CheggSolutions - Thegdp

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## Chemical Equilibrium

**Problem Statement:**

The equilibrium system given has an equilibrium constant $K = 1.4 \times 10^{-9}$. Initially, $[A] = 0.24 \, \text{mol/L}$ and $[B] = 0.36 \, \text{mol/L}$. Determine the equilibrium concentrations of all species given the reaction:

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

**Given and Introduction Step:**

- Equilibrium constant, $K = 1.4 \times 10^{-9}$
- Initial concentration of $A$, $[A]_0 = 0.24 \, \text{mol/L}$
- Initial concentration of $B$, $[B]_0 = 0.36 \, \text{mol/L}$

The equilibrium expression for the reaction can be written as:

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

Our goal is to find the equilibrium concentrations of all chemicals.

**Steps to Solution:**

**First, set up an ICE (Initial, Change, Equilibrium) table to track the changes in concentrations.**

**Step 1: ICE Table Setup**

| Species | Initial (mol/L) | Change (mol/L) | Equilibrium (mol/L) |
|---|---|---|---|
| $A$ | 0.24 | -3x | 0.24 - 3x |
| $B$ | 0.36 | -x | 0.36 - x |
| $C$ | 0 | +x | x |
| $D$ | 0 | +2x | 2x |

**Explanation:** This setup assumes that x mol/L of $C$ is produced, changing the amounts of all components according to the stoichiometry of the reaction.

**Step 2: Equilibrium Expression Substitution**

Substitute the equilibrium concentrations into the equilibrium expression:

$$K = \frac{(x)(2x)^2}{(0.24 - 3x)^3 (0.36 - x)}$$

Simplified version:

$$K = \frac{4x^3}{(0.24 - 3x)^3 (0.36 - x)}$$

**Explanation:** Substituting equilibrium values into the given equilibrium constant equation helps set up a relationship to solve for x.

**Step 3: Approximating for Very Small $x$**

Given the very small equilibrium constant, assume $x$ is small compared to initial concentrations. Thus, $0.24 - 3x \approx 0.24$ and $0.36 - x \approx 0.36$:

- $1.4 \times 10^{-9} = \frac{4x^3}{(0.24)^3 (0.36)}$
- $1.4 \times 10^{-9} = \frac{4x^3}{0.00497664}$
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- $4x^3 = (1.4 \times 10^{-9})(0.00497664)$
- $x^3 = \frac{0.00497664 \times 1.4 \times 10^{-9}}{4}$
- $x^3 = 1.7443 \times 10^{-12}$
- $x = \sqrt[3]{1.7443 \times 10^{-12}}$
- $x \approx 1.20 \times 10^{-4}$ mol/L

Explanation: The assumption simplifies the algebra, and the minor value of x confirms the assumption was accurate.

Step 4: Determine Equilibrium Concentrations

Substitute x back to find the equilibrium concentrations:

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

Explanation: The final equilibrium concentrations reflect the stoichiometry and are slightly changed by the small value of x.

Final Solution:

A: $[A]_e \approx 0.24 \, \text{mol/L}$
B: $[B]_e \approx 0.36 \, \text{mol/L}$
C: $[C]_e \approx 1.20 \times 10^{-4} \, \text{mol/L}$
D: $[D]_e \approx 2.40 \times 10^{-4} \, \text{mol/L}$

Thus, the concentrations of all chemicals at equilibrium are determined successfully.

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