

## Chemistry Topic: Chemical Equilibrium

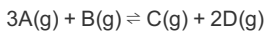
### Given Information:

Equilibrium constant  $K = 1.4 \times 10^{-9}$

Initial concentration of  $[A] = 0.24 \text{ mol/L}$

Initial concentration of  $[B] = 0.36 \text{ mol/L}$

### Reaction:



### Step-by-Step Solution:

#### 1. Introduction and Given Information:

This problem involves finding the equilibrium concentrations of reactants and products in a chemical reaction. The equilibrium concentration is determined by the initial concentrations and the equilibrium constant.

#### 2. Write the expression for the equilibrium constant (K):

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

At equilibrium, the concentrations can be described using the change in concentrations from their initial values. Let's define the change as  $x$ :

$$\text{Change in } [A] = -3x \quad \text{Change in } [B] = -x \quad \text{Change in } [C] = +x \quad \text{Change in } [D] = +2x$$

#### 3. Express the equilibrium concentrations in terms of $x$ :

$$[A] = 0.24 - 3x \quad [B] = 0.36 - x \quad [C] = x \quad [D] = 2x$$

#### 4. Substitute these expressions into the equilibrium constant expression:

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

#### 5. Simplify the expression:

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

#### 6. Assume that $K$ is very small:

Given the small value of  $K$ , the reaction tends heavily to the reactants' side. So, the changes in concentrations  $3x$  and  $x$  will be very small compared to the initial concentrations.

Thus,

$$[A] \approx 0.24 \quad (\text{since } x \text{ is negligible}) \quad [B] \approx 0.36 \quad (\text{since } x \text{ is negligible})$$

#### 7. Solve for $x$ :

Substitute these approximate values back into the simplified form to solve for  $x$ :

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

Solving for  $x^3$ :

$$4x^3 = 1.4 \times 10^{-9} \times (0.24)^3 \times 0.36 \quad x^3 = \frac{1.4 \times 10^{-9} \times 0.013824 \times 0.36}{4}$$

$$x^3 = \frac{6.991 \times 10^{-12}}{4} \quad x^3 = 1.74775 \times 10^{-12}$$

$$x = \sqrt[3]{1.74775 \times 10^{-12}} \quad x \approx 1.2 \times 10^{-4} \text{ mol/L}$$

#### 8. Final Equilibrium Concentrations:

$$[C] = x \approx 1.2 \times 10^{-4} \text{ mol/L}$$

$$[D] = 2x \approx 2 \times 1.2 \times 10^{-4} = 2.4 \times 10^{-4} \text{ mol/L}$$

$$[A] = 0.24 - 3x \approx 0.24 - 3 \times 1.2 \times 10^{-4} \approx 0.23964 \text{ mol/L}$$

$$[B] = 0.36 - x \approx 0.36 - 1.2 \times 10^{-4} \approx 0.35988 \text{ mol/L}$$

### Final Solution:

$$[A] \approx 0.23964 \text{ mol/L}$$

$$[B] \approx 0.35988 \text{ mol/L}$$

$$[C] \approx 1.2 \times 10^{-4} \text{ mol/L}$$

$$[D] \approx 2.4 \times 10^{-4} \text{ mol/L}$$