Ethanol–Water Boiling Point and Vapour Strength (x–y)

Boiling point, vapour composition and condensed vapour strength of an ethanol–water liquid near 1 atm, with the azeotrope, by a Wilson model fitted to x–y data.

Method: Ethanol–water VLE at about 1 atm: Wilson equation (Perry's Chemical Engineers' Handbook, 9th ed., sec. 4) with energies 399 and 933 cal/mol fitted to FireCAD ethanol–water x–y–T data at 101.325 kPa; ethanol vapour pressure Perry's 9th ed. Table 2-8; water IAPWS-IF97; Checked against Gmehling and Onken; ...

Input parameters

Unit system: SI

Parameter	Value	Unit
Liquid strength entered as	% vol at 20 °C	
Liquid strength	8.0000	%
Pressure Model fitted at 1 atm; use 0.9–1.2 atm.	101.33	kPa

Calculated results

Parameter	Value	Unit
Liquid mole fraction of ethanol	2.6025	%
Boiling (bubble) point	93.518	°C
Vapour mole fraction of ethanol	22.788	%
Strength of the condensed vapour	50.624	%
Relative volatility ethanol/water	11.046	
Activity coefficient of ethanol	4.9547	
Activity coefficient of water	1.0029	
Azeotrope mole fraction at this pressure	88.544	%

Notes for this case

- Above the azeotrope (about 0.885 mole fraction, about 97 % vol) ordinary distillation cannot enrich ethanol further.

Formula and method

$$y_1 P = x_1 \gamma_1 p_1^s(T), \quad y_2 P = x_2 \gamma_2 p_2^s(T), \quad \ln\gamma_1 = -\ln(x_1 + \Lambda_{12} x_2) + x_2 \left(\frac{\Lambda_{12}}{x_1 + \Lambda_{12} x_2} - \frac{\Lambda_{21}}{x_2 + \Lambda_{21} x_1} \right)$$

$$\Lambda_{12} = \frac{V_2}{V_1} e^{-a_{12}/RT}, \quad \Lambda_{21} = \frac{V_1}{V_2} e^{-a_{21}/RT}$$

Variables

basis	Liquid strength entered as	-
s	Liquid strength	-
P	Pressure	Pa
x_1	Liquid mole fraction of ethanol	-
T_b	Boiling (bubble) point	K
y_1	Vapour mole fraction of ethanol	-
q_y	Strength of the condensed vapour	-
α	Relative volatility ethanol/water	-
γ_1	Activity coefficient of ethanol	-
γ_2	Activity coefficient of water	-

x_{az}	Azeotrope mole fraction at this pressure	-
γ_1, γ_2	Activity coefficients of ethanol and water (Wilson)	-
p_1^s, p_2^s	Vapour pressures of ethanol and water	Pa
$\Lambda_{12}, \Lambda_{21}, a_{12}, a_{21}$	Wilson parameters (399 and 933 cal/mol; V_1 58.68, V_2 18.07 cm³/mol)	-

Method and standards

Modified Raoult's law with Wilson activity coefficients; bubble temperature by bisection.

Assumptions and limits

- Wilson energies fitted at 1 atm; 0.9–1.2 atm only.
- Binary ethanol–water; congeners and dissolved solids ignored.

References

• Ethanol–water VLE at about 1 atm: Wilson equation (Perry's Chemical Engineers' Handbook, 9th ed., sec. 4) with energies 399 and 933 cal/mol fitted to FireCAD ethanol–water x–y–T data at 101.325 kPa; ethanol vapour pressure Perry's 9th ed. Table 2-8; water IAPWS-IF97
• Checked against Gmehling and Onken
• DECHEMA Chemistry Data Series vol. I/1
• as quoted in Perry's 9th ed. sec. 13 (simple batch distillation example)

Report details

Report reference	FCC-N5V5-AQ9M (the same inputs always give the same reference)
Generated	17 November 2026, 19:50 UTC
Calculator	Ethanol–Water Boiling Point and Vapour Strength (x–y)
Method last reviewed	13 November 2026
Software release	FireCAD Calc, release of 17 November 2026
Release checks	3 reference cases of this calculator, computed independently, are checked on every release

Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/sugar-ethanol/ethanol-distillation/ethanol-water-vle-1atm

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.