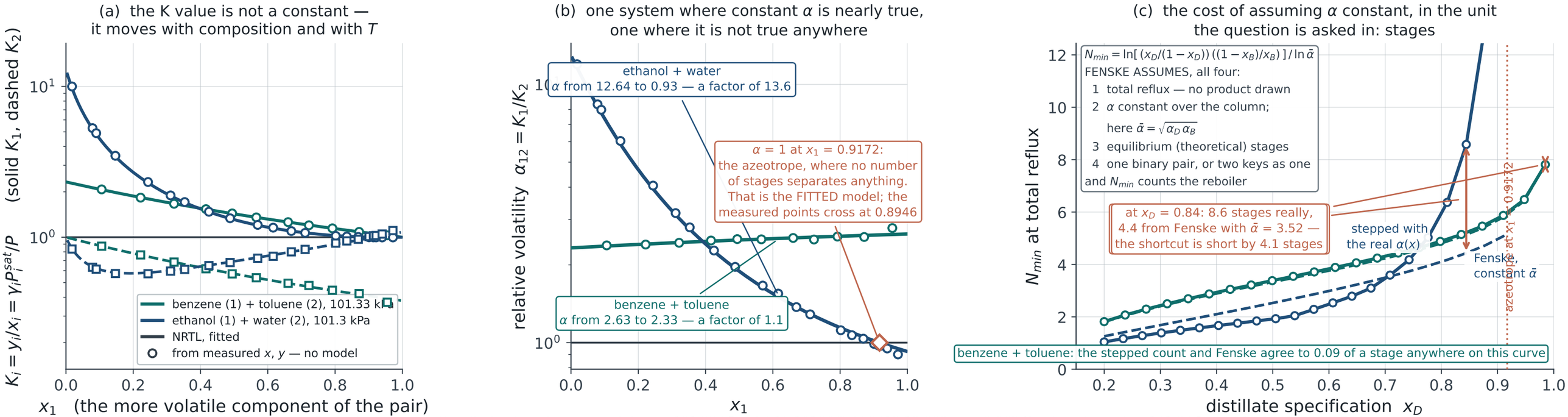
What the activity coefficient is actually for: K_i, α_{12}, and the stage count that follows from them



Curves: NRTL fitted by Barker's method to the cited data — benzene + toluene, 101.33 kPa, doi:10.1016/j.fluid.2013.12.002, rms 0.063 K; ethanol + water, 101.3 kPa, doi:10.1021/je2008704, rms 0.059 K. Markers: $K_1 = y_1/x_1$ and $\alpha = [y_1/(1-y_1)]/[x_1/(1-x_1)]$ straight from the measured pairs, with no model. $\Phi_i = 1$ (ideal vapour, no Poynting) is assumed throughout, so $K_i = \gamma_i P_i^{sat}/P$; P_i^{sat} from the Antoine sets in vlekit.data at the BUBBLE temperature of each composition, which itself moves by 30 K across benzene + toluene and 21 K across ethanol + water.

Panel (c) holds x_B fixed (0.05 for benzene + toluene, 0.02 for ethanol + water) and sweeps x_D. The solid curve steps stages off one at a time at total reflux, where $y_{n+1} = x_n$, using the same NRTL — no constant-α assumption is made anywhere in it; the last stage is interpolated in $\ln[x/(1-x)]$. The dashed curve is Fenske with $\bar{\alpha}$ the geometric mean of the two end values, which is the textbook recipe.

THE COST. benzene + toluene at $x_D = 0.98$: 7.81 stages stepped against 7.83 from Fenske, a difference of 0.02 of a stage — the shortcut is free. ethanol + water at $x_D = 0.84$: 8.6 against 4.4, short by 4.1 stages, and the gap grows without bound as x_D approaches the azeotrope at 0.9172 because the true count diverges there while Fenske stays finite. A constant α is an ASSUMPTION about the mixture, not a property of the method, and it fails silently.