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On the Viscosity and other Properties of Poly(Ethylene Glycol) 600

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Ultimate Goal

To apply methods for correlation and prediction of the viscosity of pure liquids (**PEGs**) and mixtures (**PEG + other fluids**) for sustainable processes.

What do we need?

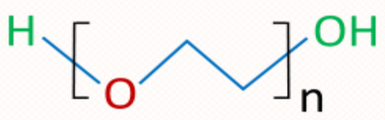
Characterise the fluids: Viscosity

Rheological Behaviour

Density

Surface Tension

Molecular Weight



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Previous studies

The effect of supercritical fluid (SCF) addition on the viscosity of PEGs:

- **PEG400-CO_2** – Simultaneous Viscosity and Density Measurement of Supercritical CO_2-Saturated PEG 400; *Journal of Supercritical Fluids* **13**, 177-185 (1998).
- **PEG200-CO_2** – Viscosity of Poly(ethyleneglycol) 200 [PEG 200] Saturated with Supercritical Carbon Dioxide; *Journal of Supercritical Fluids* **128**, 300-307 (2017)

  Share Link: https://authors.elsevier.com/a/1VWRn3BwpenW68

Outcomes

- Viscosity reduction of PEG 200 and PEG 400 due to CO_2 addition is directly dependent on the quantity of dissolved CO_2 in the polymer.
- The highest viscosity reduction observed was 79% (PEG 200) and 89% (PEG 400), at 313 K.
- The viscosity results show an initial sharp viscosity reduction, up to the critical pressure, followed by a nearly invariant zone.

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New measurements PEG 600 at atmospheric pressure

(Lot from Sigma Aldrich)

Property	Method	T range / K
Viscosity	Vibrating-wire	303-353
Viscosity	Ubbelohde capillary	303-333
Density	Vibrating-tube	303-353
Surface tension	Pendant Drop	303-340
Molecular weight	GPC; Mark-Houwink equation	323
Rheological behaviour	Parallel Plate Rheometer	303

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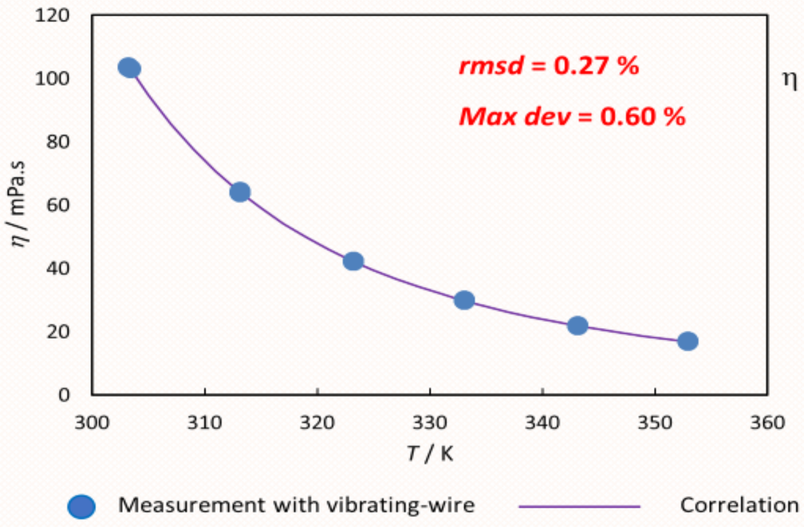
Viscosity of PEG 600

Vogel Correlation



$$\eta = \exp\left(-1.25334 + \frac{652.8098}{-192.511 + T}\right)$$

Only vibrating-wire viscosity measurements data were used in the correlation

Deviations of the Ubbelohde capillary from the correlation: ±0.35%

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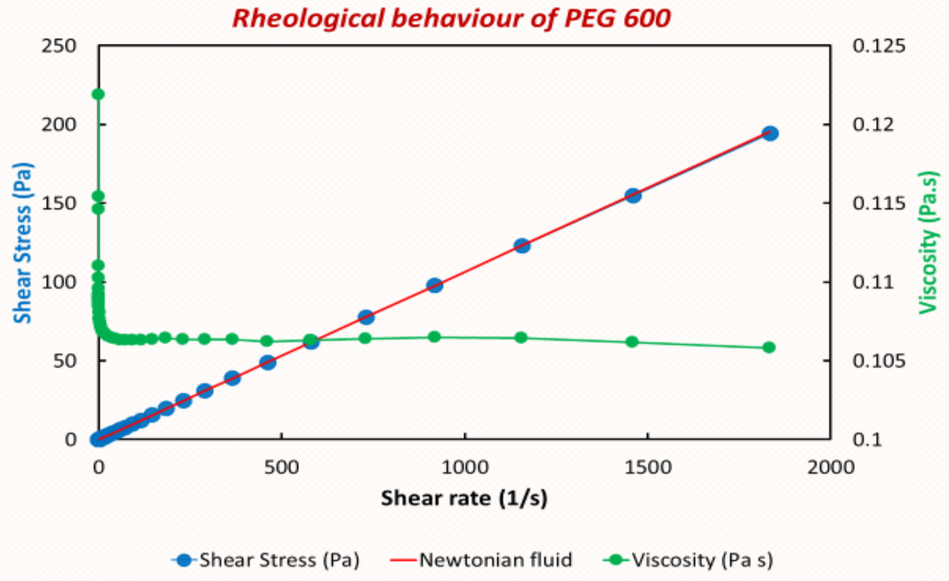
Shear dependent viscosity

Rheological behaviour of PEG 600



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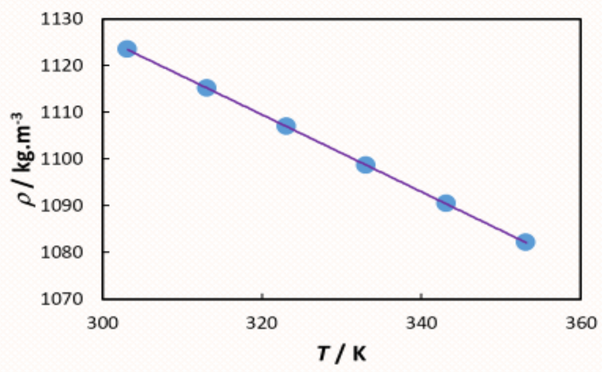
Density of PEG 600

U-tube densimeter measurements



Density correlation

$$\rho = 1368.816 - -0.79133\,T + 5.420\times10^{-5}T^2$$

rmsd = 0.0002 %

Max dev =± 0.0003%

Surface Tension of PEG 600

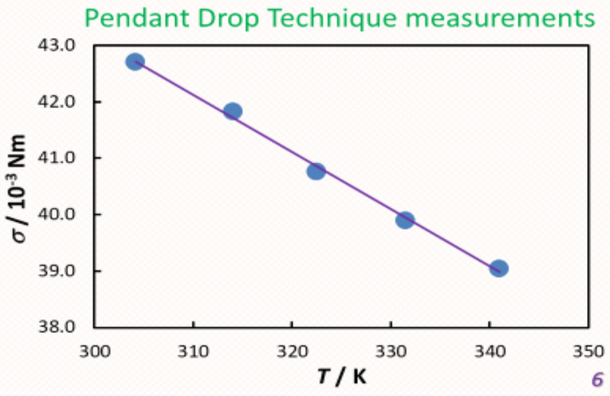
Surface Tension correlation

$$\sigma = 73.6417 - 0.1016T$$

rmsd = 0.18 %

Max dev =± 0.26%

Pendant Drop Technique measurements



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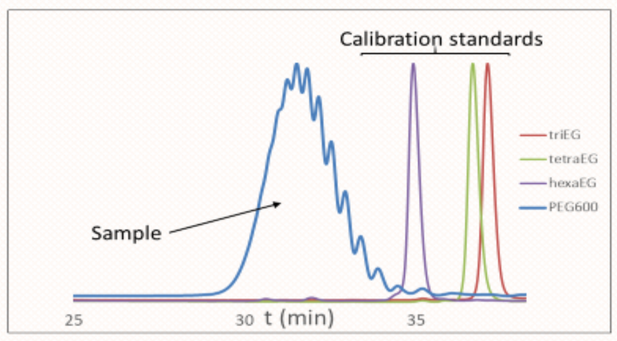
Calculating Molecular Weights

Size Exclusion Chromatography (GPC)



M_n – Number-average molar mass = 593 g/mol

M_w – Mass-average molar mass = 636 g/mol

M_w / M_n = 1.07

Mark–Houwink equation

Calculation based in M. P. J. Dohmen et al. J. Chem. Eng. Data 2008, 53, 63–65

$$[\eta] = K\,M^{\alpha}$$

[η] - Intrinsic viscosity

M – molecular mass

K and α - Mark-Houwink parameters

M - Molar mass = 603 g/mol

Work in progress *(PEG600 from Alfa Aesar)*: Molecular wheight *vs.* fluid properties

M_n – Number-average molar mass = 594 g/mol

M_w – Mass-average molar mass = 625 g/mol

M_w / M_n = 1.05

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Conclusions

- The capillary measurements agree very well with vibrating-wire measurements
- PEG 600 has a **Surface Tension** between that of water and oils
- PEG 600 has a **Newtonian Behaviour** up to very high shear rate (up to ca. 1200 s^{-1})
- The Gel Permeation Chromatography (Size Exclusion Chromatography) and Mark–Houwink equation present similar results – **Molar Mass**

Future Work

To build a correlation based on the relationship between molecular weight distribution of PEG and their Thermophysical Properties

- Viscosity
- Density

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