

All data taken at the Pacific Northwest National Laboratory
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Composite spectrum for: Oleic acid

- First Column: Position in wavenumber (cm^{-1})
- Second column: Real refractive index $n(\tilde{\nu})$ (dispersion index)
- Third column: Imaginary refractive index, $k(\tilde{\nu})$ (absorption index per unit length in centimeters)

Where the complex refractive index $\hat{n} = n(\tilde{\nu}) + ik(\tilde{\nu})$

Following Bertie (in the references below) we define the absorbance as $A = -\log_{10}(I/I_0)$ and the linear absorption coefficient $K = A/d$, where d is the path length. The connection between the imaginary refractive index and the absorbance coefficient arises from the following: $2.303K = 4\pi\tilde{\nu}k$

See the following references for a detailed description of terms and units:

- 1) Bertie, J. E., Zhang, S. L., Eysel, H. H., Baluja, S., & Ahmed, M. K. (1993). Infrared Intensities of Liquids XI: Infrared Refractive Indices from 8000 to 2 cm^{-1} , Absolute Integrated Intensities, and Dipole Moment Derivatives of Methanol at 25°C . *Appl. Spec.*, 47(8), 1100-1114 doi:10.1366/0003702934067973
- 2) Bertie, J. E., Zhang, S. L., & Keefe, C. D. (1995). Measurement and use of absolute infrared absorption intensities of neat liquids. *Vibrational Spectroscopy*, 8(2), 215-229. doi:10.1016/0924-2031(94)00038-i

Sample:

- Chemical name, formula and CAS number: Oleic acid, $\text{C}_{18}\text{H}_{34}\text{O}_2$, [112-80-1]
- IUPAC name: Octadec-9-enoic acid
- Synonyms: Octadecenoic acid; *cis*-9-Octadecenoic acid; Oleate
- Physical properties: FW = 282.468 g/mole; mp = 13°C ; bp = 286°C ; $\rho = 0.895\text{ g/cm}^3$
- Supplier and stated purity: Sigma-Aldrich, $\geq 99\%$ (Lot # 0000032783)
- Temperature of sample: 26°C ($\pm 1^\circ\text{C}$)
- Individual samples were measured at the following path lengths: MIR: 1.26, 2.85, 6.63, 8.85, 27.9, 61.1, 119, and $261\text{ }\mu\text{m}$; NIR: 125, 258, 501, 1199, and $3067\text{ }\mu\text{m}$. Final data are a composite of these spectra.
- Sample cell window material is potassium bromide (KBr) except the 2.85 (MIR) and 8.85 (MIR) cells had a potassium chloride (KCl) window.
- Preparation: None.

NIR Instrument Parameters:

- Bruker Vertex 70, purged with UHP nitrogen
- Spectral range: 10,000 to $3,000\text{ cm}^{-1}$ (1.0 to 3.33 microns)
- IR source: Quartz tungsten bulb
- Beamsplitter: Broadband Potassium bromide (KBr)
- Detector: DLTGS at room temperature
- Aperture: 3 mm
- Folding limits: 31601 to 0 cm^{-1}

MIR Instrument Parameters:

- Tensor 27, purged with UHP nitrogen
- Spectral range: 7800 to 400 cm^{-1} (1.282 to 25 microns)
- NIR source: Silicon carbide glow bar
- Beamsplitter: Broadband Potassium bromide (KBr)
- Detector: DLTGS at room temperature
- Aperture: 3 mm
- Folding limits: 15802 to 0 cm^{-1}

NIR/MIR Instrument Parameters:

- Instrument resolution: 2.0 cm^{-1}
- Number of interferograms averaged per single channel spectrum: 128
- Apodization: Norton-Beer, Medium
- Phase correction: Mertz
- Scanner velocity: 10 kHz
- Interferogram zerofill: 4x
- Spectral interval after zerofilling: 0.4823 cm^{-1}

a)



b)



Figure 1: The Bruker Vertex 70 FTIR (a) and Tensor 27 FTIR (b).

Measured Refractive Index:

The refractive index for Oleic acid was measured at $25\text{ }^{\circ}\text{C}$ using an Atago model DR-M2/1550 Abbe refractometer. Notch filters were employed in front of a white light source to make measurements at multiple wavelengths. An infrared viewer from Atago was used to detect signal at 1550 nm . The temperature was controlled to match that in the sample compartment of the FTIR using a heated circulating bath.

480 nm:	$n = 1.4650$	486 nm:	$n = 1.4640$	546 nm:	$n = 1.4603$
589 nm:	$n = 1.4577$	644 nm:	$n = 1.4555$	656 nm:	$n = 1.4552$
1550 nm:	$n = 1.4393$				

The refractive index, n , vs. wavelength in microns, λ , was fit to an equation similar to that of Sellmeier:

$$n(\lambda) = \{a + b/(\lambda^2 - c)\}^{1/2}$$

The resulting best-fit equation was used to find the refractive index at the highest energy data points in our experimental spectra. For Oleic acid, the results were

$$\begin{aligned} n(7800\text{ cm}^{-1}) &= 1.4414 \text{ at } 25\text{ }^{\circ}\text{C} \text{ for MIR data and} \\ n(10,000\text{ cm}^{-1}) &= 1.4451 \text{ at } 25\text{ }^{\circ}\text{C} \text{ for NIR and merged} \\ &\text{data.} \end{aligned}$$

Post Processing and Related Parameters:

For the MIR, a composite spectrum was created from 8 absorbance spectra (base-10) taken at 8 path lengths: 1.26, 2.85, 6.63, 8.85, 27.9, 61.1, 119, and 261 micrometers (μm). For the NIR, a composite spectrum was

created from 5 absorbance spectra (base-10) taken at 5 path lengths: 125, 258, 501, 1199, and 3067 micrometers (μm). The same cells for the ~ 120 and ~ 260 μm path lengths were used for both spectral ranges. At each path length several spectra were measured and the results averaged for better signal to noise. The measured cell lengths were adjusted using Beer's law plots in which the NIR and MIR data were analyzed independently.

- 1) The imaginary part of the refractive index, or k vector, was determined for each absorbance file as per Bertie's program "RNJ46A" (see reference above). This takes into account the reflective losses due to the KBr windows.
- 2) A composite k vector is created via a classical, weighted, linear, least squares fit using the output files of program "RNJ46A": Intercept=0, slope is fitted, individual absorbance values weighted by T^2 (transmission squared), all absorbance values ≥ 2.5 are given zero weight. For the MIR, six composite vectors were created and merged by hand.
 - a) The first k vector used the results from the 61.1, 119, and 261 μm cells. This k vector determined the final values for the range from 7800 to 5975 cm^{-1} .
 - b) The second k vector used the results from the 27.9, 61.1, 119, and 261 μm cells. This k vector determined the final values for the range from 5975 to 4810 cm^{-1} .
 - c) The third k vector used the results from the 6.63, 27.9, 61.1, and 261 μm cells. This k vector determined the final values for the range from 4810 to 3440 cm^{-1} .
 - d) The fourth k vector used the results from the 1.26, 2.85, and 8.85 μm cells. This k vector determined the final values for the range from 3440 to 2690 cm^{-1} .
 - e) The fifth k vector used the results from the 6.63, 8.85, 27.9, and 61.1 μm cells. This k vector determined the final values for the range from 2690 to 1780 cm^{-1} .
 - f) The sixth k vector used the results from the 1.26, 2.85, 6.63, and 8.85 μm cells. This K vector determined the final values for the range from 1780 to 1565 cm^{-1} .
 - g) The seventh k vector used the results from the 6.63, 8.85, 27.9, and 61.1 μm cells. This K vector determined the final values for the range from 1565 to 835 cm^{-1} .
 - h) The eighth k vector used the results from the 8.85, 27.9, and 61.1. This K vector determined the final values for the range from 835 to 400 cm^{-1} .
- 3) The resulting composite MIR k vector and the refractive index at 7800 cm^{-1} were used to create the real or n vector using the Kramers-Kronig relation, as per Bertie's program "LZZKTB."
 - a) Frequency correction (already applied): $\tilde{\nu}(\text{corrected}) = [\tilde{\nu}(\text{instrument}) * 0.999848 + 0.010722]$ as determined by comparing measured atmospheric spectral lines (H_2O and CO_2) to values from the Northwest Infrared Spectral Library Database.
- 4) For the NIR, three composite vectors were created and merged by hand.
 - a) The first k vector used the results from the 258, 501, 1199, and 3067 μm cells. This k vector determined the final values for the range from 10000 to 5947 cm^{-1} .
 - b) The second k vector used the results from the 125, 258, 501, 1199, and 3067 μm cells. This k vector determined the final values for the range from 5947 to 4780 cm^{-1} .
 - c) The third k vector used the results from the 258 and 501 μm cells. This k vector determined the final values for the range from 4780 to 3000 cm^{-1} .
- 5) The resulting composite NIR k vector and the refractive index at 10,000 cm^{-1} were used to create the real or n vector using the Kramers-Kronig relation, as per Bertie's program "LZZKTB."
 - a) Frequency correction (already applied): $\tilde{\nu}(\text{corrected}) = [\tilde{\nu}(\text{instrument}) * 0.999869 + 0.0158818]$ as determined by comparing measured atmospheric spectral lines (H_2O and CO_2) to values from the Northwest Infrared Spectral Library Database.
- 6) Finally, the MIR data were mapped onto the NIR x-axis using an interpolation routine, i.e. the Make Compatible command in OPUS 5.5. Then the composite MIR and NIR k vectors were merged by hand to generate a final composite k vector across the entire spectral range. The resulting composite k vector and the refractive index at 10,000 cm^{-1} were used to create the final n vector using the Kramers-Kronig relation, as per Bertie's program "LZZKTB."

Photograph of Sample Oleic acid:

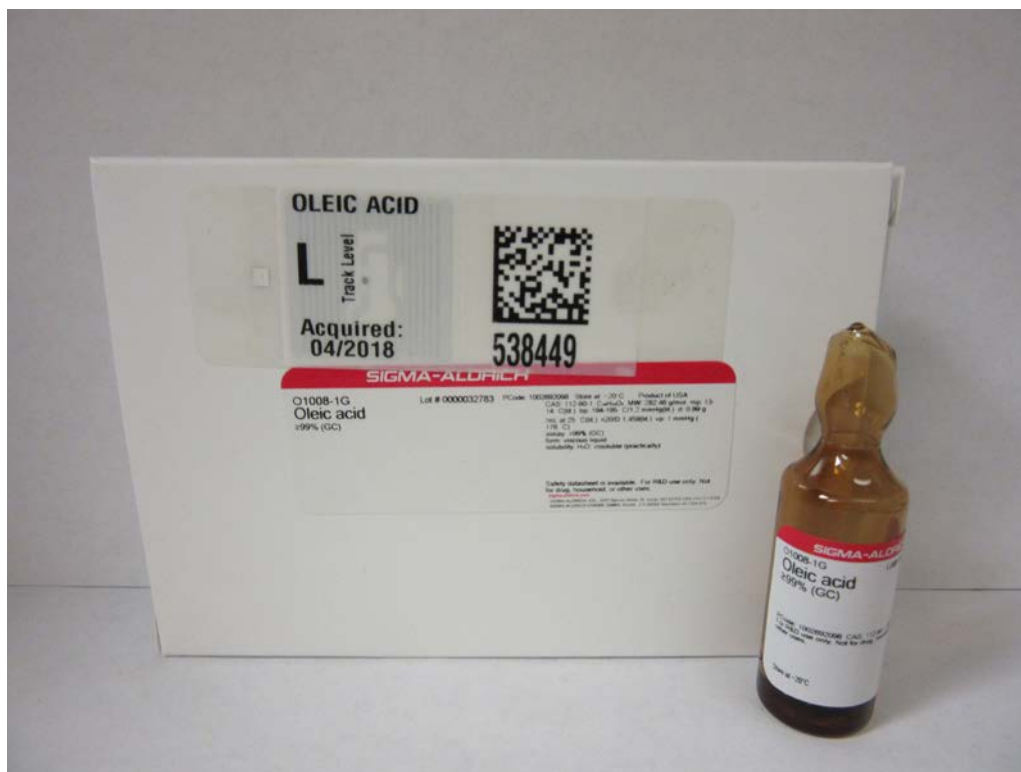


Figure 2: Oleic acid in Sigma-Aldrich container.