Viscosity measurements of compressed ionic liquid EMIM OTf

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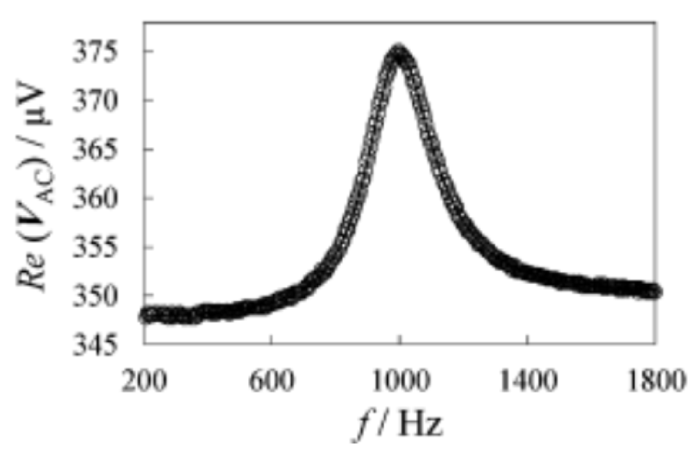
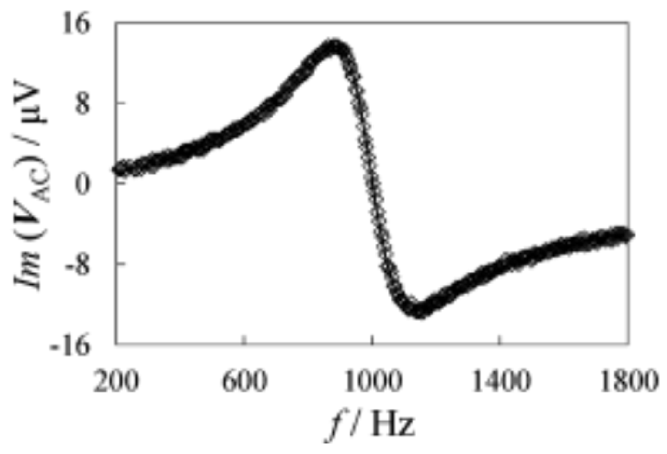
Background:

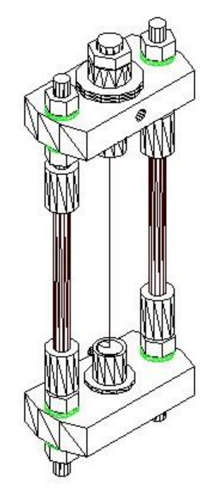
Properties for several Ionic Liquids such as viscosity, density, eletrical condutivity have been measured by our group [1 – 4]

1-Ethyl-3-methylimidazolium bis[(trifluoromethyl)sulfonyl]imide (**[C2mim][NTf2]**)
1-Ethyl-3-methylimidazolium ethyl sulfate (**[C2mim][EtSO4]**)
1-Ethyl-3-methylimidazolium trifluoromethanesulfonate (**[C2mim][OTf]**)
1-Hexyl-3-methylimidazolium bis[(trifluoromethyl)sulfonyl]imide (**[C6mim][NTf2]**)

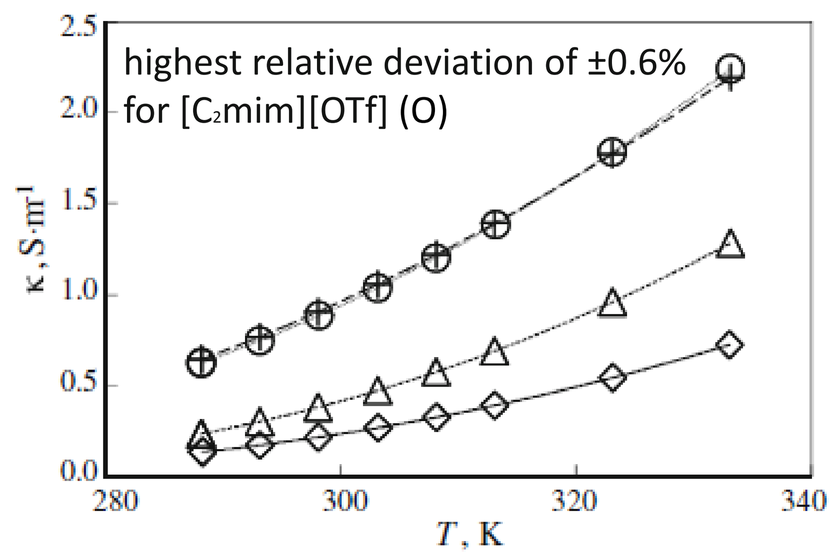
Vibrating-wire viscosity measurements – the sensor has a tungsten wire subjected to a magnetic field (>4000 Gauss). A Lock-in amplifier is used to apply a current through a range of frequencies and measure the potential drop across the vibrating-wire.







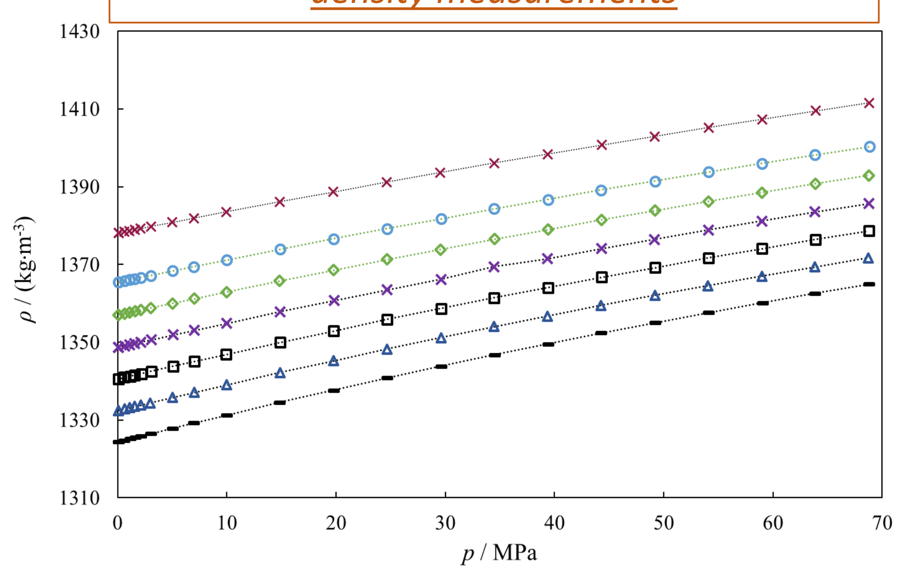
Electrical conductivity, κ, measurents of the ILs



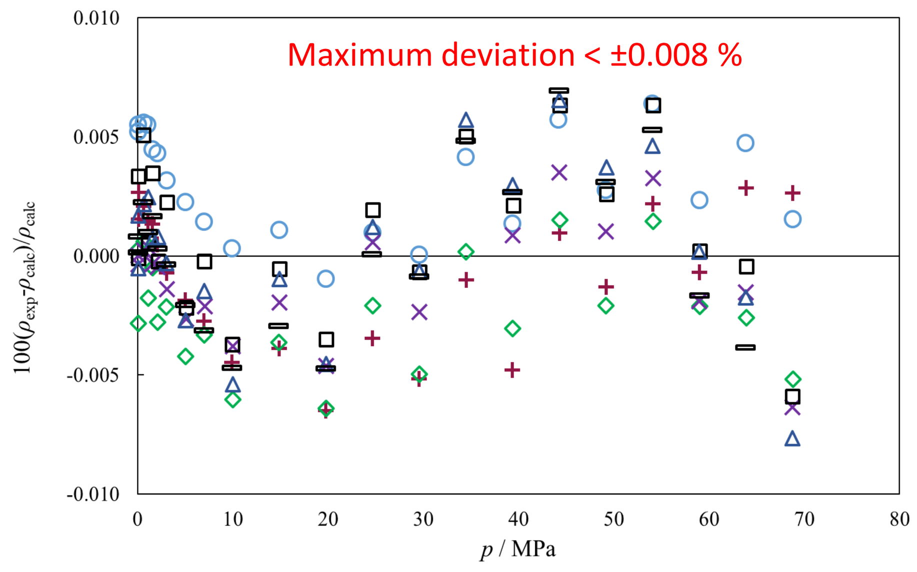
New and sustainable achievements

1-ethyl-3-methylimidazolium trifluoromethanesulfonate **([EMIM] [Otf])**

High-pressure / high-temperature density measurements

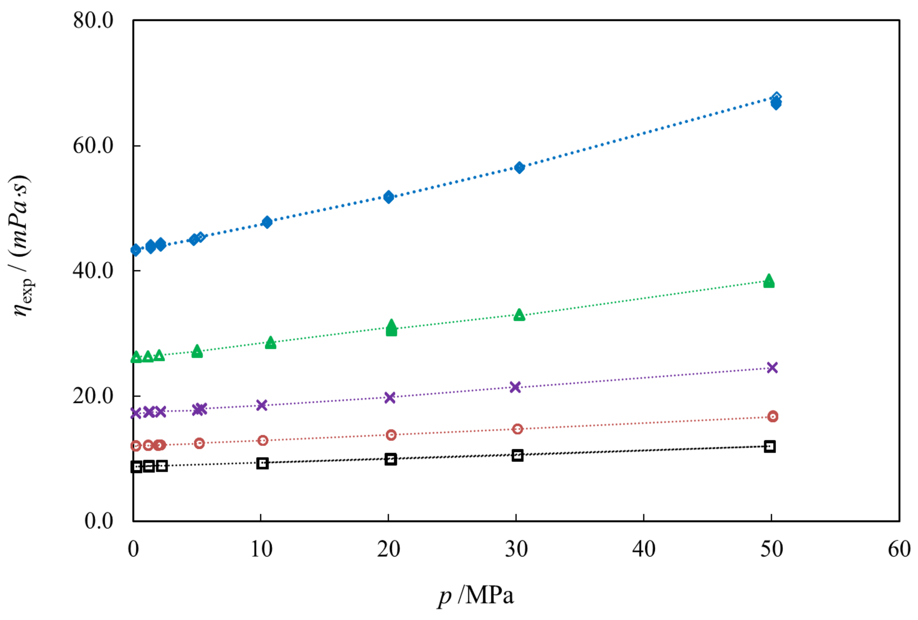


Experimental density data of EMIM OTf at temperatures: +298K; ○, 313 K; ◇, 323 K; ×, 333 K; □, 343 K; △, 353 K; ▭, 363 K



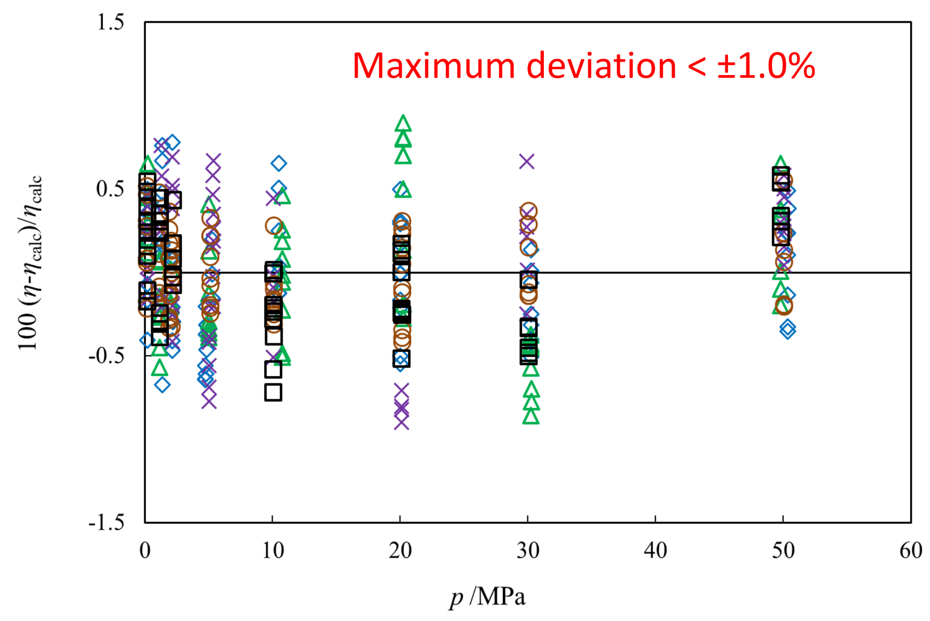
The **root mean square deviation** of the fitting is **0.003 %** and the **bias** is essentially **zero**

High-pressure / high-temperature - Viscosity measurements



Experimental viscosity data of EMIM OTf at temperatures: ◇,298K; △, 313 K; ×, 328 K; ○, 343 K; □, 358 K.

Correlation for the viscosity data, η, obtained with the vibrating-wire viscometer.



Deviations of the viscosity, η, of EMIM OTf obtained with a vibrating wire viscometer, from correlation: ◇, 298 K; △, 313 K; ×, 328 K; ○, 343 K; □, 358 K.

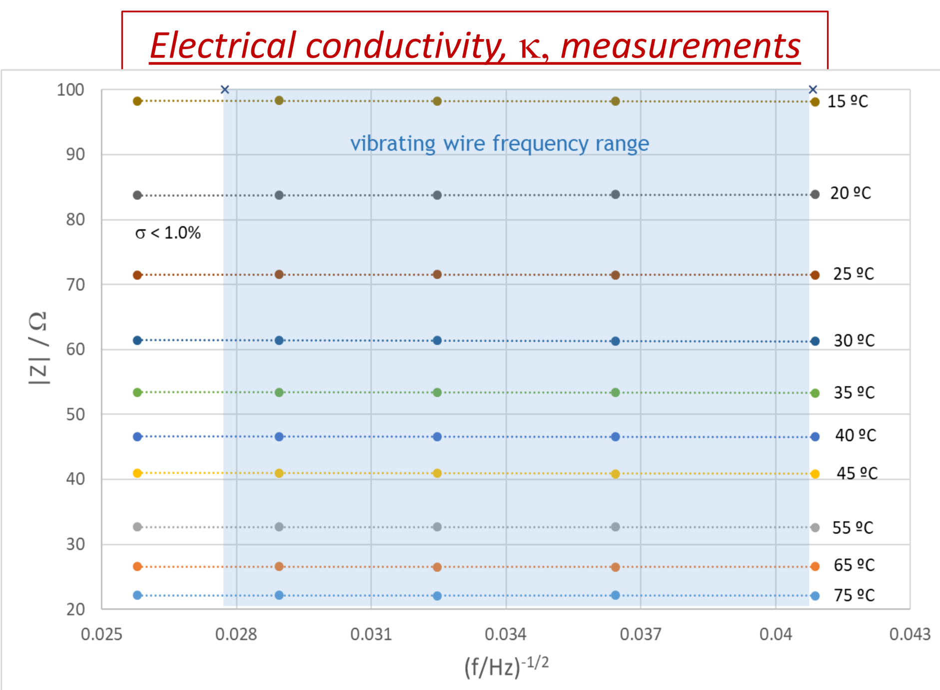
$$\eta^* = 6.035\ \times 10^8 \left(\frac{1}{MRT}\right)^{\frac{1}{2}} \eta\ (V_m)^{\frac{2}{3}}$$

$$\frac{1}{\eta *} = \sum_{i=0}^{4} a_i \left(\frac{V_m}{V_0}\right)^i$$

$$V_0(T) = V_{0,ref} + l\,(T - T_{ref}) + m\,(T - T_{ref})^2$$

✓ *The **root mean square deviation** from the correlation is **0.48 %**, and the **bias** is essentially **zero***

Electrical conductivity, κ, measurements

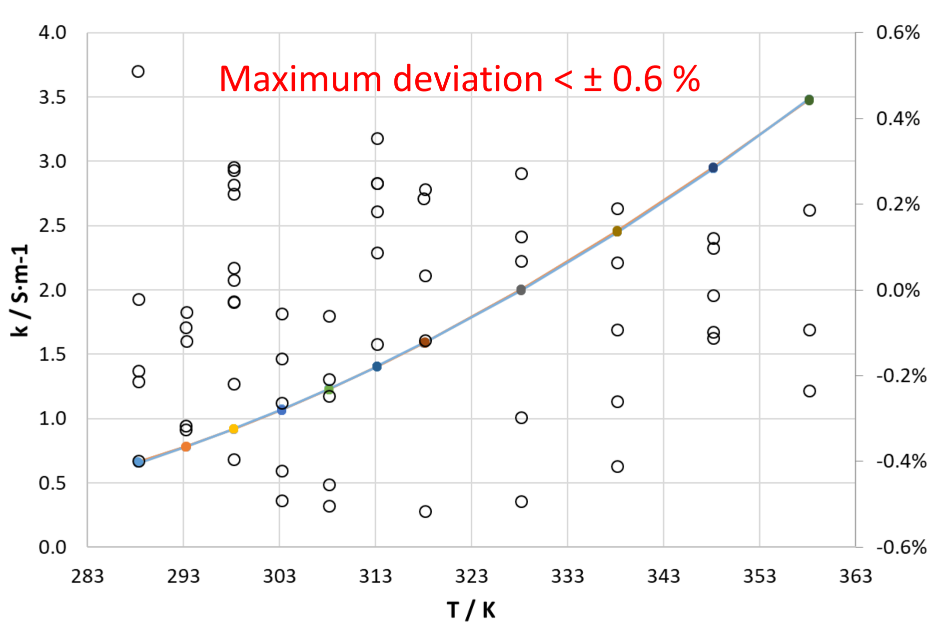


✓ Impedance measurements are **constant (σ < 1.0 %)** for the full working frequency range of the vibrating-wire measurements.

✓ *At each temperature, **viscosity measurements are not affected** by the electrical conductivity in the working frequency range.*

$$|Z| = R_\infty + b \times f^{-1/2} \qquad \kappa = \frac{K}{R_\infty}$$

Deviation plot of the fitted values of the electrical conductivity, κ, in the temperature range 285 K (15 ºC) to 358 K (75 ºC)

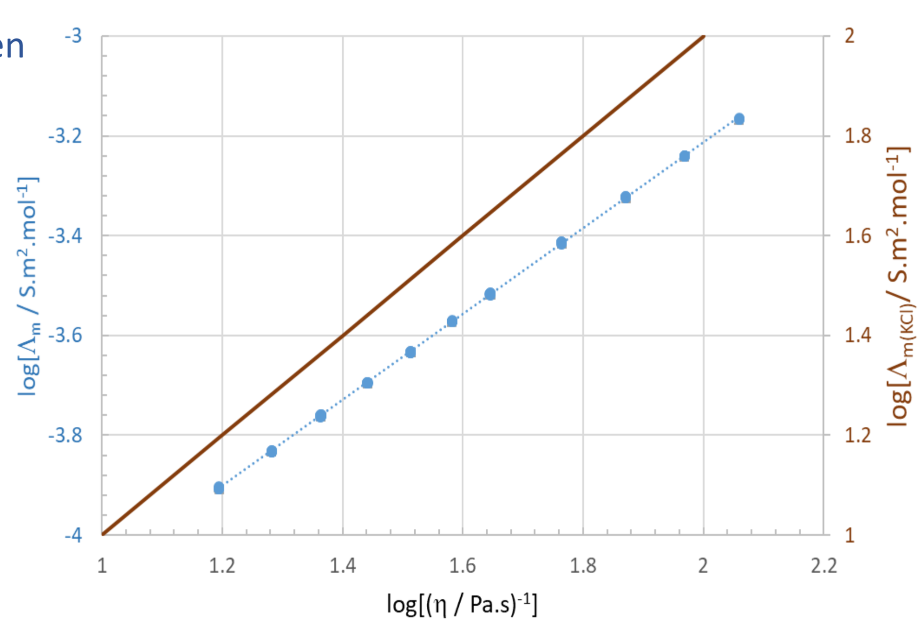


Walden plot - this IL ([EMIM] [Otf]) has the same logaritmic linear behavior as the reference, KCl, 1M

Empirically relation established by Walden

$$\Lambda_m^0 \times \eta^\alpha = C = constant$$

$$log(\Lambda_m^0) = log(C) + \alpha \times log(\eta^{-1})$$



Outcomes:

- **High quality** determination of properties: (1) **viscosity** at *high temperatures* and *high pressures; (2)* **electrical conductivity**, of the ionic liquid **([EMIM] [Otf])**.
- Vibrating-wire viscosity technique may be applied ILs without any loss of its high accuracy.
- As far as the authors are aware these are the **only IL frequency-dependent electrical conductivity** measurements, extrapolated to infinite frequency, applied to ILs.

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References:

[1] Calado, Marta S., João C. F. Diogo, José L. Correia da Mata, Fernando J. P. Caetano, Zoran P. Visak, and João M. N. A. Fareleira. 2013. "Electrolytic Conductivity of Four Imidazolium-Based Ionic Liquids." International Journal of Thermophysics 34(7):1265–79.
[2] Diogo, João C. F., Fernando J. P. Caetano, João M. N. A. Fareleira, and William A. Wakeham. 2013. "Viscosity Measurements of Three Ionic Liquids Using the Vibrating Wire Technique." Fluid Phase Equilibria 353:76–86.
[3] Diogo, João C. F., Fernando J. P. Caetano, João M. N. A. Fareleira, and William A. Wakeham. 2014. "Viscosity Measurements on Ionic Liquids: A Cautionary Tale." International Journal of Thermophysics 35(9–10):1615–35.
[4] Diogo, João C. F., Fernando J. P. Caetano, João M. N. A. Fareleira, William A. Wakeham, Carlos A. M. Afonso, and Carolina S. Marques. 2012. "Viscosity Measurements of the Ionic Liquid Trihexyl(Tetradecyl)Phosphonium Dicyanamide [P 6,6,6,14][Dca] Using the Vibrating Wire Technique." Journal of Chemical & Engineering Data 57(4):1015–25