Example 10.1 Binary system acetonitrile(1)/nitromethane(2) conforms closely to Raoult's law. Vapor pressures for the pure species are given by the following Antoine equations:

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$$\ln P_1^{\text{sat}}/\text{kPa} = 14.2724 - \frac{2{,}945.47}{T - 49.15}$$

$$\ln P_2^{\text{sat}}/\text{kPa} = 14.2043 - \frac{2{,}972.64}{T - 64.15}$$

(*a*) Prepare a graph showing P vs. x_1 and P vs. y_1 for a temperature of 75°C.

(*b*) Prepare a graph showing t vs. x_1 and t vs. y_1 for a pressure of 70 kPa.

(a) Given T (75°C) and x_1 find P and y_1 (BUBLP)

Raoult's law: $y_i P = x_i P_i^{sat}$

$$y_i = \frac{x_i P_i^{sat}}{P}, \quad \sum_i y_i = 1$$

$$\Rightarrow 1 = \sum_i \frac{x_i P_i^{sat}}{P} \quad \text{solve for } P.$$

$$P = \sum_i x_i P_i^{sat} \Rightarrow P = x_1 P_1^{sat} + x_2 P_2^{sat}$$

$$x_2 = 1 - x_1 \Rightarrow \boxed{P = P_2^{sat} + (P_1^{sat} - P_2^{sat}) x_1} \quad (1)$$

Since P is known $\Rightarrow$

$$\boxed{y_1 = \frac{x_1 P_1^{sat}}{P_2^{sat} + (P_1^{sat} - P_2^{sat}) x_1} \quad (2)}$$

$P_1^{sat}(75°C) = 83.21$ kpa

$P_2^{sat}(75°C) = 41.98$ kpa

$$\Rightarrow \quad P = 41.98 + 41.23\, X_1 \qquad \text{see eq. 1}$$

$$y_1 = \frac{83.21\, X_1}{(41.98 + 42.23\, X_1)}$$

x_1	y_1	P/kPa
0.0	0.0	41.98
0.2	0.3313	50.23
0.4	0.5692	58.47
0.6	0.7483	66.72
0.8	0.8880	74.96
1.0	1.0	83.21

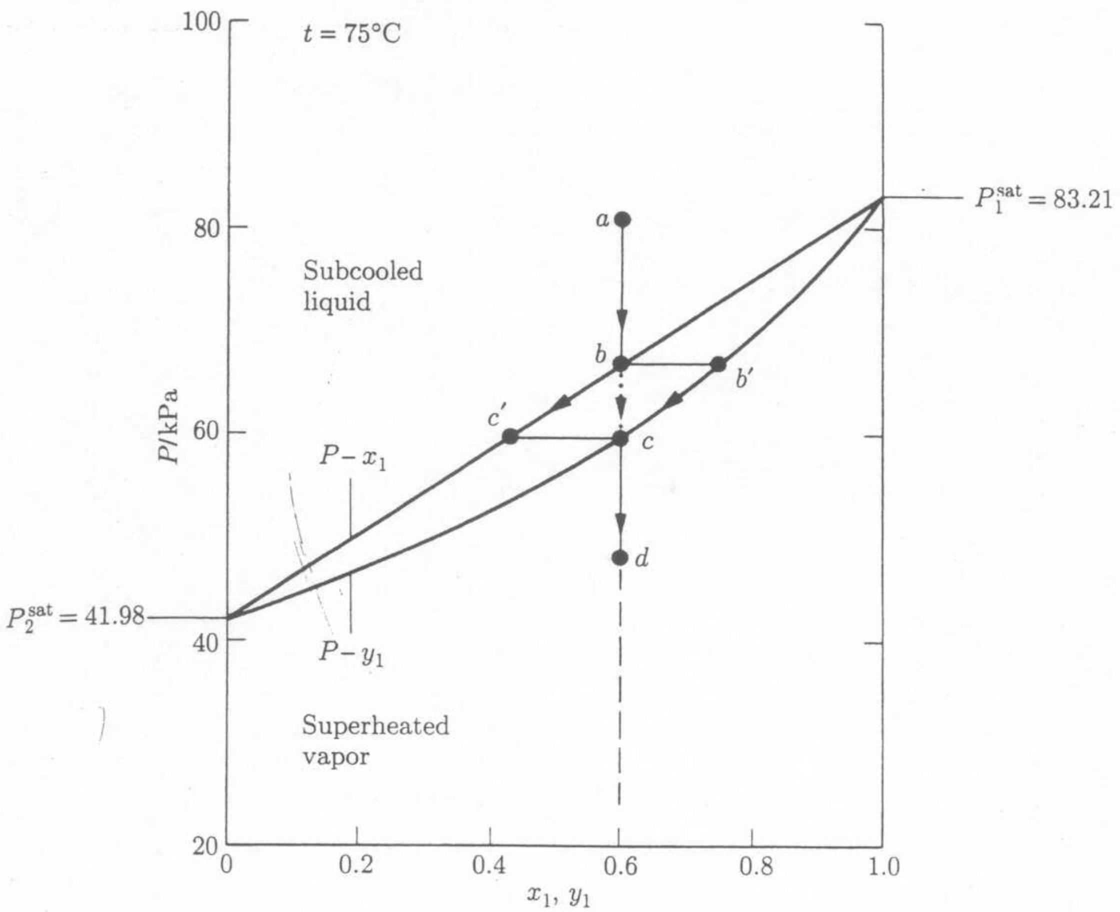

Figure Pxy diagram for acetonitrile(1)/nitromethane(2) at 75°C as given by Raoult's law.

(6) Given $P = 70$ kpa and y_1 find T & x_1 (DEWT) ③

Raoult's law: $y_i P = x_i P_i^{sat}$

$$x_i = y_i P / P_i^{sat} \quad , \quad \sum_i x_i = 1$$

$$\Rightarrow 1 = \frac{y_1 P}{P_1^{sat}} + \frac{y_2 P}{P_2^{sat}} \quad , \quad P = 70 \text{ kpa}. \quad y_2 = 1 - y_1$$

rearrange,

$$\Rightarrow \left(\frac{y_1}{P_1^{sat}} + \frac{1 - y_1}{P_2^{sat}} \right) 70 - 1 = 0$$

express P_1^{sat} and P_2^{sat} as functions of T

$$\left[\frac{y_1}{1579154.3 \exp\left[- \frac{2945.47}{T + 224} \right]} + \frac{1 - y_1}{1475193.9 \exp\left[\frac{-2972.64}{T + 209} \right]} \right] * 70 - 1 = 0 \quad \text{----} \quad (3)$$

given y_1 calculate T by trail and error from above equation. Then,

$$x_1 = \frac{y_1 P}{P_1^{sat}} = \frac{70 \, y_1}{1579154.3 \exp\left[\frac{-2945.47}{T + 224} \right]} \quad (4)$$

given y calculate T from (3) the calculate x_1 from (4)

y1	x1	T
0.00	0.00	89.58
0.25	0.15	85.85
0.50	0.34	81.52
0.75	0.60	76.36
1.00	1.00	69.84

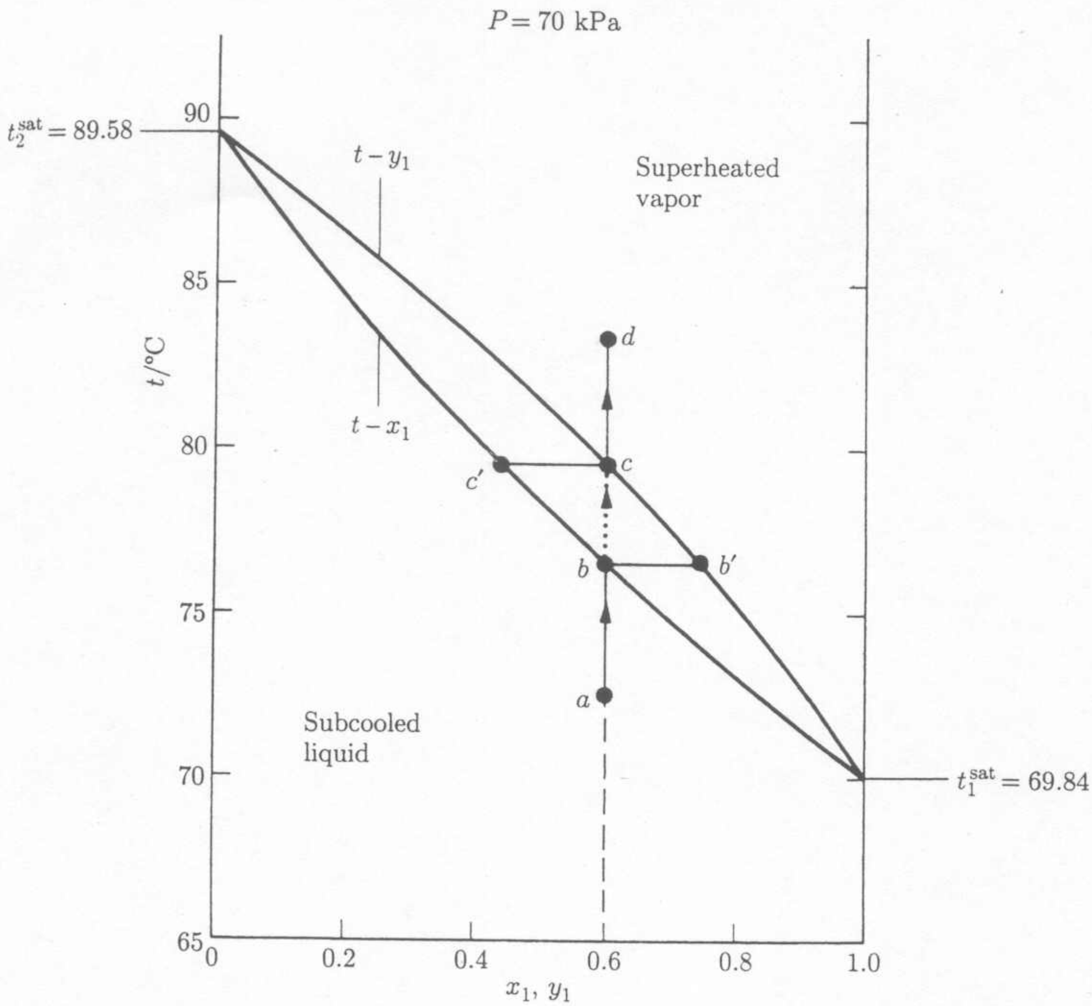

Figure *txy* diagram for acetonitrile(1)/nitromethane(2) at 70 kPa as given by Raoult's law.