Saturated Water/DMSO hybrid electrolytes for lithium-ion batteries

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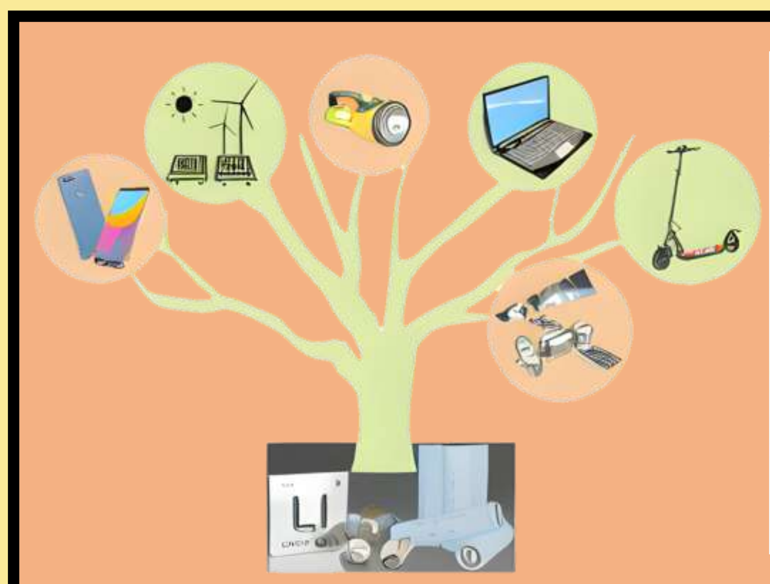
Electrochemical Energy for a Greener and more Sustainable Future Society

Ivan Claudio Pellini[1,*], Elena Polato[1], Shahid Khalid[1], Riccardo Ruffo[1]

*Email: i.pellini1@campus.unimib.it

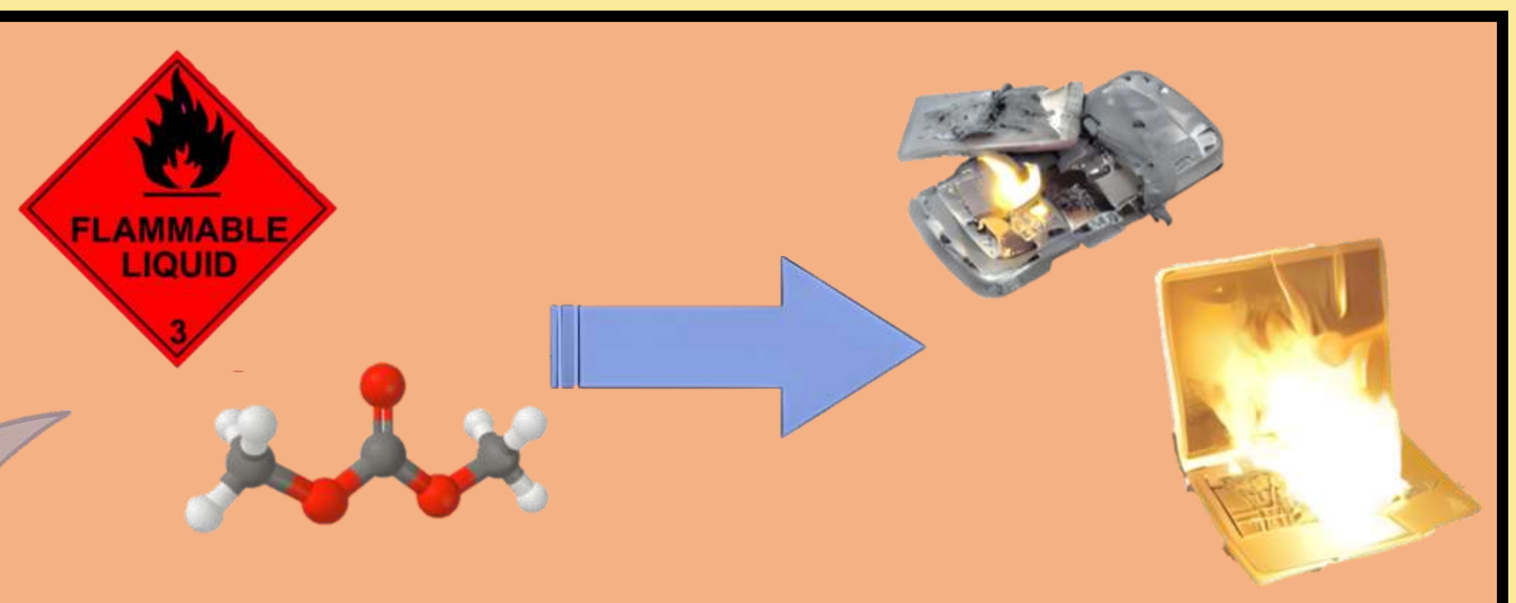
[1]Department of Material Science, University of Milano Bicocca, Via Cozzi 55, 20125 Milano (Italy)

YES,




Lithium-ion batteries are already among the most widely used devices and are becoming even more so [1].

BUT



LIBs usually contain flammable organic solvents than sometimes can cause combustions or explosions [2].

WHY WATER

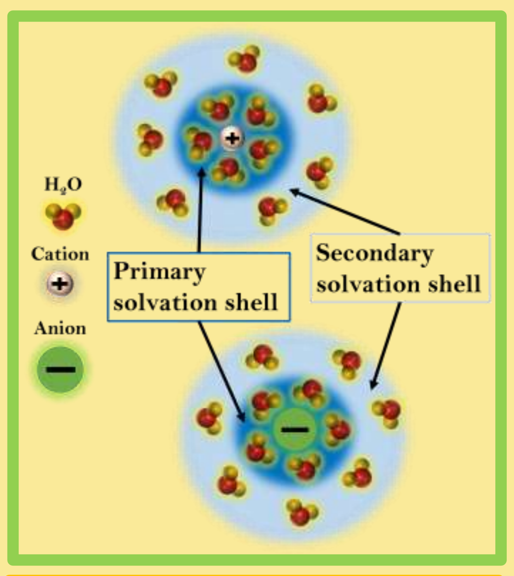
- Non-flammable,
- cheap,
- high conductive,
- environmentally friendly,
- abundant

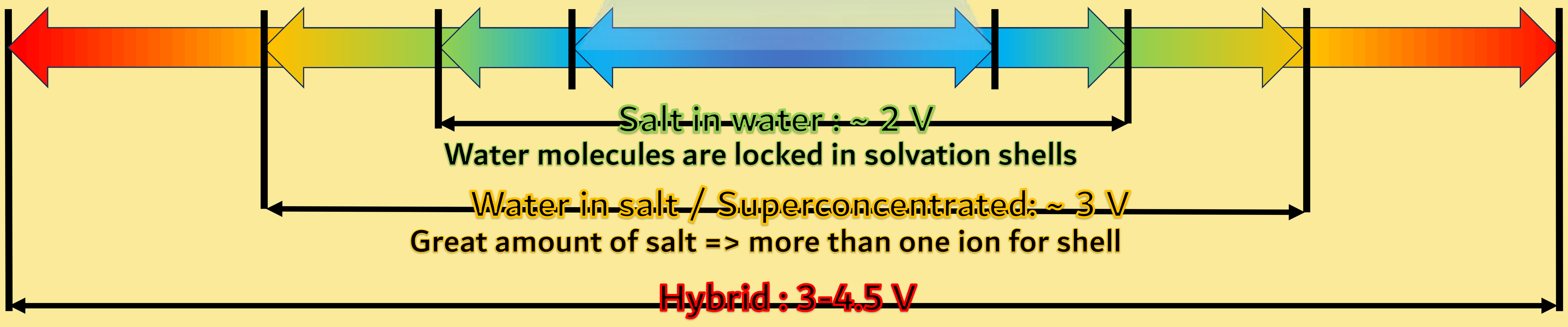
WATER'S LIMIT

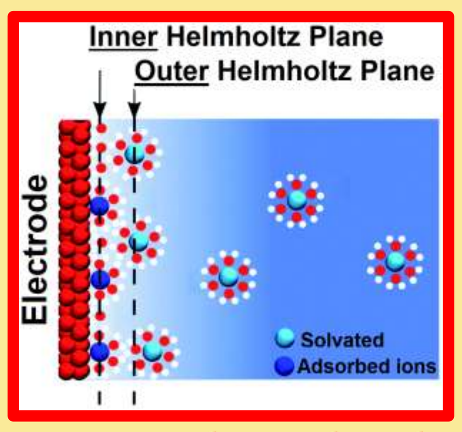
Narrow Electrochemical Stability Window (ESW): 1.23 V.

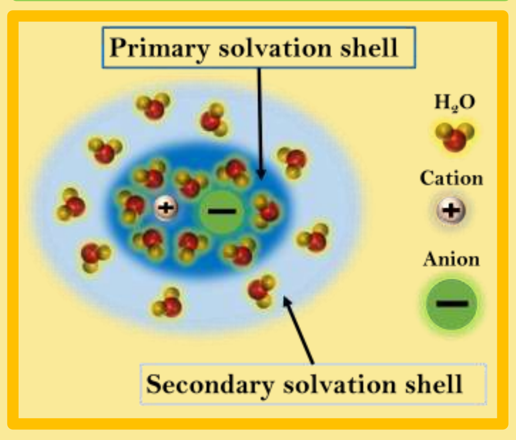
Outside this window, water is split to H_2 and O_2

Water-based electrolytes



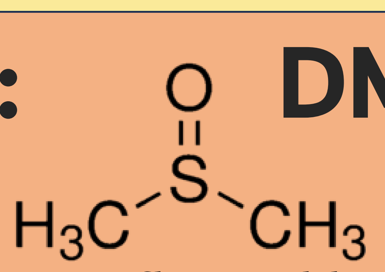




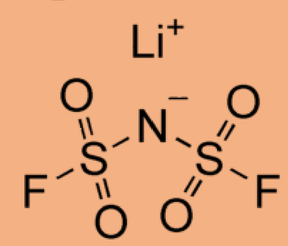


A co-solvent hinder the access of the water molecules to the Inner Helmoltz Plane (IHP), where redox reaction occurs.

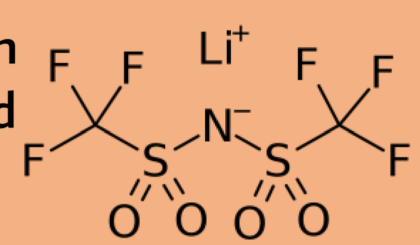
This hybrid system: DMSO + water + LiFSI or LiTFSI



Co-solvent: non-flammable, economic, safe

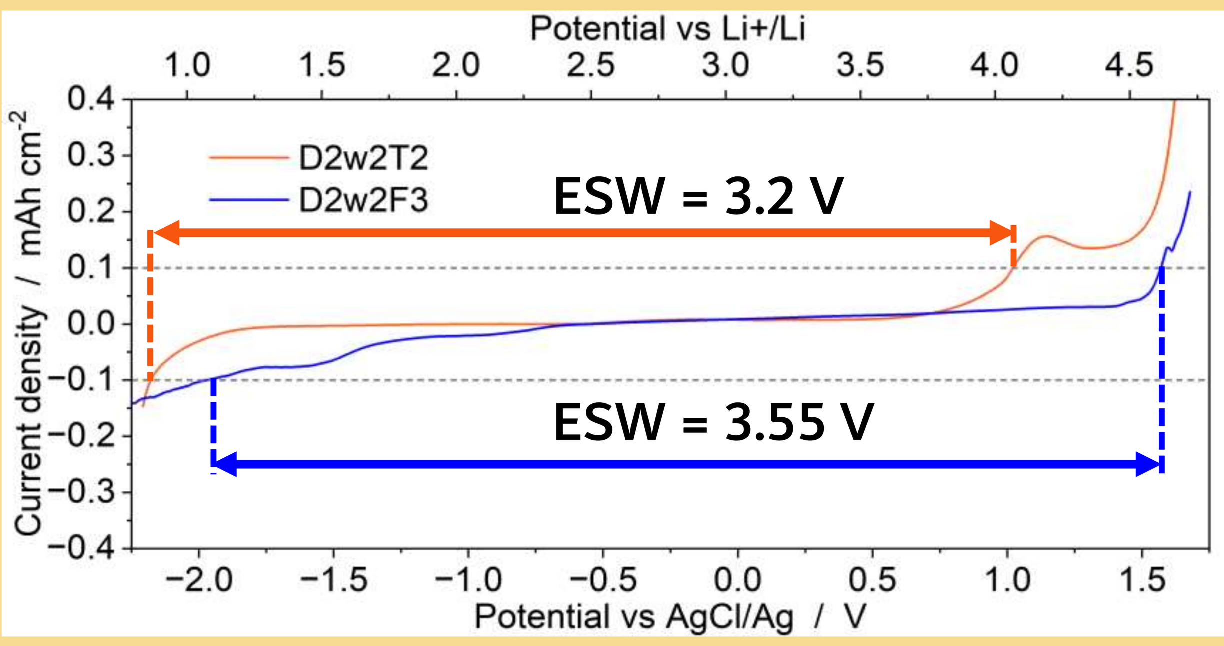


Salts: fluorinated salts can help the formation of the Solid Electrolyte Interphase



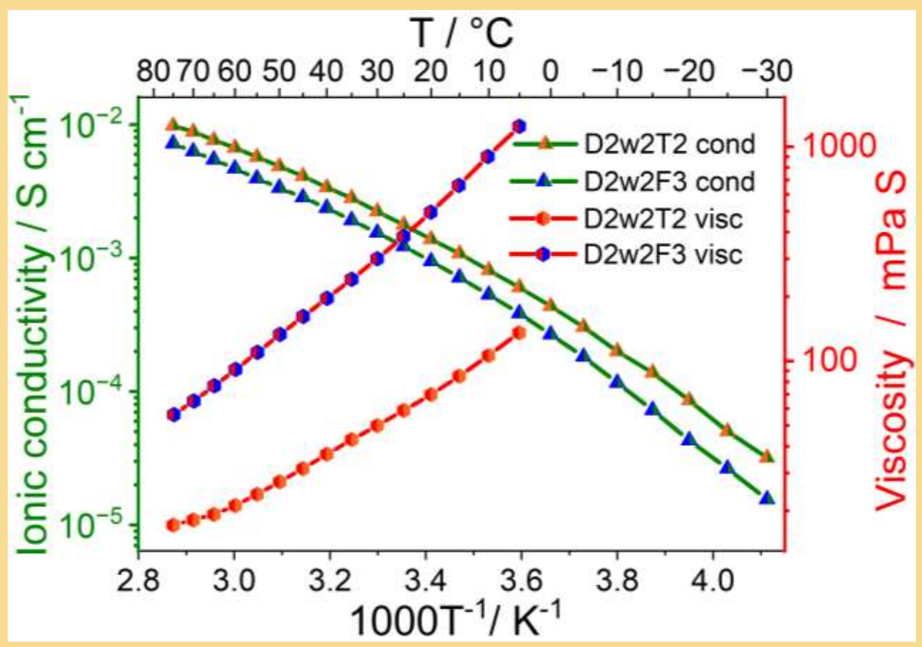
Electrolytes: DMSO:water:LiFSI = 2:2:3 & DMSO:water:LiTFSI = 2:2:2

Electrochemical Stability Window



Electrolytes	D2w2F3	D2w2T2
Conductivity at 25°C	1.2 mS cm^{-1}	1.8 mS cm^{-1}
Viscosity at 25°C	381 mPa s	58.8 mPa s
Cathodic limit	1.07 V vs Li^+/Li (Al)	0.87 V vs Li^+/Li (Al)
Anodic limit	4.62 V vs Li^+/Li (CC-Al)	4.07 V vs Li^+/Li (CC-Al)
ESW	3.55 V	3.2 V
Mean coulombic efficiency	99.3 %	98.5%

Conductivity and viscosity



Conductivity and viscosity are inversely proportional

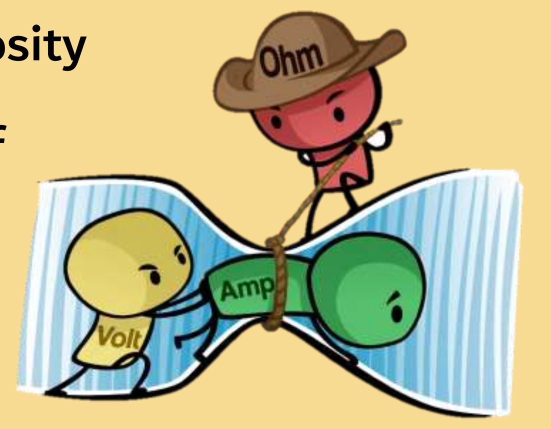
Resistance = opposition to the charge movement

In this case is represented by viscosity

Electric potential = driving force of charge movement

$$J_{ion,\,migr}(x) = \frac{z_{ion}e}{k_B T} D_{ion} c_{ion} \frac{\partial \varphi(x)}{\partial x}$$

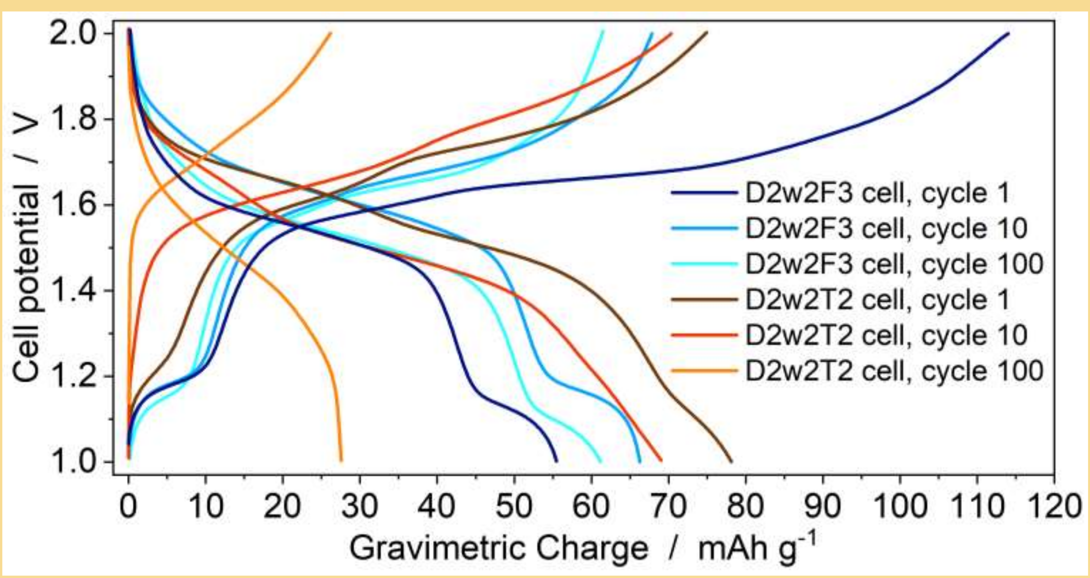
Nernst–Planck equation express the relation between potential and the ion movement



Current = charge movement

In this case is the ionic conductivity

Electrochemical performances



Cell configuration:

Al|$LiTi_2(PO_4)_3$|electrolyte|$LiMnO_2$|CC-Al

Electrodes that fit better with the ESW

Current collectors that allow to have the widest ESW

Conclusions

As expected in superconcentrated solutions, the most concentrated electrolyte, that is D2w2F3, show higher viscosity, lower conductivity and wider ESW .
This features allow to have better electrochemical performances.

References

1. Yang, C.; Chen, J.; Qing, T.; Fan, X.; Sun, W.; von Cresce, A.; Ding, M.S.; Borodin, O.; Vatamanu, J.; Schroeder, M.A.; et al. 4.0 V Aqueous Li-Ion Batteries. *Joule* **2017**, *1*, 122–132, doi:10.1016/J.JOULE.2017.08.009.
2. D. Doughty and E. P. Roth, "A general discussion of Li Ion battery safety," *Electrochemical Society Interface*, vol. 21, no. 2, pp. 37–44, Jan. 2012, doi: 10.1149/2.F03122IF/XML.