

EXAMPLE 3.16

ORIGIN := 1

$T_c := 407.7$

$P_c := 36.5$

$\omega := 0.183$

$R := 8.314$

```

root(p, q, r) :=
  v ← ( r
        q
        p
        1 )
  x ← polyroots(v)
  for i ∈ 1 .. 3
    xi ← 0 if Im(xi) ≠ 0
  x1 ← max(x)
  y ← min(x)
  x2 ← max(x) if y = 0
        y otherwise
  ( x1
    x2 )

```

a) Reversible and Isothermal Expansion

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z(T, P) :=
  Tr ← T / Tc
  Pr ← P / Pc
  A ← 0.42748 · Pr / Tr2.5
  B ← 0.08664 · Pr / Tr
  p ← -1
  q ← A - B - B2
  r ← -A · B
  Z ← root(p, q, r)1
  Z

```

$z(450, 40) = 0.659$

$z(450, 10) = 0.927$

b) Reversible and Adiabatic Expansion

$$c_p(T) := 24.108 + 2.091 \cdot 10^{-1} T + 2.166 \cdot 10^{-4} T^2 - 3.372 \cdot 10^{-7} T^3 + 11.619 \cdot 10^{-11} T^4$$

$$x(T, P) := \left| \begin{array}{l} T_r \leftarrow \frac{T}{T_c} \\ P_r \leftarrow \frac{P}{P_c} \\ A \leftarrow 0.42748 \cdot \frac{P_r}{T_r^{2.5}} \\ B \leftarrow 0.08664 \cdot \frac{P_r}{T_r} \\ p \leftarrow -1 \\ q \leftarrow A - B - B^2 \\ r \leftarrow -A \cdot B \\ Z \leftarrow \text{root}(p, q, r)_1 \\ X \leftarrow R \cdot \ln(Z - B) - \frac{R}{2} \cdot \frac{A}{B} \cdot \ln\left(1 + \frac{B}{Z}\right) \\ X \end{array} \right.$$

$$T := 350$$

Given

$$x(T, 10) - x(450, 40) + \int_{450}^T \frac{c_p(T)}{T} dT - R \cdot \ln\left(\frac{10}{40}\right) = 0$$

$$T := \text{Find}(T) = 395.938$$

$$\begin{array}{l}
 \gamma(T, P) := \\
 \left. \begin{array}{l}
 T_r \leftarrow \frac{T}{T_c} \\
 P_r \leftarrow \frac{P}{P_c} \\
 A \leftarrow 0.42748 \cdot \frac{P_r}{T_r^{2.5}} \\
 B \leftarrow 0.08664 \cdot \frac{P_r}{T_r} \\
 p \leftarrow -1 \\
 q \leftarrow A - B - B^2 \\
 r \leftarrow -A \cdot B \\
 Z \leftarrow \text{root}(p, q, r)_1 \\
 Y \leftarrow \frac{A \cdot T}{B} \cdot \ln\left(1 + \frac{B}{Z}\right) \\
 Y
 \end{array} \right\}
 \end{array}$$

This is Eq. (3.2-17)

$$\Delta U := 3 \left[\frac{3 \cdot R}{2} (\gamma(450, 40) - \gamma(T, 10)) + \int_{450}^T (C_p(T) - R) dT \right] = -1.293 \times 10^4$$