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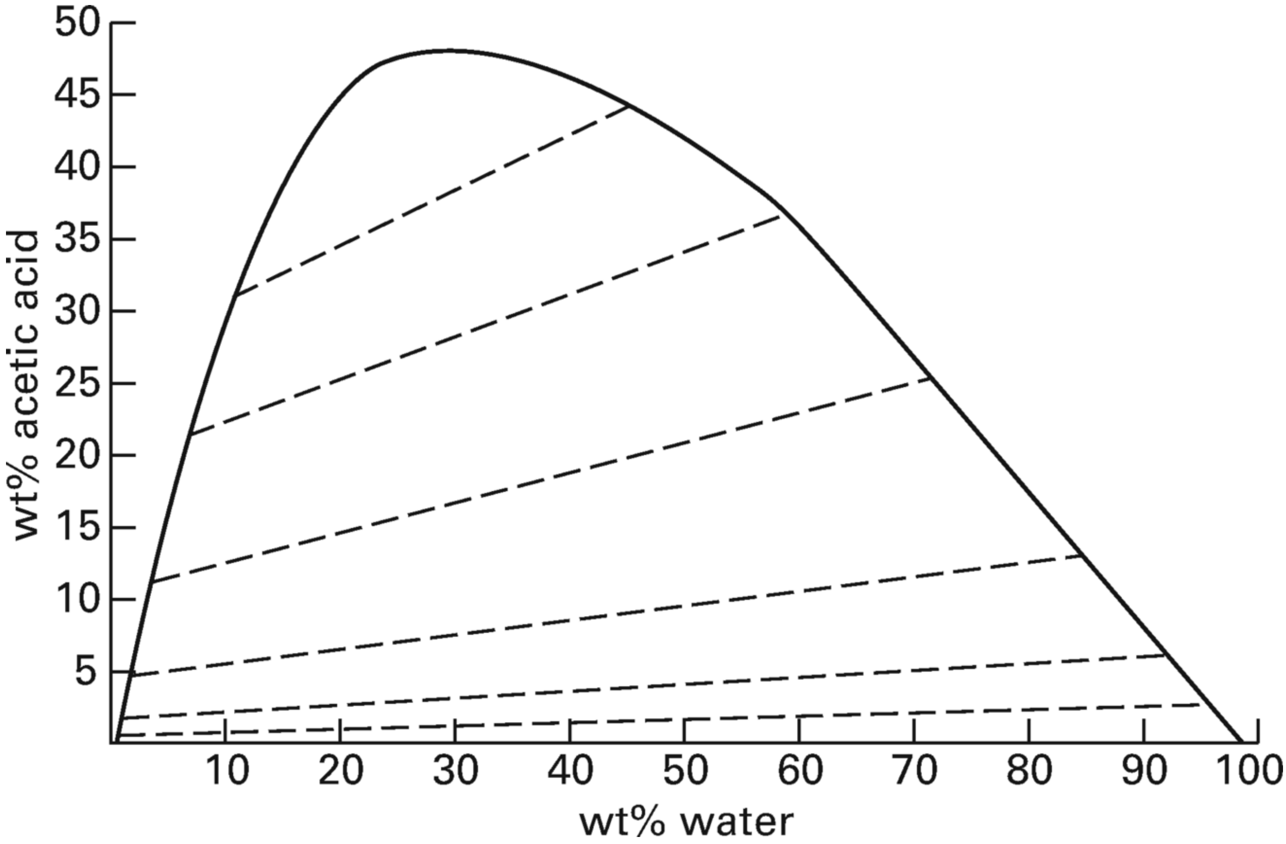
Chapter 25. Liquid-Liquid Extraction

Practice Problems

1.

100 g of 45 wt% acetic acid in water and 180 g of isopropyl ether are combined in a beaker.



Given the phase diagram shown, the equilibrium weight percentage of isopropyl ether in each phase is most nearly

(A)

0% and 80%

(B)

0% and 100%

(C)

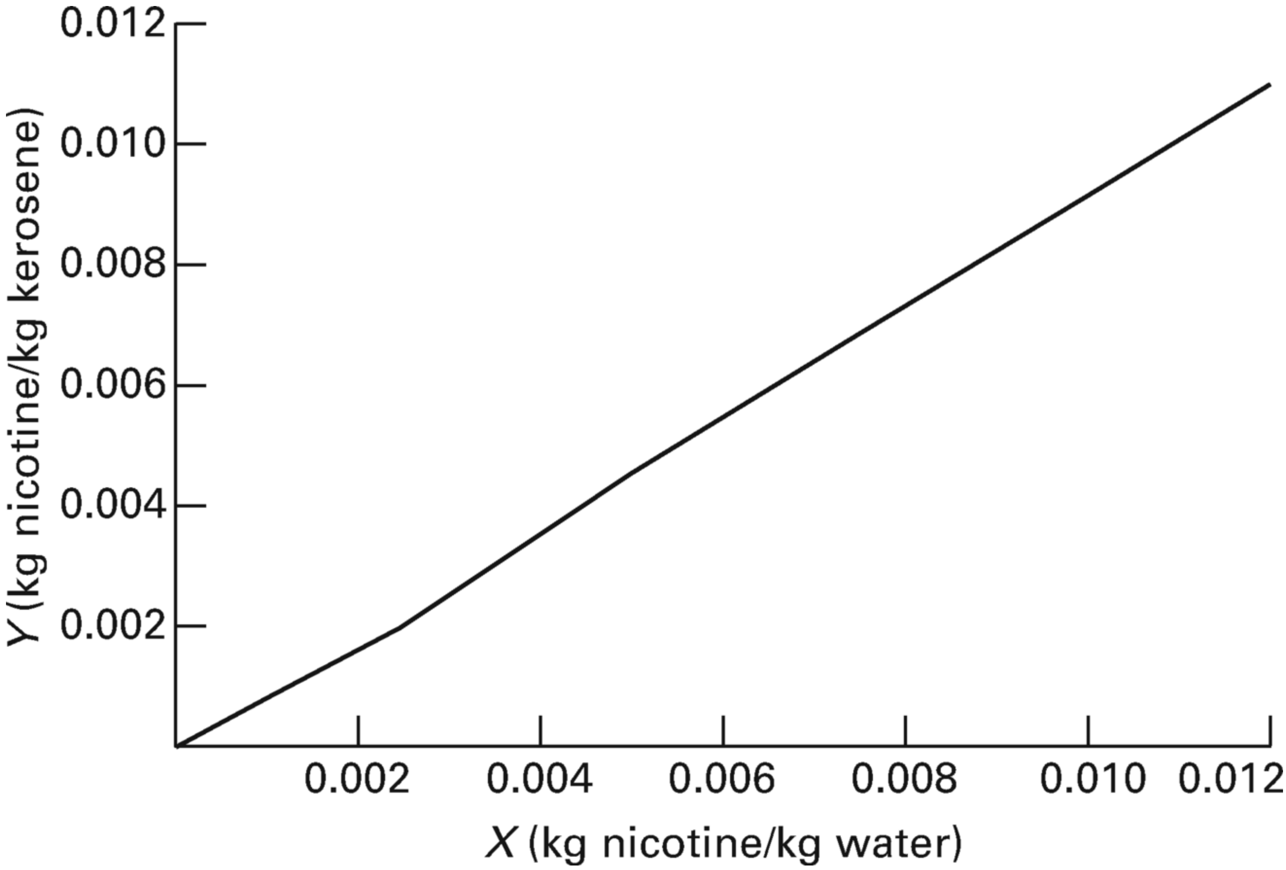
4% and 83%

(D)

64% and 64%

2.

A byproduct stream flowing at the rate of 2323 kg/h is water containing 1 wt% nicotine. The nicotine content needs to be reduced to 0.1 wt% using pure kerosene. The equilibrium data is provided.



What is the minimum solvent flow rate needed to achieve the separation?

(A)

23 kg/h

(B)

30 kg/h

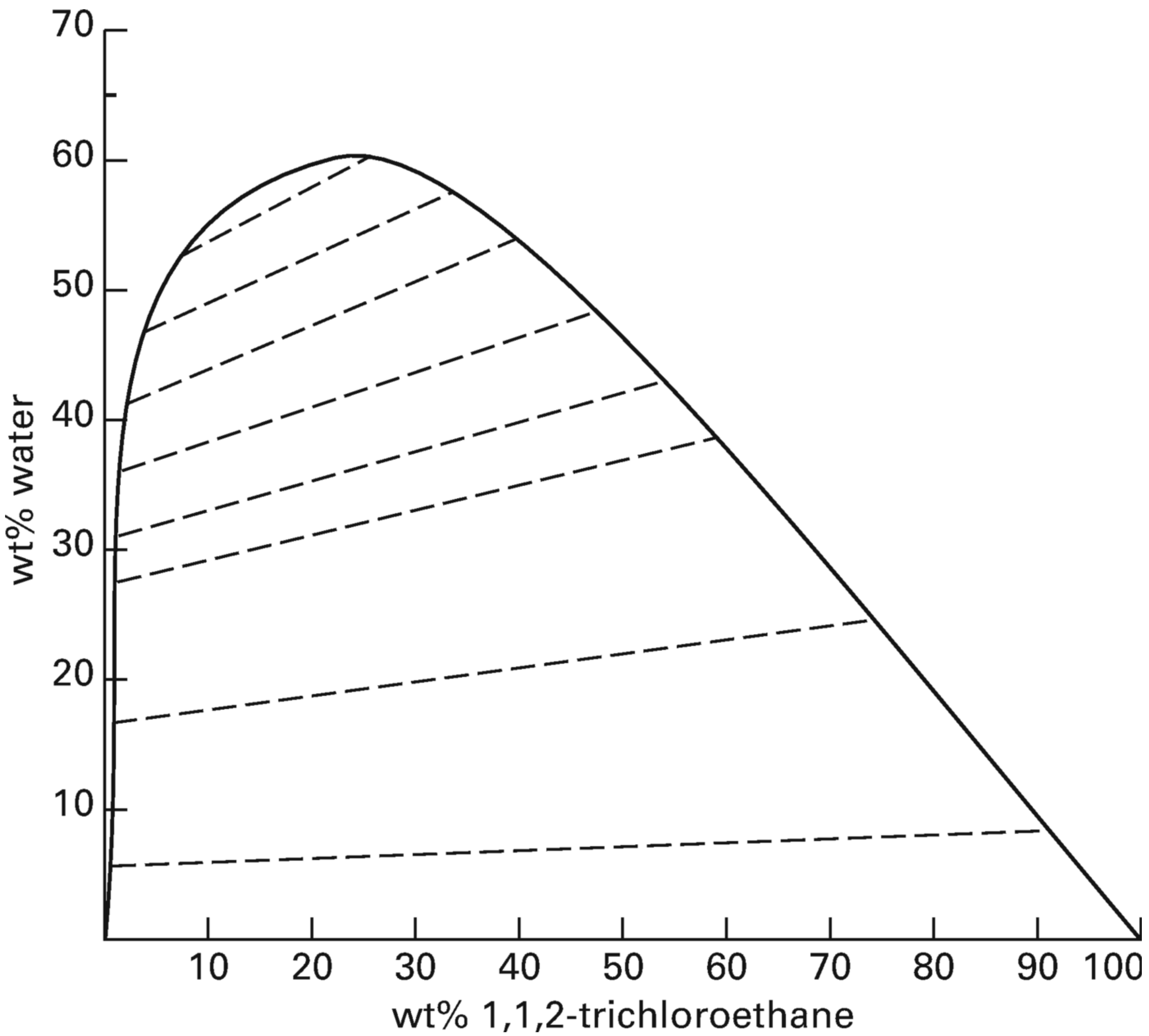
(C)

2300 kg/h

(D)

3000 kg/h
3.

Equal amounts of a solution of 50 wt% 1,1,2- trichloroethane in water and pure acetone are mixed.



Given the phase diagram shown, the equilibrium weight percentage of acetone in each phase is most nearly

(A)

0% and 100%

(B)

1% and 77%

(C)

3% and 74%

(D)

50% and 50%

Solutions

1.

This is a mixing problem.

The composition of the diluent, D (water), and of the solute, A (acetic acid), for the mixing point can be calculated using equationCHRM45008 and equationCHRM45009. See also *NCEES Handbook:* Measures of Composition.

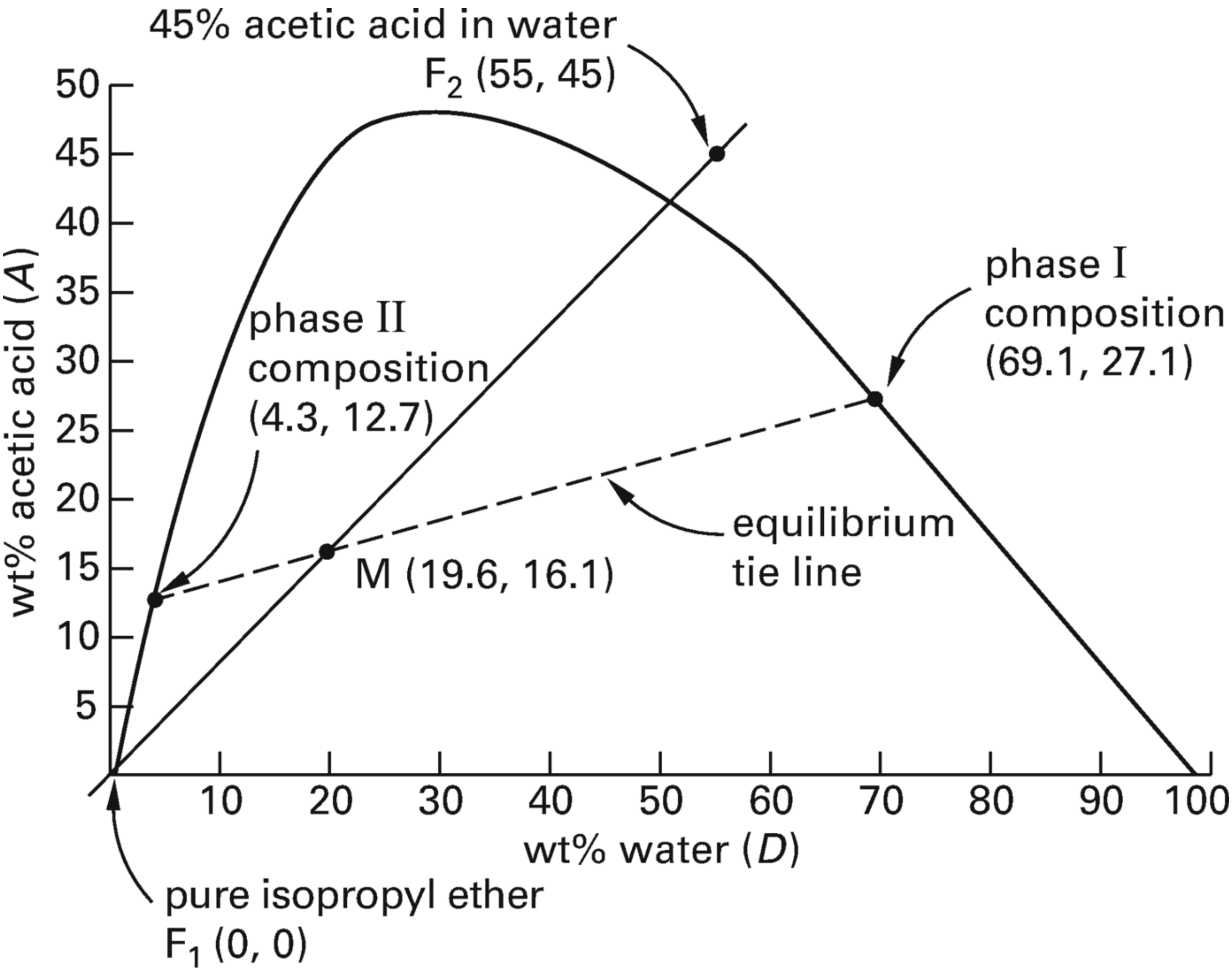
$$\begin{aligned} x_{D,\mathrm{M}} &= \frac{F_1 x_{D,\mathrm{F}_1} + F_2 x_{D,\mathrm{F}_2}}{F_1 + F_2} \\ &= \frac{(180\ \mathrm{g})\,(0) + (100\ \mathrm{g})\,(0.55)}{180\ \mathrm{g} + 100\ \mathrm{g}} \\ &= 0.196 \\ x_{A,\mathrm{M}} &= \frac{F_1 x_{A,\mathrm{F}_1} + F_2 x_{A,\mathrm{F}_2}}{F_1 + F_2} \\ &= \frac{(180\ \mathrm{g})\,(0) + (100\ \mathrm{g})\,(0.45)}{180\ \mathrm{g} + 100\ \mathrm{g}} \\ &= 0.161 \end{aligned}$$

In terms of wt%, the mixing point is at (19.6, 16.1).

By drawing the tie line that passes through the mixing point, the equilibrium compositions can be read. For each phase,

$$\begin{aligned} \text{Phase I at } (69.1, 27.1):\ & 69.1 \text{ wt\% water,} \\ & 27.1 \text{ wt\% acetic acid,} \\ & 3.8 \text{ wt\% (4 wt\%) isopropyl ether} \end{aligned}$$

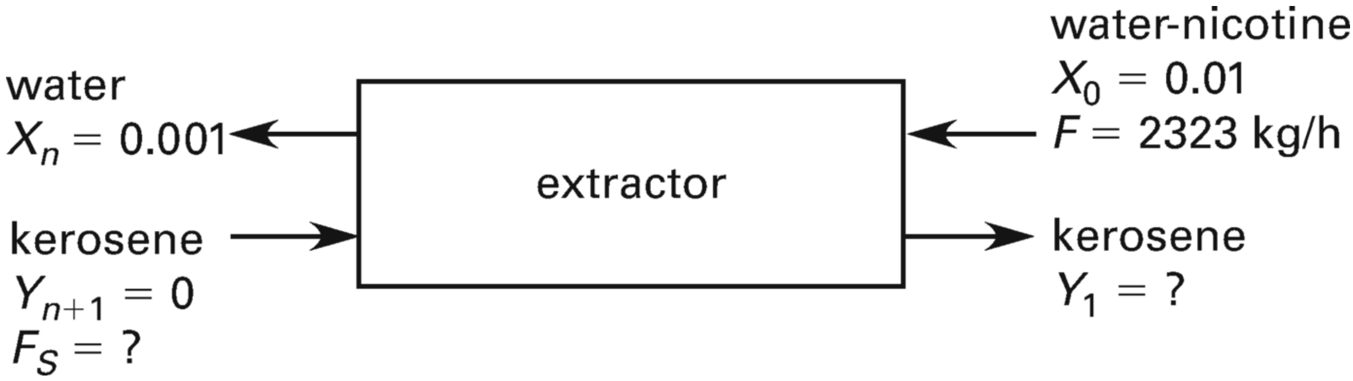
$$\begin{aligned} \text{Phase II at } (4.3, 12.7):\ & 4.3 \text{ wt\% water,} \\ & 12.7 \text{ wt\% acetic acid,} \\ & 83 \text{ wt\% isopropyl ether} \end{aligned}$$



The answer is (C).

2.

Since both streams are dilute, x is approximately the same as X, and y is approximately the same as Y.



The minimum solvent flow rate can be determined graphically or from the operating equation, equationCHRM45004. The slope of the operating line is the ratio of the diluent feed to the solvent feed, F_D/F_S. The minimum solvent flow rate will be at the maximum slope of this line. One point on the operating line is at (X_n, Y_{n+1}) or $(0.001, 0)$, which is plotted on the equilibrium diagram. The operating line is drawn from this point to intersect the equilibrium curve at $X_0 = 0.01$. From the illustration, $X_0 = 0.01$ at $Y_{1,\text{max}} = 0.0092$. The slope of this line is

$$\begin{aligned} \frac{F_D}{F_{S,\text{min}}} &= \frac{\Delta Y}{\Delta X} = \frac{Y_1 - Y_{n+1}}{X_0 - X_n} = \frac{0.0092 - 0}{0.01 - 0.001} = 1 \\ F_D &= F_{S,\text{min}} \end{aligned}$$

Since the by-product stream feed is 99% water (diluent),

$$\begin{aligned} F_D &= F(0.99) = \left(2323\ \frac{\text{kg}}{\text{h}}\right)(0.99) = 2300\ \text{kg/h} \\ F_D &= F_{S,\text{min}} = 2300\ \text{kg/h} \end{aligned}$$

This separation requires a minimum solvent flow rate, F_S, of 2300 kg/h kerosene.

The answer is (C).

3.

This is a mixing problem.

The composition of the diluent, D (1,1,2-trichloroethane) and of the solute, A (water), at the mixing point can be calculated using equationCHRM45008 and equationCHRM45009. See also *NCEES Handbook:* Measures of Composition.

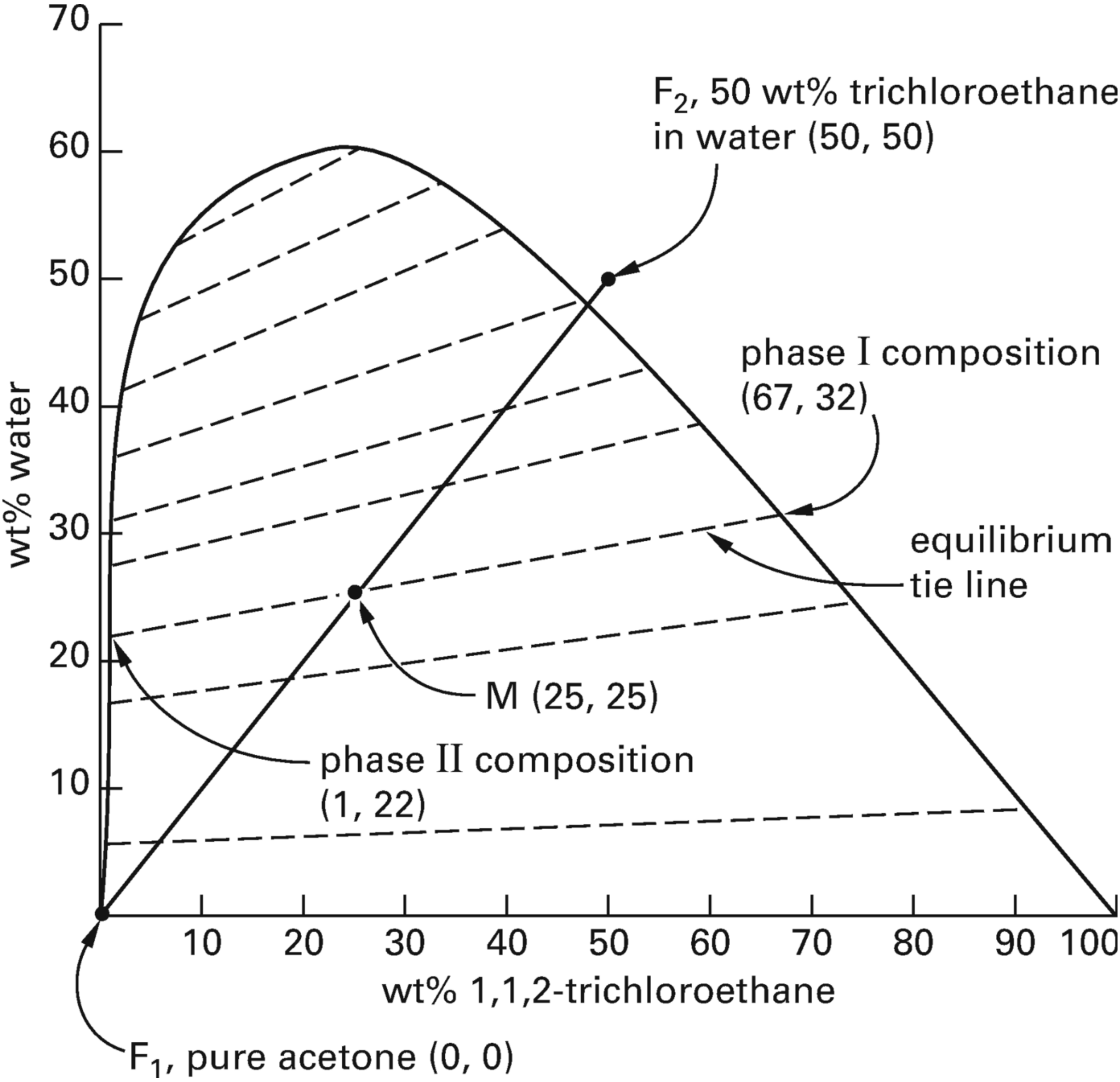
$$\begin{aligned} x_{D,\text{M}} &= \frac{F_1 x_{D,\text{F}_1} + F_2 x_{D,\text{F}_2}}{F_1 + F_2} \\ &= \frac{(100\ \text{g})(0) + (100\ \text{g})(0.50)}{100\ \text{g} + 100\ \text{g}} \\ &= 0.25 \\ x_{A,\text{M}} &= \frac{F_1 x_{A,\text{F}_1} + F_2 x_{A,\text{F}_2}}{F_1 + F_2} \\ &= \frac{(100\ \text{g})(0) + (100\ \text{g})(0.50)}{100\ \text{g} + 100\ \text{g}} \\ &= 0.25 \end{aligned}$$

In terms of wt%, the mixing point is at $(25, 25)$.

The equilibrium compositions can be read by drawing the tie line that passes through the mixing point. For each phase,

Phase I at $(67,32)$: 67 wt% 1,1,2-trichloroethane,
32 wt% water,
1 wt% acetone

Phase II at $(1,22)$: 1 wt% 1,1,2-trichloroethane,
22 wt% water,
77 wt% acetone



The answer is (B).