

Tourmaline

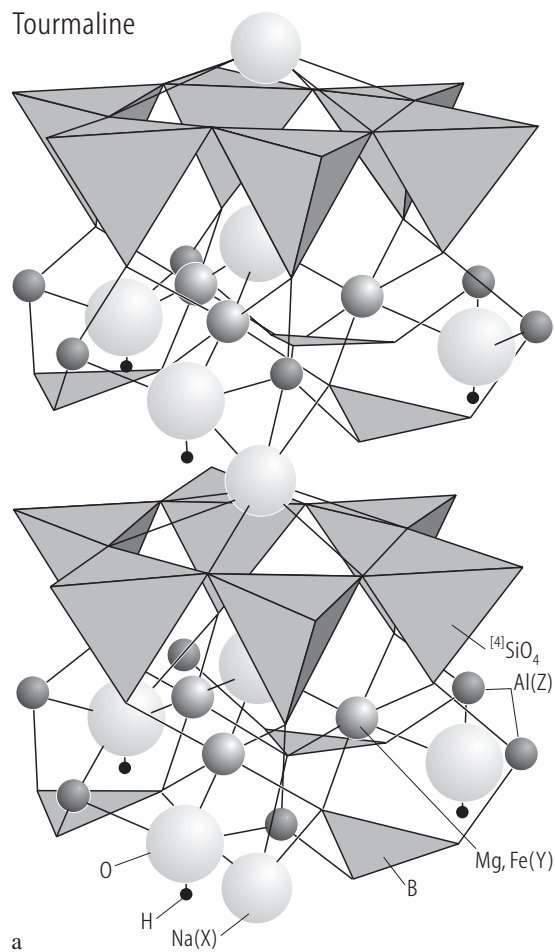
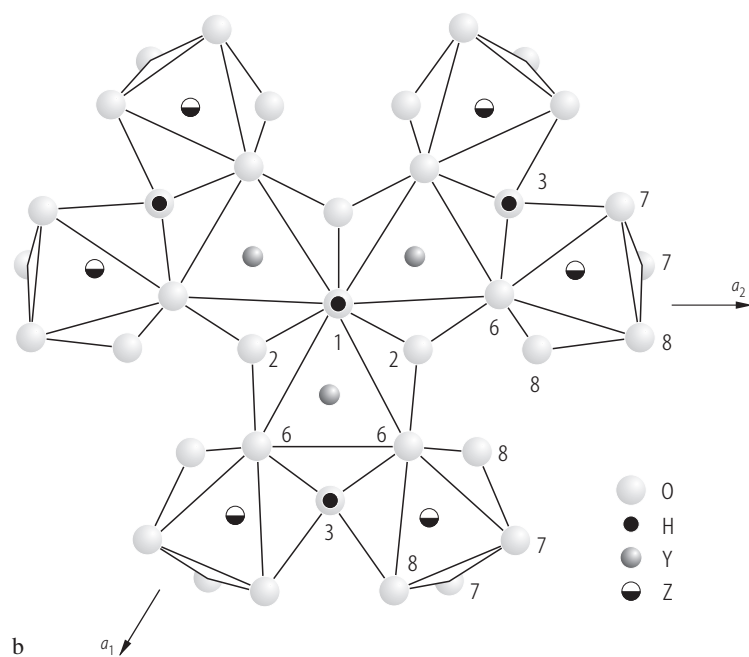


Fig. 1. Tourmaline. **(a)** Structure of Na-(Fe,Mg) tourmaline shown parallel to the *c*-axis [95F1]. **(b)** Octahedral portion of the structure viewed perpendicular to *c*-axis [99P1].



Verplanckite

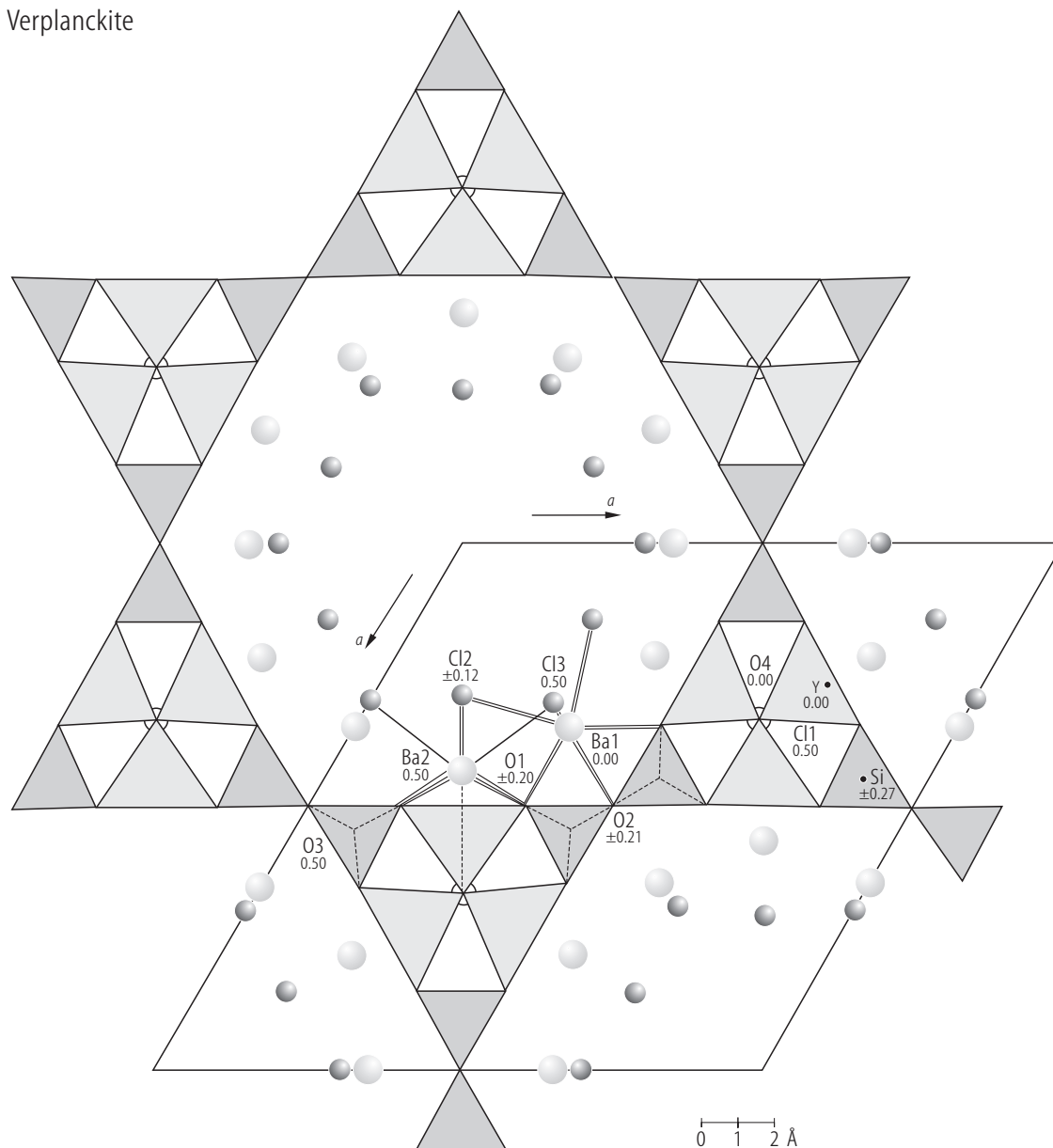


Fig. 2. Verplanckite. Crystal structure viewed parallel to the c -axis. Polyhedral representation for the framework, $Y_6(O,OH)_2Si_{12}O_{36}$, where Y represents the site occupied by Mn, Ti and Fe. Barium and chlorine atoms are shown as circles and the bonds to the barium atoms are indicated. The heights of the atoms are given as z [73K1].

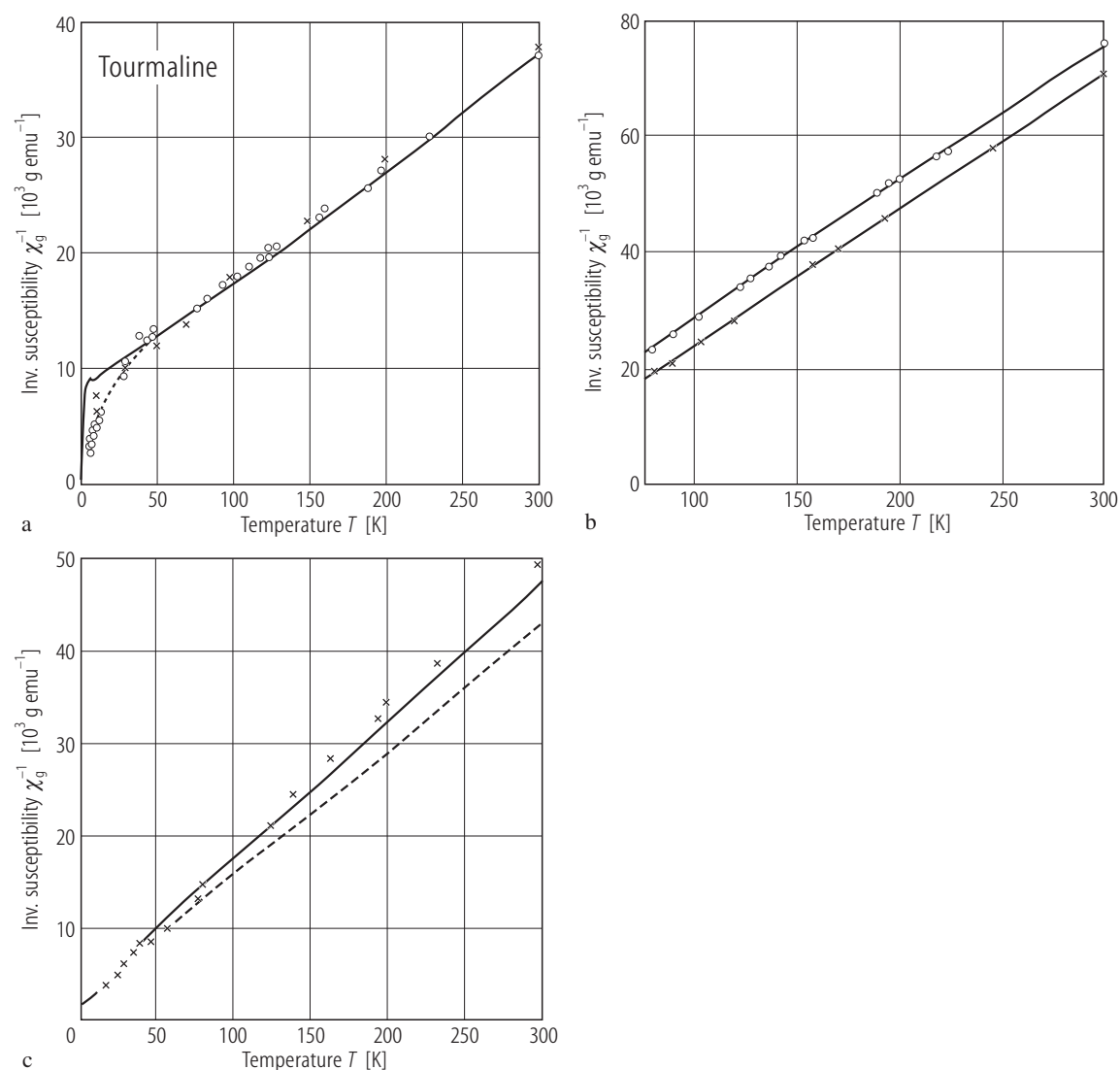


Fig. 3. Tourmalines. Temperature dependences of the reciprocal susceptibilities for: **(a)** buergerite³⁵⁾, solid curve calculated with all Fe-ions on Y-sites; dashed curve, calculated with 10 % of Fe ions on Z-sites;

(b) tourmaline³⁶⁾, crosses $H \parallel c$ and circles $H \perp c$; **(c)** tourmaline³⁷⁾, dashed curve, spin only behaviour, solid curve calculated from different values of exchange constants (see text) [71T2].

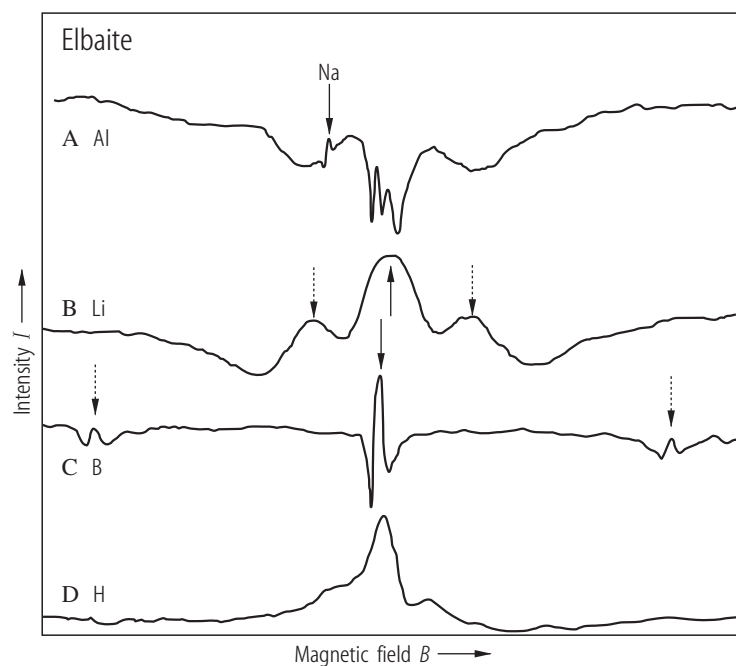


Fig. 4. Elbaite²⁷⁾. NMR spectra for $B \parallel c$. (A) ^{27}Al ; total magnetic field scan is 0.24 T. The arrow indicates ^{23}Na central transition; (B) ^7Li ; total scan is 0.012 T; (C) ^{11}B ; total scan is 0.24 T; (D) ^1H ; total scan is 0.0024 T. The central transitions ($-1/2 \leftrightarrow 1/2$) and the satellites ($\pm 1/2 \leftrightarrow \pm 3/2$) are shown as solid and dashed arrows [73T1].

For Fig. 5 see next page

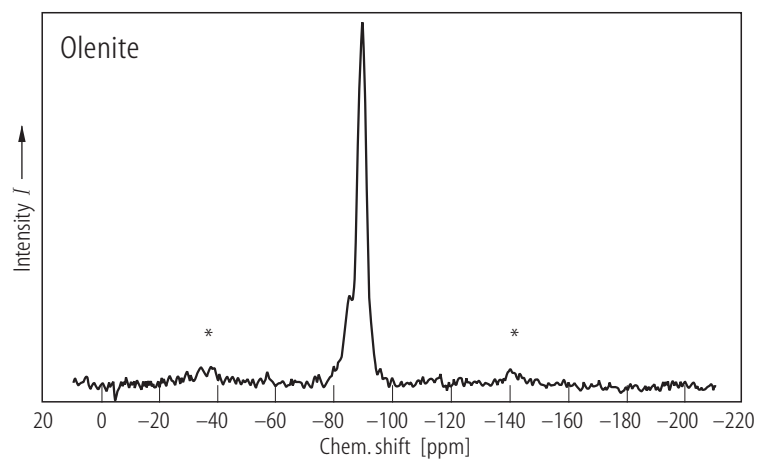


Fig. 6. Natural olenite⁴³⁾. ^{29}Si MAS NMR spectrum [02M1]. Chemical shifts are referenced to the ^{29}Si resonance of TMS (tetramethylsilane). Spinning side bands are marked by asterisks.

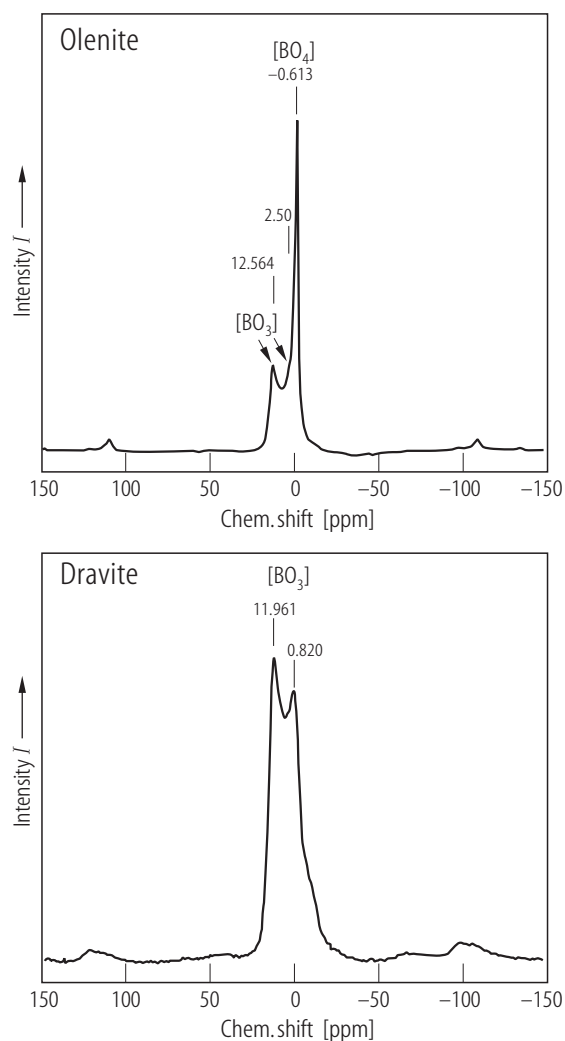


Fig. 5. Synthetic olenite²⁹⁾ (a) and natural dravite (b). ^{11}B MAS NMR spectra (Chemical shift to ^{11}B reference of NaBH_4) [00S1].

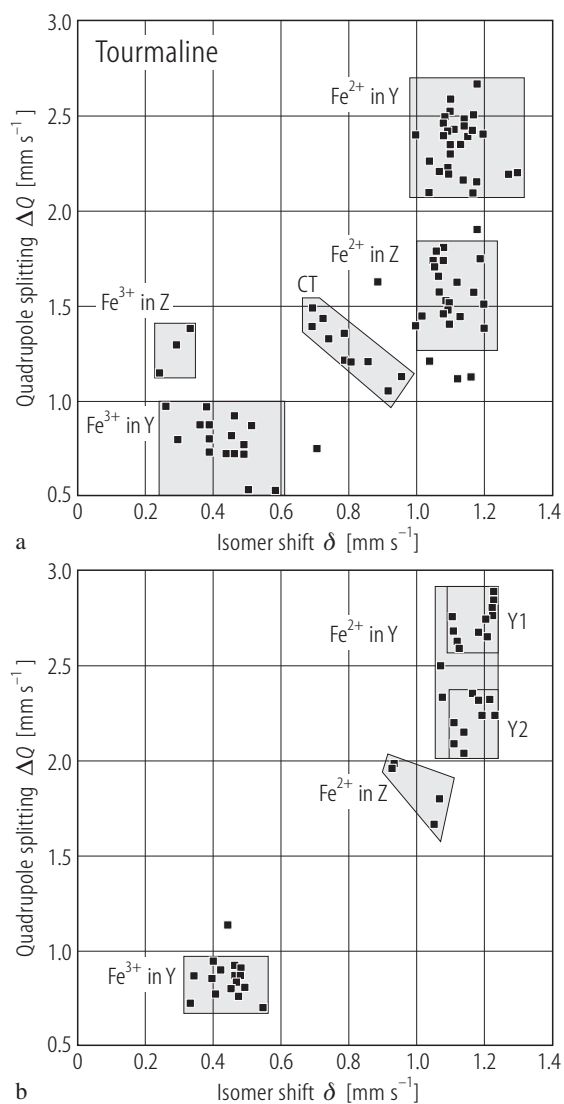


Fig. 7. Tourmalines. (a) Isomer shift, δ , and quadrupole splitting, ΔQ , for natural tourmalines [78G1, 79K1, 79S1, 81B1, 84M1, 88F1, 95F1, 98F1]. (b) Isomer shift, δ , and quadrupole splitting, ΔQ , for synthetic tourmalines [98F1].

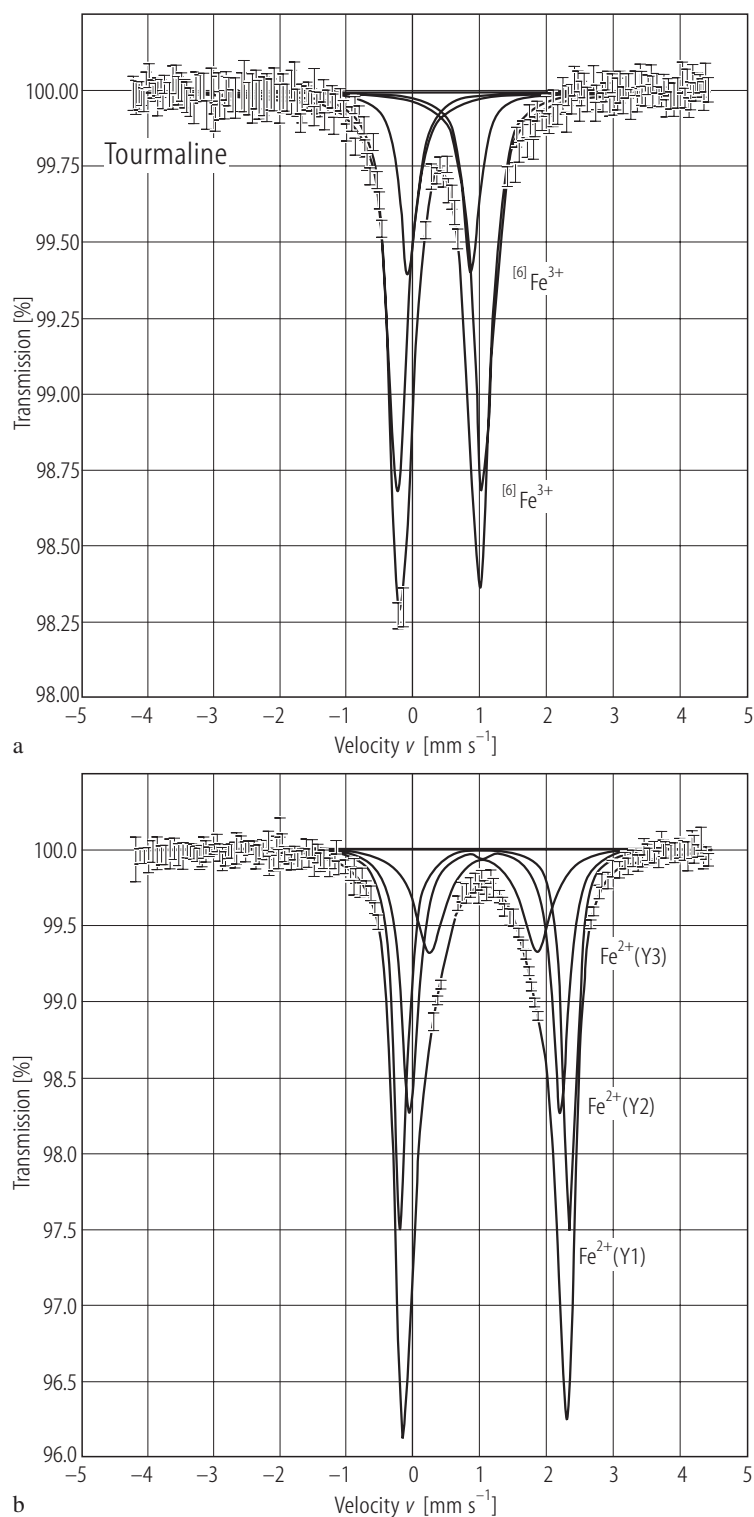


Fig. 8a,b. For caption see next page

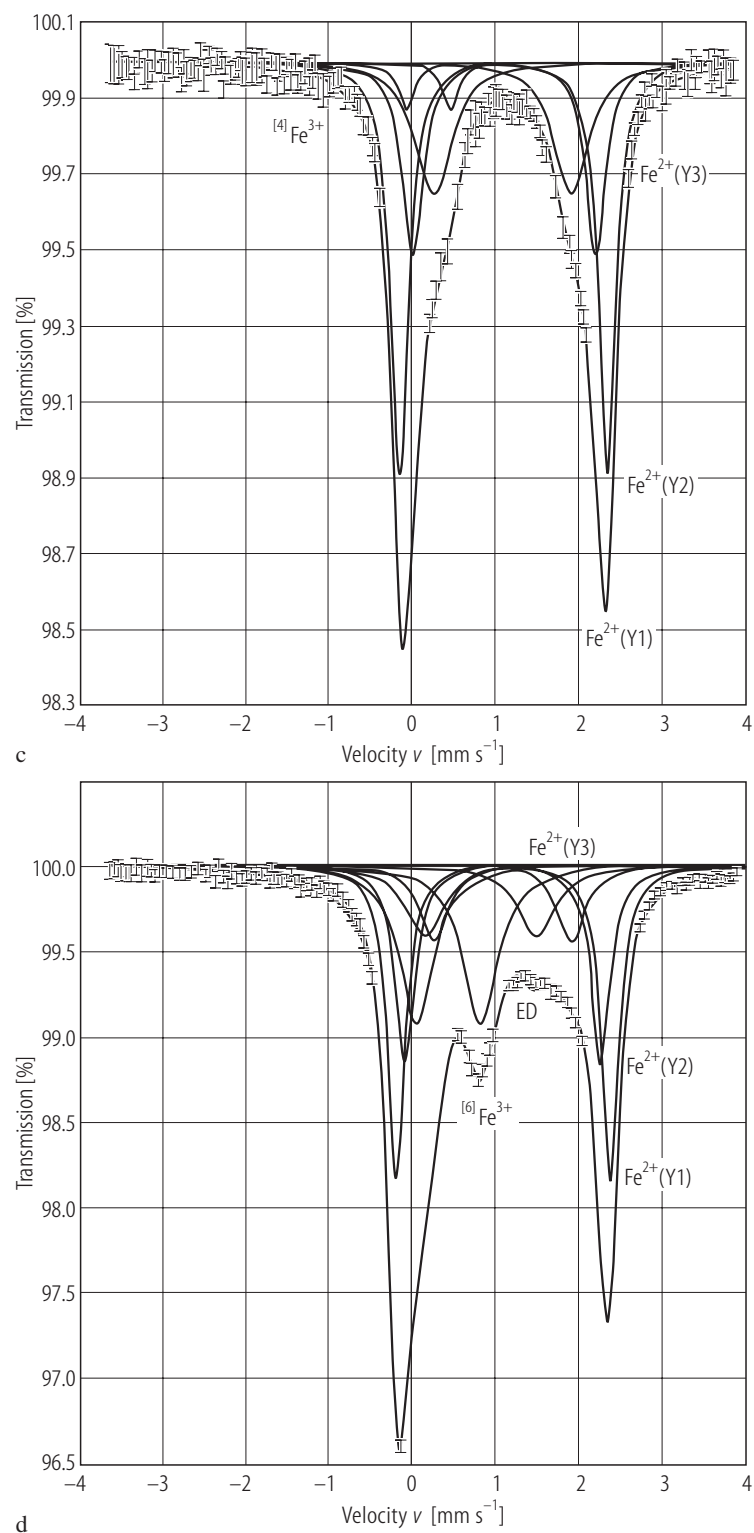


Fig. 8. Tourmalines. ^{57}Fe NGR spectra for: **(a)** buergerite⁵¹⁾ containing only Fe^{3+} , **(b)** schörl⁴⁸⁾ containing only Fe^{2+} , **(c)** schörl⁴⁹⁾ where 5 % of the Fe_{tot} is ^{54}Fe , while Fe^{2+} is distributed among three different Y-sites, **(d)** Schörl⁵⁰⁾ which shows also delocalization between iron in adjacent octahedra [98D1].

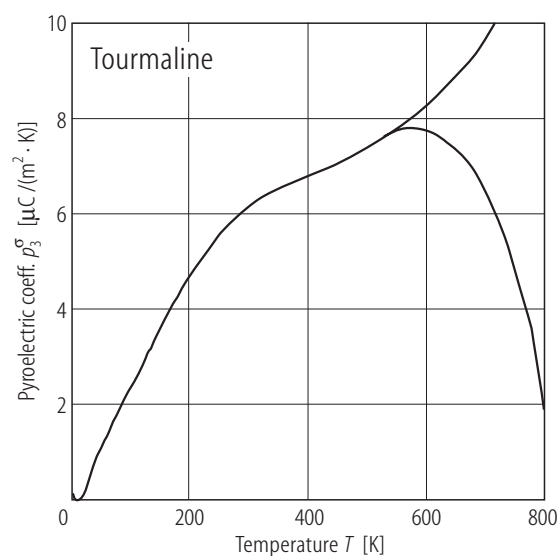


Fig. 9. Tourmaline. The general form of the pyroelectric response with temperature change. A low-temperature polarity inversion is shown at $T < 20$ K [89G1, 95H1].

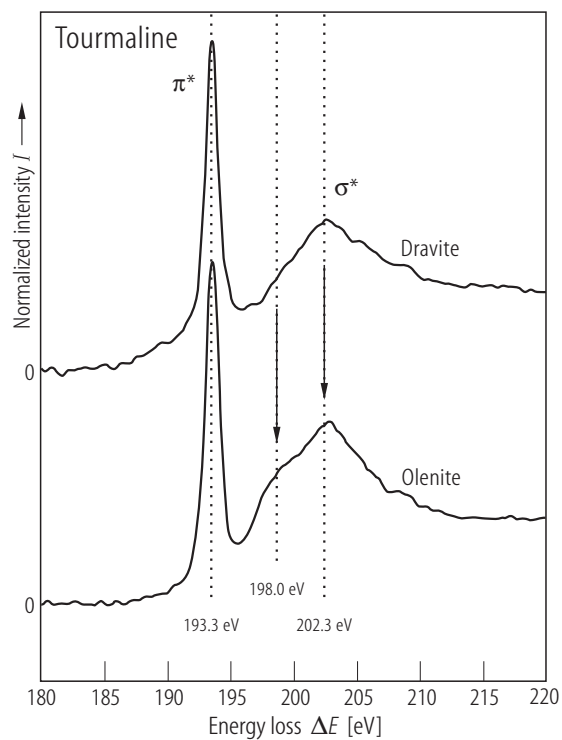


Fig. 10. Synthetic olenite²⁹⁾ and natural dravite. Boron K edge electron loss spectra of same samples as in Fig. 5 [00S1].

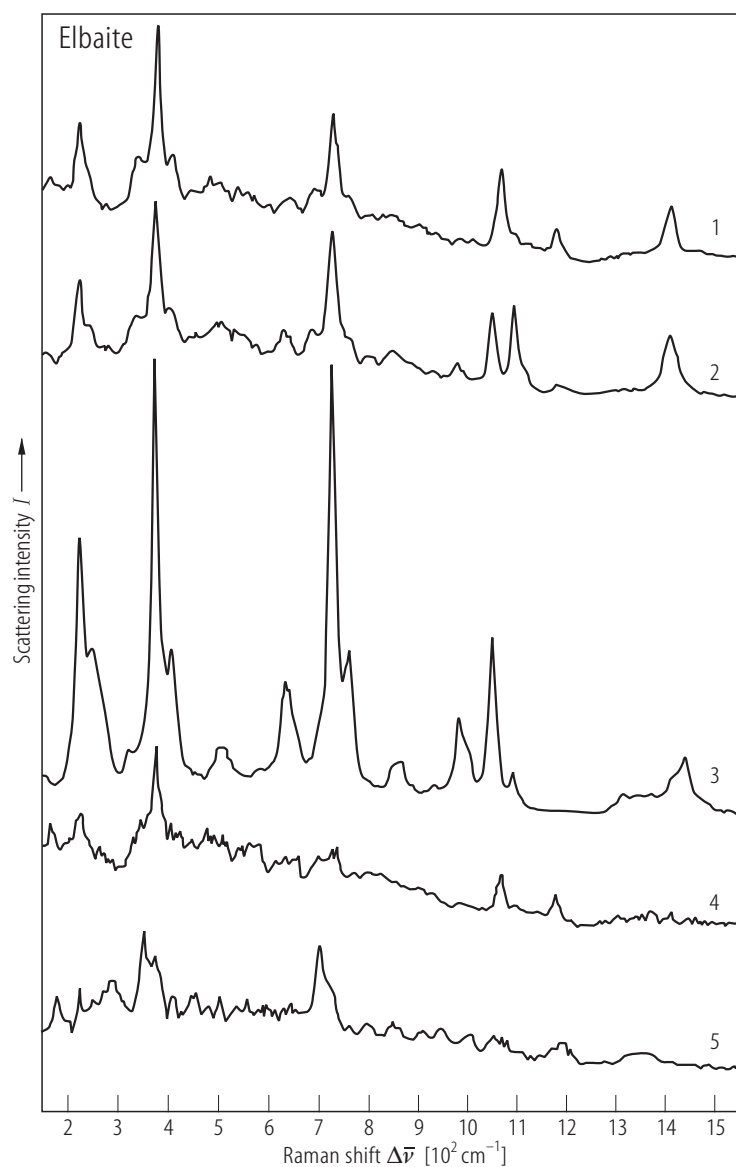


Fig. 11. Elbaite¹⁾. Raman spectra in various geometries, 1: $z(xx)\bar{z}$ ($A_1(L)$, $E(T)$); 2: $x(yy)\bar{x}$ ($A_1(T)$, $E(T)$); 3: $x(zz)\bar{x}$ ($A_1(T)$); 4: $z(xy)\bar{z}$ ($E(T)$); 5: $x(zy)\bar{x}$ ($E(T)$) [97G1].

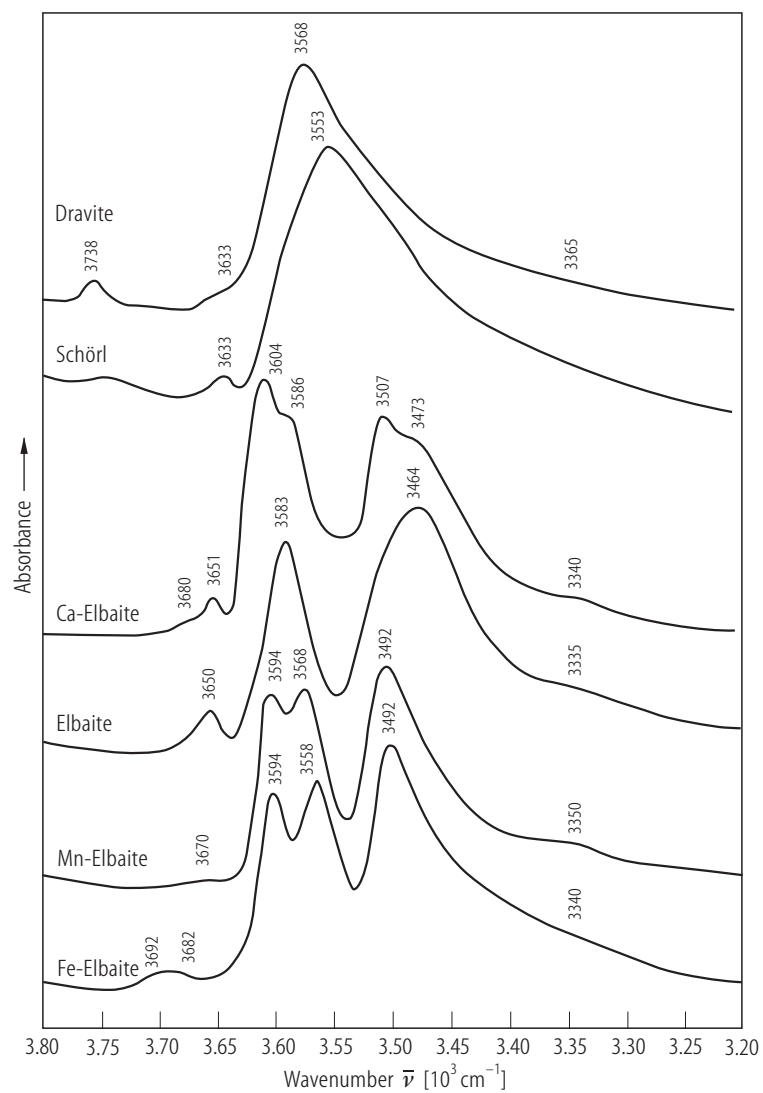


Fig. 12. Tourmalines. Hydroxyl stretching regions of IR spectrum (dravite⁵³), schörl⁵⁴), Ca-elbaite⁶⁰), Elbaite^{58,59}), Mn-elbaite^{56,57}), Fe-elbaite⁵⁵) [88G2].

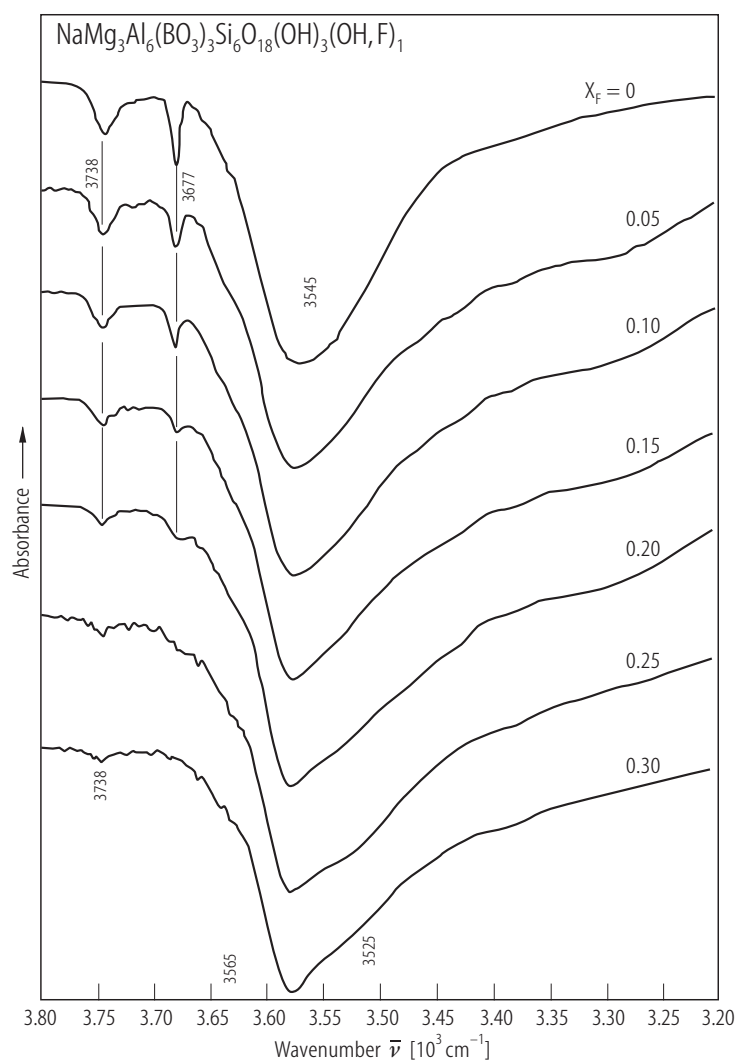


Fig. 13. Dravite, $\text{NaMg}_3\text{Al}_6(\text{BO}_3)_3(\text{Si}_6\text{O}_{18})(\text{OH})_4$. Infrared spectra in the OH-stretching region and evolution with the bulk fluorine content (x_F): 3738 and 3677 cm^{-1} , inner OH groups pointing towards Na and \square , respectively; $\approx 3550 \text{ cm}^{-1}$ outer OH group. Only the inner OH groups can be replaced by F [96R1].

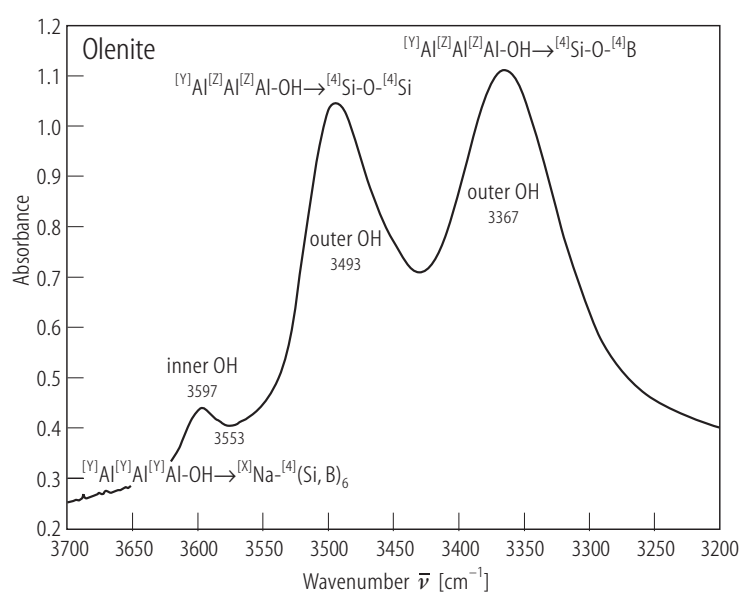


Fig. 14. Synthetic olenite²⁹⁾. IR spectrum in the OH-stretching region. Inner and outer OH refer to the structural positions of hydroxyl groups as defined by [88G2]. Element symbols accompanying the bands relate to the interaction of protons by hydrogen bonding with oxygens surrounding the cations indicated. A possible very weak band at 3553 cm^{-1} was neglected [00S1].

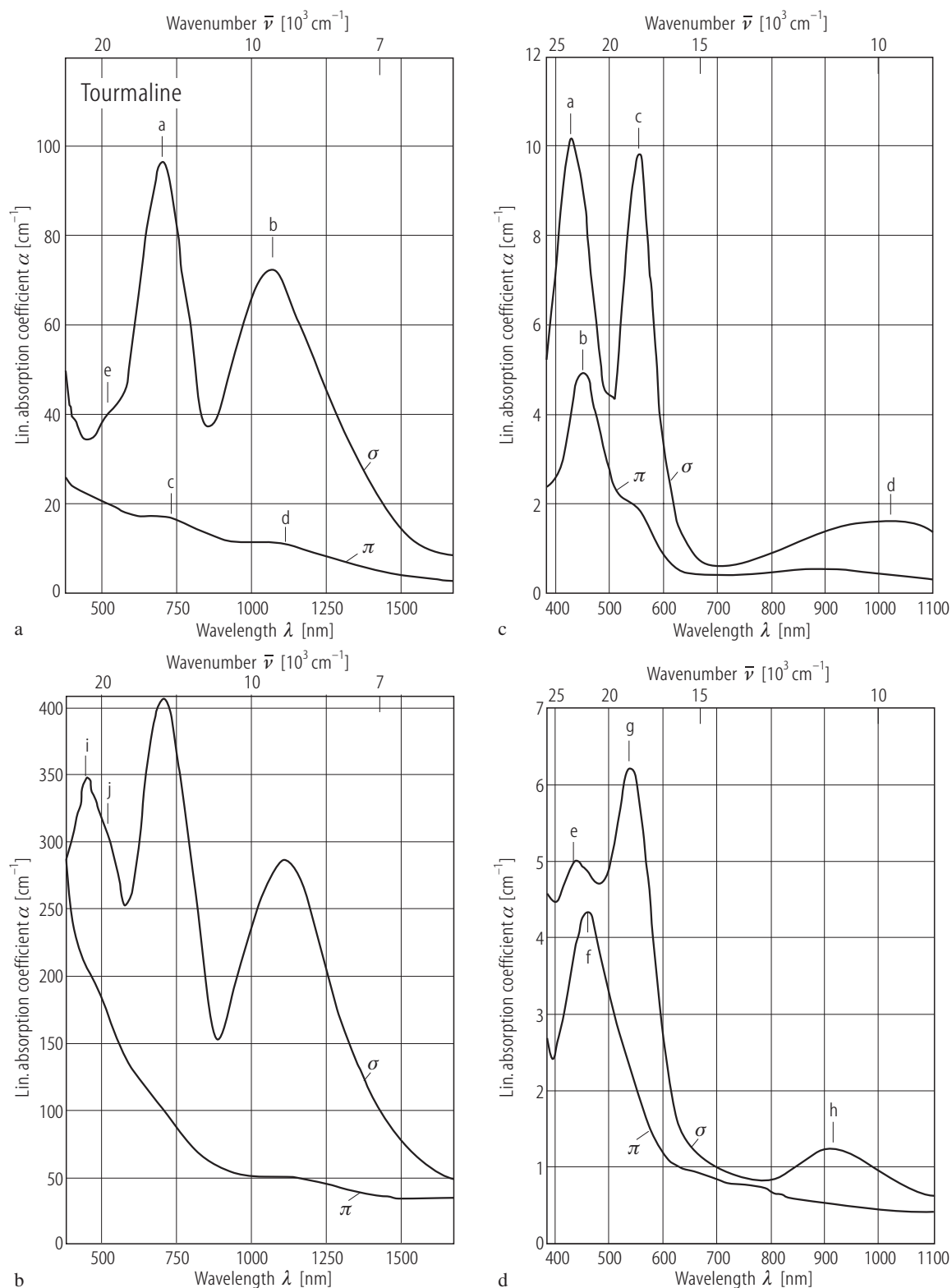


Fig. 15. Tourmalines. Polarized optical spectra at room temperature. **(a)** (Fe²⁺, Fe³⁺)-bearing tourmaline, **(b)** (Fe-Ti)-bearing tourmaline, **(c)** Mn³⁺-bearing tourmaline, Li-free, **(d)** Mn³⁺-bearing tourmaline, Li-doped [93T1].

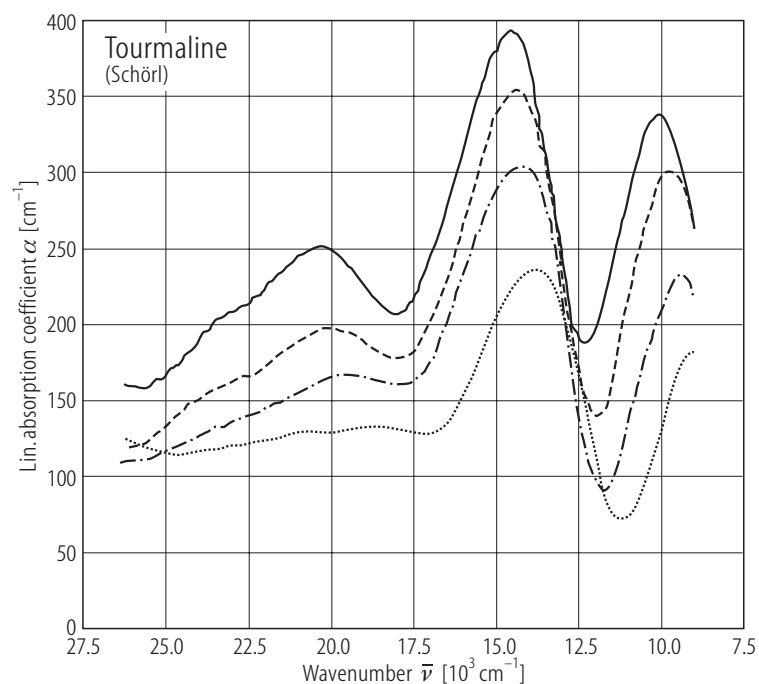


Fig. 16. Schörl⁶⁸⁾. $E \perp [0001]$ spectra at various pressures (in GPa: 10^{-4} dotted line, 3.0 dot-dashed line, 5.2 dashed line, 7.2 solid line) [96T1].

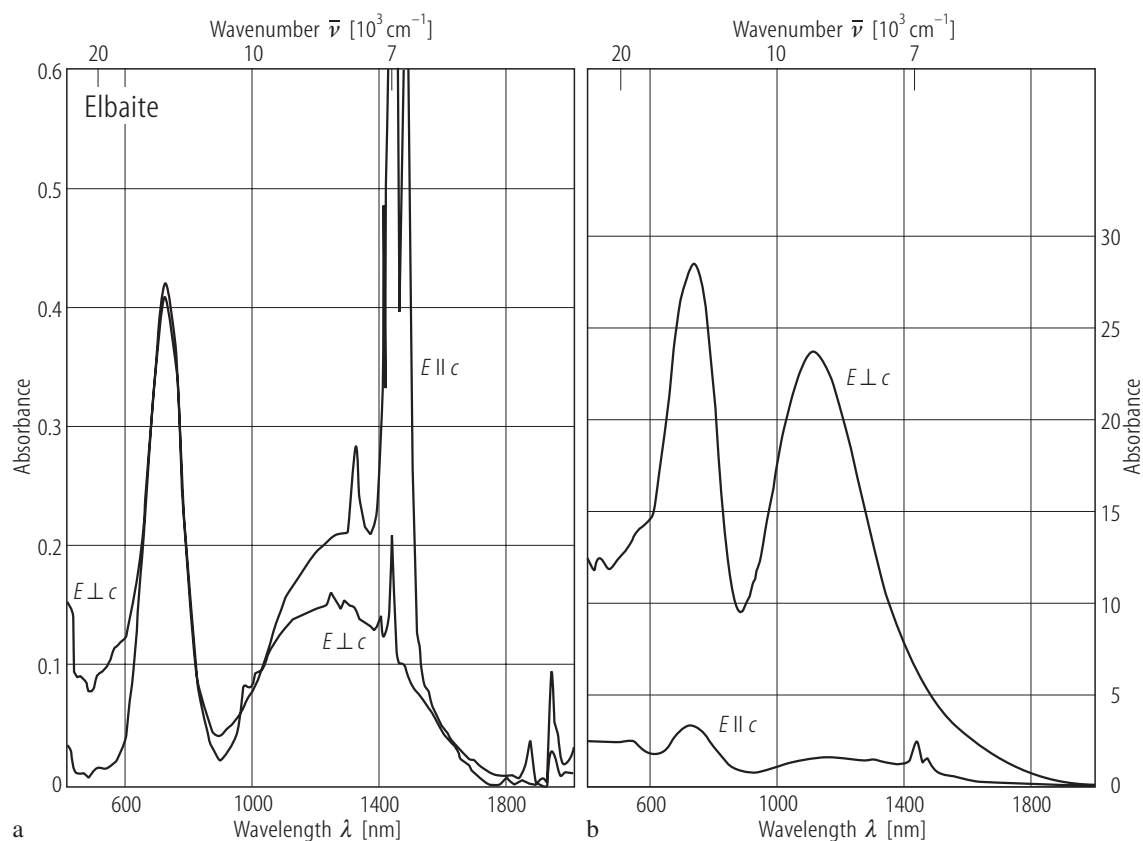


Fig. 17. Elbaite. Absorption spectra normalized to a thickness of 2.46 mm; for sample⁶⁹⁾ (a) the absorbance scale is left, while for sample⁷⁰⁾ (b) the absorbance scale is right [87M3].