CheggSolutions - Thegdp

Subject: Chemistry

Chemical Equilibrium

Given Data:

- **Equilibrium constant,** $K = 1.4 \times 10^{-9}$
- **Initial concentrations:**
  - $[A] = 0.24 \ \text{mol/L}$
  - $[B] = 0.36 \ \text{mol/L}$
- **Balanced reaction:**

$$3A(g) + B(g) \rightleftharpoons C(g) + 2D(g)$$

Step-by-Step Solution:

1. Initial Setup:

$$\begin{array}{c|c|c|c|c} & A & B & C & D \\ \hline \text{Initial (M)} & 0.24 & 0.36 & 0 & 0 \\ \text{Change (M)} & -3x & -x & +x & +2x \\ \text{Equilibrium (M)} & 0.24 - 3x & 0.36 - x & x & 2x \\ \end{array}$$

Explanation: Initially, the concentrations of products C and D are zero. x represents the change in concentration at equilibrium, adhering to stoichiometric coefficients.

2. Equilibrium Expression:

$$\text{K} = \frac{[C][D]^2}{[A]^3 [B]}$$

Substituting the equilibrium concentrations into the expression for K:

$$K = \frac{x \cdot (2x)^2}{(0.24 - 3x)^3 \cdot (0.36 - x)}$$ $$1.4 \times 10^{-9} = \frac{x \cdot 4x^2}{(0.24 - 3x)^3 \cdot (0.36 - x)}$$ $$1.4 \times 10^{-9} = \frac{4x^3}{(0.24 - 3x)^3 \cdot (0.36 - x)}$$

Explanation: This is the expression based on the equilibrium concentrations substituting into the equilibrium constant expression.

3. Simplifying the Assumption:

Given the very small value of K, an assumption can be made that $x \approx 0$ for simplification:

$$(0.24 - 3x) \approx 0.24$$ $$(0.36 - x) \approx 0.36$$

Therefore,

$$1.4 \times 10^{-9} \approx \frac{4x^3}{0.24^3 \cdot 0.36}$$

4. Solving for x:

$$1.4 \times 10^{-9} = \frac{4x^3}{0.013824 \cdot 0.36}$$ $$1.4 \times 10^{-9} = \frac{4x^3}{0.00497664}$$ $$x^3 = \frac{1.4 \times 10^{-9} \cdot 0.00497664}{4}$$ $$x^3 = \frac{6.967296 \times 10^{-12}}{4}$$ $$x^3 = 1.741824 \times 10^{-12}$$ $$x = \sqrt[3]{1.741824 \times 10^{-12}}$$ $$x \approx 1.20 \times 10^{-4} \ \text{mol/L}$$

Explanation: The value of x represents the change in concentrations at equilibrium by solving the simplified cubic equation.

5. Equilibrium Concentrations:

Substituting x back:

$$[A] = 0.24 - 3x \approx 0.24 - 3(1.20 \times 10^{-4}) \approx 0.23964 \ \text{mol/L}$$ $$[B] = 0.36 - x \approx 0.36 - 1.20 \times 10^{-4} \approx 0.35988 \ \text{mol/L}$$ $$[C] = x \approx 1.20 \times 10^{-4} \ \text{mol/L}$$ $$[D] = 2x \approx 2(1.20 \times 10^{-4}) \approx 2.40 \times 10^{-4} \ \text{mol/L}$$

Explanation: Equilibrium concentrations are determined by substituting x back into the initial concentration expressions.

Final Equilibrium Concentrations:

- $[A] \approx 0.23964 \ \text{mol/L}$
- $[B] \approx 0.35988 \ \text{mol/L}$
- $[C] \approx 1.20 \times 10^{-4} \ \text{mol/L}$
- $[D] \approx 2.40 \times 10^{-4} \ \text{mol/L}$