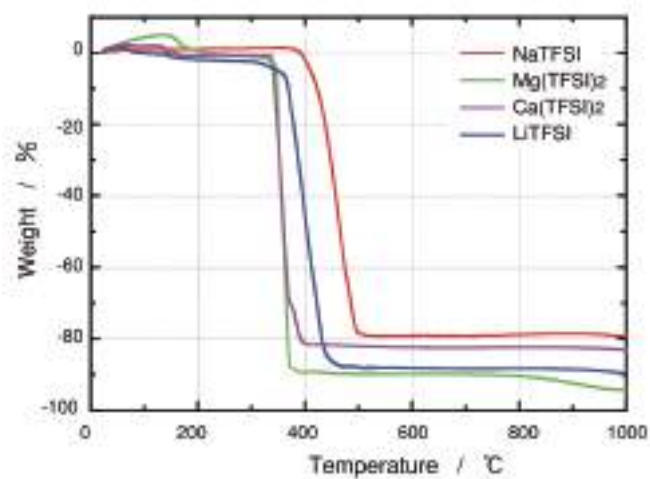
| Solvent type | $\text{Mg}(\text{TFSI})_2$ | $\text{Ca}(\text{TFSI})_2$ | $\text{NaTFSI}$ |
|--------------|----------------------------|----------------------------|-----------------|
| PC           | ○                          | ○                          | ○               |
| DMC          | ○                          | ○                          | ○               |
| DME          | ○                          | ×                          | ○               |
| GBL          | ○                          | ○                          | ○               |
| DOL          | ×                          | ×                          | ○               |
| AN           | ○                          | ○                          | ○               |
| MA           | ○                          | ○                          | ○               |
| MP           | ○                          | ○                          | ○               |
| DMF          | ○                          | ○                          | ○               |

○ indicates 1 mol/L concentration

## Metal cation characteristics



## Thermal decomposition of TFSI-based electrolytes



Decomposition temperature ranking (highest to lowest)

$\text{NaTFSI} > \text{LiTFSI} > \text{Mg}(\text{TFSI})_2, \text{Ca}(\text{TFSI})_2$

# NEXT-GENERATION STORAGE BATTERIES [ For research and development ]

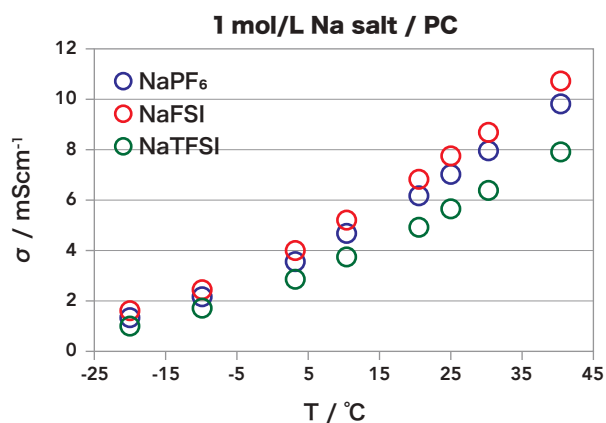
## Ionic conductivity

1.0 mol/L Na salt / PC, 25°C

NaPF<sub>6</sub> 7.0 mS/cm

NaTFSI 5.6 mS/cm

NaFSI 7.7 mS/cm



## LSV

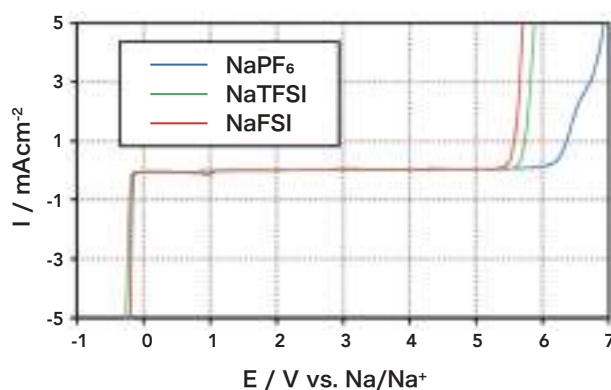
Working electrode : Pt

Counter electrode : Na metal

Reference electrode : Na metal

Sweep speed : 5 mV/sec

Electrolyte solution : 1.0 mol/L Na salt / PC



## Separator wettability (1.0 mol/L NaPF<sub>6</sub> PC)



Glass fiber

Cellulose

PTFE

Alumina coated PE

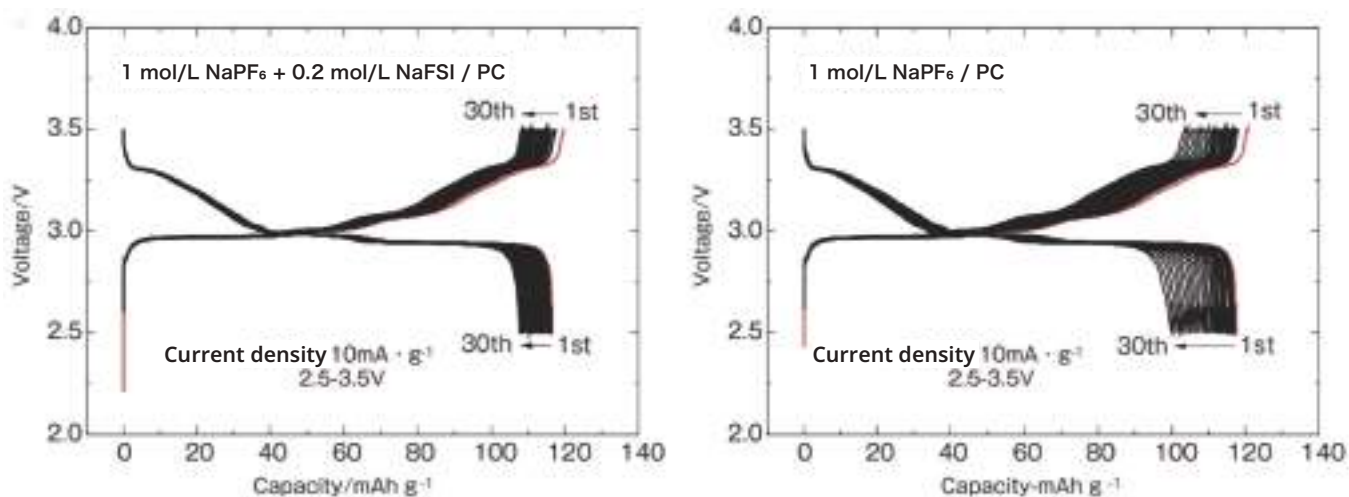
PE

## Reactivity of electrolyte and sodium metal (1 week)

| Salt       | 1.0 mol/L NaPF <sub>6</sub> | 1.0 mol/L NaPF <sub>6</sub> | 1.0 mol/L NaPF <sub>6</sub> |        | 1.0 mol/L NaPF <sub>6</sub> |        |
|------------|-----------------------------|-----------------------------|-----------------------------|--------|-----------------------------|--------|
| Solvent    | TFEP                        | PC                          | PC:TFEP 3:7 v/v%            |        | PC:TFEP 1:1 v/v%            |        |
| FEC        | —                           | —                           | —                           | 2 wt.% | —                           | 2 wt.% |
| Appearance |                             |                             |                             |        |                             |        |

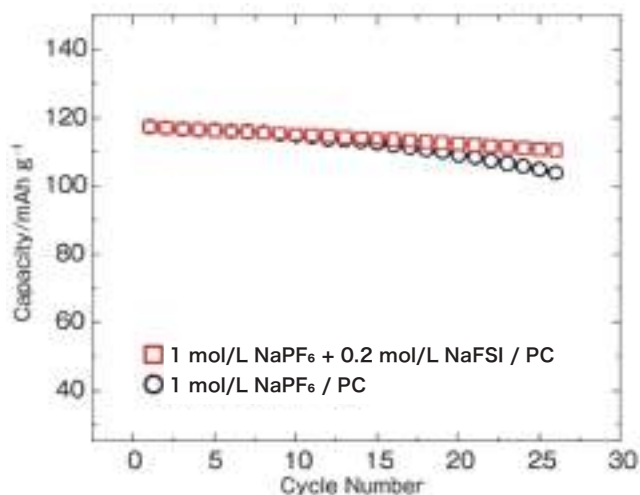
## Charge-discharge curves

NaCrO<sub>2</sub> / Na half cell



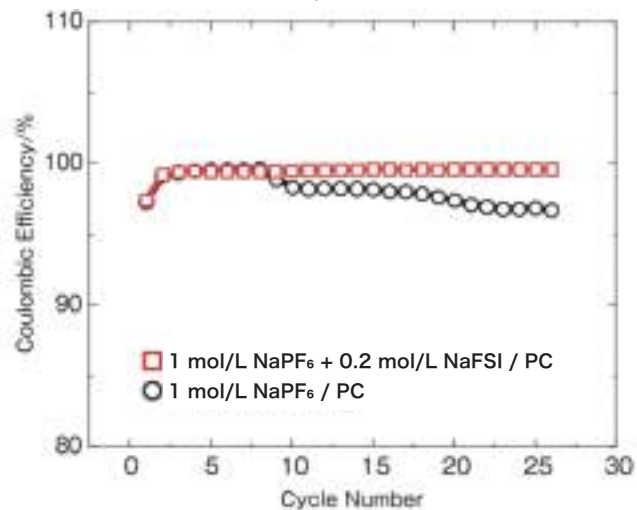
## Cycle characteristics

NaCrO<sub>2</sub> / Na half cell



## Coulombic efficiency

NaCrO<sub>2</sub> / Na half cell



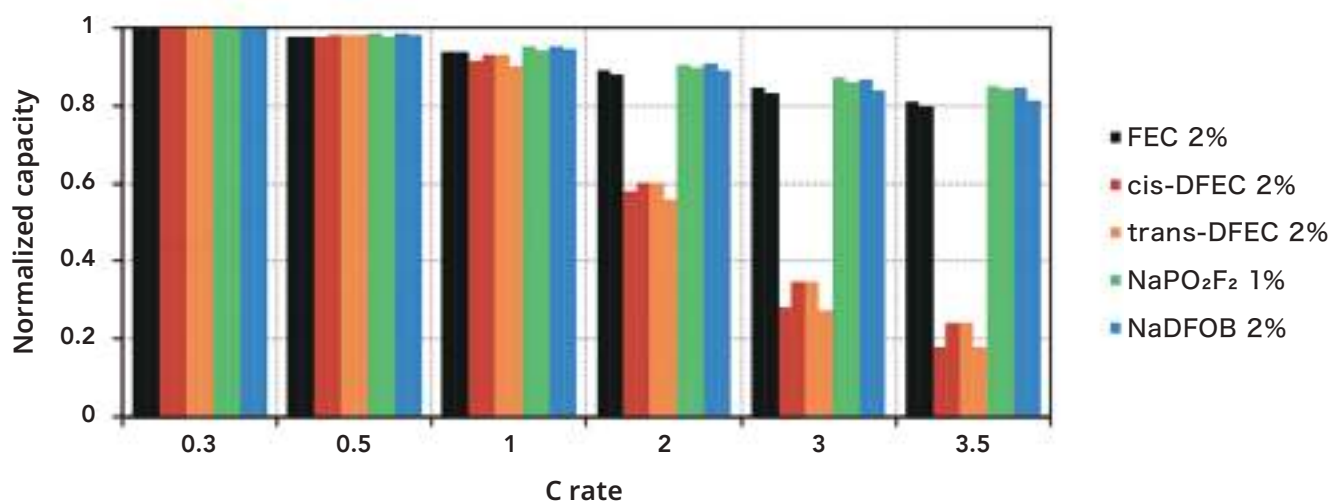
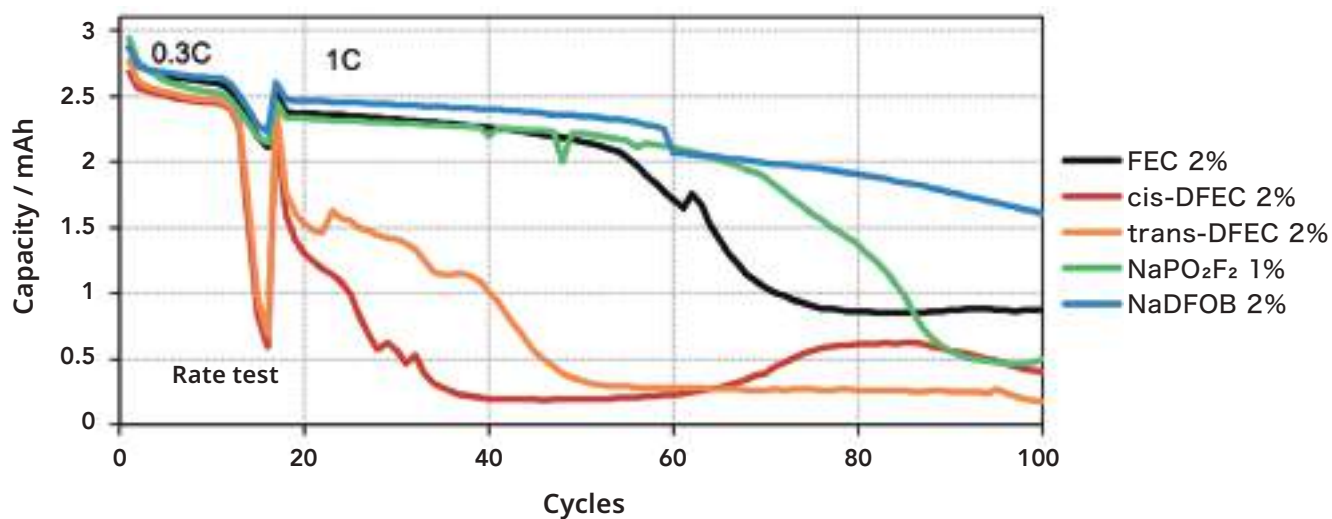
Acknowledged: The charge-discharge data provided by Dr. Naoaki Yabuuchi (Tokyo Denki Univ., Associate Prof.; now Prof. at Yokohama National Univ.)

## Cycle characteristics

Cathode : NiFeMn-based layered oxide, Anode : hard carbon

Voltage : 2.7 – 4.2V

Electrolyte solution : 1.0 mol/L NaPF<sub>6</sub> / PC:DEC 1:1 (v/v%) +additives



# SOLAR CELLS

KISHIDA CHEMICAL

## SOLAR CELLS

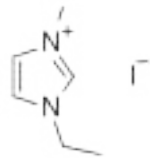
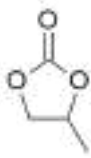
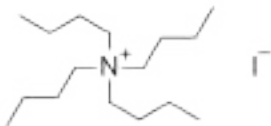
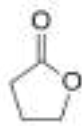
**For research and development**

Materials used in non-aqueous rechargeable batteries are also used in solar cells.

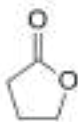
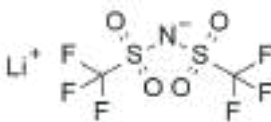
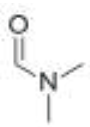
We handle electrolytes, solvents, dopants, and other materials used in dye-sensitized and perovskite solar cells.

We can also provide custom blends of electrolyte solutions and adjustment solutions that can be used in solar cells.

## Dye-sensitized solar cells — Custom blends

| Electrolyte                                                                             | Solvent                                                                                 |
|-----------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|
| EMI-I  | PC   |
| TBA-I  | GBL  |
| Other                                                                                   | AN   |

## Perovskite solar cells — Solvent/Dopant example

| Solvent                                                                                  | Dopant                                                                                       |
|------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|
| GBL   | LiTFSI  |
| DMSO  | Other Li salt                                                                                |
| DMF   | Other TFSI salt                                                                              |

*We will continue to expand our product range and support custom blending for use in R&D and the commercialization of new devices.*



MEMO

Handwriting practice lines consisting of 20 horizontal dotted lines.



# KISHIDA

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AGENT